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FLOOD SIMULATION MODEL USING XP-SWMM ALONG TERENGGANU RIVER, MALAYSIA

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ABSTRACT

Malaysia is one of the tropical countries in the world with heavy rainfall throughout the year and floods are the most common disaster in Malaysia. Flood simulation model was carried out along Terengganu River for dry and rainy seasons. The result of the simulation shows the water level reached its maximum level at the 1st two hours of the simulation at about 2:40min with the highest flow of Q = 155.90m^3/s and velocity V = 1.52m/s. Station 1 have the highest value of Q and this because it is at the upstream of the River, while stations 2, 3 and 4 are almost dry because they are at the downstream of the river. Similarly, a 10 years data was also modeled as a secondary data to validate the primary data. This shows that, the simulation was good and XP-SWMM is compatible for flood simulation.

Keywords: Terengganu River; flood; XP-SWMM; simulation; modeling.

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1. INTRODUCTION

The most common disaster in Malaysia is flood and flash floods. Floods occur especially during the wet season in the east coast area which is mainly influenced by the northeast monsoon [1-5]. Malaysia reclines in a geographically stable region that is free from volcanic activities, earthquakes and other disasters such as tropical cyclones which sporadically affect some of its neighbors. It lies geographically just outside the "Pacific Ring of Fire". It also lies too far south of the major typhoon paths, but tail-ends of tropical storms have at times hit it. Nevertheless, it is not evident to say that Malaysia is totally "Free" from the natural disasters and catastrophes, as it often experience floods, droughts, haze, landslides, tsunami and human made disasters [6-8]. Yearly, disasters such as floods account for large number of casualties, diseases epidemic, property and crop damages and other invisible losses [9-11].

Terengganu is a state in the east coast of Peninsula Malaysia that in its history has never missed a flooding event, which normally occur between October and March every year during the northeast monsoon period. The occurrence of flood in Terengganu apart from result of heavy rainfall experienced during the monsoon period, combination of physical factors such as elevation and its close presence to the sea also influence flood occurrence. More than 70% of the Terengganu has an altitude < 200 m, and therefore it is categorize as low-lying coastal area and the 30% of the area was identified as vulnerable to flashflood. Floods that hit Terengganu were classified as coastal flooding [12-15].

Simulating floods before they occur allows precautions to be taken and people near river to be warned, so that they can be prepared in advance for flooding conditions. For example, farmers can evacuate their animals from low-lying areas and emergency services provision can be put in place to relocate people if needed. Emergency services can also make provisions to have enough resources available ahead of time to respond to any incidence if floods occur [16-17].

2. METHODOLOGY

2.1. Area of Study

Terengganu is a state in Malaysia with capital Kuala Terengganu. It has a total land area of 13,035 km^2 equivalent to 1,295,512 hectares. Terengganu also covers 4% of the total

Malaysia area. Terengganu is located at the eastern part of Peninsular Malaysia. It has border with Kelantan from the northeast and Pahang from the west and south and also faces the South China Sea from the east.

The Terengganu River Basin lies in the wet tropics 4041'-5020'N, 102031'-103009'E. covering approximately 5000 km^2 and the Kenyir Lake is located in the west, which are the main channel and 5 major tributaries of the Terengganu River and finally flow towards estuary in the east. The river cross-sectional area is 987 km^2 [13].

2.2. Method

Global positioning system (GPS) was used to find the actual coordinate of the Terengganu River. About 8 river cross-sections were selected. Some of the stations were located at the upstream while some are at downstream of the Terengganu River. The distances between each cross-section area were calculated.

The hydrodynamic model used in this study is XP SWMM, a 1-dimension which models both the hydrologic and hydraulic components of the storm water management systems. Based on the cross-section data obtained from the study area, XP SWMM used a node-link concept to represent the drainage system. Similarly, links represent hydraulic elements of flow in the system and the model offered many different types of conduits for simulation such as sewer pipes, channel reaches or culvert, and nodes represented as ponds or lake, junctions, outfalls or other physical transition points along the links [18-21]. The river was modeled as conduits together with weir which added by using multi-link. Fig. 1 shows the process of modeling data.

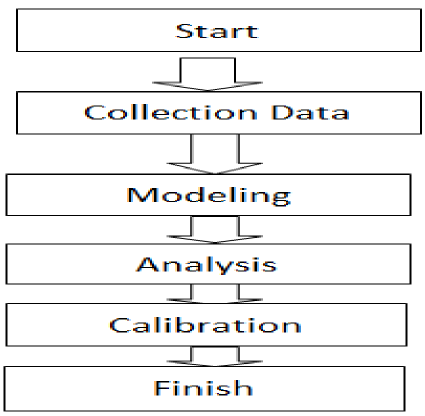

Fig.1. Process of modeling data in XP SWMM model

3. RESULTS AND DISCUSSION

3.1. Simulation During Dry Season

Terengganu River was modeled using XP SWMM software for flood simulation within the period of 6 hours. The hydraulic model includes nodes and links that represents four research stations another station was added as dummy station to represent the free outfall as shown in Fig. 2. The results of simulation period can be displayed in different profiles and dynamic views; dynamic view of section 1-D hydrodynamic is selected to view the results of this work.

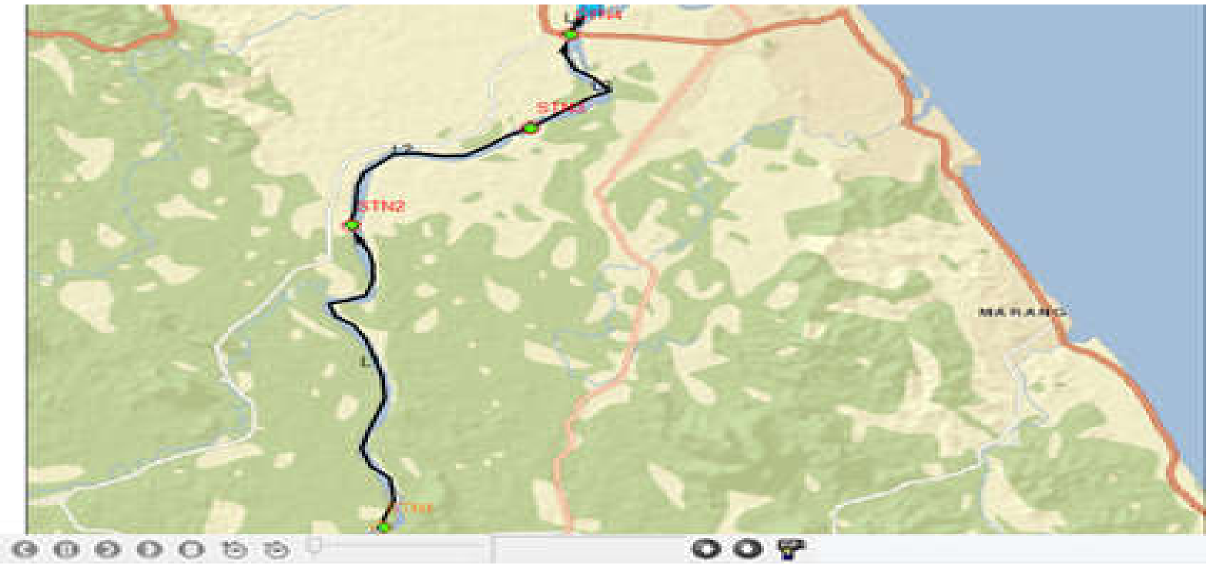

Fig.2. 1-D Dynamic plan view of Terengganu River before simulation

In this study, symbols were used as indicators of water level and river discharge as shown in Fig. 2 namely 1. Flooding, 2. Ground level, 3. Freeboard, 4. Crown and 5. Dry:

1. Flooding is the distance when High Ground Level HGR is equal or exceeds the spill crest value.
2. Ground Level is the distance when the HGL is between spill crest and invert
3. Freeboard is the distance from a user defined safety elevation to the spill crest
4. Crown is the distance when HGL between highest crown value and the invert
5. Dry is the distance when HGL is equal to invert

After inputting all the XP SWMM modeling parameters such as spill crest, the water level, the flow of the water, then the simulation may run and the process of running the simulation requires care and accuracy for each parameter. If there is error in the data inputs, then the simulation may not work properly [20]. The Tables 1 and 2 show the location of the sampling stations and the XP nodes and links input data at Terengganu River.

Table 1. Location of sampling stations

Station	Coordinate	Elevation/MSL (m)	Description
1	103˚5’18”E 5˚18’34”N	27.5	Node 1
2	103˚4’39.7”E 5˚16’35.1”N	13.29	Node 2
3	103˚2’3.7”E 5˚14’32.4”N	11.57	Node 3
4	103˚2.5’3”E 5˚8’9.8”N	9.76	Node 4
5 (Dummy)	Dummy Station	-	Node 5

Table 2. XP Table showing the nodes input data

Name	Ground Elevation m (Spill Crest)	Invert Elevation m
Node 1	27.50	7.16
Node 2	13.29	3.41
Node 3	11.57	1.58
Node 4	9.76	0.61
Node 5	8.00	7.00

After inputting all the required data for simulation, the results shows in Fig. 3. The water level has reach its maximum level at about 2 hours 28 minutes and 30 seconds of the simulation period with the flow (Q) as 155.90m^3/s and velocity (V) as 1.52m/s. Table below shows the dynamic plan view of the modeled study area.

At the end of simulation, the dynamic section view of the simulation result is shown in Fig. 4. From the simulation result, for the first hour of the simulation the water level was low and the flow was also low ranging from 19.98 m^3/s to 35.73 m^3/s with velocity ranging from 1.10 m/s to 1.95 m/s, but after 3 hours of simulation the water level was a little bit high at station 2, 3 and 4 and very high at station 1 with the flow ranging from 60.73 m^3/s and velocity from 1.33 m/s to 2.21 m/s.

Thus, at the end of the simulation, the water level for station 1 was very high and for stations 2 and 4 was very low. The stations were almost dry or shallow and flow was ranging from

60.51m^3/s to 99.99 m^3/s with velocity from 0.37 m/s to 1.94 m/s. The highest flow on Link 1 is at 04:50 with Q = 60.82 m^3/s and V = 1.78 m/s, at Link 2 with Q = 99.99 m^3/s and V = 1.94 m/s, at Link 3 with Q = 155.84 m^3/s and V = 1.51m/s and also at Link 4 with Q = 40.44 m^3/s and V = 0.15 m/s. Similarly, it can be seen that at Link 3 the flow is very high. The dynamic section view of all the stations is displayed in Fig. 4 and for station 1 is shown in Fig. 5.

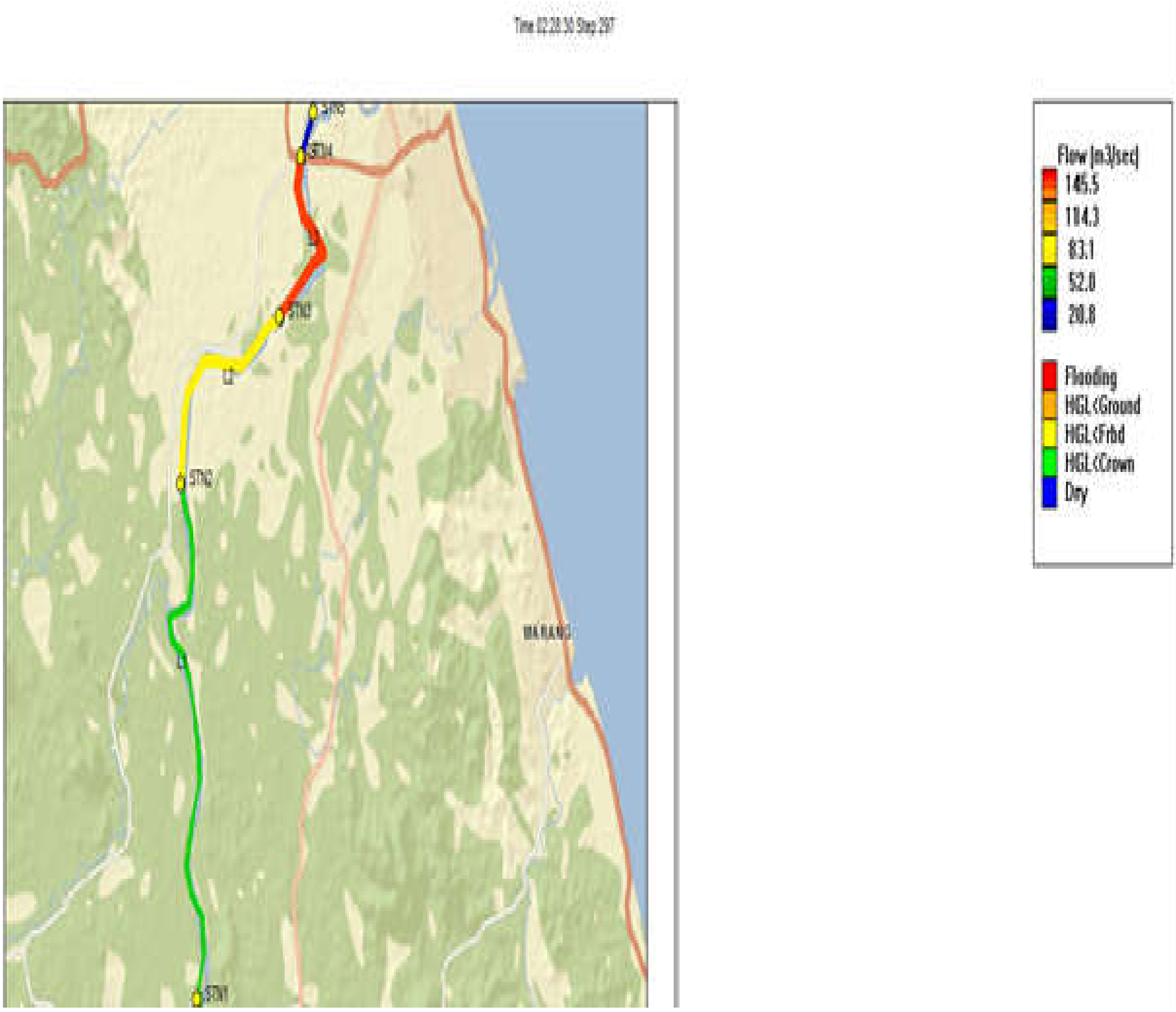

Fig.3. 1-D Dynamic plan view of study area during simulation

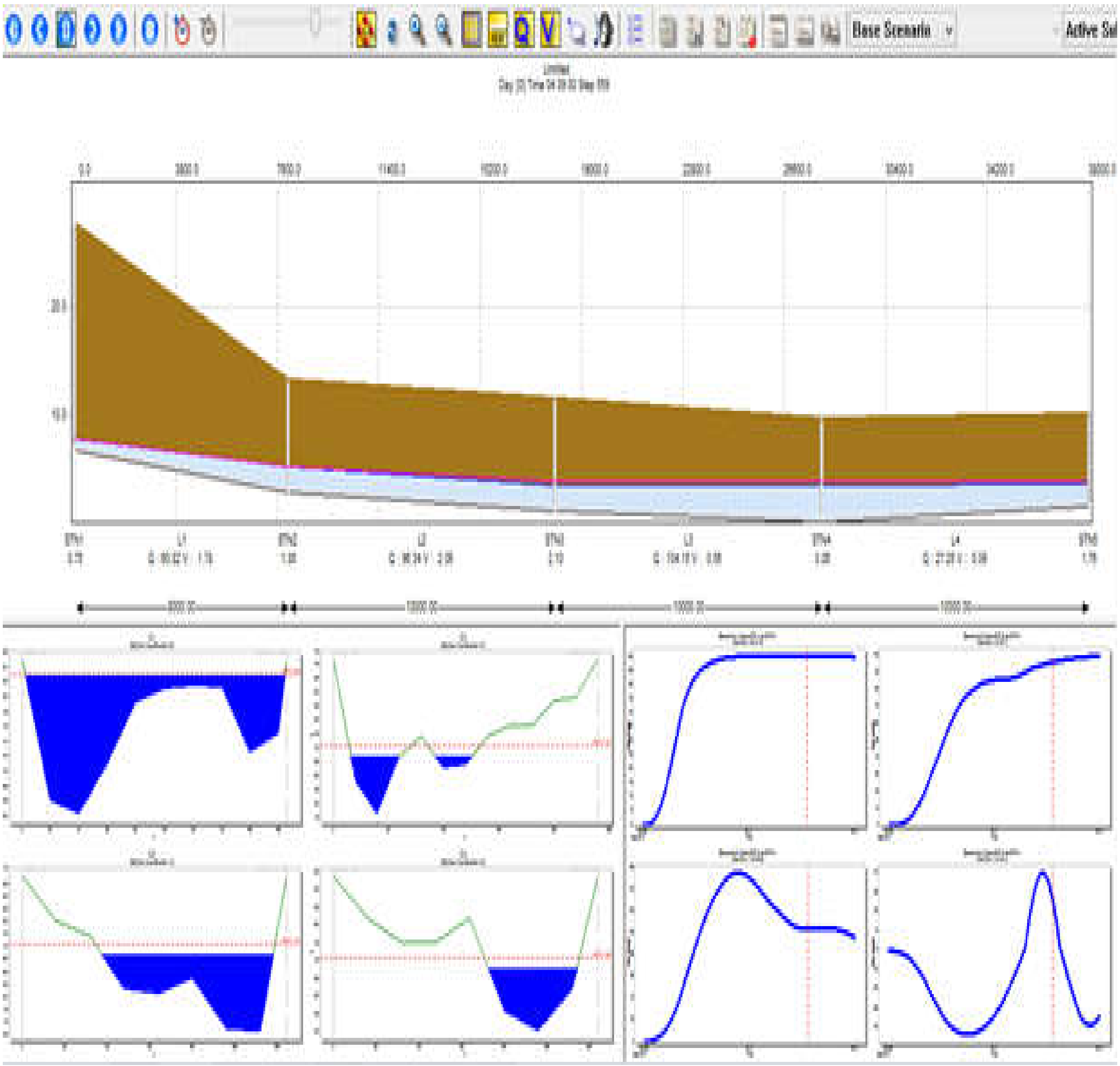

Fig.4. The multi-panel view of the simulation results

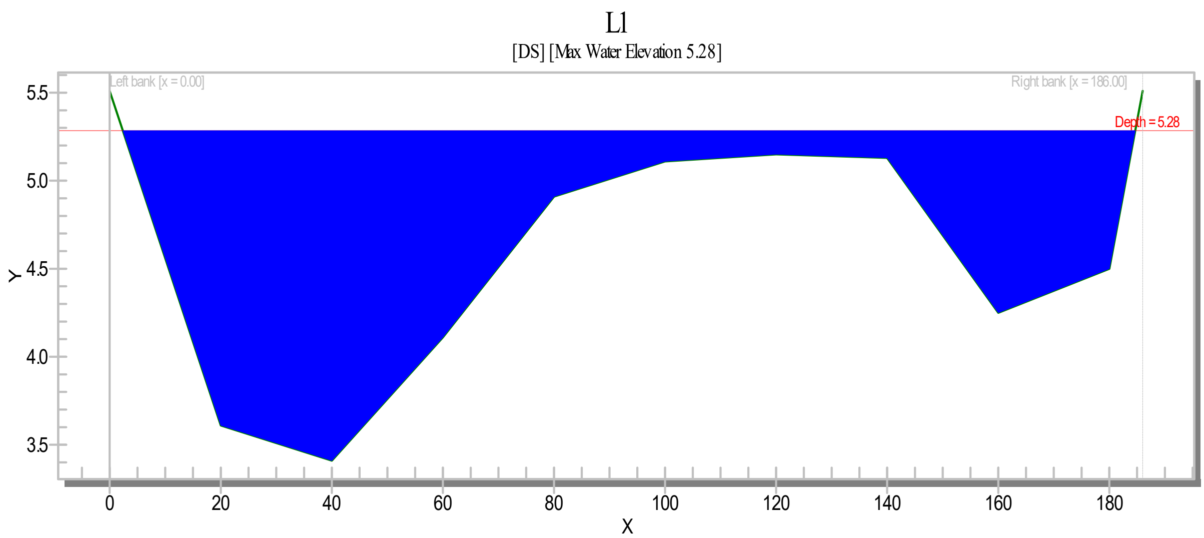

Fig.5. Cross section of the river after simulation on link 1

From Fig. 4 and 5, the red lines showed on the profile was the maximum depth water reaches during the simulation. From the simulation result, it can be observed that Link 3 have the highest flow value 155.84 m^3/s velocity of 1.51 m/s while station 4 have the lowest value of flow as 40.44 m^3/s with velocity of 0.15 m/s. From the results also clearly show that station 1 have highest water level. This is because the station 1 is at the upstream of the study area, whereas stations 2, 3 and 4 are almost dry and this is because they are at downstream of the study area. Fig. 6 shows the water level during site visit, which clearly indicate the water level was very low. Thus, there is no flood for this time of simulation.

Fig.6. Water level during sampling work

Thus, from the hydrographs we can also clearly understand that there is no flooding within the time of simulation. Fig. 7 shows review results of the hydrographs. Using review results to display the hydrographs for the simulation, the result shows that there is wide gap between the elevation and the water level which implies that the water level is very low. It is also clear that discharge and speed of the water reach their maximum peak within the first three hours of the simulation. Thus, after 3 hours of simulation, the discharge remains steady whereas the speed drop little bit and continues as steady.

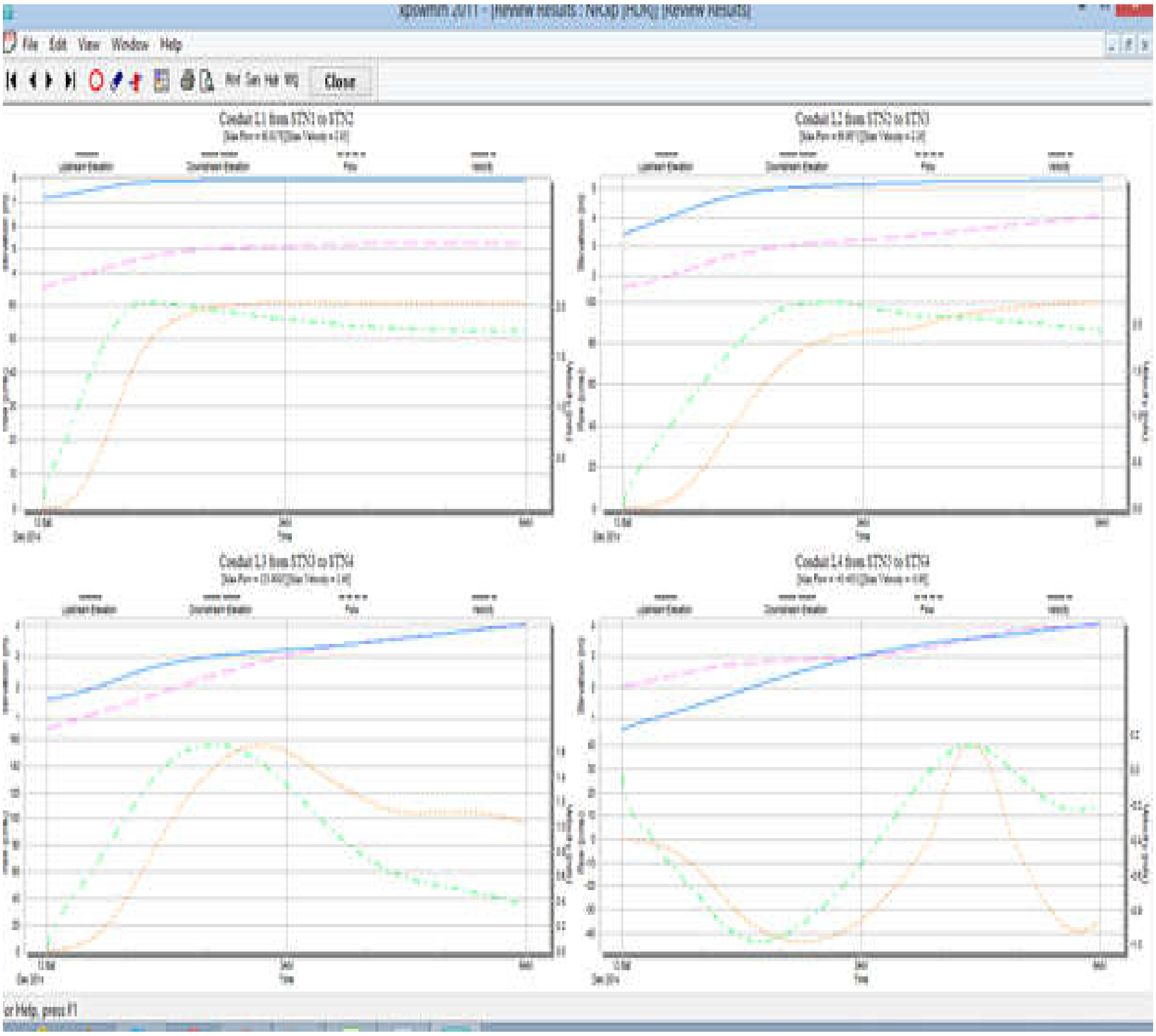

Fig.7. Hydrograph for the study area for the simulation time at Link 1 to 4

This clearly shows that the maximum water level for all the four links are below the elevation. This means that the flow and velocity of the water is not strong enough to reach the elevation level or to break the bank of the river. Therefore, we can see that there is no flooding within the simulation period 27 Nov 2014 [21].

3.2. Simulation During Raining Season

Northeast monsoon has brought excess rainfall at Terengganu at the end of 2012, Terengganu has been receiving heavy rainfall from November 2012 to January 2013 as shown from the data collected from JPS Kuala Terengganu. The highest daily rainfall has been recorded with amount of 434.0mm on 31 Dec 2012, and it is was the highest daily rainfall recorded for the past 5 years in Terengganu [22]. The hydrograph pattern of the stream flow for the past ten years 2002 to 2012 was modeled, and the Fig. 8 shown the hydrograph pattern for the study area.

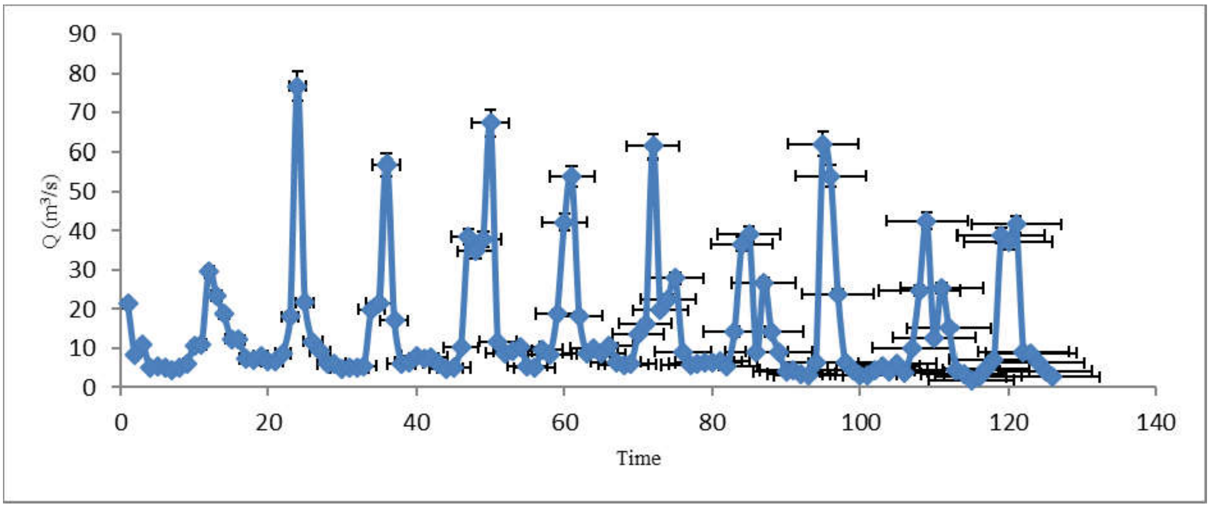

Fig.8. Hydrograph from 2002 to 2012

As it can be seen from the Fig. 9, the highest flow occurred between November and December 2003 with maximum average flow of 76.7m^3/s. Therefore, for the purpose of this work to simulate occurrence of flood, we also float a graph of November and December to find the highest fix flow of Terengganu River so as to enable our simulation for that particular time. Fig. 10 shows the hydrograph for November and December 2003.

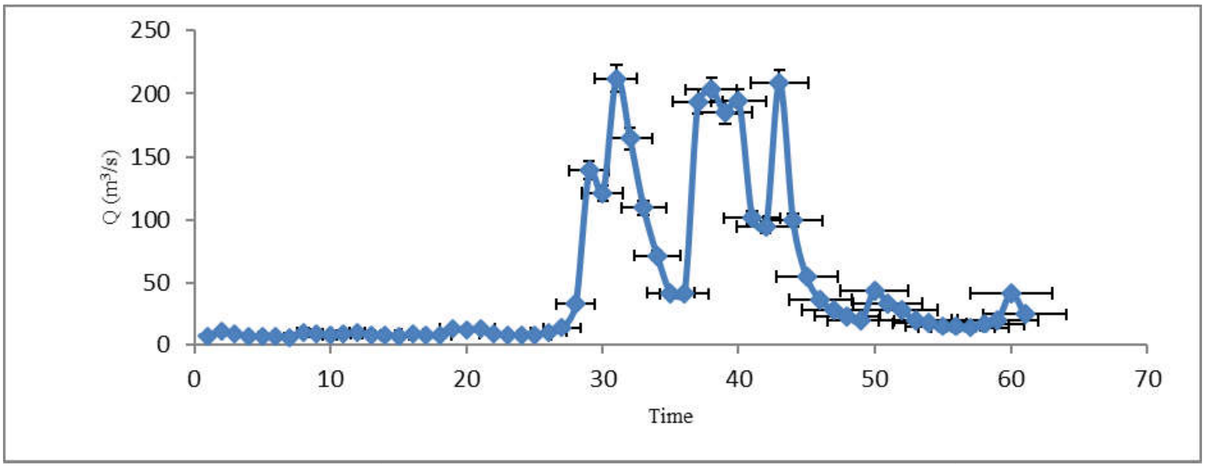

Fig.9. Hydrograph for the month of November and December 2003

From Fig. 10, we find out that the maximum flow was from 29th of November to 14th of December 2003 with the highest value of 212 m^3/s. Finally, the simulation was run within this period to find out whether or not flood occurs. Fig. 12 shows the multi panel view, 1-D dynamic plan view and also the hydrograph after the simulation. Also, the interpretations of the simulation results are presented.

The maximum flow was on the 1st day of the simulation at about 21:11:00 step 8302, and stay for the whole day until the next day of simulation. On the 5th day at about 13:08:00 step 15976, the water level was at the crown level until next day. Similarly, on the 6th day at about 22:26:00 step 19972, the water level was shallow and it was at dry level as indicated by the symbol during the simulation. After that, the level maintained at either freeboard or ground level until the 9th day of the simulation where the level was very high at about 09:55:00 step 27110 and also on the 14th day the water level rise up again.

It is clear from Fig. 10, 11 and 12 that there was no flooding for all the days of the simulation during the raining season. It can be noted that the water level has been risen up, but does not reach flooding level because throughout the simulation the water level was below the elevation.

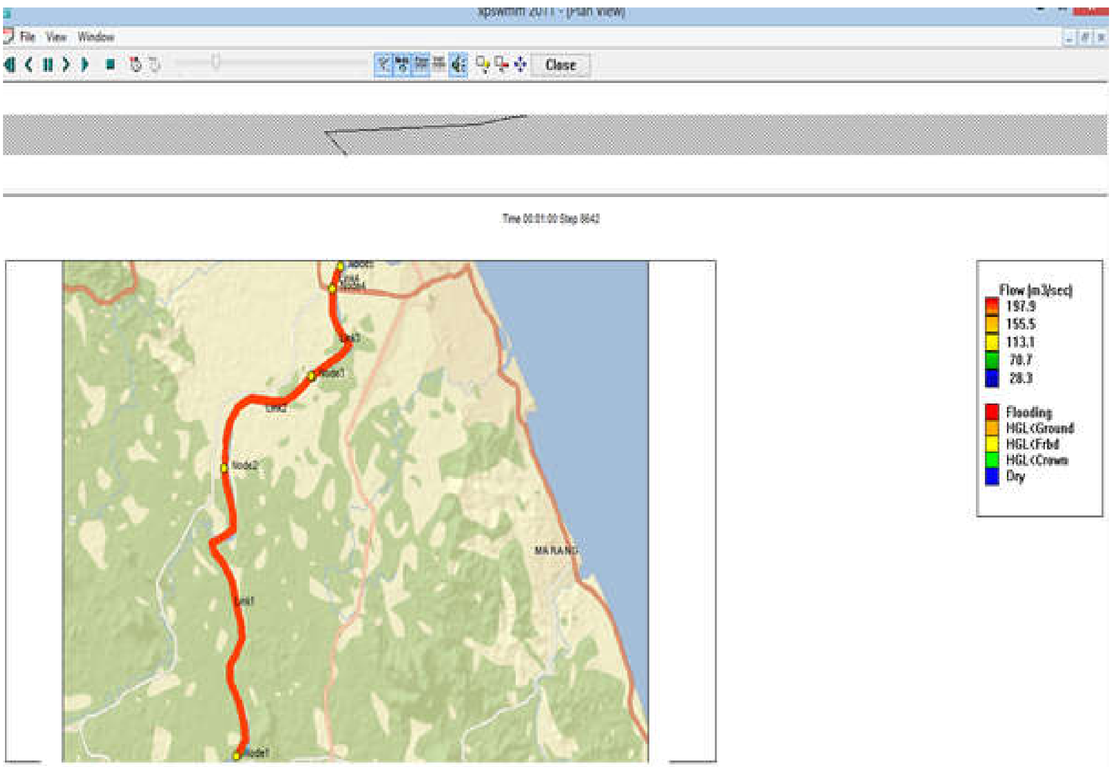

Fig.10. 1-D Dynamic plan view of study area during simulation

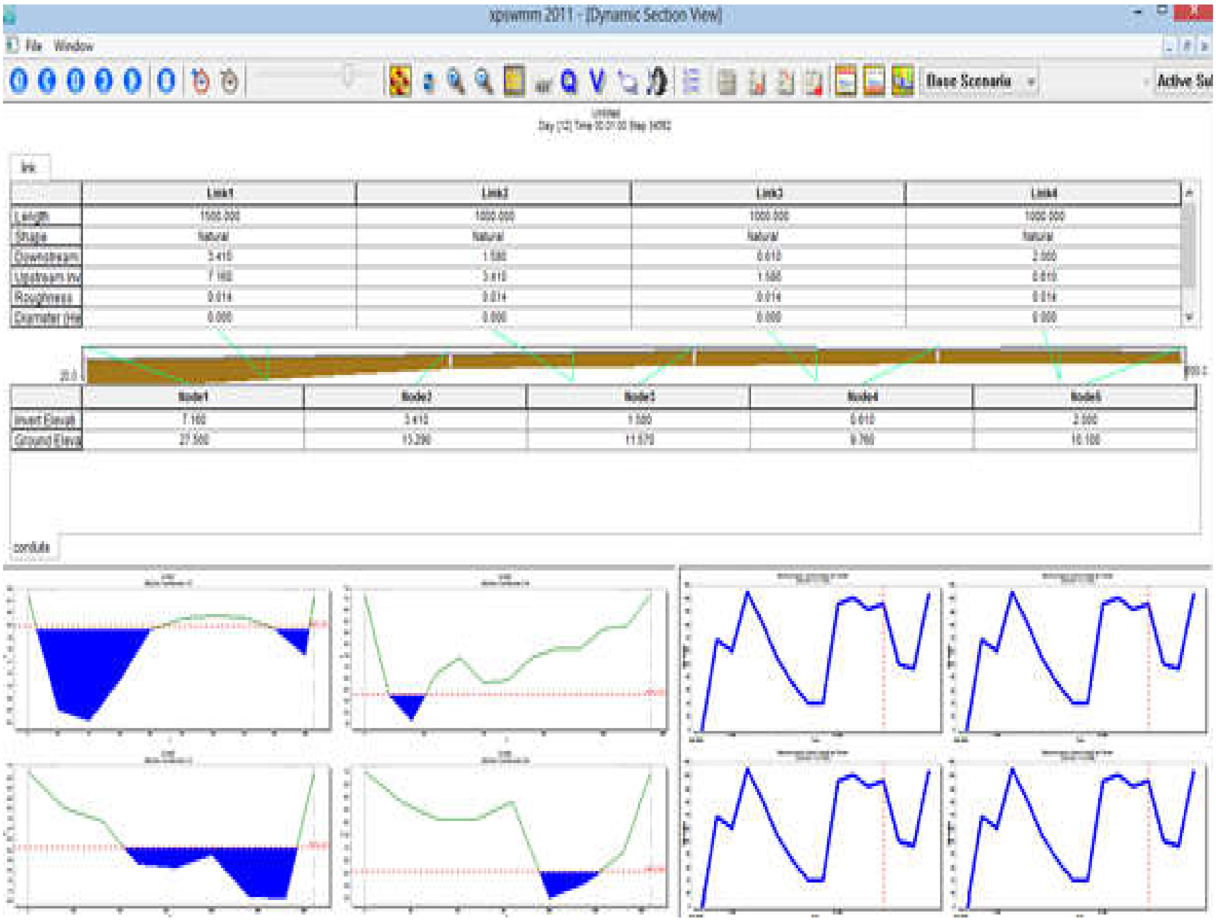

Fig.11. The multi-panel view of the simulation results

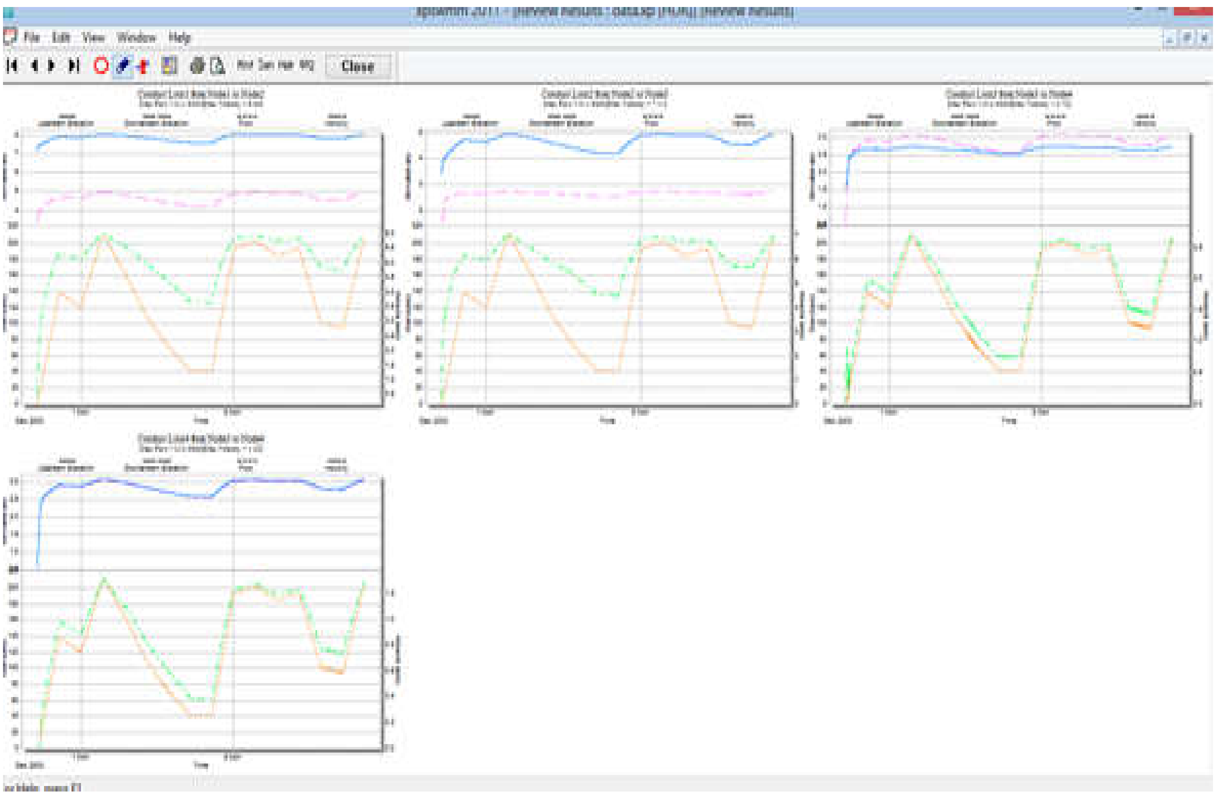

Fig.12. Hydrograph for November and December

4. CONCLUSION

Terengganu River was modeled using XP SWMM software, the simulation was carried out in two phase i.e. the dry season and rainy season in order to find out the occurrence of flood in the river. The data used comprised of primary data which was collected at the research stations and the secondary data collected from JPS. The reason of using two types of data was to use secondary data to validate the primary data. For the primary data, the simulation was conducted for six hours while for the secondary data we use 10 years data and it was observed that, the highest flow occur within November and December 2003. Therefore, the simulation was carried out only within the period that high flow observed which is from 29th November to 14th December. From the finding of this research, it was confirmed that the use of XP SWMM modeling software for Terengganu River is ideal.

The software is good for flood simulation for the study area, it can also be concluded that from the data available there has not been flooding in the study area for the past 10 years. From the primary data obtained during site visit, it was observed that there is decrease in the water level from the upstream to downstream as shown in Fig. 3, 4 and 11. It means that station 1 is almost filled up while the remaining stations 2, 3 and 4 are almost dry.

Fig. 6 confirmed that the water level at downstream in almost dry or shallow. It was also concluded that rainfall play a vital role in the occurrence of flood or not in the study area. This was also confirmed by Fig. 9 with maximum flow average of 76.7 m^3/s, and also Fig. 10 with maximum value of 212 m^3/s. Thus, this research finally concluded that there was no flood in the study area within the period of the simulation.

5. ACKNOWLEDGEMENTS

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