MAXIMUM FLOW VARIABILITY AND FLOODS CHARACTERISTICS IN THE CENTRAL AND NORTH DOBROGEA

Camelia – Eliza Telteu[1], Florentina – Iuliana Stan, Emilia Brănescu, Aurelia Berghezan

Abstract. A deep knowledge of the maximum flow is required to build the hydraulic structures, to assure a good water management and, especially, to prepare an efficient flood defence. This paper aims to analyze the maximum flow and the floods characteristics from the Central and North Dobrogea. The physico – geographical factors which influence the water resources from the studied area are: the climatic conditions, the geological conditions, fhe forest coverage and the loam – clay soils. The analysis is based on the processing of the annual and monthly discharge of 11 hydrometric stations (with observation periods which ranged between 24 and 55 years). The frequency and the characteristics of the 61 floods have been identified. The values of the maximum annual discharge ranged between 12.2 and 488 m³/s. These values exceeded the values of the maximum discharge with the probability of 0.01% (Slava River), 0.1% (Teliţa River), 0.5% (Hamangia and Cartal Rivers), 3% (Topolog, Taiţa and Râmnic Rivers) and 5% (Casimcea River). An important feature of the maximum flow, from the studied area, is highlighted by the fast character of the floods. These have a total duration which ranged between 6 hours and 47 hours and an increasing time which ranged between 2 hours and 12 hours. The analyzed floods are common, mainly, between May and September highlighting their exclusively pluvial origin.

Keywords: Central and North Dobrogea, maximum flow, floods.

1. Introduction

The maximum flow is a big piece of the hydrological regime which requires a good understanding for developing the hydraulic structures and the water management, and especially for planning the floods defense strategies.

The floods are natural phenomena which are characterized by a short time of significantly increasing discharges and levels. Some negative effects of these are: the flooding of the land use, the casualties, the destruction of some socio – economic objectives, some changes in the riverbeds and so on.

The geographical position of the Central and North Dobrogea impose some physico – geographical features (geological conditions, climatic conditions, morphological and morphometric features, soils) which, due to the human activity, have a decisive role in the

[1]National Institute of Hydrology and Water Management, Road Bucureşti – Ploieşti, 97, sector 1, Bucharest, Romania, elizapascu25@gmail.com.

formation and the variability of the maximum flow. Generally, in the studied area, the maximum flow represents a consequence of the torrential rainfall due to the intense activity of the cyclones over the Mediterranean and Black Sea (Mătreaţă and Mătreaţă, 2010).

In this paper are highlighted the variability of the maximum flow and the floods characteristics from the Central and North Dobrogea. The analysis is based on the statistical processing of the hydrological data recorded at the hydrometric stations (HS): Saraiu HS, on the Topolog River; Cheia HS and Casimcea HS, on the Casimcea River; Pantelimonu de Jos HS, on the Cartal River; Pantelimonu de Jos HS, on the Râmnic River, Ceamurlia de Jos HS, on the Slava River (Gaugagia), Satu Nou HS and Hamcearca HS, on the Taiţa River.

Studies on the river's hydrological regime from the Central and North Dobrogea were made by Pişota and Dinu, 1988; Pişota, 1993; Ilie, 2005; Pişota, 2005a; Gâştescu et al., 2006 and so on.

2. Database and methodology

The hydrological data was obtained from the National Institute of Hydrology and Water Management (NIHWM) and consists in: the maximum monthly discharge, the maximum annual discharge, the daily and hourly discharge during the floods.

The trends in the variability of the maximum annual discharge were identified by nonparametric statistical test Mann – Kendall, with Makesens software (Salmi et al., 2002).

The values of the maximum discharge with different exceedance probabilities (0.01%, 0.1%, 1%, 3%, 5%, 10%, 20%, 30%) were computed with the ASIG software (which is used in the operating activities at the NIHWM), using the Pearson III theoretical binomial distribution.

The floods characteristics have been computed by analyzing the most important events that occured at the hydrometric stations (these events exceeded the average maximum multiannual discharge, according to the data obtained from NIHWM) and using the Cavis software (Corbuş, 2010).

The analysis of the climatic conditions, from the studied area, is based on the data regarding the air temperature, the rainfall, the evaporation (from the evaporation stations which are close to the studied area) and the snow layer (orientatively due to the lack of data, only for the Medgidia and Constanţa weather stations). The data belongs to the next weather stations (WS) which are located in the area or close to the studied area: Constanţa WS, Medgidia WS, Hârşova WS, Tulcea WS and Jurilovca WS (for the period 1965 – 2000). This data was taken from the NIHWM, National Meteorology Administration (NMA), the European Climate Assessment Database & Dataset (ECA & D) and literature (Torică, 2004; Sandu et al., 2008).

Morphometrical data on the basin and on the river system were computed using GIS techniques and analysing the topographic map of Romania, scale 1:25000 (*Direcţia Topografică Militară, 1982*) and a digital terrain model with a spatial resolution of 90 m (source: geo – spatial.org, 2009). They were filled, on the one hand, with the data published in the *Atlasul Cadastrului Apelor din Români*a (1992), and on the other hand, with the data which is used in the operative activity from the NIHWM (2013).

Analysis of the spatial distribution of the lithological formations, classes and types of soils and the land use/land cover was done by processing the following sources and digital mapping: the geological map of Romania, scale 1:200000, sheets *Constanţa* (Chiriac, 1968), *Brăila* (Murgeanu and Liteanu, 1967); *Tulcea* (Ianovici et al., 1967a) and Sulina (Ianovici et al., 1967b), the soil map of Romania, scale 1:200000, sheets *Constanţa* (Florea et al., 1965), *Tulcea* (Munteanu and Conea, 1969), *Brăila* (Florea and Conea, 1964), Focşani – Galaţi (Conea and Gogoasa, 1969), the Corine Land Cover database and nomenclature of the *European Environment Agency, 2006*.

The data has been processed using, on the one hand, the classical methods (the statistical parameters, the maximum monthly discharge's frequency), and on the other hand, the GIS techniques (with the ArcGIS 9 software).

3. The studied area

The runoff in the Central and North Dobrogea is influenced, mainly, by the climatical, geological, morphological and morphometrical conditions.

The studied area has 5909 km² and is characterized by an excessive temperate – continental climate influenced by the Danube in the west and north, and the Black Sea in the east (Pişota, 2005b) (figure 1). In the period 1961 – 1990, the average annual air temperature for the analysed watersheds ranged from 10.0 ºC (catchment Slava) to 10.9 ºC (catchment Corbu) and the multiannual average amounts of precipitations ranged between 396 mm (catchment Corbu) and 436 mm (catchment Taiţa) (NMA, 2013).

The multiannual mean values of the evaporation from the water surface (for the interval March/April – October/November of the period 1958 – 2002) ranged between 866 mm, at the Siutghiol evaporimeter station on the ground, and 838 mm, at the Jurilovca evaporimeter station (the data was obtained from the NIHWM, 2013).

The snow layer, due to the presence of the Black Sea, has a small contribution in the formation and the variability of the flow. For example, at the Medgidia WS and Constanţa WS which are close to the studied area, the snow has a monthly average thickness less than 2 cm (1 cm Constanta WS and 2 cm at Medgidia WS – Geicu and Becheanu 2008; NMA).

From a morphometrical and morphological point of view, the North and Central Dobrogea is characterized by an average height of 99.9 m. The altitudes which have the values less than 250 m present the highest percent (93.9%) This highlights the lowest amounts of precipitations which reflect negatively on the flow.

Analysis regarding the spatial distribution of the lithological formations highlights a high percent of the Upper – Middle Pleistocene loessoid deposits (61.5%), which are followed by the Upper Holocene gravels and sands (13.9%).

Regarding the land use and land cover, the arable land has the highest percent (61.7%), followed by deciduous forests (13.5%).

From an edaphical point of view, on the one hand, the cernisoils have the highest percent (69.8%), followed by protisoils/antrisoils (15.9%), and on the other hand, the loamy soils have the highest percent (63.1%), followed by the loamy – clay soils (16.0%).

On the whole, the high percent of the loessoid deposits, of the cernisoils and of the loamy soils facilitate the rainwater infiltration and the high percent of the arable land facilitates the erosion, the surface runoff and the production of floods.

4. The morphometrical features of the main rivers from the Central and North Dobrogea

The studied rivers are tributaries to the Danube (Topolog River) and to the Black Sea (Corbul, Casimcea, Cartal, Râmnic, Slava, Hamangia, Taiţa and Teliţa Rivers) through the lagoons, the fluvial lakes and the fluvial – maritime lakes, such as: the Corbul River flows into the Corbul lake, the Casimcea River flows into the Taşaul lake; the Slava River flows

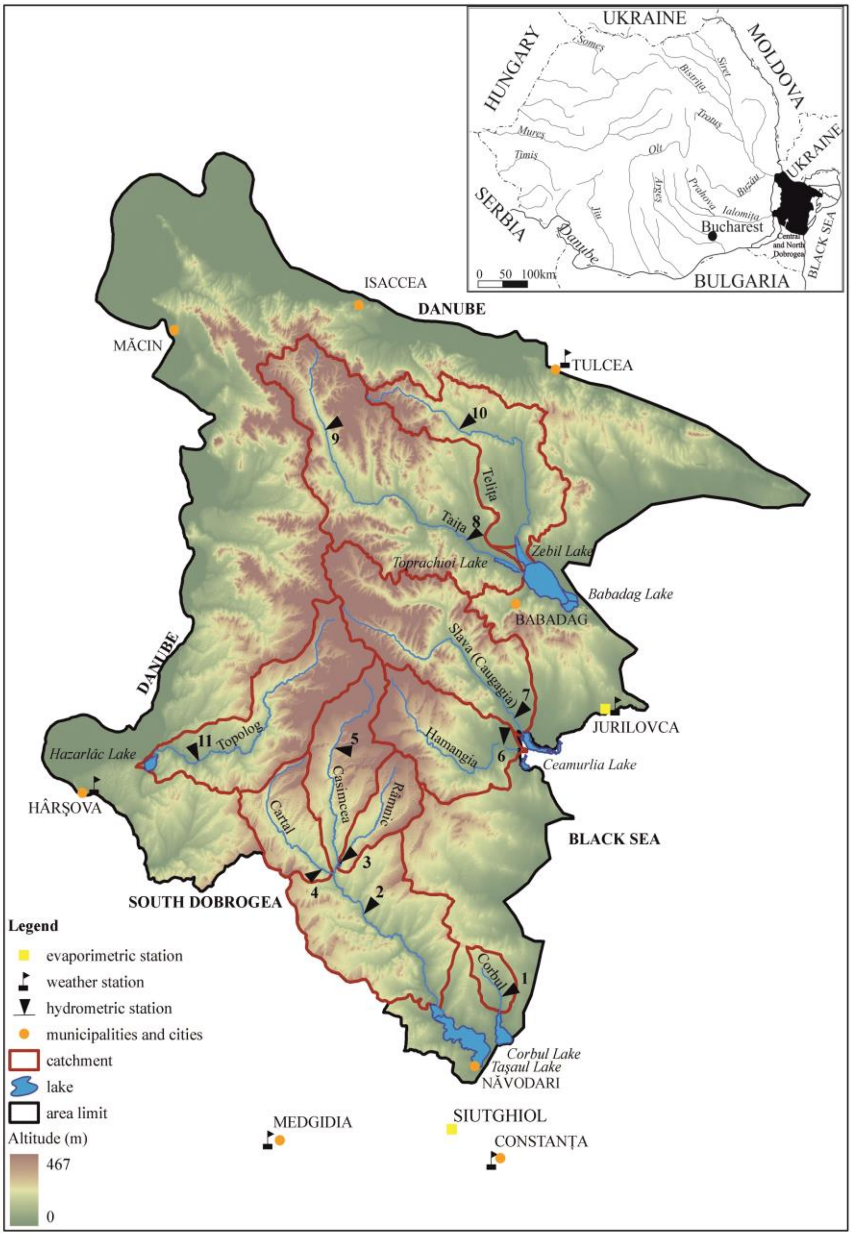


Figure 1: Central and North Dobrogea map – hydrographical map

into the Goloviţa lake through the Ceamurlia lake, the Hamangia River flows into the Ceamurlia lake; the Teliţa River flows into the Razim Lake through the Babadag lake, the Taiţa River flows into the Razim lake, the Topolog River flows into the Hazarlâc Lake. The Cartal and Râmnic Rivers are tributaries to the Casimcea River. The analyzed catchments have average altitudes ranging between 62 m (Corbu catchment) and 169 m (Slava catchment) and areas between 39 km² (Corbu catchment) and 738 km² (Casimcea catchment). The length of the rivers varies between 8 km (Corbu River) and 76 km (Casimcea River) (table 1).

Table 1: The morphometrical features of the analyzed rivers

<table>
<tr><th>No.</th><th>River</th><th>Hydrometric station</th><th>H_b* (m)</th><th>H** (m)</th><th>H*** (m)</th><th>L_c* (km)</th><th>L** (km)</th><th>L_d*** (km)</th><th>F_a* (km²)</th><th>F** (km²)</th><th>F*** (km²)</th></tr>
<tr><td>1.</td><td>Cartal</td><td>Pantelimonu de Jos</td><td>150</td><td>143</td><td>143</td><td>26</td><td>26</td><td>29</td><td>127</td><td>128</td><td>127</td></tr>
<tr><td rowspan="2">2.</td><td rowspan="2">Casimcea</td><td>Casimcea</td><td>263</td><td rowspan="2">145</td><td rowspan="2">144</td><td>16</td><td rowspan="2">69</td><td rowspan="2">76</td><td>78</td><td rowspan="2">740</td><td rowspan="2">738</td></tr>
<tr><td>Cheia</td><td>163</td><td>50</td><td>500</td></tr>
<tr><td>3.</td><td>Râmnic</td><td>Pantelimonu de Jos</td><td>166</td><td>165</td><td>166</td><td>20</td><td>20</td><td>22</td><td>87</td><td>87</td><td>86</td></tr>
<tr><td>4.</td><td>Slava</td><td>Ceamurlia</td><td>177</td><td>174</td><td>169</td><td>34</td><td>38</td><td>38</td><td>350</td><td>356</td><td>356</td></tr>
<tr><td rowspan="2">5.</td><td rowspan="2">Taiţa</td><td>Hamcearca</td><td>210</td><td rowspan="2">148</td><td rowspan="2">147</td><td>18</td><td rowspan="2">57</td><td rowspan="2">54</td><td>102</td><td rowspan="2">591</td><td rowspan="2">591</td></tr>
<tr><td>Satu Nou</td><td>151</td><td>54</td><td>565</td></tr>
<tr><td>6.</td><td>Telita</td><td>Poşta</td><td>210</td><td>100</td><td>95</td><td>14</td><td>48</td><td>48</td><td>58</td><td>287</td><td>287</td></tr>
<tr><td>7.</td><td>Topolog</td><td>Saraiu</td><td>181</td><td>166</td><td>159</td><td>41</td><td>50</td><td>58</td><td>264</td><td>342</td><td>314</td></tr>
<tr><td>8.</td><td>Hamangia</td><td>Baia</td><td>210</td><td>148</td><td>146</td><td>19</td><td>33</td><td>33</td><td>218</td><td>224</td><td>224</td></tr>
<tr><td>9.</td><td>Corbu</td><td>Corbu de Sus</td><td>76</td><td>65</td><td>62</td><td>4.5</td><td>7</td><td>8</td><td>26</td><td>39</td><td>39</td></tr>
</table>

F = catchment area (**a** = corresponding to the hydrometric station); H = average altitude of the catchment area (**b** = at the level of the hydrometric station); L = length of the stream (**c** = spring – hydrometric station; **d** = source – river mouth); bleu = minimum values; red = maximum values; *Data source: NIHWM. ***Atlasul Cadastrului Apelor din România*, 1992; ***values obtained from GIS spatial analysis of the Romania's topographic map, scale 1:25000, second edition, DTM, 1982.

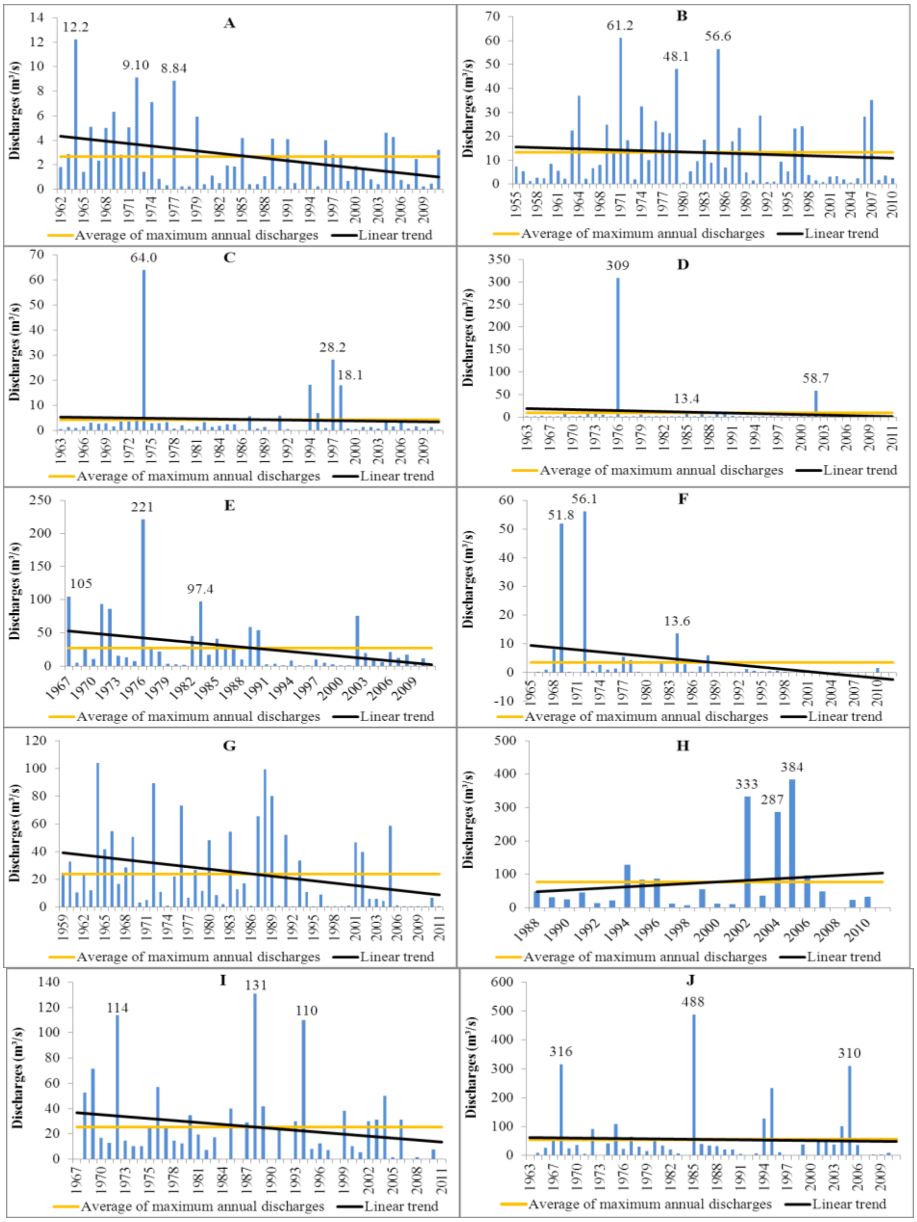
4. The variability of the maximum flow

The annual maximum discharge ranges from 0.038 m³/s (Corbu de Sus HS) to 488 m³/s (Pantelimonu de Jos HS, on the Cartal River) (table 2). The average maximum annual discharge varies from 2.70 m³/s (Hamcearca HS) and 75.9 m³/s (Cheia HS). There is a decreasing linear trend of the annual maximum discharge, statistically significant according to the Mann – Kendall with a significance level of 0.5 for Hamcearca HS and Baia HS and 0.001 for Corbu HS and Casimcea HS (figure 2). In the case of the Satu Nou HS, Poşta Frecăţei HS, Cheia HS, Râmnic HS and Cartal HS, the significance level is greater than 0.1. The Saraiu HS showed an increasing trend with a significance level greater than 0.1.

Table 2: Data regarding the maximum annual discharges occured in the Central and North Dobrogea, corresponding to the three highest maximum annual discharges

No.	River	Hydrometric station / Discharge equivalent to the alert thresholds			Date	The maximum discharge Q_{max} (m^3/s)	Precipitation which caused the Q_{max} (m^3/s)	
							flood's day (mm)	10 previous days (mm)*
1	Topolog	Saraiu			03.07.2005	214	114	20
		Q_a	Q_i	Q_p	30.05.2002	209	56	22
		5.0	14.3	62.4	01.10.1981	192	–	–
2	Casimcea	Casimcea			23.10.1964	104	–	–
		Q_a	Q_i	Q_p	13.06.1988	99.3	74	–
		1.0	5.00	28.0	03.06.1972	89.3	–	–
3	Casimcea	Cheia			03.07.2005	384	44	27
		Q_a	Q_i	Q_p	31.05.2002	333	10	27
		5.0	72.0	–	28.08.2004	287	77	25
4	Cartal	Pantelimonu de Jos			11.06.1985	488	–	–
		Q_a	Q_i	Q_p	24.09.1968	316	–	–
		6.9	16.4	80.0	03.07.2005	310	55	–
5	Râmnic	Pantelimonu de Jos			22.05.1988	131	25	–
		Q_a	Q_i	Q_p	04.06.1972	114	–	–
		6.7	60.9	–	11.06.1994	110	12	33
6	Corbu	Corbu de Sus			05.10.1972	56.1	–	–
		Q_a	Q_i	Q_p	26.02.1969	51.8	–	–
		1.1	–	–	03.08.1984	13.6	–	–
7	Hamangia	Baia			17.09.1976	221	–	–
		Q_a	Q_i	Q_p	10.07.1967	105	–	–
		11.	55.4	75.7	06.08.1983	97.4	–	–
8	Slava	Ceamurlia de Jos			17.09.1976	309	–	–
		Q_a	Q_i	Q_p	30.05.2002	58.7	–	–
		10.	50.0	–	05.03.1985	13.4	–	–
9	Taiţa	Hamcearca			23.09.1964	12.2	–	–
		Q_a	Q_i	Q_p	06.08.1972	9.10	–	–
		–	–	–	15.06.1977	8.84	–	–
10	Taiţa	Satu Nou			31.05.1971	61.2	–	–
		Q_a	Q_i	Q_p	05.03.1985	56.6	–	–
		–	–	–	19.05.1979	48.1	72	–
11	Teliţa	Poşta Frecăţei			21.07.1974	64.0	–	–
		Q_a	Q_i	Q_p	27.07.1997	28.2	101	15
		0.96	2.35	30.0	13.07.1994	18.2	70	42

Q_a = warning discharge; Q_i = flooding discharge; Q_p = danger discharge.
No data is simbolized by ”–,,.
*The accumulated amounts of precipitation for 10 previous days before floods.
Data source: NIHWM.



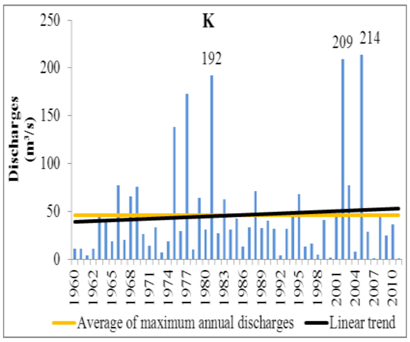


Figure 2: The variation of the maximum annual discharges and it's trend (the black line) of the rivers Taiţa, ***Hamcearca*** *HS: 1962 – 2011 (**A**) and* ***Satu Nou*** *HS: 1952 – 2010, without 1965 (**B**); Teliţa,* ***Poşta Frecăţei*** *HS: 1963 – 2011 (**C**); Slava,* ***Ceamurlia de Jos*** *HS: 1963 – 2011, without 1964 (**D**); Hamangia,* ***Baia*** *HS: 1967 – 2011 (**E**); Corbu,* ***Corbu de Sus*** *HS: 1965 – 2011 (**F**); Casimcea,* ***Casimcea*** *HS: 1959 – 2011 (**G**) and* ***Cheia*** *HS: 1988 – 2011 (**H**); Râmnic,* ***Pantelimonu de Jos*** *HS: 1967 – 2011 (**I**); Cartal,* ***Pantelimonu de Jos*** *HS: 1963 – 2011, without 1964 (**J**); Topolog,* ***Saraiu*** *HS: 1962 – 2011 (**K**). Data source: NIHWM.*

The highest values of the maximum monthly discharge occured during summer and autumn: May, Satu Nou HS (61.2 m³/s) and Pantelimonu de Jos HS (131 m³/s, the Râmnic River); June, Pantelimonu de Jos HS (488 m³/s, Cartal River); July, Saraiu HS (214 m³/s), Poşta Frecăţei HS (64 m³/s) and Cheia HS (384 m³/s); September, Hamcearca HS (12.2 m³/s), Baia HS (221 m³/s) and Ceamurlia de Jos HS (309 m³/s); October, Casimcea HS (104 m³/s) and Corbu de Sus HS (56.1 m³/s) (figure 3). They are the consequence of the heavy rainfalls. The lowest values of the maximum monthly discharge were, generally, recorded during November and December.

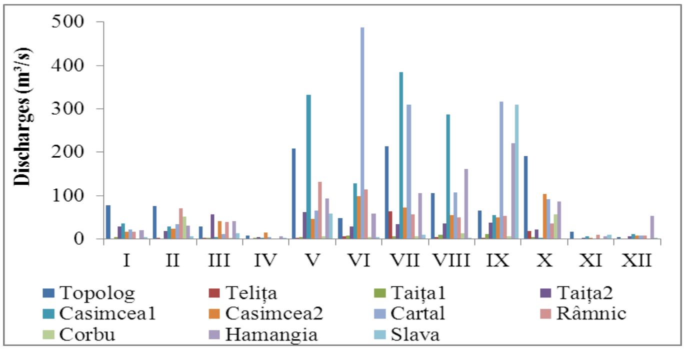


Figure 3: The variation of the maximum monthly discharge for the rivers Topolog (Saraiu HS: 1962 – 2011), Corbu (Corbu de Sus HS: 1965 – 2011), Casimcea (Cheia HS: 1988 – 2011, Casimcea HS: 1959 – 2011), Cartal (Pantelimonu de Jos HS: 1965 – 2011, without November and December of 1964), Râmnic (Pantelimonu de Jos HS: 1968 – 2011), Slava (Ceamurlia de Jos HS: 1965 – 2011), Hamangia (Baia HS: 1967 – 2011), Taiţa (Hamcearca HS: 1962 – 2011, Satu Nou HS: 1952 – 2010, without 1965 and 1966), Teliţa (Poşta Frecăţei HS: 1963 – 2011).

For a more rigorous analysis, we determined and analyzed the number of cases when the maximum monthly and annual discharge recorded at the studied hydrometric stations exceeded the warning discharge (Q_a), the flooding discharge (Q_i) and the danger discharge (Q_p). The alert thresholds (Q_a, Q_i and Q_p) are established according to the physico – geographical and socio – economical characteristics of the catchments and have a major role in the flood risk management and for the riverbeds dynamic analysis.

At the analyzed hydrometric stations, during the observation periods, were inventoried between 6 floods (Ceamurlia de Jos HS) and 217 floods (Saraiu HS) with maximum annual discharge higher than the discharge equivalent to the alert thresholds, as follows: 6 floods at Ceamurlia de Jos HS, 19 floods at Corbu de Sus HS, 60 floods at the Cheia HS, 110 floods at the Pantelimonu de Jos HS on the Râmnic River, 120 floods at the Baia HS, 124 floods at the Poşta Frecăţei HS, 125 floods at the Pantelimonu de Jos HS on the Cartal River, 197 floods at the Casimcea, 217 floods at the Saraiu HS. The flooding discharge was exceeded between 15.0% (Casimcea HS) and 66.7% (Baia HS and Poşta Frecăţei HS) from the total cases. Generally, the floods occurred most frequently between May and September due to the heavy rainfall events.

Some important flood events occured during the years: 1967 and 1969 (15 floods with discharges superior to the alert thresholds), Poşta Frecăţei HS; 1972 (9 floods at the Pantelimonu de Jos HS on the Cartal River and 15 floods at the Baia HS); 1969 (14 floods), Casimcea HS; 1966 (6 floods) at the Cheia HS; 1968, 1969, 1974, 1977, 1984 (2 floods), at the Corbu de Sus HS; 1969, 1972 and 1976 (8 floods) at the Pantelimonu de Jos HS on the Râmnic River; 1969 (13 floods) at the Saraiu HS; 1976 and 2002 (2 floods) at the Ceamurlia de Jos HS. The alert thresholds weren't exceeded in the next years: 1973, 1984, 1991, 1992, 1997, 1998, 2000, 2007, 2008, 2009, 2011 at the Pantelimonu de Jos HS on the Cartal River; 1978, 1980, 1986, 1988, 1990, 1992, 1993, 1996, 1999, 2000, 2003, 2007, 2009 and 2011 at the Poşta Frecăţei HS; 2008 and 2011 at the Cheia HS; 1965 – 1967, 1970, 1971, 1973, 1975, 1979 – 1981, 1983, 1986, 1989 – 1992, 1994 – 2009, 2011 at the Corbu de Sus HS; 1970, 1975, 1979 – 1981, 1988, 1991 – 2001, 2004, 2005, 2007, 2009 – 2011 at the Baia HS; 1984, 1986, 1990, 1992, 1998, 2001, 2005, 2007 – 2009, 2011 at the Pantelimonu de Jos HS on the Râmnic River; 1992, 1998, 2000, 2007, 2011 at the Saraiu HS; 1965 – 1975, 1977 – 1984, 1986 –1988, 1990 – 2001, 2003 – 2011 at the Ceamurlia de Jos HS.

The discharge with exceedance probability of 0.01%, 0.1%, 0.5%, 1%, 3%, 5%, 10%, 20%, 30% and 50% was estimated using the Pearson III theoretical binomial distribution, with the ASIG software. In this analysis, the asymmetry coefficient (C_s) of the maximum annual discharge series was 4 times higher than the coefficient of variation (C_v) (tables 3 and 4).

Table 3: Data regarding the maximum discharges (Q_{max}) with different exceedance probabilities (p%) of the Central and North Dobrogea's Rivers

Topolog, Saraiu HS (1960 – 2009)		Teliţa, Poşta Frecăţei HS (1963 – 2009)		Taiţa, Satu Nou HS (1955 – 2009)		Taiţa, Hamcearca HS (1962 – 2009)		Slava, Ceamurlia de Jos HS (1963 – 2009)	
p%	Q_{max} (m³/s) $C_s = 4C_v$ $C_v = 1.07$ $C_s = 4.30$	p%	Q_{max} (m³/s) $C_s = 4Cv$ $C_v = 1.29$ $C_s = 5.18$	p%	Q_{max} (m³/s) $C_s = 4Cv$ $C_v = 1.08$ $C_s = 4.32$	p%	Q_{max} (m³/s) $C_s = 4Cv$ $C_v = 1.15$ $C_s = 4.62$	p%	Q_{max} (m³/s) $C_s = 4Cv$ $C_v = 0.82$ $C_s = 3.27$
0.01	691	0.01	89.9	0.01	196	0.01	44.5	0.01	99.4
0.1	482	0.1	60.1	0.1	137	0.1	30.7	0.1	72.2
0.5	336	0.5	40.7	0.5	95.3	0.5	21.2	0.5	53.1
1	273	1	32.1	1	77.1	1	16.9	1	44.8
3	189	3	21.7	3	53.4	3	11.6	3	32.5
5	143	5	15.1	5	40.5	5	8.59	5	26.6
10	57.3	10	9.06	10	26.7	10	5.50	10	19.3
20	94.7	20	6.71	20	16.2	20	3.49	20	13.1
30	40.5	30	3.38	30	11.4	30	2.20	30	10.1

C_s = asymmetry coefficient; C_v = coefficient of variation; red = the values of the maximum discharge with different exceedance probabilities which have been overcome by the maximum maximorum recorded discharge. The results were obtained with the ASIG software (NIHWM).

By comparing the maximum discharge recorded with the statistical estimated values, it appears that the peak discharge recorded in 2005 (Topolog and Casimcea Rivers) 1964 (Casimcea River at the Casimcea HS, Taiţa River at the Hamcearca HS), 1985 (Cartal River), 1988 (Râmnic River), 1972 (Corbu River), 1976 (Hamangia and Slava Rivers), 1971 (Taiţa River at the Satu Nou HS), 1974 (Teliţa River) corresponding to 0.01% insurance (Slava River), 0.1% (Teliţa River), 0.5% (Hamangia and Cartal Rivers), 3% (Topolog, Taiţa and Râmnic Rivers) and 5% (Casimcea River). In the case of the Topolog, Teliţa, Hamangia, Casimcea (Casimcea HS) and Cartal Rivers, the danger discharges have an exceedance probability higher than 3% (Teliţa River), 10% (Topolog and Hamangia Rivers), 20% (Cartal River) and 30% (Casimcea River).

Table 4: Data regarding the maximum discharges (Q_{max}) with different exceedance probabilities (p%) of the Central and North Dobrogea's Rivers

Hamangia, Baia HS (1967 – 2009)		Casimcea, Casimcea HS (1959 – 2009)		Râmnic, Pantelimonu de Jos HS (1967 – 2009)		Cartal, Pantelimonu de Jos HS (1963 – 2009)	
p%	Q_{max} (m³/s) $C_s = 4C_v$ $C_v = 1.03$ $C_s = 4.10$	p%	Q_{max} (m³/s) $C_s = 4Cv$ $C_v = 1.04$ $C_s = 4.14$	p%	Q_{max} (m³/s) $C_s = 4Cv$ $C_v = 1.15$ $C_s = 4.61$	p%	Q_{max} (m³/s) $C_s = 4Cv$ $C_v = 1.13$ $C_s = 4.51$
0.01	383	0.01	421	0.01	429	0.01	896
0.1	269	0.1	295	0.1	297	0.1	621
0.5	189	0.5	208	0.5	205	0.5	429
1	155	1	169	1	163	1	345
3	108	3	118	3	112	3	238
5	83.1	5	90.7	5	82.9	5	178
10	55.8	10	60.6	10	53.2	10	115
20	34.1	20	36.9	20	33.7	20	71.2
30	24.5	30	26.6	30	21.4	30	47.1

C_s = asymmetry coefficient; C_v = coefficient of variation; red = the values of the maximum discharge with different exceedance probabilities which have been overcome by the maximum maximorum recorded discharge. The results were obtained with the ASIG software (NIHWM).

5. The floods characteristics

The annual floods (with the highest maximum annual discharge) have a maximum frequency in June and July, between 12.5% and 33.3% of cases, and a minimum frequency in the period October – April (lower than 2% of cases). They didn't occur in next months: January and November at the Poşta Frecăţei HS, October and November at the Hamcearca HS, December at the Satu Nou HS, April at the Baia HS, February, March and the period October – December at the Cheia HS, November at the Pantelimonu de Jos HS on the Cartal River, March and November at the Saraiu HS (figure 4).

Seasonally, the lowest number of annual floods was recorded during winter (4 and 22% of annual floods) and autumn (8 – 28% of annual floods) and the highest number during summer (33 – 67% of annual floods) (figure 5).

For the flood events which have overcome the average maximum annual discharge (61 floods), were determined and analyzed the monthly and seasonal frequency and the characteristic elements. The analysis highlights the fast character of the floods with a total average duration which varies between 6 and 47 hours and an increasing time between 2 and 12 hours. The floods are common to the period May – September which shows, mainly, their pluvial origin (table 5).

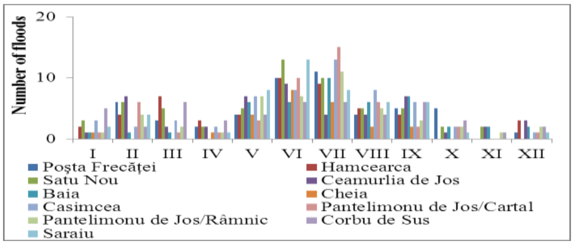


Figure 4: Monthly frequency of the annual floods at the analyzed hydrometric stations (the observation periods shown in figure 3)

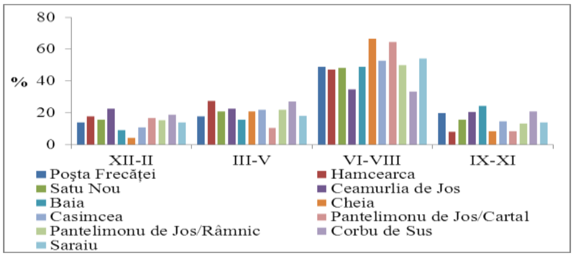


Figure 5: Seasonal frequency of the annual floods at the analyzed hydrometric stations (the observation periods shown in figure 3)

Table 5: The mean values of the floods waves

No.	River	Hydrometric station	Number of floods	T_t (hours)	T_c (hours)	T_d (hours)	W_t (mil.m³	Form factor
1	Casimcea	Cheia	9	28h 17’	8h40’	19h37’	3.91	0.2
		Casimcea	7	10h17’	3h8’	7h9’	0.41	0.3
2	Cartal	Pantelimonu de Jos	9	21h26’	6h13’	15h13’	3.88	0.3
3	Râmnic	Pantelimonu de Jos	8	28h30’	8h54’	19h36’	1.16	0.3
4	Corbul	Corbul de Sus	2	6h30’	2h	4h30’	0.05	0.3
5	Slava	Ceamurlia de Jos	4	46h30’	7h30’	39h	0.90	0.3
6	Hamangia	Baia	4	25h48’	9h	16h48’	1.31	0.4
7	Taiţa	Hamcearca	7	24h8’	7h	17h8’	0.14	0.4
		Satu Nou	5	37h48’	11h36’	26h12’	1.36	0.4
8	Teliţa	Poşta Frecăţei	3	13h	5h18’	7h42’	0.17	0.5
9	Topolog	Saraiu	3	23h	7h	16h	2.43	0.3

T_t = total duration; T_c = increasing time; T_d = decreasing time; W_t = total volume.

Conclusions

The physico – geographical factors of the Central and North Dobrogea have a decisive role in the formation and variability of the flow. The analyzed rivers could record during summer, due to the heavy rainfall, maximum discharges which exceed 50 m³/s. An important feature of their hydrological regime is the fast character of the flood events, which have a negative effect for the early alert of the people. So, the average increasing time varies between 2 and 12 hours, and the total duration between 6 and 47 hours. The floods have the maximum frequency (34% from the total number) in June due to the heavy rainfalls.

The analysis of the maximum flow variability and of the floods characteristics shows that it is necessary to grant an attention to the structural and non – structural measures and to improve these measures to reduce the negative consequences of the floods.

References

1. *Atlasul Cadastrului Apelor din România*. 1992, AQUAPROIECT, I, Bucureşti.
2. Chiriac, M., 1968. *Harta Geologică – R. S. România*, scara 1:200000, sheet Constanţa, Comitetul de Stat al Geologiei, Institutul Geologic, Bucureşti.
3. Conea, A., Gogoasa, T., 1969. *Harta solurilor României*, scara 1:200000, sheet Focşani – Galaţi, Institutul Geologic, Bucureşti.

4. Corbuş, C., 2010. *Programul Cavis pentru determinarea caracteristicilor undelor de viitură singulare*, National Institute of Hydrology and Water Management, Jubilee Scientific Conference, 28 – 30 septembrie 2010.
5. Direcţia Topografică Militară. 1982, *Harta hidrografică a României*, scara 1:25000.
6. Florea, N., Conea, A., 1964. *Harta solurilor României*, scara 1:200000, sheet Brăila, Institutul Geologic, Bucureşti.
7. Florea, N., Conea, A., Munteanu, I., 1965. *Harta solurilor României*, scara 1:200000, sheet Constanţa, Institutul Geologic, Bucureşti.
8. Gâştescu, P., Zăvoianu, I., Driga, B., Ciupitu, D., Drăgoi, I. J., 2006. *Waters.* In Bălteanu, D., Badea, L., Buza, M., Niculescu, Gh., Popescu, C., Dumitraşcu, M. (eds.), *Romania – Space, society, environment*, 107–111, The publishing house of the Romanian Academy, Bucureşti.
9. Geicu, A., Becheanu, V., 2008. *Stratul de zăpadă,* In Sandu et al. (eds.), *Clima României*, 299–31, Editura Academiei Române, Bucureşti.
10. Ianovici, V., Giuşcă, D., Mirăuţă, O., 1967 a. *Harta Geologică – R. S. România*, scara 1:200000, sheet Tulcea, Comitetul de Stat al Geologiei, Institutul Geologic, Bucureşti.
11. Ianovici, V., Liteanu, E., Mirăuţă, O., 1967 b. *Harta Geologică – R. S. România*, scara 1:200000, sheet Sulina, Comitetul de Stat al Geologiei, Institutul Geologic, Bucureşti.
12. Ilie, I., 2005. *Podişul Dobrogei Centrale – Apele,* In: Posea, G, Bogdan, O, Zăvoianu, I, eds. Geografia României, V, *Câmpia Română, Dunărea, Podişul Dobrogei*, *Litoralul Românesc al Mării Negre şi Platforma Continentală,* 736–738, The publishing house of the Romanian Academy, Bucureşti.
13. Mătreaţă, M., Mătreaţă, S., 2010. *Metodologie de estimare a potenţialului de producere de viituri rapide în bazine hidrografice mici,* Comunicări de Geografie, Vol. XIV, 197–204, Editura Universităţii din Bucureşti, Bucureşti.
14. Munteanu, I., Conea, A., 1969. *Harta Solurilor României,* scara 1:200000, sheet Tulcea, Institutul Geologic, Bucureşti.
15. Murgeanu, G., Liteanu, E., 1967. *Harta Geologică – R. S. România*, scara 1:200000, sheet Brăila, Comitetul de Stat al Geologiei, Institutul Geologic, Bucureşti.
16. Pişota, I., Dinu, I., 1988. *Râul Topolog. Observaţii hidrologice*, Analele Universităţii Bucureşti, Seria Geografie, XXXVII, 19–23.
17. Pişota, I., 1993. *Câteva observaţii hidrologice asupra râului Casimcea*, Analele Universităţii Bucureşti, Seria Geografie, XLII, 3–9.
18. Pişota, I., 2005 a. *Podişul Dobrogei de Nord – Apele*, In: Posea, G, Bogdan, O, Zăvoianu, I, eds. Geografia României-vol. V, *Câmpia Română, Dunărea, Podişul Dobrogei, Litoralul Românesc al Mării Negre şi Platforma Continentală*, 698–699, The publishing house of the Romanian Academy, Bucureşti.
19. Pişota, I. 2005 b. *Podişul Dobrogei de Nord – Caracterizare generală*, In: Posea, G, Bogdan, O, Zăvoianu, I, eds. Geografia României, V, Câmpia Română, Dunărea, Podişul Dobrogei, Litoralul Românesc al Mării Negre şi Platforma Continentală, 796–798, The publishing house of the Romanian Academy, Bucureşti.
20. Salmi, T., Määttä, A., Anttila, Ruoho – Airola, T., Amnell, T., 2002. *Detecting trends of annual values of atmospheric pollutants by the Mann – Kendall test and Sen's slope estimates – the excel template application Makesens*, Ilmanlaadun julkaisuja, Publications on air quality, no. 1, Ilmatietten laitos, Meteorologiska Institutet, Finish Meteorological Institute.
21. Sandu, I., Pescaru, V. I., Poiană, I., Geicu, A., Cândea, I., Ţâştea, D., 2008. *Clima României*. Administraţia Naţională de Meteorologie, The publishing house of the Romanian Academy, Bucureşti.
22. Torică, V., 2004.*Condiţiile climatice şi influenţa lor asupra cadrului geografic din Dobrogea de Sud*. PhD. thesis, University of Bucharest, Faculty of Geography, Bucharest.
23. http://eca.knmi.nl accesed on November, 24, 2009.
24. http://www.eea.europa.eu, 2009 accesed on February, 14, 2010.