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Application of HEC-RAS for Drainage Capacity Analysis in Sungai Jempol, Negeri Sembilan

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Abstract: Floodplain research is important for human existence and the social economy. It can be observed that the positions of buildings impacted by flooding, such as bridges and roads, cannot be properly matched to the floodplain site in stream floodplain analysis using most computer models. The purpose of this study is to develop an output of Hydrologic Engineering Center's River Analysis System (HEC-RAS) hydraulic model that will allow for one-dimensional steady flow analysis and stimulate the flood area for 20, 50 and 100 years. This study is applied to Sungai Jempol catchment area, located in Jempol, Negeri Sembilan. Floodplain data features such as length of streams, bank position, streamline and cross-sections were used to produce river flow and its cross-sectional shape for each station along the study area. Total of 3 flow rate values were used to indicate an increase in the water level in order to accommodate the additional amount of water that flow into river. The results showed that water had overflow into the floodplain at maximum flow rate of 9 m^3/s or 20 years of return period. The hydraulic model had indicated that 5 out of 30 stations were unable to accommodate the maximum flow rate and lead to flooding. By developing the hydraulic model, it clearly shows that the results are more reliable and the affected area can be identified. The developed flood model was a very useful tool in flood management of Sungai Jempol in terms of river development planning, flood mitigation measures, flood evacuation planning and addressing public awareness. This study proved that HEC-RAS is one of effective instrument for analysis and modeling.

Keywords: Floodplain, Sungai Jempol, HEC-RAS, drainage capacity

1. Introduction

Flooding is a common threat across the globe, and this includes Malaysia. When the rainy season arrives in Malaysia, flooding is a common occurrence. Flooding results in both material and emotional harm. Floods may be caused by both natural and human-caused causes. Year after year, the results of flood catastrophes were reported by the national media to have escalated drastically. Focusing on the issue of flood in Malaysia, among the common flood areas in Malaysia are in the state of Negeri Sembilan. Jempol is one of the districts that are very prone towards flooding due to its low land area. The unending rain that falls for a few hours causesome area in Jempol to flood.

Natural disasters such as floods occur when a drainage system's maximum flow rate surpasses the system's maximum capacity [1]. Because of this issue, the river was able to overflow all the way to the river bank, which led to flooding in that region. Various drainage control structures, such as culverts, bridges, and storm drains, as well as structures that regulate water quality, may be found on the borders of watersheds [2]. To accurately determine water surface profiles under varied flow circumstances, a computer model is helpful in hydraulic analysis. The computer

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programs'' inability to link data describing water profiles to their actual locations on the ground surface has been a recurrent flaw [2]. When paper maps are used to define floodplains using estimated water surface heights, hand plotting would save substantial time and resources. Ideal conditions for this sort of study may be found at the Hydrologic Engineering Center River Analysis System (HEC-RAS). The objective of this study is to simulate the flood area for 20, 50 and 100-years of Average Recurrence Interval (ARI) by using HEC-RAS mapping software and to determine the maximum drainage capacity at Sungai Jempol.

In floodplain management and flood insurance studies, HEC-RAS model outputs are often used to assess the consequences of floodway encroachments [3]. For this research, it is necessary to determine the maximum drainage capacity. The community's safety and well-being will be protected as a result. HEC-RAS can simulate flooding for periods of 20, 50, and 100 years. Floods might also occur if officials do not take enough precautions. Therefore, this research is carried out to determine the drainage capacity using HEC-RAS analysis. At the conclusion of this study, the Sungai Jempol floodplain area will be determined. As a result of this research, floodplain management, river development planning, public education, and evacuation planning may all benefit from using HEC-RAS as a data source.

2. Methodology

"HEC-RAS" is derived from the creators of the software: Hydrologic Engineering Center, which stands as a subdivision of the Institute of Water Resources, U.S Army Corps of Engineers (HEC), and "RAS" is an acronym from "River Analysis System" [4]. HEC has launched a computer model of HEC-2 to help engineers to determine the hydraulic analysis of river flows and floods.

2.1 Study Area

Sungai Jempol is a stream in Negeri Sembilan, Malaysia with the region font code of Asia/Pacific. It is located at an elevation of 61 meters above sea level. Its coordinates are 2°48'0" N and 102°22'1" E in DMS (Degrees Minutes Seconds) or 2.8 and 102.367 (in decimal degrees). Sungai Jempol has a drainage length of 20.7 km that covers 248 km^2. Length of river to simulate is only 1.5 km because there are many activities involved along this area. fig.1 shows the research area's flow.

From the river's downstream (station 1) all the way upstream (station 30), a total of 30 cross-sections were chosen in this study (station 30). Cross-sections were roughly 50 m long at one station. Industrial, residential and agricultural activity such as palm oil mills and paddy farms can be found along this river. A floodplain map should be created to aid rescue and relief efforts in the case of a flood because of the region's importance as a catchment area.

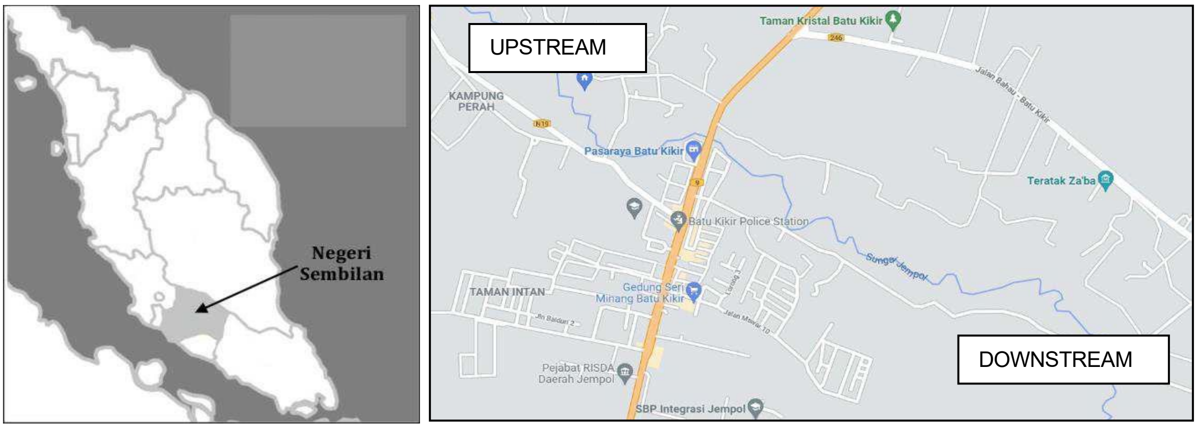

Fig. 1 - Study area of Sungai Jempol, Negeri Sembilan

2.2 Acquisition of Data

Data analysis is performed to investigate, organize, and facilitate data management. The goal of this technique is to extract usable information from existing data. Data analysis also aids in decision making and the formulation of relevant conclusions. Data analysis involves many features and approaches, including many procedures that go by different names. Data and information are essential in research and can be obtained from journals, articles, previous studies, and interviews. The statistics for Sungai Jempol are compiled by the Department of Irrigation and Drainage Jempol (DID). DID provided the river plan for this research [5].

Numerous input parameters for the hydraulic geometry of river channel flow and analysis of water movement must be provided prior to running the HEC-RAS programme. Cross-sections of the stream are calculated using these parameters. In a short amount of time, the river's flow carrying capacity and the neighbouring flood plain are defined by locating a cross section. Manning's roughness value, n of 0.03 was employed in this investigation since the river was typical with straight, clean grassed banks. Process involves for this analysis to determine the flood mapping is shown in fig. 2 below.

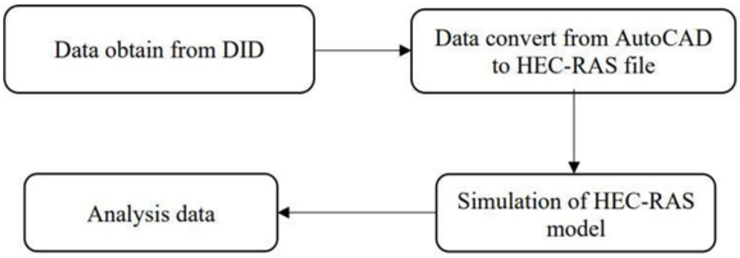

Fig. 2 - Process involve for flood mapping

2.3 Water Flow Rate

In order to obtain steady stream data that includes various profiles, it will require data on the flow of the river as well as the state of the border river system. At all times, there must be at least one flow available for each entry point to the system, and this flow may be altered at any point along the length of the river system [6]. For each profile, it required to specify the total flow.

The study has to take into account a variety of flow rates in order to assess the extent to which the drainage capacity can handle the flow rates. A total of three flow rate values, known as profile flow (PF) (8.77, 19.5 and 24.2) (m^3/s), were utilised in order to indicate that there was an increase in the water level and also to determine whether or not Sungai Jempol was capable of accommodating the additional water that flowed into the river. These flow rate values are suggested from DID Jempol Officer. While this is true, a border drainage system is essential for achieving the highest possible water level in the river system, regardless of whether in an upstream or downstream condition.

$$Q = V_1A_1 = V_2A_2 \qquad (1)$$

where:

Q = Flow rate/discharge (m^3/s)
V_n = Average velocity at cross-section n (m/s)
A_n = Area at cross-section n (m^2)

2.4 Setup of HEC-RAS

River station, a series of cross sections in HEC-RAS, was used to illustrate stream morphology. The number of river stations rises as one travels upstream from a downstream station. The reach length is the distance between adjacent cross-sections in a plan view. A set of lateral and elevation coordinates is used to represent each cross-section. These coordinates are generally generated from land surveys. Beginning on the left bank of the cross-section (looking downstream), lateral coordinates are numbered sequentially from left to right until they reach the right bank. In the HEC-RAS system, the coordinate of every given point is determined by its river station along a one-dimensional stream centerline, location along the cross-section line, and elevation [7].

HEC-RAS was launched and the new project was saved in the name sungaijempol.prj in the Document folder. fig. 3 below show main window for HEC-RAS software to open file.

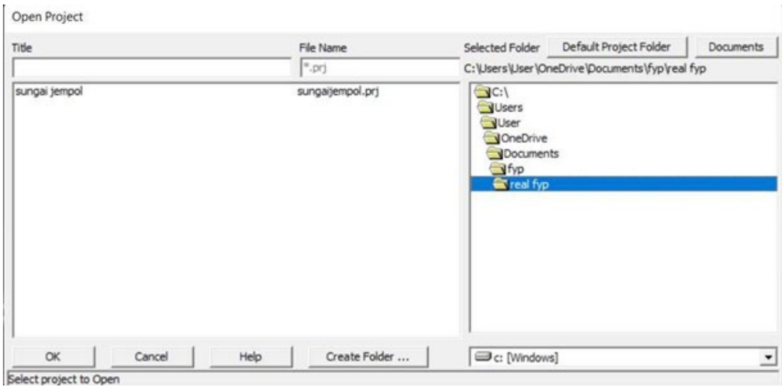

Fig. 3 - HEC-RAS file name and location saved

AutoCAD river plan data was imported into HEC-RAS by clicking Edit -> Geometric Data. fig. 4 show Geometric Data for river plan from AutoCAD.

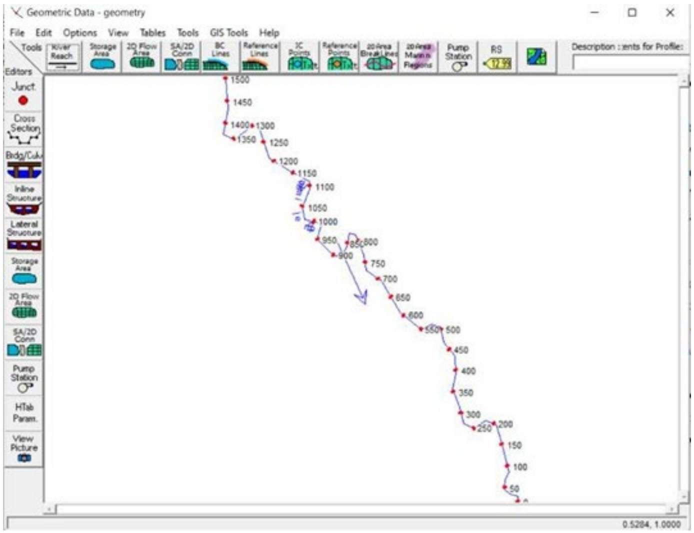

Fig. 4 - River plan for Sungai Jempol in Geometric Data

In the geometric data, elevation data for river from AutoCAD was fill into Cross Section feature (Fig. 5). At Cross Section, coordinates for Station and Elevation were fill from AutoCAD data. Downstream Reach Length was set 50 m. For Manning's n value, 0.03 was set. Then, Main Channel Bank Station was set. Flows were defined at the upstream location and the flow to be simulated is known as profile.

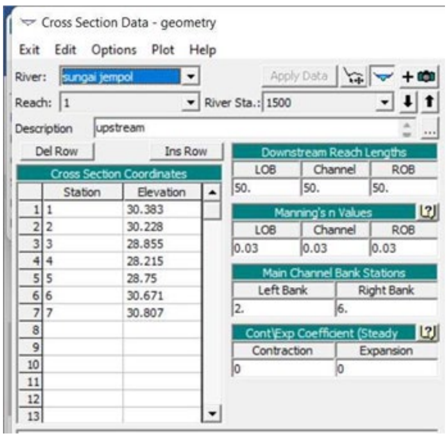

Fig. 5 - View for cross section in HEC-RAS

Steady flow analysis (Fig. 6) was performed in this study. To set a return period and discharge value, on HEC-RAS main window, click on Steady Flow Data->Reach Boundary Condition. The profile data was set for 20-year, 50-year and 100 years.

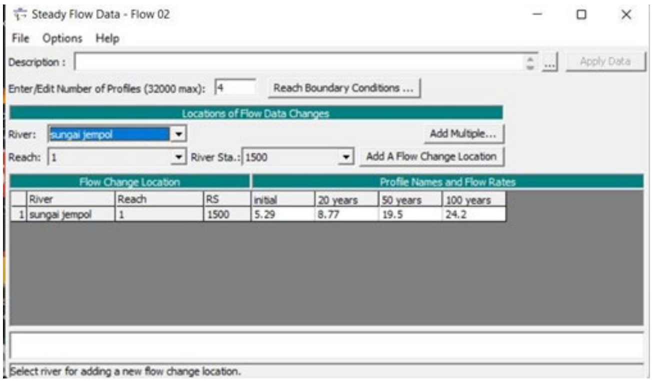

Fig. 6 - Steady flow data view for set return period.

Finally, the Steady flow analysis was done in HEC-RAS, by clicking Run -> Steady Flow Analysis in the main window. The execution was performed. The project was saved and exited as in fig. 7.

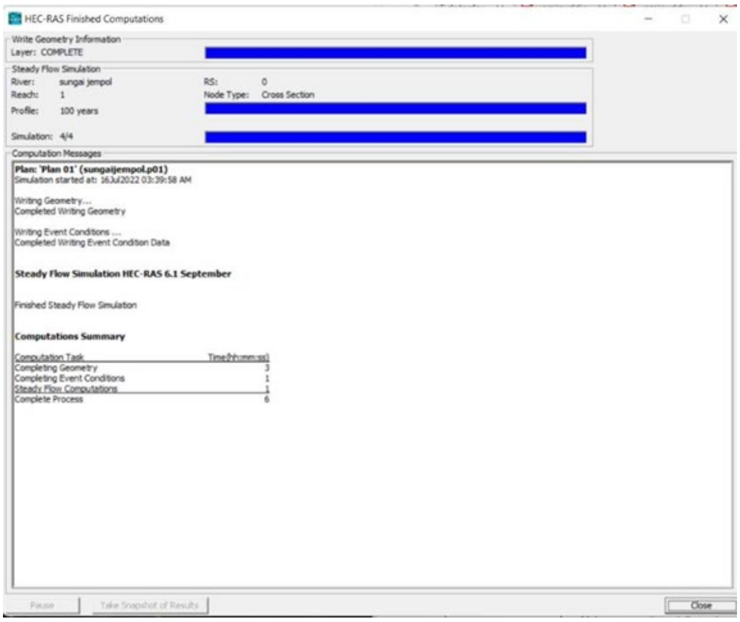

Fig. 7 - View for final step for setup HEC-RAS

3. Result and Discussion

3.1 Flood Mapping of Sungai Jempol

According to the steady flow study performed with HEC-RAS, the depth of flow for different return period of 20, 50, and 100 years is determined. In order to estimate the return time of discharge, the rational technique is used. Energy grade line (EG), water surface (WS), and profile flow (PF) are all abbreviated in the picture legend. It demonstrates that raising the flow rate causes an increase in the height of the water surface.

For the upstream, the river flow for initial condition and return period for 20 years does not overflow the riverbank, but for return period for 50 and 100 years indicating that the flood did occur after the 50 years return period. The cross section for the river upstream and downstream were shown at fig. 8-11.

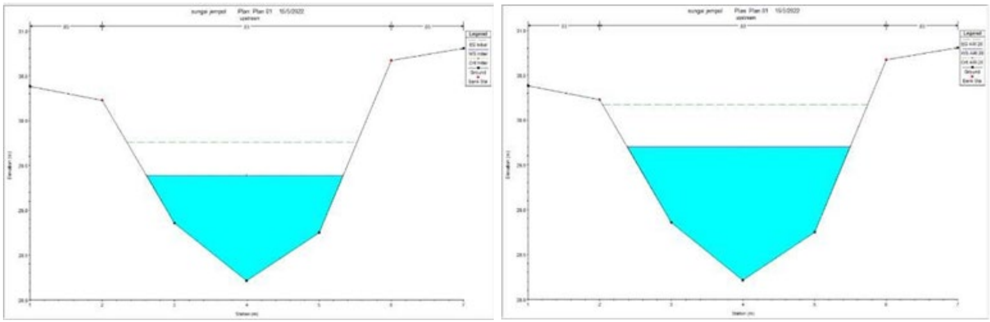

Fig. 8 - Upstream cross-section for initial condition and return period 20 years

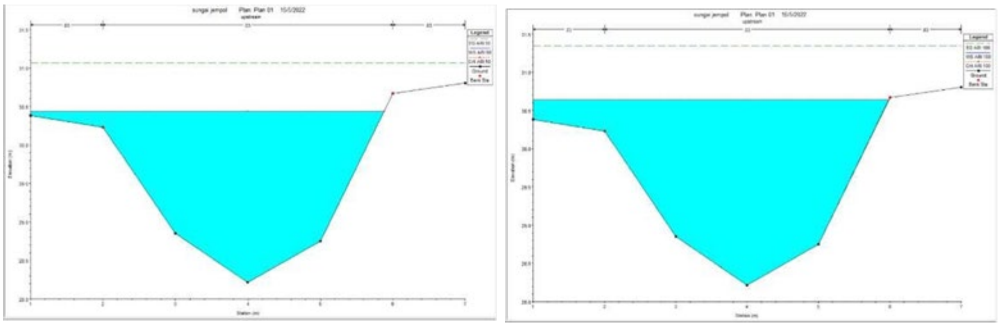

Fig. 9 - Upstream cross-section for return period 50 years and 100 years

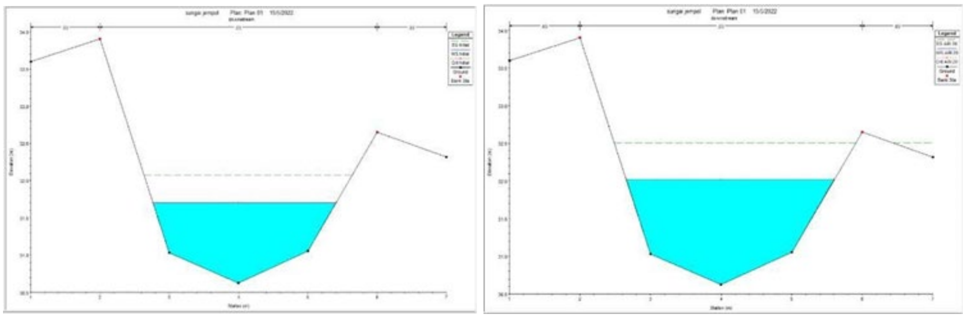

Fig. 10 - Downstream cross-section for initial condition and return period 20 years

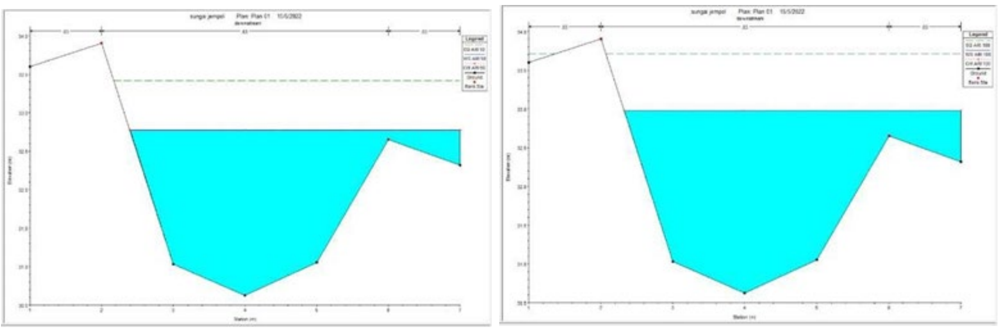

Fig. 11 - Downstream cross-section for return period 50 years and 100 years

The river flow for return period 20, 50, and 100 years is already beyond the riverbank with over 2.5 m depth difference from the beginning condition for the most important cross section, which is in the center of the river reach, meaning that the flood may occur after 50 years or higher. The plan for the XYZ perspective is depicted in the fig. 12-13.

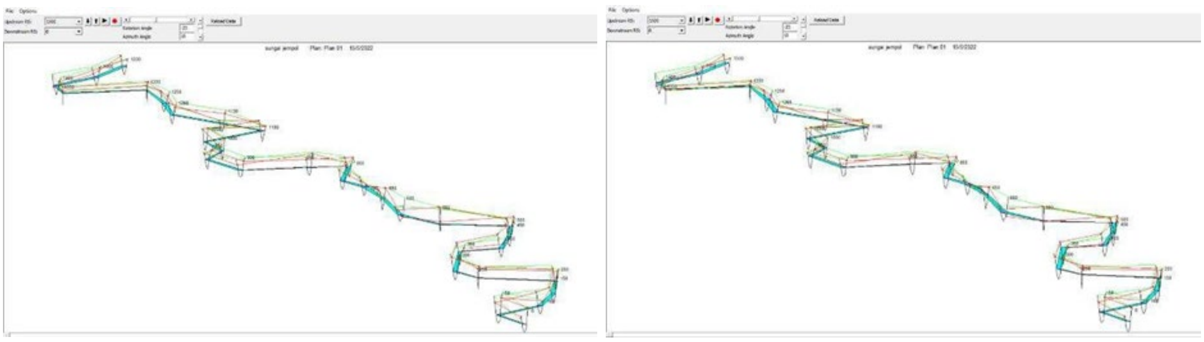

Fig. 12 - XYZ perspective plot for initial condition and return period 20 years

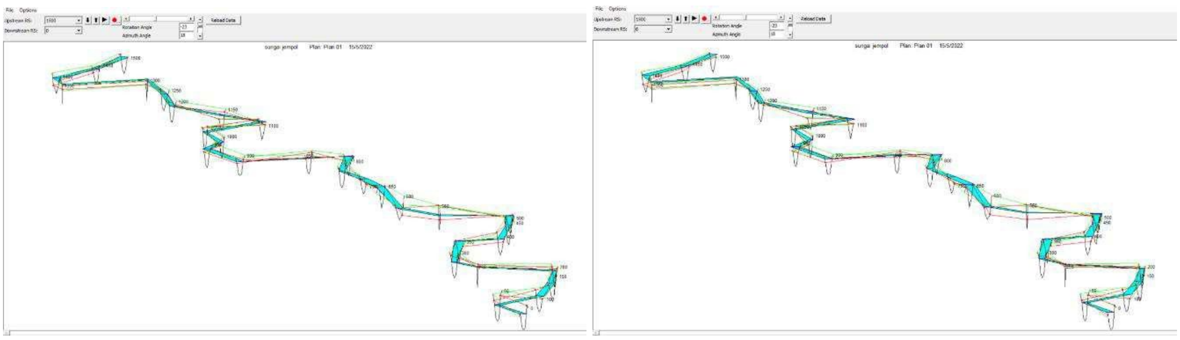

Fig. 13 - XYZ perspective plot for return period 50 years and 100 years

3.2 Critical Flood Station of Sungai Jempol

Fig. 14 demonstrates that HEC-RAS was able to provide various outputs in addition to the cross- section for each station that was the water surface profile. This was accomplished by making use of a variety of variables, including cross section, flow rate, and boundary system state.

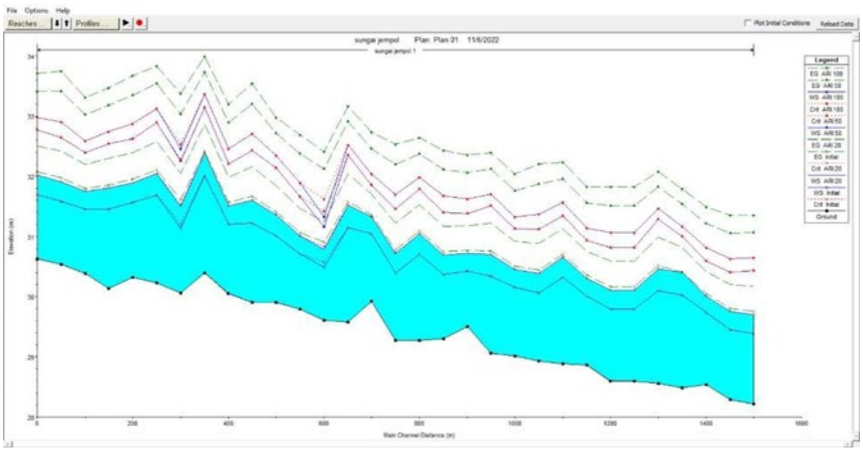

Fig. 14 - Water surface profile in general including its stations

There are noticeable changes in water surface height across steady flow simulations with different flow rate parameters. From downstream to upstream, the river's water level was increasing. Many stations were found to be submerged by the flowing water from the riverbank station. In Table 1, various flow rate values are shown for flooded stations. The station was starting to flood, as shown by the table. One station had an average flow rate of 8.77 m^3/s, while another had a maximum flow rate of 24.2 m^3/s.

Table 1 - Flooded station with different flow rate value

Station	5.29 (m^3/s)	8.77 (m^3/s)	19.5 (m^3/s)	24.2 (m^3/s)	Station	5.29 (m^3/s)	8.77 (m^3/s)	19.5 (m^3/s)	24.2 (m^3/s)
1			/	/	16			/	/
2			/	/	17		/	/	/
3			/	/	18			/	/
4		/	/	/	19		/	/	/
5			/	/	20			/	/
6			/	/	21				/
7			/	/	22			/	/
8			/	/	23			/	/
9			/	/	24		/	/	/
10			/	/	25				/
11			/	/	26			/	/
12			/	/	27				/
13				/	28			/	/
14			/	/	29		/	/	/
15				/	30			/	/

For station 4, the river flow for initial condition and return period for 20 years does not overflow the riverbank, but the flood will occur after the 20 years return period or minimum flow rate at 9 m^3/s. For station 17, the river flow for initial condition does not overflow the riverbank, but the flood will occur after minimum flow rate at 7 m^3/s. The cross section for the river were shown at fig. 15.

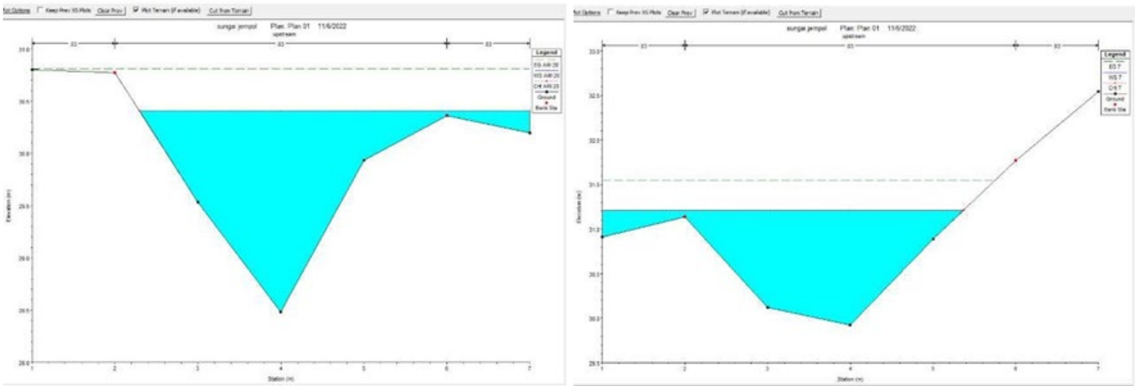

Fig. 15 - Cross section of station 4 and 17 at maximum flow rate

For station 19, the river flow does not exceed the banks in the initial condition, but the flood will occur after the minimum flow rate of 7 m^3/s. For station 24, the river flow does not overrun the riverbank throughout the initial condition and return period of 20 years, but the flood occurs after the 20 years return period or minimum flow rate of 9 m^3/s. The river's cross section is seen in the fig. 16 below.

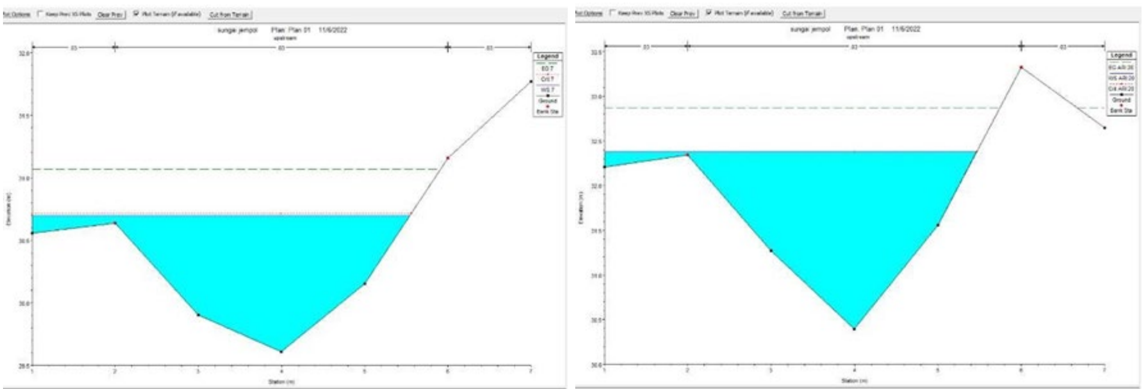

Fig. 16 - Cross section of station 19 and 24 at maximum flow rate

The river flow at station 29 does not overrun the riverbank in its initial condition or after 20 years return period, but the flood will occur after the 20 years return period or a minimum flow rate of 9 m^3/s. The river's cross section is seen in the fig. 17.

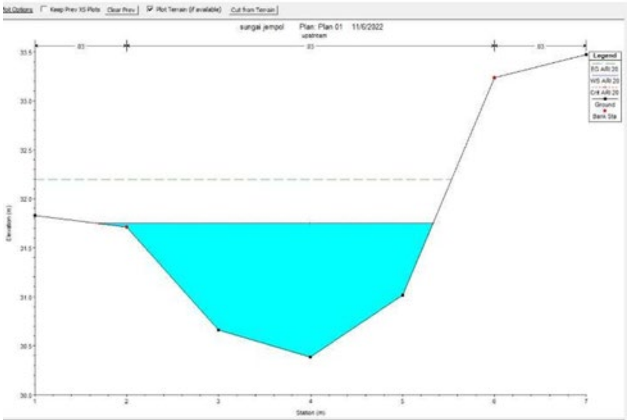

Fig. 17 - Cross section of station 29 at maximum flow rate

3.3 Discussion

As a result of the study, we predicted that the river's flows would grow as the year progressed, which is also backed by climate change, which is worsening every year. When the maximum flow rate is used, the river will flood and go beyond the station that is located on the river bank. Even to accommodate the minimal flow rate value, the cross-section was discovered to be in an unsuitable condition.

In point of fact, the water level on the surface of the overbanks is often greater than the level of the water in the main channel. As a direct consequence of this, the flow will emerge from the bank at an earlier time than anticipated, and the water surface height in the overbanks will be lower than anticipated. Flooding in locations that are geographically near to inhabited states may cause a great deal of disruption and financial damage for the general public. According to the findings of the HEC-RAS software analysis, the amount of flood water that results from all of the simulated drainage capacity is more than the height of the complete bank along the Sungai Jempol. As a consequence of this, the relevant authorities in Jempol need to focus their attention on this component in order to mitigate the effects of flooding there. The catchment area that will be affected if there is a flood is shown in fig. 18.

Fig. 18 - Catchment area for Sungai Jempol

4. Conclusion

The maximum flood drainage capacity can also be estimated using HEC-RAS software modelling. Flood mapping may also be created using HEC-RAS GIS tools, namely RAS Mapper. Because obtaining a historical flood map or stream flow data was difficult, several GPS coordinate points indicating previous flooded areas and literatures were employed to confirm the model results. This report's findings are critical as a preliminary information guide for land use planning, policy formulation, and investment decisions, as well as for security considerations.

Few recommendations based on this study are given by the fact that it can be taken into consideration for the authorities, and it can be an important decision-making element when the development area is being designed, so that a new building or other construction can be built properly without worrying about floods affecting their area. This is also a crucial decision-making resource, particularly when developing local roads, to avoid pavement failure or blockage with silt brought by the river during floods, which may influence agricultural product delivery as well as someone's economy.

Overlaying these maps on top of aerial images could raise people's awareness about floods in that specific area, where several buildings and houses are not safe, and authorities should act to create protection plans and inform the population living in these areas through campaigns or public speaking. Another suggestion is to expand on this research by employing the same problem in multiple situations, contexts, and cultures. Future research can also re-evaluate the study, developing new theories or facts, and provide a better study conclusion.

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