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Levee Break Simulation Sample Tunca River

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Abstract River floods results from excessive regional rain or mass snow melting is common throughout the world. Flood is a formation which occurs depending on climactic conditions of the region, geotechnical and topographical characteristics. However, flood damages emerge completely as a result of human activities. Uncontrolled urban activities lasting without any previous measure on the fields under risk is the most important reason of flood disaster in every corner of the world. Although Natural Disasters are experienced frequently in countries where disaster and risk management are carried out successfully; dimensions of these disasters can be predicted and loss of life and property can be minimized as much as possible due to precautions which are preventive and damage decreasing. As a result of making risk maps through modeling and simulation studies about Flood and Overflow which are the most common Natural Disasters, it is possible to determine fields under risk. Therefore, in this study, 2D propagation flood maps of Tunca River passing from Edirne will be determined and analyzed, potential risky terrains will be determined and with a possible scenario flood propagation and water depths are formed. As a result of analysis, it was observed as a result of modeling that floods were stuck within winter walls built between 1955-1957.

Keywords: Tunca River, Meric Sasin, Edirne, Levee Break, Flood, 2D Model

I. INTRODUCTOIN

Flood is a natural disaster is the overflow of a river due to some reasons such as torrential rains of a stream, sudden melting of snow cover, left uncontrolled water from the existing dam, bed from spilling over the surrounding lands, residential places, damaging infrastructure facilities and all live by their natural habitat adversely affected in effect through to disrupt normal life criteria is to create a flow of size [1].

Drought is an integral part of the natural disaster, storms, floods and other meteorological disasters, leads to continuous and significant amounts of damage and fatalities. In the past, Turkey has become less common to these types of meteorological disasters but today, as a result of population growth, wrong land use, is exposed to meteorological disasters such as excessive rainfall, avalanches, landslides and so on are increasing loss of life and property. The structure of land is changing due to growing settlements in river basins, opening new roads and new facilities. The use of unsuitable agricultural methods, destruction of forests and pastures, leads to increasingly large flood disaster and frequent. Even in the pre-flood protection measures are not required field, it becomes necessary to take precautions [2-5].

It is not possible to prevent natural disasters. However, it is possible to decrease damages of these disasters through specific structural and non-structural precautions before they become hazard. Although Natural Disasters are experienced frequently in developed countries, dimensions of these disasters can be predicted and loss of life and property can be minimized as much as possible due to precautions which are preventive and damage decreasing. As a result of making risk maps through modeling and simulation studies about Flood and Overflow which are the most common Natural Disasters, it is possible to determine terrains which are under risk. Flood modelings can be modeled with the coupled of 1D and 1D-2D [6].

Although 1D flood modeling are practical, there might be interruptions between sections since it makes unidirectional calculation and cannot give accurate results in complex flow systems and terrains where topography changes frequently [7].

It is seen that 2D flood modeling give more successful results compared to 1D model considering topographic and geometric characteristics in recent studies [8]. In 2D modeling, the field can be represented totally with free surface stream flexible network systems and flood propagation maps can be observed continuously throughout the field. However, 2D modeling cannot represent hydraulic structures totally on river bed [9].

It is more suitable to use 1D modeling in river bed to decrease calculation time and clearly represent hydraulic structure and 2D modeling in flood field. Flood propagation maps can be formed with the integration of two models and natural disaster risks can be minimized with early warning system.

In this study, flood discharge expected for Tunca River is modeled by using “Mike Flood” software. Obtained model results are analyzed and potential risk scenario is thought. Considering risk case, river is modeled again and terrains under risk are determined and water depths in living spaces in these terrains are determined.

II. METHODS AND PROCEDURES

With Arda and Ergene River, Tunca river constitutes a portion of Meric basin that is one of the largest river system in East Balkan Basin. It arises 1.940 m height in Montenegro in Bulgaria. It is 384 km long and İts basin area is 7.884 km^2. Tunca River 12 km along forms the border with Turkey - Bulgaria. Then flowing for a while inside Turkey, mixed with Meric River in the South-west of Edirne. Figure 1 shows the area of the River Tunca [10].

Fig. 1. Tunca River.

A. Topography

River cross-section of Tunca River is composed from bathymetric map in 1/1.000 sensitivity. Parts which are predicted to be exposed to flood are obtained from maps in 1/5.000 sensitivity and summer and winter bank maps made in order to prevent flood in previous years was processed on map in 50 cm sensitivity. With obtained point data, terrain model was composed as shown in figure 2 in ARCGIS 10,2 software.

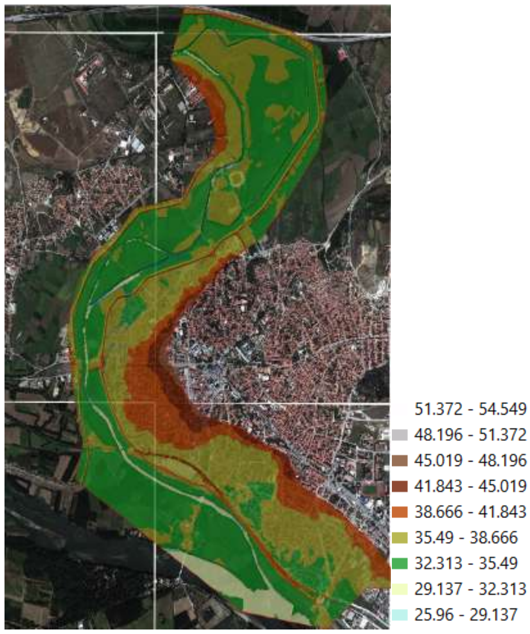

Fig. 2. Tunca River TIN.

B. Hydrological Data

In flood modeling, flood recurrence flows were calculated for 1961-2014 by using annual maximum flows of Tunca River water leakage into station no. E01A013 which is on Tunca River. This data with statistical methods is calculated as $Q_{25} = 469$ m³ / s, $Q_{100} = 531$ m³ / sec. The highest flow rate observed between 1964 and 2015 is shown in Figure 3.

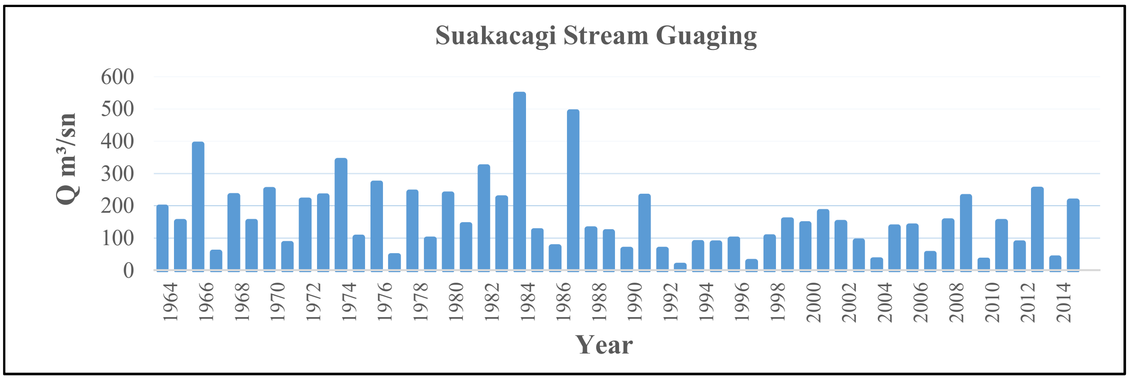

Fig. 3. Annual Average High Flow Values.

C. Hydrological Modeling

In the present study MIKE 11 (1D) software was used for modeling the river bed. However, as from the part where the stream enters the settlement area MIKE 21 (2D) software and coupled 1D-2D Mike Flood software were used to determine flood area.

1D Modeling

Running on finite differences-basis, the Hydrodynamic (HD) module of MIKE 11 software is capable to solve non-stationary current statuses in rivers and model both currents in river regimes and floods through digital methods adapted to local current conditions. Model solution system can be applied for both low slope and high slope rivers where vertical homogenous current conditions are available.

In 1D model calculations in MIKE 11 modeling system Saint-Venant equations based on the average of cross sections are taken as basis. In this way, water level (s), discharge (Q) or average rate of flow (U) can be identified. This can be set forth as a continuity equation as follows

$$\frac{\partial A}{\partial t} + \frac{\partial Q}{\partial x} = F_s \qquad (1)$$

$$\frac{\partial Q}{\partial t} + \frac{\partial}{\partial x}((\alpha Q^{\wedge}2)/A) + gA\frac{\partial}{\partial x}h + \frac{gQ|Q|}{C^2AR} = 0 \qquad (2)$$

Where;

h is the water depth, **Q** is the discharge, **α** is the velocity distribution coefficient, **x** is the stream network piece (Chainage), **t** is time, $\mathbf{F_s}$ is the source term, **g** is the acceleration of gravity, **C** is the Chezy coefficient, **A** is the wet section area, **P** is the wet perimeter, and **R** is the hydraulic radius.

The model calculates water heights at tributaries and flood beds by means of the sections obtained from the DEM (Digital Elevation Model). Afterwards, flood maps are generated with the use of MIKE 11 GIS, a GIS-based software written for MIKE 11 modeling system and runs by using MIKE 11 HD module results (Fig. 4). 1D flood modeling models Tunca River as 7,06 km. Cross sections are taken at 50 m intervals and more frequently at critical areas.

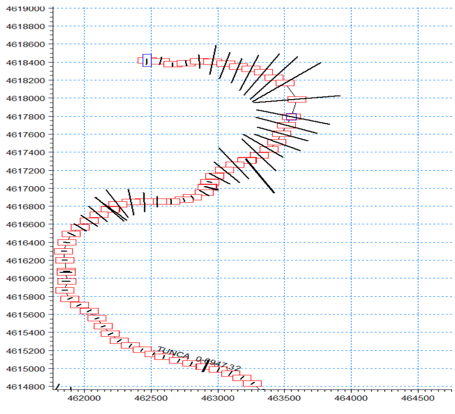

Fig. 4. Mike 11 Stream Network Arranger.

2D Modeling

MIKE 21 is capable of modeling 2D free surface through flexible mesh system. Within the MIKE 21 modeling system, 2D model calculations are solved through Saint-Venant equations based on average depth.

In this way, water level (s), Cartesian velocity components “U” and “V” can be identified. This situation can be written as a continuity equation as follows:

$$\frac{\partial s}{\partial t} + \frac{\partial}{\partial x}Uh + \frac{\partial}{\partial y}Vh = F_s \qquad (3)$$

$$\frac{\partial s}{\partial t} + U\frac{\partial U}{\partial x} + V\frac{\partial U}{\partial y} + g\partial_x s + \frac{g}{C^2 d}U\sqrt{U^2+V^2} + \frac{\partial}{\partial x}\left(K_{xx}\frac{\partial U}{\partial x}\right) + \frac{\partial}{\partial y}\left(K_{yy}\frac{\partial U}{\partial y}\right) = F_s \qquad (4)$$

$$\frac{\partial s}{\partial t} + U\frac{\partial V}{\partial x} + V\frac{\partial V}{\partial y} + \frac{\partial s}{\partial x} + \frac{g}{C^2 d}V\sqrt{U^2+V^2} + \frac{\partial}{\partial x}\left(K_{xx}\frac{\partial V}{\partial x}\right) + \frac{\partial}{\partial y}\left(K_{yy}\frac{\partial V}{\partial y}\right) = F_sV_s \qquad (5)$$

Where;

Calculation mesh is generated in MIKE Zero environment. The most important advantage of the flexibility of the mesh is the ability to generate the mesh frequently at parts where sensitive calculation is needed and less frequently at other parts (Fig.5). Accordingly, simulation duration and model stability can be adjusted in an optimum way.

Also during the generation of flexible mesh system for Tunca River at places close to the rivers where structures are dense and in order to process the levees sensitively maximum mesh interval is selected as 10 m². In order to simulate the area between stream shorelines and the structures close to the stream, small mesh area needs to be selected at these areas. In other parts, mesh area is determined to be maximum 50 m². Afterwards, a triangulation was generated and in order to ensure homogeneity the operation “smooth” was carried out 50 iterations. This operation ensures the homogeneity of the triangle structure and affects stability. During mesh generation the buildings predicted to be exposed to flooding are removed from the calculation mesh. Thereby it is possible to observe which existing building is under what level of risk in case of a probable flood.

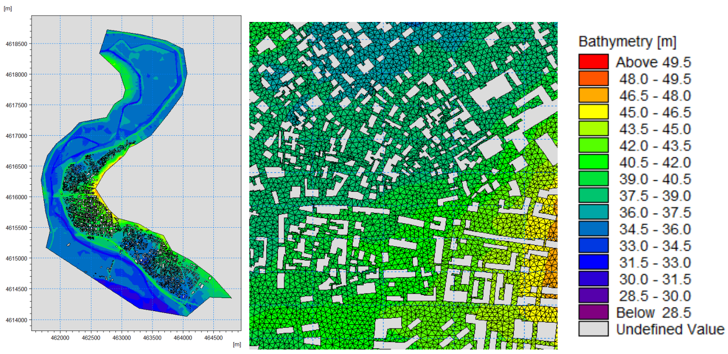

Fig. 5. Mesh File and More Sensitively Generated Flexible Mesh at Urban Areas.

D. Model Parameters

Friction Parameters

Manning “n” was used as the friction parameter. In terms of land use types, other than the river bed Settlement area: 0,020, forest, green fields etc.: 0,035 and in terms of material in stream channel Concrete: 0,017, Natural structure: 0,035

Time and Distance Parameters

Mike 11 Maximum dx and dt

Distance (dx) time (dt) and parameters are essentially related with stability. These values need to be determined independently for each incident. In order to achieve stability, the role of these parameters in meeting the Courant condition were taken into consideration. In MIKE 11 stage Tunca River dx was determined to be 100 m, while for Tunca River dx and dt were determined to be 100m and 1 second.

Mike21 Time, Distance and Courant Condition Parameters

In cases where finite difference equations are used for the solution, Courant number should be used to achieve model stability. In order to achieve model stability Courant number needs to be less than or equal to 1. This number can be determined by means of the following formula.

$$Cr = \left(\sqrt{g * D} + v\right) * \frac{\Delta t}{\Delta x} \quad (6)$$

Where;

Cr is the Courant number, Δt is time interval, Δx is distance interval, √g.D is wave velocity and v is velocity.

Performance of a stable simulation of the shallow water equation depends to time, distance and Courant condition (CFL) also in MIKE 21 environment. In the selection of these values experience and trials gain prominence. At MIKE 21 stage for Tunca River dx is read from the domain (Min: 1 m, Max: 30 m), dt is determined to be minimum 0,0001 second and maximum 0,5 second and the critical CFL number is determined to be <0,8.

E. Hydrodynamic Parameters

Wave Approx

This is an important parameter for stability. In flood simulations "High Order Fully Dynamic" wave approach was preferred. Especially in simulations where water mass inertia is significant on basis of time and distance (such as flood) it is chosen as a stability-improving factor. Also in the flood simulation study of Tunca River this choice was chosen in line with DHI's suggestion [11].

Default Values

Default values of the hydrodynamic parameters were used as they are, except for the "δ" value. The δ value was increased from "0,5", the default value in flood simulation studies, to "0,85". Because the coefficient "δ" expresses a time-centered gravity acceleration in momentum equation and is a stability factor.

III. RESULTS

As a result of 2D Numeric modeling studies, flood propagation map for Q_2, and Q_{500} recurrence intervals are obtained. As a result of 2D modeling, Q_{25}, Q_{500} flood discharge remain which made the years between 1955-1957 as seen figure 6 between kazanova 1 levees and the left bank levee of Tunca.

Casanova-1 levee on the Tunca river right bank is located 5.325 m. and is the average height of 3,80 m, 4,00 m wide crest, splay slope in the upstream and downstream side of 1/2,5 built in 1957. Levees protect 1.656 hectares of agricultural land and Edirne city neighborhoods from flood. Q_{500} discharge is able to control at current condition.

Tunca Left Bank levees of Tunca river left bank, was built in order to avoid 3.125 hectares of farmland to Edirne Center from Tunca River flooding in 1958. Levee length of 6.977 m, average height is 4,10 m. Crest width of 4,00 m, Levees splay slope was built of 1/2,5. It has the capacity to control Q_{500} levee of Tunca River.

Fig. 6. Tunca River Levee.

Flood propagation maps were colored in 50 cm sensitivity and maps were given in Fig.7. When flood propagation maps are observed, it is seen that Q_{25} and Q_{500} flood overflows has the same water propagation due to banks but there is difference in water depths.

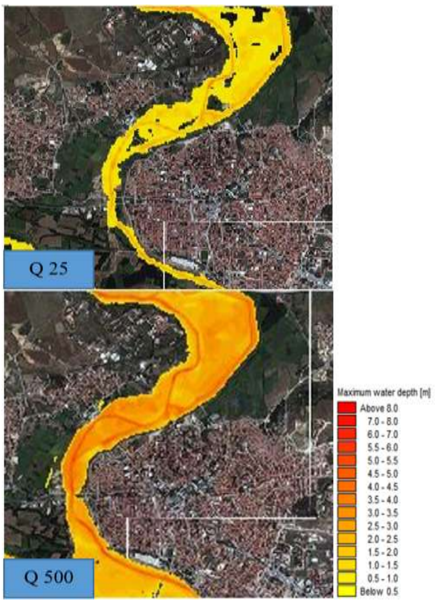

Fig. 7. Q_{25} and Q_{500} Flood Inundation Maps.

Although recent floods are stuck within banks, there might be cuts on banks damaged by the people of the terrain in arid periods like in the flood of year 2006.

A Left Levee Break Simulation

Levees are of great importance for the Tunca river floods. Flood discharge remain between levees. In the study, levee break simulation applied on Tunca river left bank as seen in figure 8. In this area, flood beneath areas have been identified in Q_{50} and Q_{100} flood discharge.

According to Q_{50} flood discharge, a total of 83 homes seen inundation. The water depth is between 0,2m and 0,8m.

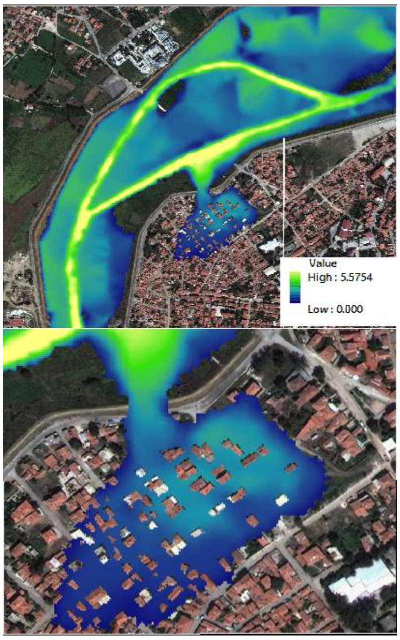

Fig. 8. Q_{50} Levee Break Simulation.

According to Q_{100} flood discharge, a total of 146 homes seen inundation. The water depth is between 0,2m and 1,3 m.

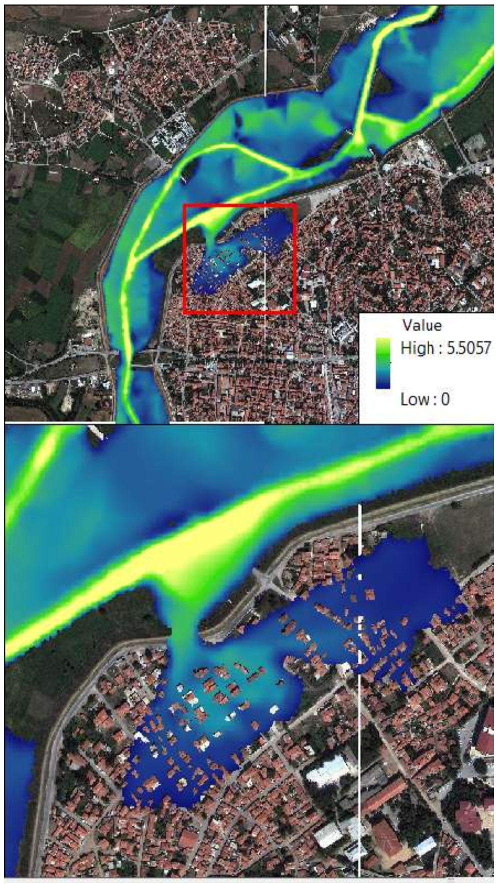

Fig. 9. Q_{100} Levee Break Simulation.

IV. CONCLUSION

It is seen that flood propagation maps obtained as a result of modeling are stuck between winter banks built between 1955-1957. However, there are many historical buildings in this terrain which is known as flood area.

Settlement areas on the right and left coasts of Tunca River can be protected by available banks. However, as it was experienced before, banks can be damaged due to construction error or harmed by the people, and flood flows may cause cuts on the bank. As it is seen in the study, cuts on banks would cause financial and moral damages. It is revealed out in current condition that wall maintenance and reinforcement is quite important.

It is seen that although available banks protect settlement places from Tunca River floods, it cannot protect historical buildings within flood terrain. Tunca River spring conditions should be analyzed well and flood prevention structures should be discussed or in order to prevent floods Tunca River bed should be disciplined and floods should be prevented independent from banks. It is thought that this solution is more sustainable to carry historical buildings to future generation.

REFERENCES

[1] V. Eroglu, “Regional Preparatory Meeting for the 5th World Water Forum in Turkey”, Turkey, 2008, pp. 7-10.

[2] S.Y. Korkanc and M. Korkanc, “Effects of Floods and Torrents on Human Life”, *ZKÜ Journal of Forestry Faculty,* Vol. 8, 2008, pp. 42-50.

[3] D.C. Mason, J. Guy and P. Schumann, “Flood Detection in Urban Areas Using TerraSAR-X”, *IEEE Transactions on Geoscience and Remote Sensing*, Vol. 48, 2010, pp. 882-894.

[4] S. Rozalis, E. Morin, Y. Yair and C. Price, “Flash Flood Prediction Using an Uncalibrated Hydrological Model and Radar Rainfall Data in A Mediterranean Watershed under Changing Hydro. Conditions, *Journal of Hydrology*, Vol. 394, 2010, pp. 245-255.

[5] A. Kryžanowski, M. Brilly, S. Rusjan, and S. Schnabl, “Structural Flood-Protection Measures Referring to Several European Case Studies”, *Nat. Hazards Earth Syst. Sci.,* Vol. 14, 2014, pp. 135–142.

[6] M.S. Horritt and P.D. Bates, “Evaluation of 1D and 2D Numerical Models for Predicting River Flood Inundation”, *Journal of Hydrology*, Vol. 268, 2002, pp. 87–99.

[7] F. Huthoff, J.W.F. Remo and N. Pinter, “Improving Flood Preparedness Using Hydrodynamic Levee-Breach and Inundation Modelling: Middle Mississippi River, USA”, *Journal of Flood Risk Management*, Vol. 8, 2015, pp. 2–18.

[8] A. Cook, V and V. Merwade, “Effect of Topographic Data, Geometric Configuration and Modeling Approach on Flood Inundation Mapping”, *Journal of Hydrology*, Vol. 377, 2009, pp. 131-142.

[9] E.A. Frank, A. Ostan, M. Coccato and G.S. Stelling, “Use of an İntegrated One -Dimensional / Two – Dim. Hydraulic Modeling Approach for Flood Hazard and Risk Mapping”, *In River Basin Management*, 2001, pp, 99-108.

[10] Orsam, “The Obligation of International Cooperation in Meric (Maritza-Evros) Basin Water Management, *Orsam Water Research Programme*, 2011, Report No 4.

[11] DHI, “MIKE 21 Reference Manual”, Mike by DHI, 2014.

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