IOP Conference Series: Earth and Environmental Science

PAPER • **OPEN ACCESS**

Application of 2D numerical simulation for the analysis of July 2020 North Luwu flood

To cite this article: M P Hatta *et al* 2021 *IOP Conf. Ser.: Earth Environ. Sci.* **841** 012028

Application of 2D numerical simulation for the analysis of July 2020 North Luwu flood

M P Hatta[1], F Fadlin[2], R Harun[4], Y Elfita[3] and I Renreng[4]

[1]Department of Civil Engineering, Faculty of Engineering, Universitas Hasanuddin
[2]Doctoral Program Student, Department of Civil Engineering, Faculty of Engineering, Universitas Hasanuddin
[3]Balai Wilayah Sungai V Padang
[4]Balai Besar Wilayah Sungai Pompengan Jeneberang

Email: mukhsan_hatta@yahoo.com

Abstract. Massamba is a district in North Luwu that is continually flooded by the Massamba river. The flood lasts for several days with tons of suspended materials affecting important places in the city, drowning people, and swamping arable land. Two-dimensional (2D) numerical simulation Hec-RAS is one of the most popular hydraulic models which is proved to be an important tool for analyzing and understanding flood events. The new version of Hec-RAS (5.07) was released and including 2D models capabilities. This study applied the new Hec-Ras version 5.07 to simulate the July 2020 flood in North Luwu. The flood simulate shows good results compared with the observation of the satellite image of the flood event. The simulation result provides some information like velocity, depth, and inundation area. Over the flooded area the depth is lower than 3,88 meters, velocity lower than 2,4 m/s-1, and swamping over 2,3 square kilometers of Massamba city. The flood depth allows identifying areas exposed based to hazard levels based. The simulation result validated by comparing the simulation result to the satellite image and calculating the root mean square error (RMSE) of water depth from the simulation result and during a flood event. The validation result shows that the determination coefficient R2 is 83,66%. The study shows the applicability and the value of the 2D capabilities Hec-RAS for flood studies.

1. Introduction

Flood is one of the most important natural disasters with the occurrence higher than the other natural disaster and affecting more people [1]. According to the Indonesian National Board for Disaster Management (BNPB) during the past ten years floods annually occur especially in South Sulawesi [2]. In 2019 there is a 107 floods event in south Sulawesi with the highest number is in Luwu as shown in figure 1. Besides, climate change is also taking a big role in the increasing number of flood probabilities and magnitude [3]. Based on data and information from weather satellite image the rainfall intensity at the Massamba river upper stream around 200 – 300 mm/day during the flood event. This condition indicates an extreme rainfall event in the Massamba watershed.

Flood management and risk assessment are the basic steps for analyzing hazards, vulnerabilities, and capabilities for reducing flood risk areas in future flood events. To propose strategies for flood management it is important to arrange a flood susceptibility map and the effect. There are three approaches to arrange a flood susceptibility map, the first is by analyzing the current flood events based

IOP Conf. Series: Earth and Environmental Science **841** (2021) 012028 doi:10.1088/1755-1315/841/1/012028

on a survey and investigation of the flooded area. The second way is by using a satellite image and the last is by using numerical models.

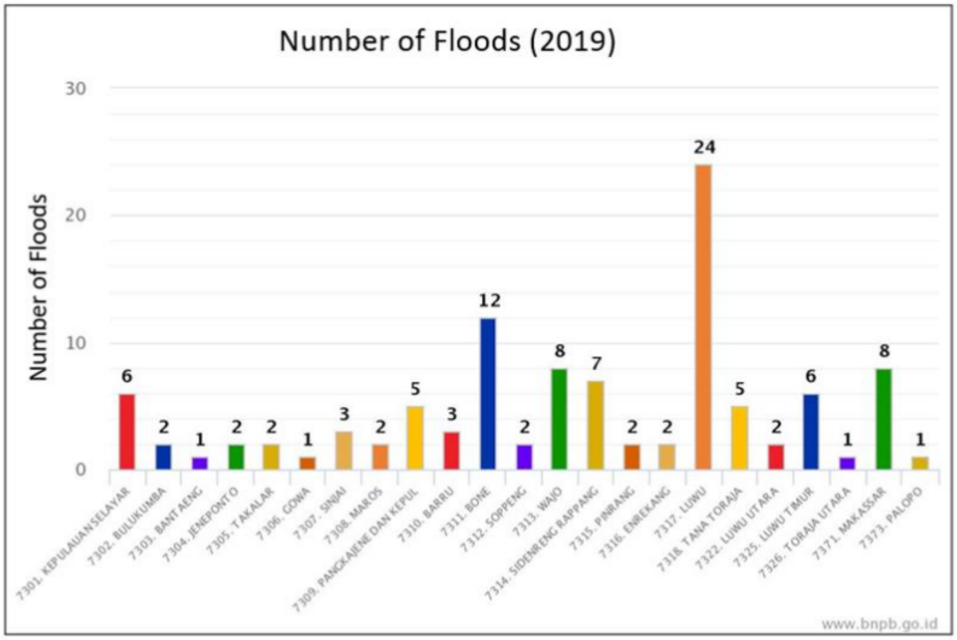


Figure 1. South Sulawesi flood data 2019

Numerical modeling allows simulating flood events with the different scenarios either one-dimensional (1D) or two-dimensional (2D) models. Regarding the flood phenomenon, the 2D model is more suitable because when water begins to overflow it becomes a 2D condition [4].

Hec-RAS is one of the most popular hydraulic models which is developed by the U.S. Army Corps of Engineers (USACE). This free software was successfully used for flood studies in many countries and has a very friendly graphical user interface [5]. In 2014 USACE released a new version of Hec-RAS which is including 2D numerical modeling capabilities and under improvement until 2018 with the new release of Hec-RAS version 5.07. This new version including 2D rain on-grid modeling which is can be used to convert rainfall to discharge directly in the watershed area. This study aims to analyze flood events in Massamba using a 2D numerical model of Hec-Ras Version 5.07. The model provides rain on-grid modeling and discharge based on current rainfall on flood events in Massamba. The simulation results also provide velocity, water depth, and inundation area of the flood. Satelite image and direct observation data were used to validate the simulation result.

2. Study area and data

2.1. Study area

The present study is located in North Luwu, South Sulawesi, specifically in Massamba. The study focused on an area located between 1200 12' E – 1200 21 E and 20 32' - 20 35' S. The location map is shown in figure 2.

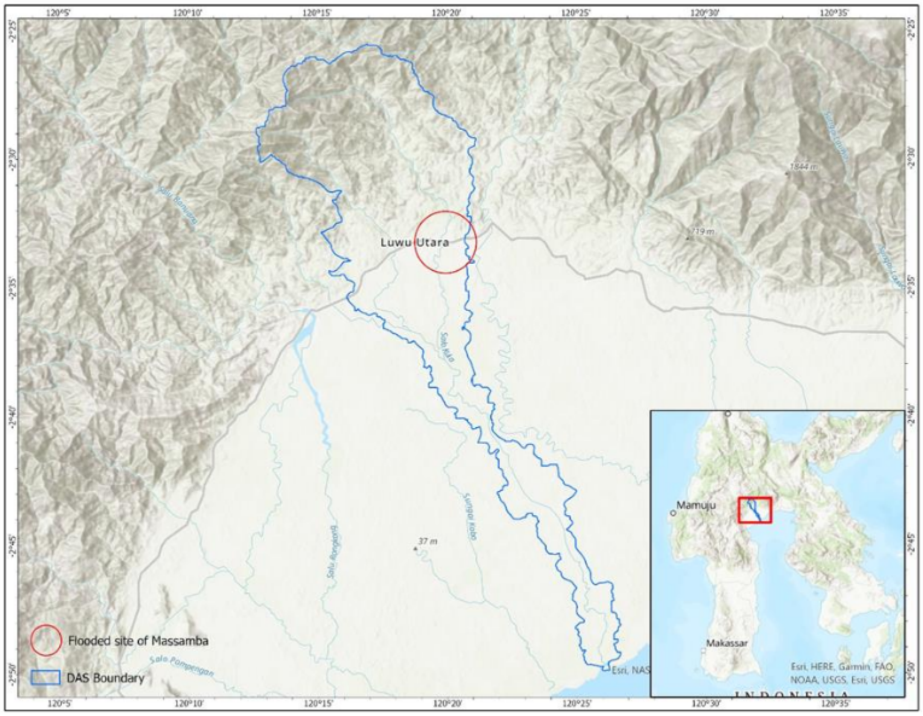


Figure 2. Study area

2.2. Data

The main data used in this study is geographic data that provides physical information of the study area and hydrologic data that provides information on rainfall intensity and discharge. The geographic data was based on Digital Elevation Model Nasional (DEMNAS) which is provided free from Geospatial Information Agency (BIG) Indonesia with grid cell 0.27 arcsecond or 8.4 meters. This study focused on the Massamba and upstream of the flood event area. The flow or discharge data was based on current rainfall in the watershed which is calculated use rain on the grid model of Hec-RAS. Rainfall and flooded area data were based on a satellite image (Himawari and Spot 6) from the National Institute of Aeronautics and Space/ LAPAN RI.

3. Methodology

3.1. Numerical simulation

The flood event was analyzed by simulating the rainfall on the grid model and unsteady flow simulation of Hec RAS version 5.07. The simulation using continuity and full 2D Saint Venant equation as shown in equation 1.

$$\frac{\partial h}{\partial t} + \frac{\partial (hu)}{\partial x} + \frac{\partial (hv)}{\partial y} = 0 \quad (1)$$

$$\frac{\partial (uh)}{\partial t} + \frac{\partial (hu^2)}{\partial x} + \frac{\partial (huv)}{\partial y} = -hg\frac{\partial H}{\partial x} - \frac{\tau_x}{\rho} + D^x \quad (2)$$

$$\frac{\partial (vh)}{\partial t} + \frac{\partial (huv)}{\partial x} + \frac{\partial (hv^2)}{\partial y} = -hg\frac{\partial H}{\partial x} - \frac{\tau_y}{\rho} + D^y \quad (3)$$

$$\frac{\tau_x}{\rho} = C_f u\sqrt{(u^2+v^2)} \qquad \frac{\tau_y}{\rho} = C_f v\sqrt{(u^2+v^2)} \tag{4}$$

$$D^x = \frac{\partial}{\partial x} + \left[v_t \frac{\partial (uh)}{\partial x}\right] + \frac{\partial}{\partial y}\left[v_t \frac{\partial (uh)}{\partial y}\right] \tag{5}$$

$$D^x = \frac{\partial}{\partial x} + \left[v_t \frac{\partial (vh)}{\partial x}\right] + \frac{\partial}{\partial y}\left[v_t \frac{\partial (vh)}{\partial y}\right] \tag{6}$$

Where h is the water depth (m), t is time (s), u and v is the velocity in the x and y directions (ms-1), g is the acceleration due to gravity (ms-2), H is the water surface elevation, τ_x,τ_yare the components of shear stress, C_f is the friction slope, Vt is eddy viscosity and ρ is the water density.

3.2. Simulation performance

The study used three types of boundary conditions; the first is a precipitation boundary condition for rain on-grid modeling, the second is flow hydrograph based on rain on-grid modeling result and the last is normal depth boundary condition for the downstream condition. Rain on-grid condition using precipitation data which is estimated from satellite image which is compared with the ground station of rainfall data from Balai Besar Wilayah Sungai Pompengan Jeneberang 300 mm/day. The inflow hydrograph was defined from the result of rain on-grid modeling and located into two upstream of the Massamba river. In this present study, Synthetic Hydrograph is not calculated because a synthetic unit hydrograph for a catchment area having different morphometry characteristics with a catchment area where the model to be developed should be adjusted to get accurate estimation [6]. The result of the rain on-grid model shows that the highest discharge is 1906,45 m3/s To make a stable model, the time step was estimated according to the Courant number condition. The performance of the model was evaluated based on the determination coefficient. The simulation performance is shown in table 1.

Table 1. Data used in the unsteady model Hec-RAS

Data	Value
Ax/grid size (m)	50
At (s)	10
n (river)	0.06
Simulation period	13 July 2020 – 14 July 2020

Source: Hec-RAS manual book [7]

Hazard classification based on National Board for Disaster Management (BNPB) shown in table 2.

Table 2. Hazard classification

Depth (m)	Class
<0,76	Low
0,76 – 1,5	Medium
>1,5	High

4. Result and discussion

The simulation of the July flood event in Massamba using Hec-RAS provides velocity, depth, and hazard classification area. Flood velocity, depth, and hazard classification map can be seen in figure 4, figure 5, and figure 6. The performance of the model was assessed by comparing the flood simulation result and observed data in the inundation area from a direct survey. Based on water depth, the simulation result shows the good performance of the numerical model with a coefficient of determination (R2) 83.66%.

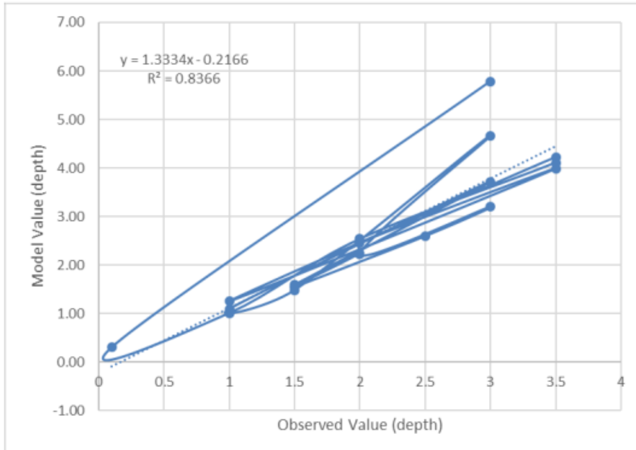
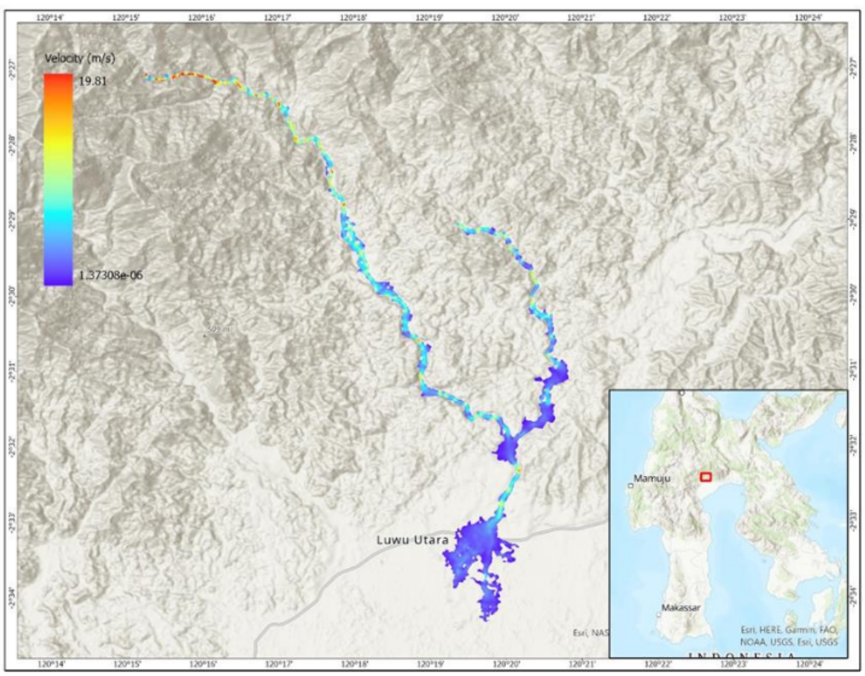


Figure 3. Determination coefficient

The velocity result shows the highest value at the upper stream around 19.81 m/s (highest velocity). While at the lower stream on the inundated area the velocity is around 0.4 – 2.4 m/s. The velocities indicate the continuity law especially in the upstream with the high slope and lowest width of the river. The highest depth is located in the middle stream of the Massamba river specifically in the confluence area of 22 meters, the meeting place of two rivers. While over the inundated area the water depth is 3.88 meters. This condition also indicating the continuity and momentum law at the flood event. Moreover, based on the classification hazard map, there are 79,04% off inundated areas at a high level, while low and middle level respectively 8,32% and 12.64%. The total of inundated area in arable land is 2.3 km2.



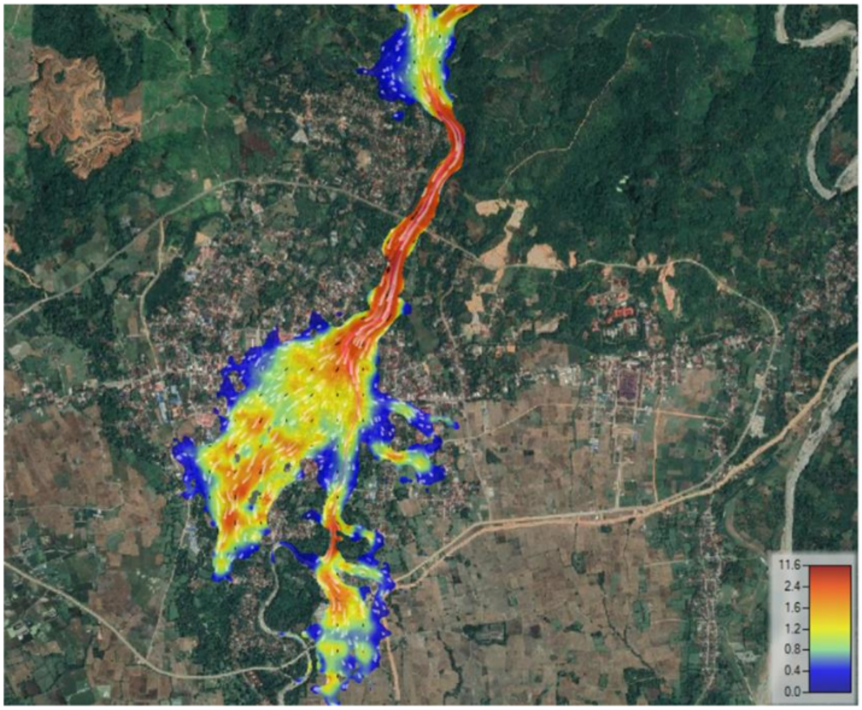
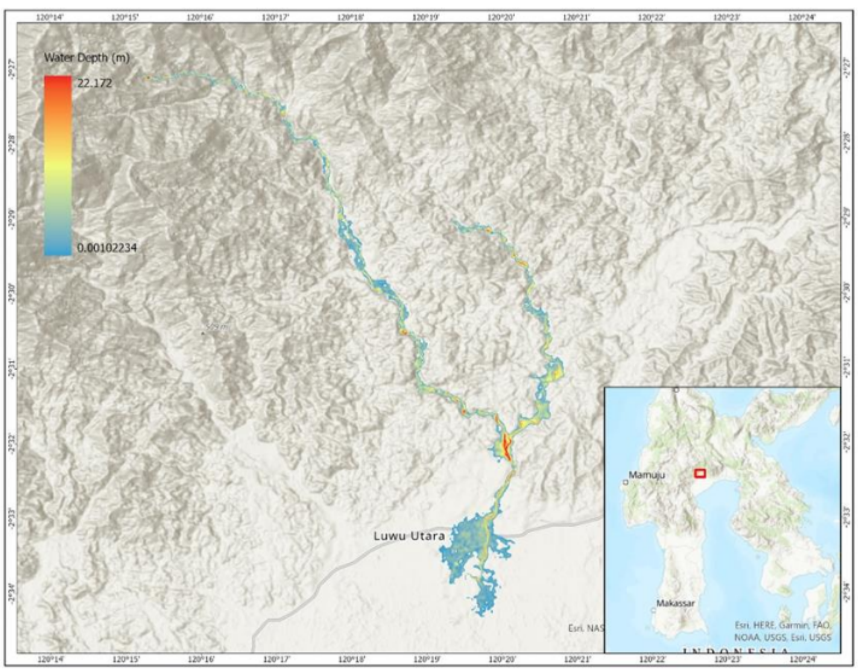


Figure 4. Velocity maps



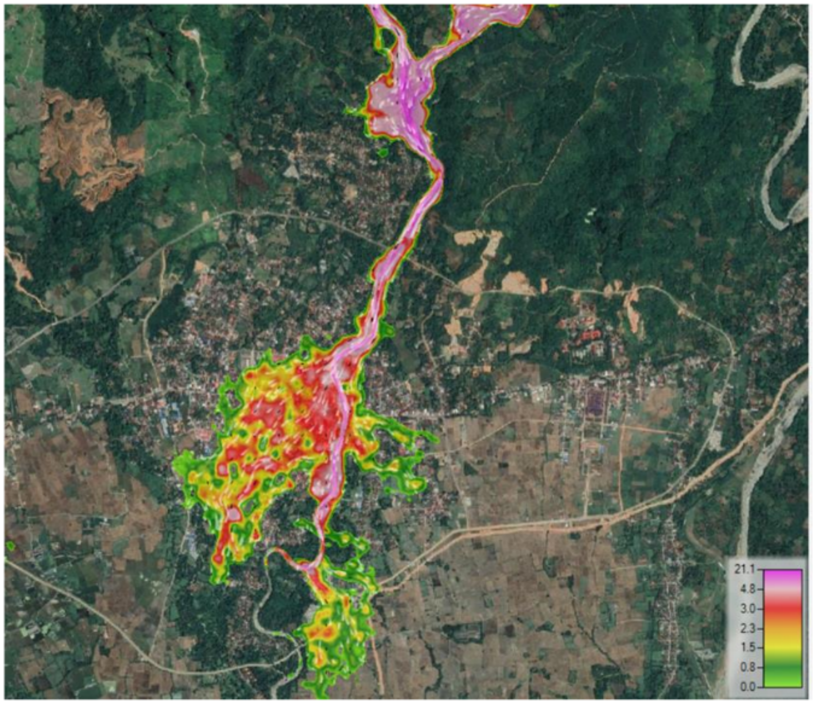


Figure 5. Water depth maps

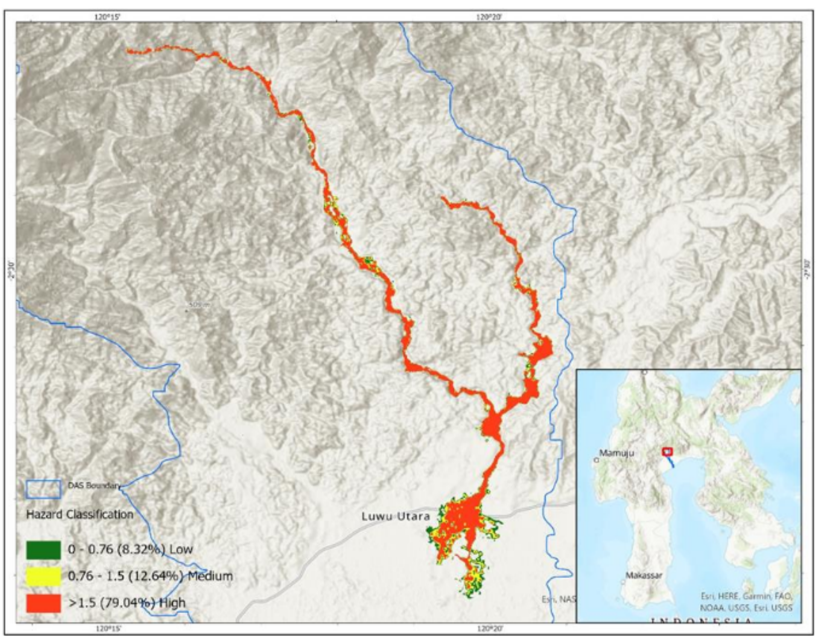


Figure 6. Hazard classification map

5. Conclusions and recommendation

The flood event of Massamba was simulated using 2D Hec-RAS 5.07. The simulation result shows good performance by comparing ater depth value with the observation value with a coefficient of determination R2 83,66%. The simulation also shows that in the upper stream has the highest velocity 19,81 m/s, while over the inundated area around 2.4 m/s. The highest water depth was found in the middle stream at the confluence site with the highest value around 22 meters. While on the inundated area the ater depth is 3.88 meters. Moreover, based on the hazard classification map result there are 79.04% off inundated area in high level, 12,64%, and 8,32% respectively in middle and lower hazard levels.

For further research, the topographic condition should be more detailed especially in the river channel. Better topographic data will support the simulation model to result in more stable and accurate. The detailed topographic data also could support the decision-maker to take action to reduce flood risk in the future.

References

[1] Quiroga V M, Kure S, Udo K and Mano A 2016 Application of 2D numerical simulation for the analysis of the February 2014 Bolivian Amazonia flood: Application of the new HEC-RAS version 5 *RIBAGUA - Rev. Iberoam. del Agu* 1–9

[2] BNPB 2016 *Risiko bencana Indonesia*

[3] Das T, Maurer E P, Pierce D W, Dettinger M D and Cayan D R Increases in flood magnitudes in California under warming climates *J. Hydrol.* **501** 101–110

[4] Khalfallah C B and Saidi S 2018 Spatio temporal flood plain mapping and prediction using HEC-RAS - GIS tools : Case of the Mejerda river, Tunisia *J. African Earth Sci.* **142** 44–51

[5] Alzahrani A 2017 *Application of two-dimensional hydraulic modelling riverine system using Hec-Ras*

[6] Musa R, Pallu M S, Samang L and Putra M 2014 Experimental study of hydrograph model of catchment area based on regional characteristic *Int. J. Civ. Environ. Eng. IJCEE-IJENS* **14** 11–16

[7] Brunner G W 2016 *HEC-RAS river analysis system 2D modeling user's manual*

atta_2021_IOP_Conf._Ser.__Earth_Environ._Sci._841_012028....

ORIGINALITY REPORT

10%	9%	1%	6%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	mafiadoc.com Internet Source	3%
2	Submitted to Unizin, LLC Student Paper	2%
3	www.mdpi.com Internet Source	1%
4	ijens.org Internet Source	1%
5	onlinelibrary.wiley.com Internet Source	1%
6	www.tandfonline.com Internet Source	1%
7	digitalcommons.usu.edu Internet Source	<1%
8	Derya Ozturk, Ilknur Yilmaz, Ufuk Kirbas. "Flood Hazard Assessment Using AHP in Corum, Turkey", Tecnología y ciencias del agua, 2021 Publication	<1%

9	www.science.gov Internet Source	<1 %

Exclude quotes	On	Exclude matches	< 5 words
Exclude bibliography	On		