CONSIDERATIONS REGARDING ECOLOGICAL RESTORATION OF DEGRADED RIVERBED

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ABSTRACT: *The ecological restoration of the secondary riverbeds is a necessity for ensuring the living conditions of the aquatic habitat. At the European level, ecological works have been carried out in the last period of time that restore the natural environment from the secondary riverbeds. Ecological restoration of riverbeds is a complex process that causes the restoration of an ecosystem that has been partially or totally degraded in the aquatic environment or in the riparian area. The research carried out on the Moldova river indicated the need for designing and carrying out ecological restoration works. Research carried out on a river sector, where two rivers (main and secondary) are present, revealed a series of changes in the aquatic and riparian environment. The changes were given by a set of natural and anthropogenic factors. The secondary riverbed is permanently degraded by intermittent water supply and human action. The intermittent feeding of the secondary riverbed determines the appearance of an aerobic-anaerobic regime, with negative influences on the habitat. The ecological restoration works are applied on the structural components of the riverbed, aiming to create an optimal hydraulic regime for the aquatic habitat.*

Keywords: *aquatic environment; ecological regularization; secondary riverbeds;*

1. Introduction

The environment represents the whole of the natural components of the Earth as well as the conditions of their existence.

The components are defined by air, water, soil and basement, flora and fauna, human values resulting in time, interaction relations between these components etc.

The environment is affected during a series of hydrological phenomena of disaster. These have caused the human society to research and apply multiple defence methods in the short and long term.

With the development of human society, there is a need for protection in the action of water, through the execution of embankment works, regularization of the banks, the defence of the banks, water accumulations etc. (Bica I., 2000, Hâncu S., 1976).

The watercourse is degraded over time by the action of a complex of natural and anthropogenic factors. The main natural factors are hydrologic (speeds, flows and maximum velocities) and geotechnical (rock type from the bedrock foundation). The anthropic factors are represented the constructions made in the riverbed (dams, regularization works) and in the riparian area (dams) and by the human activity (agriculture, economy, social, deforestation, etc.) [Luca M. et all., 2018].

The restoration of the degraded riverbeds is done by using concepts and methods specific to the type of watercourse. At present, modern concepts such as "ecological regularization" or "renaturalization of riverbeds" are used. Their applications are relatively small, and many are in the research phase [Sion, 2019, Tokner K. et al., 1999].

2. Material and research methodology

The research was carried out on the lower part of the river Moldova, where there are a number of ecologically degraded riverbeds. The investigated riverbed is located in the area of Cordun Neamţ County (Sion., 2019, Cadastral Atlas of Waters, 1992). The natural site "Tupila i - Roman" is located on the section of the surveyed river (Fig. 1).

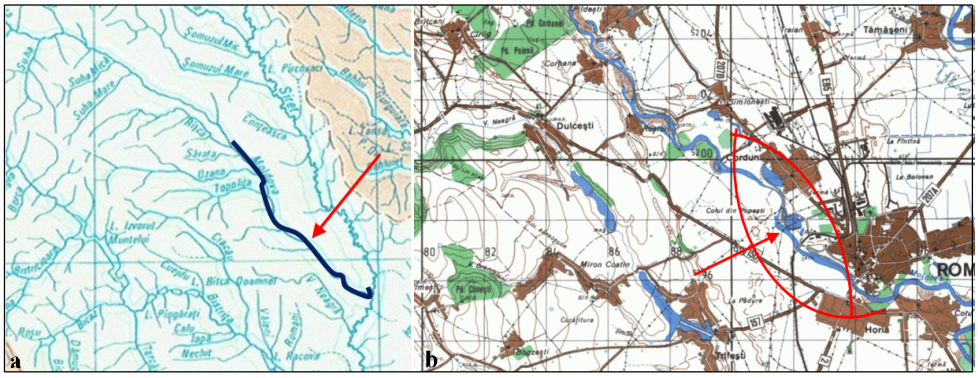

Fig. 1. Fig. 1. Location of the research area
a - map with the lower course of the river Moldova;
b - map with the study area, Cordun locality, Neamţ county [Luca M., et all., 2015].

The hydrographic network is represented by the Moldova River. In the research area, respectively at the border of the Roman oral, the main characteristics of the river Moldova are: length of the watercourse, 204 km; the surface of the reception basin, 4,260 km2; average slope for the analyzed sector, 1.30% o. The hydrological characteristics of the river Moldova in the study area the following (Luca, 2011a):

- flow: Q1% = 1850 m3/s; Q2%= 1590 m3/s; Q5% = 1220 m3/s; Q10% = 960 m3/s;
- levels: Hmax 1% = 190,33 mNMN; Hmax 2% = 190,15 mNMN; Hmax 5% = 189,70 mNMN; Hmax 10% = 189,35 mNMN.

The river of Moldova on the research section consists of two arms (Luca, 2011b):

- arm I (left); this is the main river and on which the water catchment of the Roman industrial area is located;
- arm II (right); this is the secondary river where a seasonal flow of water takes place depending on the hydrological regime of the river.

The data used in the research come from the following sources: technical expertise in the field of river and river defense construction, Synthesis Reports of Water Basin Administrations, projects for regularization works, studies for ecological reconstruction of riverbeds, technical design documentation of regularization works, etc.

The data collection in the field was done through specialized analyzes on research domains, field studies (topographic, geotechnical, hydrotechnical, biological, etc.), material sample collection, photo and video surveys.

The primary data were processed using the statistical, hydrological and hydraulic calculation programs applicable to the case studies performed.

3. Results and discussions

The "radical type" regularization has a direct influence on the morphology of the riverbed, but also an important modification of the water regime in the areas arranged with water management works. The regularization of the radical type bank

requires careful monitoring of its behaviour at medium and maximum flow rates to maintain the designed and realized parameters. The regularization of the radial-type riverbed achieves a longitudinal profile stabilized by steering dams, thresholds and sleepers, with influence on the geodesic slope. The presence of shore defense works influences the aquatic habitat, situation in which a minimum of living conditions must be ensured (Hâncu, 1976).

Ecological restoration is a complex process that achieves the restoration of the aquatic and riparian ecosystem that has been degraded or destroyed by various actions. The restoration process foresees a series of activities, which initiate or increase the recovery of the ecosystem, by considering the natural characteristics of the watercourse, the aquatic and riparian habitat and the cooperation with the other ecosystems. The restoration of the ecosystem can be realized for its integration in the new forms of existence of the natural, social and economic environment. Ecological reconstruction is a much more complex process, which aims to achieve a new type of ecosystem, if the initial one has been totally degraded or modified by natural or human actions.

The morphological modification of the riverbed and the carrying out of regularization works caused the appearance of dead arms that are no longer permanently supplied with water. These arms maintain, especially during the warm season, an aerobic / anaerobic regime of stagnant water along the length of the riverbed, with a negative effect on the habitat (Avram, 2016).

Renaturalization works can be performed on the main or secondary arms affected by the following phenomena:

– phenomena of morphological degradation of the riverbed (clogging);
– active phenomena of degradation of flora and fauna;
– degradation of the quality of the water stationed and transited through the riverbed.

Such a section was identified on the lower part of the river Moldova in the area of Cordun Neamţ county. On this section is located the water catchment for the industrial area of the Roman city. The taking of the water flows forced the arrangement of the river bank of Moldova with the following hydrotechnical constructions:

– a bottom threshold for raising the water level, followed by a sink and a downstream apron;
– construction of catch located on the river bank with the related accessories;
– the riverbed is calibrated and provided with shore defence works on a length of about 320 m.

The presence of the capture construction produced a morphological modification of the riverbed of the Moldova river. For the execution of the water catchment from the riverbed, a second arm was made to divert the water during the works (Fig. 2).

Fig. 2. Main river/ left arm of the Moldova River in the catchment area
a - status of the catchment in the catchment area;
b - the status of the downstream catchment [Luca et al., 2019]

The paper presents some of the results obtained in the first stage of research. This included the selection of the research area, the documentary study, the analysis of the characteristics of the degraded riverbed and the primary definition of the concept of ecological restoration. Phase II provides for the elaboration of the concept of ecological restoration and the design of the structural components of the works for the realization of an aquatic and riparian habitat suitable for the study area.

Hydrological data analysis has highlighted a high frequency of floods over the last 20 years. The value of the maximum debts was preponderant, and their frequency was high. From data processing at S.H. Tupilaţi resulted that the maximum annual flow for the period 1959 - 2018 has the value of 1402 m3/s (year 1991, July, calculation probability p . 3%). The lowest value of maximum flow was recorded in 1986 and 1990 (105 m3/s). The historical minimum flow was 1.00 m3/s (1991, February). The hydrological studies performed in the study area indicated the calculation and verification flows, but not including the safety increase, presented in Table 1.

– the depths of the water are variable (0.5 -2.5 m), with high speeds, situation that does not allow to ensure the living conditions for the aquatic fauna and flora.

The analysis carried out in the field highlighted for the secondary riverbed of the river Moldova (right arm) the following characteristics (Fig. 3, Fig. 4):

– the path of the right arm is curved, with a natural bank fed intermittently, more at high flows;
– between the two arms of the river an island was formed, with a land taken on the left bank occupied with agricultural crops (Fig. 3.b);
– the secondary bed has a variable width, being morphologically modified at floods by erosion and clogging phenomena (Fig. 4);
– in the secondary riverbed there are alluvial formations that block the flow of water;
– at the entrance to the riverbed there is an improvised drainage threshold, which limits the access of the water to small flows (Fig. 5); Prior to joining the main riverbed, an improvised stone spillway threshold is intermittently made (Fig. 5);

Table 1. Debits with probability of calculation by study sector from the river Moldova [Sion P.V., 2019]

p (%)	2	5	10	20	50	95
Q_{max} (m^3/s)	1650	1275	1000	558	31.0	2.13

The analysis carried out in the field in the years 2011 (Luca M.) and 2018 and 2019 (Sion P., 2019) showed for the main riverbed of the Moldova river (left arm) the following characteristics (Fig. 2):

– riverbed is calibrated on a length of 320 m, with a cross section of trapezoidal shape; flow regularization is performed with a bottom threshold, energy sink and a rhizome;
– the left bank is protected by reinforced concrete slabs;
– the right bank is protected by the beds of gabions filled with river stone;

- the water depths are small, with very low speeds, and in some areas the water stagnates with the generation of anaerobic phenomena and degradation of the aquatic environment;

- the presence of an intermittent flow in the riverbed does not allow the optimal living conditions for the aquatic fauna and flora.

The research carried out on the territory of the island showed its occupation by unorganized vegetation, consisting of areas occupied with grass, shrubs and trees. In the central area of the island there is a lake.

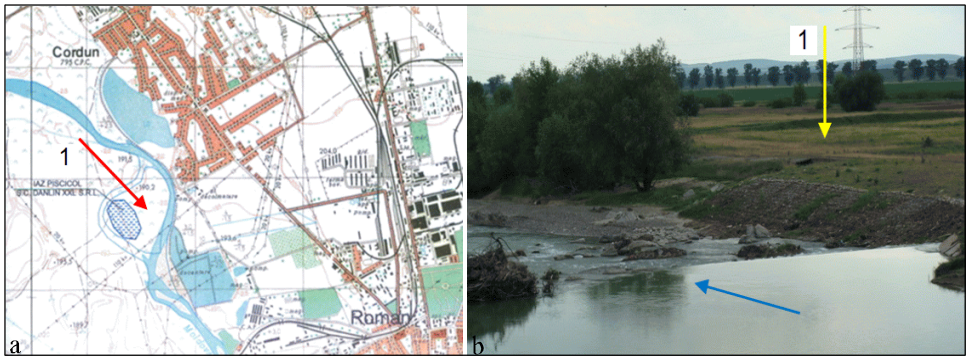

Fig. 3. Characteristics of the location of the island and the secondary riverbed
a - the situation map of the island; **b** - general view of the island (1) from the catchment area on the left arm [Luca M., et al., 2019)]

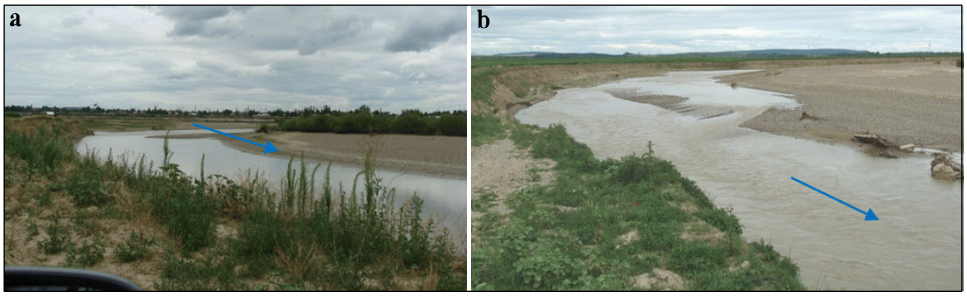

Fig. 4. Overview of the island and the secondary bank from the NW
a - shore erosion and alluvial deposits; **b** - alluvial deposits on the central sector of the riverbed [Sion, 2019]

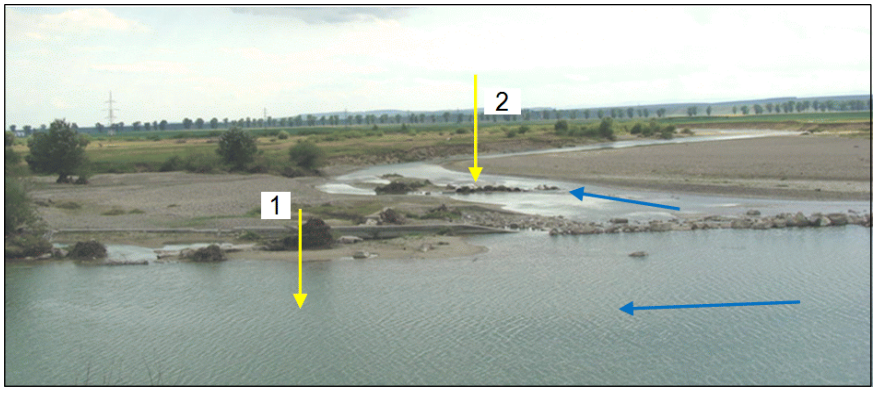

Fig. 5. General view of the bifurcation zone of the two banks of the whole Moldova river of the island
1 - main riverbed; 2 - secondary riverbed with the improvised spillway threshold (Sion, 2019)

The presence of the island allows for satisfactory living conditions for the riparian habitat.

The analysis carried out in the field for a period of about 10 years (Luca, 2011b, Sion, 2019) showed the state of continuous

degradation of the secondary riverbed of the Moldova river. During the summer and drought, the processes of degradation of water quality in the secondary arm intensify. The placement of the secondary bank in an economic and social environment existing in the area requires the carrying out of ecological restoration works.

The objectives of the ecological regularization of the secondary riverbed resulted from the research carried out in the considered area are the following:

- the management of the river bank in the most rational way, taking into account the ecological, environmental, economic and social aspects;
- mitigation, compensation and prevention of natural hydroclimatic risk factors (floods, very low flows, heavy alluvial transport) on the secondary riverbed;
- mitigation, compensation and prevention of anthropogenic risk factors (presence of ballast, shrub and tree clearing, habitat degradation) on the riverbed;
- minimizing future conflicts of interest involving various sectors (forestry, agriculture, transport, recreational activities), which intervene on the evolution of the water course over time through works in the riverbed or the riparian area;
- preserving the self-regulating capacity of the aquatic and riparian ecosystem.

The ecological restoration of the secondary bank of the river Moldova is carried out through a set of works of the type:

a - realization of a hydraulic concept for the management of the degraded riverbed to allow obtaining the living conditions for the aquatic flora and fauna;

b - achievement of an overflow threshold at the entrance to the riverbed with dimensions and characteristics that allow to take a flow from the controlled main riverbed;

c - works to regulate the riverbed to ensure the transit of a minimum flow for a depth of about 0.50 - 0.80 m; the flow through and the minimum depth required to ensure the quality of the water;

c - carrying out a hydrotechnical construction comprising a spillway threshold and a dock in the final section of the riverbed with dimensions and characteristics that allow the evacuation of a controlled flow from the secondary riverbed;

d - creation of a biotic environment in the riverbed for the restoration of flora and fauna;

d - realization of a fisheries sector for the supply with biological material of the riverbed downstream after the union of the two arms;

e - realization of the specific fauna of riverbeds in the ecologically restored sector; components of the fauna will be transferred sequentially in the main course for

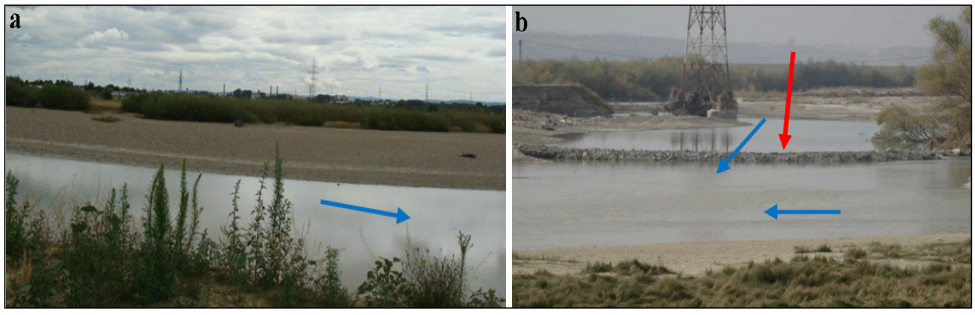

Fig. 6. Morphological elements of the secondary riverbed

a - the final sector of the riverbed; **b** - the improvised threshold in the final section of the secondary riverbed at the junction with the main riverbed [Sion, 2019]

enrichment with biological material necessary to ecologize the riverbed.

The ecological restoration of the degraded riverbeds will follow the realization of the zone of riparian vegetation that will ensure the achievement of an air flow. The regularization of the watercourses caused important changes in the vegetation of the riparian vegetation. Field research has revealed the absence of shrubs and trees on the banks of the secondary bank. Its protective effect influences air circulation and the absence of wildlife protection areas. The vegetation on the bank of the secondary bank plays an important role in preventing erosion and in protecting the river bank and the banks by the action of fixing the roots. The riverbank in the lower area, towards the water, is occupied by reed species, and on the higher slope the grass develops. This type of vegetation favors the dissipation of the energy of the water stream and reduces the speed and implicitly the flow, resulting in an increase of the depth. Rivers without regularization work are inhabited for a wide variety of aquatic and riparian vegetation (large plants combined with microscopic algae), which ensure life in rivers.

The section of the riverbed considered in the research is located in the perimeter of the Natura 2000 site, ROSCI0364 - Moldova River between Tupilati and Roman [art. 8 paragraph (1) letter c) of the Government Emergency Ordinance no. 57/2007 regarding the regime of the protected natural areas, the conservation of natural habitats, of the flora and fauna, approved with modifications and completions by Law no. 49/2011]. The works of ecological restoration must also ensure the conditions required by the protection of the aquatic habitat imposed by the structure of the natural site. The wetland represents the specific habitat for 4 species of vertebrates, 4 species of amphibians and 3 species of fish of conservative interest (Barbus meridionalis, Cobits taenia, Sabanejwia aurata) [Lengye P., Duluţă M., 2016].

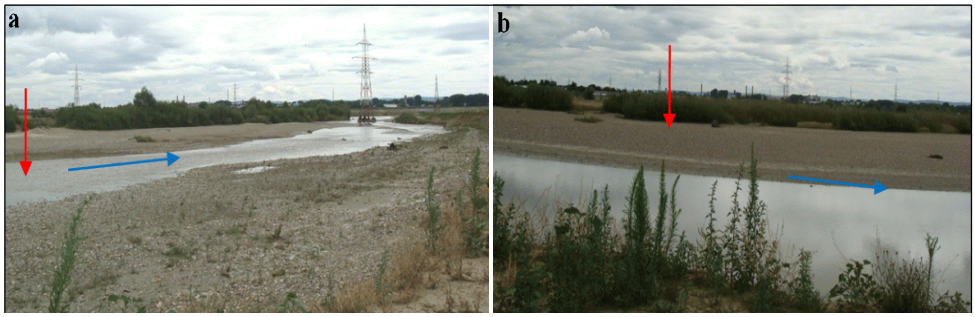

Fig. 7. Ecological restoration area of the Moldova River secondary arm in the Cordun area
a - the entrance sector; **b** - central sector with highlighting the deposit areas (Sion, 2019)

The functioning of the restored natural system in the degraded riverbed is necessary to support the aquatic and riparian biological communities.

The flora and fauna that are integrated in the biotic community depend on specific physical characteristics and a number of ecological processes that are necessary for the living environment.

Physical characteristics are made up of water, water temperature, salt content, rock from the riverbed, etc. Ecological processes in the study area include the water circuit, nutrients and nutrition relationships in the aquatic environment and in the riparian area [Amoros C., Bornette G., 2002].

Physical characteristics and ecological processes are components of the model of existence of an ecological system and together they form the ecological function. Modifying, degrading or destroying a habitat type in the riverbed may result in the loss of species that depend on that habitat type.

4. Conclusions

1. Ensuring optimal environmental protection conditions in the watercourses area requires the ecological restoration of degraded river sections in order to ensure the optimum living conditions of the flora and fauna.

2. The ecological restoration of the degraded riverbeds is carried out by applying a set of regularization works, to realize areas of growth of the biological material on the perimeter of the river, according to the zoning of the water depth and temperature vertically.

3. The ecological restoration requires the creation of areas for the growth of the fish brood for its phased introduction into the main riverbed.

4. Studies and researches have shown on the river Moldova a series of sectors where there are secondary branches in which the water is polluted and the habitat is partially or completely degraded.

5. The renaturalization works are technologically complex and require a high investment, which involves the financial and legislative participation of the authorities.

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