Application of a Rainfall-Runoff-Inundation (RRI) Model for the Kelantan River Catchment, Malaysia

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Abstract: The Kelantan River is the main river in Kelantan state, Malaysia. Rapid urbanization has resulted in the emergence of many environmental challenges in the Kelantan River Catchment especially floods along the Kelantan River. Northeast monsoon brings heavy rainfall to Kelantan and causes flood occurred annually. Floods have become the common and significant natural disaster in the state which caused many inconveniences and economic loss. This study is to apply the Rainfall – Runoff – Inundation (RRI) model in the catchment. Besides that, this study also aims to access the performance and applicability of the model to the catchment. The Kelantan River Catchment has experienced several major floods in the past and useful data that can be used for developing the model. For continue research, flood hazard map can be developed by using RRI model.

Keywords: Kelantan River, northeast monsoon, RRI model, flood hazard map.

1.   Introduction

Flood is an environmental hazard that happened every year in Malaysia especially on the east coast part of the country during the northeast monsoon. Historical records have shown that extensive damage on the human environment which caused by flooding are unavoidable (Jonkman and Kelman, 2005). Kelantan has exposed to the risk of monsoon flood every year during the northeast monsoon season (November to February). The northeast monsoon usually brings heavy and long duration rainfall to east coast state. Moreover, due to rapid urbanization, unplanned deforestation and closeness to the South China Sea, flood issue is getting serious, such as event happened on December 2014. Flood caused property damages and loss of lives. Report from Malaysia National Security Council stated that damage resulting from the flood was estimated at RM 1 billion (approximately USD 300 million) for north and eastern part of Malaysia. Damage in Kelantan state alone estimated about RM 200 million. The main objective of this research is to access the performance of RRI in the Kelantan River Catchment. Besides that, the applicability of RRI model in Kelantan River Catchment also one of important factors need to investigate.

2.   Methodology

2.1   Study area

The Kelantan River is the main river in Kelantan. Its catchment area is about 13100 km^2 which occupying almost 85% of the state (Syed Hussain & Ismail, 2013). The origin inlet point of Kelantan River is from Ulu Sepat Mountain, and the discharge point is the South China Sea. The length of the river is about 284 km long where the main tributaries are Lebir River (2500 km^2) and Galas River (8000 km^2) (refer to Fig. 1a) (Ibbitt et al., 2002). The average width of the River Kelantan is between 180 to 300 m. From the total catchment area, approximately 95% is dominated by steep mountainous country (mostly covered with virgin jungle) rising to a height of 2,135 m while the remainder is undulating land (refer to Fig. 1b).

2.2   RRI simulation

RRI model is a two-dimensional model which can use for rainfall-runoff and inundation simulation. RRI model can simulate for flood extent by using different conditions of surface and sub-surface flow. RRI also deals with the lateral subsurface flow in mountainous areas and infiltration in flat areas separately. For a detailed explanation of RRI please refer to the literature (Sayama et al., 2012). Data that used as input is 15 arc-second HydroSHEDS Digital Elevation Model (DEM) and rainfall data and discharge data from Department of Irrigation and Drainage (DID). The simulations are conducted in two different conditions which are only with overland flow and with vertical infiltration plus infiltration excess overland flow.

3.   Results and Discussions

RRI simulation results showed the flood inundation extent closely to the actual event (refer to Fig. 2). In the scenario of only overland flow (no infiltration loss and no subsurface flow), discharge hydrograph showed an overestimate trend compared to the actual monitoring (refer to Fig. 3). However, in the scenario of vertical infiltration plus infiltration excess overland flow, discharge hydrograph showed a lower discharge peak compared to the only overland flow scenario. At the same time, by comparing the second simulated results to the actual monitoring, discharge hydrograph showed a closer trend. The discharge hydrograph can be explained that in only overland flow scenario, there is no any infiltration take in consider, therefore all the water will flow into the river, and overflow occurred while the discharge exceeded the capacity of the river.

4.   Conclusions

In the conclusion of this study, RRI showed a good performance in a mountainous area or hillslope catchment and high applicability. Thus, RRI can be used for developing flood hazard map in Kelantan River Catchment.

References

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Syed Hussain, T., & Ismail, H. 2013. Flood Frequency Analysis of Kelantan River Basin, Malaysia. *World Applied Sciences Journal, 28 (12)*, 1989-1995. doi:10.5829/idosi.wasj.2013.28.12.15
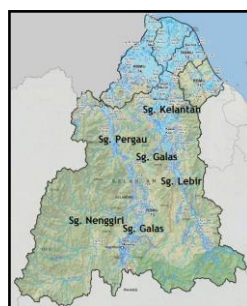
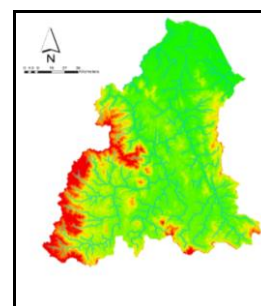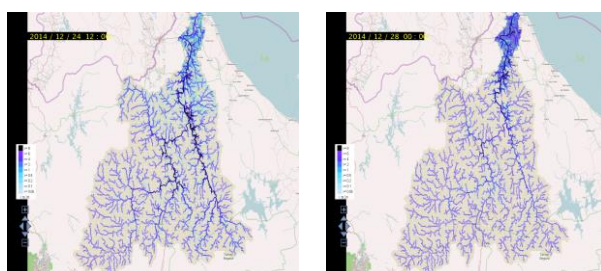| Fig. 1a River channel in Kelantan River Catchment | Fig. 1b Topography of Kelantan state |

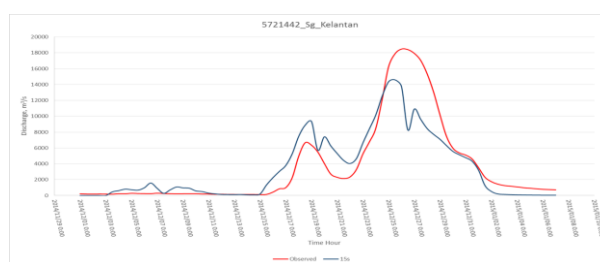Fig. 2 Flood inundation extent simulated by RRI

Fig. 3 Simulated discharge hydrograph and monitoring discharge hydrograph