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HISTORICAL FLOOD OF 2005 IN TARCĂU CATCHMENT

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ABSTRACT. – Historical Flood of 2005 in Tarcău Catchment. During the flood of 12 – 15 July the water level in the lower sector of the valley exceeded the one estimated for a 100-year flood, and the maximum discharge was almost twice larger than the previous peak. This extreme event generated the largest damage in Tarcău catchment, in total value of over 21,000,000 lei. The main affected element was the transport infrastructure. It also determined a change in flood perception of the local authorities, leading to the creation of a Voluntary Service for Emergency Situations the same year and investments in flood proofing.

Keywords: *historical flood, peak discharge, flooded area, damage, transport infrastructure.*

1. INTRODUCTION

There is a woldwide increasing trend in vulnerability to flooding, because of the altered frequency – magnitude relations, and an increased exposure of humans and their property (www.munichre.com, 2007). A similar trend can be identified for the catchment of Tarcău River too, considering the increasing discharge values for the summer months, both for average and maximum ones, although the trend slope does not have a high value.

Tarcău River is a right side tributary of Bistrița River, and its catchement drains most of Tarcău Moutains, covering 392 km^2. Its hydrological regime is a characteristic one for the Eastern Romanian Carpathians, indicating a pluvial recharge, no winter floods and high waters in spring and summer (Ujvari, 1972). The multiannual average discharge value ranges between 1.15 m^3/s at Ardeluța, the upstream gauging station, and 4.32 m^3/s at Cazaci, the downstream one. Pluvial floods are the most frequent, 66% of the annual floods occurring in summer, 26.19% in autumn, and just 7.14% in spring. The average seasonal runoff values indicate the highest runoff in summer (35.8%) and spring (34.6%). The fact that most floods occur in the same seasons may result in more intense ones, if they overlap periods of high waters. Considering the factors that influence the intensity and dynamics of a flood, Tarcău River catchment has its particularities. There is an obvious asymmetry, as the tributaries on the left are in some cases twice as long as the right side ones (fig. 7). It determines thus a fairly circular shape of the watershed, slightly elongated on the south to north flow direction of Tarcău that influences the flood range. The slope and forest cover also control the time

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of concentration. The altitudes range from 385 m to 1664 m, slopes vary dominantly between 15° and 35° (61.21%), thus the average catchment slope of 20-21° implies a rapid water flow. The forest cover intercepts a certain percentage of the rain, reducing the amount that reaches directly the river bed; the older the stand, the higher its consistence and a greater quantity of water it intercepts. Also, the interception is higher if the rain intensity is lower. Most of Tarcău catchment area (83%) is covered in forest, either in mixed stands of broad-leaf and coniferous trees, or pure stands of spruce, fir, or beech. The forest has been capitalized for the last 160 years, thus the age and consistency of stands are variable.

Floods occur yearly in Tarcău catchment, but some of them are considered extreme events because of the discharge values and corresponding water level that define them. There is always the possibility that an event with lower occurrence probability but higher magnitude than the supposed extreme event occurs (Woo, 2002). Sometimes, the term extreme event is used only to define these situations when all the historical observed water levels are exceeded.

A report of the local branch (Neamț) of the water administration indicates that the main damage generating floods on Tarcău River after 1970 occurred in 1974, 1975, 2004, 2005, 2006, 2007, 2008 and 2010. The 2005 event stands out both due to the historically maximum values of the hydrological parameters but also because of the highest losses.

2. METHOD AND DATA

The paper presents the extreme event that generated the largest damage in Tarcău catchment, in a quantitative analysis of the parameters that characterise the flood and the resulting damage. The data used consists of hydrological data, average and maximum discharge values for the two gauging stations for the last 20 years, and the hydrographs of the 2005 summer floods. The daily precipitation values were also considered, as they were the triggering factor. The flood impact was evaluated by analysing the damaged elements, a monetary value being attributed to each of them.

3. RESULTS AND DISCUSSIONS

The two highest floods of 2005, occured between 12 and 15 of July and between 17 and 22 of August. If for the latter the peak discharge (135m^3/s at Cazaci gauging station) attained the previous maximum (134 m^3/s at Cazaci gauging station on 18th of August 2002), for the former, the discharge and water level values were the highest ever observed (table 1). The peak discharge of 217 m^3/s exceeded by 61.94% the previous maximum value registered at Cazaci gauging station (134 m^3/s on 18th of August 2002), while the difference is just of 18.69% at Ardeluța, as the previous maximum reached 107 m^3/s. At both gauging stations the danger level set at 3 m was exceeded.

Characteristics of the July 2005 historical flood.

Table 1

Gauging	Q_{max}(m^3/s	H (m)	Flood start	Flood crest	Flood end
Ardeluța	127	3.5	12.07 around 6^{00}	12.07 around 18^{00}	15.07 around 6^{00}
Cazaci	217	4.6	12.07 around 6^{00}	12.07 around 20^{00}	15.07around 6^{00}

Raw data source: SGA Neamț

As their occurrence date also indicates, both floods were of pluvial origin. On the 12th of July, the historical maximum 24h precipitation value was measured, 150.7 mm at Ardeluța gauging station, and 147.8 mm at Cazaci gauging station. In the first case, the multiannual mean precipitation value of the month (147.38 mm) was exceeded, while the value measured at Cazaci was just 6.6 mm lower than July multiannual mean (154.4 mm). The heavy rain was generated by an Atlantic cyclone that occluded on the 11th of July on the polar circulation background. The occlusion and the atmospheric instability lasted around 3 days, and were maintained by a cold high altitude nucleus, that dispersed on the 14th of July. Radar images indicated a northward direction of clouds, therefore, considering the river flow direction, the rain travelled along the catchment from upstream towards downstream. Diaconu (1994) states that a flood generating rain that travels in the same direction as the river flow leads to a higher peak discharge. As shown in figure 1, the heavy rain on 12th of July generated one peak flood, the precipitation amount dropping considerably the next day, on the 13th the total rainfall reaching just 33.2 mm.

The fact that it was an extreme event is also confirmed when considering the discharge and level values calculated for different return periods and their corresponding exceedance probability (table 2), the ones of the 2005 event not matching the thresholds. The 127 m^3/s and the 3.5 m registered at Ardeluța would indicate a return period between 50 and 100 years, while in the case of Cazaci gauging station, the 217 m^3/s does not reach the 5% discharge value and the 4.6 m exceeds the estimated 1% one.

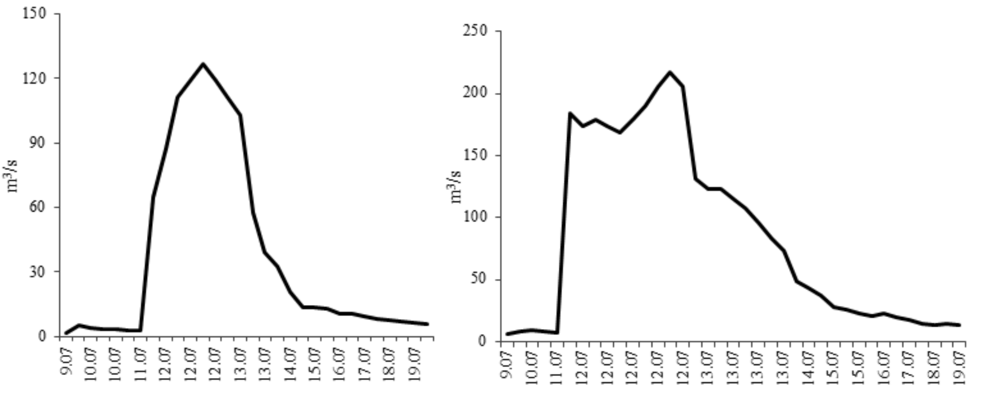


Fig. 1. Hydrograph of the historical flood of July 2005: Ardeluța gauging station (left) and Cazaci gauging station (right) (Raw data source: SGA Neamț).

Discharge and water level values of different exceedanceprobability (SGA Neamț 1995).

Table 2

Ardeluța			Cazaci		
H (m)	**Q (m³/s)**	**%**	**H(m)**	**Q(m³/s)**	**%**
4.1	177	1%	4.2	475	1%
3.3	95	5%	3.2	268	5%
3	77	10%	2.7	198	10%
2.4	43	20%	2.2	137	20%

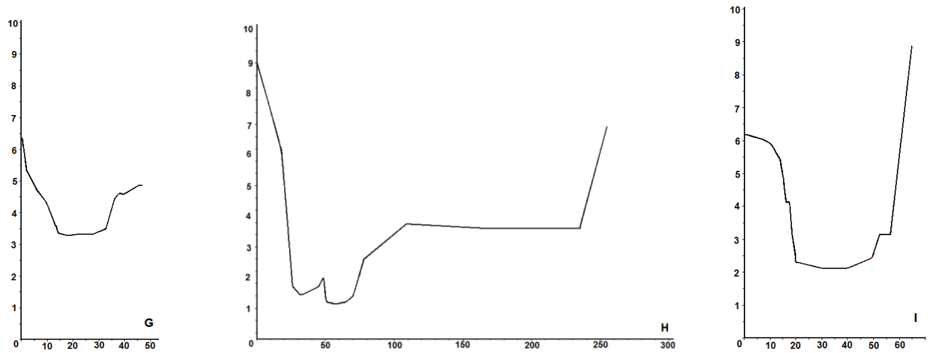
Though measurements at both gauging stations indicated a very high water level, that exceeded 3 m, the **flooded areas** were fairly reduced (fig. 3), as a result of the river bed configuration, its depth ensuring the protection of the overbanks. From a geological point of view, most of Tarcău catchment area overlaps the nappe of Tarcău, consisting mainly of two types of sandstones, Tarcău and Fusaru sandstone disposed in thick banks that reach even 10 m. The valley of Tarcău overlays theTarcău syncline, with a slight eastwards divergence from its axis (Do Hung Thanh, 1974) that determines the river to cut the strata sometimes almost vertically. Therefore, most of the river bed is cut directly into the sandstone layers, ensuring highly cohesive banks. Due to the high depth of the river bed, the flooded overbanks areas were reduced, and were present mainly downstream of Cazaci gauging station. The series of cross sections presented in figure 3 try to illustrate it and explain why the only major flooded area was Lunca Lăcătușului (cross section F, fig. 3). For the four cross sections upstream of section E (Cazaci gauging station) the average depth is larger than 4 m and the width of the invert does not exceed 40-50 m. Cross section E is a good example of the influence of the geological structure on the river bed configuration, as the river bed is cut in a thick layer of Fusaru sandstone (fig. 2). Downstream of it, the river bed widens and its depth is reduced to maximum 3 m. The sector down to cross section H is the one most prone to flooding.

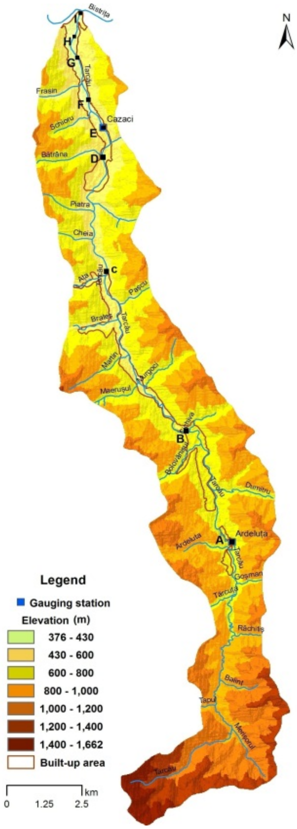
Fig. 2. The left bank of Tarcău River 25 m upstream of Cazaci gauging station (up); the water level during the historical flood in the same location (down– photo:Iulian Găină).

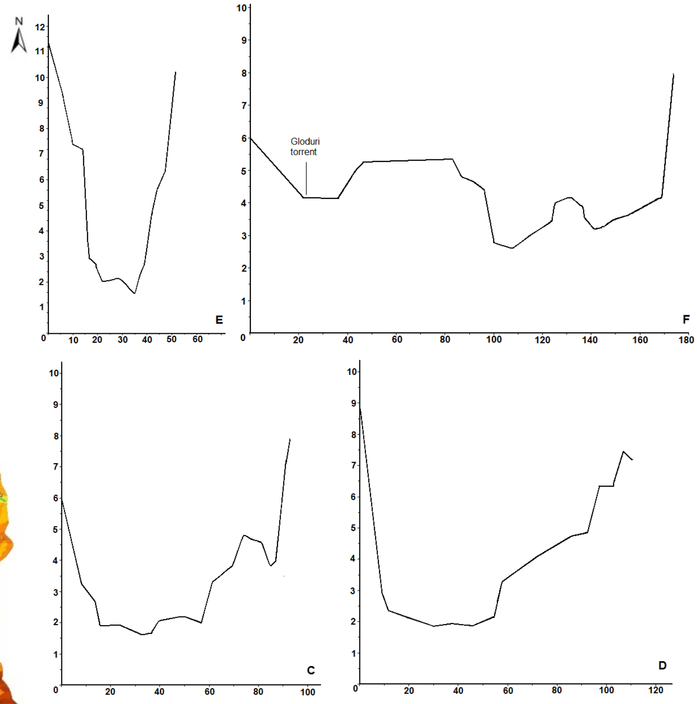
However, usually not both overbanks are flooded at once, one of them being higher, and at least one being cut directly in the layers of Fusaru sandstone (for example the right bank of cross sections F and H). Downstream of cross section G the height of the left bank increases, decreasing again close to the junction of Tarcău and Bistrița River. Cross section I depicts the sector of Tarcău valley cutting the terraces of Bistrița River, the 5–7 m one on the right, and the 2-4 m on the left (Donisă 1965).

The largest **flooded area** of about 5.5 ha, is indicated by cross section F and presented in detail in fig. 4. Lunca Lăcătușului is a former holm of Tarcău (located in its downstream part, cross section F includes also the small holm in the river bed) currently occupied by 26 households. However, although the flooded area overlaps most of Lunca Lăcătușului, the number of damaged households is reduced, the reports of the local administration ofTarcău commune indicating only 2 of them (tabel 3). This results from the low water depth in the inhabited area that did not lead to important damage to most of the households, for the situations when the water depth did not exceed the houses foundation, no compensation being needed. The high monetary value attributed to the damage registered for the households results from the partial destruction of a house (50% of it collapsed and had to be relocated), generated by the erosion of the alluvium it was built on (fig. 5). Considering the slight north-eastern flow direction, the left bank is more susceptible to intense lateral erosion as it is the concave one. Therefore, even if the overall water level in Tarcău river bed was very high, and a large part of Lunca Lăcătușului was flooded, the erosive effect of the water was the most destructive, the alluvial structure of the left bank making it easily erodible. Also the bank height in the downstream part of Lunca Lăcătușului reaches around 2 m (cross section F in fig. 3), compared to its lower upstream part, partially explaining why the water depth on the left overbank was reduced. The right bank is little susceptible to flooding or erosion due to its height and presence of a layer of Fusaru sandstones.

However, the flooding of Lunca Lăcătușului in 2005 was not caused only by Tarcău River, but also by Goduri torrent which uses Tarcău old secondary channel to direct its water towards the current river bed and the other temporary watercourses that drain the slopes. The four gullies (fig. 4) function as channels for the waters that come down the slope during heavy rain episodes or result from the melted snow, the two large patches of grassland located above the gullies representing their drainage basin. Their location on the scarp of the 35 – 40 m terrace just above the communal road determines that the gravels removed are dumped on the road during the intense erosive episodes, affecting its structure and limiting the traffic. The material transported both inside the gullies and by Gloduri torrent during the historical flood led to the destruction of the road in this location, thus interrupting the traffic upstream. The same situation occurred also 1.5 km upstream, close to the junction area of Bătrâna and Tarcău River, where the road was destroyed by the material eroded by a torrent and a large gully.







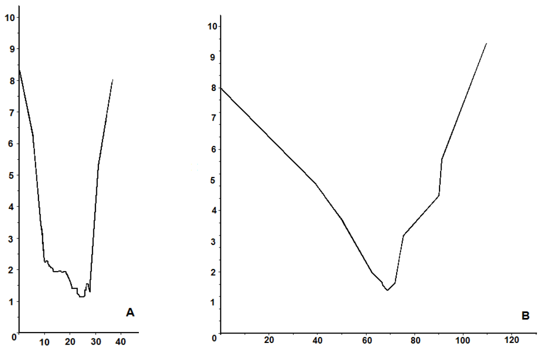


Fig. 3. Cross sections in Tarcău river bed (The map present just the valley of Tarcău due to space reasons).

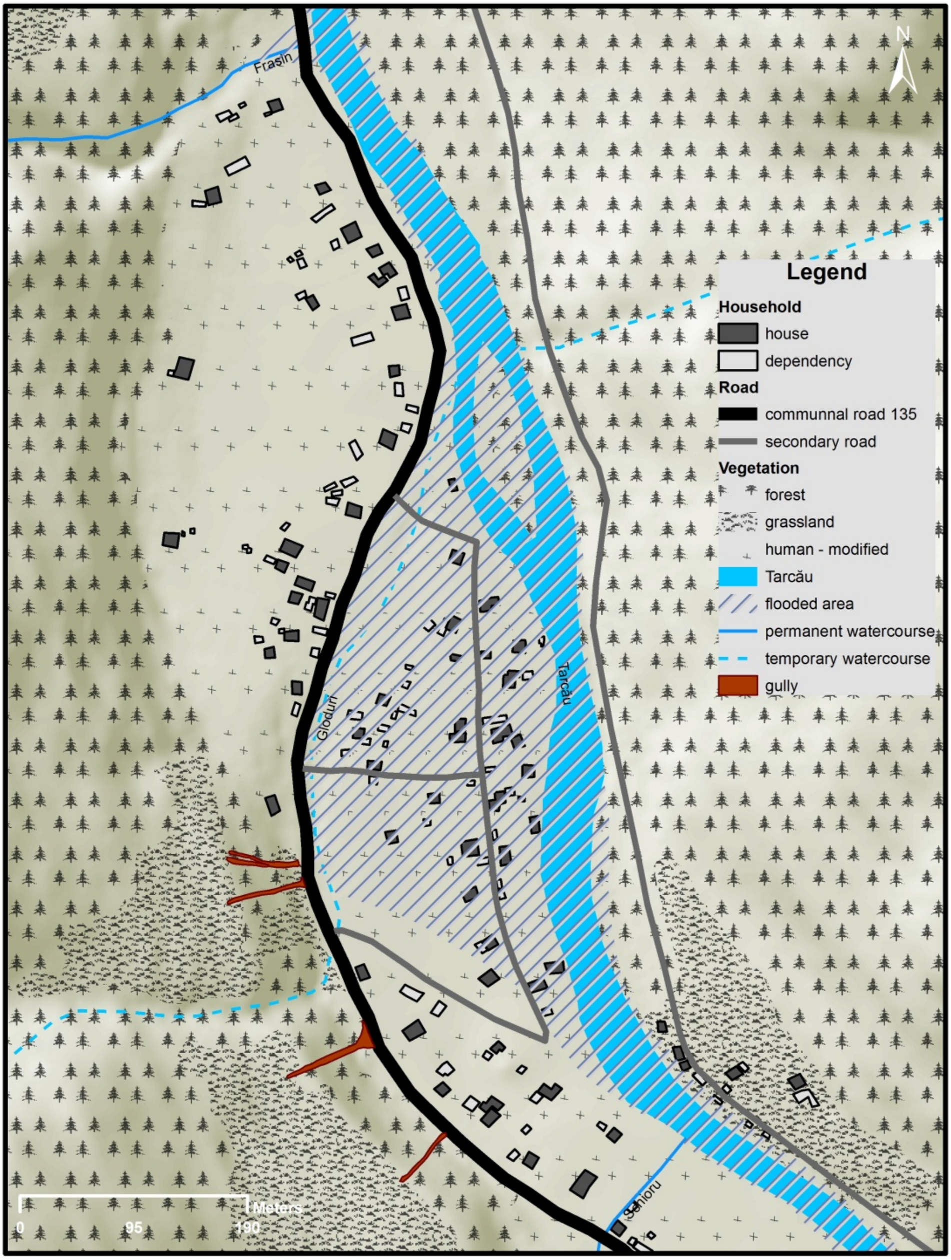


Fig. 4. The flooded area in Lunca Lăcătușului.

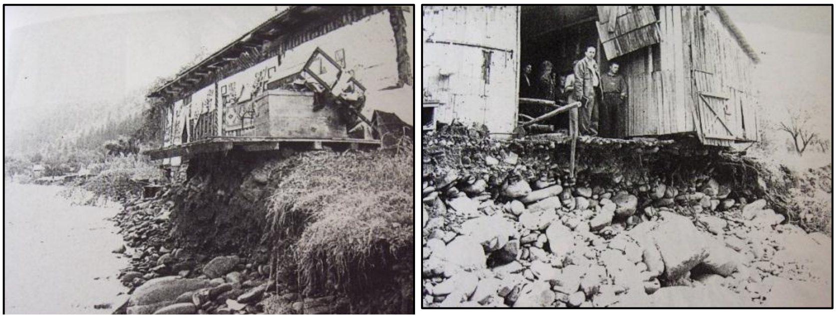


Fig. 5. House and dependency damaged by the effects of lateral erosion (photos: Iulian Găină).

The damage caused by the historical floods of 2005 in the built-up area.

Table 3

Village	Damaged elements	Value	Total
Tarcău	1 household	4,000	
	2 bridges and 2 footbridges	3,130,000	
	1.5 km of eroded banks and 2 bridge piers	-	3,134,000
Cazaci	2 households	45,000	
	0.265 km of asphalted road	428,000	
	1 footbridge	250000	
	1.3 km of eroded bank	-	723,000
Brateș	0.047 km of asphalted road	965,000	
	0.36 km of eroded bank	-	965,000
Total	3 households	49,000	
	2 bridges and 2 footbridges	3,380,000	
	0.312 km of asphalted road	1,393,000	
	3.16 km of eroded bank and 2 bridge piers	-	**4,822,000**

Downstream of Lunca Lăcătușului, at the junction of Frasin and Tarcău River, the culvert was destroyed by the flood on Frasin, the material brought by the tributary (fig. 6) including also wooden material. Considering the large percent of forest coverage, the main economic activity in the area is forest exploitation. On each major tributary valley there is a forest road that facilitates the access to the stands in exploitation. Abandonment of wood leftovers in the secondary valleys is frequent, and usually during floods this material is transported downstream, and its accumulation in narrow river bed sectors may create stoppers.

The communal road 135, the only access road that links Tarcău to the national network, was built on Tarcău lower terraces, and due to their reduced width, usually right next to the river bed (fig. 7). Therefore, as already mentioned, it can be affected by the tributaries if the culverts are badly designed, but also, by bank falls because of its proximity to the river bed. During the flood of July 2005, the lateral erosion in the left bank was so intense upstream of the junction of Măerușul Adânc and Tarcău that 70% of the road structure was destroyed for a length of 200 m. One km upstream, close to Veverița junction, the road was eroded also beacuse it was not asphalted upstream of Măerușul Adânc and there was no erosion protection for the banks.

Fig. 6. The flooding of the Frasin and Tarcău junction (photo: Iulian Găină).

The **damage** resulting from this event reached the amount of 4,820,000 lei. The affected elements included 3 households, 2 bridges and footbridges, 0.312 km of asphalted road, 3.16 km of eroded bank and 2 bridge piers. The other affected household outside Lunca Lăcătușului is located in Tarcău village, on the left bank upstream of Măciucași bridge (upstream of cross section I, fig. 3). As detailed in table 3, although the number of affected elements is not large, the important amount results from the high value of the transport infrastructure, 98.98% of the total damage being attributed to it. The fact that the villages are set on both banks of the river implied the construction of a large number of bridges, in order to maintain a good connectivity. However, since the communal road is the only one that links the entire valley to the national road 15, maintaining it in good condition is a priority. Considering that during the historical flood of July 2005 the road was blocked in 4 locations, leads to the conclusion that protection measures must be taken to avoid future similar situations. Although most

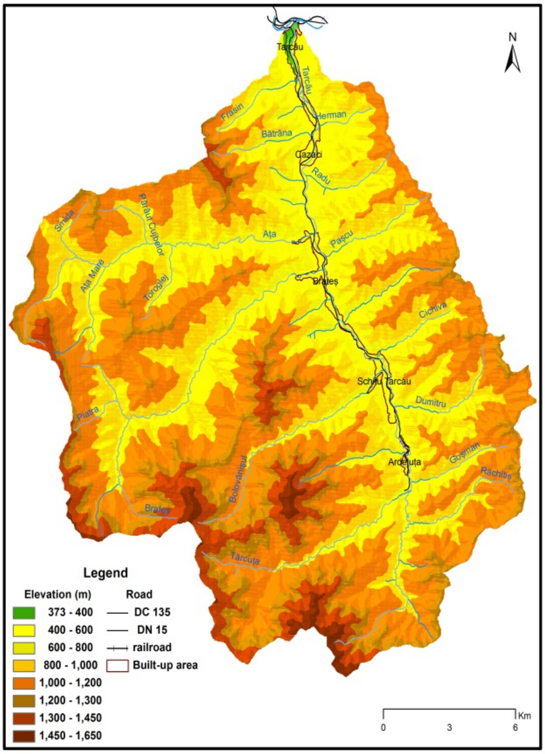


Fig.7. The catchment of Tarcău river and access roads.

of the population is concentrated in the lower part of the valley, 86% living in the villages Tarcău and Cazaci, the transport infrastructure plays an important role in the catchment of Tarcău, both from the perspective of people's safety, but also for ensuring the continuity of economic activities, the communal road being also the only option for the transport of logs, though the timber yard is located in the junction area of Tarcău and Bistrița rivers.

Most of the extremely high percentage of the damage associated to the transport infrastructure results from the affected bridges and the 2 completely destroyed footbridges. There are only 5 bridges that facilitate the access by car on both banks of Tarcău River for the 18 km of the lower sector of the valley (north of Schitu Tarcău village, where most of the population is concentrated). Considered from downstream to upstream, the distance between them is of 4.3 km (Măciucași – Cazacig auging station), 2.8 km (Cazaci gauging station -Radu forest road), 5.8 km (Radu forest road – Pașcu forest road) and 6 km (Pașcu forest road – Cichiva forest road). If the communal road is inaccessible, the only other road that links the villages is the one on the right bank, that follows the ancient path of the mountain train, but it can be accessed by car only for the lower sector, Măciucași – Radu forest road, linking the hamlet Lunca Macazului (Tarcău village) to Cazaci village. Măciucași bridge (located at cross section I in fig.4) is among the most important ones, linking the hamlets Lunca Macazului (upstream, on the right bank of Tarcău River) and Măciucași (on the right bank of Tarcău and Bistrița River, in their junction area) to the village of Tarcău. If for the former, the other access option would be by the bridge at Cazaci gauging station and the secondary road on the right bank of Tarcău, for the latter, the only access point by car is Măciucași bridge.

The total damage estimated for the built up area in the valley of Tarcău River for the historical flood of 2005 reaches the amount of 4,822,000 lei. Obtaining a correct value for the whole catchment implies the addition of the losses registered by the forest ranges that also refer to the transport infrastructure. Considering that the main forest roads in the catchment are located in the valleys of the main tributaries, their susceptibility to being flooded and eroded is fairly high. A partial estimation of the reconstruction costs for the affected roads indicated the amount of 16,265,177 lei, due to the fact that some roads were completely destroyed (as the ones on Dumitru, Polinistru and Răchitiș valleys). Therefore, the total damage value for Tarcău catchment exceeds 21,000,000 lei.

Given the circumstances and the impact of the historical floods on the small community of just 2900 people, the local administration decided on the 29th of November 2005 to set up the Voluntary Service of Emergency Situations, consisting of 61 people that are supposed to prevent, monitor and manage the emergency situations irrespective of their nature. Considering the high frequency of floods, prevention actions are important. A higher degree of preparedness may lead to lower damage.

Due to the importance of the transport infrastructure and the high damage value, while reconstructing the affected elements, protection measures for future events were also considered. Gabions were built for the eroded banks (on the left bank, downstream of Frasin, upstream of Măerușul Adânc, and Verița junction) due to the advantage of having the necessary rock on the spot, thus, making them a less expensive solution. In order to reduce the negative impact of the material evacuated from the gullies, concrete walls were built, but nothing was done to channel the waters, not even those of Gloduri torrent, which may still flood the communal road. In order to reduce the lateral erosion and flooding that affected Lunca Lăcătușului during the following years too, a 900 m long concrete wall was built in 2011.

4. CONCLUSIONS

A thorough analysis of the historical flood in Tarcău catchment was necessary, since it indicates the possible impact of an extreme event. Along with the understanding of the triggering factors, it led to the development of proper management strategies for future similar events. The floods of the following years proved the efficiency of some of the measures taken.

The very low percent of affected households indicates a good safety degree of the population, considering the floods of similar intensity and low occurrence probability. However, it does not exclude the necessity of protection measures for the inhabited areas in case of future flooding of higher magnitude. The high damage value associated to the transport infrastructure raised the awareness of the necessity to reduce maintenance costs, since it is the most affected element in the area.

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