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HYDROLOGICAL RISK ASSESSMENT FOR MILA 23 LOCALITY, DANUBE DELTA

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ABSTRACT

Danube Delta is located in the South East of Romania, being one of the largest deltas in Europe. In 1992 Delta was declared a Biosphere Reserve, with two main features, namely the presence of rich of biodiversity and human communities (29 localities from which there is one town). Human communities in the Danube Delta are represented mainly rural settlements (except Sulina locality which in fact is the only town in the Delta). The average altitude of the Danube Delta is low fact that affects the localities at high water levels. All localities are exposed to flood risk with different degree depending on the hazard to flood and vulnerability to the same hydrological event. Danube Delta is a huge natural wetland area that has no vulnerability to flood. The risk to floods implies vulnerability that is given by the presence of human. Flood risk assessment has been carried out for Mila 23 village taking into account a simple definition of risk, namely: that it is directly proportional with flooding hazard and vulnerability to flood. Flood risk calculation was performed by applying GIS (Geographical Information Systems) taking into account the hazard on one side and on the other side vulnerability. This work has as a result the flood risk map for Mila 23 locality. Flood risk map is very useful for decisions makers in order to elaborate plans for spatial planning that should include the flood risk reduction and elimination.

Keywords: Danube Delta, GIS, flood hazard, flood risk.

1 INTRODUCTION

Mila 23 (figure 1) is a rural locality from the centre of the Danube Delta Biosphere Reserve (DDBR) being on the former course of the Sulina Branch, being isolated from the main stream and navigation and the number of habitants is relatively small. From the morpho-structurally point of view there are two types of localities in DDBR: scattered village, with some of its variants and the grouped villages. As a result of the influence of natural conditions and different existing economy types the rural scattered type settlements have the greatest extension. Inside Delta and surrounding areas, localities meet loosely structured settlements. Lower housing density aspect is characterizing scattered villages as consequence of partial incorporation in the households of agricultural land. Scattered village has a narrow economic profile based on crop, livestock and crafts (Dobraca et al., 2008)

Rarefied localities network, the small number of inhabitants, reduced dry-land area, and largely exposed to the flood risk population, contributed to maintaining a low density and number of inhabitants (Damian et al., 2008).

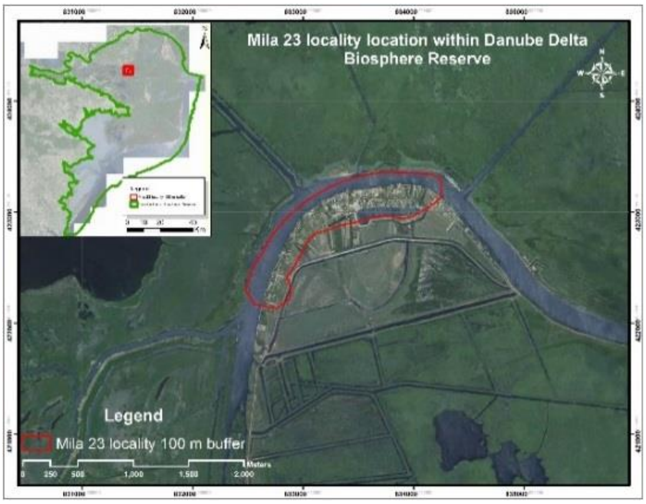

Figure 1. Location of Mila 23 locality

Having in mind the inhabitants and the entire living infrastructure (residential areas, communication ways, arable land, other resources areas etc.) there is place for making analyses regarding the risks in general and flood risk in particular. In the past 12 years the extreme hydrological phenomena like droughts and floods occurred with a higher frequency all over the World including also the Europe. At the European level there is a Directive (***Directive, 2007/60/EC of the European Parliament and of the Council elaborated in 23 October 2007, on the assessment and management of flood risks). There are two important definitions, one is about the floods and the other one is about the risk to floods. Thus, "floods mean the temporary covering by water of land not normally covered by water. This shall include floods from rivers, mountain torrents, Mediterranean ephemeral water courses, and floods from the sea in coastal areas, and may exclude floods from sewerage systems." From the same source there is the second important definition, this one regards the meaning of the flood risk. "Flood risk means the combination of the probability of a flood event and of the potential adverse consequences for human health, the environment, cultural heritage and economic activity associated with a flood event." (Directive, 2007/60/EC)

The term risk is considering the anthropogenic element. Defining and assessing this risk is the direct and indirect tracking condition of human society. In the absence of human society "risky" changes is nothing but forms of an equilibrium displacement more in one direction or another, which is very common in natural systems: the changing seasons, rising water levels of rivers and decrease, the transition from day to night and back etc. There are examples of movements balance one way or another, within certain well-defined tolerances and a predictable cyclical. A disruption of these balances would inevitably lead to the development of a risk: on one side of the Earth as night an hour longer than normal, and the other side would be on an hour shorter than normal. Risks can be associated with many phenomena and processes surrounding nature. (Mierla and Romanescu, 2013) Man cannot be treated as an external factor of geosystem, but as part of the biosphere (florosfera, faunosfera, antroposfera) (Romanescu, 1995, 2005).

Depending on the mode of manifestation can be divided into hydrological risks: the risk of floods and floods; risk associated hydrological phenomena minimum leakage; risk of excess moisture; hydrological risk phenomena induced by decrease of the water temperature; risk of increasing ocean levels; tsunami and other marine phenomena that affect the coastal zone (waves, seismic etc.); risk of lowering the groundwater and soil sealing; chemical overload risk of surface water and groundwater; risk of overload groundwater with solid material; risk of morphological changes; risk of seawater intrusion in the main river mouths etc. (Romanescu, 2009)

Risk directly affects human society and is a concept that cannot be attributed to any other components of the environment without involving socio-economic system. It is therefore very useful in the analysis, especially in risk assessment to consider converting all vulnerabilities in the same unit of measurement to be able to sum vulnerability. This amount is useful in representing the true image as vulnerability to hydrological risk study area. (Mierla and Romanescu, 2013)

The simplest definition of risk is that the risk is "the product of hazard and vulnerability" (Romanescu, 2009; Stanga, 2007). Risk is a quadratic function of hazard and vulnerability. Graphical representation of it shows that it is an exponential function of hazard and vulnerability second order (Romanescu, 2009; Stanga, 2007).

Among the phenomena of flooding risk are some of the most common hazards that have direct impact on the population. Therefore the examples are numerous and processes that have occurred recently (Grecu, 2009). A flood is caused by an excess of water that exceeds the carrying capacity of the minor bed and therefore flows into floodplain covering land areas that usually are not affected by increases in average or low levels (Grecu, 2009). A simple and comprehensive definition formulated by Ward (1978) could be mentioned as follows: A flood is "a body of water covering land that is normally emerged."

2 MATERIALS AND METHODS

The main data used in this paper in order to assess the risk to floods for the locality Mila 23 was the Digital Terrain Model (DTM). This set of data was very useful in establishment of the terrain altitude for calculating the level of water. This level could be below, equal or above the dry land surface. In the last two cases there could be discussions about the presence of the floods.

This set of data was elaborated with the help of raw data obtained from the LiDAR cloud points. The cloud points were acquired based on the LiDAR techniques that imply a source of beam and a receiver of the reflected beam. The difference of the time spent by the beam to reach a surface of an object or of the land plus the elapsed time for the reflected beam to reach the receiver is converted into distance. Thus, the result of the LiDAR survey is a list of points with coordinates (x, y and z) and other valuable information regarding the reflectance of the beam. With specific software all these lists of points with coordinates are transformed into a point cloud (figure 2).

The points cloud, resulted from LiDAR data collection is sufficient to develop a DTM for a site region. The next step is to interpolate values of these points to obtain a continuous surface. As often as they are the points do not form a surface. Interpolation is very important since it may result in a method and another method can lead to similar results, but with some differences. Most important types of interpolation are: IDW (Inverse Distance Weighted), Spline (polynomial function), Kriging, PointInterp and Natural Neighbor.(Mierla and Romanescu, 2013) The method for the interpolation that was used was the IDW because the set of points is dense enough to capture the magnitude of the change required for local area analysis. IDW determine the cell values using a set of weighted linear combination of outlets. Weight is assigned based on the distance from a point of entry and exit from the cell. The greater the distance, the smaller the influence of the cell on the output value is (Mierla and Romanescu, 2013).

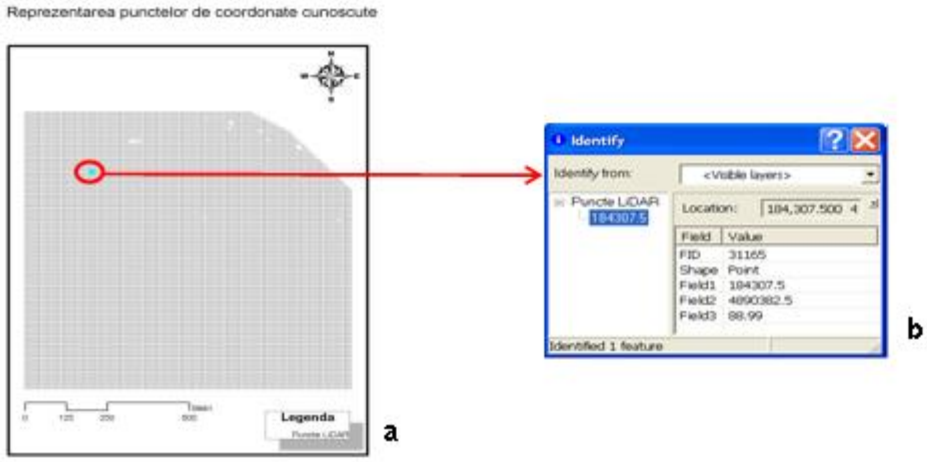

Figure 2. Graphical representation of the .shp file type (**a** - known coordinate cloud points, **b** - information about a point from a cloud of points: Field1 - coordinate x, Field2 - coordinate y and Field3 - coordinate z) (Mierla and Romanescu, 2013)

In one hand there is data regarding the terrain surface altitudes and in the other hand should be the data on the parameters of the water. In this case the most important parameter (taken into account) was the water level of the Danube and its main branches. In order to have the extreme (hydrological) situation for calculation there were taken into account the data regarding water levels from the years 2003 and a respectively 2006. In the first one there were registered minimum of water levels and for the year 2006 there were registered maximum of water levels. Having this two extreme years there were done some calculation of the amplitude and other useful steps. The water level data were stored into a table with the name of the hydrometrical gauges and all the specific data. This information was transferred into point .shp file in order to obtain the surface of the water for the studied area. To link all the data from all the hydrometrical gauging stations that were taken into account there were done some correlations between different water levels values from the stations (figures 3 and 4).

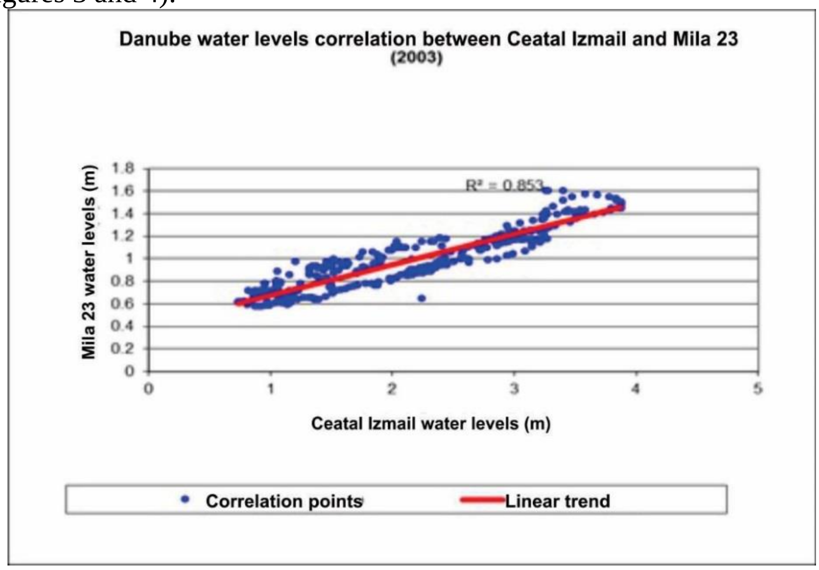

Figure 3. Correlation plot between levels values at Ceatal Izmail gauging station and Mila 23 station for 2003

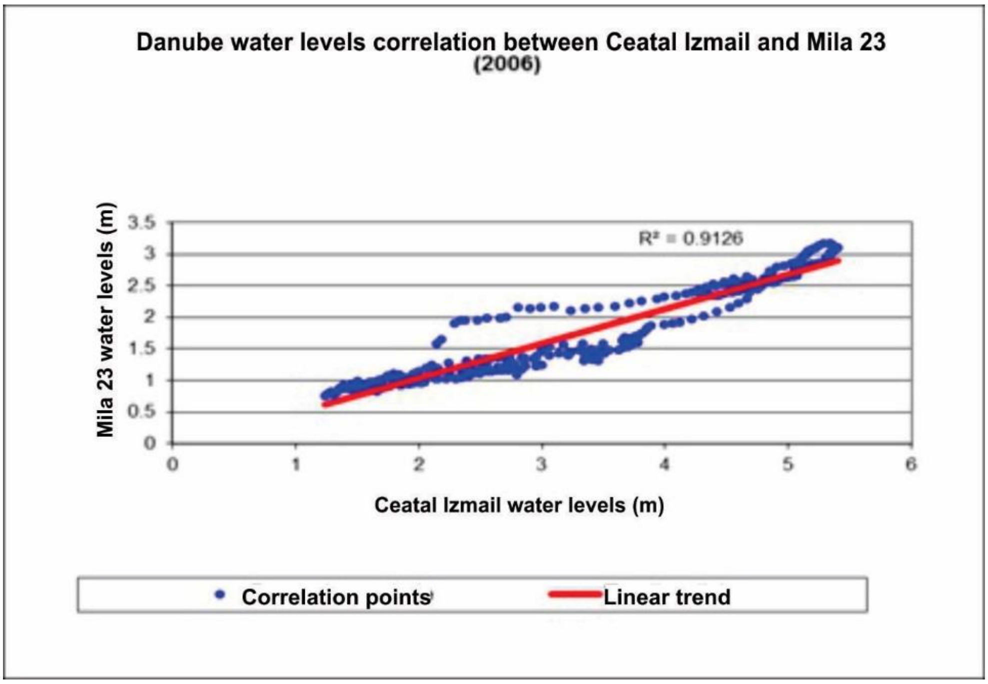

Figure 4. Correlation plot between levels values at Ceatal Izmail gauging station and Mila 23 station for 2006

For the lowest historical water levels from 2003, from Ceatal Izmail and Mila 23 stations, there is a very good correlation r2 over 0.85 (Fig. 3). The high waters of 2006 recorded at hydrometric stations Ceatal Izmail and Mila 23, have a very good correlation r2 over 0.91 (Fig. 4). Correlation between hydrometric data expresses that they are interrelated and can generate more realistic surface actually exploited later in this paper. Correlation coefficients between the low water levels from 2003 (r2 = 0.853) and high water levels from 2006 (r2 = 0.916) have a slightly difference. This difference can be explained by the following reason: the water is fairly shallow and the water follows the thalweg of main arms were hydrometer station are located along, so the water which went through hydrometric station from Ceatal Izmail reach in lower proportion to hydrometric station Mila 23, the main water amount follows the Sulina Channel (in low water levels). In the case of high water (year 2006) a higher percentage of water was “brought" from the mentioned channel. This makes the correlation coefficient to be higher. Knowing the fact that the data regarding the water levels values are linked between hydrometric gauging stations there were done interpolation between these values having into consideration also the years. The used method for interpolation was Spline; this method is applied when there are few values distributed in a vast territory. Surfaces resulted pass through all the points (values) that were taken into account.

3 RESULTS AND DISCUSSIONS

The first result of the interpolations is the Digital Terrain Model (DTM) with the altitude for each point in the field. The second set of data resulted from the interpolations are the two surfaces of the water levels one for the year 2003 (low levels) and the other one for year 2006 (high levels). Having the two surfaces mentioned above there was calculated the amplitude of the water levels. This amplitude is very important in the assessment of the flood risk.

Making the difference between the surfaces of the high water levels and the DTM it was revealed the depth of the water in the flooding time, one of the important element that is counting in the assess of the hazard. In the presented paper there were used the water level amplitude combined with the water depth in the flooding time. The result of the combination is shown in the figure 5 (the hazard to flood).

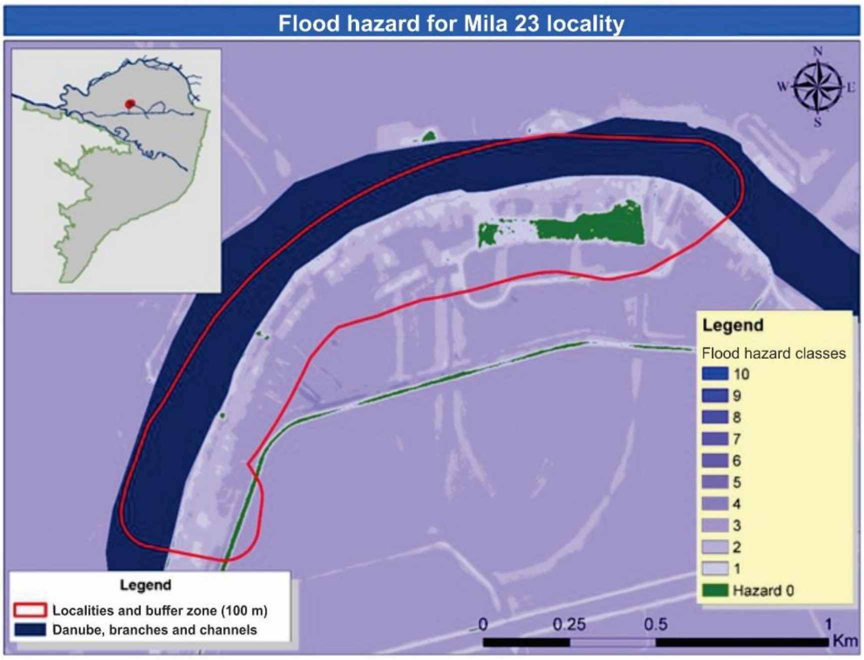

Figure 5. Floods Hazard Map for the Mila 23 locality

Figure 5 presents the flood hazard map for the locality Mila 23. This hazard is divided into 10 classes from 1 to 10, where 1 is the lowest and 10 is the highest value of the hazard. There are some areas in the studied locality that have no flood hazard. Those areas were constructed in this sense (there is one platforms and one dike) and on the map from above are shown in green, meaning hazard zero.

It is well known that the risk is composed by two main elements: first one the hazard and the second one the vulnerability. The vulnerability is "a human condition or process resulting from physical, social, economic and environmental issues that determine the likelihood and extent of damage to the impact of a particular hazard "(UNDP, 2004). It underlines the importance of anthropogenic component. For assessing the vulnerable elements within the Mila 23 Locality there were used the LPIS dataset (Land Parcel Identification System).

The data set was created under the direction of the Payments and Intervention in Agriculture (APIA). The system is used widely in Europe and aims to identify land use using orthophotos or other aerial images. In some cases there can be used also high resolution satellite images. From this data set were extracted only intersecting polygons with locality surface, plus another 100 m buffer. Settlement contour is extracted from the Corine Land Cover data set. Extracting parcels from the LPIS data set within localities was performed using command intersection. Following this extraction resulted polygons of different land uses (Mierla and Romanescu, 2013) (Table 1). For all these polygons there were created a classifying scale taking into account the vulnerability of each land cover type to the flood.

Table 1. Classes of vulnerability for polygons (Mierla and Romanescu, 2013)

Nr.	**Land use 1**	**Land use 2**	**Class of vulnerability**
1	Courts, constructions		5
2	Courts, constructions	Arable land	5
3	Courts, constructions	Permanent pasture	5
4	Courts, constructions	Mixt	5
5	Courts, constructions	Vineyards	5
6	Roads		4
7	Still waters		0
8	Unproductive lands covered with reeds or rushes, marshy vegetation		1
9	Running waters		0
10	Bogs and fens		1
11	Forest vegetation, shrubs, bushes		2
12	Gravel, dumps		2
13	Permanent pasture		2
14	Permanent pasture	Arable land	3
15	Permanent pasture	Mixt	2
16	Arable land		4

17	Arable land	Permanent pasture	3
18	Arable land	Permanent crops other than vines: orchards	4
19	Arable land	Mixt	4

The polygons that were derived from the LPIS had been classified, revering the table above. Thus, all the polygons have a vulnerability value that was transposed into a certain colour. The maximum vulnerability is marked by the value 5 and it is represented by the residential areas; the minimum vulnerability value to flood is represented by the waters (still and running). The transposed polygons into GIS format with the values of vulnerability classes can be seen on the figure 6.

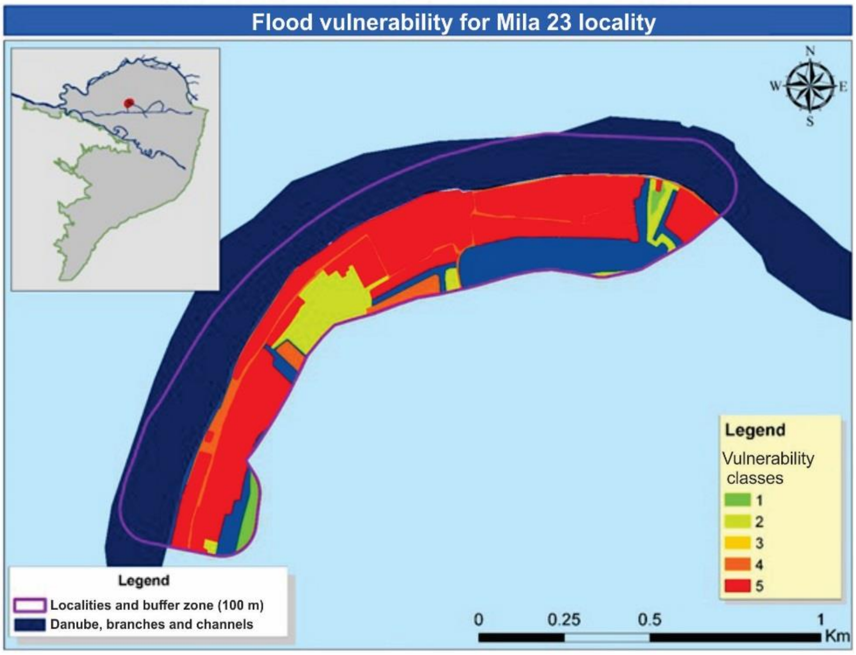

Figure 6. Map of Vulnerability Classes to flood for Mila 23 locality

Studying the figure 6 it can be easily seen the fact that there are areas in the Mila 23 locality that have zero vulnerability to floods like channels formed by constructing the dike in the South and South-West part of the locality and a basin for small boats in the South-East part of the locality.

Combining the two main elements of the risk resulted the risk map to floods for the studied locality (figure 7). For a better representation of the data regarding the risk, all the values of the assessed risk were classified into 10 categories (10 meaning the highest value of the flood risk and 1 the lowest value of the flood risk).

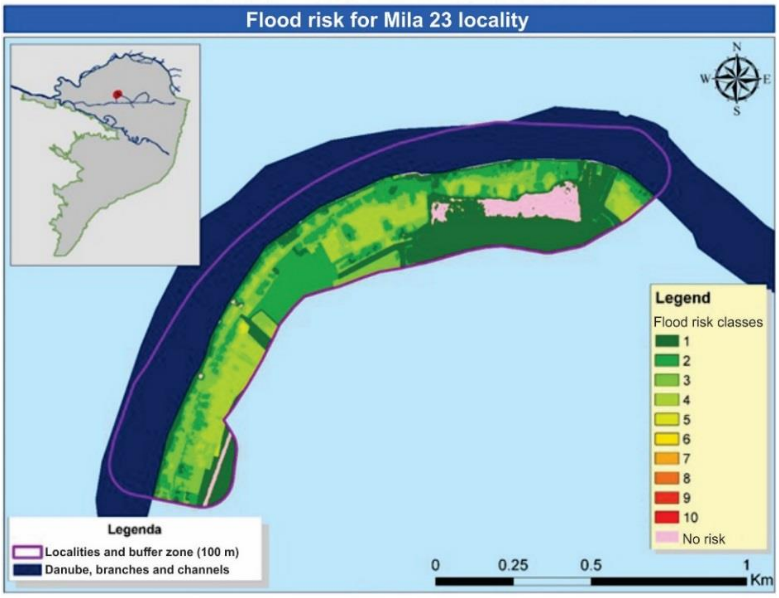

Figure 7. Flood Risk Map for Mila 23 locality

On the flood risk map for Mila 23 locality (figure 7) it can easily be spotted the areas with the zero risk to floods such as the platform built in this sense and the dike. There are areas where the risk to floods is higher (see figure 8).

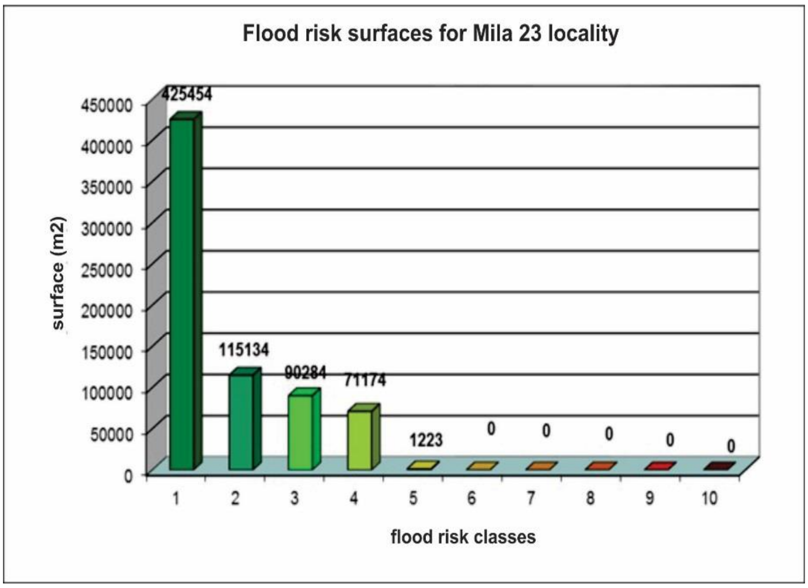

Figure 8. Areas of flood risk classes for Mila 23 locality

Areas with very low risk to flooding (grades 1 and 2) are numerous in the locality Mila 23, they occupy spaces on the fluvial levee and on the dam (figure 7). The two platforms for flood defence are under category without risk. This category is not considered for drawing the graph (figure 8). Mila 23 village have area with risk to floods is concentrated on the first four classes of flood risk (approximately 240 ha). The remaining classes from Class 5 to Class 10 are not present.

4 CONCLUSIONS

The hazard to flooding for the Mila 23 locality occurs in the low land surfaces and the high lands have low or zero hazard. The dike and the platform built in this sense have zero hazards to flooding. The built platforms has no more a regular shape fact that lead the thoughts to the idea that the altitude of the platform is not anymore uniform due to the irregular soil compaction.

The highest vulnerable areas to flood are those from the middle of the locality Mila 23 along the Danube stretch (old Sulina Branch). These areas are occupied with residential zones. The lowest level of vulnerability areas to floods consists in water bodies (basins, channels etc.).

Mila 23 locality has no surfaces very high and high risk to flood. The area with medium risk to floods is small; most of the locality has low and very low risk to floods. The platforms could be used in the future extreme hydrological event similar or lower than the one occurred in 2006.

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