International Journal of Engineering & Technology, 7 (4.35) (2018) 323-326

International Journal of Engineering & Technology

Website: www.sciencepubco.com/index.php/IJET

Research paper

Sensitivity Analysis of Storm Duration for Development of Flood Map at Bertam Catchment, Cameron Highlands.

W.N.C.W. Zanial[1]*, M.A.Malek[2], N.A.A.Aziz[3]

[1 3] Department of Civil Engineering, Universiti Tenaga Nasional, Selangor, Malaysia.
[2]Institute of Energy Policy Research (IEPRe), Universiti Tenaga Nasional, Malaysia.
**Corresponding Author E mail: wnorsyuhada@yahoo.com*

Abstract

The current changes in climate have marked significant impacts in our daily weather. The changes have affected the trend, pattern and magnitude of rainfall-runoff as compared to the events commonly experienced. Flood is one of the effects of weather and climate change. Floods can be classified as one of the most devastating natural hazards and is a major concern to the country as it causes damages to human lives, environment, agriculture, land and structures. Therefore, effective flood planning and mitigation measures should be carried out in order to reduce the effects of flooding. Flood hazard map is one of the non-structural mitigation measures that can be used for planning purposes. Flood can be directly estimated or derived from frequency analysis when long duration of stream flow records is available. However, in the case of limited or no stream flow data available, design storm are generally used to estimate design flood. Downstream of Bertam Catchment is an ungauged river station where no flow records are available. Based on this limitation, in this study, design storm was used to design the flood map. Info Works RS was used to develop the flood model and sensitivity analysis of the design storm was performed. Results obtained in this study presented the comparison of flow between 100-years Annual Recurrence Interval (ARI) at various storm durations of 0.25hr, 0.5hr, 1hr, 3hrs, 6hrs, 12hrs, 1 day, 2days and 3 days. The maximum flow is found to be at 6hrs storm duration at 1103.418m^3/s. Besides river flow, comparison of water level at 100-year ARI of various storm durations was also conducted. Results obtained from this study found that 24hrs storm duration will produce the highest water level at 1034.753m. By comparing the flow and water level, the result from river flow produces the maximum at 6hrs storm duration while the result of water level gives the maximum at 24hrs storm duration. Since, water level is preferable in producing flood hazard mapping at 2-D view, therefore, the storm duration is chosen based on results of sensitivity storm duration on water level conducted. Comparison is then conducted between 24-hrs storm duration at various ARIs. It can be concluded that 100-years ARI will lead to the maximum value of 1034.910m water level. Suitable storm duration and Annual Recurrence Interval (ARI) are to be determined in order to produce the best flood hazard map. In this study, it is found that 100-years ARI and 24hrs storm duration are the best combination, performed based on water level.

Keywords: *Flood hazard map, sensitivity analysis, storm duration, Info Works RS*

1. Introduction

Flood is one of the most serious disasters that cause damages to human lives, environment, agriculture and land. It has become a major concern since the consequences of flood affected the economic, lives and properties. During flood, river discharges are carried by the main river channel and flood plain located at its side. When flood with a peak flow larger than mean annual flood occurs, part of the over bank area will then be flooded [1]. For plantation, floods will destroy the entire plantations and disrupts the overall management of the plantation schedule. The situation is further aggravated by the fact that rainfall is also very difficult to measure at scales of interest to hydrology and climatologic. Measurement of rainfall at a single rain gauge is not an easy task to estimate since half of the total error in short-range rainfall forecasting is due to measurement errors [2].

In the last few decades, Malaysia has experienced major flood events. As in year 1886, extensive damages were experienced in the state of Kelantan due to continues and heavy rainfall accompanied with strong wind. 1926 is the year of the worst flood that occurred in Malaysia and it affected most of the states in Peninsular Malaysia. Than the floods in year 1967 and 1971 resulted to loss of lives and caused great economic damages to properties and crops. The main causes of these floods were generally due to increased runoff rates as results of rapid urbanization. In order to deal with this unforeseen phenomena, the Malaysia government has taken several initiatives such as the establishment of Permanent Flood Control Commission, setting up of flood disaster relief machinery, carrying out various river basin studies and preparation of drainage master plan for major towns, implementation of structural and non-structural measures, established flood forecasting and warning systems and setting up a nation-wide network of hydrological and stations for flood data collection [3]. In October 2013, a flood tragedy occurred at downstream of Bertam Catchment, Cameron Highlands. The latest worst flood tragedy was at Kelantan in December 2014. The tragedy has destroyed many lives, properties and damages almost all the state's developments. In this case, flood mapping is one of the important non-structural measures in flood mitigation that can be used to raise awareness. In this study, Info Works RS is used to develop and calibrate the flood model.

Copyright © 2018 Authors. This is an open access article distributed under the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

2. Study Area

Bertam Catchment is located at Cameron Highlands with catchment size of approximately 108.148 $km^{2.}$ It is considered as small catchment with short river reach. The area is mountainous and is considered as a developing rural area [4]. Upstream of this catchment has six rainfall stations available; nevertheless, the downstream of this catchment is an ungauged river basin with no river flow data available. Land use of this area included roads, buildings, municipal utilities, vegetable and floriculture farms, grass idle and weeds, forest and clearings. In this study, the catchment was delineated into 29 sub-catchments using Geographical Information System (GIS) as shown in Fig. 1.

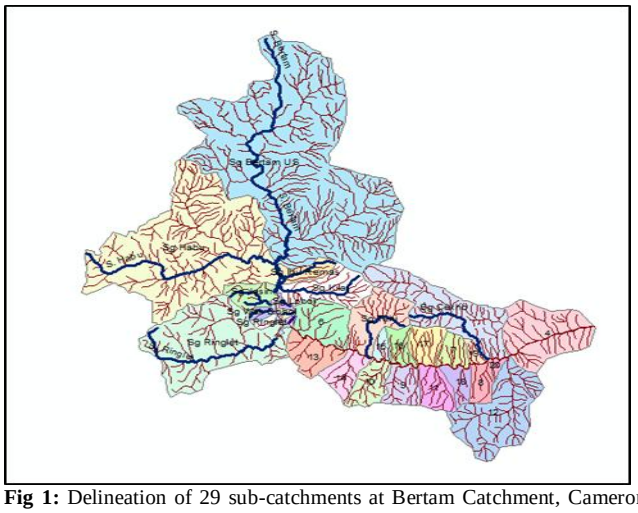


Fig 1: Delineation of 29 sub-catchments at Bertam Catchment, Cameron Highlands

3. Flood Hazard Map

Flood hazard map is a map that shows the potential flooding areas based on three probabilities namely low, medium and high. Flood hazard map is considered a non-structural mitigation measure and is beneficial to the local communities. It is a combination of various flood parameters that produces danger levels such as depth and velocity. The information from flood hazard map is represented by various color scheme used. The flood hazard map can be used as a planning tool, to create awareness on emergency responses. The data required to produce flood hazard map include catchment characteristics, river alignment, river cross-section, 3-D elevation model, satellite image, aerial photo, land use and soil types. The resulted output will be the estimated flooded areas produced based on the probability, flood depth, flow velocity and propagation of waves. The advantages of flood hazard map are the information provided on potential flood damages, warning of flood occurs, disaster prevention, and safety [5]. Flood hazard map is also important for economic, social development as it minimizes the risk of losses due to damages of property, crops, injury, human life and infrastructure. Hence, the minimization of these damages can reduce the amount of compensation to the flood victims.

Flood hazard map is not static but is dynamic in nature. The map needs to be updated on a regular basis due to several conditions such as changes in physical characteristic of the watershed which includes the land cover, construction of dams or other construction projects that alter the river flow regime. Changes in rainfall also alter the runoff hydrograph of the river basin [6]. In this study, Info Works RS was used to develop the flood hazard map at Bertam Catchment. However, before developing the flood map; a sensitivity analysis of storm duration was carried out in order to find the most suitable storm duration and the highest water level. This is to ensure the accuracy of flood map produced.

4. Model Development

In this study, GIS is used to delineate the study area into several sub-catchments which includes land cover, existing road, river, contour, and land use. Data file named shape file in GIS (.shp) is required for data to be exported into Info Works software. The combination of hydraulic, hydrologic and GIS tools is a must for this model development. Water level predicted by the hydraulic and hydrologic models will then be exported to GIS in order to produce the flood extends. Hydrological analysis conducted included the determination of IDF curves, Time of concentration (Tc) and CN number where catchment and cross-sections were imported into Info Works software. Hydrological data such as rainfall, Tc, CN number, area of sub catchments and initial condition was then keyed in into the model. There are several methods that can be used to determine Tc such as Williams (1922), Kirpich (1940), California Culvert Practice (1955), U.S Soil Conservation Service (1975,1986), National Resources Conservation Service (1997), SCS lag equation (1973), work proposed by [7] and [8]. However, in this study Tc from SCS lag equation (1973) was chosen based on the suitability of the catchment area. CN Number was also determined based on land use of the catchment area and was calculated using the weightage average. Table 1 shows the CN values used in this study.

Table 1: CN values.

Landuse	Area (m^2)	Coefficient	CN Number	Weightage Average
Road	279426.003	0.008337069	89	0.741999146
Municipal land Utilities	2239519.686	0.06681923	88	5.880092211
Vegetables farms/ Floricultural	3584783.87	0.106957085	71	7.593953012
Tea	2129360.751	0.063532482	71	4.510806251
Weeds	1338.17686	3.99264E-05	58	0.002315731
Forest	25281667.07	0.754314208	65	49.03042351
TOTAL AREA	**33516095.55**			**67.75958986**

In simulating the model, point rainfalls were converted to areal rainfall using Thiessan Polygon method into Info Work RS. The hydrograph will be generated by Info Works after all the required data were keyed in. Fig. 2 shows the example of hydrograph generated at one of the sub-catchment. The red line represented unit hydrograph and black line is the hydrograph. The peak value of hydrograph is found at 280 m^3/s and for unit hydrograph, is approximately 160 m^3/s .

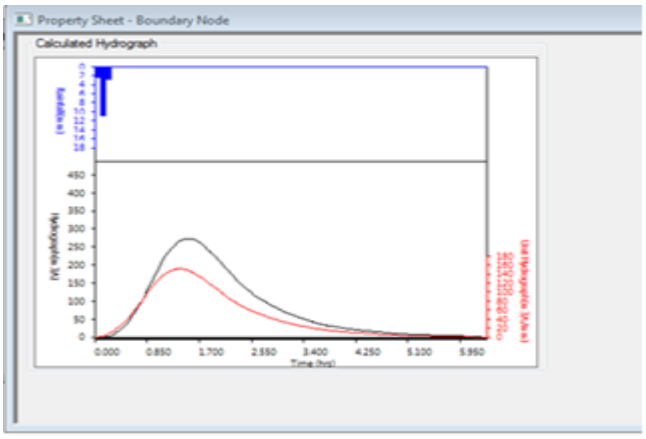
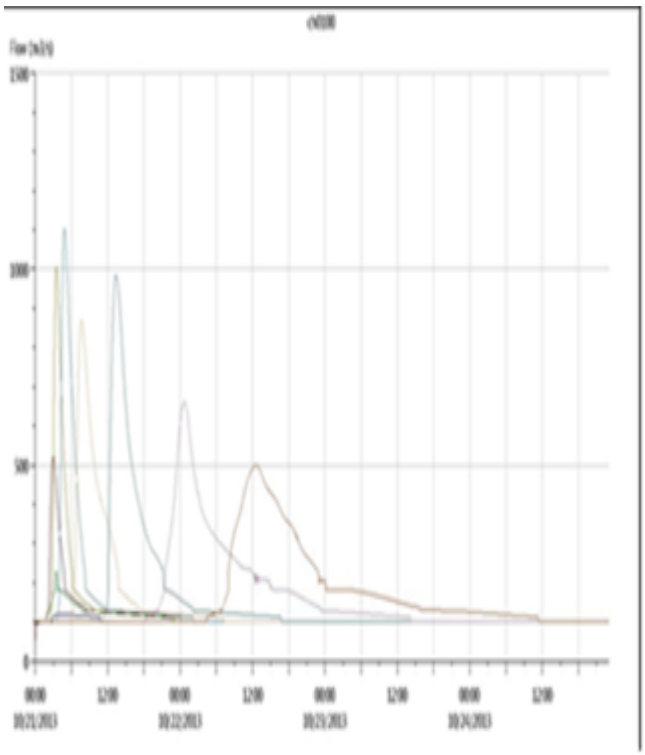


Fig 2: Hydrograph generated by Info Works RS

5. Results and Discussion

Prior to the design of flood and construction of the flood hazard map, storm duration is one of the important aspects to be analysed. Flood can be estimated or derived from the frequency analysis when long duration of stream flow data is available. Frequency analysis is a frequency of occurrence or magnitude of an extreme event. It is used to relate magnitude of extreme events to their frequency of occurrence by using probability distributions. However, in the case of limited or no stream flow data available, design storm is generally used to estimate the design flood [9]. Figure 3 shows the comparison of flow at 100-years Annual Recurrence Interval (ARI) for various storm durations of 0.25hr, 0.5hr, 1hr, 3hrs, 6hrs, 12hrs, 1 day, 2days and 3 days.

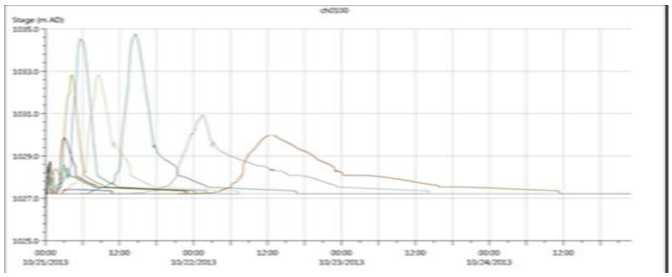


Legend	Flow	
	Min	Max
Design Rainfall 100ARI 1min>100ARI 0.25Hrs	6.0	119
Design Rainfall 100ARI 30min>100ARI 0.5Hrs	6.0	227
Design Rainfall 100ARI 1hr>100ARI 1Hr	6.0	523
Design Rainfall 100ARI 3hr>100ARI 3Hrs	6.0	1005
Design Rainfall 100ARI 6hr>100ARI 6Hrs	6.0	1103
Design Rainfall 100ARI 12hr>100ARI 12Hrs	6.0	869
Design Rainfall 100ARI 24hr>100ARI 24Hrs	6.0	984
Design Rainfall 100ARI 48hr>100ARI 48Hrs	6.0	661
Design Rainfall 100ARI 72hr>100ARI 72Hrs	6.0	498

Fig 3: Comparison of flow for 100-years ARI at various storm durations

Based on Fig. 3, results of flow at 100-years ARI for various storm durations exhibited that the maximum flow is at 6 hours (hrs) storm duration with 1103.418m^3/s. It was then followed by 3hrs storm duration with flow of 1005.367m^3/s, 24hrs storm duration with flow of 983.98, 12hrs storm duration with flow of 869.205, 48hrs storm duration with flow of 661.194, 1hr storm duration with flow of 522.65, 72hrs storm duration with flow of 497.973, 0.5hr storm duration with flow of 226.782 and 0.25hr storm duration with flow of 118.847.

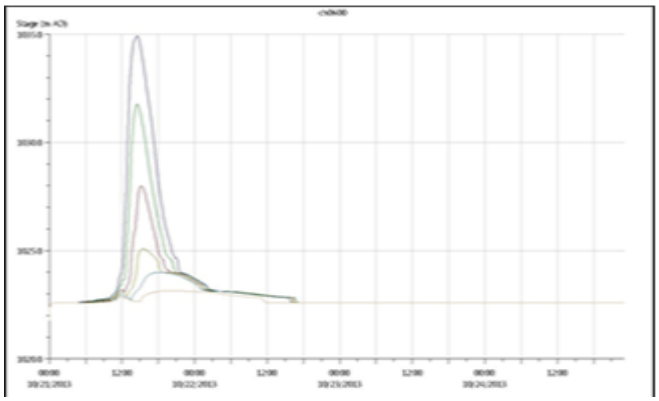
In addition to river flow, the comparison of water level is shown in Figure 4 at 100-year ARI with the same storm durations as in Fig. 3.



Legend	Stage	
	Min	Max
Design Rainfall 100ARI 1min>100ARI 0.25Hrs	1025	1028
Design Rainfall 100ARI 30min>100ARI 0.5Hrs	1025	1029
Design Rainfall 100ARI 1hr>100ARI 1Hr	1025	1030
Design Rainfall 100ARI 3hr>100ARI 3Hrs	1025	1033
Design Rainfall 100ARI 6hr>100ARI 6Hrs	1025	1034
Design Rainfall 100ARI 12hr>100ARI 12Hrs	1025	1033
Design Rainfall 100ARI 24hr>100ARI 24Hrs	1025	1035
Design Rainfall 100ARI 48hr>100ARI 48Hrs	1025	1031
Design Rainfall 100ARI 72hr>100ARI 72Hrs	1025	1030

Fig 4: Comparison of water level for 100-years ARI at various storm durations

Fig. 4 shows the results of water level compared at various storm durations. Based on this result, it was found that 24hrs storm duration produced the highest water level at 1034.753m with minimum value shown as the initial condition. Then, the second highest water level is at storm duration of 6hrs at 1034.535m followed by 12hrs at 1032.822m, 3hrs at 1032.822m, 48hrs at 1030.936m, 72hrs at 1029.977m, 1hr at 1029.863m, 0.5hrs at 1028.641m and 0.25hrs at 1028.569m. By comparing the flow and water level, it was found that the maximum flow is at 6hrs storm duration, while results obtained from water level showed that the maximum is at 24hrs storm duration. However, results based on water level are preferable in simulation of flood hazard map in order to produce 2-D flood map. Hence, the storm duration is chosen based on results obtained from sensitivity storm duration at the chosen water level. Therefore, in this study, 24hrs storm duration that produced the maximum water level was chosen as the best storm duration. Then, comparison was made between the 24-hrs storm duration and various ARIs used namely, 100-years ARI, 50-years ARI, 20-years ARI, 10-years ARI, 5-years ARI and 2-years ARI. Figure 5 shows the comparison between 24hrs storm duration and various ARIs used in order to find the best combination.



Legend	Stage	
	Min	Max
Design Rainfall 100ARI 24hrs>100ARI 24Hrs	1022	1035
Design Rainfall 50ARI 24hrs>50ARI 24Hrs	1022	1032
Design Rainfall 20ARI 24hrs >20ARI 24Hrs	1022	1028
Design Rainfall 10ARI 24hrs >10ARI 24Hrs	1022	1025
Design Rainfall 5ARI 24hrs> 5ARI 24Hrs	1022	1024
Design Rainfall 2ARI 24hrs >2ARI 24Hrs	1022	1023

Fig 5: Comparison of water level for 24hrs storm duration at various ARI

Results exhibited at Figure 5 showed that 100-years ARI has the maximum value of 1034.910m water level, followed by 50-years ARI at 1031.743m, 20-years ARI at 1028.042m, 10-years ARI at 1025.653m, 5-years ARI at 1024.630m and 2-years ARI at 1024.021m.

6. Conclusion

The novelty of performing sensitivity analysis of storm duration for the development of flood map at Bertam Catchment, Cameron Highlands is pertinent since sensitivity analysis on storm duration conducted produces the suitable storm duration and annual recurrence interval (ARI) required in order to determine the best flood map. In this study, 100-years ARI and 24hrs storm duration are the best combination obtained based on water level simulation. Analysis of flow and water level produced different results, however by considering the priority required in flood map, water level is more critical as compared to river flow. On the other hand, comparison of various ARIs shows that 100-years ARI produced the highest water level among others. Therefore, it is concluded that further hydrological analyses conducted at Bertam catchment is to be preceded at 100-years ARI and 24hrs storm duration.

Acknowledgement

This study is financially funded by Malaysia Ministry of Education (MOE) - FRGS Grant, Project Code: FRGS/2/2014/TK02/UNITEN/02/2.

References

[1] Roberson, Cassidy, Chaudry, "Hydraulic Engineering. New Jersey: Houghton Mifflin". 1988.
[2] M.A.Malek, "Rainfall Data In-Filling Model with Expectation Maximi zation and Artificial Neural Network". PhD Thesis. Universiti Teknologi Malaysia. 2008.
[3] Department of Irrigation and Drainage, "Managing the Flood Problem in Malaysia". 2013.
[4] Zakaria, N., Jahaya, M., Ying Ying, T., Abdul Rahman, M., and Mohamad, M., "The Analysis of Dry Deposition of Acidifying Substances between Urban and Developing Rural Stations of Malaysian Meteorological Department from 2007-2010". Malaysia: Malaysian Meteorological Department and Ministry of Science, Technology and Innovation. 2013.
[5] Sam, W., Zulkifli, M., Seng, C., "Flood Mapping as A Planning and Management Tool". Putrajaya. 2012.
[6] Cooper, V., and Opadeyi, J., "Flood Hazard Mapping of St.Lucia". Carribean. 2006.
[7] Ming Han, L., Paramjit, C., "Overland Flow Time of Concentration on Very Flat Terrains". Journal of The Transportation Research Board, 133-140. 2008.
[8] Natural Resources Conservation Service, "National Engineering Handbook. United State: United States Department of Agriculture". 2010
[9] Viglion, A., Bloschl, G., "On the role of storm duration in the mapping of rainfall to flood returns period". Hydrology and Earth System Sciences, 205-216. 2009