# OBSERVATIONS ON THE SEPTEMBER 2007 FLASH FLOOD IN THE TECUCEL RIVER BASIN

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**Key words**: flash flood, severe convection, climate risk, Tecucel river.

**Abstract.** The meteorological and hydrological events of September 5, 2007 in southern Moldova remained in the collective memory, mainly due to flash flood formed in the Tecucel basin, phenomenon that led to inundation of much of the city of Tecuci and death of three people in this community. This event was the first case, after the catastrophic floods of 1970, when a major city of Romania has been seriously affected by a river overflowing. Although the natural hazards represented by the heavy rains affected a much wider area (and were more intense in other hydrological basins), increased vulnerability of the confluence area of this tributary with Bârlad river (density of housing, infrastructure and economic activities in the flood) led to a increased risk to the area, resulting in a natural disaster far exceeded the previous events in rainy years 2005-2007. Field observations made in September 2007, both during the events and the subsequent analysis of their long-term effects may help to understand how climate risks caused by heavy rain of severe convective origin can be mitigated, especially in small and elongated river basins, which are the most likely to produce flash floods. Unfortunately the recent floods in Dorohoi showed again how vulnerable are the Romanian towns to flash floods caused by unregulated tributaries.

## Brief description of the Tecucel hydrological basin,

Tecucel River is located in eastern Romania, its catchment area being located to the south-western extremity of Tutova Hills, the downstream stretch of this river representing the northern boundary of Tecuci Plain. This creek is the last tributary on the right side of Barlad river before its confluence with Siret, having also many characteristics common to all right side tributaries of Barlad which flow from the Tutova Hills. The catchment area of the Tecucel river is elongated, oriented on a NW-SE direction, with the upper and middle course having a series of semi-permanent tributaries that flow oriented approximately parallel to the main

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watercourse, all of these rills being collected by the time the creek flows past Nicoreşti. The stream does not receive any other tributary in the lower half of its course up to the confluence with Barlad.

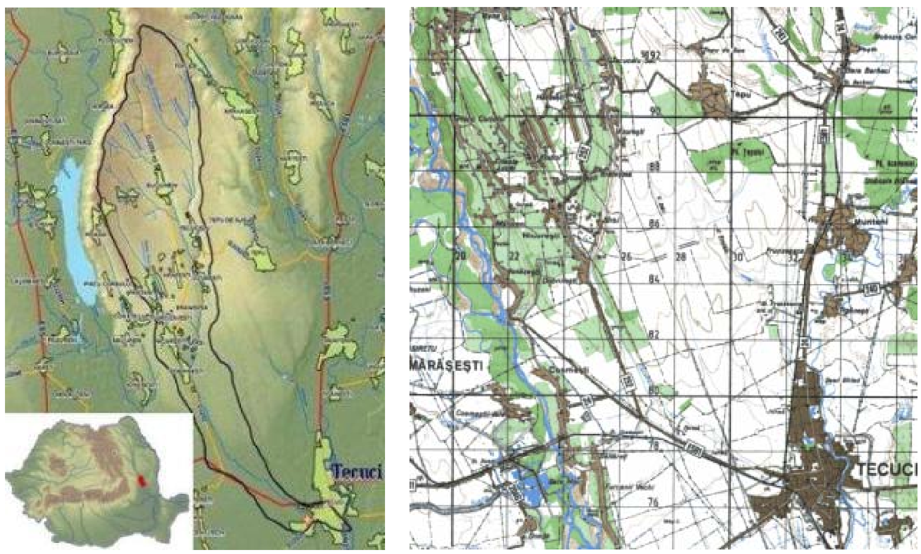


Fig.1 – Tecucel river basin (ANM, 2009); detail on the lower course of the river Tecucel (topographic map 1:100.000)

The upper area has relatively high altitudes (260m) and the northern tip and interfluve area is well covered in deep forests. The interfluve shape suggests that the Siret river (located to the west) continues to erode strongly these sloped steep hills, reducing constantly the surface of the Tecucel basin, and it can be assumed (based on the current situation) that this creek stretched northward perhaps as much as Tutova or Zeletin.

The middle course of the stream presents deepen valley (where the vast majority of settlements are located on flat interfluves, these monocline being used as agricultural land and most frequently plowed using the destructive hill-valley system). The destruction of vineyards and orchards after 1989 greatly increased the vulnerability of this area by increasing the rill and gully erosion of the slopes, these geomorphologic processes creating favorable conditions for the unrestricted manifestation of flash floods.

The lower Tecucel river basin is anything but spectacular, the channel bed and floodplain is very less defined, the stream being sometimes easily confused with the nearby irrigation channels that carry a seemingly harmless flow of water.

Near the confluence the riverbed starts to strongly deepen into the sedimentary deposit of the Barlad terraces, meandering once again more pronounced only after entering Tecuci and into the Barlad river floodplain.

Fig.2 – The natural course of the Tecucel stream (highlighted) inside the municipality of Tecuci

This strong meandering of the Tecucel waterway (fig. 2) in the inner city in contrast to linear flow, quasi-channeled profile, which characterize the rest of the river course through its catchment area determined, most likely, the huge size of the area affected by flooding and enhancing vulnerability thus generated by this natural risk. Only on the last kilometers the stream is properly channeled, which significantly reduces the risk by an order of magnitude to residents in the area southeast of the town.

**1. Meteorological causes of Tecucel flash flood**

The synoptic situation on the 5th of September 2007, at 6 pm (Romanian time, Fig. 3), indicates a low pressure area stretching from the central area of the Adriatic Sea and into the Banat area of Romania, with the low pressure center laying in southern Serbia. On the side of the depression, high pressure areas determine the advection of cold and warm air which meets over front lines strongly shaped by a branch of the jet- stream.

In its slow eastward movement, the depression determines an enhanced southern circulation over the territory of Romania both at ground level and at 500hPa, combined with a strong circulation in altitude on the west-east direction. This results in a fertile ground for the development and organization of thunderstorms especially because of the high level of CAPE and favorable Shear.

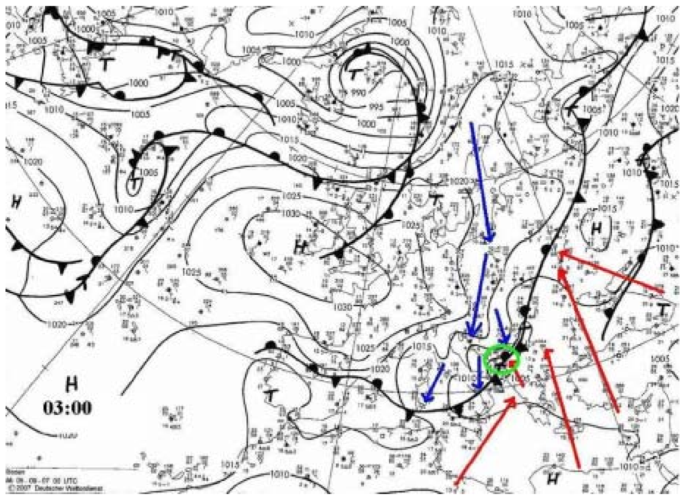


Fig. 3 - Synoptic situation at the ground on September 5, 2007, 03:00 UTC (6:00 pm Romanian time) (after Deutscher Wetterdienst, 2007)

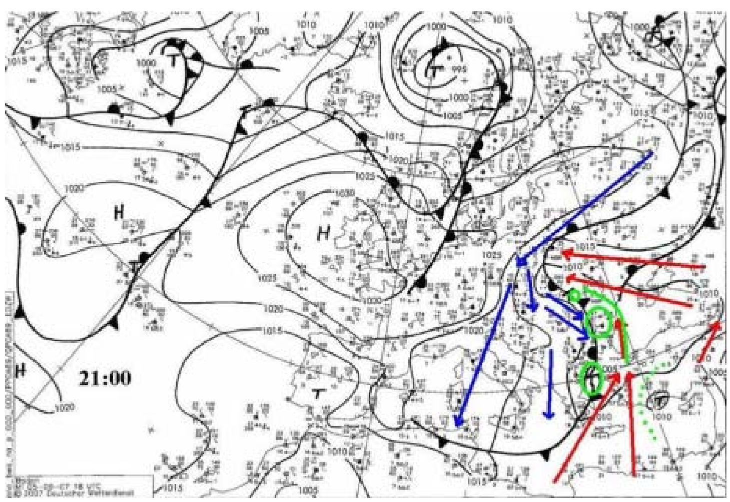


Fig. 4 - Synoptic situation on the ground on September 5, 2007, 21:00 UTC (21:00 Romanian time) (After Deutscher Wetterdienst, 2007)

At the midnight of the same day, the same initial center of the cyclone located in northern Greece had just suffered a transformation by absorbing convective cells formed in the afternoon; resulting into the creation of a new low pressure center located somewhere north of the Carpathians. From this center, a new cold front was generated (and amplified by diurnal convection) but which made a very slow progress to the east due to the strong high pressure area located there being eventually blocked somewhere over the Republic of Moldova later in the day of September 6$^{th}$.

The analysis shows that the synoptic meteorological phenomenon that has generated flooding in Tecuci happened before the Romanian territory was crossed by the area of low pressure and associated fronts, so the explanation must be sought by analyzing the mesoscale convective phenomena that day.

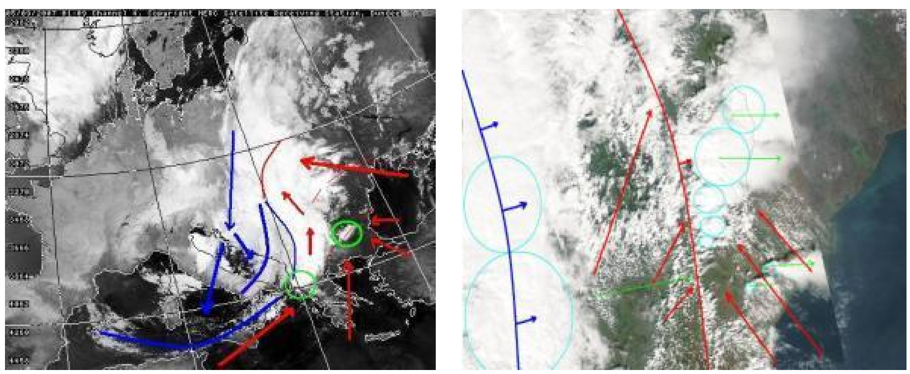

Fig. 5 - Satellite images showing the initial stage (l) above northern Bulgaria, 01 UTC, (NOAA-Dundee 2007) and mature stage (r) (Modis 2007) of the convective cell train

Fig. 5. Satellite images showing the initial stage (a) above northern Bulgaria, 01 UTC, (NOAA-Dundee 2007) and mature stage (b) (Modis 2007) of the convective cell train.

The satellite imagery taken during the early hours of the 5$^{th}$ of September show an obvious, convective disturbance appearing inside the tropical warm air advection. This disturbance will move in the morning towards the curvature of the Carpathians and develop during the day on the discontinuity line separating the dry tropical air (strongly deflected by the curvature of the Carpathians) and a new air mass of moist tropical air, transformed and enriched by the presence of the Black Sea.

The existence of the low pressure system and cold front (fig. 5.b) west of the Carpathians do not seem to have had a notable influence in the conduct of the phenomenon examined beside the fact that it generated the southern warm air circulation; so the excessive precipitation resulting in the flash flood can only be explained by micro and mesoscale analysis.

Thus, this almost stationary mesoscale convective complex managed to produce large amounts of rainfall in a short time, by the quick succession of several storm cells (in a motion pattern called "train effect" in the Romanian literature) while on the ground an important role in producing the flood was represented by the geographical area of southern Plateau Barlad with its small tributaries and catchment areas (of under 500km$^2$) strongly elongated. This elongation coincided with the main direction of movement of cells. In the end successive thunderstorm cell dropped the torrential into almost the same areas during that day.

Previous studies on this type of convective systems have identified a number of elements that can be also applied to this case:

• Convection was initiated along an extended line of discontinuity located from south to north;

• wind at 500 hPa level was parallel with the discontinuity of the low levels. Convective cells initiated along the lines moved quickly within this wind environment, but the convective processes along this system ware conducted over a long period of time. This behavior led to the accumulation of large amounts of rainfall in a relatively limited area (C. I. Oprea, 2008).

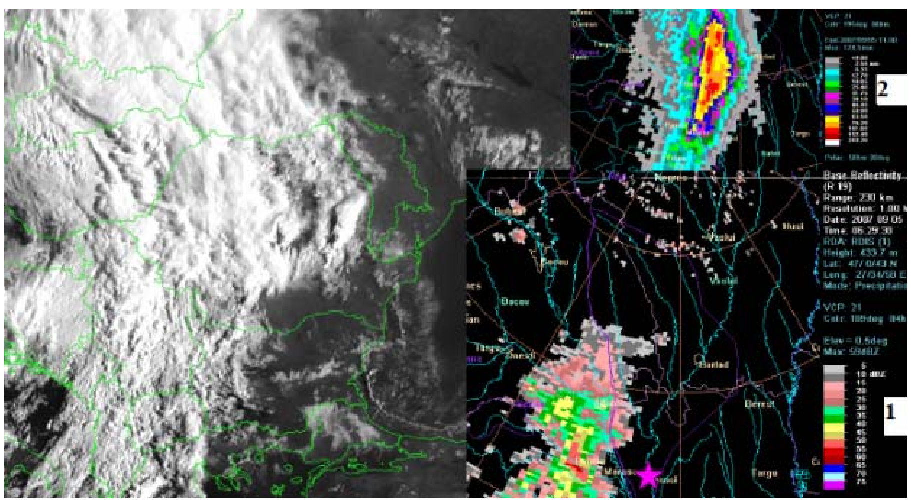


Fig. 6 - Satellite images (Meteosat 2007) showing the convective system (MCC) and radar products (ANM 2007) of rainfall that caused the first flood “1”(06 UTC, 09 Romanian time) and catastrophic flood in the afternoon “2”(12 UTC, 12 Romanian time)

Analysis of the convective processes of that day indicate that initially they were exacerbated by the specific shape of the Carpathian mountains curve (fig. 6, "a"), while the extremely heavy rainfall in the afternoon was caused by the generous contribution of heat latent and moisture coming from Black Sea (fig. 6 '2 ').

This approach tends to identify the complex of local factors that can transform simple convective cells in severe weather-generating systems, proving that a simple analysis of the synoptic level is not relevant unless it can be known in detail the structure of the atmosphere to a spatial resolution comparable to the convective cell itself (1-2 km).

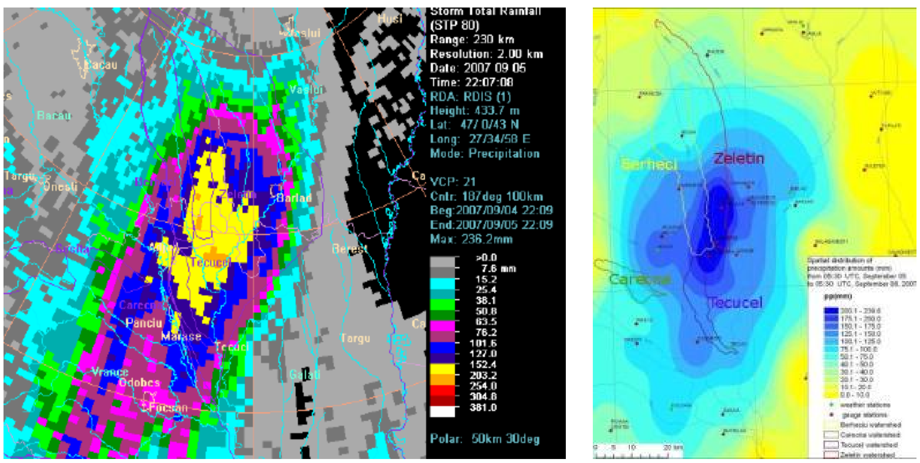


Fig. 7 - Total rainfall on September 5, 2007: radar (l) and correlation with data recorded at stations and pluviometric posts (r) (NMA 2007)

The resulting torrential rain was recorded at meteorological stations and rain gauge stations as totaling the following quantities: Podu Turcului 238 mm; Cosmeşti - 145.6 mm; Gohor - 140 mm; Nicoresti - 126.1 mm; Priponesti - 114 mm; Tecuci - 105 mm; Pogonesti - 186.9 mm; Tutova - 171 mm; Pereschiv - 151.3 mm; Coroieşti - 132 mm; Cuibul Vultures - 114.2 mm; Galbeni – 217,3 mm; Feldioara – 209 mm.

This manually collected data can be correlated with those obtained from the weather radar (fig. 7 a) to create a map of precipitation products on September 5 in southern Plateau Barlad (fig. 7, b).

The resulting flash flood manifested itself in two distinct phases: a moderate increase in the level of the Tecucel in the morning, after the first rain that had saturated the entire area of the basin, followed by successive floods caused by increasingly strong precipitations originating from the successively passing convective cells part of the "Train", all culminating in a catastrophic flood that has not only gathered large amounts of water but also released water from temporary reservoirs that appeared behind the clogged bridges (clogging caused by various waste, but most often agricultural and household waste).

This gradual increase in the intensity of the phenomenon was the reason for which the people in Tecuci did not reach for safer areas as on the arrival of the major flood roads and homes were already partly flooded making evacuation difficult, but also because local people and local authorities became complacent and have not heeded warnings thinking that the flood wave will pass without too many damages as previous floods during that day did.

This combination of factors led to the death of three old ladies that have been caught and drowned by the final flash flood.

**2. Description of flood damage from observations and images collected during and after the disaster**

Field analysis of the damage and debris left after the flood but also of the images and testimonials captured during the tragedy can make us understand the behavior of the flash flood much better than using any simulation.

Fig. 8 - Analysis of flood damage at Cozmesti, ortophotomap of studied area

Traveling by foot along the Tecucel river from Nicoreşti to Tecuci we can find in a generally flat area, the paved road leading to the former SMA Cosmeşti perpendicularly crossing the river and flood plain, this road was clearly damaged by the flood water. The witnesses' accounts to the flood (local workers) can be combined with crop and road damage and the height of the waste hauled to compute the maximum flow of the flash flood, flow can be estimated around 230 $m^3$ / s.

This value is confirmed by traces of flood crops, under different slope of the river (which led to different rates of leakage) but also about the flow calculation considering the flood reached the right height of bridges, for example bridge over DN24 (E581) from entry into Tecuci.

Fig. 9 –Appearance of the flash flood before Tecuci (bridge over DN24) ortophotomap of location

Fig. 10 – Estimated flood level and direction of the flash flood upstream Tecuci (determined after traces of the flood and witnesses account), detail the railway bridge

Both upstream this bridge, but also downstream of this initial chocking point, behind the railway bridge triangle connecting the North and South stations of Tecuci to the link to Marasesti, huge temporary reservoirs were caused by the clogging with silt and waste of the bridge spans. The clogging of these bridges (especially the last railway bridge, fig. 10) or defective flow through them (the bridge on National Road 24 was partially blocked by the foundations of an abandoned bridge) have limited the extent and velocity of the initial waves of floods and induces a state of false security in the town population. The final flash flood surpassed both the national road and railway embankment (fig. 11), powerful eroding them and releasing the temporary dams into a raging torrent that violently entered the town of Tecuci.


Fig. 11 – Erosion of the embankment of the Barlad-Tecuci railway (which needed urgent repairs for a distance of 300m) and that of the DN24, both man-made structures forming a temporary dam in the flood path


Fig. 12 – Typical flash flood damage caused by the Tecucel flood just after it entered Tecuci

After the flash flood surpassed and destroyed the temporary dams caused by the clogged bridges, it burst into Tecuci at an astonishing speed and destructive force, causing severe damage (total destruction) to the nearest houses (fig. 12). This kind of direct damages (caused by high speed torrential flow) continued only until the first road bridge, a bridge with a very small span, which was blocked entirely and the flow also stopped by a nearby structure carrying central heating pipes (fig. 13). Because this obstacle had proved to be extremely strong, flood waters started invading the side streets (fig. 14), leaving the river bed and flowing all over the city center (fig. 15). This dispersal of the water flow resulted in the annihilation of its power and speed but also established a new temporary lake, this time just inside the city. This way we can begin to understand the size of the affected area, with hundreds of homes being flooded all over the town but fortunately less violently because the energy of the flash flood was already dissipated.

Fig. 13 – The heavy concrete bridge and nearby central heating ducts that effectively blocked the flow of the flash flood

Fig. 14 – The flooding of the side streets besides the Tecucel riverbed and clues to the height of the floodwater.

All these features of the flood have led to differentiation in the damages and casualties produced (fig. 16): a rather limited area in which the destruction was total (resulting also in casualties) caused by the specific manifestation of an flash flood and a huge area (covering almost two thirds of the town) in which damages

Fig. 15 - Flood damage in Tecuci: left, the area affected by progressive flooding, right: flash flood affected area


Fig. 16 – Distribution of the damages in the town of Tecuci: in red, heavy flow affected area, in blue the area affected by stagnant water (background image Google Earth)

were caused by gradual flooding of land and housing, and the stagnation of these flood water, a more specific type of destruction slow floods on large rivers, equally destructive in the long term but posing a lot less danger to the inhabitants (which were able to walk and drive through the flood waters).

**3. Short and long term consequences of the September 5$^{th}$ 2007 flood,**

Two hundred homes flooded, dozens completely destroyed, three people dead, thousands evacuated and a major Romanian town with no: electricity, running water, sewerage, transport and communications ... a bleak picture painting the immediate effects of flooding, which began to be broadcasted relentlessly by national and international media just a couple of hours of the disaster. The severity and impact of the flood determined a rapid response from the authorities, which were reasonable prepared after the floods that affected Romania in the previous two years.

The town received containers as temporary housing and a lot of plans were made for such a catastrophe not to happen again.

Beyond the tragedy of the casualties, Tecuci was restored fairly quickly to an apparent normality especially through the efforts of firefighters and policemen that often did what would have been only the responsibility of the locals and property owners.

Because of numerous dwellings that continued to fall many days after the retreat of the flood water (due to water soaking of these adobe constructions), the total number of buildings destroyed reached the hundreds, prompting the decision to move all the containers in one place, where it was easier to assure food, hygiene and safety for the evacuees.

Some of the completely destroyed homes were repaired quite quickly by the more enterprising locals. Unfortunately many of those affected had nor the ability or willingness to properly use the building materials supplied by the authorities. These supplies ended up being sold for nothing and the evacuees were content to remain in the camp at the expense of the authorities, a situation that continues today.

Even more worryingly the steps taken to prevent the recurrence of such disaster reached also an dead end: because of the lack of funds the Tecucel stream remains as dangerous as before and the city is subject to the same risk as before September 5, 2007.

Research conducted in the area by various institutions led to the proposal of some realistic solutions:

a. The stream could be deviated into the Siret, an operation that would take place mainly on agricultural land but would require a significant investment from the state. This option would completely eliminate the risk of flooding and free up additional terrain for the development of the town.

b. Completion of the channeling of the Tecucel stream through the town, a work which is technically simple, but may turn out to be as costly as the first solution because of the necessary expropriations required to rectify the curves and meanders of the stream and also for the levies. This option would reduce much of the risk caused by future floods, but some parts of town were still be subjected to the risk of flooding.

c. Creating dams allowing for a temporary accumulation of the future flash floods upstream of the city, while also channeling the river course (like in option 2): perhaps the most expensive option, but which does not alter the river and almost totally eliminates the risk of flooding.

Currently (August 2010) the only works achieved were some sediment and garbage removal from the Tecucel riverbed and the first real steps are taken that could lead to the closure of the evacuees camp.

## Conclusions

The flash flood produced in the Tecucel basin was caused by heavy rainfall that fell from a succession of convective mezoscalar convective cells (MCS) a system that was organized in a pattern that followed the same direction ("train effect"). The particular intensity of rainfall was generated by the special conditions (influence of the curvature of the Carpathians and the moist air advection from the Black Sea) which have amplified the severity of phenomena registered on a discontinuity line oriented north-south.

The small and elongated Tecucel basin proved extremely vulnerable to such type of precipitation, resulting in a succession of floods with maximum flow of 200 m3/sec. The destructiveness of this flash flood has been exacerbated by shortcomings in infrastructure that should have regulated the flow of the stream and also on the poorly designed bridges crossing this river.

The application of simple solutions (dredging and channelizing of the stream with concrete slabs) should greatly reduces the risk of occasional floods produced in the Tecucel basin, but would not fully protect the city from flooding, while more complex solutions that would completely eliminate the danger are proving to be far too expensive to be actually put into practice.

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