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Flood Modeling of Samsun/Atakum Region by GIS Tools

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ABSTRACT: Due to climate change and effect of irregular urbanization, Samsun / Atakum region is frequently exposed to floods. The first reason of floods is the extreme precipitations in the spring season, and then inadequate sewer systems with non-planned urbanization are the major factors that turn the natural processes into catastrophic events. Also, the important reasons are inadequate of hydraulic structures and existing flood protection structures against the changing climate systems. In this study flood risks of Samsun Degirmen stream determinate by MIKE 11 and GIS. MIKE 11 hydrodynamic modeling system is a numerical model for river and channel systems. The flood modeling studies include two important steps: preparation of terrain model by ArcGIS, simulation of floods by MIKE 11 hydraulic model, following the results of models hazard maps and, flood risks can evaluate. In this study, Q100 and Q500 discharges are subjected to one-dimensional (1D) modeling. According to the 1D results, Degirmen stream cross-sections inadequate passing the flood discharges, thus particularly downstream part of the floodplain area is vulnerable to floods.
Keywords: *MIKE 11, Flood modeling, GIS, Samsun, Turkey*

1. Introduction

Environmental change has always been a source of concern for researchers. Changes in climate change and global warming, over-urbanization, and wrong land use policies have caused many natural disasters to turn into disasters. One of these disasters is the floods that have occupied the whole world. When the world economies are examined, it is understood that the losses from the floods are forcing to be at the top. The Intergovernmental Panel on Climate Change (IPCC) emphasizes that global warming will continue to increase, extreme climate events will become more frequent and more intensified. (Field and Ed 2012; Cheng et al. 2014). The most significant impact of climate change is to excess meteorological events in some regions, the most important example is the recent increase in extreme precipitation in the various regions of the world, for this reason, infrastructure systems are becoming inadequate due to the extreme precipitations. Geographic Information Systems (GIS) with software integration are the most appropriate techniques used in flood modeling studies nowadays. GIS used commonly for visualize the flood magnitude with produce flood hazard mapping and flood risk mapping. Numerical models have too many alternatives. There are different tools to define the problems accurately for each model. This is an important advantage because it affects the model as situations such as riverbed regulation or the flood control constructions are directly change the flow pattern of the river. There is a lot of study in the literature for 1D modeling (Biancamaria et al.,2009; Paz et al.,2010; Chu et al., 2013; Kumar and Tiwari, 2015)

Samsun is largest and important city in terms of economy and takes place in the central Black Sea region of the north of Turkey. The average annual precipitation for 1980-2010 period in the region is 698 mm and value are above the 574 mm national average for the same period. City is exposed to floods every two to three years which have a destructive effect on people, structures, and substructure systems. In 2012 flood event severe heavy rainfall which started at 05:00 in the morning and continued at 8:00 am, was effective in the western regions of the province, especially in the district of Atakum. Flow rate during flood calculated as 35 m^3/s. This flow is even smaller than the calculated Q_{100}=112.27 m^3/s (DSI, 2012). This also shows that flood disaster occurs because of interfering in the stream bed and inadequate infrastructure systems. Study area Degirmen and tributary Elemini streams are located in the center of Samsun/Atakum Korfez district shown in Figure 1. Degirmen basin shown in Figure 2, which has prepared with ArcGIS.

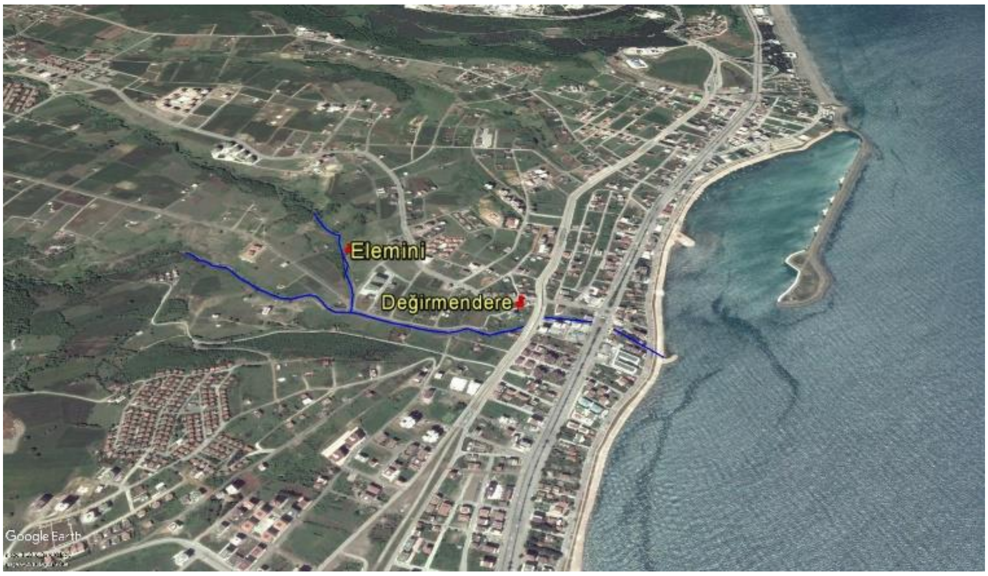

Figure 1. General View of Study Area (Korfez District)

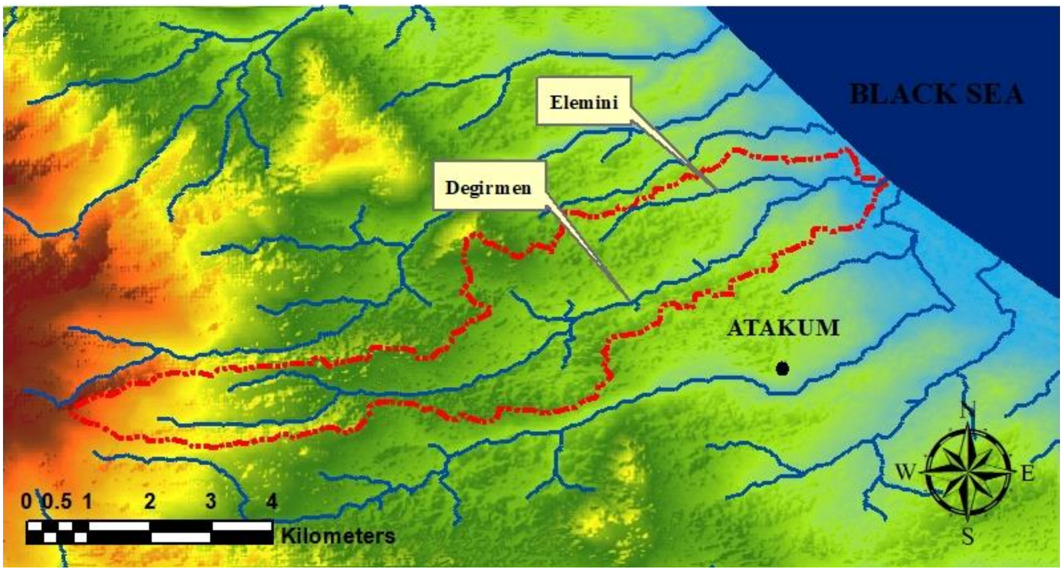

Figure 2. Location of Degirmen Basin

The precipitation area of Degirmen is 14.4 km^2, the length of the stream is 11.5 km, the height difference between upstream to downstream is 948 m, the slope is 0.05080. The precipitation area in the study area of Elemini is 2.41 km^2, the length of the stream is 3.9 km, the height difference between upstream to downstream is 306 m, the slope is 0.05724 (DSI, 2013). There is a highway and a tramway bridge over the stream. The highway bridge is in the Black Sea coastline and provides transport on the main road.

2. Material and Methods

One-dimensional (1D) model approach was used in this study. For 1D modeling, principally, river cross-section measurements are defined with river route, therefore, field surveys are very important. Then flood peak discharges are obtained in hydrological modeling phase. Hydrological modeling is the imitation of real hydrological properties and systems by using small physical models, mathematical analyses and computer simulations (Allaby and Allaby 1999). The climatic data sets for the study area were obtained from the State Meteorological Service and State Hydraulic Works of Turkey.

2.1. 1D Hydraulic Model -MIKE 11

MIKE 11 is a software for modeling water quality, sediment transport, flows in rivers or canals and inland water bodies. The hydrodynamic module (HD) of MIKE 11 solves the vertically integrated conservation of continuity and momentum equations with the dynamic wave approach (the ‘Saint Venant′ equations). The continuity and momentum equations are solved by an implicit finite difference scheme recommended by Abbott and Ionescu (1967). MIKE 11 allows the designation of hydraulic structures such as bridges, culverts, and falls, and also solves flow analysis for constructions mentioned. In Equation 1 and Equation 2, continuity and momentum formulas represented respectively.

$$\frac{dq}{dx}+\frac{dA_{fl}}{dt}=q_{in} \tag{1}$$

$$\frac{dq}{dt}+\frac{d\left(\frac{\alpha q^2}{A_{fl}}\right)}{dx}+gA_{fl}\left(\frac{dh}{dx}\right)+\frac{gq|q|}{C^2A_{fl}R}=0 \tag{2}$$

In this equation the meaning of the notations is given below (DHI, 2016);
A; flow area (m^2),
q; lateral flow (m^2/s),
h; depth above datum (m),
C; Chezy resistance coefficient (m$^{1/2}$/s),
α; momentum distribution coefficient,
x; cartesian coordinates,
g; acceleration due to gravity (m/s^2)

2.2. Modeling

The topographical map of the study area was obtained from the 1/1000 scale contour lines and the missing areas were completed with field surveys and, surveying results are used for creating the triangulated irregular network data (TIN) by ArcGIS software. Continuous surfaces are represented as interconnected triangular series in TIN. This triangular elevation model was used as the base of the digital elevation model. The triangular irregular network is used to obtain the digital elevation model (DEM) of the field, which is used as a base in the MIKE modeling. TIN model of study area shown in Figure 3.

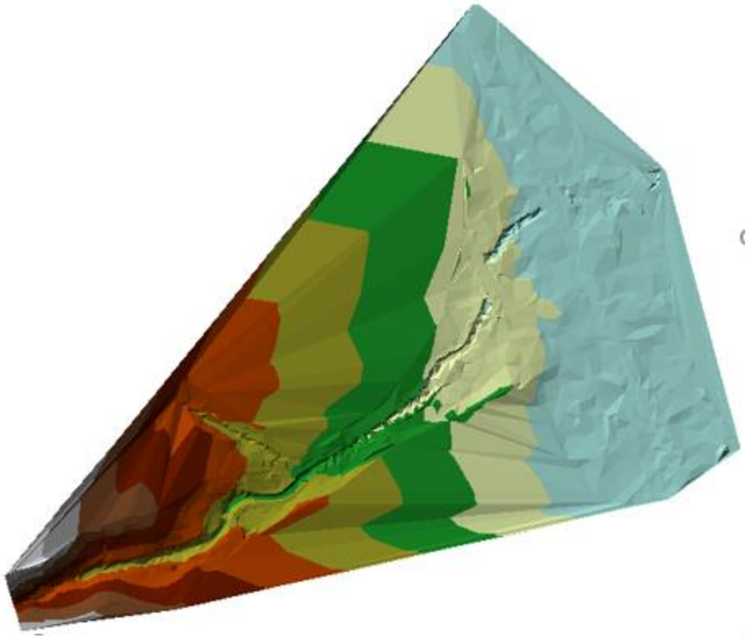

Figure 3. TIN Data of Study Area (ArcGIS)

In this study, 1D modeling was performed both with hydraulic structures and without structures, along the Degirmen and Elemini stream lines. By using ArcGIS and MIKE HYDRO modules, river cross-sections were created for every 20 meters. (Figure 4).
The capacity of the river cross-sections was obtained with the one-dimensional model MIKE 11.

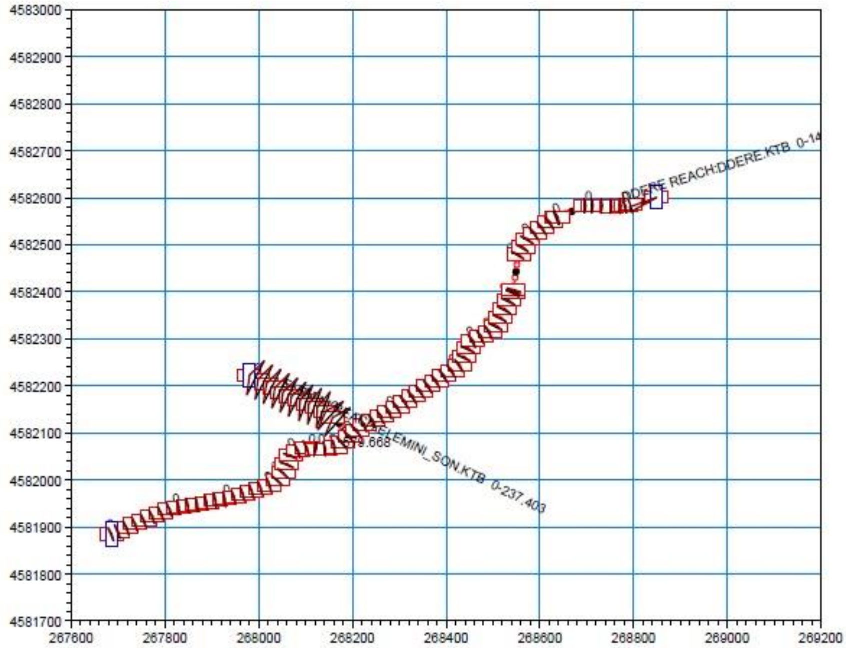

Figure 4. River Network and Cross-Sections Without Structures

MIKE 11 model has been used Hydrographs of peak flows having various frequencies. In this study, Q100 and Q500 discharges are worked in numerical analysis. The flood peak discharges with different return times has been estimated by the SCS method in this study. and given in Table 1 and Table 2. Besides, manning roughness coefficients are obtained from the State Hydraulic Works.

Table 1. Flood values of different return periods of Degirmen stream.

Return Periods	Discharges (m^3/s)
5	29.59
10	43.66
25	66.70
50	87.70
100	112.27
500	183.06

Table 2. Flood values of different return periods of Elemini stream.

Return Periods	Discharges (m^3/s)
5	8.8
10	12.8
25	19.3
50	25.1
100	32.0
500	51.7

3. Results and Discussion

According to MIKE 11 results, stream cross-sections are insufficient to pass the floods. Flood waters will tend to overshoot the cross-sections and spread to the area. Results of Degirmen stream profile for Q100 discharge is shown in Figure 5.

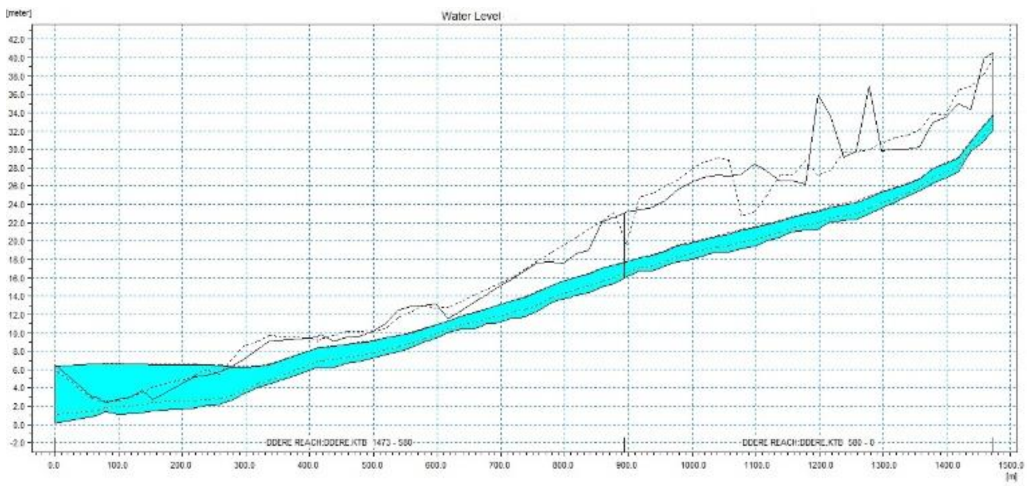

Figure 5. Stream Profile for Q100 Discharge

According to the results, especially in downstream due to insufficient sizes of sub-sections under the bridges, cross-sections along the river are inadequate to pass the Q100 and Q500 discharges in the downstream of the Degirmen stream. In Figure 6, the cross-section at 1405,03 m where the TCK bridge is located does not pass the overflow.

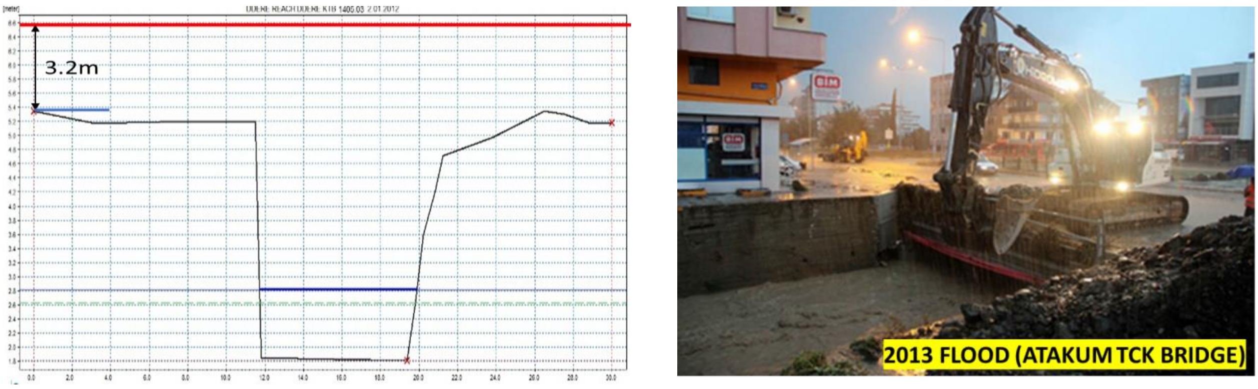

Figure 6. Cross-section at 1405.03 m (before the TCK bridge)

If water surface bigger then the cross-section height, at this stage 1D flood models shows the water column exceeding the cross-section as if the section height continued upward. It indicates that the cross-sections are insufficient and that two-dimensional modeling is required here to identify the flood propagation in the land.

According to the MIKE 11 model results, the water overflowing from the cross-sections tends to spread to urbanized areas. Here result in maps of Q100 and Q500 maximum water depth (Figure 7-8).

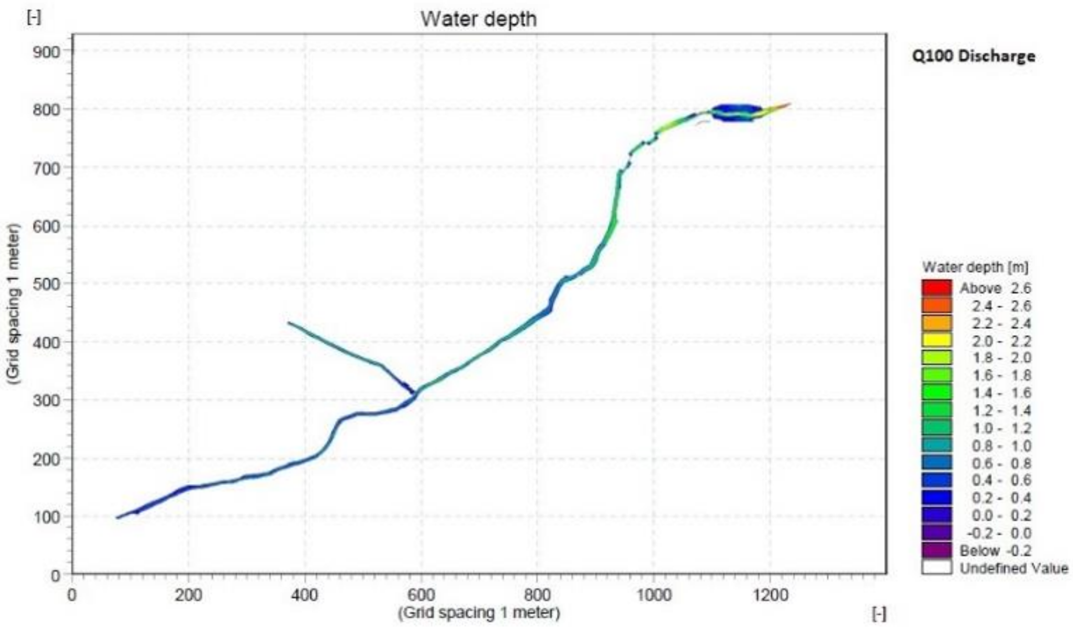

Figure 7. 1D Results for Q100 Maximum Water Depth

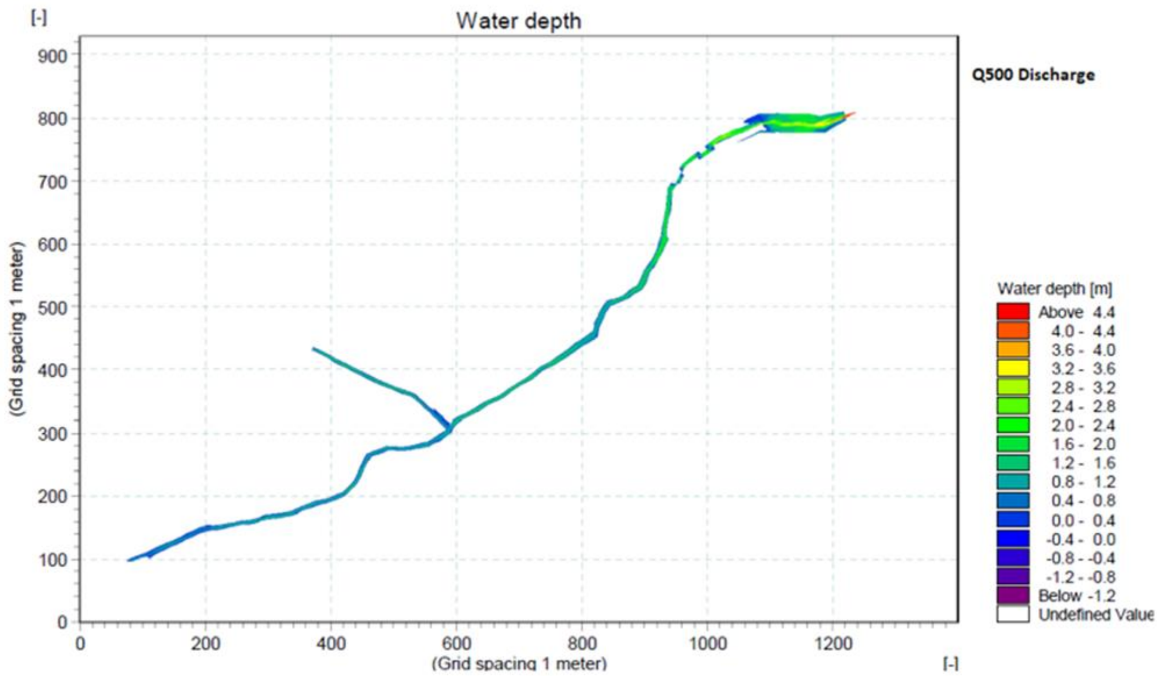

Figure 8. 1D Results for Q500 Maximum Water Depth

4. Conclusion

The geographical region and climate characteristics of the city of Samsun cause Samsun to frequently experience floods. The flood disasters that took place in the past years are the most important proof of this. Increasing of precipitation intensity, global climate change is seen to have an effect, but when it comes to the 2012 and 2013 floods, it is seen that even when rainfall values are not in disaster dimension, floods are seen. The reason is that irregular urbanization and inadequate infrastructure.

The flood inundation maps showed that some areas, especially the downstream part of the stream, are prone to overflowing at 100 and 500-year return period floods. The cross-sections are insufficient along the river to pass the Q100 and Q500 discharges in the one-dimensional hydrodynamic model. The cross-sections narrowed by the stream material should be cleaned in order to prevent the damage of the floods. Besides the sections of the TCK bridge on the Sinop-Samsun highway should be arranged according to the upper water level.

This study is a preliminary project to calculate the adequacy of river cross-sections for two-dimensional flood model.

5. Acknowledgment

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