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Flood Mapping Analysis in Selected Kuala Selangor Area Using HEC-RAS Software

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Abstract: Flood occurs due to overflow of water as a result from heavy rain, broken dam, overflowing river and lack of vegetation and affected more than 2 billion people worldwide. Flood mapping is important to identify any hazards and possible damage from the flood towards community This study determines the floodplain in selected area in Kuala Selangor and the risk of the flood to public safety and existing development. In this study, the method used are pre-processing the data using ARCGIS and using HEC-RAS for flood analysis and modelling. The result obtained from this study are the flood characteristics which is flood depth and velocity for different ARI and the mapping of the flood depth and velocity in Kuala Selangor area. This study also will help them to improve their current flood management to reduce risk and hazard to public and existing development.

Keywords: Flood Mapping, HEC-RAS, Kuala Selangor, Floodplain, Flood Simulation

1. Introduction

Flood occurs occasionally and causing many problems to the affected people as well as infrastructure and belongings. Flood occurs due to overflow of water as a result from heavy rain, broken dam, overflowing river and lack of vegetation. Flood also can occur when there is no proper management of drainage flow system and lack of awareness among users. Therefore, flood mapping is important to identify any hazards and possible damage from the flood towards community. Hydrology Engineering Center-River Analysis System (HEC-RAS) is a program that creates hydraulic model of water flow through natural-river and other water channels by using its Digital Elevation Model (DEM) data. By using HEC-RAS, it can provide hydraulic model of the area and the area affected during last flood occurs. Based on the hydraulic model, we can determine the affected area during flood and analyze the risk of flood to the public and existing development.

The aim of this study is to determine the characteristic of floods occur and produce the flood map based on 10, 20 and 50-years ARI. This study on mapping of the flood will be using HEC-RAS (Hydrology Engineering Center-River Analysis System) and DEM (Digital Elevation Model) data from

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local authorities. For the analysis, the hydrological data is use as input in HEC-RAS software and ARI 5, 10, 15 and 20 years. Kuala Selangor has been chosen as the location of the project as Kuala Selangor is one of the coastline cities that frequently affected by the flood especially due to the overflow of Selangor River during raining season.

This study will contribute to the benefit to public safety considering that flood mapping plays an important role in flood management. From the flood mapping, there are analysis which help the decision maker to provide recommendation to reduce any possibility for recurrent. The study also will help them to improve their current flood management to reduce risk and hazard to public and existing development. For the public, this study can increase their awareness on the flood and help them to be prepare for any possibilities when flood happen.

2. Literature Review

2.1 Flood

Flood is an overflow of water from water channel that submerges land. The term can also be applied to the inflow of the flowing water. Floods are a part of study in the hydrology and one of the major discussions about the effect to the agriculture, civil engineering, and public health. Flash floods are one of the world's most devastating natural disasters related to the weather. At least after six hours of a rainfall occurrence, these flash flood happens and create dangerous situation for people and impactful damage to property. Flash floods can develop at a very rapid rate with little or no warning. It is critical to be warned in a timely manner about flash flood conditions to lower the impacts among people and development.

2.2 Flood Mapping

Flood mapping is a method to determine flood depth and extents by comparing between channel water levels and ground level. The flood plain, topographic relationships and the judgment of the hydraulic model is the process that required understanding of flow dynamics. There are three existing method that can be categorized for flood plain mapping which is physiographic method, analytical method, and historical method. These methods have two similar steps in flood mapping which is transfer of water elevation from profiles to maps and determination of water surface profiles. All these three methods can be differentiated by their way of determining the water surface profile.

To simulate the flood mapping using physiographic, basin network data, elevation, and land cover and geological is needed. HEC-RAS were used to extract the water surface profile and then a flood map was incorporated through Geographic Information Systems (GIS). Simulation of the flooded area using the water surface data and DEM are created for the basin under different return period floods. Most of the analysis for flood mapping were simulated for multiple return periods such as 10, 50, 100, 200, 500, and 1000 years, but most of the study only presenting until 100-year return period flood mapping.

2.3 Flood Hazard Mapping

The flood hazard mapping can enhance the knowledge about the risk of flood that happened in the study area, and it can be used as a first step to identifying most affected areas by the flood, to configure suitable strategy to reduce the risk and to take action to sustain and manage land for future uses. Furthermore, surveys can be conducted to the specific authorities to provide more accurate data analysis in correspondence of high flood risk areas. Flat area that located close to the main channels are the most highly effected by the flood, while vegetation covered areas with high slope gradients are less effected to flood.

2.4 Impact of flood

The flood simulation outcome of HEC-RAS indicated that the flood risk area would be higher referring to 2, 5, 10, and 20-year return floods, respectively, and with comparison to 2-year floods, the increased flood area would be 62% (5 years), 118% (10 years), and 238% (20 years), respectively. The model flood extent layer of each return cycle was intersected with the ward boundary forward-wise effect research.

Based on different flood probabilities, the likely impacted area under different land uses. However, the area affected by the maximum probable flood (about 65 percent). There is open/green space against each return flood such as parks, plantation, water channel, and all these land uses are pervasive to the nature, so economic damage is not going to be so notable. On the other hand, in terms of possible damage/economic damage, residential, commercial such as market and shops, public and semi-public services such as utility services, health and educational, roads/transportation, and industrial land uses are the most vulnerable in the built-up area.

3. Methodology.

3.1 Study Area

The study area of this study is Kuala Selangor which is a coastal town located at the coastline of Selangor, Malaysia. It is located approximately 42 kilometres north-west of Shah Alam, capital city of Selangor and 55 kilometres north-west of Kuala Lumpur, capital city of Malaysia. The district of Kuala Selangor is located at the west of Selangor. Kuala Selangor district consists of an area of 1.194.55 km^2 (119452.46 hectares) and divided into 9 sub-districts. Urbanization in this area is growing rapidly focus on agricultural activities and housing development with a population of more than 150,000 people. The administrative town of this district also was named Kuala Selangor. The study area or location of the project is focus on the river called "Sungai Selangor" which flows along the town of Kuala Selangor.

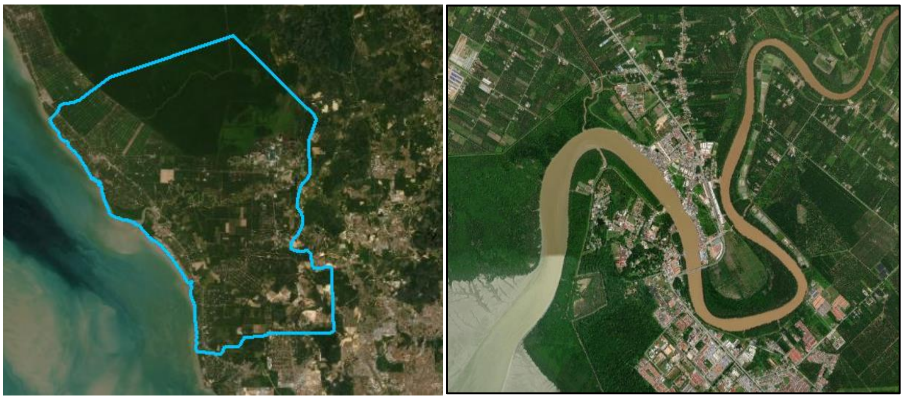

Figure 1: Kuala Selangor district (blue border)

3.2 Data Input

Data for this study were using SRTM 30m Data Elevation Map and imported to the GIS software then DEM data was converted into TIN file. From TIN file, it can determine the river elevation and easier to determine river flow.

For river hydrology and hydraulic data were obtained from Department of Drainage and Irrigation (DID) Malaysia at Site 3414421 in Selangor River. The data were the monthly flow rate of the river from year 1960 to 2000.

3.3 Rational Methods

According to Urban Stormwater Management Manual for Malaysia (MSMA), rational method is the most frequent techniques for runoff peak estimation in Malaysia and other countries around the world. Rational Method can be expressed as:

$$Q = \frac{CiA}{360} \; Eq. 1$$

For average rainfall intensity, i, can be expressed as:

$$i = \frac{\lambda T^{\kappa}}{(d+\theta)^{\eta}} \; Eq. 2$$

3.4 HEC-RAS Software

HEC-RAS utilizes various information boundaries for pressure driven examination of the stream channel math and water stream. These boundaries are utilized to set up a progression of cross-areas along the stream. In each cross-area, the areas of the stream banks are distinguished and used to partition into sections of left floodway, principal channel, and right floodway

3.5 Pre-processing of the data

The Raster DEM file of Kuala Selangor was loaded in ArcMAP 10.8. The next step is to do the pre-processing of the data. First, DEM data file was converted into TIN file by using ArcToolbox. For the preprocessing this TIN data, the geometry file is created using HEC-GeoRAS extension in ArcMAP. Selected attributes for this pre-processing were Stream centreline, Bank lines, Flow path, Centrelines, and XS Cutlines for this study.

By using the feature Assign River Code/ Reach code, the reaches were then named as the upper reach and lower reach. The elevation data were extracted to create the ground profile across the channel and creation of cross-sections as they are the main input to HEC-RAS. Cross sections were digitized by selecting the XS cutlines and selecting line segment in the create feature window. Cutlines were digitized by drawing line perpendicular to the streamflow, spanning over the entire flood extent and digitized from left to right for left and right bank.

3.6 Model Processing using HEC-RAS.

Exported GIS data then imported into HEC-RAS. The imported data from GIS were the river reach, bank lines, cross section lines. Flows were defined at the upstream location and the flow to be simulated is known as profile. Steady flow analysis was performed in this study. To perform the analysis, the hydrology data of Selangor River such as river discharge flow rate were used for steady flow data for HEC-RAS simulation. Upstream Boundary conditions were also determined as critical depth.

The steady flow analysis was done by HEC-RAS software. The simulated data such as depth and velocity of the flow were mapped using HEC-RAS GIS tool which is RAS Mapper.

4. Results and Discussion

4.1 Flood Characteristic of Kuala Selangor

According to the steady flow analysis run using HEC-RAS, the result for the depth of flow for different ARI, which is 10, 20 and 50 years are obtained. The discharge for the ARI is calculated using Rational Method.

For the upstream, the river flow for ARI 10, 20 and 50 years does not over the riverbank, which mean the flood did not happen before 50 years return period. The cross section for the river upstream were shown at Figure 2 and Figure 3.

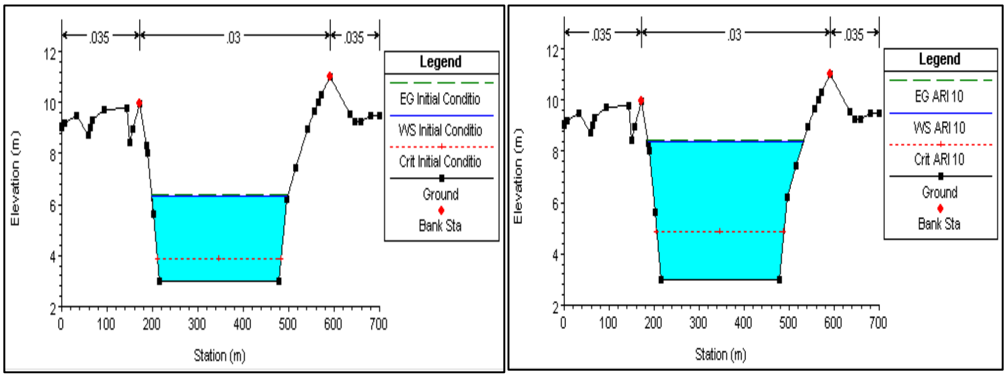

Figure 2 : Upstream cross-section for Initial condition and ARI 10 years

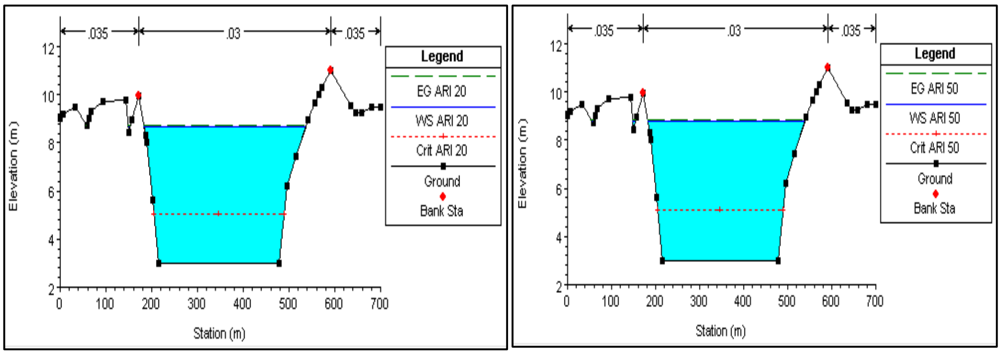

Figure 3: Upstream cross-section for ARI 20 and 50 years

Meanwhile for downstream, the river flow for does not flow over the riverbank for ARI 10, 20 and 50 years, which mean the flood may did not happen before 50 years return period. The cross section for the river downstream were shown at Figure 4 and Figure 5.

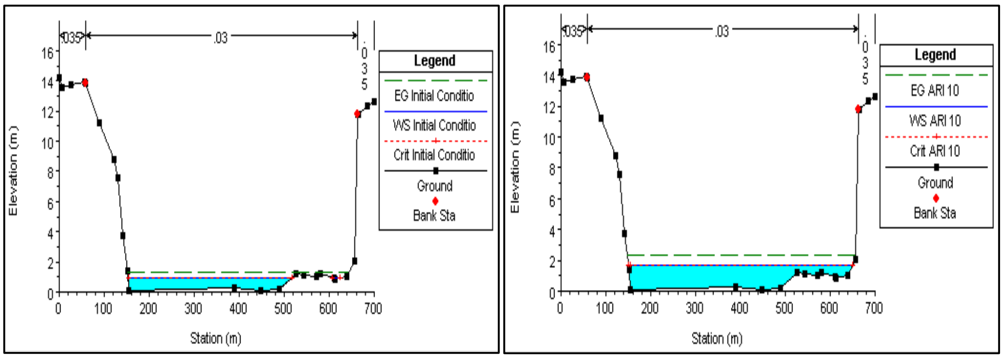

Figure 4: Downstream cross-section for Initial condition and ARI 10 years

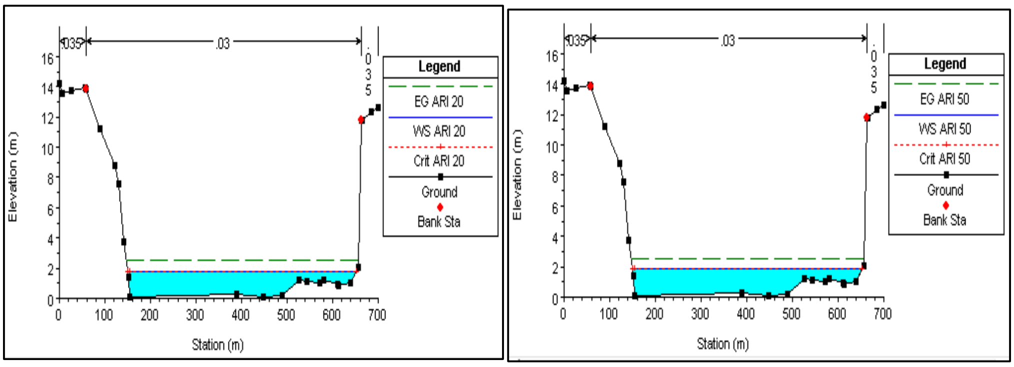

Figure 5: Downstream cross-section for ARI 20 and 50 years

For the most critical cross section, which is in the middle of the river reach, the river flow for ARI 10, 20 and 50 years are already over the riverbank with over 2.5m depth different than initial condition, which mean the flood may be happen after 10 years and upward. The cross section for the river upstream were shown at Figure 6and Figure 7. Meanwhile the plot for XYZ perspective were shown at Figure 8 and Figure 9.

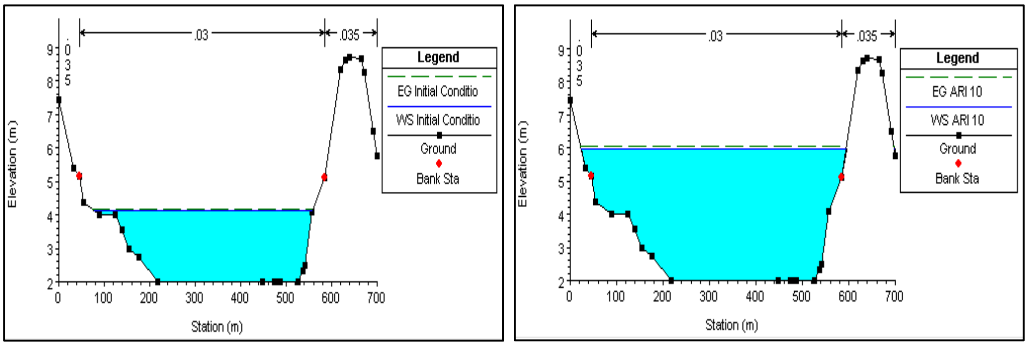

Figure 6: Critical cross-section for Initial condition and ARI 10 years

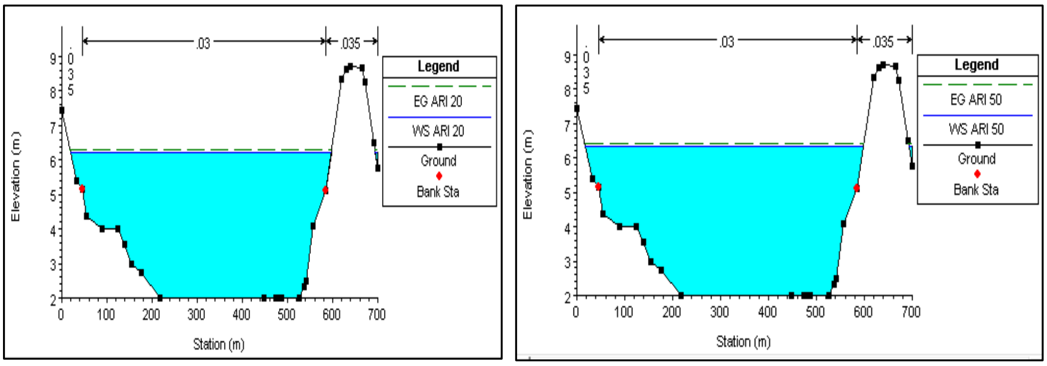

Figure 7: Critical cross-section for ARI 20 and 50 years

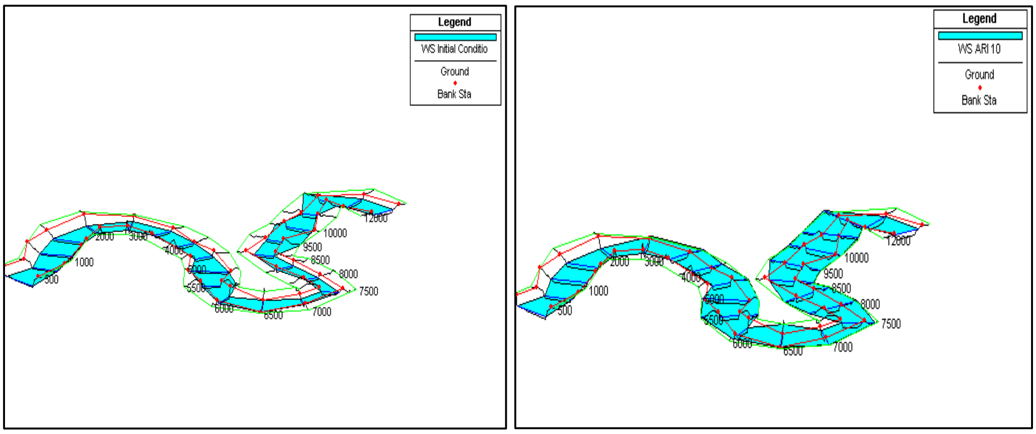

Figure 8: XYZ Perspective plot for Initial condition and ARI 10 years

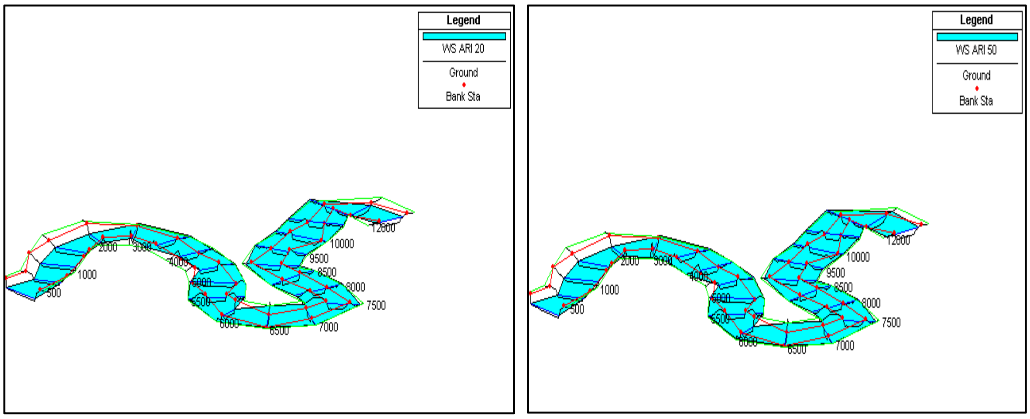

Figure 9: XYZ Perspective plot for ARI 20 years and ARI 50 years

3.2 Flood Mapping of Kuala Selangor Area

By using RAS Mapper in HEC-RAS, layer of the depth and velocity of flow are created to determine the limit of the flood zone for different ARI. The flood zones were used to determine the possible flood hazard toward the habitable area that may affected human and surrounding building.

The area of the flood was calculated based river flow depth and velocity on the river section. The higher the depth and velocity of the river flow, the larger the area of the flood. The flood areas for different ARI were shown in Figure 8, Figure 9 and Figure 10.

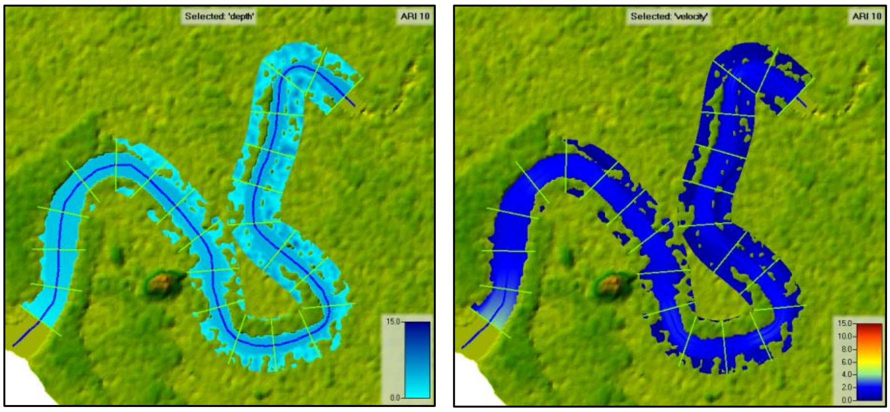

Figure 10: Depth and Velocity map of the flow for ARI 10 years

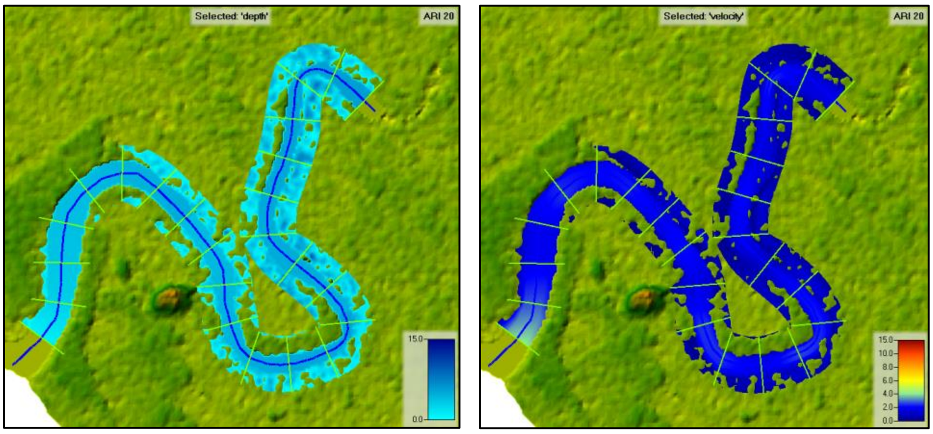

Figure 11: Depth and Velocity map of the flow for ARI 20 years

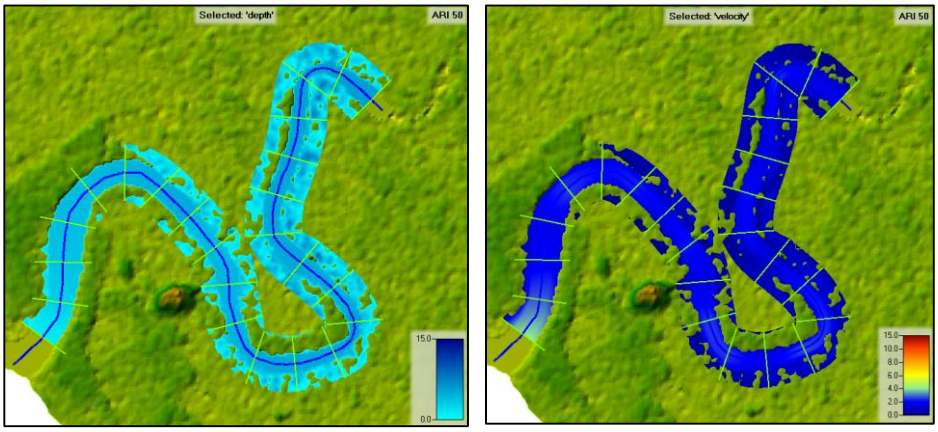

Figure 12: Depth and Velocity map of the flow for ARI 50 years

3.3 Discussion

From the analysis result, the causes of flood were heavy rainfall especially during the monsoon season. Monsoon seasons bring heavy rainfall for over 3 hours that causing overflow of Selangor River. From analysis result. The depth and velocity of the flow are differed which is 3.51m^3/s, 3.65 m^3/s, 3.69 m^3/s for different return period which is 10,20 and 50 years respectively. The increasing velocity of river flow also causes increasing in depth and width, the increasing of this perimeter resulting to overflow which is also known as flood.

According to a study by Suhaila (2010) stated that the total amount of rainfall was found to have decreased insignificantly at most of the stations during the Southwest Monsoon (SWM) period. However, a significantly decreasing trend in the frequency of wet days was observed at most of the stations in the northwestern, eastern, and southwestern areas. In contrast, an increasing trend in the total amount of rainfall was detected during the Northeast Monsoon (NEM) season. Besides, the frequency of wet days was also observed to have increased significantly in the eastern and western regions.

From the result, we expected that the discharges of the river may be increase as the year increase as this is also supported by the climate change that getting worsen every year. The result maps are Hazard and Water depth maps. The hazard map consists of a flood band line for a very specific climatic and hydrological event, in this case, taking into consideration a certain flow rate and water level, at a different ARI. As it can be observed in above Figure 8, 9 and 10, the flood areas extend into the land, but the damaged area is not that great.

Based on the previous study, the most affected area during flood is agricultural area followed by open area and built-up area. According to study by Shantosh (2010) in Kankai River Basin, Nepal, The Kankai River Basin flood hazard area increased from the 25-year return period flood to the 50-year return period flood and the agricultural land was the most affected by high flood hazard zone. Based on this study analysis, we found that the most affected area around Selangor River is agriculture area considering this town are known by its paddy field and agriculture activities.

A study in a region of Ghana using available topographical data, land use data and demographic data along with GIS software shows that most of agricultural areas were highly affected during the flood happen (Forkuo and Erik K, 2011). Abera Z (2011) in the study of flood risk in Dire Dawa Town, Eastern Ethiopia, stated that these categories of land use indicated that cultivated, open land, sand deposit, built up area and open shrub land faces are low to moderate flood hazard. Meanwhile, the built-up areas were categorized into high to very high hazard.

5. Conclusion

As a conclusion, we determined that the main cause of the flood along Selangor River is the intense rainfall especially during the monsoon season. The characteristic of the flood also can be determined by using HEC-RAS software modelling and the pre-processing of the data using ARCGIS software. The maximum flow rate of the river from the HEC-RAS simulation was $3.69m^3/s$ at the downstream of the river for 50 years ARI. The mapping of the flood also can be produced using HEC-RAS GIS tools which is RAS Mapper. We also determine that the depth and velocity of the flow are differ depending on different ARI which 10,20 and 50 years

Since it was hard to get a historical flood map or stream flow data, some GPS coordinate points that indicate historical flooded area, and literatures were used to validate the model results. The result of this report is very important as a preliminary information guide for land use planning, policy making, and investment decision as well as for security reasons.

Few recommendations based on this study is 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 design, so that a new building or other construction can be built properly without worrying that the flood may affected their area. This is also an important decision-making material especially during building local roads, to avoid pavement failure or their clogging with silt transported by the river during floods, which may affect transportation of the agriculture product as well as effecting someone’s economy.

Overlaying these maps on top of aerial images, could increase people’s awareness about flood on that specified area, where there are several buildings and houses that are not safe, and authorities should act and create protection plans and inform the population living in these areas by using campaign or public speaking. Another recommendation is to extend this study by using the same problem with different settings, context, and culture. Future studies also can re-assess the study, emerging new theory or evidence and create better outcome of the study.

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