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Flood Mapping by Using Hydrologic Engineering Center River Analysis System (HEC-RAS) in Kota Tinggi, Johor, Malaysia

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Abstract: Flood disaster are a natural disaster which cause widespread destruction and loss of life. Flood is an overflow of water from water channel that submerges land. The target of this topic is to determine the probability that the flood could happen in Kota Tinggi, Johor, Malaysia. The main objective of the research is to produce the flood mapping on the Sungai Johor that flows along the town of Kota Tinggi. The choice of using HEC-RAS software is to prove that is suitable to use in flood mapping or flood plain process by simulating the potential flood area by using various hydrological data such as geometric data and flow data. The flood plain mapping is produced according to the ARI of 2, 10, 25, 50 years with a discharge of 6084 (m^3/s), 9850 (m^3/s), 11619 (m^3/s), and 13926 (m^3/s) respectively by using the HEC-RAS software is proven. The source and characteristic of flood in the town of Kota Tinggi is due to the river flood by the Sungai Johor that flows along the town. Along the 50 years flood simulation, the inundated area will increase in size compared to the simulated flood years before.

Keywords: Floodplain Mapping, Sungai Johor, Kota Tinggi, Hydrologic Engineering Center River Analysis System (HEC-RAS), Geographical Information System (GIS), Data Elevation Model (DEM), Average Recurrence Interval (ARI), Boundary Condition (B.C.)

1. Introduction

Floods are a natural disaster which cause widespread destruction and loss of life. Flood is an overflow of water from water channel that submerges land. Floods are a part of study in the hydrology and one of the well-known disasters that can effect to the agriculture, civil engineering and public health. Floods are a very dangerous disaster that can cause the death of millions of people and the destruction of buildings and environments. It is important that people must be warned in a timely manner about the flood disaster in conditions to lower the impacts among the people and development.

Flood inundation Mapping is an important tool to predict flood behaviors and protect infrastructures. To produce the flood inundation mapping, the behaviors of the stream at different points needs to be acquired in response to a flood and these results need to be translated into a visual form. In

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this project we have coupled GIS with HEC-RAS. The -RAS models flood events by producing water surface profiles at required points on the stream. The process begins in GIS with clipping the DEM to the area of study. The clipped DEM is then converted to a TIN file. All the data collected from the DEM is then exported to HEC-RAS and an unsteady flow model is synthesized using flood data in the form of stage hydrograph. The results obtained using HEC-RAS are then exported back to GIS to form a visual display called Flood Elevation Maps.

The HEC-RAS software is a computer programme for simulating water flows via open channel systems and producing water surface profiles. The HEC-RAS programme is particularly useful in floodplain management and flood insurance studies to analyse floodway encroachments. It may also be used for bridge and culvert design and analysis, levee studies, and channel alteration studies. It may be used to analyse dam breaches; however other modelling approaches are now more commonly utilised for this purpose.

1.1 Problem Statement

Due to its geographical location on the planet, Malaysia is immune to numerous catastrophic and widespread natural catastrophes, yet it is regularly impacted by floods, which inflict significant flood damage. Extreme rainfall occurred in several regions of Peninsular Malaysia in 2006 and 2007, causing serious floods in numerous major towns. The town of Kota Tinggi was chosen as the research site since it is one of the most severely impacted areas in Johor state. In the year 2006, Kota Tinggi, Johor, Malaysia had experienced a massive flood that is caused by a problem at an unknown reservoir area. The extreme rainfall occurred in the city of Kota Tinggi in the state of Johor, Malaysia was probably the main factor or reason for the problem to happened at the unknown reservoir area. The people of Kota Tinggi were not aware of the situation and were to faced difficulties due to the flood. The target of this topic is to determine the probability that the flood could happen again and when could it happen again. The choice of using HEC-RAS software is to prove that is suitable and easy to use in flood mapping or flood plain process compared to other related type of software. The target is to overcome a possibility of flood from happening and to prepare to face it as well.

1.2 Objective

The aim of this study is to use HEC-RAS to determine natural disasters. The main objective are as follows. To produce the flood mapping according to ARI 10, 25 and 50 years. To simulate the potential flood area by using various hydrological data. To determine the characteristic of flood occur.

2. Methodology

2.1 Study Area

Kota Tinggi is a town in the Malaysian state of Johor (Figure 1). It is around 40 kilometres northeast of Johor Bahru, the state capital of Johor. The district of Kota Tinggi is located in the east of Johor state, with the sea encircling 65 percent of its borders. Kota Tinggi district consists of an area of 3,500 (km^2) (364,399 hectares) and divided into 11 sub-districts. With a population of over 200,000 people, urbanisation in this area is quickly increasing, with a concentration on agricultural operations and housing construction. This district's administrative town was also named Kota Tinggi. Kota Tinggi's average elevation is 6 metres above mean sea level [12].

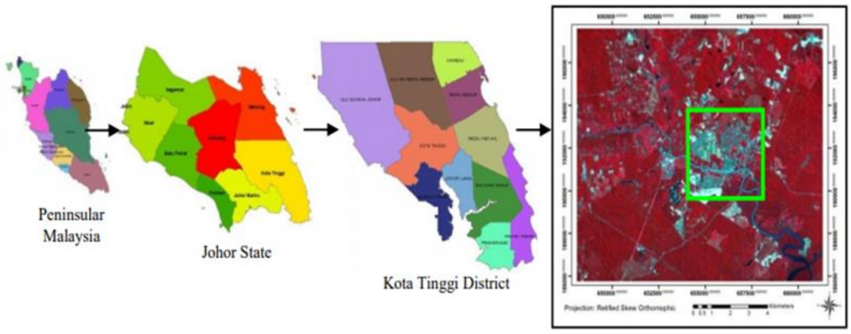

Figure 1: The location of study area (Green box shown the location of Kota Tinggi city).

The study area will be more specific or targeted on the Sungai Johor that flows along the Kota Tinggi town as shown in Figure 2. Sungai Johor is the major river in Malaysia's Johor state. The river is 122.7 kilometres long, has a catchment area of 2 636 kilometres, and runs generally north south.

Figure 2: The Sungai Johor flows along the town of Kota Tinggi

2.2 Analytical Method

Before continuing to use the HEC-RAS programme, the GIS software is designed to generate the desired maps and other graphic representations of geographic information for presentation and analysis. Following that, the HEC-RAS programme is intended to generate and simulate one-dimensional (1-D) steady and unsteady flow by utilising computations for both natural and prismatic channels to establish water-surface profiles.

2.2.1 Geographic Information System (GIS)

GIS software can be used to visualise spatial data or to create decision support systems for your organisation. In this case, the GIS software is used to collect the desire geographic information about the town of Kota Tinggi for analysis purposes before proceeding using the HEC-RAS software.

2.2.2 Hydrologic Engineering Center River Analysis System (HEC-RAS)

The HEC-RAS software can be used to perform a one-dimensional analysis of steady flow, unsteady flow, sediment transport (mobile bed vs. rigid bed), and water temperature modelling.

The required information needed for the HEC-RAS software to operate is geometry data such as channel dimension and flow data such as discharge. The boundary conditions (B.C.) like downstream flow depth and upstream flow depth. The requirement of B.C. are different due to the depending on flow type whether it is super or sub critical. Subcritical flow is where downstream flow condition is required whereas supercritical flow is where upstream and downstream flow condition are required. Other information such as existence of structures such as embankment, bridge pier and junction are also required if needed.

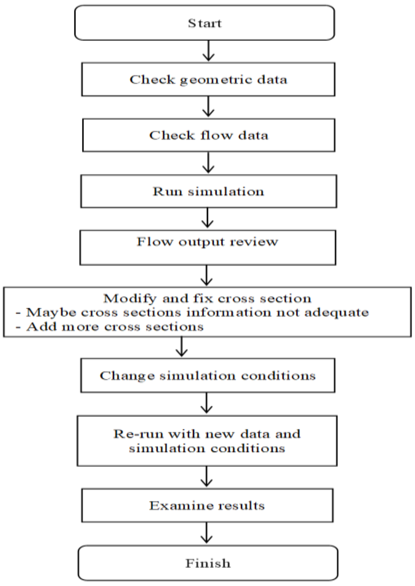

Figure 3: The procedures of using HEC-RAS software

2.3 Data Analysis

The findings of hydrological data (water level and discharge), Digital Elevation Model (DEM), river networks and cross sections, cadastral data, and real estate value information will be analysed. Cadastral data and real estate valuation information were collected from the Kota Tinggi District Council and the Johor Bahru Valuation and Property Services Department. To finish the study, the study must go through three major stages: pre-processing, primary processing, and analysis [12].

2.4 Parameters

The study will be conducted with some parameters to analyse the map areas in the town of Kota Tinggi, Johor, Malaysia that are at risk of flooding. With the help of GIS and HEC-RAS software to provide flood hazard mapping about the selected area. Thus, making the public more aware of the flood disaster that will happen in the future.

2.4.1 Geometric Data

Geometric data analysis refers to the geometric elements of image analysis, pattern analysis, and form analysis, as well as the multivariate statistics method that analyses arbitrary data sets as clouds of points in n-dimensional space. In this case, the geometric data will be referred as RAS layers in the HEC-RAS software. The use of RAS Mapper in the HEC-RAS software or in the GIS software will create the RAS layers for the simulation to be run.

2.4.2 Flow Data

The flow discharge data in the river is referred to as flow data. There are two forms of flow data in the HEC-RAS software: steady flow data and unstable flow data. There are various values of flow discharge according throughout the years. In this case, the simulation is run by using or input steady flow data that is obtained.

3. Results and Discussion

3.1 Results

A HEC-RAS hydraulic model was set up to generate water level based on various flow data insert and will show inundation in the floodplain area. The results of successful input of data in the HEC-RAS is shown in the Figure 4. The water elevation at the cross section of each station is obtained from the results of steady flow. Once the station condition is completed, the floodplain mapping can be shown.

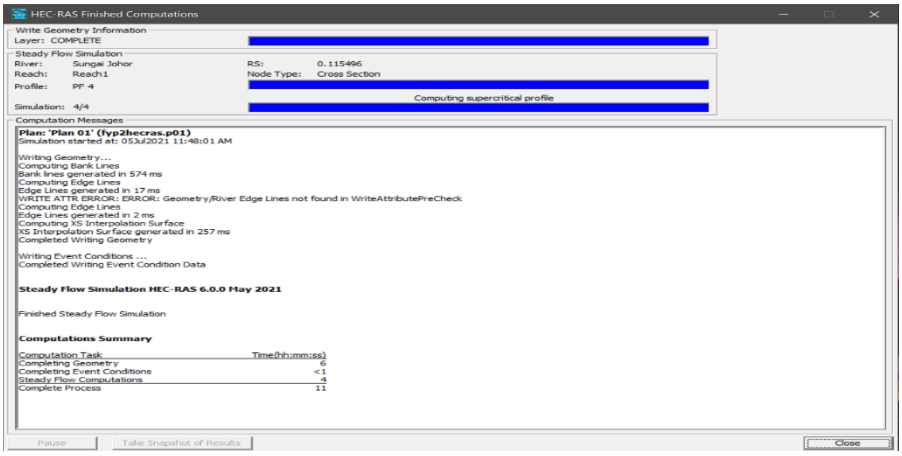

Figure 4: The results after running the data in the HEC-RAS software

3.1.1 Station Cross Section

After the steady flow analysis is performed, there are different water elevation level produce in various stations. Table 1 shows the flow data in meter cube per seconds (m^3/s) respect to the Profile (PF) or ARI.

Table 1: The flow data in meter cube per seconds (m^3/s) respect to the Profile (PF) or ARI

Flow Data (m^3/s)	Profile (PF) / ARI
6084	PF 1 / 2 Years
9850	PF 2 / 10 Years
11619	PF 3 / 25 Years
13926	PF 4 / 50 Years

The water elevation level in selected station is produce respecting to the Profile (PF) or ARI values as shown as in Figure to Figure based on the importance of each station.

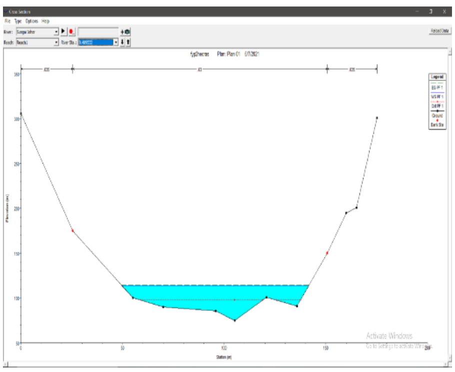

Figure 5: Station 9.409532 based on PF 1

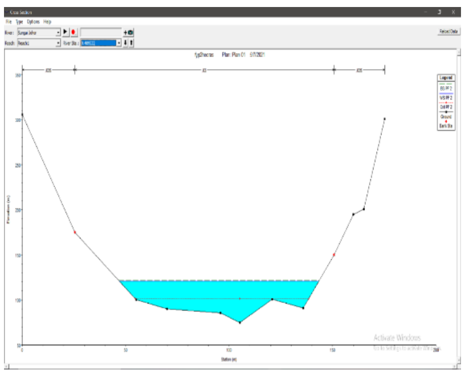

Figure 6: Station 9.409532 based on PF 2

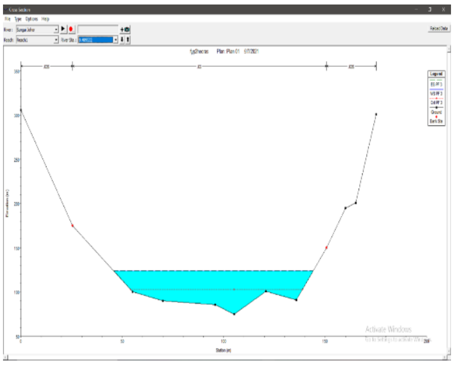

Figure 7: Station 9.409532 based on PF 3

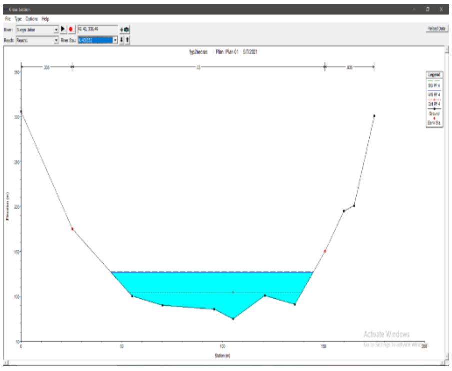

Figure 8: Station 9.409532 based on PF 4

The water elevation level at the station 9.409532 which is located on the upstream of the river will increases or rises from the initial ARI to ARI 10, 25 and 50 accordingly due to the value of discharge throughout the ARIs is increase respectively.

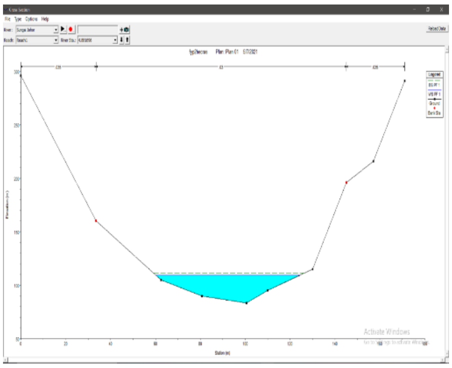

Figure 9: Station 4.881696 based on PF 1

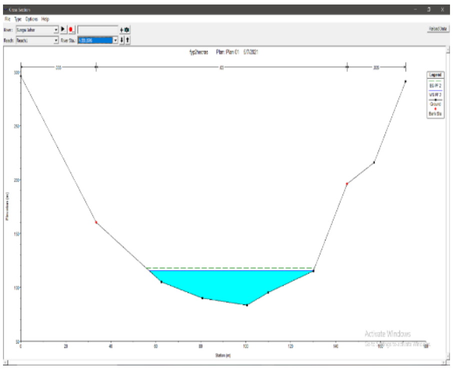

Figure 10: Station 4.881696 based on PF 2

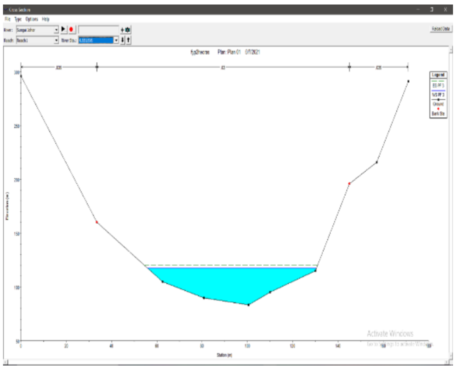

Figure 11: Station 4.881696 based on PF 3

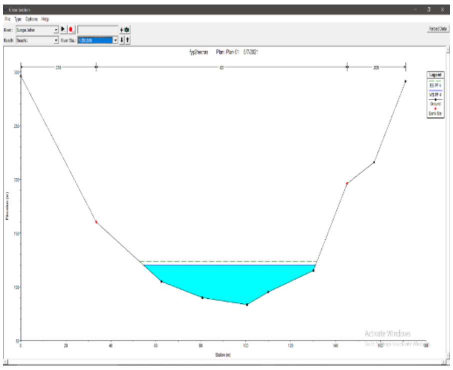

Figure 12: Station 4.881696 based on PF 4

The water elevation level at the station 4.881696 which is located on the center of the river which is the most critical station due to it is located at the center of the Kota Tinggi town. The water elevation level at the given station will increases or rises up from the initial ARI to ARI 10, 25 and 50 accordingly due to the value of discharge throughout the ARIs is increase respectively.

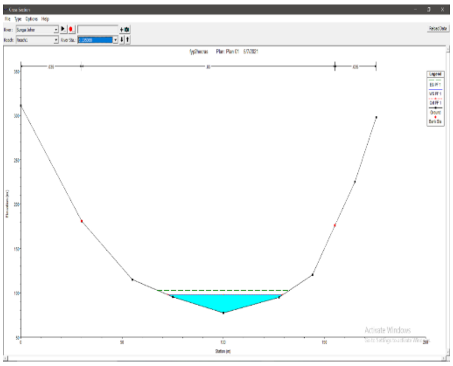

Figure 13: Station 0.105088 based on PF 1

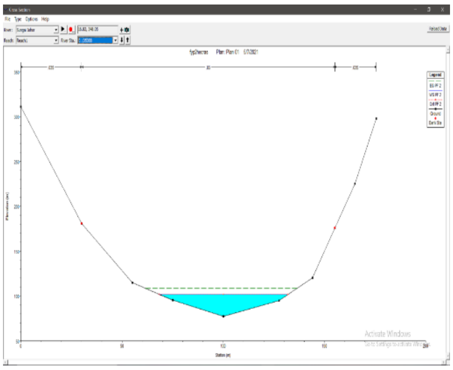

Figure 14: Station 0.105088 based on PF 2

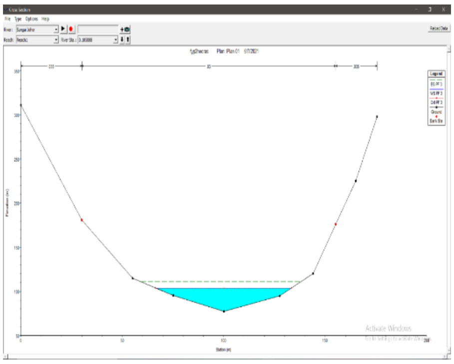

Figure 15: Station 0.105088 based on PF 3

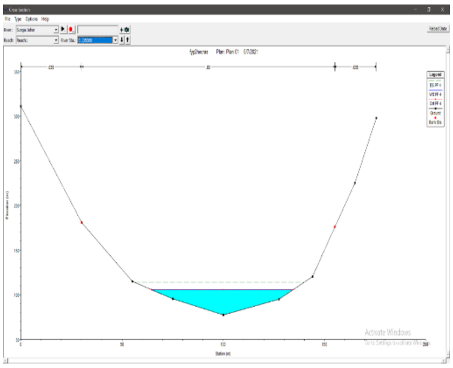

Figure 16: Station 0.105088 based on PF 4

The water elevation level at the station 0.105088 which is located on the downstream of the river will increases or rises up from the initial ARI to ARI 10, 25 and 50 accordingly due to the value of discharge throughout the ARIs is increase respectively.

3.2 Floodplain Mapping

Figure 17 shows the location of the Sungai Johor located at the area of Kota Tinggi while in Figure 18 shows the process of layering the river by using HEC-RAS software.

Figure 17: The Sungai Johor located at the area of Kota Tinggi

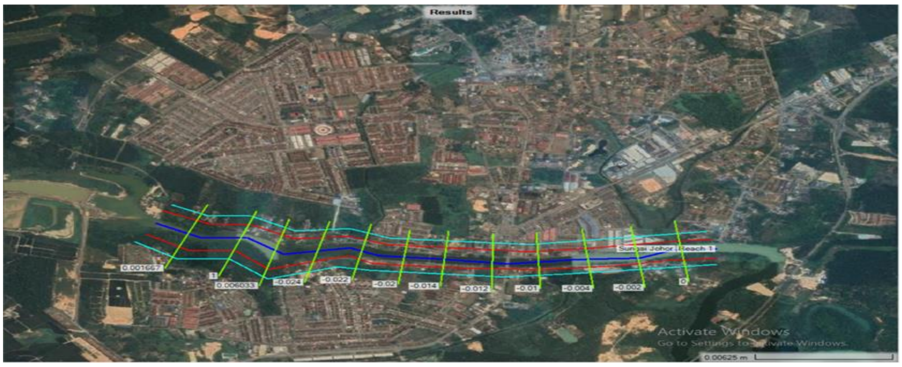

Figure 18: The layering Process of Sungai Johor by using HEC-RAS software

Figure 19 to Figure 22 shows the floodplain map at Sungai Johor located in Kota Tinggi. The residential area such as Kampong Tembioh which is located near the Sungai Johor is affected. The inundation of floodplain area will slightly become bigger in area. All of the station experience water overflow from the riverbank. The surrounding of the Sungai Johor is mainly buildings such as residential buildings.

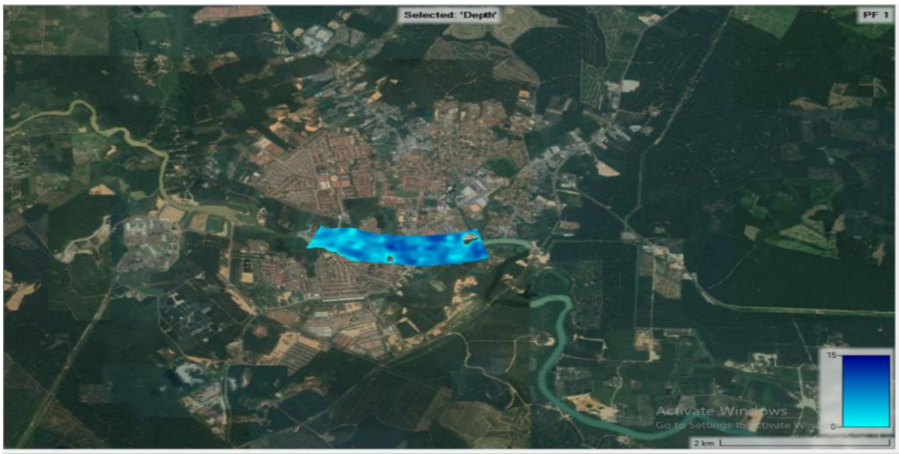

Figure 19: Floodplain map for PF 1

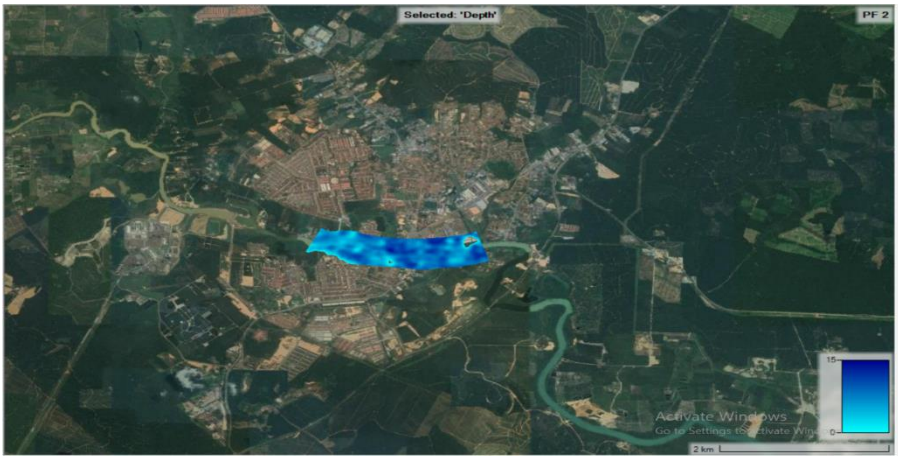

Figure 20: Floodplain map for PF 2

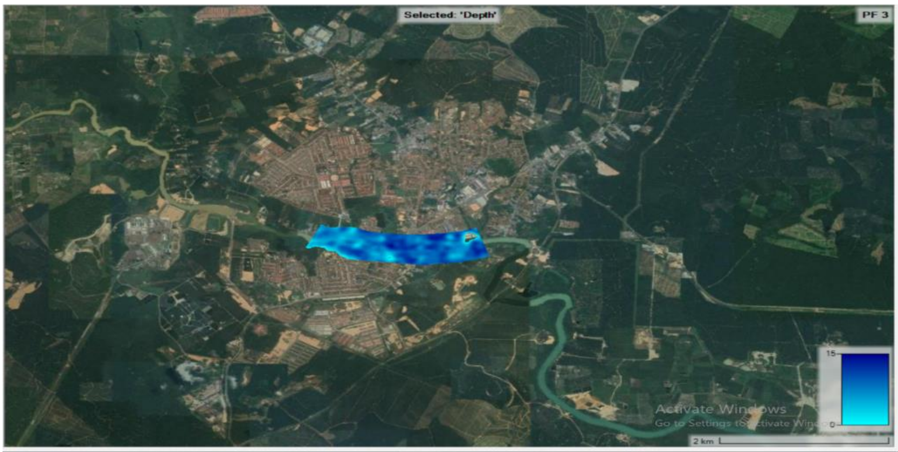

Figure 21: Floodplain map for PF 3

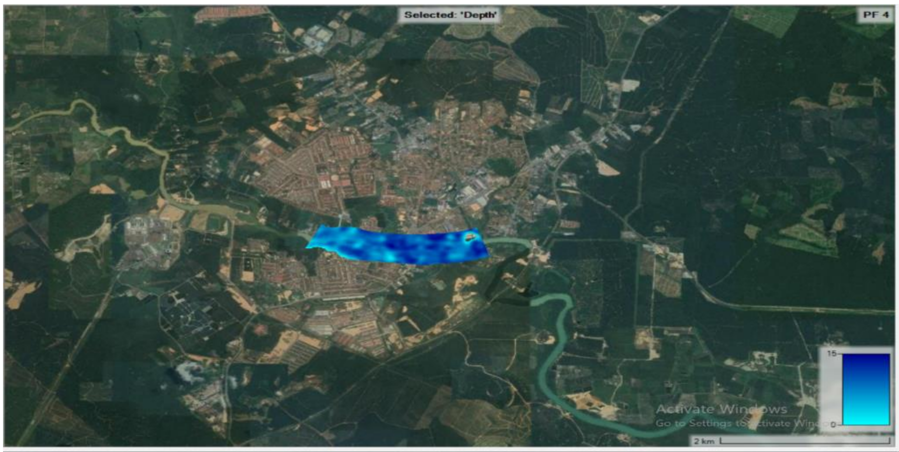

Figure 22: Floodplain map for PF 4

3.3 Discussion

The results of floodplain modelling of Sungai Johor located in the area of Kota Tinggi by using HEC-RAS analysis were presented in this chapter. The results were shown as the floodplain for initial ARI to ARI 10,25 and 50 were shown from Figure 18 to Figure 21 respectively. The area of the floodplain will increase as the ARIs goes. This is due to the value of discharge of each respectively ARIs increase. The potential flood area is simulated successfully by entering geometric data that we obtain from the process of layering by using GIS software and HEC-RAS software. Next, the flow data which is characterized as a steady flow data also crucial to the simulation process. The characteristic of flood occur in the town of Kota Tinggi is river flood due to the overflow from the Sungai Johor source. The station can be seen to be inundated because of overflowing water into the riverbank. Floodplain is the area that will be affected when flood event occurs.

4. Conclusion

The inundated area of Kota Tinggi town was map by applied the use of HEC-RAS software during the 2006 flood occurrence and simulate the flood map under various return periods. The accuracy of the modelling was validated based on observed flood marks of 2006 flood event. The estimated peak flows of Sungai Johor located in Kota Tinggi town for 10, 25, and 50 ARIs are 9850 m^3/s, 11619 m^3/s, and 13926 m^3/s respectively. The floodplain area will increase from the initial ARI to ARI 10,25 and 50 due to the increase of discharge value from the initial ARI to ARI 50. The flood area is successfully simulated by entering the geometric data and flow data which characterized as a steady flow data by using the HEC-RAS software. The characteristic of the flood occur is due to river flood from the Sungai Johor in the town of Kota Tinggi.

Most of the inundated areas of 50 years flood were also affected by the 2006 flood occurrence was stated by the simulation. Along the 50 years flood simulation, the inundated area will increase in size compared to the simulated flood years before.

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References

[1] Romali, N. S., Yusop, Z., & Ismail, A. Z. (2018). Application of HEC-RAS and Arc GIS for floodplain mapping in Segamat town, Malaysia. International Journal, 14(43), 125-131.

[2] ShahiriParsa, A., Noori, M., Heydari, M., & Rashidi, M. (2016). Floodplain zoning simulation by using HEC-RAS and CCHE2D models in the Sungai Maka river. Air, Soil and Water Research, 9, ASWR-S36089

[3] Azizat, N., & Omar, W. M. S. W. (2018). Assessment of Three Flood Hazard Mapping Methods: A Case Study of Perlis. In E3S Web of Conferences (Vol. 34, p. 02028). EDP Sciences

[4] Musa, S., Adnan, M. S., Ahmad, N. A., & Ayob, S. (2016). Flood Water Level Mapping and Prediction Due to Dam Failures. MS&E, 136(1), 012084.

[5] Reba, M. N. M., Halim, M. K. A., & Roslan, N. H. INTEGRATION OF GIS AND HEC-RAS HYDRAULIC MODEL FOR FLOOD INUNDATION MAPPING IN SUNGAI su BASIN.

[6] Adib, M. R. M., Saifullizan, M. B., Wardah, T., Rokiah, D., & Junaidah, A. (2011). Flood inundation modeling for Kota Tinggi catchment by combination of 2D hydrodynamic model and flood mapping approach. Lowland Technology International, 13(1, June), 27-35.

[7] Wibowo, W. H., Saraswati, R., & Rahatiningtyas, N. S. (2020). Tidal flood hazard in coastal area of Tangerang Regency. In E3S Web of Conferences (Vol. 211, p. 02001). EDP Sciences.

[8] Devanand, M. R., & Kundapura, S. Flood Inundation Mapping of Harangi River Basin, Kodagu, Using GIS Techniques and HEC-RAS Model. Trends in Civil Engineering and Challenges for Sustainability, 665-678.

[9] Khattak, M. S., Anwar, F., Saeed, T. U., Sharif, M., Sheraz, K., & Ahmed, A. (2016). Floodplain mapping using HEC-RAS and ArcGIS: a case study of Kabul River. Arabian Journal for Science and Engineering, 41(4), 1375-1390.

[10] Chakraborty, S., & Biswas, S. (2020). Application of Geographic Information System and HEC-AS in Flood Risk Mapping of a Catchment. In Applications of Geomatics in Civil Engineering (pp. 215-224). Springer, Singapore.

[11] El Morjani, Z. E. A., Ennasr, M. S., Elmouden, A., Idbraim, S., Bouaakaz, B., & Saad, A. (2016). Flood Hazard Mapping and Modeling Using GIS Applied to the Souss River Watershed. In The Souss-Massa River Basin, Morocco (pp. 57-93). Springer, Cham.

[12] Tam, T. (2014, February). Development of flood risk mapping in Kota Tinggi, Malaysia. In IOP Conference Series: Earth and Environmental Science (Vol. 18, No. 1, p. 012192). IOP Publishing.

[13] Asmara, T. T., & Ludin, A. M. (2014, February). Mapping perception of community preparedness towards flood in Muar river, Johor Malaysia. In IOP Conference Series: Earth and Environmental Science (Vol. 18, No. 1, p. 012126). IOP Publishing.

[14] Romali, N. S., Yusop, Z., & Ismail, A. Z. (2018, March). Hydrological modelling using HEC-HMS for flood risk assessment of Segamat Town, Malaysia. In IOP Conference Series: Materials Science and Engineering (Vol. 318, No. 1, p. 012029). IOP Publishing.

[15] Saleh, A., Yuzir, A., & Abustan, I. (2020, January). Flash Flood Susceptibility Modelling: A Review. In IOP Conference Series: Materials Science and Engineering (Vol. 712, No. 1, p. 012005). IOP Publishing.