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EXCEPTIONAL FLOODS ON THE RAZNIC RIVER (SOUTH-WESTERN ROMANIA)

INUNDAȚII EXCEPȚIONALE PE RÂUL RAZNIC (SUD-VESTUL ROMÂNIEI)

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Abstract: The paper examines the exceptional floods that appeared within the Raznic river basin, more specifically, their amplitude, causes, and consequences. In order to accomplish the objectives, hydrological data were used to identify the characteristics of flash floods recorded in the years 1972, 2006 and 2023. Finally, the inventory of the socio-economic damages recorded led to the analysis of structural and non-structural measures proposed and implemented by local authorities. The research offers an insight on the dimension of the maximum discharges recorded during exceptional floods (1972 – 190 cm/s; 2006 – 188 cm/s; 2023 – 210 cm/s), their frequency and return period. The importance of the study lies in the fact that it manages to revive both the insufficient scientific and stakeholder concerns on this kind of hydrological risk, issued in a small catchment, considering their recorded effects and the high frequency of occurrence.

Key-words: *maximum discharge, flash flood, damages, mitigation measures, the Raznic river*
Cuvinte cheie: *debit maxim, viitură, pagube, măsuri de atenuare, râul Raznic*

1. INTRODUCTION

1.1 European framework

Floods are among the most important weather-related loss events in Europe due to their large economic consequences, producing total losses of over 50 billion over the past decade (EEA, 2010). The prevention and protection against floods represent a high-priority long-term action in the European Union, which commits to concentrate all efforts by the Floods Directive (60/2007/CEE).

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Extreme precipitation events and floods are frequent, and projected to increase, in many European countries, with a great concern in Eastern Europe, one of the existing flood hot spots (Vautard et al., 2014). Flash flood events all over Europe were also analysed through numerous international research projects between different institutions, such as the HYDRATE Project, *Integrated flood risk analysis and management methodologies* – FLOODsite and *European flood forecasting system* - EFFS.

1.2 Romanian context

At national level, in recent years progress has been made in flood risk management by implementing of the *National Strategy for Flood Risk Management* (2005) and *the National Strategy Flood Risk Management on medium- and long-term* (2010). According to Arghiuş et al. (2014), at the level of these documents, there are still many issues that must be solved: a lack of or no feedback on the educational activities among the population regarding flood risk; a lack of sustainable awareness of the administrative authorities involved in operative management of flash flood risk.

Due to the climate changes occurred in the last decades, the frequency and intensity of hydrological risk phenomena are increasing. In this context, national research targets aspects such as:

- structural measures (Moroșanu, 2012);
- GIS Assist system to raise awareness of forecasters over a particular context (Ștefănescu, 2013);
- hydro-meteorological conditions (Dunca, 2013) and hydraulic models (Popescu & Bărbulescu, 2023);
- historic flood events using open-source optical imagery (Romanescu et al., 2017) and potential flash floods risk areas using physiographic method (Minea et al., 2017);
- flash flood susceptibility potential (Prăvălie & Costache, 2014; Iosub et al., 2020; Dragomir et al., 2020);
- Flash Flood Potential assessment using hybrid models (Costache, 2019) or Flash Flood Potential Index integrating statistical methods: frequency ratio and weights-of-evidence (Costache & Zaharia, 2017);
- flood susceptibility and the accessibility using field observations and GIS techniques (Popescu & Bărbulescu, 2022).

In 2015, Chendeș et al. proposed a database design for better understanding the patterns of socio-economic vulnerability to floods at regional and national scales and of the adaptive capacity of living areas along the main rivers of Romania. In recent years, the GIS method has become the most popular in the analysis of geospatial data, especially in the flood risk management. Flash Flood Potential Index (FFPI) represents an index that allows us to identify the areas with high susceptibility to flash floods (Zaharia et al., 2017; Costache, 2019; Costache, 2023). Geographic Information Systems and Unmanned Aerial Vehicles have been used in Romania with practical application in the study of flood risks in small river basins where measurements and digital spatial databases are missing (Bilașco et al., 2022). In the last years, the assessment of flash-floods and flood susceptibility is Romanian scientific topic propose solutions for reducing the economic damage and diminishing the number of victims (Costache et al., 2021).

In this context, the present paper aims to to identify and analyze the first three exceptional floods produced by on the Raznic river in Southwestern Romania.

2. DATA AND METHODS

2.1 Study area

The Raznic river is the most important river in Bălăcița Piedmont, a right tributary of the Jiu River, with a length of 13 km and a basin area of 498 skm. The Raznic river has seven tributaries: the Mereţel, the Recea, the Urdiniţa, the Brabova, the Răchita, the Pleşoi, and the Breasta, according to the Romanian Water Cadastre Atlas (Fig. 1).

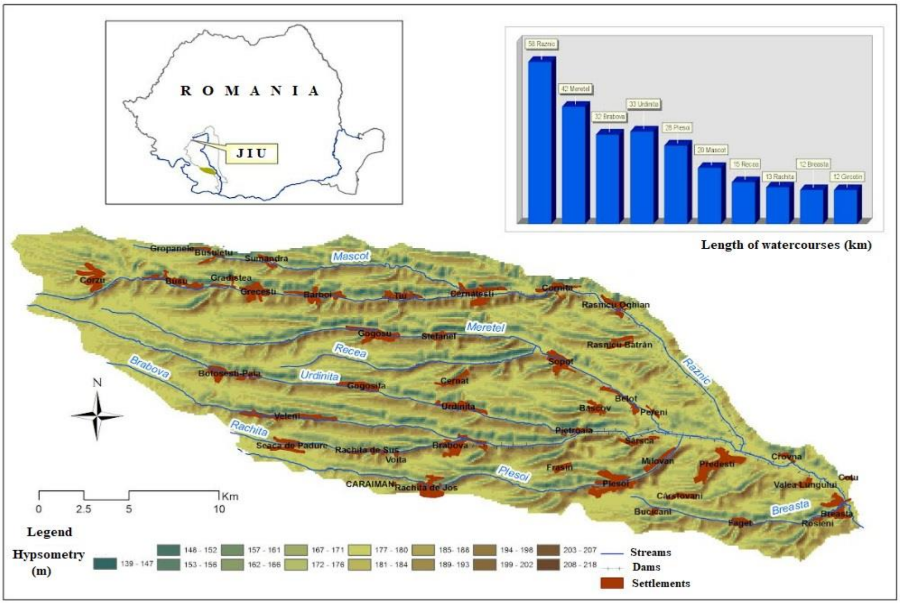

Fig. 1 Hypsometric map and hydrographic network – the Raznic river basin
(Source: author's processing using SRTM, 30m- https://www.usgs.gov; https://geoportal.ancpi.ro/portal/home)

In the Raznic basin, the interfluves are bordered by slopes with wavy appearance, that often end with a glacis at their base. The relief fragmentation density, with values between 0.5 and 1.0 km/km^2, has the highest share, occupying half of the hydrographic basin (51.87%) (Boengiu, 2008).

The Razniv river flow is monitored at Breasta hydrometric station, which closes the catchment basin (approximately 800 m from the confluence with the Jiu River), the multiannual average flow recorded being 1.30 m^3/s (Savin, 2008).

From the analysis of the maximum annual flows recorded in the last 30 years on the Raznic river, the years 2005, 2006, 2013, 2014, and 2023 stand out. These years are characterized by high values appearing in a relatively small data set, which confirms the abrupt alternation of years with water deficit (2000, 2001, 2020, 2021, and 2022) with those in which significant floods were recorded (Fig. 2). Maximum flows (flow peak) higher than 150 m^3/s generated floods and only those in 2006 (188 m^3/s) and 2023 (210 m^3/s) have the status of being exceptional due to the damages recorded.

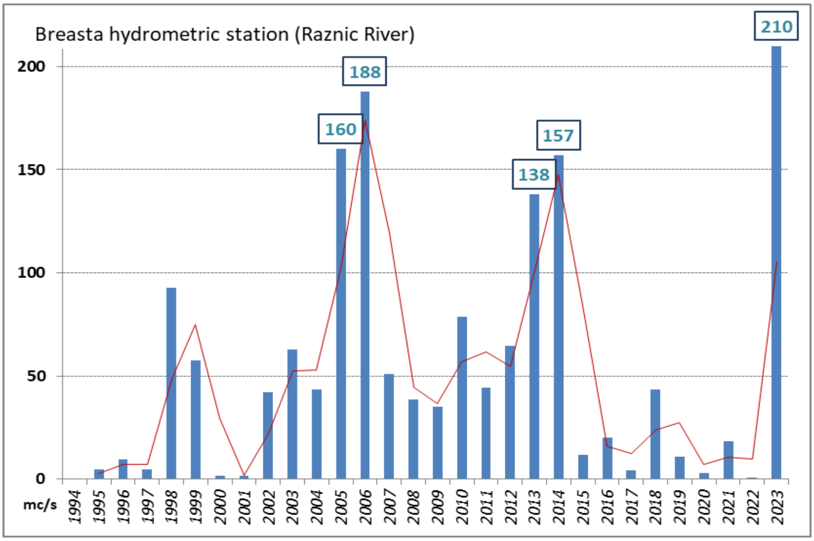

Fig. 2 Variation of the maximum annual flow recorded at Breasta hydrometric station

(Source: Jiu Water Basinal Administration – A.B.A. Jiu)

2.2 Data and methods

In order to achieve the hydrological analysis of the return periods of the maximum discharge registered at Breasta hydrometric stations, the authors applied statistics analysis by using a software package named CumFreq: cumulative frequency analysis with probability distribution; this statistical program, which calculates the cumulative frequency and realizes probability fitting of data series, was developed by *The Institute for Land Reclamation and Improvement* (ILRI), from Netherlands. This statistical method is based on input data from a long observation period; the information was supplied by the 'Romanian Waters' National Administration - Jiu Branch, and covered a 30 years period. Furthermore, the distribution preference selected is Gumbel (Fisher-Tippett I), a particular method of the generalized extreme value distribution used in hydrology.

To fulfill the purposes of the research, we used the historical method, statistical methods, and graphical method. The analysis of the flash floods territorial impact was achieved on the basis of the data provided by the central and territorial specialized services of *Jiu Water Basin Administration* and *Inspectorate for Emergency Situations "Oltenia" of Dolj County*, of those provided by the local officials, as well as on the basis of local press publications.

3. RESULTS AND DISCUSSIONS

3.1 Hydrological analysis

More than 150 flash flood events have been observed in the last 30 years in Romania. Torrential rain is key to the onset of flash flooding but the drainage and topography of the surrounding area determines the scale and impact of the event (Stăncălie et al., 2009). Precipitations, lower than in Western Europe, are unequally distributed in time and space in Romania. Their volume is sometimes concentrated in one or two months, while in the rest of the year, weeks or months without precipitation are recorded, leading to floods followed by soil deprivation of water and further, erosion and desertification (Ciulache & Ionac, 2007; Romanescu & Stoleriu, 2017).

The last years have proved, also in Romania, that the current trend of climate patterns is changing towards a consistent rising in great rainfalls episodes that are generating flash floods and their associate hazards for human settlements. Although, 2022 and 2023 were considered dry years, in terms of total amount, the torrential rain episodes were responsible for the issuing of more than 900 threat warnings for the two years combined (Zaharia et al., 2024).

In Southwestern Romania, most floods occur as a result of heavy rains in the transitional seasons, when the receptor substrate bed is saturated, floods then being associated with flash flood phenomenon (Moroșanu, 2014). For the Raznic river, previous studies have highlighted the flow peaks registered at Breasta hydrometric station and their different exceeding probabilities: 471 cm/s – 0.1%; 271 cm/s – 1%; 144 cm/s - 5%; 96 cm/s – 10% (Telteu et al., 2014).

In the Raznic river basin, numerous floods occurred, which led to increased flow discharge, recorded at Breasta hydrometric station. The highest flows were recorded in 1972, 2006, and 2023. The flood of April 3, 1972, was triggered at 17:00, the flow began to increase on April 4. The flood peak (Qmax) was recorded on April 8 at 2:00, reaching 190 cm/s, with a height level of 616 cm. The decrease time took place on the 14^{th} day, in 317 hours. The total duration of the flash-flood was almost 18 days (422 hours).

In 2006, flood began on March 11, which led to the recording of a significant flow. The flood peak (Qmax) was recorded on March 13, reaching 188 cm/s, with a height of 635 cm. The maximum flow in 2006 is lower, compared to the one in 1972; the total number of days in which floods occurred decreased, but an increase in flow discgarge, between 1972 and 2006, is observed (Table 1).

The 2023 flood, produced on June 12, at 06:00 am, recorded a maximum discharge (Qmax) of 210 cm/s and a maximum level of 920 cm. The total propagation time of the flash-flood was 10 days. Compared to the 2006 flood, the 2023 flood had a stronger impact. The flow peak, the level, and total propagation time were higher. The flow discharge recorded in 2023 was higher in the Raznic basin, compared to the Jiu basin, because the Raznic river basin is smaller in terms of depth and surface. Also, being located in a piedmont area, more precisely in Bălăcița Piedmont, torrential rains lead to the accumulation of a larger amount of precipitation in a relatively short time. Thus, morphometric elements played an important role in the occurrence of the flood from June 12, 2023 (Fig. 3).

Table 1 Main parameters of historical floods on the Raznic river at Breasta hydrometric station

	Parameters	1972	2006	2023
Flood triggering	Day	3	11	12
	Hour	17	12	06
	Qb (cm/s)	0.197	3.62	0.420
	H (cm)	148	230	340
Growth values	Days/Hours	4/105	2/51	4\102
	+ΔQ (mc/s)	190	184.3	193
	+ΔH (m)	4,68	405	430
Flow peak	Day	8	13	16
	Hour	2	17	12
	Qmax (cm/s)	190	188	210
	Hmax (cm)	616	635	920
Descent values	Days/Hours	14/317	4/72	6/144
	-ΔQ (cm/s)	189	184.7	130
	-ΔH (cm)	3.99	415	270
Time total	Tt Days/Hours	18/422	6/123	10/246

(Source: Savin, 2008; Jiu Water Basin Administration data)

Fig. 3 Propagation of the July 2023 flood peak on the Raznic river - middle sector

(Source: Gazeta de Sud, 16.06.2023)

The frequency of the maximum discharge and return period during the 30 years (1994-2023) was established by using a statistical method – cumulative frequency analysis with probability distribution. The analysis of the statistical values highlights a low frequency of occurrence of the maximum flows recorded on the Raznic river in the analyzed years (5% for 188 cm/s - 2006 and 2% for 210 cm/s - 2023), which leads us to classify the respective floods as exceptional (Fig. 4).

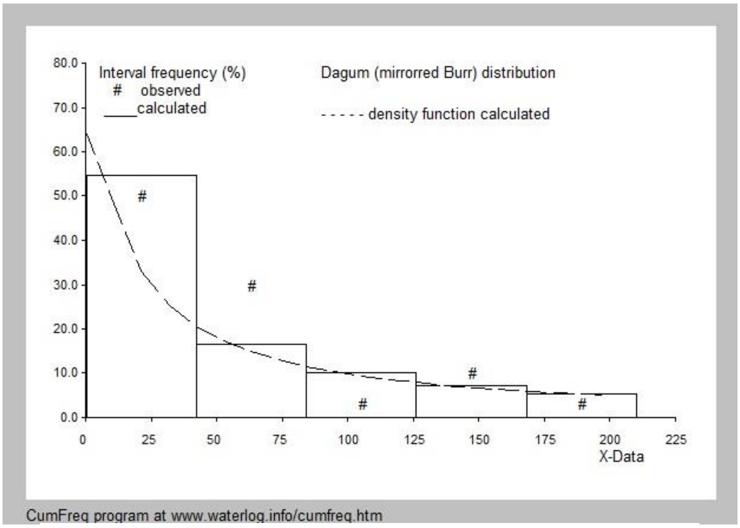

Fig. 4 Frequency analysis of the maximum discharge at Breasta hydrometric station (1994–2023)
(Processing of the data supplied by Jiu Water Basin Administration)

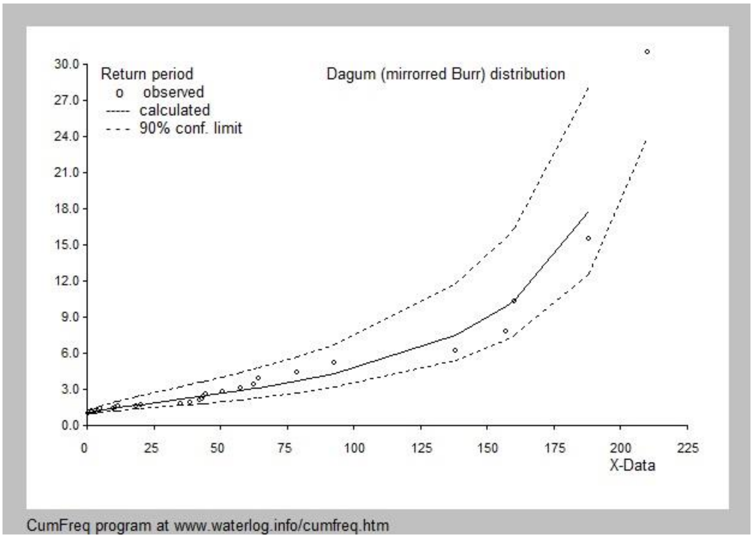

Fig. 5 Return period of the maximum discharge at Breasta hydrometric station (1994–2023)
(Processing of the data supplied by Jiu Water Basin Administration)

Certainly, if the data series in the analysis is extended, up to the level of 1972, these frequency values would decrease even more.

The results obtained, in the case of return period, are 15 years of return for a flow of 188 cm/s and 31 years of return for 210 cm/s (Fig. 5). In the case of this analysis, the magnitude of the 2023 floods and the socio-economic damages recorded are confirmed.

3.2 Impact assessment

The risk associated with extreme hydrological processes (flash floods, floods) is more present than ever, taking into account the global climate changes, the expansion of inhabited areas and the changes emerging as a result of inadequate land management (Rîndașu-Beuran et al., 2020; Kocsis et al., 2022).

According to EEA 2017, river floods are estimated to affect approximately 300,000 people per year in the EU by the 2050s and 390,000 people by the 2080s.

In the small tributary drainage basins, floods may have occurred due to the existent conditions of deforestation, inappropriate anthropogenic structures (such as dams, bridges, and culverts) and low-flow channel occupancy due to location of economic objectives or housing (Cojoc et al., 2015; Romanescu & Nistor, 2011).

By comparing the unit peak discharges with other specific flash flood peak discharges from Romania (the Siret River basin, the Prahova River basin and Transilvania Depression), it was noticed that flash floods on the Raznic river are rare events and have a moderate intensity. Nevertheless, in some settlements (Cernătești and Grecești) even moderate intensity flash floods can trigger disasters (Table 2).

Table 2 Flood damage from July 2023 – the Raznic river

Settlement	Institutions (no)	Roads (no)	Househo lds (no)	Arable land (ha)	Evicted persons (no)
Cernătești	2 schools	-	26	50	80
Grecești	-	- county road 606 B - county road 606 C	120	-	70
Găiești	-	-	3	-	-
Breasta	-	- county road 606 A	16	14	-
Total	2	3	165	64	150

(Source: Inspectorate for Emergency Situations "Oltenia" of Dolj County)

The hydrological situation in Dolj County was constantly monitored, with resources being allocated depending on the evolution of the situation, gradually, both at the local level and county level. The most affected settlement is Grecești, with Grecești, Busu, and Gropanele villages (Fig. 6a,b). Here, over 100 l/km^2 were recorded in a 30-minute period. Heavy rainfall was recorded in a short period of time, runoff from the slopes, and the overflow of the Raznic River, determined the flooding of over 140 households. About 2 km of DJ 606B county road, between Grecești and Busu villages, was flooded and traffic was interrupted during the evening. In Gropanele village, a bridge over the Mascot stream (a tributary of the Raznic) was damaged (*Inspectorate for Emergency Situations "Oltenia" of Dolj County*) (Table 2, Fig. 7a,b).

Fig. 6 a Flooding of the Raznic floodplain and DJ 606B in Cernătești
(Source: Gazeta de Sud, 17.06.2023)

Fig. 6 b. Household affected by flood, caused by Raznic river in Grecești
(Source: Digi24, 17.06.2023)

Fig. 7a Involvement of the local authorities in the evacuation of inhabitants from Cernătești
(Source: Sursa Zilei, 17.06.2023)

Fig. 7b Jiu Water Basin Administration intervention by raising sandbag piers in Cernătești settlement
(Source: Cuvântul Libertății, 06.06.2023)

3.3 Structural measures and mitigation actions

Under EU Directive 2007/60/EC on the *Assessment and Management of Flood Risks* (Floods Directive), the first stage prior to hazard and risk mapping, consisted of a preliminary flood risk assessment and delimitation of areas with significant potential flood risk. Flood risk mitigation is a key issue and a permanent challenge in developing policies and strategies at various spatial scales (Zaharia et al., 2015; Zaharia et al., 2017).

The main structural measures taken by the Jiu Water Basin Administration for flood risk reduction in the Raznic river basin concern the defence levees constructed along the Raznic and its tributaries. These types of actions were taken in accordance with the Flood Directive and the Flood Risk Management Plan in Jiu basin (2022):

- Breasta-Raznic dam, 1530 m long, 2.2 m high;
- Predești-Raznic dam, 5000 m long, 1.5 m high.

Within the areas with potentially significant flood risk, established in the IInd cycle of the implementation of the Floods Directive for the study area, the Raznic river, downstream of Busu locality, is identified over a length of 49 km (identification code RO2-07.01.043....-01A). In this case, through the *Jiu River Basin Flood Risk Management Plan* (2022), green measures as M31-RO17, M31-RO19, and M33-RO36 type are imposed, that aim to protect, enhance or restore the natural functioning of watercourses, with an emphasis on measures to ensure lateral connectivity, improve the morphology of the banks.

Regarding transport infrastructure, there are remote areas in the upper Raznic basin where *Inspectorate for Emergency Situations "Oltenia" of Dolj County* intervention is very difficult and time consuming. To improve the intervention capacity, we recommend the modernization of the county road between Breasta and Grecești (DJ 606 B).

According to UNISDR (2013), resilience stands for the ability of a community or society that is exposed to hazards to resist, absorb, adjust, and recover in a rapid and efficient manner after a crisis. At regional level, the main institutions that deal with flood risk management are the Jiu Basin Water Administration (provides the *Flood Risk Management Plan for the Cerna - the Danube - the Jiu hydrographical space*) and the County Inspectorate for Emergency Situations (provides the *Leaflet concerning the Proper Actions in Flood Situations; the Risk Coverage and Analysis Plan for Dolj County*).

Raising awarness of flood risk reduction in Cernătești and Grecești settlements could be supported by a local preparation campaign, conducted with the goal of motivating inhabitants to develop capacities of social adaption before the occurrence of a new exceptional flood.

4. CONCLUSIONS

This research proposes a holistic approach to flood risk management that combines quantitative and qualitative aspects for a rural flooding area.

We conclude that the results could lead to a better knowledge and understanding of flood characteristics in the study area, in order to mitigate the flood risk through a more effective management, both at catchment scale, as well as local scale (in Cernătești and Grecești villages). Furthermore, the decision-makers will have a clearer image regarding the places they must implement measures to reduce the water runoff on the slopes, to arrange the torrential valleys, and to protect the areas exposed to floods. Finally, future studies regarding the analysed area will focus on risk assessment concerning all territorial infrastructures and the solutions meant to mitigate these risks.

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