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17. Hazard Analysis on the Rainwater Runoff in Tulcea City, Romania

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Abstract: Floods are natural processes. Urbanization and increasing population density, as well as a concentration of economic values in flood prone areas have increased the risks in many regions. Natural flood plains all over the world are being urbanised or used for industrial purposes. Perception of the flood hazard and the associated risks in many cases is low, if not inexistent, particularly in such areas considered to be safe, e.g. behind dams or levees. New spatial planning approaches, though, try to cope with these developments and create suitable flood protection concepts. In this process, the delineation of flood-prone areas is a very important first step. The torrential rains of very high intensity and large amounts of water (Flash Flood), generated in a short period of time, are the main cause of floods in the city of Tulcea. The most useful and comprehensive way to understand the runoff of the rainwater is to use maps from the hydraulic modeling results. This type of results gives a clear impression of the runoff in time and space. For viewing, ArcMap (GIS Software) is used, where the results of running over the same geographic data are loaded. The main results of this type are records that can track the evolution of flows or levels over time. Flood hazard maps of runoff of the rainwater shows that the evolution of the rainwater runoff is natural, taking into account the digital terrain model of the city (as the geographic support of the relief of Tulcea), as well as the state and construction of the rainwater sewage system (the collector size calculations were not made at the current precipitation level). Above all, climate change, that brings more and more extreme hazard events with flows above historical values is another determinant factor in producing the current effects of runoff floods in the studied area.
Keywords: Floods, flood hazard maps, runoff, rainwater drainage system

INTRODUCTION

Flooding is a natural phenomenon that means temporarily covering a land with water which is not usually covered with water. The occurrence of floods is caused by a number of climatic factors – climatic conditions that generate large amounts of precipitation, storms, melting snow, but also of the deforestation made by man. These phenomena can create impressive material damage, depending on the magnitude and duration of the flood. It is very important to note that, besides these material destructions, the floods have, unfortunately, also caused loss of human lives. New spatial planning approaches are designed to keep up with these developments and implement appropriate concepts for protection against floods.

Additional information in this delineation process is achieved by the calculation of water levels at any given point at different times during a flood event. Such information delivers very important basic data for the determination of the risk potential. In addition the possibility to simulate the temporal dynamics of the flood event produces important information for disaster management plans. (Geomer GmbH, 2017)

Floods are an increasingly acute problem. Floods endanger lives and cause human tragedy as well as heavy economic losses. In addition to economic and social damage, floods can have severe environmental consequences, for example when installations holding large quantities of toxic chemicals are inundated or wetland areas destroyed. Intense precipitation has become more frequent

and more intense, growing manmade pressure has increased the magnitude of floods that result from any level of precipitation, and flawed decisions about the location of human infrastructure have increased the flood loss potential. Flooding cannot be wholly prevented. Flood risk increases with ongoing climate change. Risk reduction in large international basins can only be achieved through transnational, interdisciplinary and stakeholder oriented approaches within the framework of a joint transnational research project. (FloodServ Project, 2016)
Flood risk analysis for different vulnerable areas is done using specialized softwares, the ultimate goal being to display the results obtained as digital or graphical maps.

Effects of the big recent flood events in Tulcea

Rainwater is the water that comes from atmospheric precipitation, such as snow, rain, hail, etc. The rainwater from the city of Tulcea is discharged into the public sewerage system of the city. The water is not only loaded with suspensions but during runoff, it is loaded with different particles from tire abrasion, petroleum residues, oils, lead from fuels, etc., which amplify the pollution.

In the last period, in Tulcea, the number of exceptional rain events has increased significantly, which has led to more and more flood events in the city - Figure 1, Figure 2, Figure 3. These floods in terms of their intensification are a consequence of climate change, and their proprieties are a lot different now, comparing to how they evolved some decades ago. Since the calculation of the sewage system was done using the values of the rainwater flows and intensity in the early 1900’s, the new values of the flows, speeds, and currents are overflow the local system, creating a lot of losses.

Figure 1. Floods effects in Tulcea - Hotel Delta area (Source: Facebook)

Figure 2. Floods in Tulcea city – Gavrilov Corneliu Street (Source: Facebook)

Figure 3. Floods in Tulcea city – Babadag Street (Source: Facebook)

In Tulcea, the problems caused by the lack of a well-sized pluvial water take-up system have appeared for many years in several areas of the city, especially the city center, Piaţa Nouă, Pelican area (*****a, 2017).

The torrential rains of very high intensity and large amounts of water (Flash Flood), generated in a short period of time, are the main cause of floods in the city of Tulcea.

The pollution of the flooded areas in Tulcea municipality is due to the water supply of various substances, such as chemical fertilizers, hydrocarbons, various products such as those used in the washing of city streets, bacteria, etc. Water during flooding carries sediments that can contain heavy metals and other pollutants, thus affecting the quality of water over a longer period (*****b, 2017).

MATERIALS AND METHODS

For flood risk analysis, the main tools used in data processing are specialized programs GIS (ArcMap, Global Mapper) and programs that perform hydraulic modeling 1D and 2D such as HEC-RAS, SOBEK, MIKE. GIS programs are mainly used to manipulate the digital terrain and bringing it to the corresponding reference system. GIS programs are also useful in processing the final results obtained from hydraulic modeling. Hydraulic modeling programs work and run based on different equations, in particular on the basis of flow equations.

The rainwater flow direction in Tulcea was established using the Global Mapper V17 specialty software using the Digital Terrain Model (DTM). The direction of flow is presented as arrows oriented according to the terrain configuration, or its slope. Figure 4 and Figure 5 show the street network of the city overlaid on the DTM along with the direction of rainwater flow. Arrows are actually a point network distributed 50 meters across the two main directions x and y. In Figure 4, each direction of flow is assigned the pitch of the plot, expressed as a percentage.

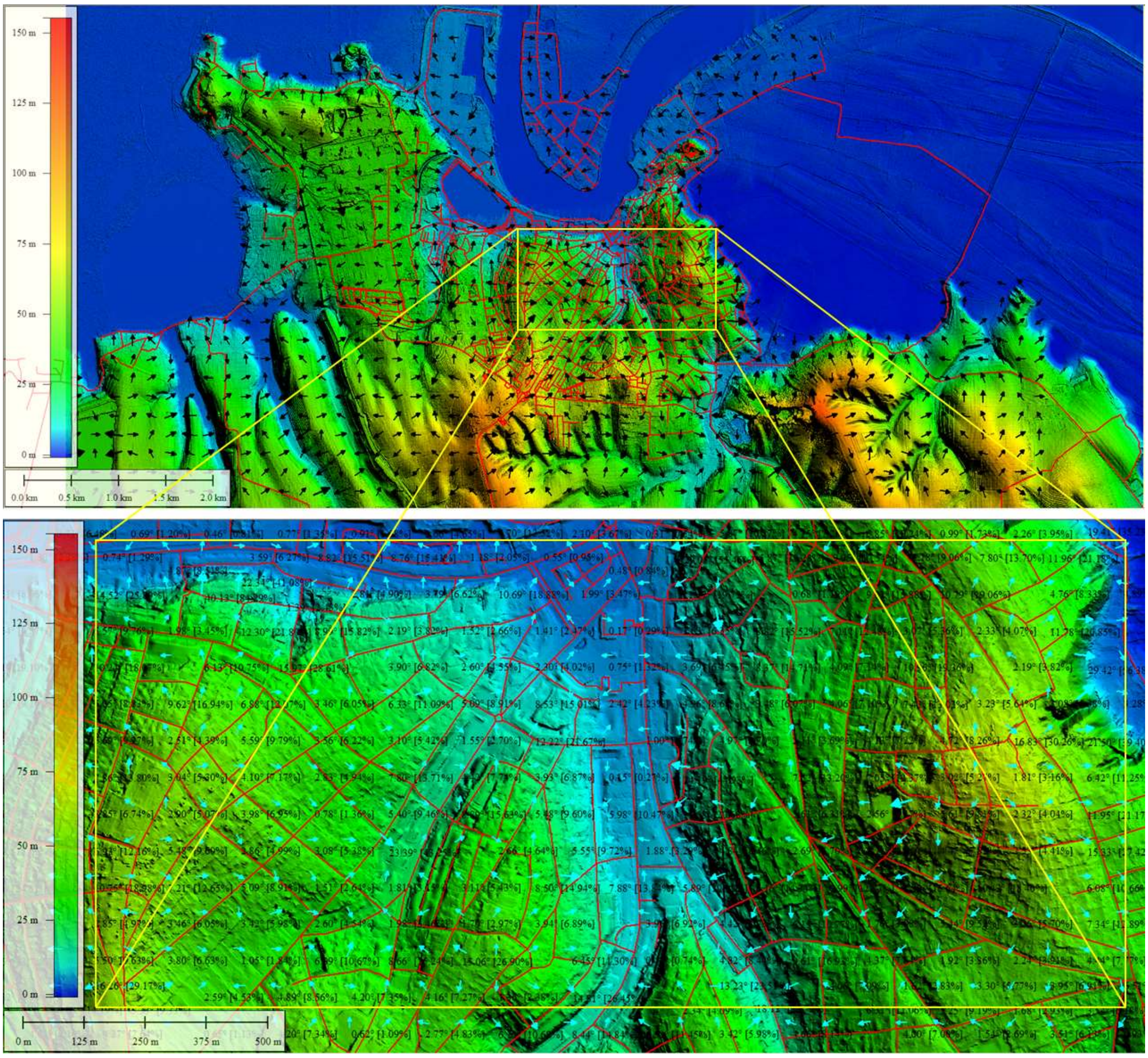

Figure 4. Flow direction of the rain water over the Digital Terrain Model - Tulcea city

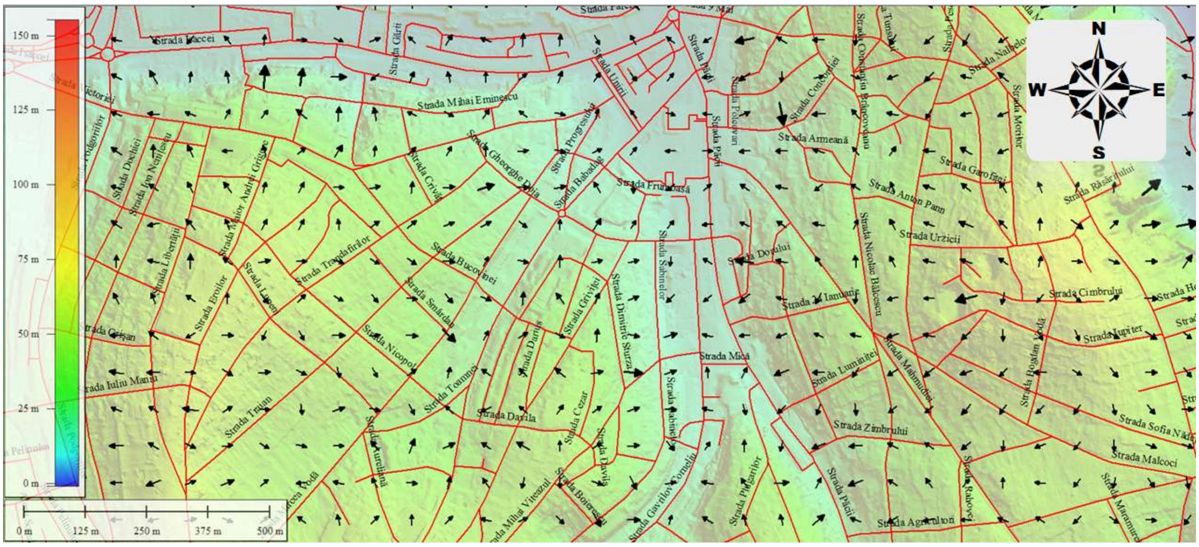

Figure 5. Detail Flow direction of the rain water over the Digital Terrain Model - Tulcea

Flood hazard map

The most useful and comprehensive way to view modelling results is to use maps. This type of results gives a clear impression of the results in time and space. For viewing, ArcMap (GIS Software) is used, where the results of running over the same geographic data are loaded. The main results of this type are records that can track the evolution of flows or levels over time.

The results thus obtained can be processed in GIS for further processing and interpretation. In the category of hazard maps results there is also the option of downloading short videos including flood scenarios, depending on the presumptions made in the model. (Nichersu, 2016)

In addition to these scenarios, the most used result of hydraulic modelling is actually flood hazard map - the map with the maximum limit to which the flood can expand, or the hazard map.

The flood hazard map is the document on which the floodplain areas of major floodplain riverbeds are represented, the maximum flow rate of which is characterized by the following probability of overtaking: 0.1% (low probability), 1% (mean probability) and 10 % (high probability). The flood risk map is the documentation that indicates, for floodplains, various probabilities of exceeding the maximum flow, potential material and human damage at the level of administrative-territorial units. The hazard map and flood risk map are part of the county spatial planning documentation and are included in the general, zonal and local urban planning plans of each county and Bucharest municipality. (HG 447/2003, 2013)

Designing maps of existing historical floods are not accurate enough or reliable for flood risk management. In addition, they appear to be based only on observations made during recent floods. Consequently, specific flood-specific studies will be needed to develop accurate risk analysis of floods, taking into account existing defence structures, real topography, exposed goods, and floods for various return periods. However, two types of studies need to be implemented in Romania, given the objectives, the deadline, the cost and the skills needed for both approaches. (MMDD, 2008)

The traditional approach based on the hydraulic modelling of sufficiently accurate and dense topographical data is necessary for water courses with potentially high damage where it is necessary to precisely establish the level and depth of water in the flood areas. However, this method continues to have a fairly long duration and is very costly, requiring a huge experience and skills that are not very common in Romania at present. In addition, with regard to the limited quality of basic data (topography, hydrology, historical floods, etc.), the accuracy obtained with this method averages 0.5 meters in altitude for reference floods. Only some major improvements in the future can lead to improving this average accuracy and lowering the total cost of the method. (MMDD, 2008)

FloodArea desktop software

FloodArea HPC -Desktop enables the user to do both types of analysis. Relevant examples are being given. FloodArea HPC -Desktop is an ArcGIS extension, which is completely integrated in the graphical user interface of ArcGIS desktop, utilizing Spatial Analyst functionality. The user is assumed to be familiar with the use of ArcGIS in general and ArcMap and Spatial Analyst in particular. FloodAreaHPC -Desktop is a joint product of geomer GmbH, Heidelberg, Germany, and Ingenieurgemeinschaft Ruiz Rodriguez + Zeisler +Blank, Wiesbaden, Germany.
The main purpose of FloodArea HPC -Desktop is the delineation of flooded (inundated) areas. Calculations are based upon:

- a drainage network raster with water levels assigned to it. Though the water levels can vary spatially (e.g. along a river stretch) they remain constant during the simulation process. The water levels can be changed, however, by modifying them between single model runs, or
- one or more hydrographs at user definable coordinates, or
- a rainstorm simulation over a wider area, specified by a possibly weighted raster.

Model results are stored as rasters at user defined intervals, providing the possibility to reproduce the temporal aspect of the flooding process. The values of the resulting rasters can be stored as absolute height levels or as values relative to the surface. If needed, the flow direction vectors can be output for each individual raster. Additional parameters can be specified for a simulation run. Flow barriers (e.g.

road embankments), which are not represented by the elevation model, can be included. Locations of dam failures can also be defined determining at which points flow barriers fail, making dike break scenarios possible. To adapt the flow velocities to real world conditions, the user can specify roughness values. (Geomer GmbH, 2017)

RESULTS AND DISSCUSSION

The drafting of the torrential rainfall model for Tulcea municipality was made using the FloodArea application in ArcMap (GIS software) and follows the following steps în Figure 6:

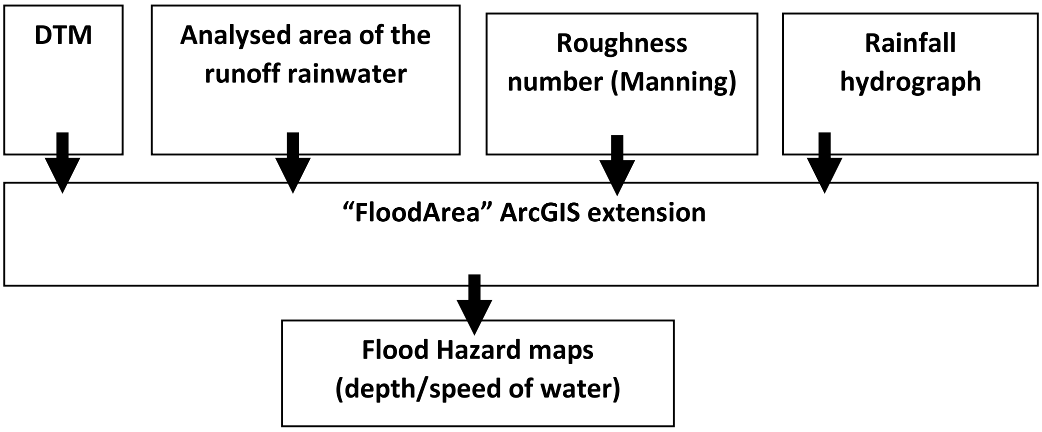

Figure 6. The stages of drafting the torrential rainfall pattern

DTM- Digital Terrain Model

For the flood calculations caused by the rainfall, as mentioned above, two sets of spatial data are used:

- The drainage network formed by the streets of Tulcea (Figure 7)
- Digital terrain model (Figure 8)

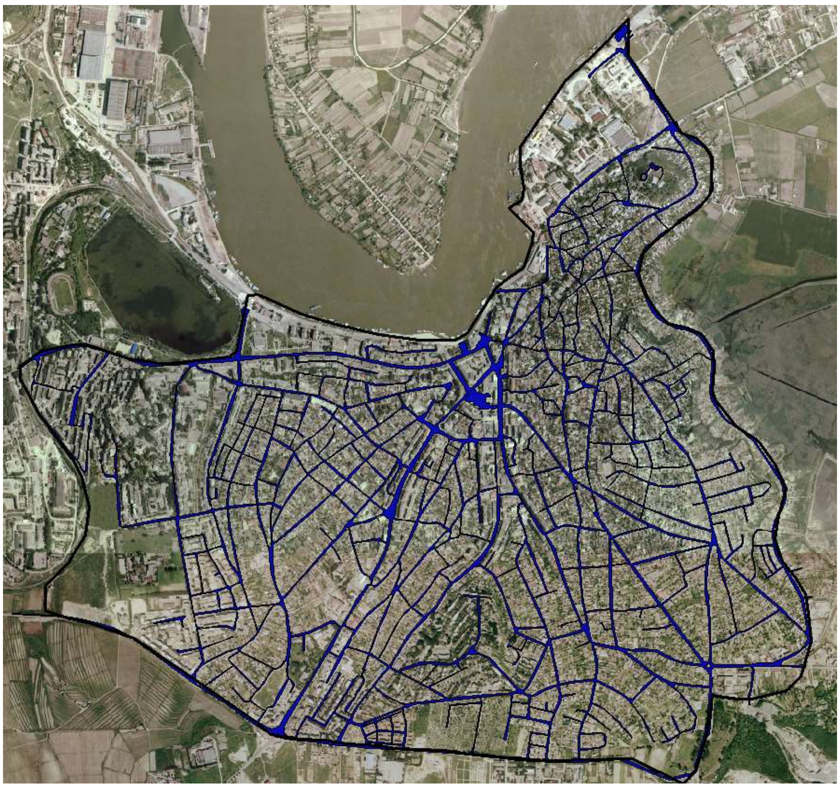

Figure 7. Definition of the street network

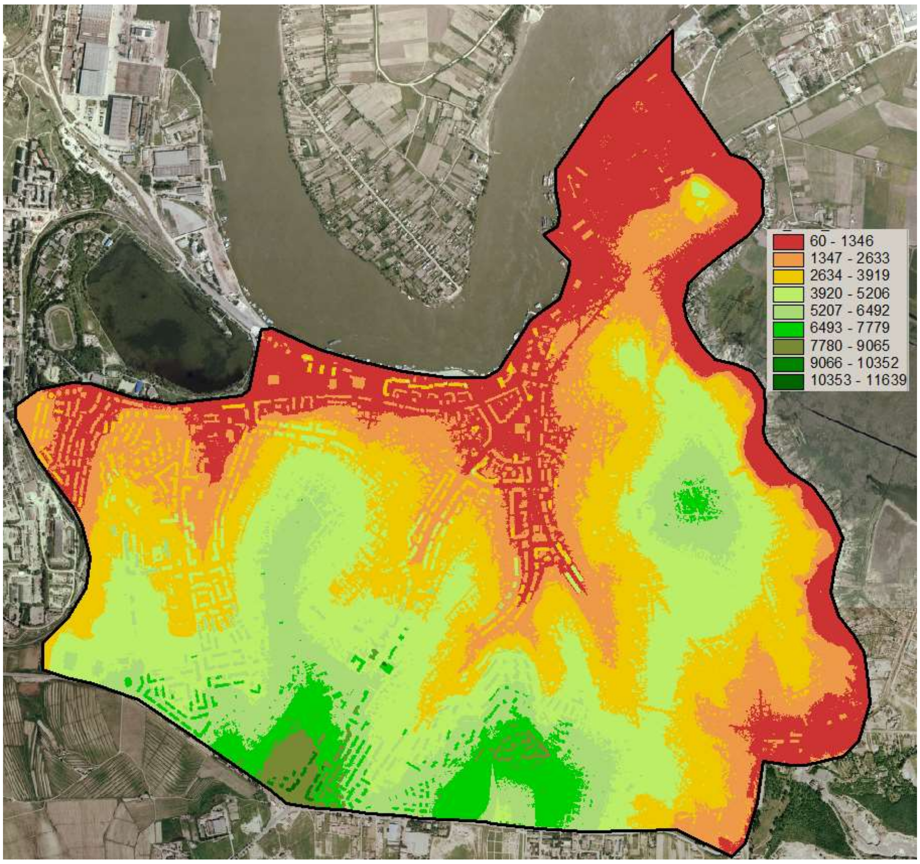

Figure 8. Digital terrain model (cm, Stereo 70, MN75)

Analysed area of the runoff rainwater
In order to establish the drainage network and to delimit the outline of the precipitation capture area, satellite images (Figure 7) and the topographic map were used.
The spatial data used was processed in stereographic projection 1970 on the Dealul Piscului datum.

Coefficient of roughness (Manning)
Roughness is the friction between the water flow and the bottom of the bed. This force has the opposite direction to the flow of water. Along with gravitational force, this force determines the conditions of flow, the rest of the forces involved being negligible.

Rainfall hydrograph
The precipitation data tracked in the project was collected in real time in the areas identified as vulnerable, depending on the risk and the affected area. Within the model, precipitation values were used for the worst-case scenario: 1 hour with 100l / m2.

All input data sets were processed in the same cartographic projection, Stereo 70. The format of data sets (DTM, roughness, street network) is raster type, and for geographic maps and satellite imagery the format is Geotif.

Hydraulic modelling used the "Rainstorm" option, since the input boundary was the pluviometric hydrograph used for the entire surface analysed (there is also the multiple hydrograph option with different values). Vulnerable areas are defined in the FloodArea application. The option used provides information on the temporal variation of water levels. (after (Geomer GmbH, 2017)).

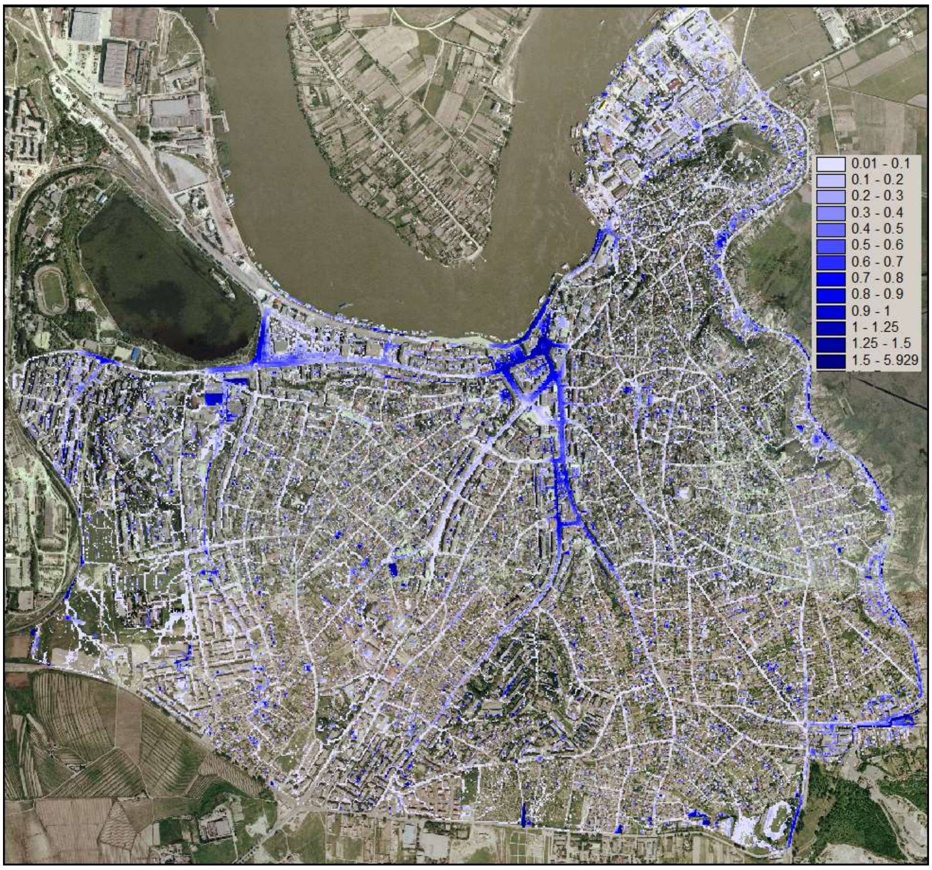

Figure 9. Flood after 60 minutes (depths are expressed in m)

The evolution of the rainwater runoff is natural, taking into account the digital terrain model of the city (as the geographic support of the relief of Tulcea), as well as the state and construction of the rainwater sewage system (the collector size calculations were not made at the current precipitation level). Above all, climate change, that brings more and more extreme hazard events with flows above historical values is another determinant factor in producing the current effects of runoff floods in the studied area.
Using the flood model presented above (Figure 9), the most vulnerable areas can be extracted in case of the torrential rains of Tulcea. During the hazard event, the large amounts of rainwater flowing from the slopes in the case of torrential rains gather in four main areas: the Pelican area (Figure 10), the West area, Delta Hotel area and the New Market Park area.

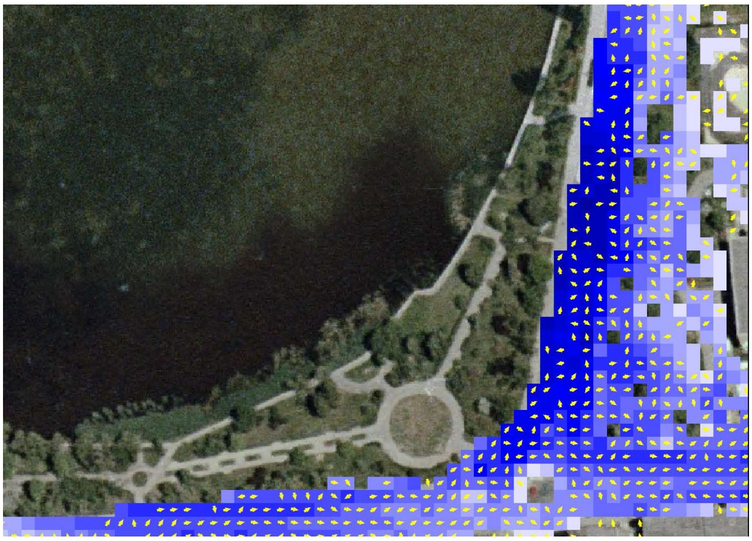

Figure 10. Flood Hazard Map- detail on the depths and flow direction in Pelican area (depths are expressed in m)

CONCLUSIONS

For the preparation of this study, data from the significant torrential rains during the summer and autumn of 2018 were collected, both hydrological information necessary for the hydraulic modelling, as well as information on the rainwater quality, physical and chemical properties of the water collected on the slopes on the streets of the city, to vulnerable areas.After data collection, the hydraulic model was developed using the FloodArea application in the ArcMap software for an equivalent of 100 liters / hour rainfall.

At the first sight of the flood pattern, the evolution of the phenomenon seems natural considering the geographical support of Tulcea Municipality relief, as well as the state and construction of the rainwater drainage system (the collector size was not made at the present precipitation level). However, the flood pattern provides important information on flow collection areas and it is a starting point for updating knowledge about rainwater leakage in the new context of climate change and the evolution of extreme events. The model can also offer the basis for opening the discussions for the update of the rainwater sewage system, in the new context of heavy flash floods.

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