How to cite: Ziya Kaya, Y., Üneş, F. Demirci, M. (2022) Flood Modeling Based on The Precipitation Data by Using Hec-Ras Software Version (5.0.7). *2022 "Air and Water – Components of the Environment" Conference Proceedings*, Cluj-Napoca, Romania, p. 47-56, DOI: 10.24193/AWC2022_05.

FLOOD MODELING BASED ON THE PRECIPITATION DATA BY USING HEC-RAS SOFTWARE VERSION (5.0.7)

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DOI: 10.24193/AWC2022_05

ABSTRACT. Floods are one of the most destroyable disasters that affect human life directly. It is important to model floods for the determination of the vulnerable areas, and planning of the dangerous zones. For this purpose, HEC-RAS software is in use to create complex flood models. In general, for the modeling of a flood by using any software, an accurate topography of the area, boundary conditions, Manning coefficients, and the flow data are essential. However, it is not always possible to have the flow rate of all streams located in the study area. Because of the mentioned reason, in this study authors preferred to directly use precipitation data for modeling the flood. A model was created by using SRTM satellite data for the digital elevation model. A two-dimensional geometry was created, and the precipitation data was added to the model. The main output of the performed model showed that using precipitation data directly on a flood model is not fully representative of the extent of flooding. According to the model result, the flood is spread over a wider area than it actually was.

Keywords: Flood Modeling, HEC-RAS 2D, Precipitation, Digital Elevation Model

1. INTRODUCTION

Extreme weather conditions as a result of global climate change affect human life in different ways. Floods are one of these destroyable effects. Determination of the flood vulnerable areas by computer-aided approaches is very important cause it supplies a possibility to see how the area will be affected under different meteorological and hydrological conditions before it is actually affected. Even it is very useful to create computer models for the detection of flood vulnerable areas, it is not easy to do certain models because of the complexity of the hydrological and topographical conditions.

As a result of this complexity, recently scientists developed different approaches and strategies to increase the created models' accuracy. Lim and Brandt, (2019)

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evaluated the performances of the different digital elevation models (DEM) and roughness coefficients to understand the effects of both input data. According to the results they obtained they saw that high-resolution DEMs have better performance with high Manning's values and lower resolution DEMs have better performance with lower Manning's values. Jafarzadegan et al., (2018) emphasized that it is challenging to prepare floodplain mapping in case of data-scarce, and also it is computationally difficult to create hydrodynamic models, especially over large stream networks. For this reason, Jafarzadegan et al., (2018) proposed a reliable geomorphic approach as an alternative for delineation of 100- year floodplains for the Conterminous United States. Abd-Elhamid et al.,(2018) performed a case study for the Hurghada, Egypt coastal tourism areas flood prediction. They announced the aim of the study as a derivation of the runoff flow paths and their flow magnitudes to protect the important coastal areas.

According to the results they shared, it is seen that the site is under danger of flash flood risk and protection is essential for the site. Zeleňáková et al., (2019) published a study about the risk modeling of floods in the Kruzlov village of Slovakia. In this study, authors were focused on three stages of flood modeling separately. In the first part, they developed a flood model by using HEC-RAS software, in the second part they identify the vulnerable areas by using ArcGIS, and finally, they performed a cost analysis for flood damage. As a result of the study, the authors indicated cost analysis is a useful approach for the evaluation of the property damage due to the floods.

Quiroga et al., (2016) modeled the flood that occurred in the Bolivian Amazon in February 2014. By comparing the HEC-RAS 2D results with the satellite image they found that HEC-RAS software has a good performance on mentioned flood modeling. They had some valuable information such as water depth, velocity and temporal variability of the flood February 2014 as a result of the outputs of the HEC-RAS 2D. Further information about different type of flood modeling approaches can be found from Ben Khalfallah and Saidi, 2018; Cho et al., 2018; Feng et al., 2020; Jafarzadegan and Merwade, 2019; Kowalczuk et al., 2018; Logah et al., 2017; Reil et al., 2018; Romali, 2018; Tsakiris, 2014.

2. METHODOLOGY

In this study, the flood that occurred in Amik plain in 2012 was modeled by using directly recorded precipitation data. HEC-RAS version 5.0.7 was used for modeling and visualization of the results. The 2D approach was considered as the best way to model the flood because the study area is a large plain including complex stream networks.

2.1. HEC-RAS software

HEC-RAS is an open-source software developed by the US Army Corps of Engineers that allows users to generate different types of river-based models. It is possible to create 1D steady flow models, 1D and 2D unsteady flow simulations, water temperature models, sediment models, etc. by using HEC-RAS based on the hydrodynamic approaches. Generally, to perform a reasonable HEC-RAS model; the topography of the study area, Manning coefficients, precipitation or discharge data, and the general information about the stream network are essential. A google map capture was given with figure 1 to show the study area roughly.

HEC-RAS software uses shallow water equations for 2-dimensional modeling. For the modeling process, a terrain was created by using SRTM (NASA JPL, 2013) topographic data. Because the created terrain was not included streams located in the Amik Plain, an improvement was performed on the created terrain by adding all the main streams by using directly the GIS tool of the HEC-RAS namely Ras Mapper.

Another critical parameter which is the Manning coefficients of the catchment were determined based on the MODIS (Friedl, M. and Sulla-Menashe, 2019) satellite data. After the definition of the area based on the satellite data such as mixed forests, agricultural lands, grassland, water surface, etc. an appropriate Manning coefficient was chosen from the related literature (Asante et al., 2008; Dayal, 2015) and it was appointed to the specific area for the creation of the Manning layer.

2.1 Study area and the precipitation data

The study area is located in the southeast part of Turkey. Amik Plain is within the lands of the Hatay province. The plain has productive farmlands, non-dense urban areas, and one airport that serves the Hatay region. The plain plays an important role for the economy of the region and also for the whole country. A google map capture was given with figure 1 to show the study area roughly.

In this study flood that occurred in Amik plain in 2012 was modeled by using directly precipitation data. The flood that occurred in 2012 was a long-term flood. The precipitation data used for modeling starts from 1 Jan 2012 and ends 29 Feb 2012. A total of 369.8 mm of precipitation fell in January at the same station in the relevant year. In February, 217 mm of precipitation was recorded. Thus, a total of 586.8 mm of precipitation fell in two months. The distribution graph of the precipitation (mm) was given in figure 2.

Precipitation data was implemented to the model daily. The rainiest day recorded at the Antakya meteorological station during the flood in the Amik plain in 2012 was 27 January with 45.6 mm.

Fig. 1. A rough marked map of the study area (google earth view)

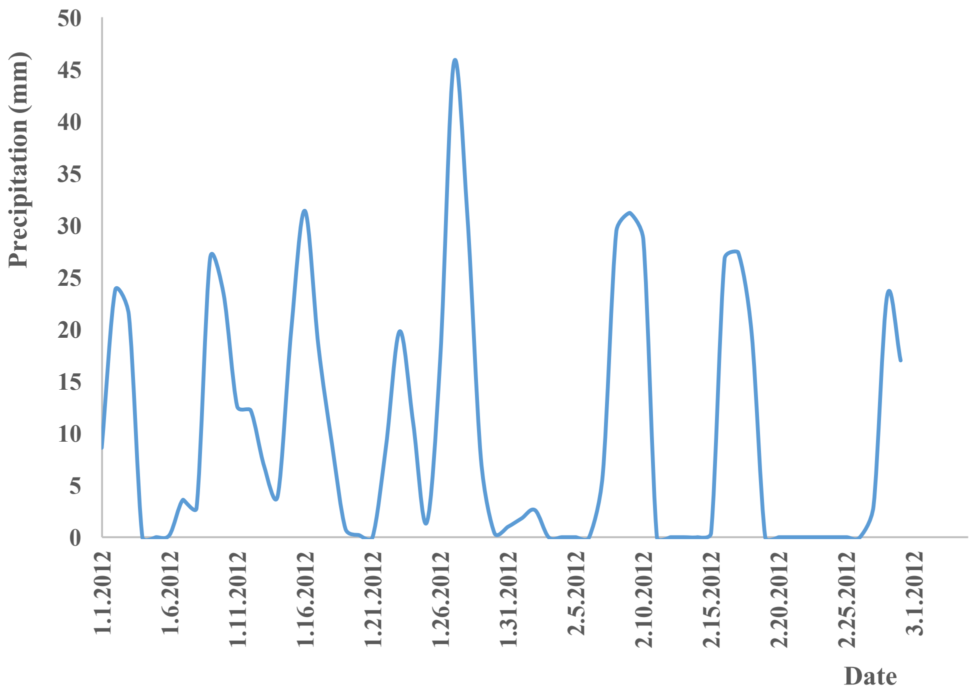

Fig. 2. Distribution graph of the precipitation used for flood modeling (Hazır et al., 2016)

3. RESULTS AND DISCUSSIONS

The precipitation data (mm) recorded in the Antakya meteorology station was added to the HEC-RAS model to see the extension of the flood 2012 by using precipitation data.

The 2D model geometry contains the Amik plain and all the surrounded hills. An outlet for the model was defined at the boundary of the Asi river reaching the Mediterranean Sea. For the maximum flood model results of the 2D HEC-RAS, an output was given in figure 3.

At the top of figure 3, results of the 2012 flood were presented on the improved SRTM DEM. And, at the bottom of figure 3, the same results were shared on the google earth view.

In both images shared in figure 3, the depth change is shown according to the tones of the blue color. In the visuals, which means that the depth increases as the color gets darker, 0 m is the lightest color and 15 m is the darkest color. When the results were examined, it was observed that the depth around the airport reached 5 m.

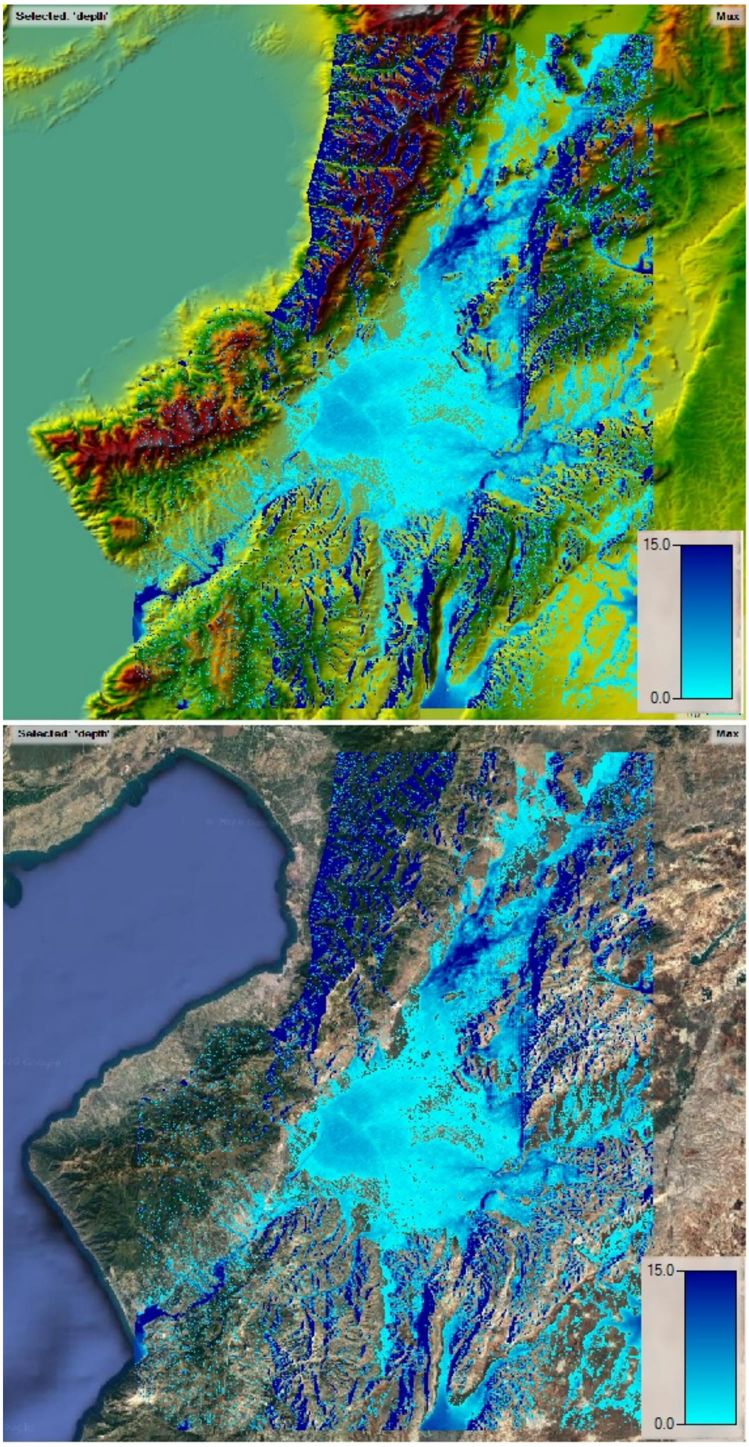

Fig. 3. Presentation of the results both in DEM and google earth

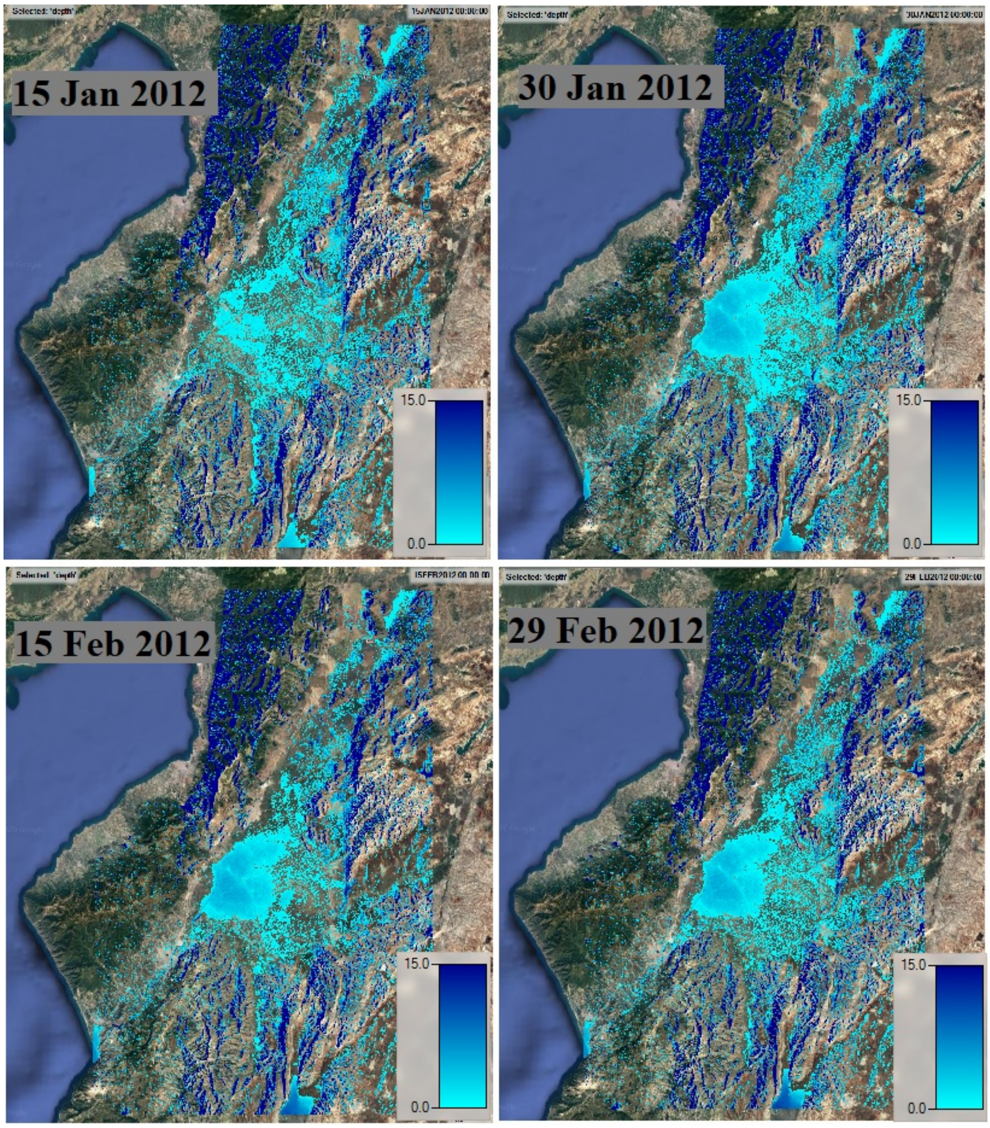

Fig. 4. Showing the change of the modeled flood on google earth

It has been shown with this model that the airport and the surrounding area, which is the region with the lowest natural elevations, are in the position of a concentration center in case of precipitation in the bowl-shaped terrain model. It is clearly seen in the terrain model that the waters flowing with precipitation naturally flow from high elevations to low elevations. In the digital elevation model, it is also seen that the depth has reached serious dimensions in the mountainous regions of the plain. This is an indication that there are natural storage pockets in these regions as well.

However, as observed in the model simulation, the discharge region of these pockets, which receive precipitation above the storage capacity, is the Amik plain.

The variation of the results of the model, which was created using precipitation data, overtime is given in Figure 4. While there is no ponding in the region where the Amik plain is located close to the start date of the precipitation, it is seen that there is a ponding that increases in-depth as time progresses and spreads to the whole plain. The colored measurement scale which is numbered 0 to 15 was added to each time period to show the depth changes during time as well. It is possible to see that the Amik plain is being a lake after 30 Jan 2012 as it was historically a dried lake. And by the following time the, depth of the waters accumulated in the Amik plain increasing step by step. According to the model results, hills located at the east part of the plain have a greater effect on floods occurring. Hazır et al., (2016) declared that more than 13000 ha areas were underwater during the flood of 2012. But, as a main result of the study, it is seen that a much larger area is being covered by waters by using directly precipitation data.

A cross-section of the Asi river was shown in figure 5 while the flood reach the maximum level. The location of the cross-section was chosen at the end of the Plain where the Antakya city center boundary starts.

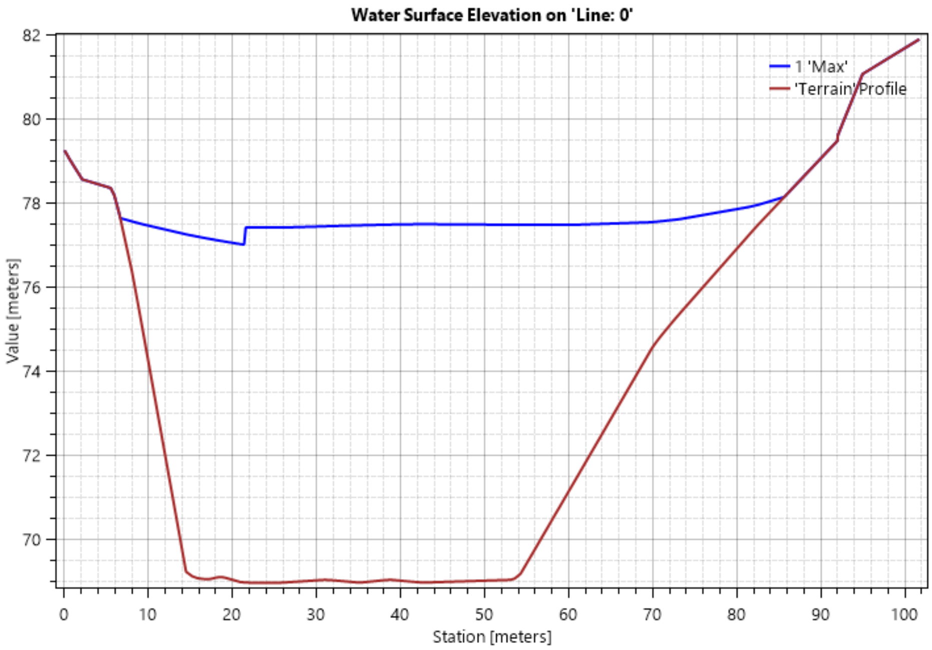

Fig. 5. Cross-sectional view of the Asi river

The cross-section of the Asi river is important because it is located after the connection of all streams of the plain. Even the plain is almost fully underwater, as it is seen from figure 5, the elevation of the water level is about 77 m and the flow is inside the channel. According to this obvious result, it is understood that the reason the floods occurred in Amik plain is not only about the dimensions of the Asi river but it is also about the dimensions of the other streams while all the other streams cannot reach the flow to the Asi river safely.

4. CONCLUSION

In this study, a 2D flood model was created by using a relatively new version of the HEC-RAS software (5.0.7). It was investigated how the precipitation data will be effective on flood modeling in case of scarcity of the runoff data. However, it was seen, the model results affect a larger area than affected. It is thought that there are several possible reasons for the model results to spread over a wider area than analyzed using flow data. The most important reason is the assumption that the precipitation data recorded at the Antakya meteorological station is effective in the whole study area. However, in the case of any precipitation, precipitation measurements are likely to show regional differences. In fact, some regions may not receive any precipitation at that time. In addition, while creating the DEM, improvements were made only on the stream networks in the plain. However, any improvements were not performed for the mountain region. The mountain region is just like the original terrain of the SRTM data. In a conclusion, it can be said, using directly precipitation data for flood modeling may cause overestimation. To increase the reliability of such models more sensitive precipitation data for small catchments are necessary. And also, the topography of the has primary importance for precipitation-based modeling as well it has great importance for runoff-based modeling.

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