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XXVI CONFERENCE OF THE DANUBIAN COUNTRIES
ON HYDROLOGICAL FORECASTING AND
HYDROLOGICAL BASES OF WATER MANAGEMENT

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Lessons learned from disastrous floods: the case of Tecuci City (Romania)

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Abstract/Introduction

Learning from catastrophic flood events is a fundamental starting point for understanding future flood risk and for taking appropriate measures in order to mitigate this risk (Chorynski et al., 2012). The lessons derived from the catastrophic floods that affected Romania in the early '70s (1970, 1972) and in 2005 - 2006 led to the enforcement of new policies and strategies in the field of water and flood risk management. However, the flood-related damages recorded in recent years have shown that there still is a lot to be learned, especially at regional and local scales.

This paper presents the disastrous flash-flood that hit Tecuci City in September 2007, the main lessons learned from this event and the actions that were or should be taken in order to mitigate the flood risk in this city.

1. Study area, data and methods

The study focuses on Tecuci City (about 43,000 inhabitants), which is located in eastern Romania (in the north-eastern extremity of the Romanian Plain) (Fig. 1a), at the confluence of Bârlad (L = 207 km; A = 7220 km²) and Tecucel rivers (L = 24 km; A = 112 km²) (Fig.1b); the altitude ranges from 30 to 60 m a.s.l. The Rateş channel (L = 13 km) was achieved in 1980 along a tributary of Bârlad River, east from the built city area, as a safety measure against floods. This channel regulates Bârlad River's flow, through derivation, especially during high discharges. Almost 1/3 of the city area (and about 2/3 of its built perimeter) is located in the Bârlad River floodplain, which highly exposes it to flooding. In the past, local flooding events have mainly been caused by the Bârlad River overflowing. While its average multiannual discharge is of 8.33 m³/s (between 1950 and 2007, at Tecuci gauging station, controlling 97% of the total catchment area and 92% of the river's length), the maximum discharges recorded during the largest floods have exceeded 300 m³/s. Such events took place in 1972 (331 m³/s), 1973 (322 m³/s), 2003 (460 m³/s) and 2004 (579 m³/s), and caused significant flooding and damages in Tecuci City. Following the events of the '70s, major engineering works were implemented on the Bârlad River: channel regularisation, embankment on both banks (Fig. 1b), water derivation in the Rateș channel (with an average multiannual discharge of 4.32 m³/s between 1984 and 2007, and a maximum flow capacity of 350 m³/s).

Tecucel River has a very low multiannual discharge (0.15 m³/s, during the 1950 – 2007 period). Annual flood peaks have a large variability: between 1968 and 2007, they ranged from 0.230 m³/s (in 1994) to 183 m³/s (in 2007). The highest flood peaks were recorded in 1971 (122 m³/s), 2005 (99.4 m³/s), 2006 (98.8 m³/s) and 2007 (183 m³/s). As until 2007 it hadn't caused considerable flooding in Tecuci city, no embankment operations were attempted, except for the inferior sector where, on the upstream left bank, a 500 m-long levee was built (Zaharia *et al.*, 2009).

Economically, the city is important due to its role of transport ways junction (railways and roads), as well as to industrial, agricultural and commercial activities, most of which of local importance.

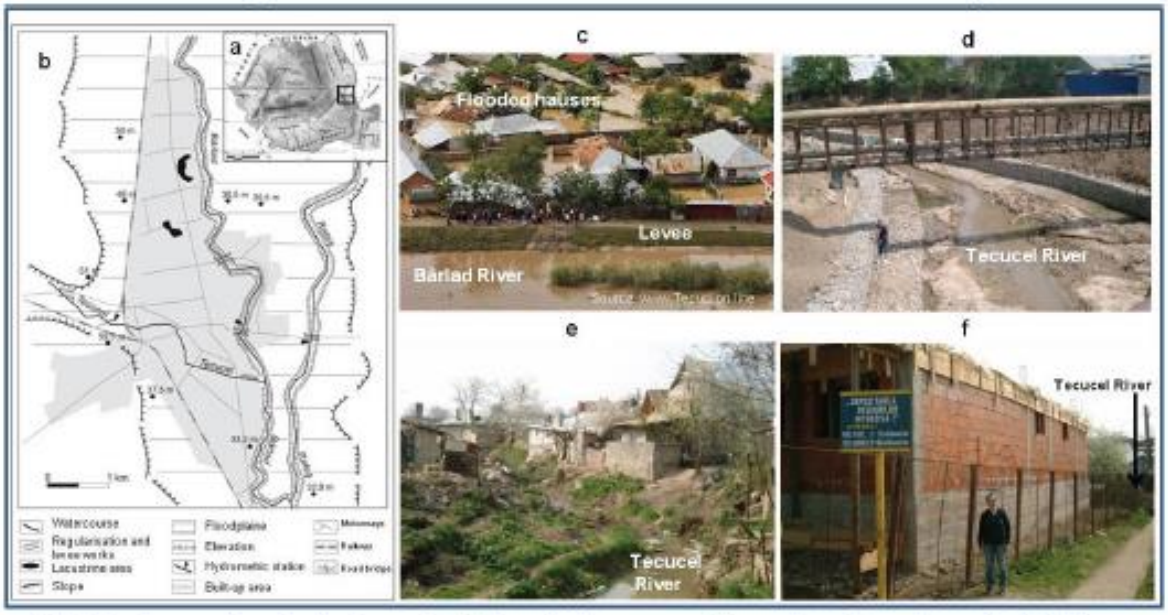

Fig. 1. Study area location in Romania (a). Tecuci city area and the main engineering works (b). Houses flooded in September 2007, behind the levee on the right side of the Bârlad River (c). Engineering works on Tecucel River in August 2009 (d). Buildings close to Tecucel River channel (e). New house adapted to the flood risk (with an elevated foundation) and a billboard for banning the waste storage on the river bank (f).

The study is mainly based on hydrologic and fieldwork-generated data. The hydrologic data comprise average, maximum and minimum monthly and annual discharges recorded at 3 gauging stations located on the Bârlad and Tecucel rivers, and on the Rateş channel, and hourly discharges of the 3 watercourses recorded during the September 2007 flash-flood. The data were provided by the "Romanian Waters" National Administration– Water DirectoratePrut. The field investigations were performed in many campaigns, between September 2007 and May 2014, which included observations and questioning of city residents affected by the September 2007 flood. The main method was the statistical analysis of hydrologic data and survey answers.

2. The flood event of September 2007 and its disastrous consequences

In September 2007, Tecuci City was severely affected by a flood with significant social and economic damages. It originated from an exceptional rainfall event for this region: in the afternoon of September 5th, in the central part of Bârlad catchment and in the upper sector of Tecucel catchment, rainfall amounts exceeded 100 mm in 3 hours, while the 24 hour total precipitation exceeded 200 mm (almost 40% of the region's annual rainfall amount) (Zaharia et al., 2008). As a result, a flash-flood occurred on Tecucel River, with a 6 hour rising time and a total duration of 26 hours. Between 3:00 p.m. and 9:00 p.m. on September 5th, the discharge increased from 0.54 to 183 m³/s. This was the highest discharge recorded on Tecucel River, since 1968 (when Tecuci gauging station was installed), with a return period of 500 years (Zaharia et al., 2009). The September 5th heavy rainfall also generated flash-floods on the other 2 rivers in the Tecuci City area, as well: Bârlad's discharge has grown in 20 hours from 1.40 m³/s to 245 m³/s, and that of the Rateş channel, through an important water volume of Bârlad River was

derived, increased from 0.09 m³/s to 326 m³/s in 22 hours. While the Tecucel River flash-flood was the main cause of the Tecuci City flooding, its expansion and consequences were amplified by local factors, including morphological features (specific for a floodplain) and the dam role that the transport infrastructure and the levee on Bârlad's right bank played. Tecucel River's flow was therefore blocked at the entrance in Tecuci City by the undersized road and railway bridges and by the embankment-structure for railway elevating; the water subsequently

overflowed these "barriers" and flowed through the city, heading, according the slope, towards the Bârlad River, and accumulated in a layer of over 2 m behind the levee along Bârlad's right bank (Fig. 1c) (Zaharia et al., 2009). As the flooding affected approximately 70% of the built city area (with water layer thickness exceeding 1 m), the consequences were disastrous: 3 fatalities, 2210 houses were damaged (of which 392 were completely destroyed, and 425 suffered serious structural damage), and the city's infrastructure was gravely deteriorated. The total cost of the damage amounted to approximately 6 million euro (Zaharia et al., 2008).

3. Learned lessons and measures already adopted or necessary for flood risk mitigation

In the case of Tecuci City, the most important lessons learned from the disastrous September 2007 flash-flood were:

1. Small and apparently harmless water courses (such as Tecucel River) may generate catastrophic damages, in the context of favorable circumstances (natural and anthropogenic). As a consequence, since 2008, engineering and maintenance works were set up on Tecucel River (re-calibration and dredging works, levees, bank protection and consolidation, vegetation clearing) (Fig. 1d).
2. Not only natural hazards are responsible for flooding and its consequences, but an important role can also be played by the human factor: in this case, mainly by the transport infrastructure built in an embankment-like manner, undersized bridges, the inadequate maintenance of river channels (the watercourses, especially the Tecucel River, were used for the riverine population as a garbage deposit), buildings located in the immediate vicinity of the Tecucel's channel (Fig. 1e), sewerage system dysfunctions, etc. After 2008, some measures were taken, such as: riverbed vegetation and waste clearing, banning waste storage on river banks and riverbeds (Fig. 1f), razing certain buildings located very close to Tecucel River (which obstructed the river flow).
3. The levees cannot always guarantee protection against flooding, but, on the contrary, can become one of their causes and can aggravate the damage. In order to avoid such situations, engineering techniques allowing a faster drainage of the water which is blocked by levees should be envisaged (e.g. spillways, drainage systems).
4. For the improvement of flood risk management in Tecuci City, special attention should be paid also to non-structural measures. In this respect, we deem it necessary to:

- Appropriate information and training of the population with regard to flood risk. The May 2014 survey (when 101 persons were interviewed) revealed that 59% of respondents have considered they were insufficiently trained and informed about the flood risk, and expressed their desire to know more in this respect. As opposed to an August 2009 survey (totalling 163 respondents), an increase in population informing and training levels can be noticed, as the 2009 share was of 92% (Zaharia et al., 2009). This rising was partly due to local information campaigns. Thus, at the end of May 2013, the Tecuci City Hall completed the *Analysis and Risk Coverage Plan in Tecuci City)*, which comprised potential risks locally identified (out of which flooding is representative),

as well as the measures, actions and resources needed for properly managing these risks (Tecuci City Hall, 2013). This information is available online on the City Hall's website. Moreover, several public disaster alarm exercises were scheduled in Tecuci.
- The buildings located in flood prone areas must to be structurally adapted (elevated building). The houses that were rebuilt after the September 2007 flood have high foundations, sometimes exceeding 1 m (Fig. 1f).
- Insurance policies need. After the September 2007 flooding experience, the percentage of residents with life and asset protection insurances increased from 19% (in 2009) to 31% (in 2014). It is however noteworthy that a large share of the population (69%) is not covered by any type of insurance, which is mainly due to the lack of trust in the insurance system, and the dissatisfaction with the compensation fees (only 22% of respondents insured before 2007 were satisfied with the compensation, 36% were dissatisfied, and 42% were partially satisfied).
- Necessity for improving the organizing and activity of institutions responsible for flood risk management, from national to local scale. Although significant progress has been made, a higher efficiency of these institutions' activity is required.

4. Conclusion

Learning from past catastrophic floods is an important factor in building the social capacity for these natural hazards (Komac et al., 2010). In the case of Tecuci City, the lessons learned from the September 2007 disastrous flood led to the implementation of a series of both structural and non-structural local measures, for a better adaptation of the community to similar future events. Although in the meantime significant improvements have been made in the field of flood risk management, many measures must be translated from theory to practice when switching from national to local scale.

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