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FLOOD VULNERABILITY VS. STRUCTURAL MEASURES RELATED TO JIU VALLEY DEVELOPED IN THE AREA OF CRAIOVA CITY

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Abstract

The main purpose of this paper is to identify and analyze the extreme hydric phenomena which can occur around Craiova and to highlight the structural and nonstructural measures undertaken by the local authorities in order to reduce the probability of risk retention as low as possible. Craiova area overlaps a section of the middle basin of Jiu River, at the confluence with Amaradia River; Craiova was protected in time from floods, droughts, unlike other urban centers developed on the terraces of large rivers. The only significant and memorable flood was in October 1972, when two large districts, located in the South of the city - Mofleni and Ciuperca - were covered by a layer of water between 1 and 2 meters. Taking the data from Jiu Basin, and from the literature and processing some GIS techniques, like Kernel Distance and Buffer Zone methods, we analyzed the factors that determine the production of floods, as well as those that trigger them. Making the physical and geographical analyze of the area, we identified their qualitative and quantitative parameters and the induced adverse effects, together with economic, social and ecological damage.

Keywords: Jiu River, waterborne risks, structural measures, dams, vulnerability.

1. INTRODUCTION

The research aims at identifying the connection between the structural measures in order to prevent floods in Craiova area and the description of the elements which can be put in peril in case of a flood. In order to reach the objectives, after a brief examination of the physical-geographical features of Craiova Area, representing the basis of the evolution of a flood, the paper mentions some special aspects regarding the climatic conditions which may influence the occurrence of high waters in this sector of Jiu River Basin. A very important part of the paper includes a case study of the last and most powerful flood event having affected Craiova City (the flood of 1972), in order to demonstrate that not only the climatic and hydrological conditions made it possible, but also the lack of hydro technical measures in that time, which is not the case anymore nowadays. The most specific chapter of the paper, for which the GIS techniques were needed, conducted us to the realization of two maps that are able to offer significant information about the potentially affected sections of the studied area. Last but not least, the research was completed by the discussion on the structural measures taken along the Jiu Valley and along some of its tributaries, which became very efficient in the fight with hydrological risk phenomena. This section was conceived thoroughly, by taking into account not only the good facet of the hydro structures built in the area, but also the negative one.

1.1. Methodology

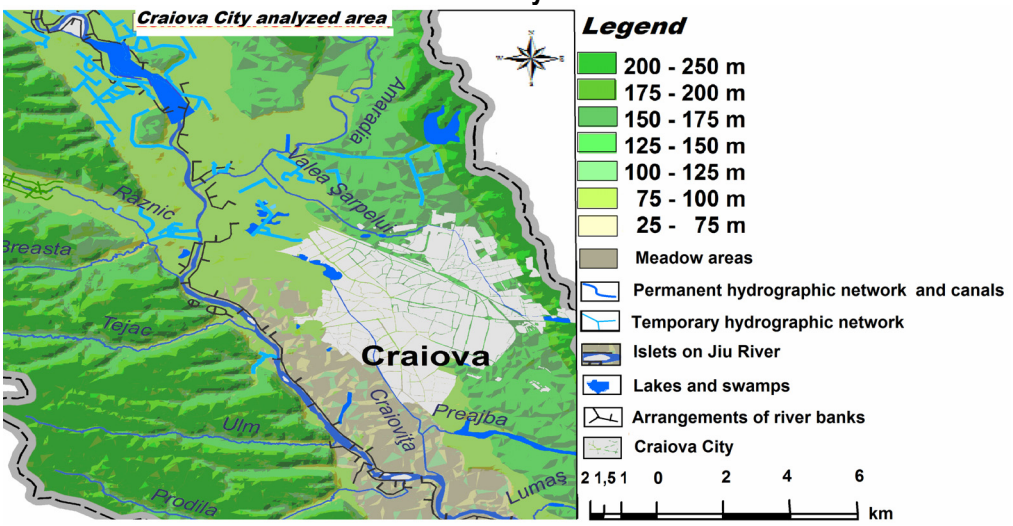
Based on a various quantitative data (length of the rivers and of confluences, the flow direction, the hydrographic density etc.), extracted and calculated from the topographical map in electronic format, scale 1:200.000, we could generate two useful maps, the first one about the river sections that can potentially induce flood risk, with the aid of Kernel Distance function, and the second one representing the potentially floodable zone caused bu a hypothetical high waters event of Jiu River, using the ”Buffer zone” analysis. Flood phenomena in the geomorphological context of the location of Craiova City were analysed both considering physical factors and hydro technical ones, the date being taken from the Annuars of Hydrology and Meteorology, the Administration of Jiu River Basin, as well as from the literature on the topic.

2.1. Physical – geographical characterization of Craiova City area

Craiova City is located where the Romana Plain and the Getic Plateau are brought together, and it is surrounded by: Leu-Dioşti field in the South, the Piedmontaneous Plain of Oltet in the East North-East, Jiu river meadow in the West and Amaradiei river meadow in the North. The perimeter of Craiova is crossed by three rivers: Jiu, Amaradia and Rasnic, and several brooks and streams that flow in this area, as tributaries of Jiu River. In this category we can also include the collector canal of Craiova, which is regularized and

scaled to the needs of the city, and collects effluents (wastewater and industrial water) from the intravilan of the municipality. The effluents are taken to the wastewater treatment station, in order to be discharged in the Jiu River, downstream of Făcăi (Figure 1).

Figure 1. Physical-geographical map of Craiova Area. Source data: Jiu Basin Administration, Craiova, Dolj County.

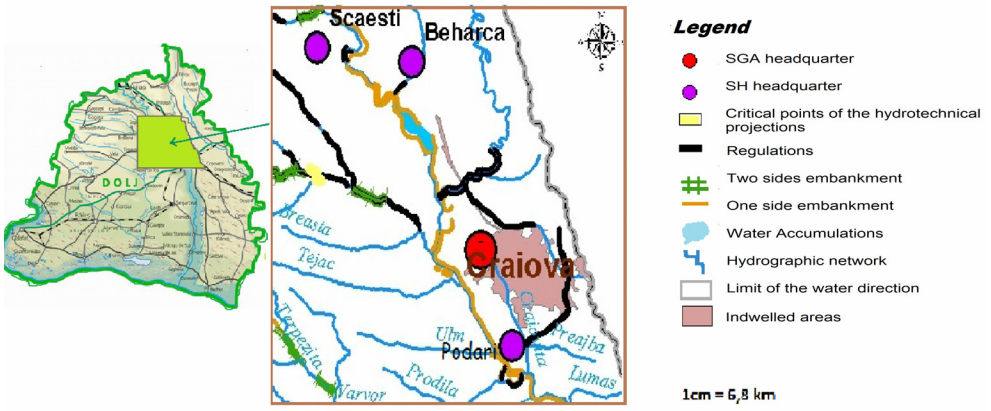


Landscape features (weak fragmentation, energy of relief and moderate cliff), lithological constitution (gravel, sand, loess deposits), showing a high permeability (Savin, 2000); together with the characteristics of climate (low precipitations, thermal regime favorable to intense evapotranspiration), are all reasons that determine the local hydrographic network to be poorly represented, temporarily or permanently, but with insignificant values of the volumes (in lakes) or discharges (rivers).

2.2 Organization of the hydrological and meteorological station network in Craiova area and general characteristics of the flow

Podari Hydrometric Station is the one responsible for recording the river flows on Jiu, in Craiova area; its location is being favorable, because it is downstream of the confluence with Amaradia River, Jiu's largest tributary near Craiova, which may significantly change its hydrological characteristics.

Figure 2. Hydro technical and Hydrometric network in Craiova Area.



On all water courses, hydrometrically controlled in two or more stations, from upstream and downstream of the confluence of Jiu with Amaradia, the discharged water layer decreases from upstream to downstream (Figure 2). Exceptions are noted in the case of Argetoaia River, Raznic River and Amaradia River, which have large drainage losses. The hydrometric network inside the city of Craiova is dense (table

1). Both the surface waters of Craiova and the underground water are included in a priority program of monitoring water quality[1].

Also, the climatic factors that may influence the production of hydrical risk phenomena in Craiova area are very important. Precipitations represent the crucial climate element in shaping and in the existence of water risks.

The best known forms of precipitation that fall in Craiova area are rain and snow. From observations made over time at the two weather stations of the Craiova, The Airport (192 m altitude) and sometimes at Balta Verde Station (72 m alt.), - that worked a short period of time at the water meadow of Jiu River, it was observed the discontinuous character and the uneven territorial distribution of rainfall[2]. and snowfall. This feature is due to the quite varied relief of the area, both as altitude (between 70 -200 m) and as orientation, that produces direction and load detours of low cloud formations (Topor, 1964).

3.METHODS OF REPRESENTATION OF THE INDUCED FLOOD RISK IN THE STUDIED AREA

In order to complete the sets of investigations regarding the vulnerability of the elements subdued to risk in Craiova area, we made two analyses that highlight the sectors with affection potential, in case of break-throughs made by Jiu and its tributaries. In the fist map, named "Map of river sections that can potentially induce flood risk in the administrative area of Craiova by using Kernel Distance function", the hot spots that are reached in the case of a possible flooding were accentuated, without taking into considetation the quantitative characteristics of the water, such as: water flow, cliff coefficient or the direction of the flow. Kernel function utilised as hydrometric access data the length of the river, the length of the confluence between rivers, as well as the density of the hydrographic array.

Map of river sections that can potentially induce flood risk in the administrative area of Craiova City by using Kernel Distance function

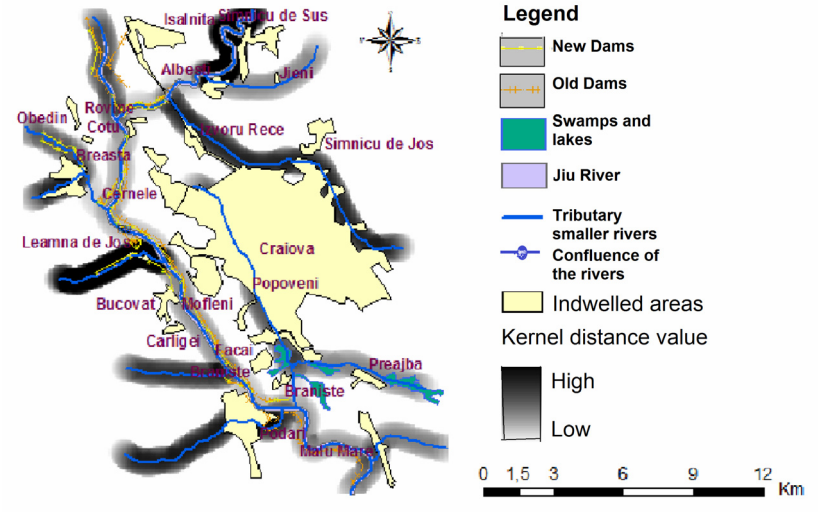


Fig. 3

Furthermore, the function took into account both the protected and the unprotected sectors - with dams and barrages. After reaching all stages, those of vectorising, calculus of hydrometric parametres, the formation of attribute tables with the necessary data, some areas – propounded more or less to flooding risk – came forward.

Some of the places with a high probability of flooding are (considering a counter- clockwise enumeration):

- Şarpelui Valley (North-West canal), along the railway from north of Craiova;
- Amaradia Rivulet, in the neighbourhood of Şimnicu de Sus and Albeşti localities;
- Breasta Rivulet at the confluence with Jiu river, in the neighbourhood of Breasta village;
- Tejac Rivulet in the neighbourhood of Leamna de Jos;
- Ulm Rivulet, in the neighbourhood of Branişte.
- Prodrila Rivulet, upstream and in Podari, until the confluence with Jiu river;

[1] For example, the accomplishment of DESWAT project (the most important monitoring program in Hydrology) allows the cover of a wide range of applications, with obvious economic advantages and structural, but also nonstructural aid in case of the prevention of floods

[2] For instance, the most devastating flood on Jiu river in 1972 was the result of highest amounts of precipitation in Craiova, fallen in the same year (794.4 mm), nearly 200 mm more than the average. Source data: *Hidrological Annuar, 1972*.

Due to the fact that Jiu river is almost fully banked, the lands and localities near it are in medium peril of being flooded, the highest values were recorded at the confluence areas and where there are systems of old dams – that had not been doubled with new ones. A mediun risk of flooding is present along the callow and lacustrine complex from Preajba, from which a bourn springs. The bourn has a semihydrologic regime, but in the case of abundant precipitations, it can flood the surfaces near Braniste, Preajba, Facai (especially in the case of a correlated effect with the flooding wave coming from Jiu river), or even the South of Craiova.
The second map ”Map of Craiova City and the neighbourhood area representing the potentially floodable zone caused bu a hypothetical high waters event of Jiu River, using the ”Buffer zone” analysis” complets the information provided by Kernel model map, offering a general image on the area subjected to flooding risk, induced only by Jiu river, if it were not protected by hydrotechnical arrangements. The programme offered informations regarding the length in sinous and stright line of Jiu river in the analized area, Jiu’s wideness and the density of hydrographical network, as well as the altrimetry and the disposal of valley and slopes.

Map of Craiova City and the neighbourhood area representing the potentially floodable zone caused by a hypothetical high waters event of Jiu River , by using the "buffer zone" analysis

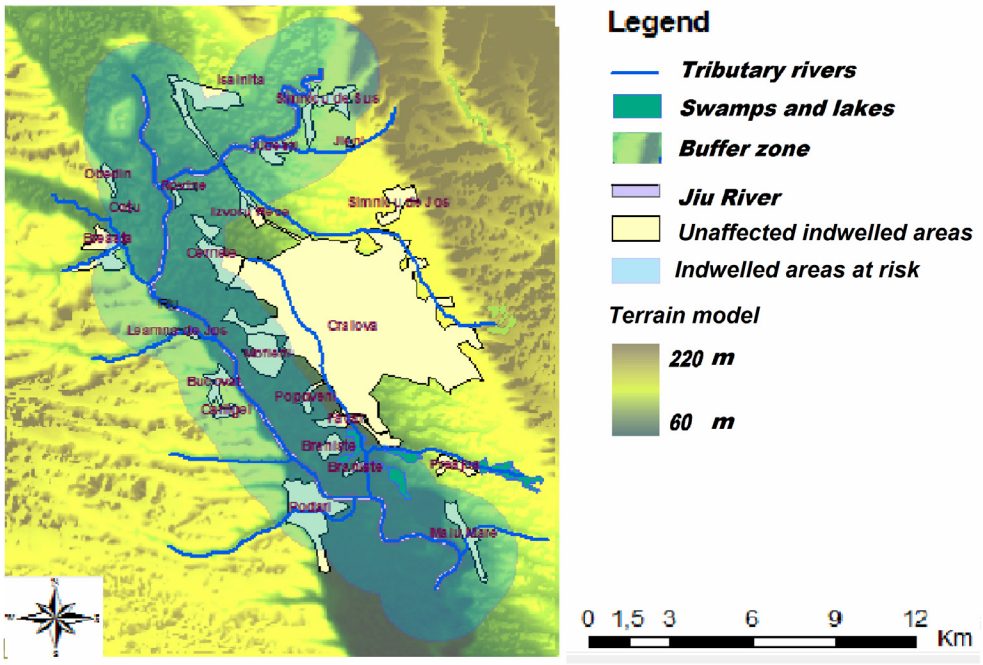


Figure 4.

The area was analized through the numerical altitudinal model of the land. The radius of the buffer area was 3km wide, and was considered to be the medium thickness of Jiu’s water meadow, in this sector of its its basin, as well as the radius of action of the maximun speed wave. In this map there are presented the cut-offs of the localities, as well as Craiova city, represented in two colours: with beige – the indwelled areas that are unaffected by a potential flood -, and with light blue - the indwelled areas that are affected by the flood. After reading the map, we can see that the widest action area is found in the North and North-East of Craiova, in the part with most numerous and ample confluences (Jiu, Breasta, Amaradia), and where the propagation power of the waters comes from Jiu and Amaradia’s reservoire, from the Getic Piedmont towards the subsidence portion of the relief, at the contact with Romanian Plain. The flood limit follows the Jiu river inner front of terrace between the suburban village Cernele and the lake complex, Preajba-Făcăi.

Between Cernele and Breasta, the risk area narrows, so that it follows the alignament of the localities that have one endong at Jiu river, oriented NW-SE, parallel with Craiova. The small proportion of land with a potential to floods widens considerably after the confluence of Tejac and Jiu rivers, downstream of Bucovăț village, so that it finally covers about two thirds of Podari and the entire space of Malu Mare and Branişte.

The two maps were useful for confronting the two dimensions of the our investigation, namely the binomial vulnerability – the risk to flooding and structural measures (materialized in dams, barrages, alignaments of river courses, leaving the aquatic surfaces grow naturally) and for estimating the surface area from Jiu’s meadow and its tributaries (mostly agriculturally arranged), as well as the indwelled area, that can be affected at a possible hydrological event.

4. Case Study: The flood of 1972

The genesis of maximum flow of the rivers of Craiova area must be linked to the one of the rivers upstream of the city, namely of the ones crossing the Getic Piedmont and flow into Jiu, Desnățui, or Baboia. However, in the case of the flood of October 1972, which affected the Southern and South-Western part of Craiova, the maximum water flow and the level of Jiu were relevant, - recorded downstream of Craiova, in Podari Village, due to relief configuration, and to course direction in that part (Savin, 2008). The explanation is that on its Southern and South-Western side, the city is surrounded by the Getic Piedmont that enters the Romanian Plain. Thus, Podari hydrological station is at a higher altitude than the buildable area of Craiova, with which Podari village shares common borders, Jiu waters drain back, towards Craiova at a possible flood.

The flood in 1972 was the largest in territory extent, affecting not only Craiova city by the outpouring of the Jiu River, but also other cities in the surroundings of other smaller rivers in Oltenia. Therefore, in October 1972 it was recorded in MS Craiova-Tarom not less than 238 mm, of which 216 mm during the flood, from 3-11.10.1872 (Savin, 2008), so the amount of precipitation in October 1972 was higher than the "normal" value in October, 3-6 times higher, which fully justifies, the name of "exceptionally rainy" of that month;

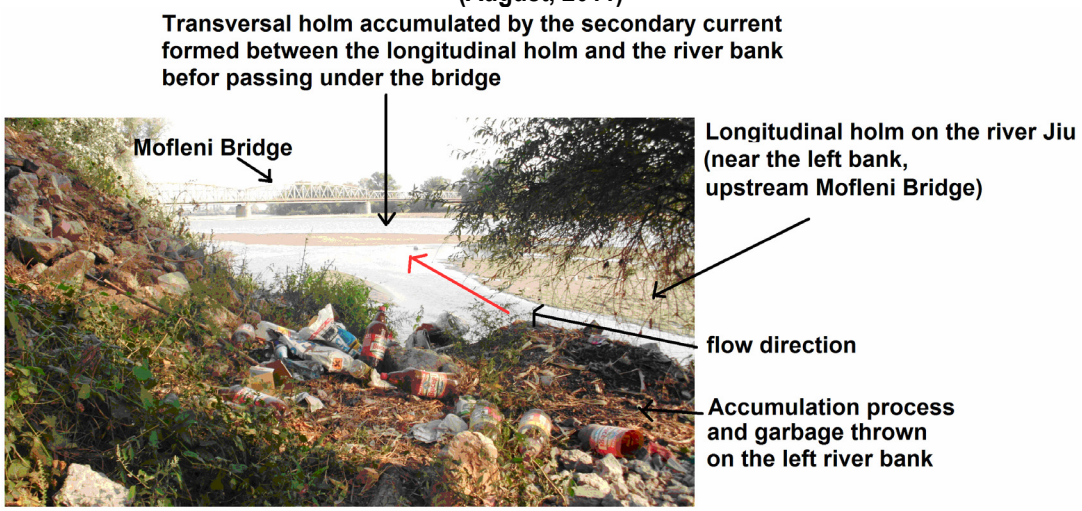
Jiu River's high waters near Podari station are also due to the intake of smaller streams that flow into this space in the Jiu, including Tejac Rivulet. We may conclude that the flood of October 1972 had a rare frequency value, we may say historical. As a consequence, water had a meter and a half until it had reached the dam, came through the galleries made by animals and threatened to reach the access road to the landfill. In front of Mofleni neighborhood, the dam measures 2.5 meters, but it was observed that water had indeed passed through the dam.

5.1. Negative aspects of Craiova area organization against floods

The influence of the relief and water meadow hydrogeology on the discharge occurs locally, in all phases of regime, but more strongly in flood stages, when the water meadow plays an important role in flood attenuation and amplification, storing large volumes of water. Hence the importance of establishment works of the water meadow, as well as those of exploitation of aquifers in the area of Craiova, most of which are in some polluted periods because of industrial activities made on Işalnita platform. On Jiu River, between Mofleni and Bucovăţ, it can be defined a storage area on both its sides. The rapid silting of the riverbed can change in the near future the direction of the discharge on some sectors, depending on water speed and nature of deposits

The chaotic deposited rubbish under the bridge, on the left bank of Jiu River upstream the Mofleni Bridge (Fig 5) can change its route, by increasing the rate flow and the erosion process on the right bank and the accumulation process on the left bank. The consequence would be submitting Jiu River to the North, i.e. towards Craiova and decreasing the distance between the riverbed and residential neighborhoods at the outskirts, in the case of increased discharge rate.

Figure 5. Garbage thrown under the bridge of Jiu River between Mofleni and Bucovăţ Village, S-SW of Craiova (August, 2011)



Another negative aspect is that of the poorly preserved existing canals in Craiova, all of them being included in the last functional category, mostly because of the changing of their use, unsuitable anymore for their initial purpose.

Table 1. Results of the implementation of the Flashflood Strategy in Craiova City. Information taken from the Administration of River Jiu Basin, Craiova

Name	Water course	Owner	Dam class [3]
Hanul Doctorului I	N-W Canal	Craiova City Hall	D
Hanul Doctorului II	N-W Canal	Craiova City Hall	D
Şarpelui Valley I	Craiovita	Craiova City Hall	D
Valea Şarpelui II	Craiovita	Craiova City Hall	D
Şarpelui Valley III	Craiovita	Craiova City Hall	D
Fetii Vally	Fetii Valley	Craiova City Hall	D
Ciliboaica	Preajba	A.J.V.P.S	D
Craiova –F Făcăi	Colector Canal	Craiova City Hall	B
Craiova – agrarian land and CF	S-E Canal	Craiova City Hall	B

5.2 Monitoring of hydrological phenomena in Craiova area and flood prevention structural measures

Since 2005, through the implementation of DESWAT project (*Water Abatement and Control of Water Disasters*), the activity of hydrology and water management entered a new stage of development and modernization in what concerns the monitoring of the rivers by installing automatic stations, as well as in the case of improved hydrological forecasts using forecasting models.

Some basic positive effects[3] thought to be seen in the next future in the Craiova administrative area could be:

- Anticipation of flood occurrence and of possible areas to be flooded;
- Anticipation of the occurrence of severe maximum flow that would affect water supply services;
- Anticipation of extreme discharges and volumes for the good management of large accumulations;

Flood protection through works along the river has proved its effectiveness in the attenuation of Jiu River high waters during the abundant rainfall period of 2005, not long after the most and solely catastrophic flood (1972) occurred in Craiova. The table below focuses on showing the numerical information (length, height and placement) of the existing dams built along the main water courses which can be found in Craiova area. As we can plainly see, the majority of them were designed along the Jiu River, proportionally left side and right side situated, but Amaradia River also has a significant length of dams, entirely situated on its right side, towards the city. Those data also helped to point out the discrepancy between the dams and structures built along the canals of the city (Table 1), which were economically supported from the local administration funds (which obviously has led to a classification of them all in the category ”D”- poor consolidations), and the works made along the rivers that flow in the proximity of Craiova City (Table 2), better taken care of, due to the intervention of the Jiu River Administration, more competent in dealing with such problems. The positive consequence is that all of the works from outside the city were appreciated with the”B” mark.

Table 2. Centralizer table with the main characteristics of the hydrotechnical developments for protection against floods in Craiova area

The name of the work	The name of the river	Bank	L (m)	H (m)	Technical data	Protected items
Breasta	Jiu	R	1534	2,2	B	Agrarian land. Households
Almăj - Beharca-Işalniţa	Jiu	L	500	4	B	Economical aims, Agrarian lands
Combinatul ch. Işalniţa	Jiu	L	1600	5	B	Economical aims, Agrarian lands

[3] According to the specifications in the Action Plan for 2009-2039, included in the National Flood Strategy, instrumented after the stipulations of the Flood Directive on long and medium term, regarding the management on the flood risk.

Cernele + Rovine	Jiu	R	1534	1,5	B	Agrarian land
Baza sportiv DoljChim	Amaradia	R	500	2	B	Sports centre
Işalniţa Cernele+ Troaca	Amaradia	R	2500	1,9	S	SPPL Işalniţa, Agrarian land
Cernele-Craiova-Mofleni	Jiu	L	6700	2,5	B	Agrarian lands Mofleni Abattoir
Bucovăţ-Leamna de Jos	Jiu	R	900	2,5	B	Households, Bucovăţ, Leamna de Jos
Bucovăţ	Jiu	R	1000	2,5	B	Agrarian land, Households
Bucovăţ (dig inelar)	Jiu	R	1600	2,5	B	Pick up frontlines
Craiova-Mofleni-Podari-Branişte	Jiu	L	5700	2,5	B	Agrarian lands, Craiova, Mofleni, Popoveni, Balta Verde
Podari	JIu	R	1100	1,7	B	Oil and Sugar Factory şi Podari
Pr. Abator Podari	JIu	L	100	1,5	B	Abattoir Podari, Households
Pr. Abator Podari	Jiu	R	300	1,5	B	Agrarian land, Households
Podari	Jiu	R	2500	1,7	B	Agrarian land

Analyzing all the data in the table above, it is noted that Craiova is protected by a network of more than 28 km of dammed river beds. As it can be seen, the two large rivers that can cause hydrological problems for Craiova, such as floods, are properly dammed, with a mostly good state of construction, and with heights designed in accordance with the maximum levels achieved in historical large discharges, so that they protect the lands from the meadow of lifting of water level well above the average. The collector canal was redimensioned after 1970 in order to take exceptional discharges, knowing that in compact urban areas, due to paved street surfaces, the discharge coefficient may increase from the periphery to the central area, from 0.30 to 0.80 or more (Savin, 2000). Works were done both on the right and left side of the two rivers, and in the case of the Collector Canal, from Romaneşti District, the dam was provided both at the North, towards the town, and at the South, towards Făcăi, so that the water transport is done longitudinally, towards the confluence with Jiu River, beyond Făcăi, and not transversal, bursting its banks, in order not to put under threat the lands in Craiova or Făcăi. In addition, dams were not placed in front of barren land - with a lower degree of risk vulnerability, but taking into account the objectives that could be affected in the absence of these nearby constructions. Correlating some hydrological data with ground reality, of the nature of riverbeds and of the portions where the discharge can be quicker, these dams were projected to protect in particular the areas with economic and industrial destination of the city, but also the inhabited areas in the floodplain. We are talking about agricultural land, about the Oil and Sugar Factory from Podari, about Podari Butchery, sports, SPPL Işalnița. Water risks such as floods and breakthroughs are likely to occur more in the West and South-West of the town, where the river is more dense and where the landscape is more asymmetric and changing cliffs (at the contact of the last piedmontaneous hills of Getic Plateau and Romanați Plain), than in the East or Northeast, where we find a landscape of plateaus, flat shapes, which makes the flow to be more constant.

6. CONCLUSIONS

Craiova is a good example of a city characterized in most of the time by a dynamic equilibrium between climatic and geomorphologic factors, generating a stable flow, and overall physical-geographical and geological factors causing loss and excess water from the terraces and floodplain. In the intake areas, the necessity of organizing the hydro technical structures comes from the fact that these comprise agricultural areas, populated areas, electrical lines and riparian ecosystems. By dint of all the hydrological works finished in the Craiova area, almost 28.67 km in length of the hydrographic network were defended. Even though the methods applied in GIS environment may contain some errors and subjective estimations, the resulted maps ascertain the portions of the river meadows prone to create floods and a valuable assessment of the agricultural and indwelled surfaces in and around Craiova City, which are vulnerable at such phenomena. Some of the most important points to be further discussed are: the protection activity against flooding, the structural measures as well as the vulnerable population and elements at risk, the ampleness of the efforts made on the management of various precedent situations of the phenomenon (the flood of 1972, that caused effects never repeated again in other similar meteorological situations after-that). In perspective, we intend to improve the preliminary risk methods of valuation and also to validate the data regarding the hydro-technical

engineering works completed or/and already degraded along the Jiu River in the study area. Last but not least, a more thoroughly analysis of the local communities' vulnerability along the areas where embankments and other reinforcing works were done is compulsory. Inasmuch as the hydrometric phenomena have a random character and, as any hydro technical work, no matter how good it is designed, performed and maintained, it can be put out of operation, we appreciate that preparing the population of Craiova City (mainly the owners of the land put on risk) - in accordance with the *National Strategy of risk management at flooding* (2012) - may lead to a series of measurements and actions, in knowing and practically implementing them.

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