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STUDIES AND RESEARCH ON NATURAL AND ANTROPIC RISK THE MOLDOVA'S LOWER COURSE

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Key words: constructive degradation, erodible riverbed, morphology, shore defence

Abstract: The paper presents the studies and researches on the natural and anthropic risk parameters on the Moldova riverbed in the Soci area, Iasi County. In this area are located hydrotechnical structures for regulation of the riverbed and shore defence for the protection of the undercrossing of the Timisesti-Iasi adduction pipeline. The theoretical study analyzed hydrological risk parameters (especially liquid and solid flows) recorded over the last 30 years. High flow rates have a high hydroclimatic risk for bed and river construction. Anthropogenic risk parameters were manifested in the morphological modification of the minor riverbed of the Moldova River. An important anthropogenic risk is the uncontrolled exploitation of the ballast in the bed and river banks of Moldova. The effects of this risk contributed to the descent of the bed of the bed at an accelerated pace, along with the erosion of the banks. The accumulation of the effects caused by the natural and the anthropic risks led to important morphological changes in the riverbed of Moldova. These modifications have altered the safety state of the construction of the undercrossing of the Timisesti-Iasi adduction pipeline. The result of the hydrological and also human actions was the degradation of the pipelines until their rupture.

Introduction

Global climate changes also occur in Romania. Climate change is present in Romania's regional and local evolution of temperatures, precipitation distribution, intensification of the desertification process, degradation of environmental conditions, etc. A direct influence is felt on the hydrological cycle at the basin level and mainly on the annual distribution of precipitation and flow. Climate change creates risk factors in the decade, monthly and annual evolution of hydrological

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and hydraulic parameters on rivers in a river basin. The effect of these factors was extremely strong in the natural and human environment.

The impact of anthropogenic risk factors has been felt in the last period of time. Studies and researches conducted at both international and national levels highlight the influence of anthropogenic risk factors on the current climate evolution (Luca M., 2012, Romanescu G., Stoleriu C., 2013).

The hydrological regime of the rivers in Romania is characterized in the last period of time by the high frequency of the floods. During one year, one or two floods with maximum flows were recorded on the same river. Hydrological changes also influence the behaviour of existing buildings in the bed and on their banks (Luca M, Stoenescu I., 2007, Romanescu G., Stoleriu C., 2008).

Hydrological risk factors are floods with flows reaching and exceeding the calculation probabilities imposed on the design of bed constructions (bridges, adjustments) and shore (shore defence works, dams). Hydrological risk factors affect locally, but also along the river bed morphology and indirectly, the habitat existing in the minor and major river bed (Luca M., 2016).

1. Study area and research method

The studies and research were carried out on a Moldova Riversector located between Moţca and Miroslovăşti, with details in the Soci area, Iaşi County (Fig.1). The study area presents a number of hydrological, biological, economic and social features. In this area there is a groundwater basin that supplies a number of extensive localities in the counties of Iaşi and Neamţ. In the area of Soci locality is placed the subdivision construction of the Moldova River for three adduction pipes from the water supply system of Iasi county (Fig. 2). The Moldova River has two arms in the study area with a length of 380-400 m, of which the left one is more developed in cross-section. The undercrossing area is regularized and the shores are protected by shoreline defences of 500 m in length.

The Moldova River has up to the undercrossing section of the Timişeşti - Iaşi adduction pipes the length of 160 km, the area of the basin 3,567 km^2 and the slope of the talveg on the study sector 1,30‰. The river presents a morphologically modified meander, in the study area. An exception is the construction sector of the undercrossing construction of the pipelines, where the river has a rectilinear route. The considered river sector has an NW - SE orientation. The geographic coordinates of the analyzed sector are: latitude $47^0$10'50.00"N, longitude $26^0$37'10.11" E.

The analyzed river sector has a large number of rural localities, where the main activity is agriculture and animal husbandry. In the study area located on the Moldova River there is a number of ballasts, especially on the left bank, with an important yearly ballast production.

Conservation geographical areas with special flora and fauna imposed creating "natural sites" protected by law. Europe was created ecological network "Natura

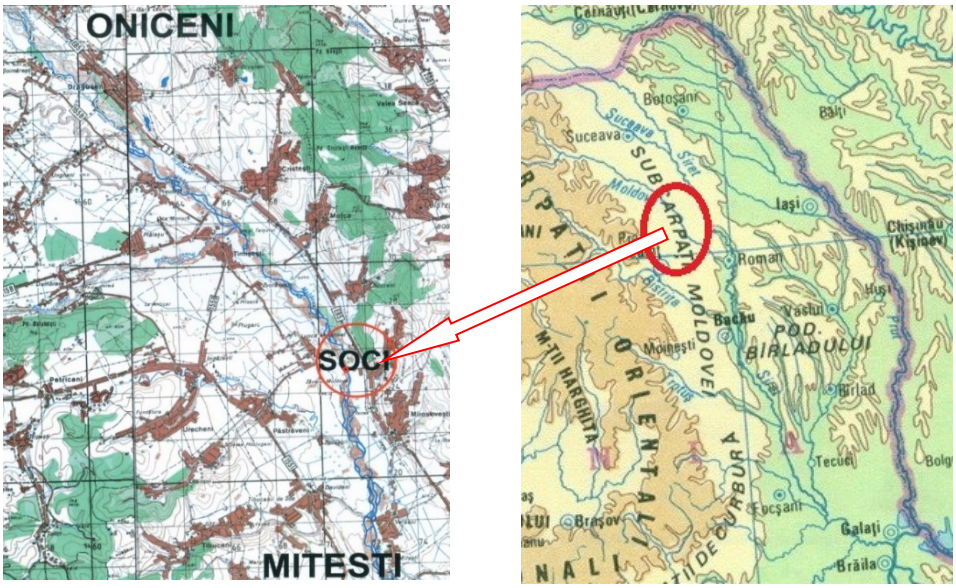

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Fig. 1. Study and Research Areas on the Moldova River: a - study area of risk factors; b - the influence zone for "Oniceni Natural - Miteşti Natural Site".

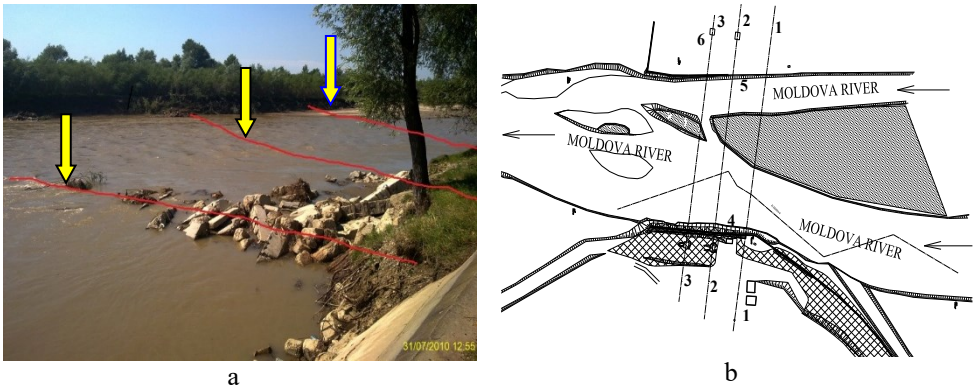

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Fig. 2. Map of the undercrossing Moldova River in Soci zone: a – image of undercrossing adduction pipes; b – scheme of the protection works; 1, 2 and 3 – adduction pipes; 4 - protection works of the left bank; 5 – protection works of the right bank; 6 - inspection chambers.

2000", which was implemented in Romania through a series of community sites protected by law. These sites include protected areas where human action is

limited. Part of the Moldova River and waterside fall into the "Site of community importance ROSC10363 Moldova River between Oniceni and Miteşti" (Fig. 1.b).

The research material is carried out on the river sector and consists of hydrological, hydraulic, topographic, geotechnical, safety studies in hydrotechnical, environmental, etc. Studies are conducted over a period of about 30 years, and experimental research is being carried out since 2004.

Primary data was processed using statistical, hydrological, hydraulic calculation programs as well as special programs on the field of study.

2. Results and discussions

The research focused on defining the natural and anthropic risk factors formed on the studied river sector. The research also analyzed the influence of risk factors on the evolution over time of components of the natural and human environment existing on the studied river sector.

Natural risk factors and anthropogenic risk act in the area of study on the following natural, economic and social areas (Fig. 3):

a - sector on the Moldova River (the minor bed and the riparian area) analyzed;

b – Hydraulic installation undercrossing for the three adduction pipes;

c - hydrotechnic constructions for riverbed regulation and shore defence works;

d - the existing habitat in the riverbed and in the riparian area, belonging to the natural site "Natura 2000" Oniceni - Miteşti.

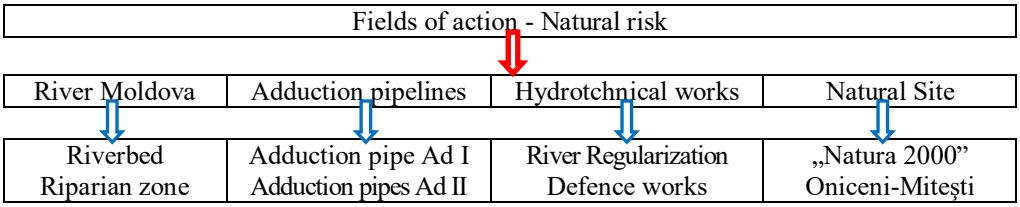

Fig.3. Fields of action of natural and anthropic risk in the study area

Natural risk forms acting on the river sector can be defined in the following forms (Fig. 4):

1. Hydrological risk expressed by torrential rainfall, maximum flows, high frequency of peak flows, flood rate overruns levels.

2. The hydraulic risk on the river sector is represented by the maximum flow rate in the analysis section, erosion rates, sedimentation rates, and hydrodynamic erosion depths.

3. The geotechnical risk on the researched river sector is represented by the structural state of the rock that constitutes the minor bed. In this case, the

geotechnical risk is represented by the alternation of ballast, sand and gravel layers found in the base of the minor bed, but also of the major river bed (Luca M., 2012).

4. The biological risk on the researched river sector is represented by the degradation phenomena of the river bedside and riparian habitat. The main degradation phenomena are as follows: degradation to total destruction of the habitat areas of fish protected by the natural site; the degradation of the riparian area where there are a number of species of protected amphibians and reptiles.

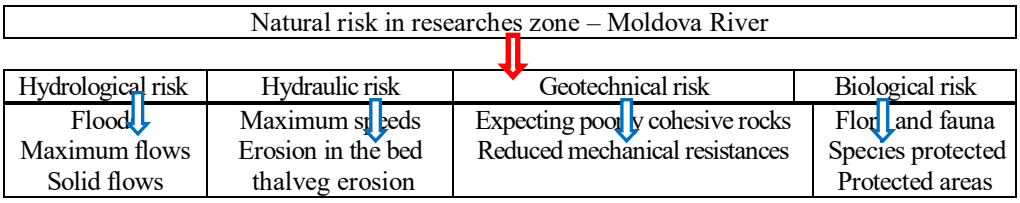

Fig. 4. Natural risk factors and mode of action on the Moldova River

With regard to hydrological risk factors, the high frequency of floods has been mentioned over the past 20 years. In the research were used the climatic and hydrological data taken from the nearest hydrometric station on the Moldova (SH Tupilati). For a more accurate analysis hydrological and hydraulic parameters have been calculated in characteristic sections on the investigated river section. The analysis of transit flows was analyzed at characteristic intervals of 10 years, 25 years and 55 years.

The analysis shows that the torrential precipitations are much more present in the last 20 years on the territory of the river basin of the Moldova River. These have led to changes in the multiannual rainfall rate and have generated maximum flows in a very short time. Such situations were recorded in the years 1992, 2005, 2008, 2010, 2014 and 2016. The floods generated on the Moldovan river in recent years have negatively influenced the riparian area, the river habitat, the adjacent agricultural land, the regularization works, the bridges, the roads and so on (Luca M., 2012).

From the data processing for the Soci section on the Moldova River, the average multiannual flow between 1959 and 2016 was 31.806 m^3/s. Data processing between in the period 1990 - 2016 shows a value of 29.298 m^3/s. The annual average flow with the lowest value for the analyzed period (1959-2016) is 9.59 m^3/s, and the highest value for the same period is 57.80 m^3/s (Luca M., 2012).

The Moldova River crossed the Soci section in 2005 with a flood with Q_{max} = 1154 m^3/s; in 2010 there were two floods: first in summer with Q_{max} = 660 m^3/s; the second in autumn with Qmax = 965 m^3/s (Fig. 5). The flows and quotas on the Moldova River in the Soci section research area were calculated and are presented in Table 1 (Luca M., 2012). The maximum flow rate of 1402 m^3/s was recorded in

1991 at the Tupilati hydrometric station. The historical minimum flow rate of 0.85 m^3/s was recorded in 1987. The ratio between historical maximum and minimum historical flow is about 1649. High values of the coefficient of torrentiality are present also in the case of monthly average flows (about 170 ... 175) and even annual ones (about 5-6).

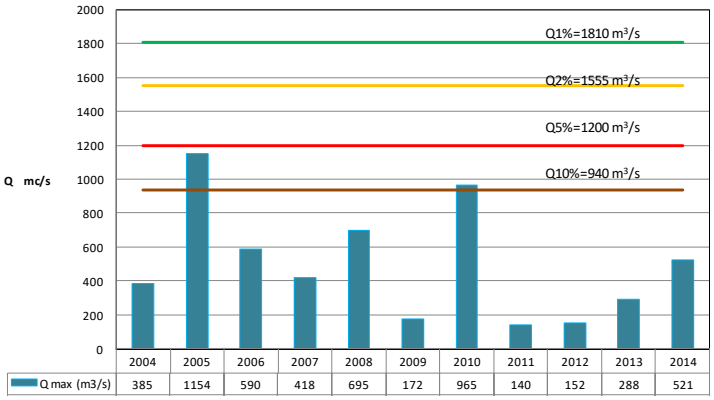

Fig. 5. The frequency of annual maximum flows during the 2004 - 2014 periods in the Soci section, Moldova River (Luca M., 2012)

Table 1 Calculus discharges and levels in the Soci section, Moldova River

Probability, (p %)	1%	2%	5%	10%	50%
$Q_{p\%}$ (m^3/s)	1810	1555	1200	940	28.8
H (m)	257.15	256.95	256.50	255.90	253.10

Solid flows are directly proportional to liquid flows, increasing the latter by increasing the amount of slurry conveyed in suspension and crawling.

The hydraulic risk on the river sector is represented by the erosion velocities with high values in the analysis sections on the Moldova River. Hydraulic risk factors (especially the hydrodynamic erosion rate), corroborated with geotechnical risk factors (especially non-wood-based rock from the bed of the river bed), determine high erosion depths. The researches carried out in 13 characteristic sections located on the 280 m long river section revealed average speeds in the range 1.81 - 2.21 m/s for flows of 460-1210 m^3/s. These primary data allowed the calculation of erosion depths of 0.56 - 0.81 m, values that were used to design the hydro-technical works in the Soci area (Luca M., 2012).

The hydraulic risk corroborated with the geotechnical risk led to the deterioration of the stability of the adduction pipes mounted in the ballast layer forming the riverbed of the Moldova River. Thus, the adduction pipe Ad I

Timisesti - Iasi was stripped and broken into the river bed, being completely removed from operation. The two pipe sections of the adduction pipe Ad II were stripped to depths of 0.80 - 1.40 m by lowering the bottom of the bed following the hydrodynamic erosion phenomenon (Luca M., 2012).

The natural risk forms that act on the regularization works of the Moldova riverbed as well as on the shore defence works can be defined in the following forms: hydrodynamic risk, geotechnical risk, hydraulic risk, seismic risk. Of these an important influence is the hydraulic risk through the phenomenon of hydrodynamic erosion, which corroborated with the geotechnical risk caused the degradation and the total destruction of the shore defence works.

The impact of anthropogenic risk factors has been felt in the last period of time. Studies and researches in the research area conducted of levels highlight the influence of anthropogenic risk factors on the current riverbed evolution (Fig. 6).

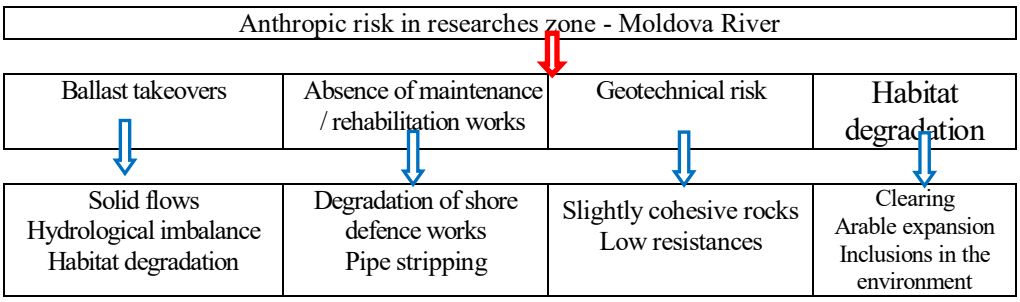

Fig. 6. Anthropic risk factors and mode of action on the Moldova River

Research carried out between in the period 2004 - 2015 analyzed in detail the degraded phenomenon of shore defence works in the undercrossing area of the adduction pipes. The shore defence was carried out in 1971. It consists of two overlapping constructive structures (Figures 7.a, 7.b). The first structure is a massive stone 1.80 m high on a fascia mattress. The second structure consists of concrete slabs (50x50x10 cm) mounted on a ballast bed and supported on a simple concrete beam. The tile wall has a tilt slope of 1: 1.5 and is mounted at a height of 1.70 m (Figure 7.a). On-site research analyzed how the construction behaved over time at site factors.

During the first years of exploitation there was a clogging of the shores defence works. During the period 2005 - 2015 the hydrological and hydraulic regime was modified on the section with the undercrossing construction located on the Moldova River. Natural risk factors, corroborated with those of anthropogenic risk, have accelerated the degradation of shore defence works until their total destruction. The degradation of shore defence works was more intense on the left

bank, where the phenomenon was accelerated by the anthropic risk factor represented by ballast exploitation (Fig. 8).

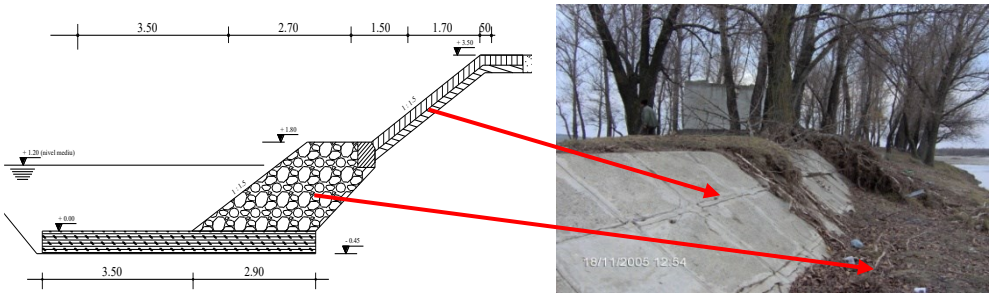

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Fig. 7. Images of the protection works on the Moldova River: a - execution detail; b - shore defence in 2005.

Anthropic risk in researches zone – Regularization works and shore defence		
Hidrological - hydraulic risk	Management risk	Geotechnical-seismic risk
Limitation of studies and research on hydrodynamic erosion of river bedside	No inspection, repair and maintenance work Rehabilitation works absent	Limiting studies and research on the behaviour of works

Fig. 8. Anthropic risk factors and mode of action on the Moldova River

The degradation of shore defence works was carried out through the following destructive processes during the years 2005 - 2012. The degradation process included the steps: a - washing the alluvial offshore defence (Figure 9.b); b - removing the cement mortar from the joints and washing the ballast layer under the tiles; c - cracking and cracking of concrete slabs; d - the entrainment of the rock from the supporting mass and the collapse of the defence structure (Fig. 9.a); e - breaking of the support beam and the collapse of the concrete slabs; f - the entrainment of concrete pieces in the riverbed and the erosion of the bank (Fig. 9.b) (Luca M., 2012).

A special problem is represented by the classification of the Soci study area on the Moldova River in the "Oniceni Mitesti" natural site. In this case, hydrological and anthropogenic risk factors influence the evolution of the habitat in the natural site. Natural site "Oniceni - Miteşti" is located in the river Moldova and Suceava, Iasi and Neamt County. Site area is 3215 ha. Site coordinates are latitude N 47^0 17' 22"; E longitude 26^0 29' 3". Site elevation is 235 m minimum, maximum 339 m and middle 271 m (Fig. 1). Biogeographically region is of "Alpine Continental Pannonian Pontic". Natural site „Oniceni-Miteşti" contains habitat type classes rivers, lakes, arable land, grassland and deciduous forests. Natural site contains mammal species

listed in Annex II of Council Directive 94/43 / EEC (*Lutra Lutra and Spermophilius citellus*). The site area is present protected species of amphibians and reptiles (*Triturus cristalus, Bombina bombina, Bombina Variegata*). In Moldova and tributary river is protected fish species (*Barbus meridionalis, Rhodeus sericeus amarus, Gobio uranoscopus, Sabanejewia aurata and Cobitis taenia*).

a b

Fig. 9. Images of the protection works on the Moldova River: a - degraded left bank defence (2012); b - total left destroyed defence (year 2012) (Luca M., 2012).

The analysis carried out in the research area on the amplitude of the degradation of the undercrossing construction of the Moldova River by the Timisesti - Iasi adduction pipes, as well as the total degradation of the shore defence works, indicated the effect of the corroboration of the natural risk with the anthropic one (Fig. 10).

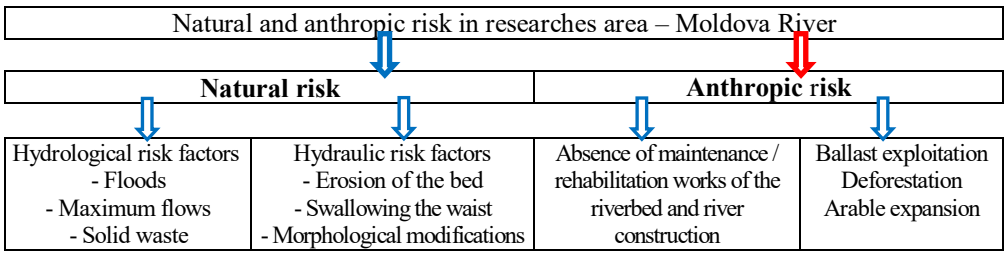

Fig. 10. Corroboration of natural and anthropogenic risk factors on the Moldova River - Soci area

The accumulation of natural risk factors in the study area (floods, maximum flows, high frequency of peak flows, erosions, noncohesive rocks in the basin of the riverbed) with the anthropic ones (ballast exploitation, deforestation, absence of regulation and shore defence, the extension of the arable land) caused excessive degradation of the riverbed in the transverse and longitudinal plane (Fig. 11).

The excessive morphological modification of the riverbed caused the degradation of the stability and integrity of the adduction pipes Timisesti - Drinking for drinking water. Also, shore defence works and regularization works have been degraded differentially on both sides of the river. The shore defence on the right arm of the Moldova River was degraded by 90%, where the anthropic factor (ballast exploitation) occurred substantially.

a b

Fig. 11. Anthropic risk factors (ballast exploitation) in the morphological modification of the river bed of Moldova: a - anthropic modification of the river flow paths; b - partial blocking of flow ballast deposits through the right arm of the river in the research area.

Conclusions

1. The territory of the river basin of the Moldova River has been affected in the last 15 years by disastrous hydrological phenomena, which have significantly influenced the morphology of the minor bed, with important influences on the constructions located in the riverbed and in the riparian environment.

2. During the period 2004-2016 they occurred on the Moldova River in the area of the locality Soci, Iasi County, where the Timisesti - Iasi River adduction pipes are located in the undercrossing, a series of floods with high flow rates and high frequency at reduced intervals, which morphologically modified the bed and eroded the regularization and shore defence works.

3. The non-rational exploitation of ballasts upstream from the undercrossing area induced an extremely high anthropic risk and influenced the morphological stability of the riverbed of Moldova River.

4. The accumulation of natural risk factors (floods, erosions, non-cohesive rocks) with the anthropic ones (ballast exploitation, deforestation, absence of regularization works and shore defence) caused excessive degradation of the riverbed, adduction pipes and shore defence, and ultimately led to the breakdown of the undercrossing pipes.

5. Climatic phenomena produced in the river basin of the Moldova River in the last 15 years can be characterized as hydroclimatic risk phenomena due to their destructive influence on the morphological evolution of the riverbed and implicitly on the riparian habitat.

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