An Overview: Flood Catastrophe of Kelantan Watershed in 2014

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Abstract One of the challenging topics in Malaysia is flood occurrence, which have important impacts in human life and socioeconomic subjects. Malaysia, periodically, have faced with huge floods since previous years. Kelantan river basin, which located in the northeast of Peninsular Malaysia, is prone to flood events in Malaysia. Kelantan River has been badly affected with flood during recent monsoon season on December 2014 due to heavy monsoons rainfall and climate change issues. In this study, available rainfall and water-level data are analyzed and presented based on the flood event on December 2014. Generally, the flood area affected includes the districts of Kota Bharu, Kuala Krai, Machang, Pasir Mas, Pasir Puteh, Tanah Merah, Gua Musang, and Tumpat at Kelantan State. In the northeast monsoon season, the Kelantan State suffers from two phase of flood. The first phase began on December 14–17, 2014, and the second phase occurred on December 20–24, 2014. A comparison between accumulated rainfall on December and whole year of 2014 at Gagau station shows that contribution of rainfall on December is roughly 50 % of all of 2014. Overview of water-level results at Kelantan watershed shows that all areas are involved with highest record in 2014 in comparison with previous decades except Golok area. Results of water-level ranges show that most of the parts of Kelantan watershed are involved with over danger values for flood in 2014, which Lebir and Kelantan rivers have high increasing. In conclusion, it is suggested that there is a need to have study on flood mitigation and recognition of critical hydrological phenomena for sustainable strategies in Kelantan watershed. Consequently, this research provides primary information as baseline study for upcoming research for water resource management projects.

Keywords Flood · Rainfall · Kelantan · Water level · Malaysia

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1 Introduction

Natural disasters happened every year and their impact seem to have greatly increased in recent decades, mostly because of environmental degradation, deforestation, intensified land use, and the increasing population [1]. Climatic events such as heavy rainfall and floods usually rise upon the arrival of monsoonal season in the eastern part of Peninsular Malaysia. Usually, rainfall is the main factor of flood event and other main that gives rise to main contributory factors might be intensity and duration of rainfall, the wetness of the ground, and the response of the rainfall catchment. Moreover, flood events are controversial natural disaster owing to human and economic losses to the country. Flood has caused considerable financial damages to roads, highways, villages, agriculture, and livelihood. Some of the human actions that have contributed to the event are deforestation and squatters' residence location that was built along riverbank. Besides, other structural component such as most of the drainage pipelines that were old designed is also one of the contributions to this flood event [2]. Furthermore, Sani [3] investigated case study of one of the most extreme flood events occurred at Kelantan river basin during flood event 1967. Sani [3] also discussed about the "six factors" that reasoned the contribution to 1967 flood such as the unusual heavy rain, the closing up of the Kelantan estuary by sand bars, the very low ground level along main riverbanks, the poor conditions of the various drainage systems, the small tidal range along the Kelantan coast and finally the indiscriminate developments of the upper reaches of the river and throughout its catchments resulting in rapid runoff from the hills and heavy silting in the rivers. The magnitude of the flood impacts that resulted about 84 % of the population and at least about 125,000 people were affected and had to be evacuated during the 1967 flood [3].

Moreover, the condition of precipitation in Malaysia is greatly under the influence of monsoon. There are typically three phases of monsoon seasons that Malaysia undergoes in a year such as the southwest monsoon, northeast monsoon, and transitional monsoon. Southwest monsoon starts from the mid of May or early of June and ends in the end of the September. Meanwhile, northeast monsoon starts from early of November and ends in the end of the March. For the transitional monsoon, it starts from the mid of September and ends in the end of the October. Furthermore, in this modern highly risk societies, it is not peculiar to define "extreme" hydrological events in higher recurrence intervals of more than 100 ARI [4]. Average recurrence interval (ARI) is the average or expected value of the periods between exceedances of a given rainfall total accumulated over a given duration. It is implicit in this definition that the periods between exceedances are generally random [5]. Average recurrence interval (ARI) is one of the critical elements in water resource management and are calculated or projected with the assumption of a stable and stationary climate and the stationarity assumption requires that the mean and variance of climatic conditions do not change over time [6].

There are a few of rainfall and stream flow stations in the catchment area including telemetry devices as shown in Fig. 2. In this study, application of chronological information and primary analysis on past hydrometeorological extreme events such as rainfall and flood is presented. The hydrometeorological data required for this study were collected from the Department of Irrigation and Drainage (DID) Malaysia from 1965 to 2014 [7].

2 Materials and Methods

2.1 Case Study

Kelantan is located at the eastern region of peninsular Malaysia shown in Fig. 1. Kota Bharu is the capital of Kelantan as well as the growth development in North Kelantan. The area of Kelantan State is of 15,099 km^2 which is equivalent to 4.4 % of Malaysia's area [8]. The population of Kelantan State is 1.539 million [2], and Kelantan river basin has annual rainfall of about 2500 mm and most of rainfall during northeast monsoon events that is between mid-October and mid-January. Kelantan river basin has four main tributaries, namely Galas, Nenggiri, Lebir, and Pergau. The length of the Kelantan River from the upstream to downstream is 388 km and drains area about 13,000 km^2 occupying more than 85 % of the Kelantan State [9]. The Kelantan River is approximately 105 km, and it includes Lebir and Galas rivers at Kuala Krai. Kelantan River passes through the several urban areas, namely Kuala Krai, Tanah Merah, and Kota Bharu. Downstream of Kelantan River has a population around 0.5 million which can be in a medium level of population. Roughly, population density (ppl) in the urbanized most downstream area is exceeding 20,000 ppl/km^2 [3, 10]. Figure 2 shows the river network of the Kelantan basin and location of hydrological stations. Based on previous rainfall records, Kelantan River is potential to have severed flood frequently. Therefore, study on flood events and attributed research are required as baseline in Kelantan River such as flood early warning system because evaluation of Kelantan River based on hydrological and flood studies offer to provide sufficient time for the authorities to evacuate the downstream communities to safer places and take necessary measures to protect physical properties in vulnerable areas. For hydrometeorological studies in Kelantan river basin, there are water-level stations under authority of Department of Irrigation and Drainage (DID) of Malaysia that provides previous flood records and attributed information for public view. Usually, water-level stations are used to issue flood warnings to the downstream communities [7].

Fig. 1 Map of Malaysia highlighting the Kelantan State as the study area

2.2 Accessible Data and Primary Assessment

In this section, it comprises of the overall information regarding the contribution of rainfall and water levels for Kelantan State in 2014. Satellite imagery related with the government agencies Malaysian Meteorological Department Malaysia (MetMalaysia) in Fig. 3 that functions in providing climatological services to users in all sectors and monitors the atmospheric composition in Malaysia and provides information and other meteorological aspects. Review of Radar image of MetMalaysia shows the cumulus clouds have formed on December 20, 2014, until December 25, 2014 [11]. Moreover, Fig. 3 also shows that Kelantan River has involved with more rainfall during the period December 20–23, 2014, which leads flood in downstream of the Kelantan River. It shows that the cloud formation began on the December 20 until December 25, 2014. The green and blue patterns show the rainfall rate in mm/h for the flood event in 2014. The blue pattern indicates the intensity of the rainfall between the ranges of 0.05–0.5 mm/h. Meanwhile, the green pattern indicates the rainfall rate between 0.5 and 8 mm/h. From the weather

Fig. 2 Location of hydrometeorological stations at Kelantan State

status, heavy rain warning (red level) is released at 8:58 am on December 24, 2014, by the Malaysian Meteorological Department. Warning situation reported as intermittent rain occasionally occurring in Kelantan State (Tumpat, Pasir Mas, Tanah Merah, Machang, Pasir Puteh, Jeli, Kuala Krai, and Gua Musang) is expected to continue until December 24, 2014 [11].

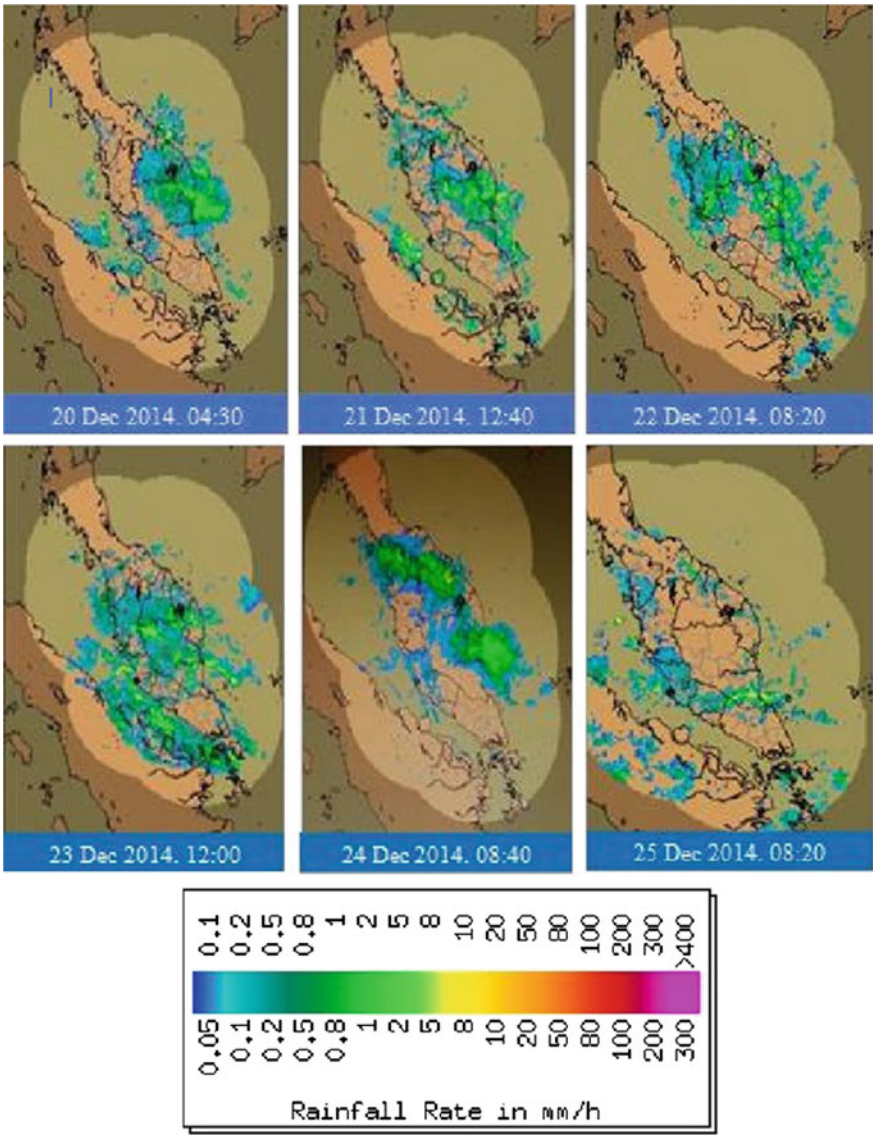

Fig. 3 The cloud formation images on December 20–25, 2014 [11]

The recorded rainfall from telemetry station at Kelantan shows that the highest amount of rainfall is during the period December 15–25, 2014. The highest value of accumulated rainfall recorded during the flood event on December 2014 for duration of 10 days is at Gunung Gagau station about 1898 mm, while the lowest value of accumulated rainfall during the flood event is at Lojing station about 476 mm. Figure 4 represents Isohyetal map for Kelantan State on December 20–25,

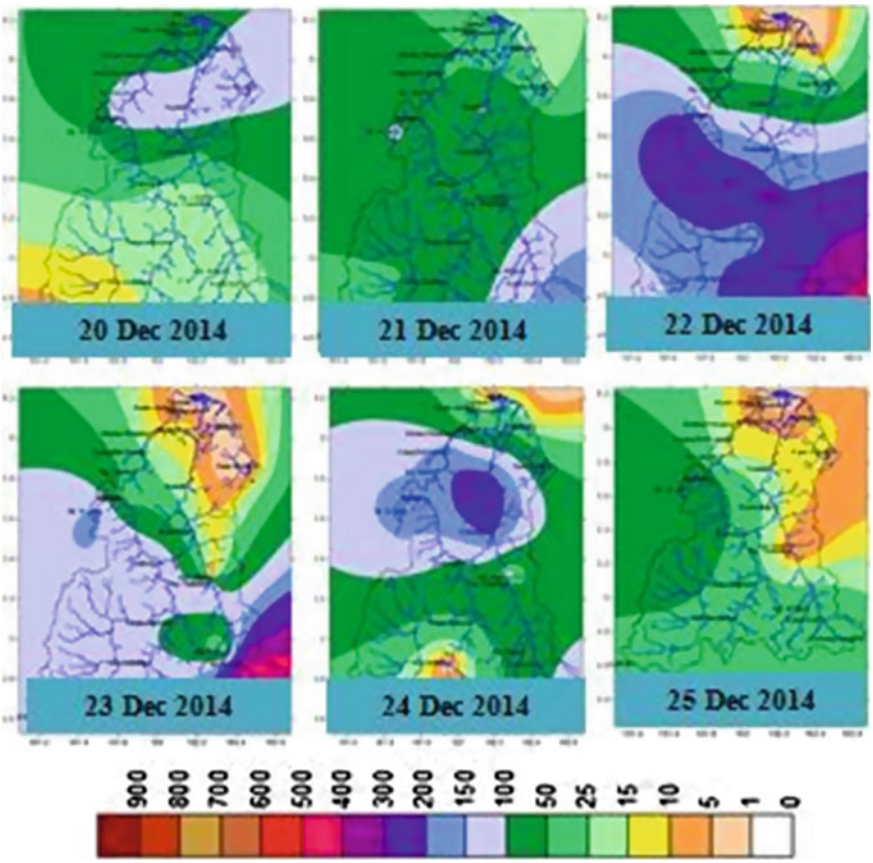

Fig. 4 Isohyte map for Peninsular Malaysia started during the period December 20–25, 2014 [12]

2014. It shows that on December 22, 2014, the heavy rainfall estimated more than 150 mm for a day especially at Gunung Gagau station and along the Golok River. However, on the December 24, 2014, the rainfall intensity is concentrated near Kelantan River especially at Kusial and Kuala Krai rainfall stations. It is clear that the total rainfall recorded during every flood is different. It mostly do not follow a fixed trend of neither ascending nor descending since rainfall amount is greatly dependent on atmosphere climate during flood event.

Table 1 shows the comparison between accumulated rainfalls for 10 days from December 14 to December 24, 2014, during the massive flood event on December 2014 for the rainfall stations with the comparison of average rainfall for December since previous years. It indicates that the comparison of accumulated rainfall of 10 days for Gunung Gagau station is 2.7 times with the average rainfall for

Table 1 Rainfall Station at Gunung Gagau, Kusial, and Kuala Krai [12]

Rainfall station	Accumulated rainfall of 10 days during flood event December 2014 (mm)	Annual average rainfall for December year 1965–2013 (mm)	Comparison of accumulated rainfall of 10 days during flood event December 2014 with the average rainfall for December
Gunung Gagau	1898	700	2.7
Kuala Krai	848	585	1.5
Kusial	1048	757	1.4

December while Kusial rainfall station is 1.4 times the annual average rainfall for December.

Table 2 shows the comparison between the accumulated rainfalls within 10 days on December 2014 with the accumulated annual rainfall for 365 days at Gagau Rainfall Station. Accumulated rainfall for the period of 10 days at Gunung Gagau Station shows that during December 2014 flood event, it already achieved 50 % of

Table 2 Comparison of accumulated rainfall of 10 days with an annual rainfall [12]

Rainfall station name	Gagau station	
Duration of rain (days)	10 days	365 days (1 Year)
Accumulated rainfall (mm)	1898	4000
Comparison with the annual rainfall	~50 % of annual rainfall	

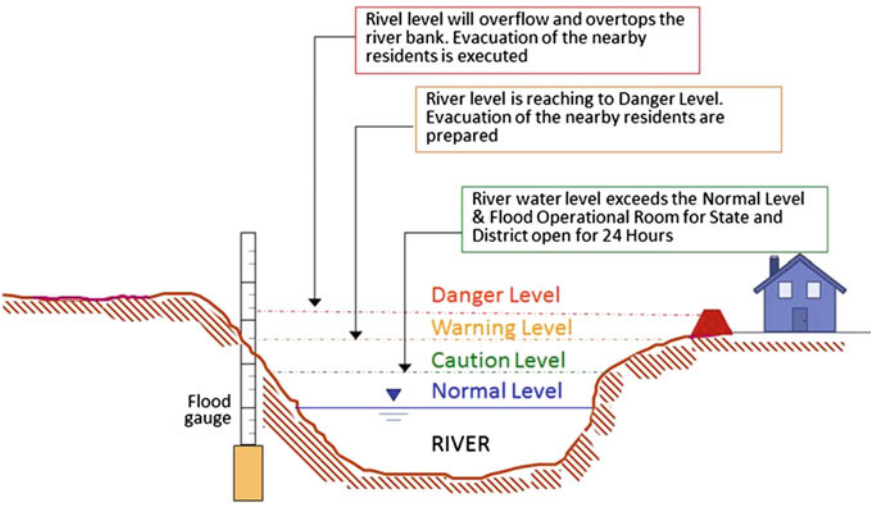

Fig. 5 The standard of critical river levels termed by DID Malaysia [7]

the total annual rainfall. This value shows extreme and huge amount of precipitation that occurred during the event. Based on the standard of critical river levels termed by the DID Malaysia organization shown in Fig. 5, there are 4 types of level such as normal level, caution level, warning level, and danger level. These standards are followed for the implementation of flood forecasting and public evacuation. Caution level alerts the public when the river level exceeds the normal level. Meanwhile, warning level alerts the public when the river level is reaching to danger level and evacuation of the nearby residents is prepared. Danger level is when the river level will overflow and overtops the riverbank and the evacuation of the public is executed.

Table 3 shows the recorded water level on December 2014 for Kelantan river basin in line with the standard critical river levels set by DID for each rivers. Clearly, Lebir and Kelantan rivers are involved with over danger level values. Lebir River has an over danger level value roughly 9.51 m which is highest in comparison with other stations while Golok River at Rantau Panjang exceeds danger level by 1.84 m.

Figure 6 shows the accumulated rainfalls for each rainfall stations for duration of 10 days from December 14 to December 24, 2014, during the flood event December 2014. It shows that Gunung Gagau station received the highest amount of rainfall in value of 1898 mm and Kg. Laloh station received the least amount of precipitation in value of 476 mm. Gunung Gagau station situated at the upstream part of Kelantan river basin and it experienced the most rainfall during the December 2014. However, Kg. Laloh station caters the least amount of rainfall during the December 2014.

Figure 7 shows that Galas and Lebir River experienced the highest water-level flows during the December 2014 flood event while Semarak and Golok rivers

Table 3 Recorded maximum water level for Kelantan river basin [12]

No	River	Location	Normal level (m)	Warning level (m)	Danger level (m)	Water level on December 2014	
						Date and time	Water level (m)
1	Galas	Dabong	28.00	35.00	38.00	24/12/14 16:00	46.47
2	Lebir	Tualang	23.00	31.00	35.00	27/12/14 04:00	44.51
3	Kelantan	Tangga Krai	17.00	22.50	25.00	25/12/14 15:00	34.17
4	Kelantan	Guillemar d Bridge	10.00	14.00	16.00	26/12/14 00:00	22.74
5	Kelantan	Tambatan DiRaja	1.00	4.00	5.00	27/12/14 07:00	6.96
6	Golok	Jenob	19.00	22.50	23.50	11/1/14 21:00	25.44
7	Golok	Rantau Panjang	5.00	8.00	9.00	18/12/14 11:00	10.84
8	Semerak	Pasir Putih	0.40	2.30	3.00	18/12/14 07:00	2.67

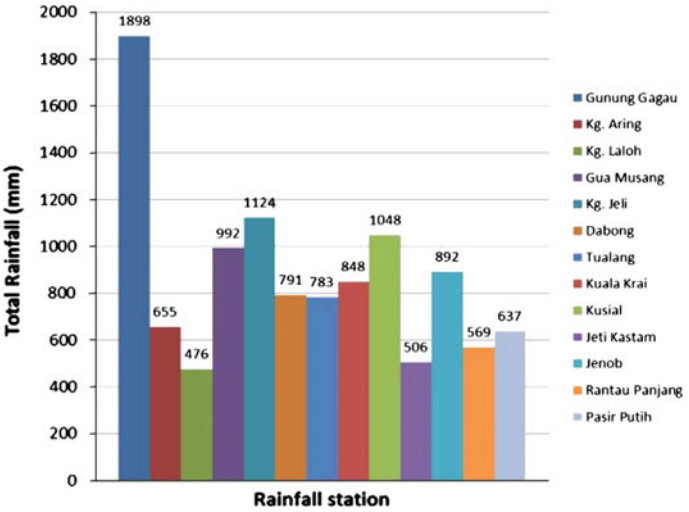

Fig. 6 Accumulated rainfall for 10 days from December 14 to December 24, 2014

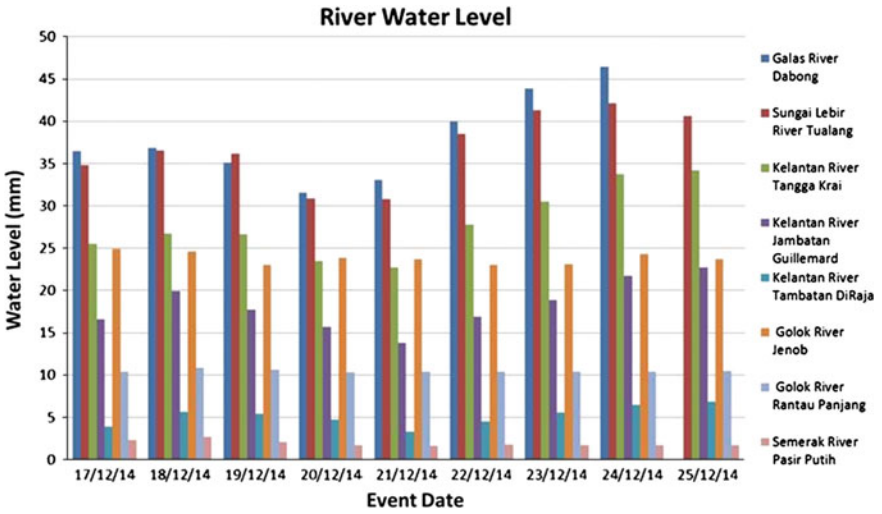

Fig. 7 The water level in Galas, Lebir, Kelantan, Golok, and Semerak rivers on December 17–25, 2014

experienced the least flows during the flood event. It seems that urban and rural area around two rivers Lebir and Galas might be vulnerable for flood event because the area experienced high level of flow in rivers.

3 Discussion and Conclusion

Floods can have decimating results and consequences for the economy, environment, and individuals. Indeed, disadvantages of flood can be transmission of pollution, erosion, and losing freshwaters as well financial and lives damages. The recent flood in December 2014 at Kelantan State seemed to have taken Malaysians by surprise, including the authorities responsible for disaster management. It is vital in ensuring that during flood event, the Disaster Operation Control Centers is functioning immediately in affected areas to coordinate and provide accurate information about where the affected people were so that relief efforts could be directed there. It is important to convey immediate information on central portal or Web site providing daily updates on the flood situation, road accessibility, where relief effort can be taken and location of any stranded victims can be identified. However, institutional capacity and preparedness of agencies in responding to disasters should be further enhanced through the improvement of overall capacity and preparedness of response agencies, procurement of high tech equipment, conducting seminars/drills and exercises to reflect the complexity of disasters. The disaster management framework should be strengthened, especially at the local government level. Therefore, the government should conduct activities that could enhance inter-agency cooperation especially at the local level. Based on the evaluation from the impacts of Kelantan Flood 2014, it actually results in a challenging enforcement, operation, and implementation for upcoming years at national and international scale for study such as vulnerable urban area, contribution of flood on landscape, socioeconomic influenced by flood and damages on human life and infrastructures.

This research is done to prepare the vital information regarding the flood event happened at Kelantan State on December 2014 as a baseline for future studies. Two sets of data such as rainfall and water-level data are obtained and analyzed to get the general idea on the flood event for Kelantan State on December 2014. Kelantan watershed is roughly 13000 km^2, which include urban and rural area in up and down streams. Major rivers, namely Nenggiri, Lebir, Galas, and Kelantan, are located at Kelantan watershed that is flood prone area. Further study reveals that highest accumulative rainfall is related with Gunung Gagau in December 2014. Evaluation of water-level records illustrates that highest water level is for Kuala Krai (34.17 m) on December 2014. Analysis on available data of water level

illustrates that most rivers experienced with phenomenon of exceedance of danger level during the December 2014. Statistic shows that Lebir River experienced highest rate accordance over danger warning value of about 9.51 more than danger level. Most rainfall stations have received high rate of rainfalls showing that Gunung Gagau had highest record at Kelantan watershed which value is 1898 mm.

Therefore, there is a need to encourage and highlight more study on flood protection and warning systems. In addition, stream flow modeling and recognition of flooded area can be an optimistic method along the Kelantan River from upstream to downstream. Hence, it is crucial to compile and analyze major hydrological extreme events, which could serve as a reference in the planning, and management of water resource projects especially for introducing additional safety factors in the design of water resource projects.

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