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Flood Simulation Using HEC-RAS for Sg Suloh, Batu Pahat

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Abstract: Flooding was one of the actions on water on overflowing from the water source onto land which is normally dry and river flooding that mentioning in this article journal is about the overflowing of water from the river onto the dry land and flooding has caused some issues on economy and social aspect in one country. Hence, the Flood Inundation was carried out for identify the risk so that the damage can be reduce after the alternative solution is further discussed and carried out. The HEC-RAS model was being applied in this research as it can fulfil the objective of this research. The objective of this research is to identify the river conveyance capacity and generating the flood inundation map by using HEC-RAS model to examine risk of flooding along the Sg Suloh, Batu Pahat as that area is a flooding zone with the consideration of probability of flood repeat occurrence period, which also mentioned as return period. Before the use of the software for simulating the flooding of the region, some input data were required such as topography data, Manning's roughness coefficients (n) of the river of this study area which were 0.035 and 0.050. The flow data which consists of flow rate, boundary conditions with the values of 0.0025 for upstream and 0.00089 for downstream. By inputting these data, the HEC-RAS model was simulated the flow conditions on steady as the simulation is based on standard step by step numerical methods to calculate the water surface elevation between the required return periods of 50 years, 100 years and 100 years with climate change factor. Furthermore, the method used was applied according to the relationship in terms of energy that initializing the calculation on flows downstream. The flow charge of the river was estimated using the rational method. A set of flood depth were obtained as the output of the hydraulic model such as at the flood depth is at the range of 1.41 m to 2.53 m.

Keywords: Flood, Simulation, Overflowing

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1. Introduction

Flood simulation modelling is a widely used tool to simulate the hydrologic response of the watershed to peak flood discharge. It provides a better understanding of prevention at the flood hazard level, and it is a main key for ensuring the prediction of floodplain with accurate manner inside a watershed and predicting the responses in the further progress. Development in the field of flood simulation models can be synchronized to increase vigilance and provide information on important environmental matters such as water resource assessment, engineering channel design, wastewater impact assessment and more. Moreover, in this generation of floodplain conservation and integrated management, it is fair to know that flood simulation modelling associated with characteristic flow and peak flow data is of great importance. In this study, Sungai Suloh is located on the southwest coastline of Peninsular Malaysia and this area is subject to annual flooding which the potential cause is low elevation profile of the catchment area which included the climate change factor. Hence, the HEC-RAS program was used to calculate and simulate the floodplain in the catchment area of Sungai Suloh.

Climate change is the most serious threat to life and their impacts are weather phenomena and high temperatures. Even Though these conditions may lead to flood and drought that can severely affect agriculture, natural resources, the entire ecosystem and livelihood. The optimization issues of water resources management and reservoirs is the incorrect predictions that are running in the basins. Therefore, the ideal solution to budgetary is flood modelling run that predicting the surface flow inside the basin at rate get precipitation and flows in channels play an important role in the hydrology study. Most Serious flood disasters that cause damage and disturbance to property and ordinary human life are captured through one or more in nearly every year. The sewerage has not been able to function effectively in order to control the flooding. Some of the latest major flood disasters have occurred in residential areas.

2. Materials and Methods

2.1 Case Study

Nowadays, the most damaging environmental disaster that Malaysia has gone through is the flood. All over Malaysia, there are 189 river basins in Peninsular Malaysia, 89 in Sabah and 22 in Sarawak, with the main channels straight down into the South China Sea [4]. Generally, flooding that occur in Malaysia has two categories which being classified by Malaysian Drainage and Irrigation Department such as Flash Floods and Monsoon Floods. In addition, ocal weather fluctuations are among the natural causes of flash floods, whereas non-natural factors such as an ineffective urban drainage system and an increase in the number of structures in urban areas are the causes of the majority of flash floods in the Klang Valley Peninsular. Another large flood happened in Malaysian flood history, affecting four states which are Melaka, Johor, Pahang, and Negeri Sembilan. The flooding began when the monsoon season that heavy rainfall run through a series of severe storms, triggering disastrous floods in Kota Tinggi, Johor. Floods that occurred were caused by two waves that lasted 13 days from December 19 to December 31, 2006, and 7 days from January 12 to January 17, 2007. The floods were remarkable in that the average return period of rainfall in 2006 was 50 years, whereas the return time in 2007 was more than 100 years.

From the case study on Johor State, the extremely strong monsoon winds in combined with the uplift-inducing conditions in upper atmospheric levels during an extreme storm event of North-easterly monsoon in January in the year of 2007 formed an intense and strong rainfall with tidal effect, this rainfall has causing tons of destructive damage on the infrastructure and housing at the town in Kota Tinggi, Johor. For the flood modelling of Kota Tinggi, HEC-HMS has been well utilized to state out a satisfactory outcome for the simulation of the river peak flow which led by the date of rainfall-runoff for the storm event. Furthermore, the combination of generating the flood mapping with hydrodynamic model which will giving a big advantage in the study of control measure for flooding, flood housing area evacuation strategy, flood prediction namely forecasting for the lowlands. For the case study area of this study, Sungai Suloh is located on the southwest coastline of Peninsular Malaysia and this area is subject to annual flooding. The major cause of the flood in this area is due to the low elevation profile of the catchment which will be affected by sea-level rise and inundated runoff from the upstream reaches within the catchment. The capacity of the existing drainage system has not been able to absorb intense rainfall and excessive runoff due to heavy rainfall [2].

2.2 Extreme Climate Change

In general, Malaysia could be considered a climate-related disaster-free zone. However, mild climate-related disasters have been occurring quite frequently recently. These refer to the occurrence of floods and droughts which had significant socio-economic impacts on the nation, while the occurrence of landslides due to excessive rainfall and high winds caused minimal damage in the hilly and the latter in the coastal areas. Furthermore, the potential impacts of climate change in the Malaysian context would include sea level rise, lower crop yields, more diseases among forest species and loss of biodiversity, coastal erosion, higher intensity of flooding, bleaching of coral reefs, increased incidence of diseases, tidal inundation of coastal areas, reduced availability of water, loss of biodiversity and more droughts.

The rainfall intensity will change with the exist of climate change in the future time. The changes in rainfall intensity can be seriously affect the probability for the occurrence of flooding especially for the lowland area. As for designing storm which considering the climate change as a factor in Malaysia, the climate change factor is necessary to be utilized in the calculation and this statistical value includes minimum, median, mean and maximum climate change factors for both West and East Coast rainfall stations in Peninsular Malaysia from National Hydraulic Research Institute of Malaysia (NAHRIM). For the selected region for design storm, the median values of that particular area that under design consideration is selected for the calculation on the peak flow. For the utilization of Climate Change Factor, it is used as a multiplier with the rainfall intensity that has been calculated from the historical data which shown in equation 1.

$$I_{future} = I \times Climate\ Change\ Factor\ Eq.1$$

where I_{future} is future design storm rainfall intensity, I is the historical design rainfall intensity.

According to Hydrological Procedure No.1, Estimation of Design Rainstorm in Peninsular Malaysia, for Station in Batu Pahat, Johor which relating with this study, the value for the Climate Change Factor for 10 years, 50 years and 100 years of ARI is under the table for region 2 since Johor is under region 2 and it can be shown in Table 1.

Table 1: Climate Change Factor (CFF) for All Rainfall Station in Batu Pahat, Johor (Region 2)

Climate Change Factor (CFF) for All Rainfall Station in Batu Pahat, Johor (Region 2)		
Return Period, T		
10	50	100
1.32	1.45	1.49

2.3 HEC-RAS

Hydraulic modelling software plays an important role in floodplain modelling as practice and analysation purpose in several way. HEC-RAS allow the analysis to be faster and the way on formulating the model was widely accepted by the engineers in hydraulic field. By introducing this software, it provided a huge improvement in floodplain mapping as the flexibility has been greatly improved due to the advance computer technology in hydraulic simulation. GIS and HEC-RAS are the main keys on floodplain mapping as well as other disaster management since the inherent characteristic in multi-dimensional and spatial component in natural hazards. Nowadays, the flood events could be well predicted and having a better analysis as there is improvement in modelling capabilities. Furthermore, this provides a greater benefit from this modelling software as it helps engineers to generate various type of flooding cases with different range studies with specific period for the worst-case scenarios which is better than the way of take guesses by referring to the record events or having a long wait for the occurrence of the event. For engineers, HEC-RAS is one of the most important tools for making decisions and stimulating planning. HEC-RAS is used by engineers around the world for calculating steady-state water surface profiles, simulating unstable flows, calculating sediment transport at moving boundaries, and analysing water quality [3]. In addition, this program is widely distributed, which allows it open to more people. HEC-RAS is the most widely available, cost-free, and most frequently used hydraulic model in the U.S. In HEC-RAS, uncontrolled flow analysis varies in several respects from conventional steady state analysis. A popular one-dimensional flood simulation modelling software is HEC-RAS, which was introduced by the US Army Corps of engineers. Moreover, in steady-state simulation, HEC-RAS calculates the water surface profile, the method of standard displacement is a constant process that analyses and solves the energy equation from one cross-section to the next [5].

2.4 Flow of process

Figure 1 shows the flow of the processes involve in flood simulation using HEC-RAS. This process analysis uses observed river flow data of Sungai Suloh.

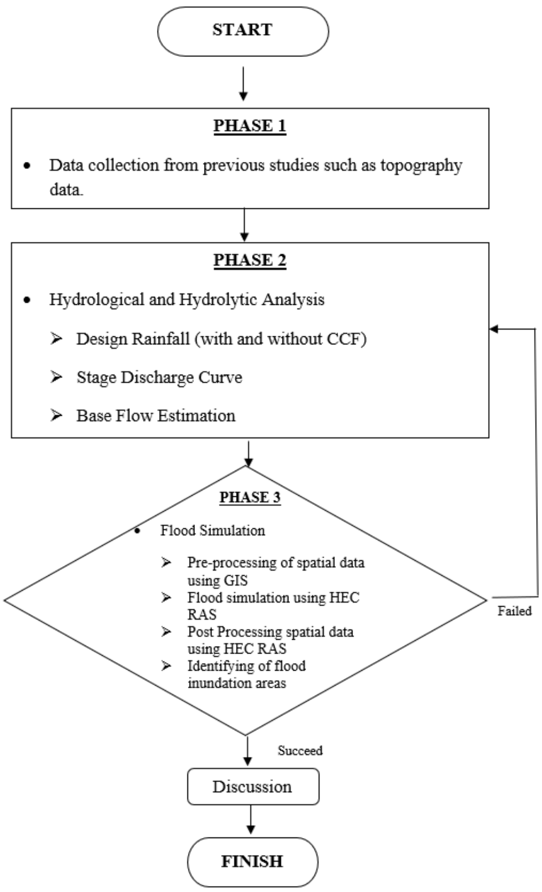

Figure 1: Steps involved in the flood simulation using HEC-RAS

2.5 Study Area

In this project, Sungai Suloh has been selected as the study area and the location of this study area as well as its boundary of the river for this project has shown in Figure 2.

Figure 2: Map showing the location of the study area of Sungai Suloh

The length of the stream is 10 km which indicated with blue line with the catchment area of 13.759km^2 which is equivalent to 1375.9 ha which covered with red boundary line. This value of catchment area was determined by using grid method. Furthermore, the peak flow estimation applied rational method although the total area for Sg Suloh catchment more than 80 ha as this is just the estimation on the flood depth of Sg Suloh.

2.7 Hydrological Data Collection

In this survey, it has produced 108 cross sections profile which along the Sg Suloh with each profile having a 4m distance between cross section profiles. The cross sections profile consists of elevation level and distance from left riverbank to right riverbank has been insert into HECRAS database for plotting out the river of the study area. The energy equation is the basic fact of this computational procedure which can be explain as the energy loss of the flow can be evaluated by the expansion or contraction of the flow and which also included the friction inside the flow. The standard step approach, which is one of the interactive procedures used in the solution, must be used to solve the energy equation from one cross section to another depending on the water surface profile. For the data input, this procedure requires some information which are river system schematic, reach length, water flow rate, cross-sectional geometry of the involved channel and Manning's roughness coefficient. Besides, the basic data input of steady flow is the basic requirement for this simulation.

2.8 Model Set

Hydrographic network modelling of Sungai Suloh requires the concern on selection of reach station which have the data of runoff water data that covering the watershed. In this case study, all the cross section, which is from CH0 to CH5795 has been considered in the simulation as this will provide a more detail analysis for the flood depth.

2.9 Boundary Condition

The boundary condition is the parameter that from the measurement of flow discharge from the time of historical events and the depth of water flow which has been observed (Aicha Saad, 2019). According to the survey data of Sg Suloh, the boundary condition set up for hydraulic simulations was assigned as normal depth with the slope value on upstream and downstream are 0.0025 and 0.00089, respectively.

2.10 Manning Roughness Coefficient

The Manning Roughness Coefficient can be obtained by observing the study area and estimate it with the observation from survey data from site visit and refer to the table of Manning Roughness Coefficient. For the main channel of the river, the coefficient is 0.035 as it has short grass covering the main channel while for the left bank and right bank, it is covered with tall grass, therefore the Manning Roughness Coefficient value will be 0.050 for both left bank and right bank.

2.11 Hydraulic Model Simulation

Three flows were simulated for this purpose: a 10-year, a 50-year, and a 100-year. These flows were calculated using the Rational Method which the equation 2 as below

$$Q = \frac{CiA}{360} \; Eq. 2$$

where C is Runoff Coefficient, i is rainfall intensity and A is the area of the study location.

The area of the study location is obtained from the survey data shows that the area of the study location is 13.759km^2 which is equivalent to 1375.9 ha, and this has fulfilled the requirement for using the Carter equation for calculating the time of concentration before proceeding to rainfall intensity.

$$T_c = 0.0015476L^{0.6}S^{-0.3} \; Eq. 3$$

Where, L is Length of the watershed along the main channel from the hydraulically most distant point to outlet, m, S is average slope of watershed, m/m and Tc is Time of Concentration, h.

For this study, the fitting constants were obtained from the rainfall station named Setor JPS Batu Pahat with the value that shows in Table 2.

Table 2: Fitting constants were obtained from the rainfall station named Setor JPS Batu Pahat

Station ID	Station Name	Constant			
		λ	κ	θ	η
1829002	Setor JPS Batu Pahat	64.099	0.174	0.201	0.826

Peak flow for various return periods was calculated using rational method and the table of the peak flow for respective ARI which are 10 years, 50 years, 100 years, and 100 years with climate change factor. The peak flows are shown in Table 3.

Table 3: Peak Flows with Respective Return Period

Return Period, ARI, years	Storm Duration, T (hr)		
	1.283	1.5 hr	2.0
		Flow Discharge, Q (m^3/s)	
10	158.343	141.490	114.363
50	209.519	187.216	151.322352
100	236.375	211.214	170.719
100 with climate change (1.49)	352.199	314.711	254.372

3. Results and Discussion

3.1 Results

The findings and analyses for flood simulation are based upon the simulations produced from the HEC-RAS computer program. The data of the runoff have been recorded at Sungai Suloh with a period of 10 years, 50 years and 100 years. The monitored precipitation data was first analysed to acquire for the highest possible event based upon the recorded data.

From the figure 3, it is shown that the peak discharge of the channel for the 100 years with storm duration of with Climate Change Factor, the total peak discharge value, Q_{total} is 238.79 m^3/s and the peak discharge for the channel is 180.67 m^3/s

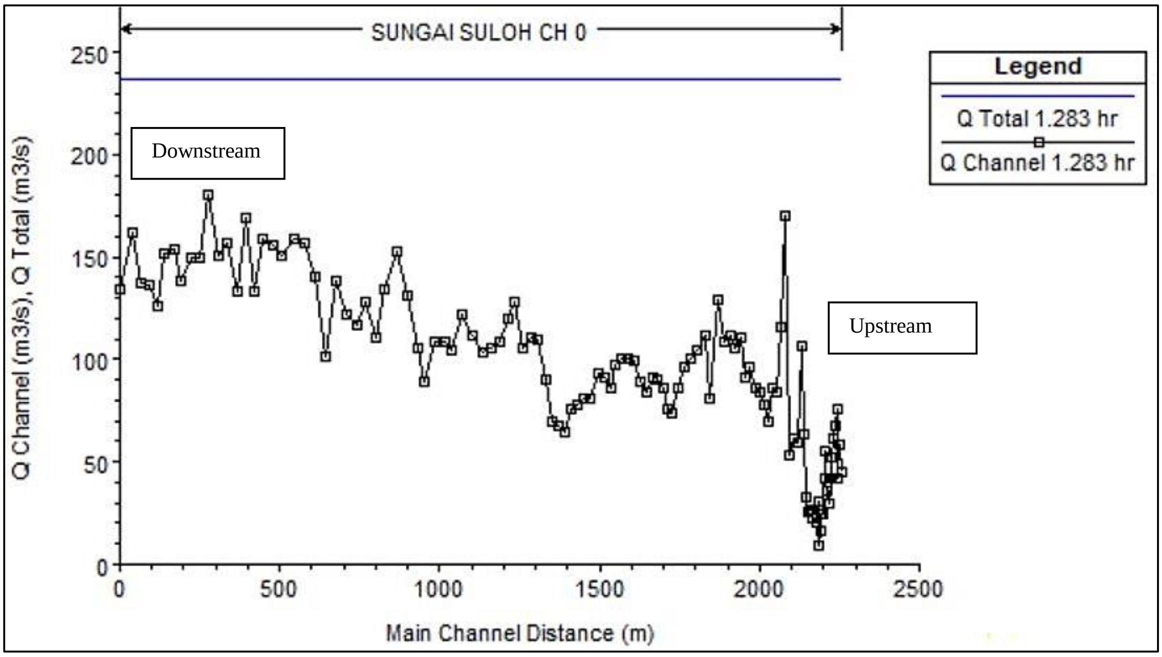

Figure 3: Validation of downstream flow discharge for 100 years with climate change factor flood event.

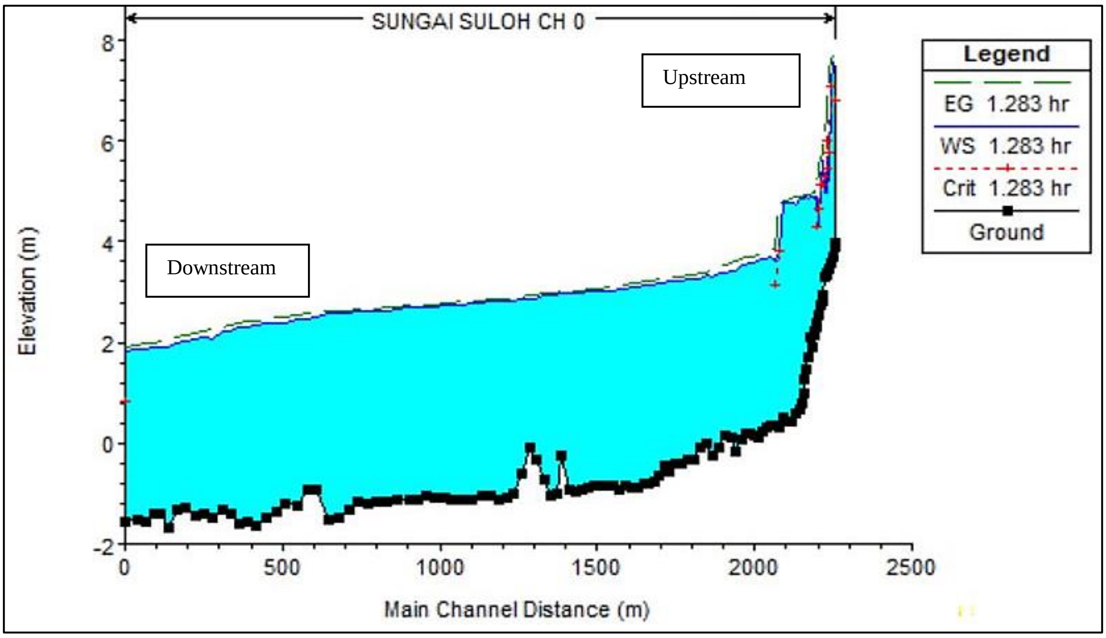

Figure 4: Sg Suloh maximum longitudinal water surface elevation profile with 100 years ARI with Climate Change Factor

The integrative water surface profile simulation output for 100 years ARI and 100 years with Climate Change Factor events indicated that there is an irregularity in the flow behaviour of the river as can be seen in Figure 4.

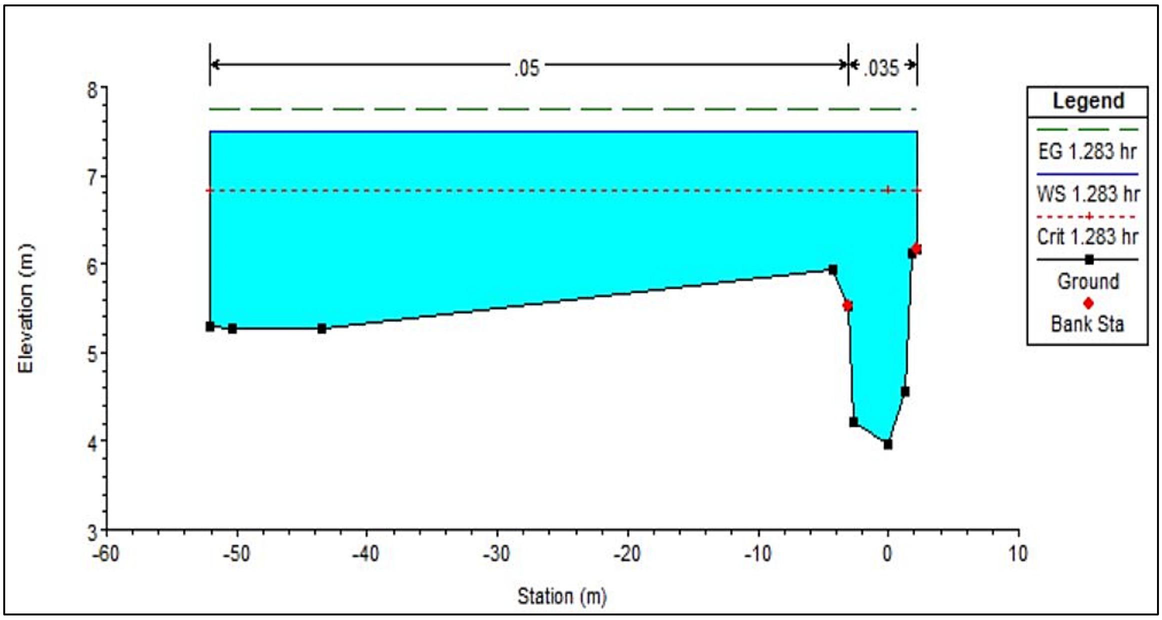

Figure 5: Water surface elevation of simulated flood event at CH5795

For the figure 5, the danger level is an indicator when the water level in the river is as high as the riverbank and water may burst the bank and flooding which has a higher probability to be occur. Flooding will be occurring when the water level exceeds the danger level.

3.2 Discussions

The water level of simulated for 100 years with Climate Change Factor flood events exceeded the danger level and riverbank elevations indicating the occurrence of the flood at the respective chainage.

For the 100 Years ARI with climate change factor flood event, the water level reaches over the danger level at CH 5795 stations resulting the level of 7.86 m. In this simulation shows higher water surface elevation with water level also exceeding the danger level which is a critical situation for the study area where flood will be occur in a serious condition. However, based on the estimation made in the calculation for this simulation, it should be noted that the model predicts higher water surface elevation compared to an actual flood event for both scenarios, with and without climate change factor.

Table 4: Flow Characteristic for 1.283 hours Storm Duration Profile Output for the Respective Chainage such as CH 0, CH 1000, CH 3000, CH 5300 and CH 5795 100 years with Climate Change Factor.

CH	W.S Elevation	Top-width Bank Elevation	Flood depth	Velocity	Flow Area	Wetted Parameter	Hydraulic Radius	Froude Number	Flow Characteristics
m	m	M	m	m/s	m^2	m	m	Fr	
0	2.4	-0.13	2.53	1.86	268.7	106.01	2.5347	0.33	Subcritical
1000	3.17	0.67	2.5	1.92	256.16	100	2.5616	0.33	Subcritical
3000	3.66	1.16	2.5	1.99	280.5	108.54	2.5843	0.33	Subcritical
5300	5.43	4.02	1.41	2.51	103.76	76.62	1.3542	1.12	Supercritical
5795	7.86	6.16	1.7	3.4	130.77	54.23	2.4114	0.59	Subcritical

From the flow characteristic shows in table, it shows that the hydraulic jump has higher probability occur at CH 5300 since the profile is change from Subcritical to Supercritical due to the sudden change in flow velocity and the hydraulic depth as the Froude number can be affected by the flow velocity and hydraulic depth, this will become one of the factors of the occur of flood which caused by the sudden change in flow characteristic which led by the problem in hydraulic capacity of the river.

4. Conclusion

In a nutshell, there are several advantages in utilizing software applications for simulation for flood mapping. Furthermore, the public-domain model HEC-RAS is being used for flood simulation of Sungai Suloh. The reason for choosing this model is that this software can be downloaded from the internet for free. From the simulation, the flood depth for the study area, Sg Suloh reaches the minimum of 1.41m which occur at the upstream and maximum of 2.5m at the downstream. The water surface elevation for all cross section has exceed the critical level as this means that the flood will occur. The total peak discharge value, Q_{total} is 238.79 m^3/s and the peak discharge for the channel is 180.67 m^3/s, The high flow discharge with insufficient in hydraulic capacity in the CH 5300 will lead to the flow become supercritical and hydraulic jump will occur as this will also become one of the factors of the occurrence of flooding. Moreover, although major analysis is analysis in hydrological, the model can be expanded to study the hydraulics and any other study related to hydraulics.

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References

[1] Aicha Saad, A. M. (2019). Flood Frequency Analysis and Urban Flood Modelling of Sidi Ifni Basin, Southern Morocco. *American Journal of Geographic Information System*, 206-212.

[2] Bernama. (8 September, 2018). *104 Evacuated in Batu Pahat Flash Flood*. Retrieved from New Straits TImes: https://www.nst.com.my/news/nation/2018/09/409520/104-evacuated-batu-pahat-flash-flood

[3] Mowinckel, E. K. (2011). Flood Capacity Improvement of San Jose Creek Channel Using HEC-RAS. 1-98.

[4] Sani G. D/iya, M. B. (2014). Floods in Malaysia: Historical Reviews, Causes, Effects and Mitigations Approach. *International Journal of Interdisciplinary Research and Innovations*, 59-65.

[5] Zhang, L., & Peng, M. (2016). Analysis of Dam Breaching Flood Routing. In M. P. Limin Zhang, *am Failure Mechanisms and Risk Assessment* (pp. 222-239). John Wiley & Sons Singapore Pte. Ltd.