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An unusual ice jam on Bistricioara river in the winter of 2013 – 2014

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AN UNUSUAL ICE JAM ON BISTRICIOARA RIVER IN THE WINTER OF 2013 – 2014

Claudiu Găman [1]

Abstract. This article presents the development of ice formation phenomena on Bistricioara River in the winter of 2011 – 2012, as compared to the winters 1962 – 1963 and 1963 – 1964, and the ice jam phenomenon in January 2014, on a river sector where there were no records of ice formation phenomena over the previous years, not even shore ice during the harshest winters.

Moreover, the fact that down the river course there are records of some sectors, under identical climatic conditions, with well developed ice formations and quite close there are sector with poorly developed or even no ice formations proves that there are some other factors besides the meteorological land hydrological ones that could have a strong influence on the development of ice formations (e.g., the hydraulic relations developed between the river and the areas it crosses).

Keywords: *Bistricioara River, ice formation phenomena, frazil pan, ice jam (dam), ice cover, hydraulic relations*

1. Introductory notions

The reason behind my approaching this topic is the insistently recurrent statement of Ciaglic V. (2008, 2009). He considers the Bistricioara River a "large natural laboratory" which provides "less costly solutions" for reducing up to "full removal" of the disastrous effects caused by the "huge" "anthropic and atypical" ice dam (jam) that occurs periodically on the River Bistriţa, triggering significant damage, including casualties.

The article was drafted based on hydro-meteorological data recorded at the hydrometric stations Bilbor, Tulgheş, Bistricioara, mapping carried out by Agapi O. – head technician at the Hydrological Station Piatra Neamţ, and the information collected by the author following reconstructions on 09/07/2014 (Cristinoi Ş. – secretary Mayoralty of Corbu, Bartis C. – head of Voluntary Service for the Emergency Stations Tulgheş, and Butnaru V. – Firebrigade Detachment Gheorghieni, Guard III). Every winter, various ice shapes and formations (e.g., bottom ice, frazil ice, ice slush, shore ice, ice cover, etc.) develop on rivers both at the surface of water and inside the stream, depending on the physical and geographical conditions, mainly the climate factors.

From among the numerous ice phenomena developing on rivers, the ice jam ("zăpor") is considered to be the most dangerous as it causes significant damages and even casualties (Minea, Romanescu, 2007). This is the reason why Ashton (1986) defines it as "*the greatest hazard of winter phenomena on rivers*" – quoted by Maria Rădoane *et al*. (2008). The

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blockage of the flow sector determines a drop of the water level in the downstream sector and a rise of the level upstream, "behind", the ice dam where energy builds up and react within the body of the ice jam so that in case of fast unblocking these energies can cause damages downstream (Gaman, 2014).

Depending on the moment the phenomenon develops, two types of ice dams (jams) can be distinguished: freezing up and break-up (melting) jams.

Freezing-up ice dams (jams) are recorded during the occurrence and development of ice formation phenomena on rivers (onset of winter). They are caused by the accumulation of frazil ice under the ice cover. The evolution of the development and structure of the ice jam can be notices in figure 1. Mention should be made that in case of ice jams developed on the Bistricioara and Bistriţa Rivers, this "vaulting" of the ice bridge does not occur due to the geological structure of the two valleys, which favours loss of water by infiltration.

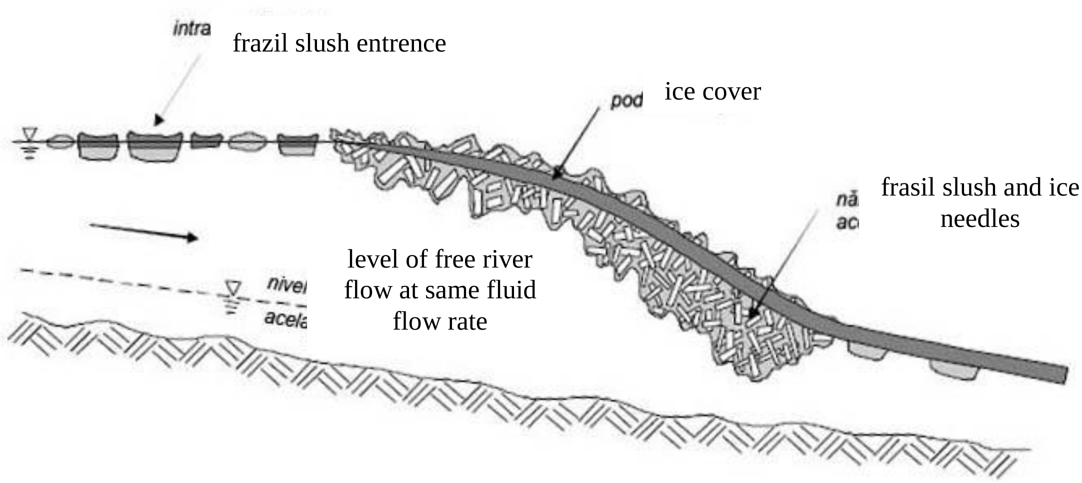


Figure 1: Ice jam under development – longitudinal section.
The high level of the river due to the roughness and thickness of the ice jam is worth noticing
(Beltaos *et al.,* 2001)

Break-up (melting) ice dams (jams) are caused by the accumulation of ice floes in certain sectors, resulting from the break-up of the ice cover due to the rise of air temperature (onset of spring). In the Bistrita basin (upstream the Izvoru Muntelui – Bicaz Reservoir), the frequency of the phenomenon is high in the upper sector of the river (Depresiunea Dornelor down to Zugreni) and a lower frequency in the sector Zugreni – Crucea (Ştefãnache, 2003, 2007; Surdeanu *et al*., 2005; Rădoane M. *et al*. 2009; Giurma and Ştefãnache D., 2010).

An ice dam (jam) belonging to this category developed in mid-winter 2014, i.e., January, on the Bistricioara River due to the floes building up and later frazil pans.

2. History of the research

In a study commissioned by the company HIDROELECTRICA SA, Bistriţa – Piatra Neamţ Hydropower Plant Branch (2009), Ciaglic V. states that in Romania, the research of the winter phenomena on rivers started "only" in the 60s. The first studies were conducted by M. (1960), Constantinescu C. (1964), and Ciaglic V. (1965).

Referring to the study of winter phenomena, Ciaglic V. underlined that "more intense" research was required after the occurrence of the "huge" ice jam" in the winter of 1972 –

1973, a phenomenon that began to manifest periodically, sometimes even two or three times per winter, causing material loss and claiming lives in the riverside localities. The search for ways to prevent the extremely dangerous development of the phenomena led to two different opinions:

a. Ştefănache D. (2007) in the abstract of his doctoral thesis he suggested that disastrous consequences could be limited by close "monitoring" of the areas at risk and a warning system (alarm) for evacuation and measures to limit the floods caused the ice accumulation. The solution accepted by the competent authorities was implemented and has been in use to this day.

b. Ciaglic V. (2008) considers this approach to be wrong, claiming that the only efficient way to solve the issue is to "remove the causes" generating the phenomenon mainly because they are well known.

The idea embraced by many researchers was also agreed by HIDROELECTRICA SA, who supported it by funding some surveys. But the first researches began long ago, I.E. Bistriţa (1973), whose results were partially published by Ciaglic V. *et al*. (1975). They were followed by Ciaglic V. (1984), Hidroelectrical Company – I.S.P.H. (1997, 1998, 2008), Ciaglic V. (2008), Rădoane M. *et al*. (2008), Ciaglic V. (2009), Rădoane M. *et al*. (2009), SC HIDROELECTRICA SA – RMD CONSULT (2009).

Surdeanu V. *et al*. have also contributed to a better knowledge of the ice jam phenomenon in the upper basin of the Bistriţa River (2005).

During the winter of 2011 – 2012, researches on the development of the winter phenomena on the rivers Bistricioara and Bistriţa (the Moldavian sector) were resumed. Thus, following on site studies, Ciaglic V. and Gaman C. drafted three mappings of the ice formation phenomena on the Bistricioara River and they were published by Gaman C. (2014). Gaman C. continued research on the Bistrita River in the winter of 2012 – 2013, the results being partially published in 2014.

Returning to the Bistricioara River, we would like to specify that the only studies were conducted by Ciaglic V. between 1962 and 1964, including the warm season of the year, identifying thus the mechanisms involved in the development of winter phenomena. The results were partially published: the development of winter phenomena, Ciaglic V. (1965) and the hydraulic relations between the river and the groundwater in the floodplain, Ciaglic V., Vornicu P. (1973). Special hydrological maps were not compiled. These studies constitute the basis underlying current research.

3. The area under study

Bistricioara was one of the main right-side tributaries of the Bistriţa River, the Moldavian sector before its hydrotechnical training, currently the river being tributary to the Izvoru Muntelui – Bicaz Reservoir (Figure 2).

The interfluve that separates them comprises: on the N – NW of Munceii Bilborului (that belong to the Călimani Massif) (on some 20% segment of the total length). The main segment of the interfluve (some 80 % of the length) is made up of the Bistriţei Mountains. It starts from the Alunişul Mare summit (1,448 m) and the interfluve, it continues through the peak Vaman – Harlagia, whose shape is arched with a wide opening onto E – NE (some 26 % of length), continues then onto the general direction, W – E, through Munceii Muncelu – Tibles, Grinţieşul Mare Mount and Munceii Grinţieşului until the Izvoru Muntelui – Bicaz Reservoir (some 50 % of the interfluve length).

The 25° 54' 02" East longitude meridian intersects the 46° 52' 05" North latitude parallel in the Valea Frumoasa (Sângeroasa) area, immediately downstream from the confluence of Bistricioara with the Azod creek (on the area of commune Tulgheş – N – NW limit).

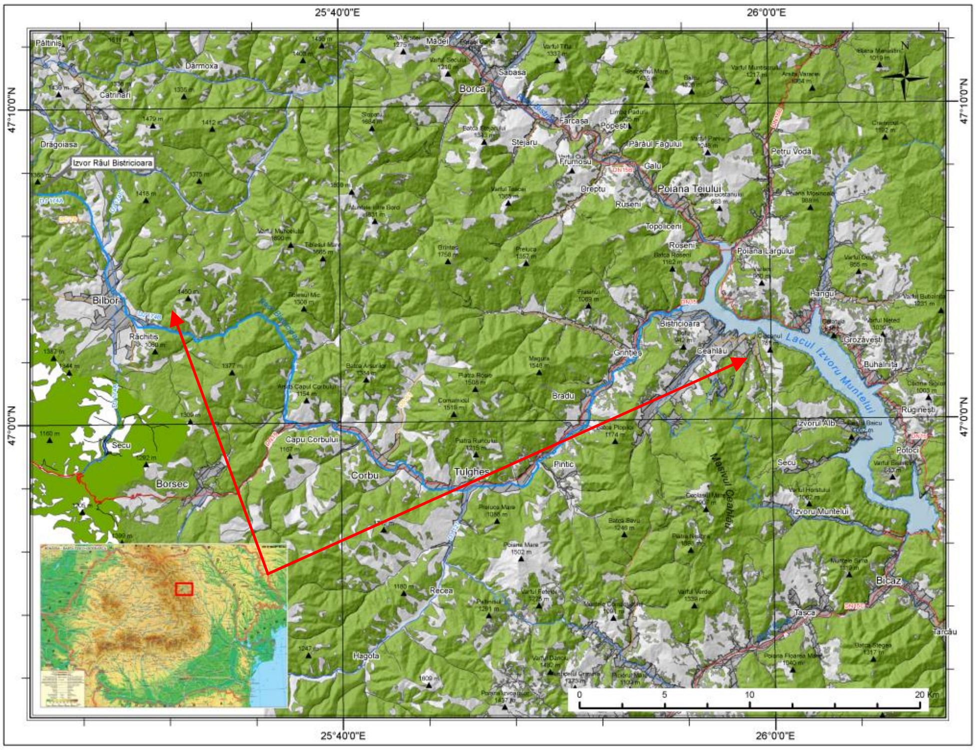


Figure 2: The geographical location of the area under study

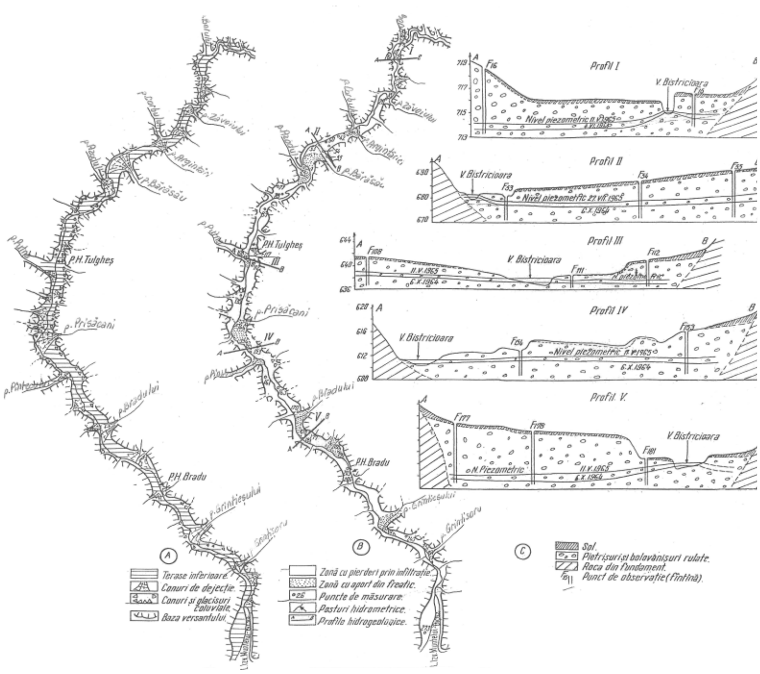
4. Physical and geographical characterisation

The Bistricioara River basin overlaps a medium-height mountain area which belongs to the central group of the Oriental Carpathians. Due mainly to the large development of the dejection cones of the main tributaries, which pushed the riverbed sometimes to the left bank some other times to the right bank, the middle and lower course of the river has many convolutions. The longitudinal section of the minor riverbed displays frequent slope breaks and thresholds.

From the climate point of view, the Bistricioara River basin is situated in the continental temperate climate area. In the sector under study, air temperature oscillates between a maximum of 32°C and a minimum temperature of –30°C (between 1896 and 1915 and 1926 and 1940); in terms of precipitations, they range between 700 and 800 mm/year (Ciaglic V., 1965, 1973).

From Capul Corbului until the confluence with the Pintec creek, the riverbed is dug in epizonal-type crystalline schist (Ciaglic and Vornicu, 1973). Downstream the confluence with the Pintec creek, limy conglomerates and breccias are predominant and there are intercalations of sandstones occur, marls, and conglomerates and in the river mouth area. On top of the formations mentioned, there are deposits of alluvial nature represented by coarse gravels of different sizes, largely spread at the surface and in depth (Figure 3 C).

On the entire bottom of the riverbed, the lower terraces are more developed and at the contact with the slopes, the terraces are parasitized by gentle slopes and small colluvial dejection cones, the most representative being the creeks Bărăsău, Prisecani, Bradu, and Ginţieşul Mare (Figure 3 A).



A. *Distribution of alluvial deposits on the bottom of the Bistricioara riverbed* (lower terraces, dejection cones, cones and colluvial gentle slopes, base of the slope)
B. *Types of hydraulic relations by areas* (area with loss by seepage, area with contribution from water table,measurement point, hydrometricunits, hydrogeological sections
C. *Hydrogeological cross sections through the Bistricioara River* (soil, gravel and rolled boulders, bedrock, observation point (well)
(after Ciaglic V., Vornicu P., 1973)

Figure 3: Geohydromorphological factors determining the hydraulic relations between the Bistricioara River and the water table in the major river bed (apud Ciaglic and Vornicu, 1973)

Measurements conducted on the Bistricioara River between 1963 and 1965 by Ciaglic V. and Vornicu P. highlighted the presence of a rich water table quartered in the alluvial deposits mentioned herein above. The hydrological cross section in Figure 3 B highlight the fact that the water table is shared by the lower terraces and the dejection cones occupying different positions on the vertical against the water level in the river (in the terraces area, the piezometric level of the water table is below the river level whereas in the dejection cone areas it is above the river level). The piezometric level is high in the cone areas as the water table received a supplementary amount of water from the tributaries of Bistricioara that give water to the river through seepage.

5. Development of ice formation phenomena on the Bistricioara River during the winter of 2011 - 2012

The existence of some sector with well-developed ice formation on the Bistriţa and Bistricioara rivers, under identical climate conditions, and of some strictly neighbouring river sectors with very poorly developed ice formations or no formation at all proves that there are some contributing factors other than the meteorological and hydrological ones that could have a significant influence on the ice formation phenomena. **The hydraulic relations established between the river and the areas it crosses** play an important role as the phenomena display a characteristic behaviour manifested sometimes by a total lack of ice due to the underground feeding. (Figure 3 B and C).

This theory that Ciaglic V. proposed (1965), was confirmed by the hydrometric observations conducted since 1964 to date, recorded in the logs of Tulgheş and Bistricioara Stations on the Bistricioara River as well as by our personal observations conducted on site in the winter of 2011 – 2012, when records water temperature was measured in various areas and the mapping of the phenomenon was conducted.

Although the climate conditions as well as the geological and morphological ones were identical, the Bistricioara River basin covering a small area (the length of the river reaches only 68.5 km), in the upper half of the basin, upstream the confluence with the Azod creek, the ice cover, with thickness ranging between 35 and 40 cm, covered with very little exception the entire surface of the river, whereas downstream, the ice cover would disappear suddenly under the same air temperature conditions (Figure 4 a, b).

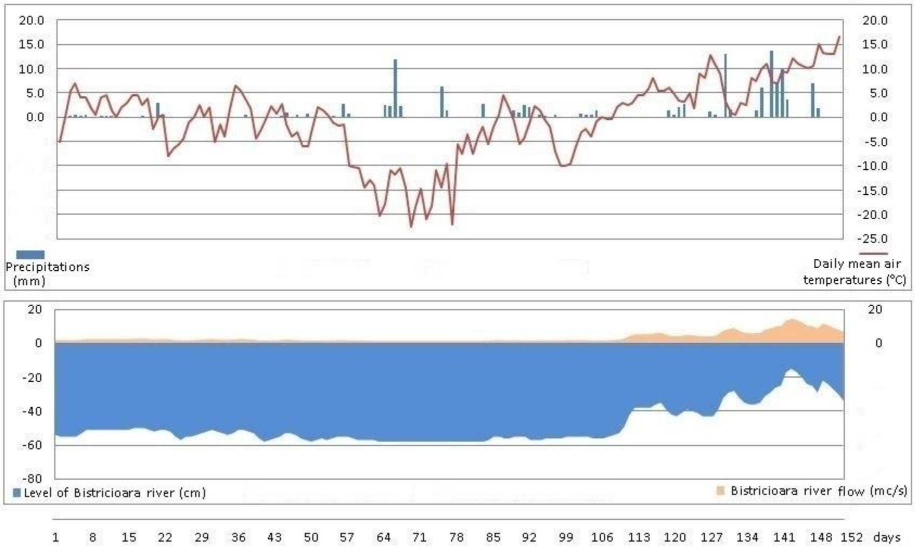


Figure 4: a. Variation of hydro meteorological factors at Bistricioara hydrometric station – Bistricioara River, 1 December 2011 – 30 April 2012
(source of the data processed by the Hydrological Station Piatra Neamţ)

In the winter of 2011 – 2012, the average daily temperatures at the two hydrometric stations displayed alternating periods of positive and negative values (the extremes being of – 22.5°C on 07/02/2012 and 16.5°C on 30 April 2012), which had a great importance in the development of the ice formation phenomena.

During the on site research, we have ascertained that the development of the freeze along the river displays significant differences with respect to the degree of development and the duration of the phenomena, highlighting three sectors.

In the *first sector*, i.e., from the spring until a little downstream of the Azid creek, ice formation phenomena started at mid-December when average daily temperatures at Tulgheş hydrometric station, in the time interval 19 – 27/12/2011 ranged between – 0.9°C and -9.7°C. The onset of full freeze was recorded around 01/02/2012 (Figure. with Mapping), the river displaying throughout this sector an ice cover with rare eyes of ice-free water and some small areas where the ice formation phenomena were completely absent or poorly developed. The average daily air temperature between 26/01 and 14/02/2012 varied between -7.5°C and -20°C at Tulgheş hydrometric station and between -10.2 °C and -22.5°C at Bistricioara hydrometric station.

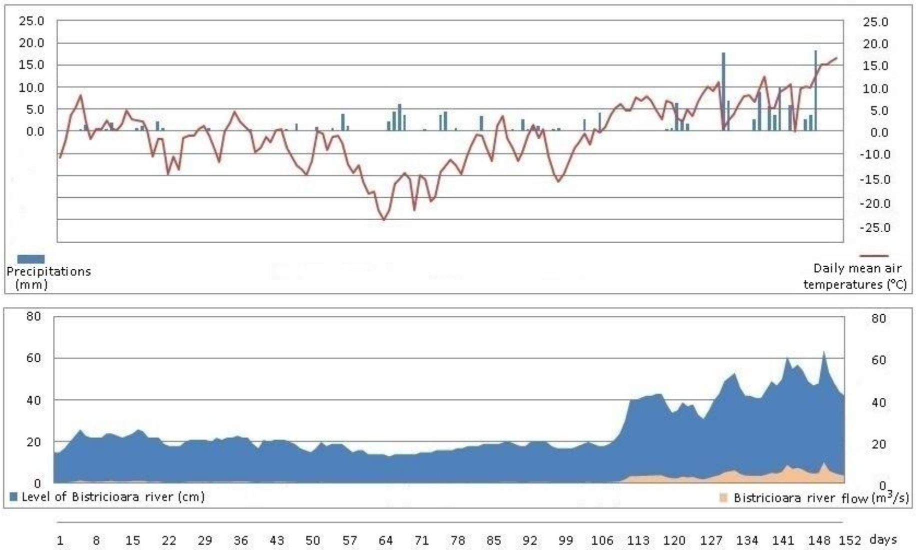


Figure 4: b. Variation of hydro meteorological factors at Tulgheş hydrometric station – Bistricioara River, 1 December 2011 – 30 April 2012
(source of the data processed by the Hydrological Station Piatra Neamţ)

On 16/02 and 09/03/2014, the status was similar except for the river sector upstream the confluence with Borului creek and downstream the confluence with Valea Seacă creek, where the Bistricioara displayed shore ice, the ice cover with eyes existing until then being thin was destroyed as a result of a slight level rises (Figure 5). The increased flow velocity and water pressure due to the rise of the river level by snow melting determined a thinner lower ice (in the water course) by melting caused by the rise of flow velocity and of water pressure on the ice following the rise of the river level following the snow melting (air temperature being on the rise as can been seen in the graph with average temperature variation at Tulgheş hydrometric station.

Figure 5: Shore ice covered with snow on the Bistricioara River, upstream the confluence of with Borului creek – locality Capul Corbului, 16/02/2012 (T water = 2°C and T air = -5°C) and 09/03/2012

This phenomenon was also signalled in 1963 by Ciaglic V., when the third decade of December 1963, on this sector there were floes slightly flowing downstream which resulted from the ice cover break up. Moreover, the phenomenon recorded special intensities along the river, such as the re-emergence of spring in the riverbed (the case downstream the Corbului creek, where the collapse of the ice cover was caused by some springs in the riverbed at the point of the dejection cones of the Argintăriei creek (Ciaglic V., 1965).

Downstream the confluence with the Zăvoiului creek, the ice cover on the Bistricioara river resisted until mid-March (due to the thickness of the ice), when owing to the positive temperatures, the ice cover remained with channel and shore ice (Figure 7).

The second sector starts immediately downstream the mouth of the Azod creek until the confluence with the Prisecani creek. In this sector, a considerable reduction of the ice formation phenomena can be noticed, with the ice disappearing suddenly at the limit with the first sector (Figure 6). In winter with excessively freezing temperatures, such as 1962 – 1963, the only phenomenon recorded was shore ice (Ciaglic V., 1965).

Figure 6: Bistricioara River (09/03/2012) downstream mouth of Azod creek – sudden disappearance of the ice cover, T water = 2 °C and T air = 6 °C) and (16/02/2012 at Tulgheş hydrometric station – river flows freely)

In the *third sector*, which extends from the mouth of the Prisecani creek until its flow into the Izvoru Muntelui – Bicaz Reservoir (the Bistriţa River), the ice formation phenomena are recurrent but with a slightly reduced duration and intensity as in the first sector. The mapping conducted on 16/02 and 09/03/2012 revealed shore ice on some 65% of the length of river sector, downstream the mouth of the larger creeks (i.e., Pintecului, Bradului, and Grinţieşului) at the limit of the dejection cones such phenomena not being present.

Unlike the main river, in the winter of 2011 – 2012, most of the tributary creeks were affected by freezing (e.g., shore ice, ice cover with eyes, ice cover and frozen to the bottom).

6. The ice jam phenomenon in January 2014

On 28/01/2014, the Inspectorate for Emergency Situations Harghita, Guard III Corbu was informed that in the area of Valea Frumoasa, the riverbed of Bistricioara was blocked on 1.5 km with ice floes and frazil pan reaching a 1.5m height (Figure 7).

The ice cover existing until the 28/01/2014 in the Capul Corbului sector (downstream the confluence of the Bistricioara River with the al de Borului creek) and the cover at the entrance in Tulgheş broke up (at low temperatures, ice contracts) and collapsed, the floes being driven to the area where they met an islet in the middle of the river. This information was also confirmed by the inhabitants of Capul Corbului, who reported they had heard a "roar" in the morning of 28 January.

Between 26 and 28/01/2014, air temperature in this area was very low (at Tulgheş hydrometric station, temperature measured at 7 a.m. was -12.2°C on 26 January, -10.5°C on 27 January, and -11°C on 28 January), whereas night temperatures reached -20°C (Figure 8). Analysing the daily temperature variation graphs (reading at 7 a.m. and 5 p.m.), it can be noticed that between 20 and 30 January, due to thermal inversions, air temperature at Bilbor hydrometric station was higher than that read at Tulgheş hydrometric station.

Also, the low level of water (during the night) and the thickness of ice, i.e., some 15 cm (downstream the confluence with the Borului creek), allowed the ice cover to collapse. Due to the large thickness of shore ice (as can be noticed in the cross section of the Bistricioara River – 20 March 1964 drafted by Ciaglic V. in 1965, Figure 9), only the floes in the middle of the stream were driven downstream (Figure 10).

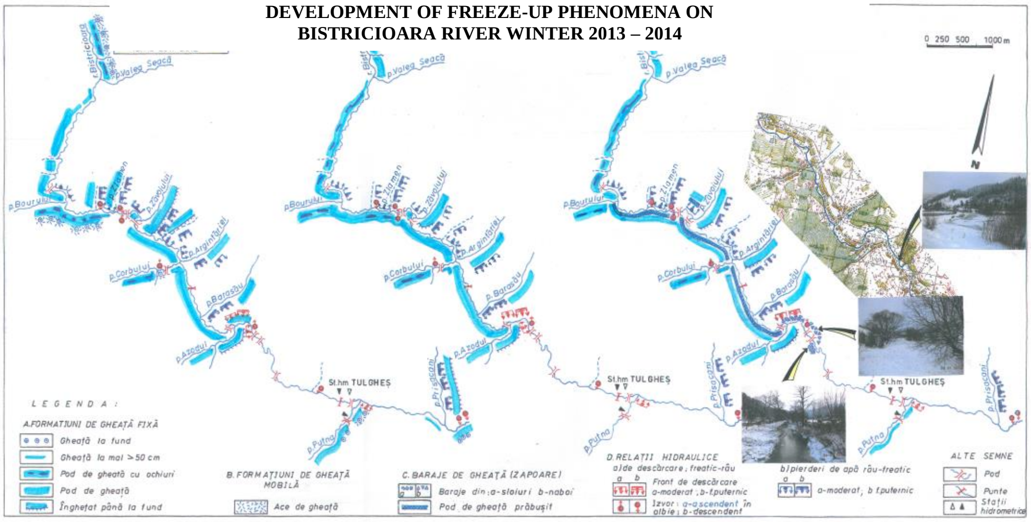


Figure. 7: Reconstruction of the ice jam developed on 28/01/2014 – mapping of ice formations on the Bistricioara River : maximum stage winter of 2011 – 2012 (Ciaglic V. and Gaman C.), on 27/01/2014 (Gaman C.) and 28 – 30/01/2014 (Gaman C. and Agapi O.)

B. Mobile ice formations: ice needles

C. Ice dams (jams) : Dam developed from – a.frazil cakes; b.frazil pans
Ice cover collapsed

D. Hydraulic relations : a). Of discharge water table – river; Discharge front : a. moderate; b. very strong b). Water table river loss : a. moderate; b. very strong

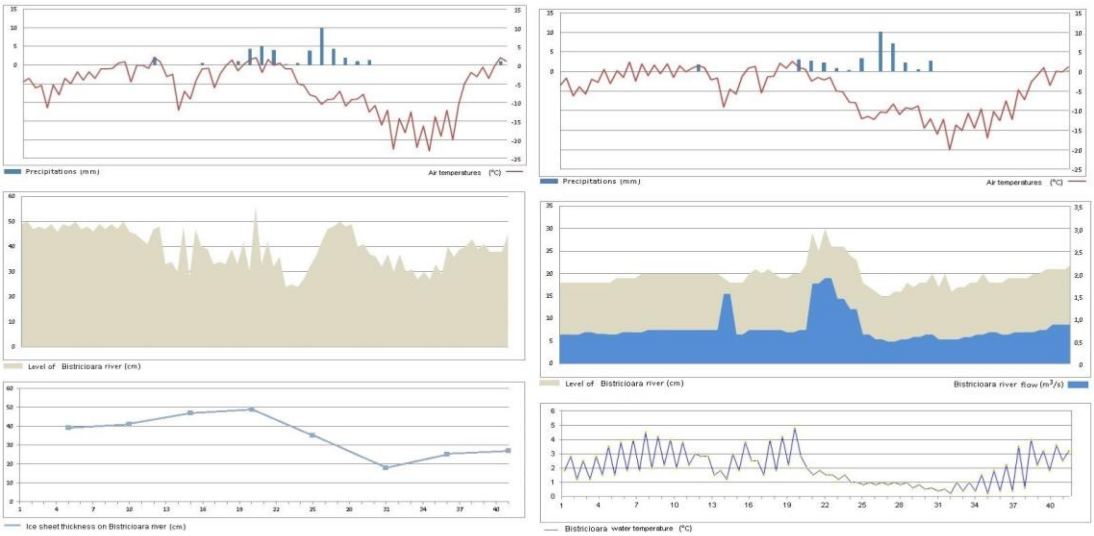


Figure 8: Variation of hydro meteorological factors at Bilbor and Tulgheş hydrometric stations – Bistricioara River, 1 January – 10 February 2014
(source of the data processed by the Hydrological Station Piatra Neamţ)

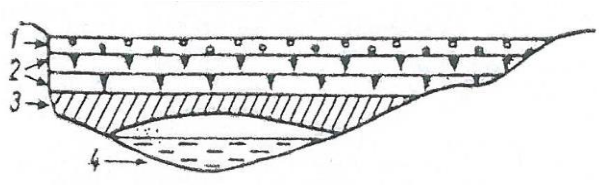


Figure 9: Cross section on the Bistricioara River upstream the confluence with Corbului creek – 20 March 1964 (apud Ciaglic V., 1965)
1. granular ice; 2. mat ice; 3. crystalline ice, 4. water

Figure 10: Shore ice on the Bistricioara River after the break up of the ice cover (photo Agapi O.)

The graph (figure 9) shows that upstream the locality Capul Corbului, i.e., at Bilbor, the thickness of the layer of snow reached 49 cm.

The analysis of the level variation graphs and the flow at the two stations, it can be noticed that at Bilbor hydrometric station there was a blockage, should we consider that on 22 January the level of Bistricioara dropped suddenly whereas downstream, at Tulgheş hydrometric station, the level and the flow rose.

Six households were flooded on the left bank of Bistricioara, with material loss or casualties (Figure 11). Between 28 – 31/01/2014, representative of the Volunteer Service for emergency Situations in Tulgheş tried to unblock the riverbed with a forklift equipment but they did not fully succeed (Figure 12).

Figure 11: Flooded courtyard on the left bank of the River, 28/01/2014

Figure 12 Unblocking the Bistricioara riverbed with equipment, 28/01/2014

(photo Bartis C.)

Due to the low temperatures recorded between 30/01 – 06/02, a new dam developed by frazil pan accumulation over a length of some 400 m. On 02/02/2014, the stream of the Bistricioara River unblocked without any equipment.

Conclusions

The observations conducted on site in the winters of 2011 – 2012 and 2013 – 2014 led to the conclusion that differences with respect to the degree of development of ice formations on the Bistricioara river among various sectors cannot be considered to be the effect of climatic conditions, the hydraulic relations set between the river and the areas it crosses playing a leading role.

The loss of water contributed to the development of the freeze (measurements of liquid flow conducted by Ciaglic V. on 7 March 1963 revealed that in the sector Capul Corbului – Sângeroasa, the river lost by seepage 35% of the total flow) and the contribution of seepage prevented the occurrence and development of ice formation, as the penetration of groundwater into the river causing its temperature to increase. The river being fed from the water table occurs in two situations: a). at the more developed dejection cones, which parasitize the major river bed or the terrace levels; b). in the areas where the river has large bends, similar to meanders, in the major riverbed.

Ice dams (jams) on the Bistricioara River can be considered natural risks in case they cause casualties and loss of property (large land areas and households affected by floods due to river bursting its banks or river infiltration).

In order top prevent such hydro-meteorological phenomena, structural measures are required, e.g., embankment along the inhabited areas, removal of silt from the minor river bed where ice pan blockage developed over the previous years, and non-structural measures, e.g., close monitoring of the ice formation phenomena at Corbu and of water temperature at the Bilbor and Tulgheş Hygrometric Stations, which would allow to anticipate the onset of the phenomena, warning and evacuating the population in the risk areas.

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