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Flood modelling at Bandar Batu Pahat, Johor using HEC-RAS software

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Abstract. Flood catastrophe continuously hit Malaysia through monsoonal flood and flash flood as well posing threat towards people, infrastructure and environment. Batu Pahat is among the district in Johor affected by flood disaster for almost every year. This study conducted to determine the hydraulic and hydrological characteristic and the ability of drainage system in Parit Besar and Jalan Pontian-Batu Pahat catchment area at Batu Pahat using HEC-RAS software. Through HEC-RAS, floodplain map was also produced to access the overview of potential floodplain areas. Survey data, geometric data and flow data were computed in HEC-RAS to produce drainage flow and cross-sectional area along the catchment area. Four (4) flow rates of 0.05284, 0.05894, 0.06910 and 0.07113 (m^3/s) were utilized to identify the drainage ability to accommodate additional water. Several stations in Parit Besar catchment cannot accommodate the runoff with the minimum flow rate of 0.05284 (m^3/s). Meanwhile, Jalan Pontian-Batu Pahat catchment cannot accommodate flow rates of 0.06910 and 0.07113 (m^3/s). This is due to the catchment area has low elevation and insufficient drainage system. From the results, floodplain areas were identified. Modification of drainage cross-section was proposed to reduce the floodplain areas. This study is vital for better understanding of flooding and help the authorities to produce better flood management plan.

1. Introduction

Flooding is major natural disaster that has significant impact towards people, infrastructure and environment. Over the past few decades, flood intensity has risen worldwide due to climatic changes, land use changes and anthropogenic activities. Flood are general or temporary conditions characterized by rapid accumulation and release of large volume of runoff waters that is come from the channel upstream went to downstream on a normally dry land which is caused by very heavy rainfall [1]. Flood usually occur in several hours or days depending on geographical factors or river conditions. Generally, 9% of Malaysia's total land area is prone to flood disaster and Malaysia experiences several flood events every year. Floods in Malaysia can be classified into two types which are monsoon floods and flash floods [2].

Monsoon flood in Malaysia influenced by the dual monsoon season of Northeast Monson and Southwest Moon that occur between October to March and May to September. These dual monsoon season usually brings heavy rainfall and lead to the occurrence of flood event around Malaysia. Meanwhile, flash flood is defined by a failure of drainage system when heavy rainfall occurs in urban area with limited access to land that can be utilised to store water [3]. In these past years, Malaysia has become one of the most urbanised nations resulting in severe flash flooding and the flooding is worsening as a result of industrialization and urbanisation. A country's industrialization and development if not supported by long-term planning, it will lead to environmental disaster [4]. Hence, conducting flood modelling can help to assess the ability of watershed management especially during heavy rainfall and to evaluate the impacts of urban development.

Flood modelling is essential in accessing flood hazard since it shows the magnitude of flood to specific exceedance probability and able to identify the main problems of drainage systems where flooding might occur based on the simulation results [5]. The Hydrologic Engineering Center (HEC) of the U.S. Army Corps of Engineers developed a model known as the River Analysis System (HEC-RAS), which widely utilized as flood modelling software for analysing channel flow and floodplain delineation. This software able to perform river flow analysis in 1-dimensional (1D) and 2-dimentional (2D) of steady and unsteady flow simulations along with the change of river bed, sediment transport and others. Studies by Armain *et.al* [6] also stated that HEC-RAS can develop flood inundation maps for various applications including give an overview of flooding that might occur from data acquisition.

As HEC-RAS model has wide range of capabilities, this paper focuses on HEC-RAS software in determining the hydraulic and hydrological characteristic and the ability of drainage system in study area. The floodplain map was also produced to access the overview of potential floodplain areas. This study is vital for better understanding of flash flooding and help the authorities to produce better flood management plan.

2. Materials and methods

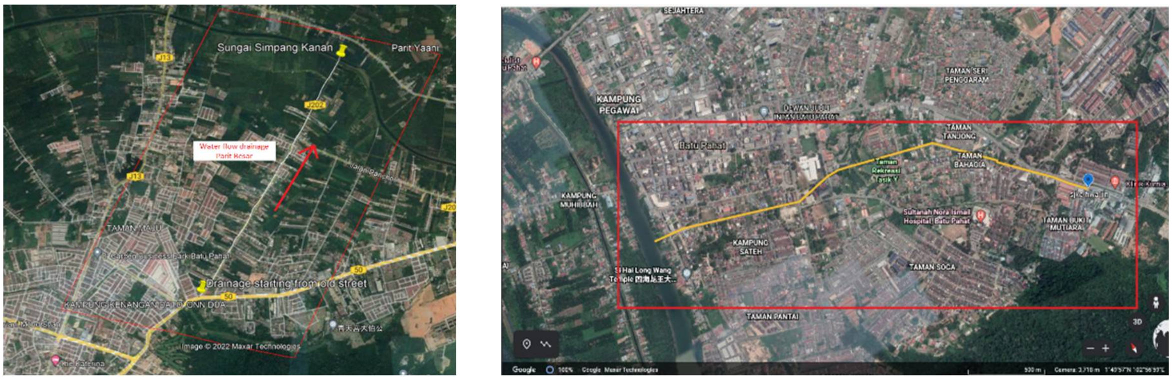
The methodology involved in developing flood modelling by using HEC-RAS software for study area was presented in Figure 1. The data needed for floodplain analysis was obtained through site visit and field investigations and was collected from Department of Irrigation and Drainage (DID). Then, the data was simulated in HEC-RAS through unsteady flow analysis to generate floodplain model.

Figure 1. Methodology for this study.

2.1. Description of study area

The study area covers the catchment area along Parit Besar and Jalan Pontian-Batu Pahat in Batu Pahat district. The length of drainage for Parit Besar is 3.979 km that covers 1371.92 hectares of Batu Pahat area and Jalan Pontian-Batu Pahat has drainage length of 2.889 km that is 794.7469 hectares of study area. Batu Pahat has a population of 417,000 people (in 2010) which around 21% of Johor's total population. Over the past three decades, Batu Pahat experienced several flood disasters due to its location in the lower basin of Sungai Batu Pahat which is a natural floodplain area. Rapid development of surrounding area and the presence of Sembrong dam affects the area's flood storage and drainage capacity. Batu Pahat is also known as one of Johor's frequently flooded areas [7]. Therefore, this study conducted to determine the ability of catchment in Batu Pahat during heavy rainfall. Figure 2(a) and

Figure 2(b) shows the location of Parit Besar and Jalan Pontian – Batu Pahat catchment from Google Earth.



(a) (b)

Figure 2. (a) Location of Parit Besar; (b) Location of Jalan Pontian-Batu Pahat.

2.2. Data Collection

HEC-RAS software require several parameters for developing hydraulic modelling output and floodplain analysis.

2.2.1. Survey data

Numerical terrain model that represents the actual condition of study area was generated in order to perform flood simulation. The most appropriate approach and data that was gathered for this purpose were topographic maps. The terrain data in HEC-RAS was generated using Digital Elevation Model (DEM) data of study area in float (.flt) format. The RAS Mapper extension in HEC-RAS will convert the float file to a GeoTIFF (.tif) file, resulting in a smaller storage capacity, faster computational speed, and a dynamic map [8]. Figure 3 shows the DEM data and drainage geometry in RAS Mapper.

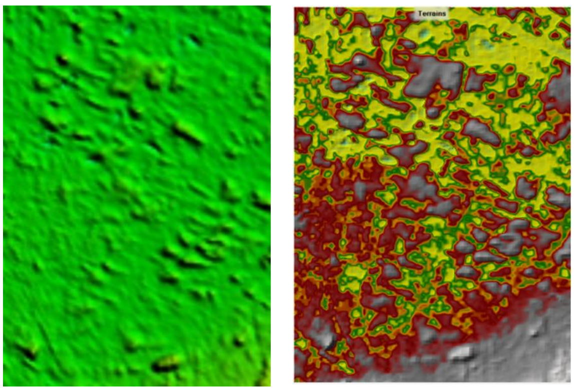


Figure 3. DEM data and drainage geometry of study area in RAS Mapper.

2.2.2. Geometric data

Site visit and field investigation was conducted to measure the width and depth of drainage. The width, length and depth of drainage resulting in the cross-sectional data as shown in Figure 4. At each cross-section, HECRAS uses several parameters including river station, left and right bank station, channel contraction and expansion coefficient and Manning's roughness coefficient. Manning's coefficient, ŋ of

0.015 and 0.050 for grassed drain and line concrete drain was obtained from Urban Stormwater Management Manual for Malaysia (MSMA).

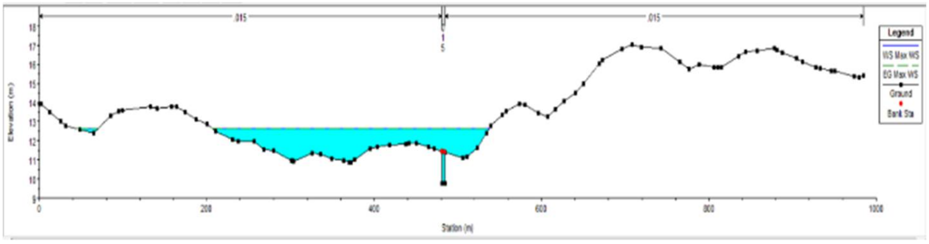


Figure 4. Cross-section of drainage.

2.2.3. Flow data

In order to generate drainage data that consists of multiple profiles, flow data and condition of boundary system are required. Different flow rates were considered in the analysis to determine the peak level and capacity of drainage to accommodate the various flow rate. The total flow rate was calculated using Rational Method. The rainfall intensity considered in Rational Method was obtained from Department of Irrigation and Drainage (DID). There are 4 flow rates of 0.05284, 0.05894, 0.06910 and 0.07113 (m^3/s) were utilized to represent increase water level in the drainage system.

2.3. HEC-RAS Software

HEC-RAS program require three (3) main input data that consist of plan data, geometry data and flow data. There data requirement must be fulfilled before performing flood simulation [8]. The geometry and flow results will represent the physical state for each cross-section where varies cross-section was obtained depending on depth and width of each drainage's station. All data was computed using unsteady flow simulation to obtain the floodplain mapping and simulation.

3. Results and discussion

3.1. Floodplain mapping

The hydraulic analysis of unsteady flow simulation that conducted with four (4) flow rates shows difference elevation of surface water. Floodplain mapping is an effective tool to display the geographical condition and the flooded areas for Parit Besar and Jalan Pontian-Batu Pahat catchment area. For Parit Besar, the right and left bank of the catchment area prone to flooding due to the turquoise color represent overflow of water. Parit Besar catchment started from Old Street Batu Pahat to Sungai Simpang Kanan. Meanwhile, catchment for Jalan Pontian-Batu Pahat flow from SJK(C) Hwa Jin to Sungai Batu Pahat. This catchment area recorded overflow of water mostly on the left side of catchment area. Figure 5(a) and figure 5(b) represent the floodplain mapping obtained through analysis in HEC-RAS software.

(a) (b)

Figure 5. Floodplain mapping (a) Parit Besar; (b) Jalan Pontian-Batu Pahat.

3.2. Floodplain Simulation

Total of four (4) flow rates of 0.05284, 0.05894, 0.06910 and 0.07113 (m^3/s) were computed in HEC-RAS software for each station along the catchment area. Several stations experienced submerged due to overflowing of water into the river bank. The 1-day simulation of floodplain area were also conducted for detecting the time taken for the flood to recede. It can be seen that the affected area in Parit Besar catchment are Taman Sri Wangsa, Taman Pelangi and Taman Flora Jaya residential area. This is due to the area has low elevation and the existing drainage system cannot accommodate the runoff with the minimum flow rate of 0.05284 (m^3/s). After 1-hour simulation, the overflow water started to recede resulting in less flooded area on chainage CH0 to CH1056 as shown in figure 6.

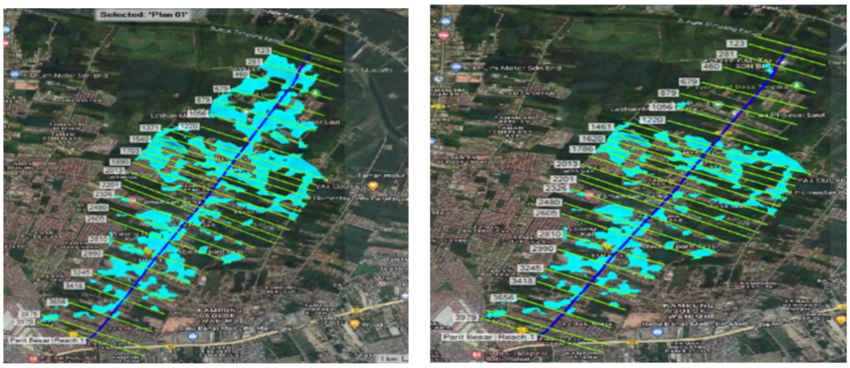


Figure 6. Flood simulation at 7.45 a.m. and 8.45 a.m. at Parit Besar catchment.

Figure 7 shows the elevation of Taman Sri Wangsa that is lower than the elevation of Parit Besar drainage hence flooding might frequently occur which affected the population in the residential area. The authorities must come up with proper flood management plan to overcome flooding in this area.

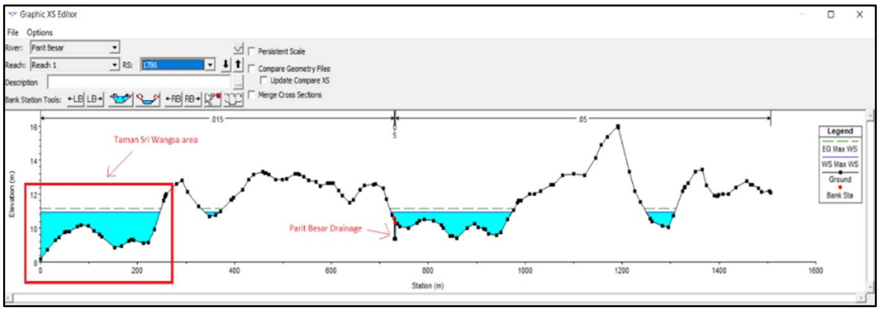


Figure 7. Cross section of CH1786 in Taman Sri Wangsa.

For Jalan Pontian-Batu Pahat catchment, the affected area for flooding is Y Lake Recreation Park area, Jalan Bahagia and Jalan Pejabat. This is because of the area experienced rapid development and the incapability of drainage system worsen the flooding. The drainage system in this area cannot accommodate flow rates of 0.06910 and 0.07113 (m^3/s) hence flooding occurred. The chainage involved are CH923 to CH2142 as shown in Figure 8. After 1-hour simulation, the flooded area starting to recede and less flooded area can be seen.

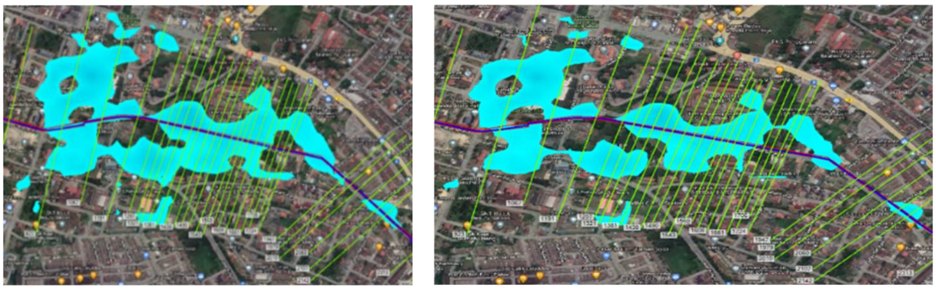


Figure 8. Flood simulation at 7.45 a.m. and 8.45 a.m. at Jalan Pontian-Batu Pahat catchment.

Previous studies conducted by Hasrul *et.al* [4] stated that flooding issues in urban area generally caused by heavy rainfall and insufficient drainage capacity resulting low-lying areas near the catchment are inundated. Studies by Nor *et.al* [8] also indicated that in HEC-RAS software, cross-sectional area of drainage plays important role to sustain the runoff water during heavy rainfall. This shows the drainage system that unable to accommodate high volume of water can lead to flooding. The situation worsens with the changes in land uses that comes with more impervious surface resulting in more surface runoff which the drainage system unable to sustain.

3.3. Proposed drainage modification

From the analysis, overflow occurred and exceed the drainage left and right bank station when maximum flow data was entered. The cross-section of existing drainage unable to hold the water. Hence, it was proposed to modify the existing drainage by increasing or deepening the right and left banks to evaluate the capacity of drainage after modification. For chainage CH281 to CH2201 of Parit Besar catchment, it was suggested to modify the depth from 1.2 m to 2.5 m and the width from 2.61 m to 3.90 m. The drainage types also were changed from ditch to concrete drain. The depth of drainage increased from 1.5 m to 3.0 m for CH0 to CH281. The proposed modification resulting in the flooded area reduced about 90% from 150,000 m^2 to 15,000 m^2 as shown in figure 9.

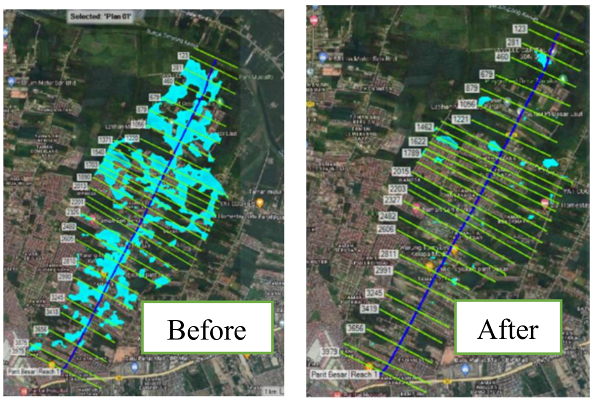


Figure 9. Before and after modification for Parit Besar catchment.

For Jalan Pontian-Batu Pahat catchment, it was proposed to modify the depth of CH0 to CH2889 from 3.7 m to 4.0 m. Flooded area has decreased about 30% especially around Y Lake Recreation Lake and Temenggong Ibrahim Girls School (TIGS) area as shown in figure 10. The overflow water also can be reduced with the presence of retention pond. This indicated by Hasrul *et.al* [4] that deepening can drainage system and constructing new retention system can prevent flood event from occurring. The new retention system can be constructed at upstream to collect water and rainfall before entering the major drainage system.

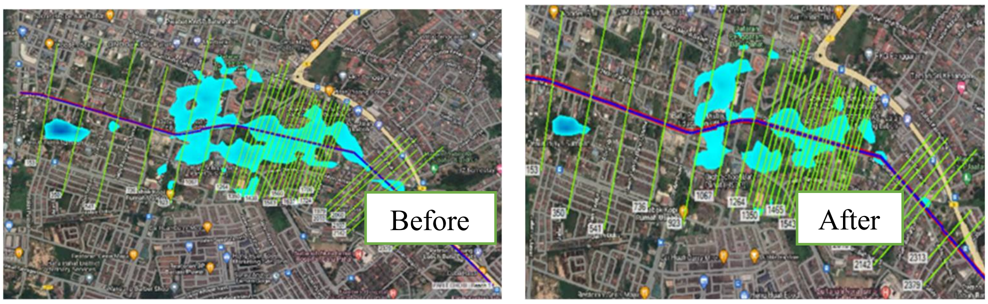


Figure 10. Before and after drainage modification for Jalan Pontian-Batu Pahat catchment.

4. Conclusion

HEC-RAS was applicable to be good flood modelling software in developing floodplain maps. Through this study, the floodplain areas along Parit Besar and Jalan Pontian - Batu Pahat catchment were identified. Flood event will occur on several stations because the stations unable to accommodate additional water during heavy rainfall. Flooded areas cause great impact towards populations nearby. Hence, modification on the cross-section of drainage was performed to evaluate the drainage capacity. About 90% and 30% of flooded areas along Parit Besar and Jalan Pontian - Batu Pahat catchment has decreased after modification. This is vital for future planning of flood management in Batu Pahat district. The authorities also must perform frequent maintenance and reconstructing the drainage to reduce the occurrence of flood. It is recommended to perform future analysis on other catchment area in Batu Pahat district to identify more floodplain area.

5. References

[1] Marimin N A, Razi M A M and Ahmad M A 2019 Integration of hydraulic model (HEC-RAS) with Geographical Information System (GIS) in developing flood evacuation center along Sembrong River, *IOP Conf. Ser. Earth Environ. Sci.* **220** 012057

[2] Amin N F A and Othman F 2018 Generation of flood map using infoworks for Sungai Johor, *Int. J. Integr. Eng.* **10** 142–145

[3] Buslima F S, Omar R C, Jamaluddin T A and Taha H 2018 Flood and flash flood geo-hazards in Malaysia, *Int. J. Eng. Technol.* **7** 760–764

[4] Hasan H H, Razali S F M, Zaki A Z I A and Hamzah F M 2019 Integrated hydrological-hydraulic model for flood simulation in tropical urban catchment, *Sustainability* **11** 1–24

[5] Romali N S, Yusop Z and Ismail A Z 2018 Application of HEC-RAS and Arc GIS for floodplain mapping in Segamat town, Malaysia, *Int. J. GEOMATE* **14** 125–131

[6] Armain M Z S, Hassan' Z, Mohd Remy Rozainy M A Z and Kamarudzaman A N 2021 Hydrodynamic modelling of historical flood event using one dimensional HEC-RAS in Kelantan basin, Malaysia, *IOP Conf. Ser. Earth Environ. Sci.* **920** 012031

[7] Bukari S M, Kaamin M and Ahmad M A, Rahman M A and Yusof S 2015 Flood Prone Areas Detection Through Geographical Information System (GIS) and Water Balance Model in Batu Pahat, *Int. Conf. on Sustainable Env. and Water Resour.*

[8] Marimin N A, Razi M A M, Ahmad M A, Adnan M S and Rahmat S N 2018 HEC-RAS hydraulic model for floodplain area in Sembrong River, *Int. J. Integr. Eng.* **10** 151–157

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