BULETINUL INSTITUTULUI POLITEHNIC DIN IAŞI
Publicat de
Universitatea Tehnică „Gheorghe Asachi” din Iaşi
Volumul 64 (68), Numărul 2, 2018
Secția
HIDROTEHNICĂ

STUDIES AND RESEARCH OF THE FLOOD EFFECTS OF THE JUNE 2016 ON THE RIVER VORONET, ”CÂMP CRISTEA” – ”POIANA LUI MACARIE” ZONE

BY

MIHAELA AVRAM*, MIHAIL LUCA and PAUL VIVIAN SION

“Gheorghe Asachi” Technical University of Iași,
Faculty of Hydrotechnics, Geodesy and Environmental Engineering

Received: May 18, 2018
Accepted for publication: June 30, 2018

Abstract. The paper presents an analysis of the hydroclimatic risk parameters in the Voroneț River basin. The studies and research were carried out on Voroneț river on the section between "Camp Cristea" and "Poiana lui Macarie", after the June 2016 flood. Floods morphologically modified the minor and the major river bed of the Voroneț River, a situation that has influenced riparian floodplains within and out of town. The effect of the floods resulted in the total destruction of the road DJ177D on a length of about 425 m. The flow calculated in the "Camp Cristea" section on the Voroneț River was 71.61 m3/s with a 1% probability of calculation. The flow recorded in the downstream section of the river was 118.12 m3/s (p = 1%). The county road DJ 177D was partially degraded on 1,600 m and two bridges were destroyed. Floods have resulted in the destruction of some economic and social objectives in the coastal area.

Keywords: defence works; degradations; flows; precipitation; road; riparian area.

1. Introduction

During 1990–2016, a number of global climate changes with direct impact on the hydrological cycle were recorded. This type of changes are

*Corresponding author: *e-mail*: mihaelaavram30@yahoo.com

present on Romania's territory and have an influence on the annual distribution of rainfall and flow rates on hydrographic basins (Vamanu & Olariu, 2002). The high level of climate change has led to the occurrence of a hydroclimatic risk factor, which has an excessive influence on river flow rates. The hydrological changes recorded in recent years have a radical influence on the behaviour of the river and also the collaboration with existing constructions in the riverbed and riparian area (Romanescu & Stoleriu, 2013).

The hydrological regime of rivers in Romania is defined by the high flood frequency in the last period of time. The studies conducted have shown the recording of two or three high value floods during the same year (Luca & Stoenescu, 2007).

Hydrological risk factors influence the riverbed morphology, the stability of riverbed structures (bridges, regularisation works) and shore constructions (shore defence works, dikes). Hydrological risk factors affect the existing riverbed habitat. The floods of destructive nature have produced degradation of riparian area social and economic objectives. The value of the flood damages has become very high, which requires large investments for environmental restoration works. The effect of the changes can be immediately noticed or it manifests itself after a longer period of time. Riverbed regularisation and shore defence works restorations depends on values of modified hydrological parameters. The disturbance of the hydrological parameters dictates the behaviour of regularisation works and, implicitly, the river habitat existence conditions (Luca, 2016).

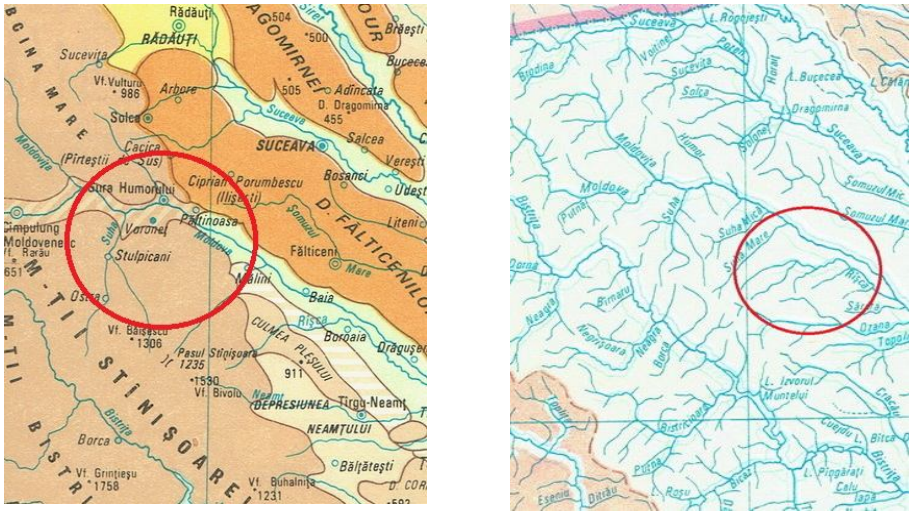
2. Research Material and Methods

The studies and research were conducted in the Voroneț River hydrographic basin. The Voroneț River is a right side tributary of Moldova River. The Voroneț River hydrographic basin is located in the relief area of the Eastern Carpathians, in Stânişoarei Mountains geomorphologic unit (Fig. 1 *a*). The elevation of the river basin is 510,…,750 m and on average 730 m. A number of heights called hummocks or hills are found in the area, such as Voroneț Hummock, Bătrânei Hummock, Brusturosului Hummock, Mânăstirii Hill etc.

Voroneț River cadastral code is XII-1-40-26. Voroneț River has a length of 10 km and a slope of 3.17%. Voroneț River has a number of streams and torrents tributaries: on the left side are the Maghernița, Brusturos, Slătioara streams and on the right side Varnița, Moara, Râla, Poiana etc. streams (Fig. 1 *b*). Voroneț River hydrographic basin has an oval shape with a surface of 35 km^2.

The research material consists of documentary studies and field research. The studies conducted are: topographical, hydrological, hydraulic, geotechnical, safety in operation of constructions located in the riverbed and on Voroneț River shores etc. Part of the studies was taken from technical literature and other were conducted for the existing hydrographic basin circumstances. The research was carried out

in „Camp Cristea” and „Poiana lui Macarie” degradation areas location. The research was conducted during a technical expertise.



a *b*

Fig. 1 – Voroneț hydrographic basin features: *a* – study area physical map; *b* – Voroneț River hydrographic basin (Atlasul Cadastral al Apelor).

„Camp Cristea” - „Poiana lui Macarie” section theoretical and experimental research was conducted on the following fields:

1. Research of hydrological parameters in the study area. The analysed parameters were: flows (liquid, solid), levels, floods frequency, flood areas etc.

2. Research of hydraulic parameters on the river sector between „Camp Cristea” and „Poiana lui Macarie”. The analysed parameters were flows, levels, velocities, erosion lengths and depths in river study sections.

3. Research of hydrological risk parameters on the minor and major riverbed morphology on the river sector under study.

4. The effect of risk parameters on the riparian constructions and habitat.

3. Results and Discussions

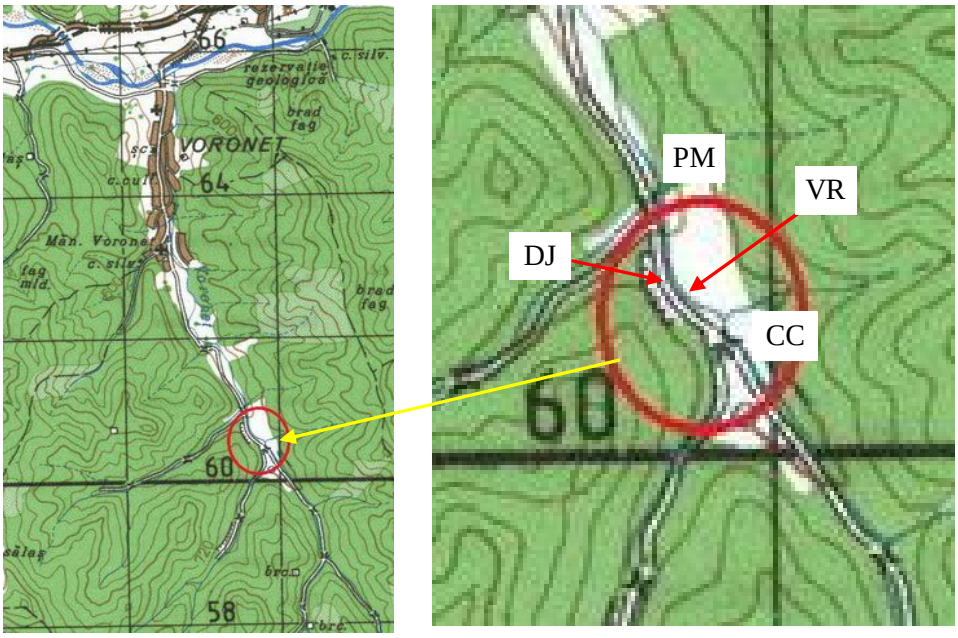
The research was conducted on a river section and a riparian area sector, where significant degradation was recorded. The river section is located between two characteristic sections Fig. 2:

– Section 1: Voroneț River – Slătioara Stream (Camp Cristea area) confluence;

– Section 2: Voroneț River – Brusturos Torrent (Poiana lui Macarie area) confluence.

DJ 177D county road has a parallel route with Voroneț River between the two analysis sections on a length of about 60%.

The research used climatic data taken from meteorological stations located in the analysed hydrographic basin. The meteorological data were taken on variable time intervals (from 5 to 45 years). The hydrological data were collected from hydrometric stations located in the study river characteristic sections. The data from hydroclimatic risk periods were analysed by considering the data over a long time period.



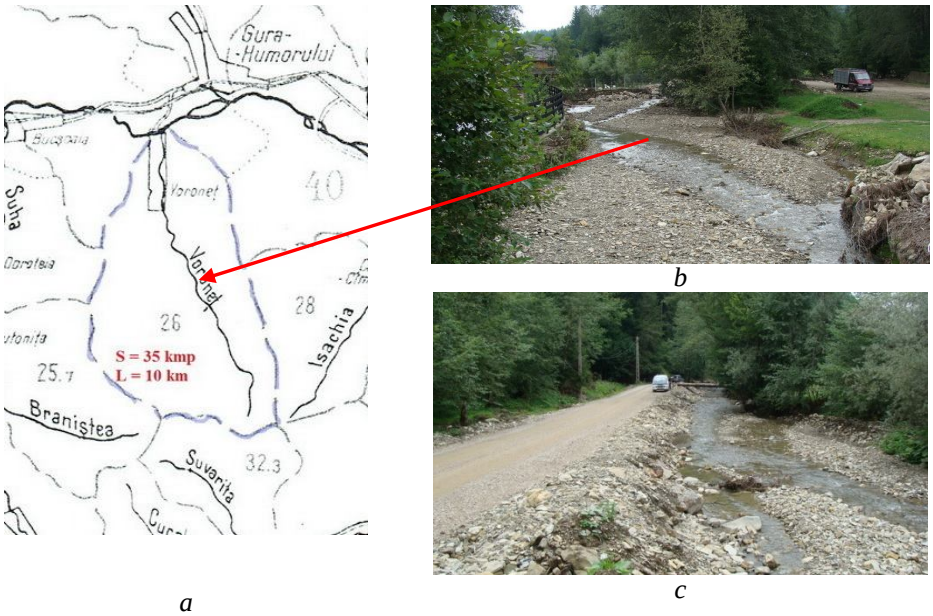
a *b*

Fig. 2 – Voroneț hydrographic basin features: *a* – study area; *b* – detail of the area study, VR - Voroneț River, PM – „Poiana lui Macarie" are, CC – "Camp Cristea" area, D J177D – county road.

The Gura Humorului hydrometric and meteorological stations were used for Voroneț River. In May and June 2016 an abundant rainfall regime was recorded in the Voroneț River hydrographic basin. The rainfalls with the highest value in the analysed area were recorded during 18 – 20 June. The values recorded at Gura Humorului Hydrometeorological Station were 71.6 l/m^2. During 24 – 25 May, 30.1 l/m^2 were recorded at Gura Humorului meteorological station. Voroneț River does not have a hydrometric station. The maximum 1% probability flow rate for hydrographic basins larger than 10 km^2 was determined using the rational equation (Stăncescu *et al.*, 1984):

$$Q_{1\%} = \frac{K \cdot \alpha \cdot I_{60\ 1\%} \cdot F}{(F+1)^m}, \quad (1)$$

where: k = 0.28 coefficient of rainfall transformation from mm/hour to m/s and of surface from km^2 to m^2; α – global leakage coefficient; $I_{60\ 1\%}$ - maximum hourly rainfall with 1% probability of exceedance; F – basin area in km^2 (Fig. 3).



a *b* *c*

Fig. 3 – Voroneț River hydrographic basin features: *a* – study area; *b*, *c* – detail of Voroneț River in the Camp Cristea area (photo aug. 2016).

The parameters values in eq. (1) were taken from the paper (Stăncescu, *et al.*, 1984) in accordance with the river basin characteristics. For the geographic area under consideration the resulting values were: $I_{60,\ 1\%}$ = 125 mm, α = 0.55, m = 0.49. The flow was determined in two characteristic sections of the Voroneț River and the results are as follows:

1. Section 1: Voroneț River – Slătioara Stream (Camp Cristea area) confluence, $Q_{1\%}$ = 71.61 m^3/s, for a surface of 14 km^2.

2. Section 2: Voroneț River – Brusturos Torrent (Poiana lui Macarie area) confluence $Q_{1\%}$ = 118.12 m^3/s, for a surface of 32 km^2.

These flow rates weren't entirely taken over by Voroneț River, aspect shown through the discharge on the two river banks and significant changes in the riverbed. The simulation and examination of Voroneț River flood flow rates with the probability of exceeding of p = 1% for the flood from June 2016 are presented in Table 1.

The rainfall concentrated over a short time period influenced the water flow in Voroneț hydrographic basin. The floods caused by Voroneț River were intensified by the rapid discharge of water from the slopes by torrential formations (Brusturosu Stream case). The concentration time was reduced by the circular / oval shape of the hydrographic basin.

Table 1
$Q_{1\%}$ Flows Calculated and Estimated on Voroneț River During June 2016 flood (Luca, 2016)

No.	S, [km^2]	Q_c, [m^3/s]	Q_{sp}, [m^3/s]	Q_{re}^*, [m^3/s]
1	36.0	118.12	141.74	130,0
2	14.6	71.61	85.93	68.0

* – ABA Bacău 2016 source, Q_{re} – re-established flow; Q_{sp} – flow increased by 25%.

The streams have engaged alluvial material made of rocks (medium and large dimensions), alluvial and forest material. The forest material was of variable dimensions and even large, hence the erosive effect on the riverbed, bridges and shore defence works was significant. In confluence and bridge areas blockages and riverbed narrowings have resulted. The blockages have led to discharges in the riparian area occupied by houses, agricultural land, landmarks, roads etc.

The forest material and rocks were engaged outside the Voroneț River bed and produced degradation phenomena on the riparian objectives (houses, agricultural land, landmarks, catchments etc.). In some areas the shore was eroded for 2 – 5 m depths. A number of citizens' goods were taken by the flood leaving the riverbed and carried downstream. The erosive water action has resulted in a wide minor riverbed, with meandering areas and alluvial deposits. The presence of alluvial deposits enables significant riverbed morphological changes.

The river banks were eroded (2,600 m of shore) and the riverbed was morphologically transformed (Fig. 4).

DJ 177 D county road was degraded on a route starting from Voroneț District up to „Camp Cristea" area. The road is located parallel to the Voroneț River bed, at 1.0 – 45 m distances. The degradation forms consist of erosion of shore defence, of road shoulder, with intrusion in road structure and its breaking on differentiated lengths.

The degradation of the county road resulted over 1500 m in length. The hydrodynamic erosion caused by the flood led to a differentiated degradation of DJ 177D road, up to its total destruction on a length of 400 m (Fig. 5). This situation led to traffic interruption over a period of time.

The „Camp Cristea – Poiana lui Macarie" sector degradation was favoured by several anthropic and natural factors. The main natural risk factors are:

– torrential rainfall in an oval shaped hydrographic basin, resulting in reduced concentration time;

– the significant flow contributions of torrential water courses into Voroneț River;

– the geometric shape of the riverbed between the two analysis sections (the transition from a very wide riverbed to a narrow one, where the shrinkage ratio is 1:3 – 1:5);

– the maximum flow rate of the flood ($Q_{1\%}$ = 118.12 m^3/s) in the study area;

– the transport of an important solid flow consisting mainly of stone and gravel;

– the geotechnical characteristics of the road base rock (low cohesive rocks, gravel and ballast);

– high value velocities which exceed the riverbed constituent material limit driving values, resulting in the increase of road erosion.

a *b*

Fig. 4 – Erosion forms on the Voroneț River left bank at the DJ 177D road limit „Camp Cristea" downstream area after June 2016 flood: *a* – general view; *b* – detail of the erosion bank (photo aug. 2016).

The main anthropic risk factors are as follows:

– the advance wear of shore defence works on „Camp Cristea" downstream section (Figs. 4 and 5);

– the lack of shore defence works on „Poiana lui Macarie" upstream section where the riverbed is calibrated on a great length; this situation determines velocities which increase progressively and exceed the admitted erosion velocities value (Fig. 5);

– the lack of maintenance and repair procedures for the shore defence works on this sector; this situation has favoured the excessive degradation of shore defence works;

– the Voroneț stream current structure upstream of „Poiana lui Macarie" in the shape of a linear sector with a great length and reduced flow section (Fig. 5); this situation favours the formation of a large kinetic energy at flood flows, which turn into a riverbed and road bevel deformation mechanical work.

The road degradation was done through the Voroneț stream advance into the bank (Fig. 5 *a*) and then into the road structure, until the water reached the versant (Fig. 5 *b*). The phenomenon was accelerated by the river's curvature area lack of shore defence. The geotechnical constitution of the land on which the road is located (ballast and gravel alluvial deposits layers) contributed to the road foundation accelerated erosion.

The reduced dimension of the Voroneț River flow section in the degradation area, as well as the lack of shore defence works were the factors which allowed the excessive road erosion (Fig. 6). The old shore defence works

were degraded and no longer had a functional role in the county road protection (Fig. 4). The hydrodynamic riverbed erosion phenomenon has led to the lowering of shore defence works base elevation. The retaining wall and shore defence concrete slabs were fissured and cracked and later were carried by the water during floods. The lack of rehabilitation works led to a decrease in the shore defence works protective capacity.

a *b*

Fig. 5 – Voroneț Stream erosive action on the left bank and DJ 177D road: *a* – the starting section of the shore defence and road degradation („Camp Cristea" downstream area); *b* – the ending area of the eroded road section up to the versant (upstream of Brusturos Stream).

The field analysis has highlighted the flow section blockage at bridges, footbridges, pedestrian bridges, riverbed areas with small sizes. In this context, the water and alluvial material transit was carried over the bridge, road and through the minor and major riverbed neighbouring areas. The destructive phenomena had a high intensity, over a significant river length, and the damage is important, requiring large investment for remediation.

The analysis conducted in Voroneț River hydrographic basin has revealed a number of hydroclimatic risk factors, namely:

– rainfall concentration on short time intervals (1 – 2 days);

– high torrential rainfall frequency over short time intervals;

– low riverbed transit capacity in case of high flow floods;

– riverbed morphological change, with thalweg and shore erosion, riverbed blockage etc.;

– the erosion areas have a negative impact on the riverbed and riparian area constructions and installations stability;

– the increase of riverbed forest material transportation due to uncontrolled deforestation.

DJ 177D county road reconstruction must be correlated with the design and execution of shore defence works on river sectors affected by hydrodynamic erosion. The shore defence works must withstand the water erosive action and also the action of solid flow made of gravel and large stone. Shore defence works must ensure the riverbed banks stability, together with the road shoulder.

a *b*

Fig. 6 – Details on the Voroneț Stream riverbed structuring mode at the DJ 177D road limit: *a* –„Camp Cristea" area; *b* – „Poiana lui Macarie" upstream area.

4. Conclusions

1. The Voroneț hydrographic basin area has been affected in the past 15 years by disastrous hydrological phenomena, which have significantly influenced the riverbed morphology, with important influences on the riparian environment.

2. The Voroneț River June 2016 floods have recorded maximum flows with 1% exceeding probability ($Q_{max,1\%}$ = 118.12 m^3/s downstream and $Q_{max,1\%}$ = = 71.61 m^3/s in the research area), a situation which produced extremely destructive effects on the riparian area.

3. The Voroneț River June 2016 flood produced significant degradation on DJ 177D county road, on „Camp Cristea – Poiana lui Macarie" sector, including the it's entire breaking on about 400 m.

4. The Voroneț stream hydrographic basin climatic phenomenon from June 2016 can be defined as hydroclimatic risk phenomenon through their destructive influence on the riparian area occupied with houses, on the county road and on the riverbed morphology.

REFERENCES

Avram M., *Cercetări privind impactul factorilor de risc hidroclimatic asupra proiectării, tehnologiilor de realizare şi exploatării lucrărilor de regularizare a râurilor*, Raport 2 de cercetare, Universitatea Tehnică „Gheorghe Asachi" din Iaşi, 2016.

Luca M., E*xpertiză tehnică Obiectiv 2 „Refacere apărare de mal la Pârâu Voroneț în lungime de 300 m (zona Poiana lui Macarie) prin lucrări de gabionare pentru punere în siguranță drum DJ 177D, sector aflat în administrația oraşului" Gura Humorului*, S.C. Polias-Instal Iaşi, 2016.

Luca M., Stoenescu I., *Current Issues Concerning Regularization Works Behavior under Disaster Conditions*, International Conference „Disaster and Pollution Monitoring – IC.DPM. 3". 1-2 nov., Iaşi, 93-98, 2007.

Stăncescu L., Moraru N., Ionescu V., Leinweber L., *Îndrumător tehnic pentru lucrări de îmbunătățiri funciare*, Editura Ceres, Bucureşti, 1984.

Ujvari I., *Geografia apelor României*, Edit. Ştiinţifică, Bucureşti, 1972.
Vamanu E., Olariu P., *Riscuri hidroclimatice în Spaţiul hidrografic Siret în contextul modificărilor geografice*, Culegere de lucrări, Sesiunea ştiinţifică anuală INMH Bucureşti, 2002.
* * * *Atlasul Cadastrului Apelor din România*. Ministerul Mediului, Bucureşti, 1992.
* * * *Atlasul geografic al României*, 1985. Editura Didactică şi Pedagogică, Bucureşti.
* * * *Rapoartele de sinteză privind apărarea împotriva inundaţiilor, fenomenelor hidrometeorologice periculoase, accidentelor la construcţii hidrotehnice şi poluărilor accidentale din judeţul Bacău, 2016*, Admin. Bazinală de Apă Siret.

STUDII ŞI CERCETĂRI ASUPRA EFECTELOR VIITURII DIN IUNIE 2016 DE PE RÂUL VORONEŢ ÎN ZONA „CÂMP CRISTEA" – „POIANA LUI MACARIE"

(Rezumat)

Este prezentată o analiză a parametrilor de risc hidroclimatic în bazinul hidrografic al râului Voroneţ. Studiile şi cercetările s-au efectuat pe râul Voroneţ, pe sectorul cuprins între secţiunile "Câmp Cristea" şi "Poiana lui Macarie", după tranzitarea viiturii din luna iunie din anul 2016. Viitura a modificat morfologic albia minoră şi cea majoră a râului Voroneţ, situaţie ce a influenţat zonele de inundaţie riverane din intravilan şi extravilan. Efectul viiturii s-a concretizat prin distrugerea parţială a drumului DJ 177D. Pe o lungime de circa 425 m, DJ 177D a fost distrus total. Valoarea precipitaţiilor în BH Voroneţ a fost de 71,6 l/m^2 în două zile. Debitele calculate în secţiunea "Camp Cristea" pe râul Voroneţ a fost de 71,61 m^3/s cu probabilitatea de depăşire de 1%, iar în secţiunea aval a râului de 118,12 m^3/s (p = 1%). Efectele inundaţiilor s-au materializat prin degradarea excesivă a lucrărilor de apărare de mal (circa 2 600 m) pe râului Voroneţ amplasate în intravilanul oraşului Gura Humorului, cartier Voroneţ şi în extravilanul oraşului. Viitura a degradat total două poduri. Inundaţiile au produs degradări ale obiectivelor sociale şi economice din zona riverană.