# Kelantan Big Yellow Flood 2014: Statistical Analysis on Relationship between Rainfall Intensity and Water Level

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# Kelantan Big Yellow Flood 2014: Statistical Analysis on Relationship between Rainfall Intensity and Water Level

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**Abstract**. This paper interpreted statistically the relationship between event of weather activities and flooding in the affected area of Kelantan State in Malaysia during the Big Yellow flood event in December 2014. This is an extreme flood event in Kelantan since 1927 with the return period approximately 1 in 1000 years. The rainfall intensity and river discharge dataset from Department of Irrigation and Drainage (DID) Malaysia in four selected study areas were descriptively analysed and interpreted using hyetograph and hydrograph. Furthermore, this descriptive results have been validated inferentially using Chi-Square statistical test that are applied into the primary data gathered from observation and distribution of a questionnaire to flood victim during a field visit at the same selected study area used in analyzing secondary data from DID. The results from descriptive analysis using hyetograph and hydrograph showed two phases of extreme rainfall in the Kelantan river basin. The first phase from 15 to 19 December 2020 pointed out that the heavy rainfalls contribute to the increase of water levels in Galas, Lebir, and Kelantan rivers. Areas of affected flooded are Kota Bharu, Tualang, Kursial, and Kuala Krai from 17 to 19 December 2014. The second phase from 20 to 24 December shows higher intensities of rainfall, especially at the upstream of the River basin in Gunung Gagau and the flooded situation become more severe due to the full capacity of soils, river, and drainage. This study also shows that the flood depth that occurred in the flood-prone area has a significant association with rainfall intensity but not with the distance of the area from the river. The findings can significantly conclude that the Kelantan big yellow flood 2014 is totally influenced by heavy rainfall.

## 1. Introduction

Flooding due to heavy rainfall not only causes property damage but also causes the victims loss of life and serious trauma. Heavy rainfall is the primary cause for floods in major parts of world include Malaysia. Floods are a common occurrence in Malaysia because its geographical location that near to equatorial and surrounded by seas makes this country exposed to the climate with uniform temperature and high humidity [1]. Therefore, the rainfall distribution in Malaysia is influenced by the monsoon seasons. Particularly, Peninsular Malaysia receives the highest amount of rainfall during the transition period of the monsoon season [2]. The two monsoon seasons are the northeast monsoon from December to March and the southeast monsoon from June to September. The most intense rainfall usually occurs

in the months of April, October and November annually [3]. During these monsoons, wind carrying moisture from the seas dump plenty of rainfalls at the East-Coast and West-Coast of the peninsular [4]

From a historical perspective, several significant flood events witnessed in the last few decades on the east coast of Peninsular Malaysia dates back to 1988, when one extreme flood was confirmed to have caused Kelantan intense damage [5]. Next was the flood of 1926 and 1967, in which catastrophic floods spread again across Kelantan, Terengganu and Perak on the east coast [6]. In 1971, another catastrophic flood event was reported and in this event, Pahang is the one that severely affected [7]. The Kelantan Big Yellow flood event was considered as one of the most destructive floods to hit the east coast of Peninsular Malaysia in recent decades, with over 100,000 flood victims evacuated from their homes in Kelantan [8]. The flood was mainly due to the continuous heavy rainfall from 21-23 December 2014 which was equivalent to more than 60 days of rainfall, whereby the water level in the river exceeded those of recorded where the maximum is at 46.47 meters [9].

Most of major historical flood events in peninsular Malaysia occurred were related to the north-east monsoon season which carries abundant of rainfall to east coast [5, 10, 11]. Records on heavy rainfall amount and events were also reported to have an increasing trend [3,4,12]. Therefore, it is important to relate current flood events to historical rainfall records to provide facts on the rarity and the extreme level of the rainfall causing the flood. This study attempt to response to this issue by analyzing the relationship between rainfall intensity and water level by using 2014 flooding data in Kelantan. The descriptive Hyetograph and Hydrograph analyses are applied to the secondary data of rainfall and river discharge obtained from Department of Irrigation and Drainage (DID) Malaysia and the frequency analysis with Chi-Square statistical test are applied to the primary data from observation and questionnaire survey gathered during field visit in the selected study areas to validate the results of data analysis using secondary data from DID.

## 2. Study and Catchment Area

### *2.1. Study Area*

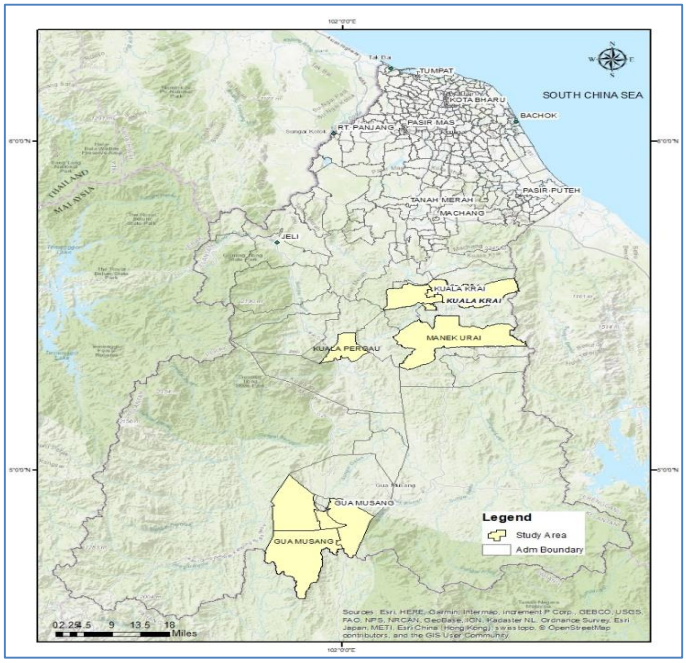


**Figure 1.** Location of four specific study areas in Kelantan Malaysia: Gua Musang, Kuala Krai, Manek Urai and Kuala Pergau

The data of this study was collected from two districts in Kelantan state namely Kuala Krai and Gua Musang. Those districts have been divided into four specific research areas namely Gua Musang, Kuala

Krai, Manek Urai and Kuala Pergau (Figure 1) to ensure the primary data can be rigorously collected during the field visit for the purpose of future study on flooding. The selection of those specific research areas are based on similarities on administrative status and flooding exposure among locations.

### *2.2. Catchment Area*

Three catchment areas have been developed in this study to represent the flooding in Kuala Krai, Gua Musang and Manek **Urai.** These catchment areas have been named as Galas, Ulu Kelantan and Lebir river catchment area shown in Figure 2.

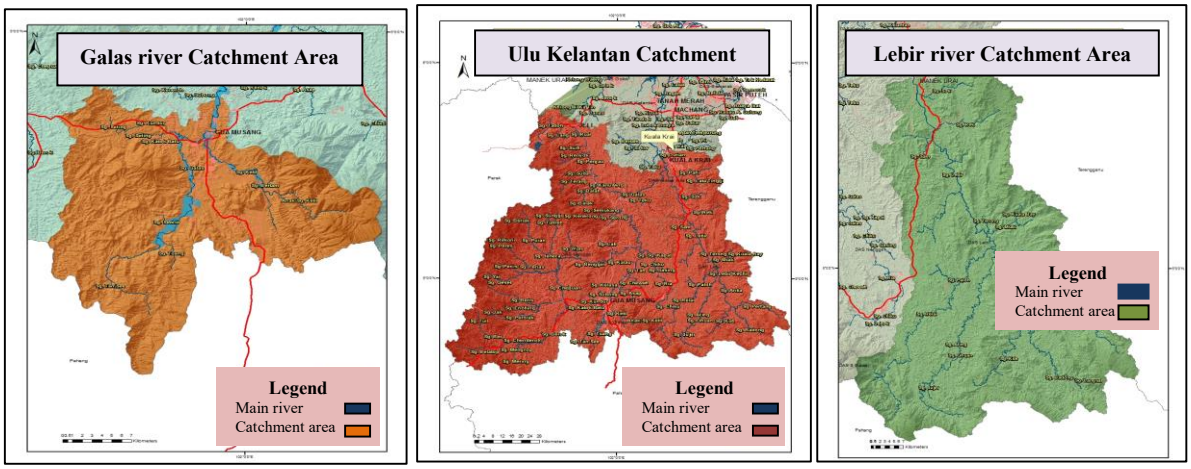


**Figure 2.** Galas River, Ulu Kelantan and Lebir River Catchment Area for flooding in Gua Musang, Kuala Krai and Manek Urai

## 3. Methodology

### *3.1. Data Collection*

This study involved both type of data which is primary and secondary data to ensure trustworthy findings with a high level of reliability. The field to the four aforementioned specific flood-prone research area i.e., Gua Musang, Kuala Krai, Manek Urai and Kuala Pergau has been done after six month of 2014 yellow flood event in Kelantan. In this field visit a primary data has been collected through observations, photography and household survey interviews. There were two hundred households where fifty samples that randomly chosen from each prone-area have been interviewed during the fieldwork. Through this brief interview from each of the households, data on flood depths and flood durations were gathered. The flood depths data was map directly to the indication of flood mark in the building. The position of all sampling location was also recorded using Garmin handheld Global Positioning System (GPS). Hence, using the same device the elevation of each points and distance of each houses to the nearest river were also measured. Those primary datasets have been validated using open asses secondary data from DID and also formal interview with the officers in the related agenises.

### *3.2. Descriptive Hyetograph and Hydrograph analysis*

First stage in this research is to analyze the secondary data of recorded daily rainfall and water level data on December 2014 from DID based on hyetograph and hydrograph that auto generated from http://publicinfobanjir.water.gov.my/. Hyetograph is a graphical representation of rainfall over time. It is the plot of the rainfall depth drawn on the Y-axis against time on the X-axis. The area under the hyetograph gives the total rainfall occurred in that period. This chart is very useful in representing the characteristics of storm, and particularly important in developing the design storm to predict extreme flood. Hydrograph is a graphical plot of discharge of a natural stream or river versus time. It shows variations of time, at a particular point of a stream. It is also shows the time distribution of total runoff at the point of measurement. The discharge is plotted on Y-axis and the corresponding time is plotted

on X-axis. Hydrograph analysis is the most widely used method of analyzing surface runoff. Based on those graphs the descriptive interpretation will then being narrated together with the information gathered through face to face interview with the flood victims and officers from related agencies.

### *3.3. Inferential Chi-Square Statistical Analysis*

Better understanding of real dataset is essential to ensure an appropriate statistical test is applied so that an unbiased statistical inferences could be made in particular study [13]. In this study, almost of the primary data collected from questionnaires that have been distributed to flood victims can be categorized as nominal or categorical variables that related to flood. To analyze this type of data Chi-Square hypothesis test has been applied to inferentially support the descriptive findings from secondary data. This raw data has been organize to two by two contingency table beforehand. To analysis those types of variable Chi-square test of independence has be used to determine if there is a significant relationship between two nominal (categorical) variables. The hypothesis of this test will be:

$H_o$: Variable A and Variable B are independent.

$H_a$: Variable A and Variable B are not independent.

The test statistic is a chi-square random variable ($X^2$) defined by the following equation.

$$X^2 = \Sigma \left[ (O_{r,c} - E_{r,c})^2 / E_{r,c} \right] \quad (1)$$

where $E_{r,c}$ denoted as ( $E_{r,c} = (n_r * n_c) /n$) is the expected frequency count for level *r* of Variable A and level *c* of Variable B, $n_r$ is the total number of sample observations at level r of Variable A, $n_c$ is the total number of sample observations at level *c* of Variable B, and n is the total sample size. This test will automatically computed by using any statistical software.

## 4. Result and Discussion

### *4.1. Extreme Hydrological Event in Kelantan on December 2014*

The descriptive findings of extreme hydrological events on December 2014 in Kelantan are reported based on four selected study area namely Gua Musang, Kuala Krai, Manek Urai dan Kuala Pergau.

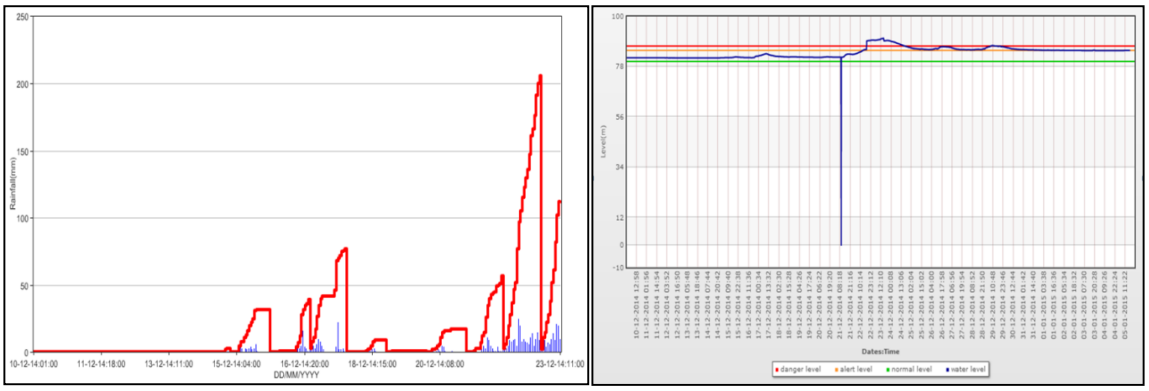

**Figure 3.** Hyetograph and Hydrograph for Sg. Galas at Gua Musang from 10 - 23 Dec 2014

The river basin of Gua Musang is Galas river. Galas river normal water level is around 79 to 95 meter. If more than 95 meter it has been claimed as danger level. Based on Figure 3 on 22nd December 2014 at 10.40 am, the water level was reached at alert level which was around 90 meters and continued rise until it reached a danger level of 85 meters at 11.12 pm. On 23rd December 2014, the water level was reached above the danger level at 12.16 pm which was around 97 m. The water level started to decline an reached to the below of the danger level on 24th December 2014 at 12.08 am with the water level reading at 90m. It is shows that on 23rd December 2014 flooding occurred in Gua Musang with water level reading was above 95 meter. During the flood happened, the amount of rainfall was heavy. Thus, it filled the river basin of the Sg. Galas and the level of water depth in the river increased rapidly until above the danger level.

The River Basin in Kuala Krai district consist three rivers which are Kelantan River, Lebir River and Galas River. Kuala Krai area has three hydrology stations, located at Kelantan River, Lebir River at Kg Tualang and Galas River at Kuala Pergau. The main factor Kuala Krai district having severe flood due to the continuous rainfall from the Gunung Gagau. The location at Gunung Gagau is between boundaries of Terengganu and Kelantan state. From Terengganu state the water is flown into the Tasik Kenyir and the water from opposite side is flown into the Kelantan River. Gunung Gagau is the source of rainfall. Based on hyetograph for Kelantan river at Kuala Krai in Figure 4 heavy and reach rainfall from 16 to 23 December 2014 compared to the normal level causing the water level of the rivers increased and caused the Kula Krai district getting the severed flood on 2014. Further, the hydrograph in Figure 6 shows the water level for Kelantan River at Kuala Krai, on the 1st December 2014 until 15th December 2014 is in normal level (17.0 m). Then starting on 16th to 17th December 2014, the water level is getting higher and reached above 20.0 meter that gave an alert level for Kelantan River. The water level in Kelantan River dropped and then stayed in normal level on 22nd December 2014. However, on the 23rd December 2014 until 30th December 2014 is second wave in Kuala Krai area when the water level is 34.17 m and this is above the danger level when the rainfall is continuous occurred in 8 days.

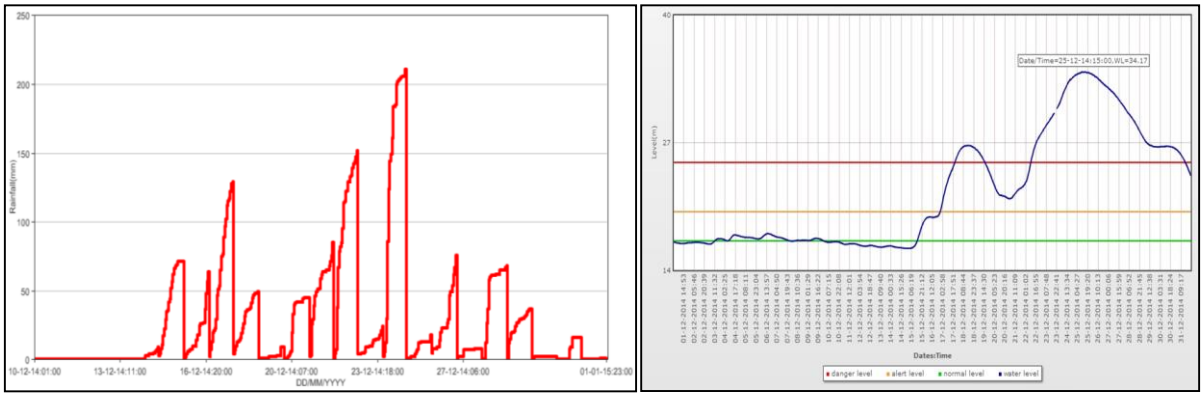


**Figure 4.** Hyetograph and Hydrograph for Kelantan river at Kuala Krai from 10 - 31 Dec 2014

Figure 5 shows hyetograph and hydrograph for Lebir river to demonstrate the occurrence of flood event in Manek Urai. It clearly shows that heavy rainfall occurred between 21st until 24th December 2014 recorded the highest intensity in Kelantan which caused major flooding occurred throughout Kuala Krai including Manek Urai. These prove that, major floods that happen in Kelantan are caused by heavy rainfall. All runoff Kelantan basin more sloping and received heavy rainfall almost throughout the country led to a very large water capacity. The impacts of the floods across the state because of rain accumulated in the basin starting from upstream. Figure 6 shows that on 15th December 2014 the water climbed from the normal level (23 m) to the alert level (27.0 m) on 16th December and then it increased rapidly in the early morning of 18th December. From 18th December, the water level reached to the danger level (35.0 m). However, water level dropped steadily on 19th December 10.10 am until reached the alert level on 21st December around 5.00 am. After that, on 21 December around 11.00 am the water level increased steadily and reached beyond danger level on the 23rd December until 24 December around 12.40 pm. The information from the Department of Irrigation and Drainage, the recorded of water level is cut off on the 23rd December and 26 December because the disturbance the telemetry of Kg Tualang station and the reading cannot be recorded.

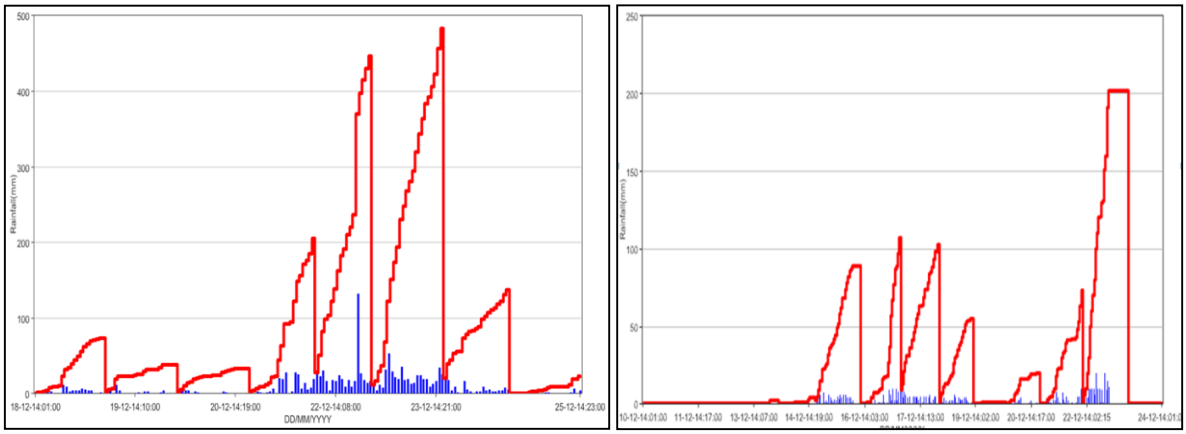


**Figure 5.** Hetograph for Lebir river at Gunung Gagau and Kampung Laloh from 10 - 24 Dec 2014

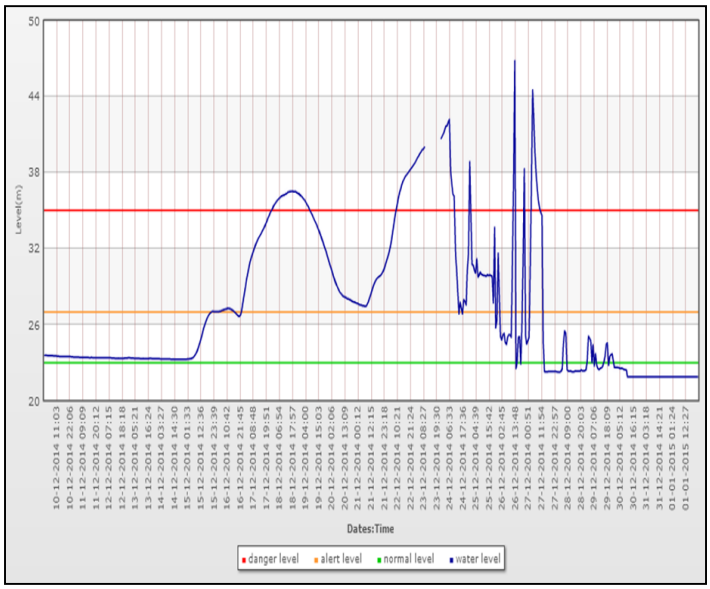


**Figure 6.** Hydrograph for Lebir river at Tualang,Manek Urai from 10 - 31 Dec 2014

Lastly for Kuala Pergau, flooding data from hydrology station located at Galas river have been observed and analyzed to descriptive interpreted the relationship between rainfall intensity and water level. Figure 7 shows the hyetograph and hydrograph of rainfall distribution and river discharge at Sungai Galas, Kuala Pergau during 2014 flood. The hyetograph recorded the heavy rainfall started to occur from 21 December 2014 until 25 December 2014. Further, based on the hydrograph, the water level at Galas River at Kuala Pergau specifies a normal level which are 28 metres and below from 10 December 2014 until 15 December 2015. However, the water depth started to increase to 29 metres exceeded the normal level at 10.42 am on 15 December 2014 until 21.45 pm on 16 December 2014. After that day, the heavy and continuous rain occurred in Kuala Pergau forced the water depth level of Galas River dramatically increase starting from 8.48 am on 17 December 2014 until 06.54 am on 18 December 2014. The highest record of water depth level along that day was 36 meters exceeded the alert level. During that time, the probability of flood occurrence was high because the increased of flood depth level and amount of rainfall at Kuala Pergau. The real heavy and continuous rainfall occurred from 00:12 am on 21 December 2014 until 17:36 pm on 24 December 2014 in Kuala Pergau.

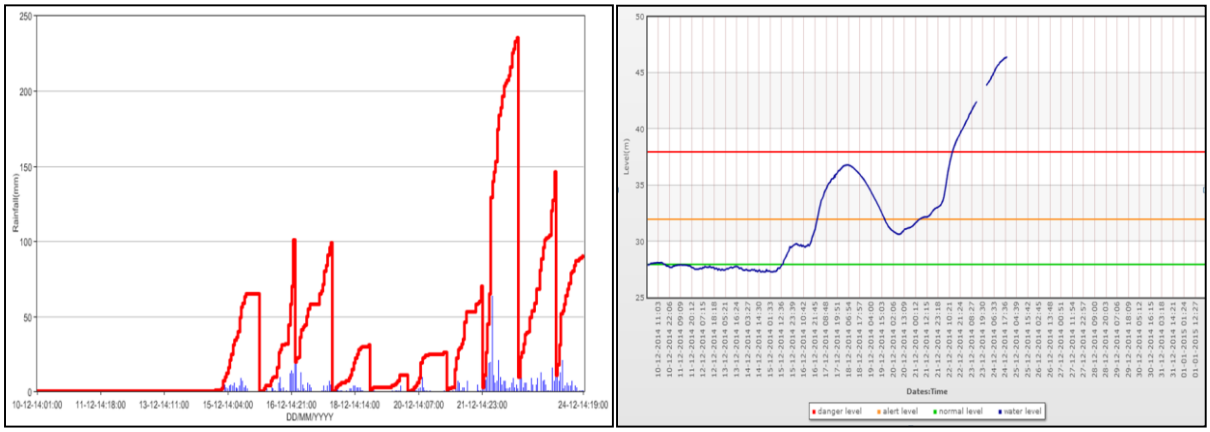


**Figure 7.** Hyetograph and Hydrograph for Galas river at Kuala Pergau from 10 - 24 Dec 2014

*4.2. Relationship between Rainfall intensity and Water Level*

Some inference statistical method using chi-square test has been used in further analysis of the data to support the descriptive result given by hyetograph and hydrograph analysis. Since the depth of the flood is one of the key elements that can represent river discharge, further investigation on the relationship between this variable with another important variables in this study need to be determined. Another three important variables in this study that felt be effected the flood depth are 'distance from river' and 'total amount of rainfall'. Table 1 shows a two by two contingency table between variables 'flood depth' and another two variables which are "distance from river' and 'total rainfall' respectively. The chi-square statistics are reported together at the bottom of those tables with the p-value at 0.05 level of significant. From the results of chi-square test, it is clearly shows that the variable 'flood depth' that represent the flooding because of river discharge has an association with the variable 'total rainfall' but not with the 'distance from the river'. Therefore, we can significantly say that, the Kelantan big yellow flood 2014 is totally influence by heavy rainfall.

**Table 1.** Chi-Square test for two by two contingency table of 'flood depth' with 'distance house from river' and 'rainfall intensity'

| Flood depth | Distance house from river (m) | | | | Total rainfall intensity (mm) | | | |
|---|---|---|---|---|---|---|---|---|
| | < 20 | 20 - 60 | 60 - 100 | > 100 | 195 - 210 | 210 - 220 | 220 - 295 | 295 - 515 |
| < 1m | 4 | 3 | 2 | 15 | 1 | 6 | 3 | 2 |
| 1m - 2.5m | 2 | 1 | 8 | 8 | 1 | 13 | 5 | 6 |
| 2.5m - 5m | 3 | 5 | 7 | 17 | 1 | 8 | 9 | 15 |
| > 5m | 14 | 31 | 25 | 63 | 47 | 23 | 33 | 27 |
| | * chi-square statistics = 12.2614 p-value = 0.19896 | | | | * chi-square statistics = 38.78097 p-value = 0.00001 | | | |

## 5. Conclusion

Rain is an agent which can lead to flood event. Descriptive analysis using hyetograph and hydrograph showed that there are two phase of extreme rainfall occurred in Kelantan river basin that influenced the approximately 1 in 1000 years flood event that known as Kelantan big Yellow Flood. The first phase on 15 to 19 December has heavy rainfalls falling at both the eastern and western side down stream of the Kelantan river basin. This contributes to the increase of water levels of Galas, Lebir and Kelantan rivers. During this period, flood occurred at areas of Kota Bharu, Tualang, Kursial and Kuala Krai from 17 to 19 December 2014.

The second phase of rainfall was from 20 to 24 December 2014. During this time higher intensities of rainfall were recorded especially at the upstream of the River basin in Gunung Gagau. Flood situation become more severe due to the full capacity of soils, river and drainage. Area worst hit was Kuala Krai, Dabong and Manek Urai on 22 to 30 December 2014. A lot of record breaking rainfall events occurred

during the flood period especially stations at the upstream of the river basin with the ARIs near and over 100 years and several of them having ARIs more than 500 years. This contributes the extreme volume of river discharge and some of the river monitoring stations damaged and cannot record the water level as showed in hydrographs. The December 2014 events is one proof of an extreme rainfall event unexpectedly occurring contributing to record breaking rainfall amounts.

This huge rainfall amount hence contributing to the extreme flooding in Kelantan where the relationship has been statistically investigated further. From this further analysis, we found that the flood depth that occurred in flood prone area have a significant association with rainfall intensity but not with the distance of the area from the river. This finding lead us with no doubt to conclude that the Kelantan big yellow flood 2014 is totally influence by heavy rainfall. Therefore for future study, it is important to investigate further the relationship between current flood events to historical rainfall records to provide facts on the rarity and the extreme level of the rainfall causing the flood hence an effective flood prediction modeling can be proposed for practical used in mitigating flood disastrous effect.

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