DEVELOPMENT OF RAINFALL TEMPORAL PATERN IN UNIVERSITI MALAYSIA PAHANG

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ABSTRAK

Cuaca dan iklim adalah berkaitan tetapi berbeza dalam masa perubahan dan ramalan. Cuaca terdiri daripada variasi jangka pendek seperti suhu tekanan udara dan kelembapan hujan. Oleh kerana perubahan yang tidak dapat diramalkan, ramalan cuaca terhad pada hari-hari sahaja. Rutin harian kami dipengaruhi oleh keadaan cuaca; pemerhatian keadaan cuaca dapat membantu dalam memahami aktiviti. Adalah penting untuk memerhatikan dan mengkaji perubahan cuaca di kawasan tertentu dengan menggunakan mana-mana ciptaan yang kita ada sekarang. Perubahan dan corak cuaca di Gambang dan kawasan setempat boleh dikaji dengan menjalankan analisa data hidrologi dari Jabatan Pengairan dan Saliran (JPS). Pengedaran hujan telah lama diteliti oleh penganalisis untuk membantu inovasi semasa dan kerja-kerja kejuruteraan. Salah satu siasatan adalah untuk mewujudkan RTP. Terdapat beberapa pendekatan untuk membuat RTP, contohnya, menggunakan Kaedah Variabel Purata (AVM), Perkhidmatan Pemuliharaan Tanah (SCS), Kaedah Masa Huff dan Kaedah Segitiga. Berdasarkan objektif kajian ini, untuk menubuhkan Corak Temporal Hujan (RTP) untuk Universiti Malaysia Pahang, Gambang dengan menggunakan kaedah Huff Time Distribution Method (HTDM) dan kaedah Institut Penyelidikan Sumber Air (WRRI) untuk menganalisis data yang dikumpulkan. Data diperhatikan dan dibahagikan kepada dua peristiwa iaitu 60 minit dan 120 minit peristiwa hujan. Dari analisis data, ringkasan kejadian hujan yang berlaku di sekitar Universiti Malaysia Pahang telah dibuat. Di stesen id 3731018, nama JKR Gambang, terdapat 17 kejadian curah hujan yang berlaku dalam tempoh 60 minit, 11 lagi peristiwa hujan berlaku dalam masa 120 minit. Sebanyak 28 peristiwa hujan direkodkan dari tahun 2013 hingga 2018. Kemudian, data yang diperhatikan dibahagikan kepada empat kuartil yang sama. Data tersebut dianalisis mengikut setiap kaedah dan hasilnya adalah dalam bentuk peratusan. Untuk tujuan kajian seterusnya, hasil daripada kedua-dua kaedah tersebut dibandingkan. Semua empat hasil keluk diwakili setiap kuartil masing-masing, pertama, kedua, ketiga dan keempat. Untuk membandingkan hasil dari kedua-dua kaedah, perbezaannya dikira dari segi peratusan yang diplotkan. Corak Temporal Hujan digambarkan dengan menggunakan Kaedah Pengagihan Masa Huff dan kaedah Institut Penyelidikan Sumber Air berdasarkan penganalisaan data. Perbezaan dalam setiap grafik yang diplot berubah dari kira-kira 17.31% kepada 74.08%.

ABSTRACT

Weather and climate are related but different in time of changes and prediction. Weather consists of short-term variations such as precipitation air pressure temperature and humidity. Due to unpredictable changes, weather predictability is limited to days only. Our daily routine is affected by weather conditions; observation of weather conditions can help in understanding the activity. It is crucial to observe and study the weather changes in that particular area by using any of the invention that we have now. The changes and pattern of weather at Gambang and the local area can be studied by running an analyzation of hydrological data from Department of Irrigation and Drainage (DID). Rainfall distribution has for some time been researched by analyst to help with current innovations and engineering works. One of the investigations is to create RTP. There are a couple of approaches to create RTP, for example, utilizing Average Variability Method (AVM), Soil Conservation Services (SCS), Huff Time Method and Triangular Method. Based on this study objective, to establish Rainfall Temporal Pattern (RTP) for Universiti Malaysia Pahang, Gambang by using method of Huff Time Distribution Method (HTDM) and Water Resources Research Institute method (WRRI) to analyze the data collected. The data were observed and divided into two events which is for 60 minutes and 120 minutes rainfall event. From the data analysis, the summary of rainfall event happening around Universiti Malaysia Pahang was concluded. At station id of 3731018, name of JKR Gambang, there are 17 rainfall events that happening in 60 minutes time period, another 11 rainfall events happened in 120 minutes time period. A total of 28 precipitation events were recorded from year 2013 until 2018. Then, the observed data were divided into four equal quartile. The data were analyze according to each method and the result are in term of percentage. For the next study objective, the result from both method were compared. All of the four curve produce are represented each quartile which is first, second, third and fourth respectively. In order to compare the result from both methods, the difference are calculated in term of percentage are plotted. Rainfall Temporal Pattern are plotted by using Huff Time Distribution Method and Water Resources Research Institute method based on the analyzation of the data. The differences in each graph plotted varies from about 17.31% to 74.08%.

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LIST OF SYMBOLS

P(t)	Depth of precipitation of time
P	Total depth of precipitation
Δτ	Time based
	Dimensionless fraction
H	Height of triangle
I	Rainfall Intensity
%	Percentage
%cum	Cumulative of Percentage
Ave	Average

LIST OF ABBREVIATIONS

Met Malaysia	Jabatan Meteorologi Malaysia
MSMA2	Manual Sistem Saliran Air Malaysia Second Edition
HTDM	Huff Time Distribution Method
WRRI	Water Resources Research Institute
RTP	Rainfall temporal pattern
DID	Department of Irrigation and Drainage
AVM	Average Variability Method
SCS	Soil Conservation Service
JPS	Jabatan Pengairan dan Saliran
JKR	Jabatan Kerja Raya

CHAPTER 1

INTRODUCTION

1.1 Background Study

Weather and climate are related but different in time of changes and prediction. Weather consists of short-term variations such as precipitation air pressure temperature and humidity. Due to unpredictable changes, weather predictability is limited to days only.

Climate is the statistic of weather that counted over months or years. It also includes probabilities of event that happening on Earth. Climate is generated by climate system, which has five components that is atmosphere, hydrosphere, cryosphere, lithosphere and biosphere.

The climate of specific place is affected by latitude, altitude and terrain. Most common variables are temperature and precipitation. In the other hand, weather and climate are factors which decide how a society develop in a specific place. Weather generally shows the specific condition for short period, for example, hours or days while climate shows the characteristic changes to a place over a long period. Temperature, precipitation, humidity and wind are the included in weather while climate shows the overall conditions of a particular places in a long period of time.

Weather information are crucial in our everyday life. The information gathered, for example, precipitation and temperature can be utilized to be a step-by-step care against regular catastrophe, for example, flood and drought. The main worry with the climate change is the efficiency and accuracy. Unpredictable weather such as rain and flood can cause to danger of safety and health, increasing the danger of recordable injuries and making unsafe working conditions. Higher temperatures can cause heat pressure and lead to heat stroke and even death. However even with planning, the greatest danger is unpredictability. As temperatures rise, higher temperatures make longer curing process, which increase the time and skyrockets costs (Grant, 2018).

Another worry for people that doing external work such as construction project is the impact climate change on building materials and current structures. Unpredictable changes in temperatures cause materials like brick and wood to rot and break quicker. People will most likely be unable to control the climate change, however climate can be adapted and climate change is not all bad for the construction industry. Every day, solutions and improvements are underway to help to solve the problem of weather changes that are happening right now. From there, the improvisation of the quality of raw materials or processes that have been used in today's construction. Climate cannot be controlled, yet there still a way that can be taken as a precaution step.

A weather station is an equipment that collect information identified with the weather and condition using a wide range of sensors. Nowadays, weather forecast can be collected with many way and equipment. It depends on the individuals to choose what are the most efficient ways and equipment to be rely on. For example, satellite forecast, automated rain gauge or just a manual rain gauge that can be made by self-innovation. The accuracy for all these equipment are clearly not the same and this study are made to provide information for upcoming research.

1.2 Problem Statement

Daily routine is affected by weather conditions; observation of weather conditions can help in understanding the activity. It is crucial to observe and study the weather changes in that particular area by using any of the invention that we have now. The changes and pattern of weather at Gambang and the local area can be studied by making analyzation of hydrological data from Department of Irrigation and Drainage (DID).

1.3 Research Objective

The objectives of this study are as following:

- To identify amount of rainfall at Kolej Kediaman 2 at UMP Gambang.
- To establish Rainfall Temporal Pattern for UMP Gambang using WRRI and Huff Time Distribution Method.
- To compare the result of both method.

1.4 Scopes of study

Some of the scope of the study should be conducted to ensure that the objectives are met.

This study will be conducted at Kolej Kediaman 2 at Universiti Malaysia Pahang, Gambang. The data from Department of Irrigation and Drainage were collected for the station of Jabatan Kerja Raya Gambang. Then, the data will be analyse by using Huff Time Distribution Method (HTDM) and Water Resources Research Institute method (WRRI).

The study use the 5 minutes interval of rainfall event from 2013 to 2018. Total of 5 years of data were then analysed. The collected data were sorted into 60 and 120 minutes rainfall event. Based on the objective, to develop Rainfall Temporal Pattern by using HTDM and WRRI, the data were calculated.

The result from the data analysation were used to develop RTP for the selected area which is UMP Gambang. Lastly, for the objective of comparing the result from both method, the result were concluded in term of percentage difference. From the result, the objective can be achieved.

1.5 Significant of Study

This study can help many various parties that working externally and future researchers for planning their schedule to complete the undergoing project on the time and avoid delay in any of the working process. From this study, based on the method of calculation, the best method can choose and which of the ways that can be rely on. All the result collected in this study will be compile and a weather database for UMP can be recorded. The study also can identify the rainfall pattern of Gambang area. The Rainfall Temporal Pattern (RTP) created in Urban Stormwater Management Manual for Malaysia (MSMA) depends on area in Malaysia (Department of Irrigation and Drainage, 2012). For this investigation in any case, RTP were created dependent on station that are situated near to Universiti Malaysia Pahang. By having this, an increasingly dependable transient example can be acquired. So the new RTP can be utilized as another rule to plan pressure driven and hydrology structure. Hence, the seepage framework can be improved by utilizing another rainfall distribution as the information.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter present the review of previous studied related to the study title and gather information about the weather forecasting system used nowadays and its effect towards the community. In order to elaborate the accuracy of the system used for forecasting, collection data and comparison are made. Other than that, temporal pattern were developed based on the data extracted from weather station. Convective rain (sort of rain which causes flash flood) happens when warmed air is rising and cooled until the build-up happens and cloud beads develops then turned out to be sufficiently extensive to fall as rain.

2.2 Satellite Forecast System

Based on the study title that have been proposed, equipment used for the comparison purposes are between satellite forecast and weather station. For the satellite forecast system, the data was taken from Department of Irrigation and Drainage in the region of East Coast. The data taken will be analysed the accuracy since rainfall has a large variability in time and space. Habets et al. (2004) talk about that the capability of numerical weather prediction precipitation figure to be utilized by hydrological models for flood forecast is affected by the three kinds of error:

i. Localisation of the events. Wrong watershed in rainfall are cause from an error of a few kilometres.

ii. Timing of the events. The response of the basin depends on previous events and on timing of the present event.

iii. Precipitation intensity.

For these reasons, numerical weather prediction (NWP) rainfall forecast are rarely directly used to forecast river-flows. In other hand, by using satellite and radar data can improved the quality of rainfall forecast spatially or within a smaller scale but in a shorter time (Nakakita, 2002). Figure 2.1 shows the standard of rainfall forecast as a operate interval for many completely different forecasting method. NWP would enable larger interval however in a very large scale. Mesoscale numerical and conceptual rainfall models have higher spatial resolution but the accuracy is poorer than NWP. Extrapolation using satellite and radar system observation is capable to supply a good prediction at intervals with a smaller spatial grid scale but with less interval.

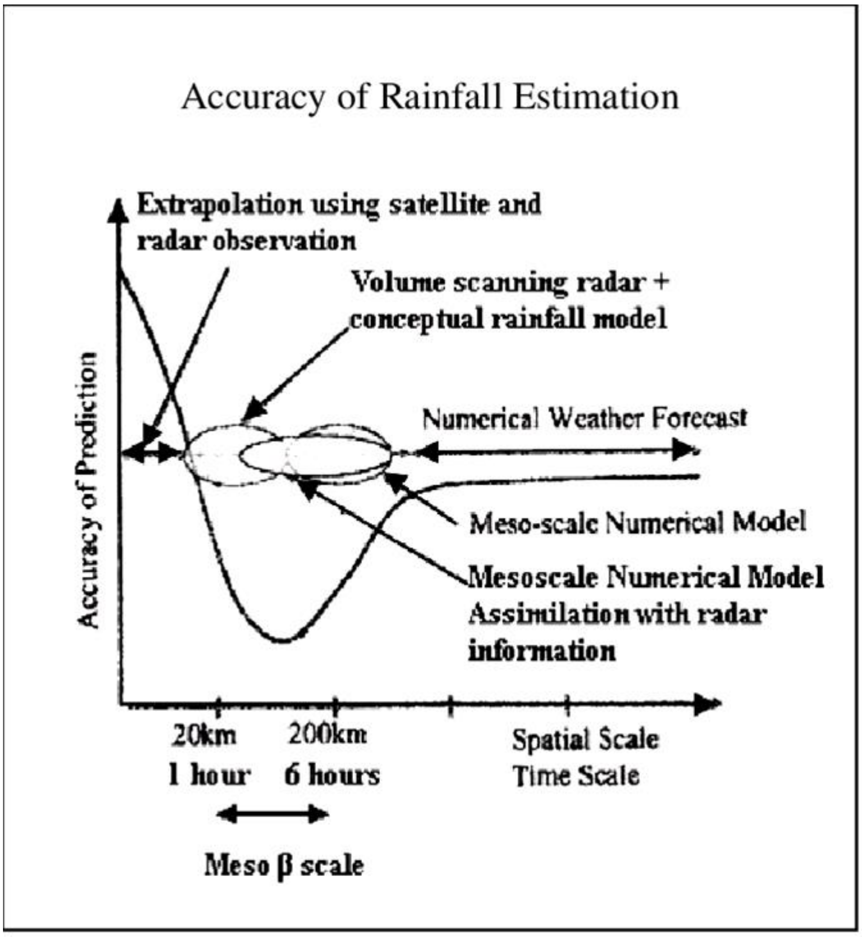

Figure 2.1: Shows the accuracy of rainfall estimation between various methods (Nakakita, 2002)

Many satellite based estimation study have been done before, for example by Griffith et al. (1978), who have built up the Griffith-Woodley technique. The technique use characterizes the cloud caught by the satellite picture that are colder than 253 K and expect the related radar echo for each cloud. Other than that, utilization of index of convention dependent on the METEOSAT IR information and precipitation estimations to investigate the convective action and its relationship to precipitation (Ba, M. B., and Nicholson, S. E., 1998). A cloud indexing calculations for the polar orbiting National Oceanic and Atmospheric Administration (NOAA) satellites and for geostationary satellite imagery have been created by Todd et al. (2001). Prior, Adler et al. (1988) and Anagnostou et al. (1999) have made a one-dimensional cloud model, correlation of the cloud max temperature to the rate of rainfall zone which also known as the Convective Stratiform Technique (CST).

Study based on satellite forecasting system for rainfall estimation used with variety of method are developing and changing with the target to improve the accuracy in rainfall prediction, with a smaller spatial and developed temporal pattern (Anagnostou, E. N., Negri, A.J., Adler, R.F., 1999). But, because of the unpredictability of nature and the relationship with the satellite measured radiance in the infrared area and the interrelated rainfall data, based on the observation conclude that the developed techniques cannot be used widely. This is because, the data obtain from satellite forecasting at the area of extratropical area might not accurate. Plus, the techniques created to predict the monthly rainfall data might not perform as much as expected for hourly prediction.

Theoretically, type of rain that can be related to flash flood also known as convective rain are affected when the air are heated up to a certain temperature and lowering down until condensation occurs. The cloud droplets gets larger then become dense enough to fall known as rain. The greater the air carried by the cloud, the lower the cloud temperature. Thus, the lower the temperature of the cloud detected, the brighter the image reflected to the infrared sensor at the satellite. Next, there are a relationship between the brightness of the image reflected to the satellite infrared and the temperature of cloud. Those cloud that potentially carried too much air that can cause flash floods can be recognize and detectable in high definition images. Van Hees et. al (1999) says that the cirrus anvils associated with well-maintained convection can catch up to 105 km^2, and it does last for a long period after the actual convection has finish, but the actual convection undergoing at an isolated area, where the rising air density penetrate the entire troposphere in under an hour. Other than that, the convective system is more active and give the greatest rainfall intensity when the tops become lower in temperature and expanding continuously (Griffith, C. G., Woodley, W. L., Grube, P. G., Martin, D.W., Stout, J., and Sikdar, D.N. , 1978).

In Figure 2.2, shows the multicell storm. It shows that the individual storm cells created successfully at the side of a large storm complex (Rogers, R.R., Yau, M.K. , 1988). The systematic creation of the cells produces a long-lived storm even though each cell has limited life cycle.

Initially, the thunderstorm containing four cells at a various stages of development. The development from the youngest cell at the successive period is marked. The heavy dashed arrow is the flow of the cloud in the developing cell.

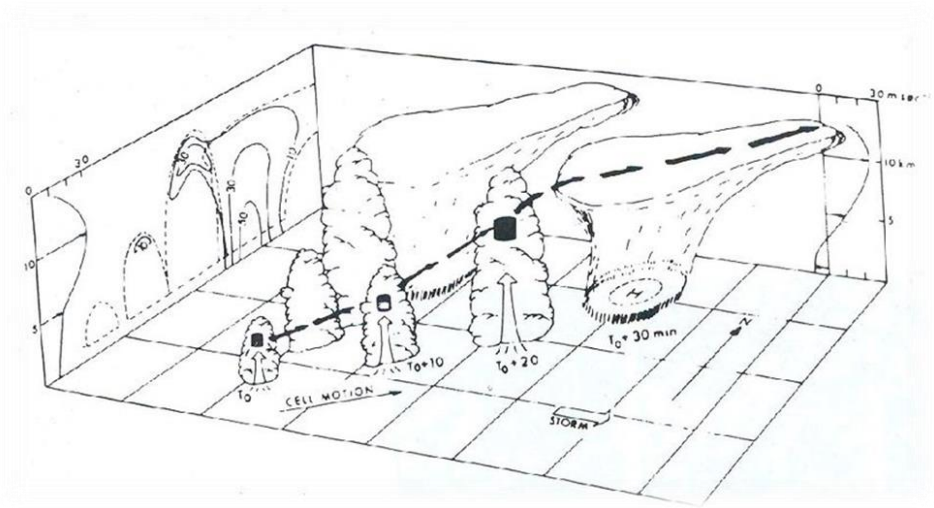

Figure 2.2: Schematic view of a multicell storm (Rogers, R.R., Yau, M.K. , 1988)

2.3 Weather Station System (Tipping Bucket)

Rainfall is a basic data for all scientific studies about hydrological cycle. But, rainfall or precipitation is unpredictable to be measured accurately due to the periodic nature, spatial and temporal variation and sensitivity to environmental behaviour (M. Savina, B. Schappi, P. Molnar, P. Burlando, B. Sevruk, 2012). In addition, rain gauge are the common devices used for measuring the rainfall intensity and period (X. Liu, T. Gao, L. Liu, 2013). Tipping bucket rain gauge not only accurately measure rainfall intensity from low to medium rate, but also record remotely with reliability and suitability (Marsalek, 1981). For weather radars that are controlled remotely sensing device which can cover a large resolution in time and space are used widely in determining rainfall prediction in meteorological and hydrological system (J. Testud, E. Le Bouar, E. Obligis, M. Ali-Mehenni, 2000). Several study from Brandes (1975), Krajewski (1987) and J. Creutin et al. (1988), said that rain gauge and satellite forecast in producing a high resolution combined products with accuracy than rain gauge or satellite itself in rainfall fields. However, search for reliable prediction of rainfall still exist because of the spatial and temporal variations between rain gauge and satellite forecast.

Satellite forecast can give an instant and high temporal resolution rainfall pattern from interpreting infrared imagery from satellite into rainfall intensity on the ground (J. Garcia-Pintado, G. Barbera, M. Erena, V. Casttillo, 2009). In other hands, the rainfall data calculated from tipping bucket rain gauges often ignored the rainfall variability especially short period rainfall event (E. Habib, W. Krajewski, A. Kruger, 2001). Since the high temporal resolution of precipitation is crucial in developing the satellite rainfall intensity calibration and lowering the ambiguity of rainfall reading as well as important to hydrological feedback of flash flood in isolated urban catchment. From tipping bucket rain gauge, it is expected a high resolution precipitation intensity at time scale can be developed.

Previous study shows a high resolution rainfall intensity recover based on tipping bucket rain gauge have been used the cubic spline algorithm to fit the increasing precipitation quantity gathered by the tipping bucket during the event and differentiated the cubic spline to derive the precipitation intensity at one minutes time scale. Result that shows high accuracy and easy implementation from the cubic spline algorithm give a head start for the method to be compared to old method such as linear and quadratic approach. However, this cubic spline algorithm method maybe not achievable for precipitation reading that is sensitive to the smoothness of the third derivative or higher because of the continuous state. J. Wang et al. (2008) said negative precipitation intensity can be derived about large droplet gradients occur at low rainfall intensity. Thus, an acceptable hypothesis should defined neatly. Furthermore, the tipping bucket volume are divided by the time between tips to enhance the visualisation of rainfall intensity regression scheme (C. Duchon, C. Biddle, 2010). The regression then can be utilised to develop a relationship model between input and output variables (Freedman, 2005). Thus, rainfall prediction can be taken by this method.

Improvement that have been endured in developing the system, many optical and electronic equipment are created. For example, the disdrometer is like an integral part to compute the droplets size transportation and calculate the velocity of dropping hydrometeors at very high temporal size, which happens in the same time of the precipitation rate are computed (L. Sieck, S. Burges, M. Steiner, 2007). Since that, disdrometer are installed in many type of rain gauge, satellite remote sensing studies (J. Joss, J.C. Thams, A. Waldvogel, 1970). The disdrometer are invented to help to identify the cause of error that have been happening in satellite precipitation prediction and many other advantages such as high calibration and reflective monitoring that give a huge probable in rain gauge system. The most common used disdrometer are created by Joss-Waldvogel (JW) are relied to act as reference equipment to compute the rain drop size distribution and calculation on the ground surface. As the conclusion, precipitation rate that have been collected from the disdrometer are the reference used widely in estimating the rainfall intensity.

The purpose of this study is to develop a high temporal resolution precipitation intensity from the rain gauge (tipping bucket) referred to the Joss-Waldvogel disdrometer reading. Latest improvement that have been successfully developed in the practised ANN (Artificial Neural Network) access in water content, precipitation intensity and satellite radar reflection prediction established upon the size of the droplets distribution (S. Tengeleng, N. Armand, 2014). Consequently, in this study, a dataset for 5 years are obtained from the tipping bucket and 5 minute rainfall estimation model are developed.

2.4 Method to Develop Rainfall Temporal Pattern

Rainfall distribution has for some time been researched by analyst to help with current innovations and engineering works. One of the investigations is to create RTP. According to Golkar and Farahmand (2009), rainfall temporal distribution pattern is an important factor in irrigation and drainage, watershed management, damming, civil engineering and flood potential studies. There are a couple of approaches to create RTP, for example, utilizing Average Variability Method (AVM), Soil Conservation Services (SCS), Huff Time Method and Triangular Method.

2.4.1 Triangular Hyetograph Method

For triangular hyetograph method, an example of hyetograph is as shown in Figure 2.3. The first step are to compute P/i calculated either from Depth Duration Frequency (DDF)/ Intensity Duration Frequency (IDF) curves or equation.

For equation, the first step are to recognise T_d that is hyetograph base length which it is equal to precipitation duration. Next, time before the peak, t_a, were determined from the curve.

$$P = \frac{1}{2}(Th) \qquad \text{(Equation 1)}$$

$$h = 2\frac{P}{T} \qquad \text{(Equation 2)}$$

In this calculation, the coefficient of storm advancement, r, are included. Below was the coefficient formula;

$$r = \frac{ta}{Td} \qquad \text{(Equation 3)}$$

Next step is to determine the recession time, t_b, where the recession time is the period of time after the peak until the end of precipitation event. The formula for recession time given by;

$$tb = (1 - r)T\mathrm{d} = \mathrm{Td} - \mathrm{ta} \qquad \text{(Equation 4)}$$

Use above equations to get t_a, t_b, T_d, and h. For the recession time, the r is available for various locations.

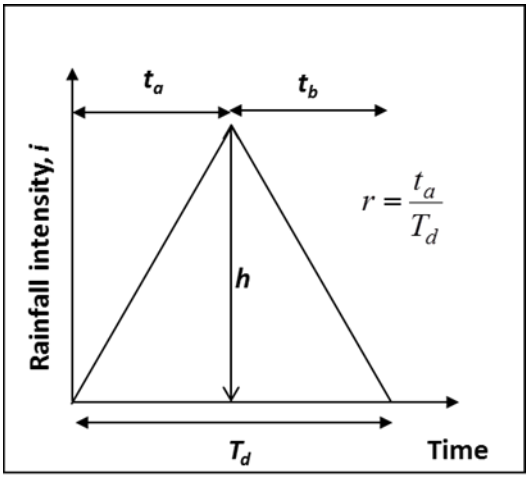

Figure 2.3: An example of hyetograph triangular method

Source: A triangular model for the generation of synthetic hyetographs (https://www.tandfonline.com/doi/pdf/10.1623/hysj.54.2.287)

2.4.2 Alternating Block Method

For this method, the steps are, using T, find I for Δt, 2Δt, 3Δt, nΔt using the Intensity Duration Frequency (IDF) curve for the specified location;

$$i = \frac{c}{(Td)^e + f} = \frac{96.6}{(Td)^{0.97} + 13.90} \qquad \text{(Equation 5)}$$

i = Design rainfall intensity

Td = Duration of storm

c, e, f = Coefficients

Using i, compute P for Δt, 2Δt, 3Δt and nΔt. This will gives cumulative P. Next is to calculate the incremental precipitation from cumulative P that are calculated before. The highest incremental precipitation (maximum block) and place it in the of the hyetograph.

After that, pick the second highest block and place it to the right of the maximum block. The third highest block were picked and place it to the left of the maximum block.

The next step is pick the fourth highest block and place it to the right of the maximum block (after the second block), and continue until the last block.

2.4.3 Average Variability Method (AVM)

For this method, it was likewise utilized by Malaysia in MSMA2. Bustami et al. (2012), use AVM in the study on Development of Temporal Rainfall Pattern for Southern Region of Sarawak. In the study, the fleeting example is taken for 10 minutes, 15 minutes, 30 minutes, an hour, 120 minutes, 180 minutes and 360 minutes span.

Next, the first 10 ranked rainfall for each duration are selected to present the temporal rainfall pattern for individual station in line chart for all stations. In the meantime, the mean for each temporal pattern also calculated. Next, calculation of the average percentage of rainfall for each period of time of the temporal precipitation patterns for individual station are required.

Last but not least, the temporal rainfall patterns for the specified location are developed.

2.4.4 Huff Time Distribution Method

As indicated by Smith (2010), Huff proposed a group of non-dimensional, storm dispersion designs. The events were separated into four gatherings in which the pinnacle precipitation power happens in the main, second, third or final quarter of the tempest length. Inside each gathering the appropriation was plotted for various probabilities of event. MIDUSS utilizes the middle bend for every one of the four quartile disseminations. A non-dimensional bend is shown in Figure 2.4.

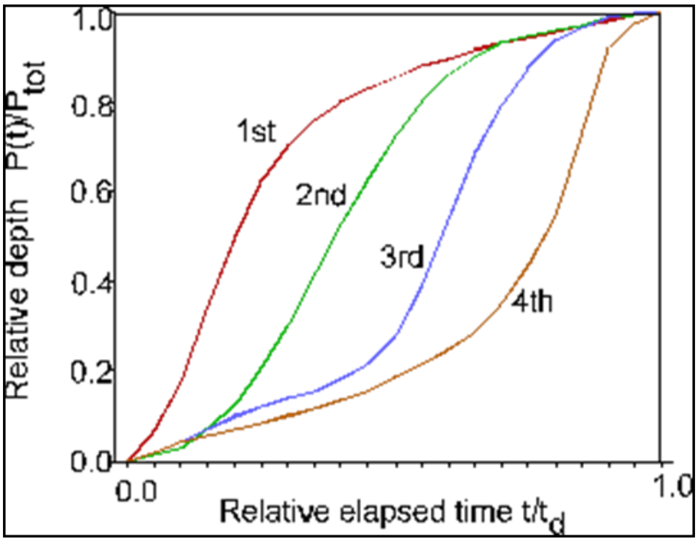

Figure 2.4: Non-dimensional curve of Huff's storm distribution

Source: MIDUSS Version 2, Reference Manual – Chapter 7 © Copyright Alan A. Smith Inc. (http://www.alanasmith.com/theory-Derivation-Huff-Storm.htm)

To characterize a tempest of this sort give esteems to the complete profundity of precipitation (in millimetres or inches), the term of the tempest (in minutes) and the quartile conveyance required (for example 1, 2, 3 or 4). The four quartile Huff appropriations are approximated by a progression of harmonies joining focuses characterized by the non-dimensional qualities in the Figure 2.5 demonstrates a normal bend (not to scale) which for lucidity utilizes just an exceptionally modest number of steps. The time base for the NH dimensionless focuses characterizing the 'bend' is subdivided into dimensionless time steps characterized by,

$$\Delta\tau = \frac{(NH - 1)}{NDT} \quad \text{(Equation 6)}$$

Where,

NH = number of points defining the Huff curve (shown as NH = 7 but usually much more).

NDT = number of rainfall intensities required (shown as only 15 in Figure 2.5).

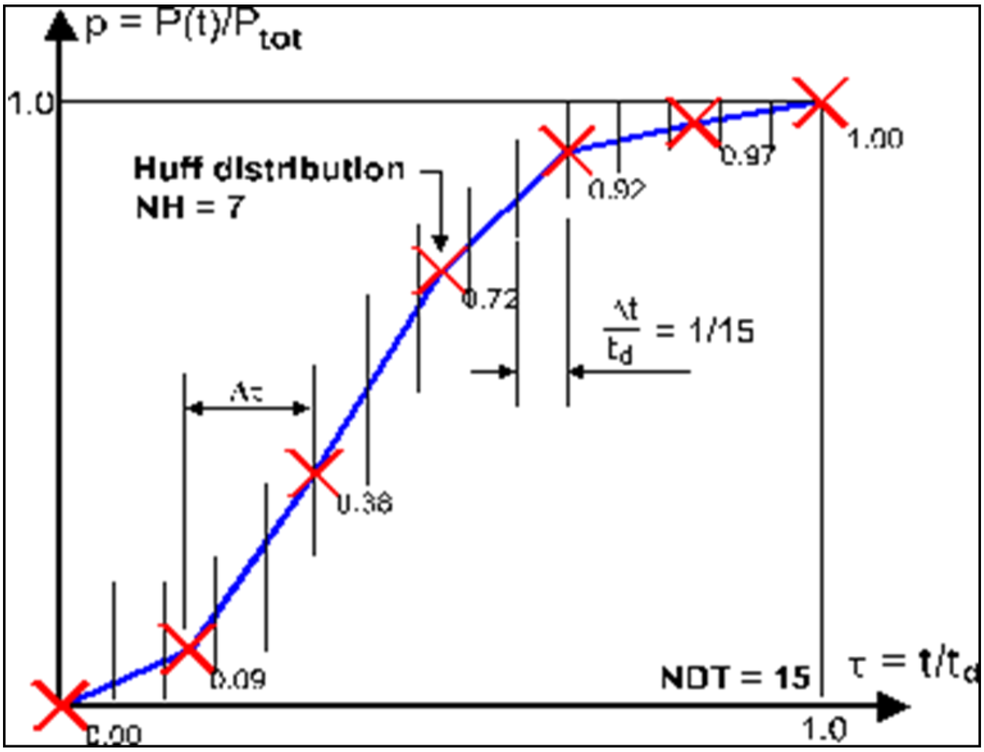

Figure 2.5: Discretization of a Huff curve.

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The values of the dimensionless fractions Pk and Pk+1 at the start and finish of each time-step are obtained by linear interpolation and the corresponding rainfall intensity is then given as:

$$ij = \frac{(p_{k+1} - p_k)P_{tot}}{\Delta t} \qquad \text{(Equation 7)}$$

Where,

$$p_{k+1} = p_m + (p_{m+1} - p_m)(h - m)$$

$$m = INT(h)$$

$$h = j\Delta\tau + 1$$

2.4.5 Soil Conservation Method

Alharty (2006) notice that SCS type bends are as percentage mass (combined) bends dependent on 24-hour precipitation of the ideal recurrence. In the event that a solitary precipitation profundity of wanted recurrence is known, the SCS type bend is rescaled (duplicated by the known number) to get the time dispersion. For terms under 24 hour, the steepest piece of the sort bend for required span is utilized.

The means for creating hyetograph utilizing SCS firstly is to compute P/i that are calculated from Depth Duration Frequency divided by Intensity Duration Frequency curves or from equations. Then, pick a SCS type of curve dependent on the selected area.

Furthermore, for 24 hours, duplicate or rescale the sort curve with P to get the plan mass curve. On the off chance that is under 24 hours, pick the steepest piece of the curve for rescaling.

Lastly, determine the balance precipitation from the rescaled mass curve to build up the plan hyetograph

2.5 Calibration

In Hydrological application of weather satellite precipitation, some adjustment may be needed in collecting the reading reflected from satellite, because of too many issues, to synchronise the data with the ground truth. This is what called as calibration of radar. Rain gauge data are required to calibrate the satellite rainfall information.

This bias between satellite precipitation reading and rain gauge reading can be ignored by using the information extracted from the rain gauge itself. The simplest ways in correcting the bias is to multiply the satellite rainfall data with calibration factor (G/R) (Chumchean et al., 2006). The proposed method of adjustment are including the factor that is predicted as the ratio of accumulated precipitation intensity, G, and the accumulated satellite precipitation, R.

CHAPTER 3

METHODOLOGY

3.1 Introduction

To finish the analysis, the procedure began with choosing the investigation territory dependent on issue explanation and centrality of study acquired. The investigation region likewise included choice of precipitation station at UMP Gambang. Next is information gathering process. The information taken is in 5 minutes interval of precipitation event information from 2013 to 2018. In the wake of gathering the information, the procedure continued to separating the precipitation events of an hour and 120 minutes. From that point forward, continue to break down the information obtained. In the investigation, the method chose is WRRI and Huff Time Method as the two techniques were both created same kind of yield. So the terms in looking at both method was of a similar parameter. In this part, the procedure is being detailed more on study region, information accumulation and information analysis.

3.2 Radar-derived rainfall calibration

The hydrological information, for example, precipitation, stream release and water levels were gotten from the Department of Irrigation and Drainage (DID). For every radar station, the closest programmed rain check stations accessible in peninsular Malaysia were recognized. Information from 24 rain measure in figure 3 worked by DID and situated inside 100 km run from the radar area were utilized for radar precipitation correlations and adjustment.

In this study, the proportion technique was utilized to evaluate the proportion between radar-derived precipitation information and the rain gauge information. The radar precipitation evaluated from all radar stations accessible in peninsular Malaysia were increased by the proportion factor with the end goal that radar assessed precipitation esteems are around equivalent to the gauge rainfall values (Stellman et al., 2001).

3.3 Implementation of radar-derived rainfall

Many implementation using radar-derived rainfall can be highly performed such as, civil infrastructure design, irrigation water management, landslide assessment, watershed management, rainfall variability mapping and flood forecasting operations.

In this investigation, for the usage of radar precipitation, the Kuantan river basin was considered as study region. Kuantan river basin is situated in the north-eastern of Pahang, spreading over the capital city of Pahang. Geologically, the basin is situated at the directions of 30 12' 27.66" N and 103 07' 39.99" E, covering the water supply for different activities in the capital of Pahang, with the number of inhabitants in 607,778 occupants. The aggregate length of the basin is around 86 km and the aggregate zone is 1638 sq. km. The Kuantan town is an urbanized zone, which is arranged near the South China Sea. The basin begins from Gunung Tapis and it streams in an easterly heading through Sungai Lembing to Kuantan town before releasing into the South East China Sea. As per the government expert, the sum total of what stations have been checked by the Department of Environment, Malaysia (DOE).

This river basin gets yearly precipitation of 2470 mm and the upper east storm twist from November until March. The encompassing of Kuantan River is commanded by agribusiness (32.05%), lodging territories (2.99%), street and transportation (2.01%), industry (1.97%), establishments (0.95%), recreational regions (0.75%), framework (0.57%), and timberland (54.71%).

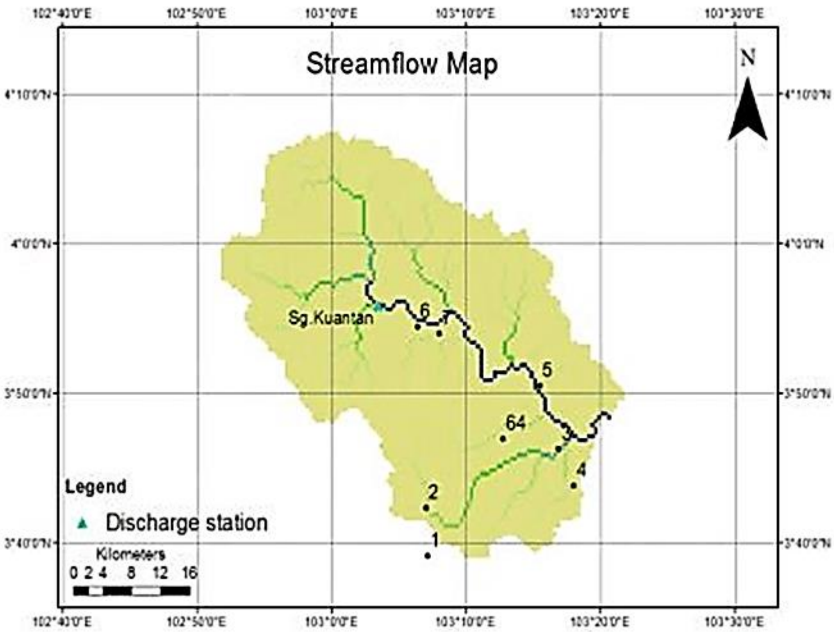

Figure 3.1: Streamflow map of Sungai Kuantan

Source: Weather Radar Based Quantitative Precipitation Estimation for Flood Forecasting Model (https://www.researchgate.net/publication/313892384_Weather_Radar_Based_Quantitative_Precipitation_Estimation_For_Flood_Forecasting_Model)

3.4 Tipping bucket mechanisms

The precipitation intensity is predicted by the tipping bucket rain gauge is simply by dividing every tip volume by the period between consecutive tips. A tipping bucket rain gauge has a few parts that enable it to precisely quantify precipitation. As rain falls it arrives in the pipe of the tipping bucket rain gauge. The rain goes down the pipe and dribbles into one of two cautiously aligned 'containers' adjusted on a turn (like a see-saw).

The best basin is held set up by a magnet until the point that it has filled to the aligned sum (more often than not around 0.001 creeps of rain). At the point when the can has filled to this sum, the magnet will discharge its hold, making the pail tip. The water at that point exhausts down a waste gap and raises the other to sit underneath the pipe. At the point when the basin tips, it triggers a reed switch (or sensor), making an impression on the showcase or climate station.

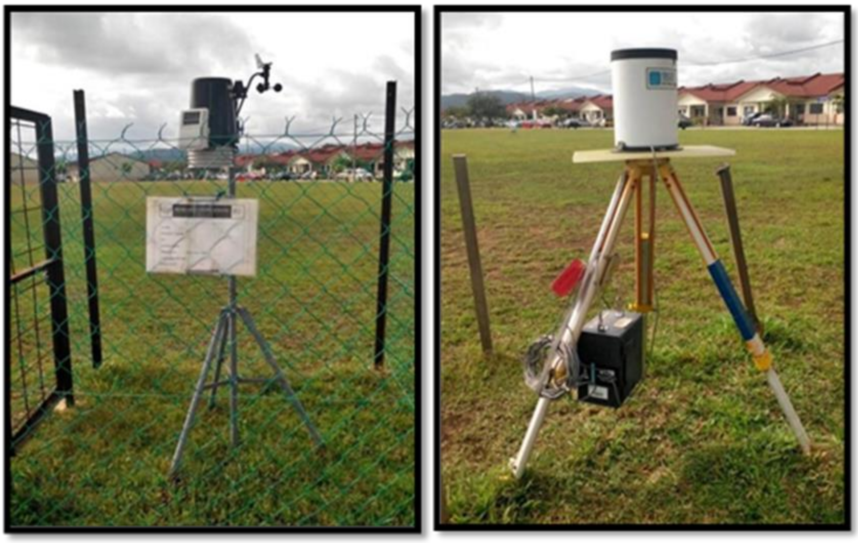

Figure 3.2: Example of tipping bucket rain gauge placed at Kolej Kediaman 2, Universiti Malaysia Pahang, Gambang.

3.5 Flowchart

Figure 3.3 shows the flow chart of the study methodology starting with study area followed by data collection, analysis and conclusion from the results.

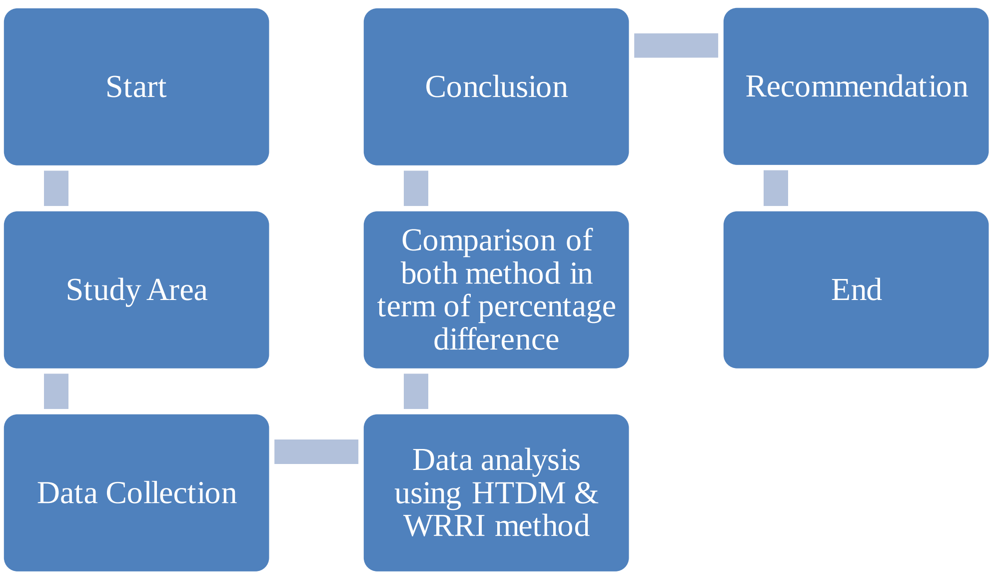

Figure 3.3: Flowchart of methodology

3.6 Study Area

The area chose for this study is Universiti Malaysia Pahang which is situated at Gambang, Kuantan, Pahang. Kuantan is situated at east coast zone where Monsoon season happen each year. Thus, the zone is managing flood each year. The most noticeably awful flood happen is amid December 2013. Figure 3.4 is the guide of Hydrological Stations in Pahang.

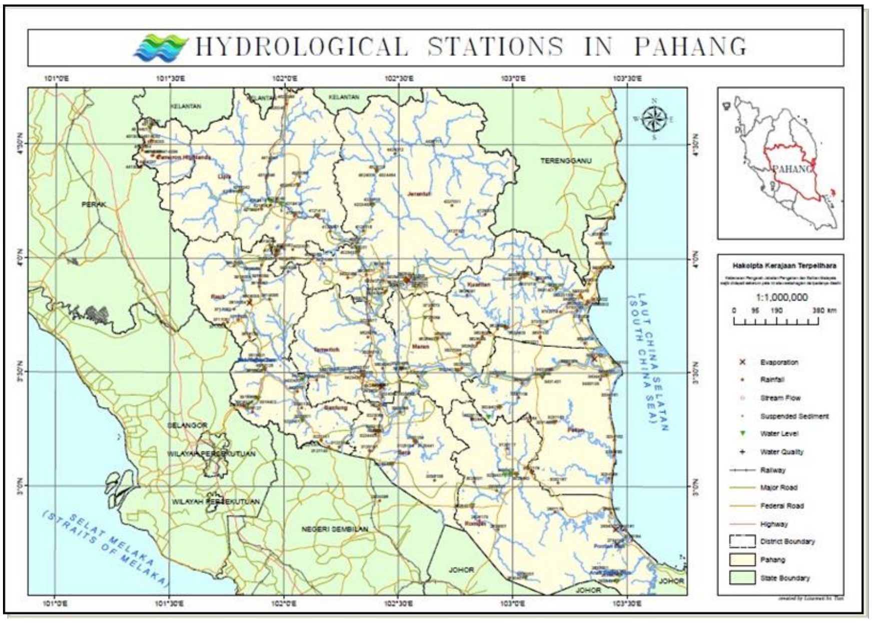

Figure 3.4: Hydrological stations of Pahang

Source: http://h2o.water.gov.my/v2/fail/rhnc/locrfe/PDF2/pahang2.pdf

3.7 Data Collection

The information use for the investigation is 5 minutes interval of precipitation which taken from JKR Gambang station situated in Kuantan river basin. For a progressively solid outcome, the information is taken from 2013 to 2018. The information is gathered from Department of Irrigation and Drainage Malaysia. The data was accumulated from DID is each day precipitation data for a significant period of time at station JKR Gambang.

3.8 Method of Calculation

After collection of data, the analysis will be using two methods. The method used is Water Resources Research Institute Method and Huff Time Distribution Method.

3.8.1 Huff Time Distribution Method

For Huff strategy, it is practically comparative with SCS technique. The example of the join circulation is somewhat unique. Viessman et. Al (2003) notice that methodology for Huff Time Method are first to distinguish the tempest and separate it dependent on the record of precipitation acquired. At that point, the recorded tempest is separated to dispersion examples of four equivalent likelihood gathering (quartile) from most serious to mildest. From that point onward, begin developing conveyance design (middle curve) for all quartile.

The formula used to develop the curve is where NH is number of points defining the Huff cure NDT is number of rainfall intensities needed.

3.8.2 Water Resources Research Institute Method (WRRI)

WRRI technique is another method in creating rainfall temporal pattern. This method is practically indistinguishable to Huff Time Distribution Method. As indicated by (El-Sayed, 2017) the precipitation events is organized in such manner that the most elevated profundity of precipitation is in the centre and the least is the first and the last. Figure 3.5 is the straightforward advance to pursue to create utilizing WRRI strategy.

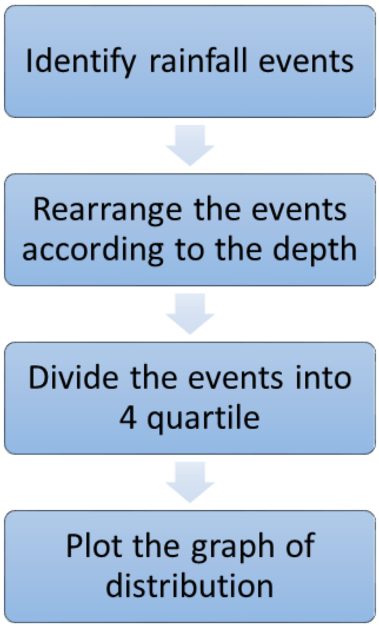

Figure 3.5: Step using WRRI

3.9 Comparison

Since both strategy has a similar method to create and the outcome acquired were of a similar parameter and measurement, the comparison were made dependent on the level of combined precipitation depth of every event. For instance, the first point of cumulative percentage from first purpose of first Quartile of HTDM's hour precipitation event of JKR Gambang was compared and first purpose of first Quartile of WRRI's hour precipitation event of JKR Gambang. Both strategy was of a similar measurement. Taking out the contrasts between the two point and include with the following contrasts of the following point. The total of contrasts was determined and separated with complete point from HTDM since HTDM is the current technique utilized and it is the more old method.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

In this study, the precipitation information is gathered from Department of Irrigation and Drainage (DID) and the precipitation events of an hour and 120 minutes were taken so as to build up the rainfall temporal pattern. The outline of precipitation events are recorded. The examples are created utilizing Huff Time Method and Water Resources Research Institute method and were thought about a short time later. The investigation and study of the two techniques are talked about further in this section.

From the data analysis, the summary of rainfall event happening around Universiti Malaysia Pahang was concluded. At station id of 3731018, name of JKR Gambang, there are 17 rainfall events that happening in 60 minutes time period, another 11 rainfall events happened in 120 minutes time period. A total of 28 precipitation events were recorded from year 2013 until 2018.

4.2 Huff Time Distribution Method

The precipitation events used to create utilizing this method are an hour and 120 minutes. This is because that this method required the event to be separated into four equivalent quartiles. Thus, such choices are picked as the event can be similarly divided by four quartiles. The outcomes are spread out in type of curve by associating each purpose of precipitation event of 5 minutes interval plotted. The analysis for JKR Gambang Station is shown in Table 4.1 and Table 4.2 for (a), (b), (c) and (d) are first, second, third and fourth quartile separately

Table 4.1 (a): Analysis using HTDM for 1st Quartile of 60 minutes rainfall events of JKR Gambang

1st Q	%Cum	Depth																
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	33.33	0.2	1.5	0.2	0.1	0.9	0.2	0.3	0.3	1.1	1.4	2.5	0.3	0.1	1.7	1.3	0.3	0.1
5	66.67	3.1	2.5	0.2	0.2	5.4	0.2	0.3	3.9	4.7	7	0.1	0.2	0.1	1.3	4.2	2.3	0.1
5	100	0.7	0.1	0.2	0.2	3.9	0.2	0.2	7.7	3.7	7.3	0.1	0.2	0.1	0.4	3.3	0.4	0.1

From the analysis above by using Huff Time Distribution Method for the 1st quartile of 60 minutes rainfall events of JKR Gambang, the average rainfall intensity are calculated. For the 1st five minutes, the average rainfall intensity calculated is 0.735mm. For the 2nd five minutes, the average rainfall intensity recorded is 2.106mm. Next, for the 3rd five minutes, the average rainfall intensity obtained is 1.694mm.

Furthermore, the percentage of the average rainfall intensity need to be calculated. For the 1st five minutes, the percentage calculated is 16.21%. For the 2nd five minutes, the percentage recorded is 46.44%. Next, for the 3rd five minutes, the percentage obtained is 37.35%.

Last but not least, the cumulative percentage are calculated as the data need to be included for developing the curve of Rainfall Temporal Pattern. So, for the 1st five minutes, the cumulative percentage calculated is 16.21%. For the 2nd five minutes, the cumulative percentage recorded is 62.65%. Next, for the 3rd five minutes, the cumulative percentage is 100%.

Table 4.1(b): Analysis using HTDM for 2nd Quartile of 60 minutes rainfall events of JKR Gambang

2nd Q	%Cum	Depth																
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	33.33	0.1	0.1	0.2	0.4	1.7	0.2	0.2	5.8	1.6	6.1	0.1	0.2	0.1	0.1	8.7	0.2	0.1
5	66.67	0.1	0.1	0.2	0.6	0.6	0.5	0.1	6.8	1.3	4.8	0.1	0.2	0.1	0.1	7.5	0.2	0.1
5	100	0.1	0.1	2.4	0.2	0.1	0.7	0.1	3.4	1.4	1.4	0.1	0.2	0.1	0.1	2.9	0.2	0.1

From the analysis above by using Huff Time Distribution Method for the 2^{nd} quartile of 60 minutes rainfall events of JKR Gambang, the average rainfall intensity are calculated. For the 1^{st} five minutes, the average rainfall intensity calculated is 1.524mm. For the 2^{nd} five minutes, the average rainfall intensity recorded is 1.376mm. Next, for the 3^{rd} five minutes, the average rainfall intensity obtained is 0.800mm.

Furthermore, the percentage of the average rainfall intensity need to be calculated. For the 1^{st} five minutes, the percentage calculated is 41.19%. For the 2^{nd} five minutes, the percentage recorded is 37.19%. Next, for the 3^{rd} five minutes, the percentage obtained is 21.62%.

Last but not least, the cumulative percentage are calculated as the data need to be included for developing the curve of Rainfall Temporal Pattern. So, for the 1^{st} five minutes, the cumulative percentage calculated is 41.19%. For the 2^{nd} five minutes, the cumulative percentage recorded is 78.38%. Next, for the 3^{rd} five minutes, the cumulative percentage is 100%.

Table 4.1(c): Analysis using HTDM for 3rd Quartile of 60 minutes rainfall events of JKR Gambang

		Depth																
3rd Q	%Cum	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	33.33	0.3	0.1	6.7	0.2	0.1	0.1	0.1	2.6	0.9	0.4	2.8	0.2	0.1	0.1	2.1	1.7	0.1
5	66.67	0.4	0.1	4.6	0.4	0.1	0.1	0.1	1.2	0.5	0.2	4	0.1	0.1	0.7	0.8	0.8	0.1
5	100	0.1	0.1	2.2	1.8	0.1	0.1	0.1	0.5	0.4	0.1	0.7	0.1	0.1	1.3	0.6	1.3	7.5

From the analysis above by using Huff Time Distribution Method for the 3rd quartile of 60 minutes rainfall events of JKR Gambang, the average rainfall intensity are calculated. For the 1st five minutes, the average rainfall intensity calculated is 1.094mm. For the 2nd five minutes, the average rainfall intensity recorded is 0.841mm. Next, for the 3rd five minutes, the average rainfall intensity obtained is 1.006mm.

Furthermore, the percentage of the average rainfall intensity need to be calculated. For the 1st five minutes, the percentage calculated is 37.2%. For the 2nd five minutes, the percentage recorded is 28.6%. Next, for the 3rd five minutes, the percentage obtained is 34.2%.

Last but not least, the cumulative percentage are calculated as the data need to be included for developing the curve of Rainfall Temporal Pattern. So, for the 1st five minutes, the cumulative percentage calculated is 37.2%. For the 2nd five minutes, the cumulative percentage recorded is 66.8%. Next, for the 3rd five minutes, the cumulative percentage is 100%.

Table 4.1(d): Analysis using HTDM for 4th Quartile of 60 minutes rainfall events of JKR Gambang

4th Q	%Cum	Depth																
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	33.33	0.1	0.1	1.1	1.4	0.1	0.1	0.1	0.2	0.3	0.1	0.3	0.1	0.1	1.4	0.2	1.8	3.6
5	66.67	0.1	0.1	1.8	0.3	0.1	0.4	0.1	0.2	0.2	0.1	0.5	0.1	0.1	0.4	0.2	0.5	0.3
5	100	0.1	0.1	0.7	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.1	0.1	0.2	0.1	0.4	0.1

From the analysis above by using Huff Time Distribution Method for the 4^{th} quartile of 60 minutes rainfall events of JKR Gambang, the average rainfall intensity are calculated. For the 1^{st} five minutes, the average rainfall intensity calculated is 0.653mm. For the 2^{nd} five minutes, the average rainfall intensity recorded is 0.324mm. Next, for the 3^{rd} five minutes, the average rainfall intensity obtained is 0.171mm.

Furthermore, the percentage of the average rainfall intensity need to be calculated. For the 1^{st} five minutes, the percentage calculated is 56.88%. For the 2^{nd} five minutes, the percentage recorded is 28.22%. Next, for the 3^{rd} five minutes, the percentage obtained is 14.9%.

Last but not least, the cumulative percentage are calculated as the data need to be included for developing the curve of Rainfall Temporal Pattern. So, for the 1^{st} five minutes, the cumulative percentage calculated is 56.88%. For the 2^{nd} five minutes, the cumulative percentage recorded is 85.1%. Next, for the 3^{rd} five minutes, the cumulative percentage is 100%.

Table 4.2(a): Analysis using HTDM for 1st Quartile of 120 minutes rainfall events of JKR Gambang

1st Q	%Cum	Depth										
		1	2	3	4	5	6	7	8	9	10	11
0	0	0	0	0	0	0	0	0	0	0	0	0
5	16.67	0.1	1	0.1	0.1	0.2	1.3	0.2	3.3	0.5	0.1	0.2
5	33.33	0.1	1.9	0.1	0.1	0.2	10.2	0.4	0.4	1.5	0.1	0.4
5	50	0.1	1.2	0.1	0.1	0.4	12.8	0.6	0.2	0.1	0.1	0.1
5	66.67	0.1	1.1	0.1	0.4	0.2	11.5	0.4	0.2	0.1	0.1	0.1
5	83.33	0.1	1.5	0.1	0.3	0.1	3.8	0.5	0.4	0.1	0.1	0.1
5	100	0.1	3.2	0.1	0.1	0.1	0.8	1.3	0.1	0.1	0.1	0.2

From the analysis above by using Huff Time Distribution Method for the 1st quartile of 120 minutes rainfall events of JKR Gambang, the average rainfall intensity are calculated. For the 1st five minutes, the average rainfall intensity calculated is 0.645mm. For the 2nd five minutes, the average rainfall intensity recorded is 1.4mm. Next, for the 3rd five minutes, the average rainfall intensity obtained is 1.436mm. For the 4th five minutes, the average rainfall intensity calculated is 1.3mm. For the 5th five minutes, the average rainfall intensity recorded is 0.645mm. Next, for the 6th five minutes, the average rainfall intensity obtained is 0.563mm.

Furthermore, the percentage of the average rainfall intensity need to be calculated. For the 1st five minutes, the percentage calculated is 10.77%. For the 2nd five minutes, the percentage recorded is 23.38%. Next, for the 3rd five minutes, the percentage obtained is 23.98%. For the 4th five minutes, the percentage calculated is 21.71%. For the 5th five minutes, the percentage recorded is 10.77%. Next, for the 6th five minutes, the percentage obtained is 9.4%.

Last but not least, the cumulative percentage are calculated as the data need to be included for developing the curve of Rainfall Temporal Pattern. So, for the 1st five minutes, the cumulative percentage calculated is 10.77%. For the 2nd five minutes, the cumulative percentage recorded is 34.15%. Next, for the 3rd five minutes, the cumulative percentage is 58.13%. For the 4th five minutes, the cumulative percentage calculated is 79.84%. For the 5th five minutes, the cumulative percentage recorded is 90.61%. Next, for the 6th five minutes, the cumulative percentage obtained is 100%.

Table 4.2(b): Analysis using HTDM for 2nd Quartile of 120 minutes rainfall events of JKR Gambang

2nd Q	%Cum	Depth										
		1	2	3	4	5	6	7	8	9	10	11
0	0	0	0	0	0	0	0	0	0	0	0	0
5	16.67	0.1	2	0.1	0.1	0.1	0.2	1.4	0.1	1	1.3	0.2
5	33.33	0.1	4.5	0.1	0.1	0.1	0.2	1.1	0.1	3	0.5	0.6
5	50	0.1	3.9	0.1	0.1	0.6	0.2	0.3	0.1	1.5	0.5	0.3
5	66.67	0.1	0.9	0.1	0.1	0.3	1.4	0.4	0.1	0.7	1.2	0.2
5	83.33	0.1	0.2	0.1	0.1	0.4	0.9	0.6	0.1	0.6	2.1	0.1
5	100	0.1	0.2	0.1	0.1	0.3	1.3	0.7	0.1	2.8	3.6	0.1

From the analysis above by using Huff Time Distribution Method for the 2nd quartile of 120 minutes rainfall events of JKR Gambang, the average rainfall intensity are calculated. For the 1st five minutes, the average rainfall intensity calculated is 0.6mm. For the 2nd five minutes, the average rainfall intensity recorded is 0.945mm. Next, for the 3rd five minutes, the average rainfall intensity obtained is 0.7mm. For the 4th five minutes, the average rainfall intensity calculated is 0.5mm. For the 5th five minutes, the average rainfall intensity recorded is 0.482mm. Next, for the 6th five minutes, the average rainfall intensity obtained is 0.855mm.

Furthermore, the percentage of the average rainfall intensity need to be calculated. For the 1st five minutes, the percentage calculated is 14.7%. For the 2nd five minutes, the percentage recorded is 23.15%. Next, for the 3rd five minutes, the percentage obtained is 17.15%. For the 4th five minutes, the percentage calculated is 12.25%. For the 5th five minutes, the percentage recorded is 11.81%. Next, for the 6th five minutes, the percentage obtained is 20.95%.

Last but not least, the cumulative percentage are calculated as the data need to be included for developing the curve of Rainfall Temporal Pattern. So, for the 1st five minutes, the cumulative percentage calculated is 14.7%. For the 2nd five minutes, the cumulative percentage recorded is 37.85%. Next, for the 3rd five minutes, the cumulative percentage is 55%. For the 4th five minutes, the cumulative percentage calculated is 67.25%. For the 5th five minutes, the cumulative percentage recorded is 79.06%. Next, for the 6th five minutes, the cumulative percentage obtained is 100%.

Table 4.2 (c): Analysis using HTDM for 3rd Quartile of 120 minutes rainfall events of JKR Gambang

3rd Q	%Cum	Depth										
		1	2	3	4	5	6	7	8	9	10	11
0	0	0	0	0	0	0	0	0	0	0	0	0
5	16.67	0.1	0.2	0.3	0.1	0.1	1.1	0.3	0.1	4.4	1.4	0.2
5	33.33	0.1	0.4	0.6	0.1	0.1	4	0.2	0.1	0.8	0.9	1.4
5	50	0.1	0.4	3.8	0.1	0.1	1.6	0.1	0.1	0.5	0.6	2.8
5	66.67	0.1	0.3	4.1	0.1	0.1	0.7	0.1	0.1	0.4	0.1	1.3
5	83.33	0.2	0.2	2.7	0.1	0.1	1.8	0.1	0.1	0.2	0.1	0.9
5	100	0.2	0.2	3.4	0.1	0.1	1	1.2	0.1	0.2	0.1	0.7

From the analysis above by using Huff Time Distribution Method for the 3rd quartile of 120 minutes rainfall events of JKR Gambang, the average rainfall intensity are calculated. For the 1st five minutes, the average rainfall intensity calculated is 0.755mm. For the 2nd five minutes, the average rainfall intensity recorded is 0.791mm. Next, for the 3rd five minutes, the average rainfall intensity obtained is 0.927mm. For the 4th five minutes, the average rainfall intensity calculated is 0.673mm. For the 5th five minutes, the average rainfall intensity recorded is 0.591mm. Next, for the 6th five minutes, the average rainfall intensity obtained is 0.664mm.

Furthermore, the percentage of the average rainfall intensity need to be calculated. For the 1st five minutes, the percentage calculated is 17.16%. For the 2nd five minutes, the percentage recorded is 17.97%. Next, for the 3rd five minutes, the percentage obtained is 21.06%. For the 4th five minutes, the percentage calculated is 15.29%. For the 5th five minutes, the percentage recorded is 13.43%. Next, for the 6th five minutes, the percentage obtained is 15.09%.

Last but not least, the cumulative percentage are calculated as the data need to be included for developing the curve of Rainfall Temporal Pattern. So, for the 1st five minutes, the cumulative percentage calculated is 17.16%. For the 2nd five minutes, the cumulative percentage recorded is 35.13%. Next, for the 3rd five minutes, the cumulative percentage is 56.19%. For the 4th five minutes, the cumulative percentage calculated is 71.48%. For the 5th five minutes, the cumulative percentage recorded is 84.91%. Next, for the 6th five minutes, the cumulative percentage obtained is 100%.

Table 4.2(d): Analysis using HTDM for 4th Quartile of 120 minutes rainfall events of JKR Gambang

4th Q	%Cum	Depth										
		1	2	3	4	5	6	7	8	9	10	11
0	0	0	0	0	0	0	0	0	0	0	0	0
5	16.67	0.1	0.2	1.7	0.1	0.1	0.3	0.3	0.1	0.2	0.1	0.7
5	33.33	0.1	0.2	2.7	0.1	0.1	0.1	0.8	0.1	0.2	0.1	0.6
5	50	0.1	0.2	1.4	0.1	0.6	0.1	0.6	0.1	0.8	0.1	0.5
5	66.67	0.1	0.1	0.5	0.1	0.3	0.1	0.8	0.1	3.2	0.1	0.2
5	83.33	0.1	0.1	0.2	0.2	0.6	0.1	0.2	0.2	1.8	0.1	0.2
5	100	0.1	0.1	0.2	0.3	0.1	0.6	0.2	0.2	0.4	0.1	0.2

From the analysis above by using Huff Time Distribution Method for the 4th quartile of 120 minutes rainfall events of JKR Gambang, the average rainfall intensity are calculated. For the 1st five minutes, the average rainfall intensity calculated is 0.355mm. For the 2nd five minutes, the average rainfall intensity recorded is 0.464mm. Next, for the 3rd five minutes, the average rainfall intensity obtained is 0.418mm. For the 4th five minutes, the average rainfall intensity calculated is 0.509mm. For the 5th five minutes, the average rainfall intensity recorded is 0.345mm. Next, for the 6th five minutes, the average rainfall intensity obtained is 0.227mm.

Furthermore, the percentage of the average rainfall intensity need to be calculated. For the 1st five minutes, the percentage calculated is 15.31%. For the 2nd five minutes, the percentage recorded is 20.02%. Next, for the 3rd five minutes, the percentage obtained is 18.03%. For the 4th five minutes, the percentage calculated is 21.96%. For the 5th five minutes, the percentage recorded is 14.88%. Next, for the 6th five minutes, the percentage obtained is 9.79%.

Last but not least, the cumulative percentage are calculated as the data need to be included for developing the curve of Rainfall Temporal Pattern. So, for the 1st five minutes, the cumulative percentage calculated is 15.31%. For the 2nd five minutes, the cumulative percentage recorded is 35.33%. Next, for the 3rd five minutes, the cumulative percentage is 53.36%. For the 4th five minutes, the cumulative percentage calculated is 75.32%. For the 5th five minutes, the cumulative percentage recorded is 90.2%. Next, for the 6th five minutes, the cumulative percentage obtained is 100%.

4.3 Data Analysis at Station JKR Gambang for HTDM

At the station of JKR Gambang, there were 17 events recorded for the period of 60 minutes. Analyzation was made and shown below. The lowest curve plotted was in the first quartile while the highest is in the fourth quartile. The curves plotted represented at JKR Gambang is in an hour period of time by using Huff Time Distribution Method are as shown in Figure 4.1.

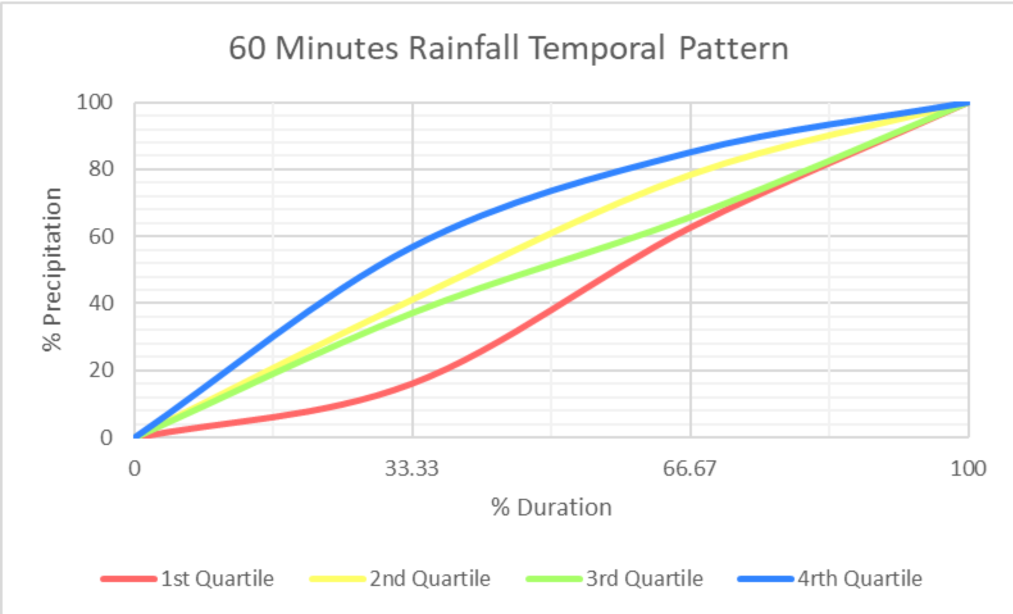

Figure 4.1: 60 minutes graph using HTDM

For a 120 minutes period of time curve, here were 11 events of precipitation are recorded at Station JKR Gambang. The lowest and the highest curve plotted was in the first quartile. All the quartile have almost the same curve by the period of 120 minutes. The curves plotted represented at JKR Gambang is in 120 period of time by using Huff Time Distribution Method are as shown in Figure 4.2.

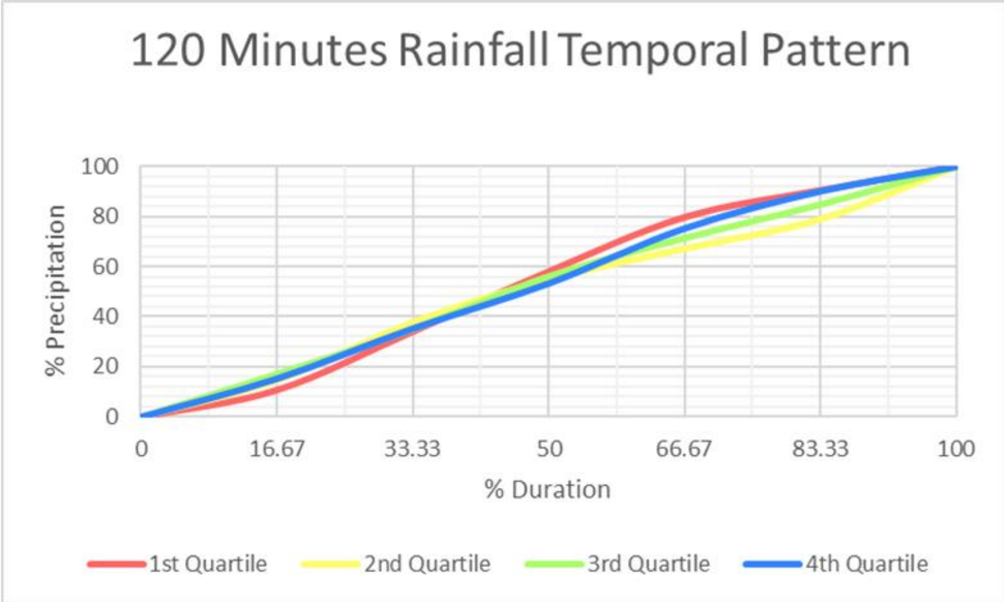

Figure 4.2: 120 minutes graph using HTDM

4.4 Water Resources Research Method

Precipitation events of 60 minute and 120 minutes was analysed by using this method. This way of calculation was almost the same as Huff Time Distribution Method where it have to be equally divided into four quartiles. However, rearranging the data was necessary before dividing the data into four quartiles, the precipitation depth is arranged so the lowest is in the first and last while the highest depth is in the middle. The results are plotted in the form of curve, same as the previous method and the rainfall event of 5 minutes interval are plotted. Analyzation of Station JKR Gambang is in Table 4.3 and Table 4.4 for (a), (b), (c) and (d) are first, second, third and fourth quartile accordingly.

Table 4.3 (a): Analysis using WRRI for 1st Quartile of 60 minutes rainfall events of JKR Gambang

1st Q	%Cum	Depth																
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	33.33	0.1	0.1	0.2	0.2	0.1	0.1	0.1	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.1
5	66.67	0.1	0.1	0.2	0.2	0.1	0.1	0.1	0.3	0.4	0.1	0.1	0.1	0.1	0.1	0.6	0.3	0.1
5	100	0.1	0.1	0.2	0.2	0.1	0.2	0.1	1.2	0.9	0.4	0.2	0.1	0.1	0.4	1.3	0.4	0.1

From the analysis above by using Water Resources Research Institute method for the 1^{st} quartile of 60 minutes rainfall events of JKR Gambang, the average rainfall intensity are calculated. For the 1^{st} five minutes, the average rainfall intensity calculated is 0.135mm. For the 2^{nd} five minutes, the average rainfall intensity recorded is 0.182mm. Next, for the 3^{rd} five minutes, the average rainfall intensity obtained is 0.359mm.

Furthermore, the percentage of the average rainfall intensity need to be calculated. For the 1^{st} five minutes, the percentage calculated is 19.97%. For the 2^{nd} five minutes, the percentage recorded is 26.92%. Next, for the 3^{rd} five minutes, the percentage obtained is 53.11%.

Last but not least, the cumulative percentage are calculated as the data need to be included for developing the curve of Rainfall Temporal Pattern. So, for the 1^{st} five minutes, the cumulative percentage calculated is 19.97%. For the 2^{nd} five minutes, the cumulative percentage recorded is 46.89%. Next, for the 3^{rd} five minutes, the cumulative percentage is 100%.

Table 4.3(b): Analysis using WRRI for 2nd Quartile of 60 minutes rainfall events of JKR Gambang

2nd Q	%Cum	Depth																
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	33.33	0.1	0.1	1.1	0.4	0.6	0.2	0.1	3.4	1.3	1.4	0.5	0.2	0.1	0.7	2.9	0.8	0.1
5	66.67	0.3	0.1	2.2	0.6	1.7	0.4	0.2	5.8	1.6	6.1	2.5	0.2	0.1	1.3	4.2	1.7	0.3
5	100	3.1	2.5	6.7	1.8	5.4	0.7	0.3	7.7	4.7	7.3	4	0.2	0.1	1.7	8.7	2.3	7.5

From the analysis above by using Water Resources Research Institute method for the 2nd quartile of 60 minutes rainfall events of JKR Gambang, the average rainfall intensity are calculated. For the 1st five minutes, the average rainfall intensity calculated is 0.824mm. For the 2nd five minutes, the average rainfall intensity recorded is 1.724mm. Next, for the 3rd five minutes, the average rainfall intensity obtained is 3.806mm.

Furthermore, the percentage of the average rainfall intensity need to be calculated. For the 1st five minutes, the percentage calculated is 12.97%. For the 2nd five minutes, the percentage recorded is 27.13%. Next, for the 3rd five minutes, the percentage obtained is 59.9%.

Last but not least, the cumulative percentage are calculated as the data need to be included for developing the curve of Rainfall Temporal Pattern. So, for the 1st five minutes, the cumulative percentage calculated is 12.97%. For the 2nd five minutes, the cumulative percentage recorded is 40.1%. Next, for the 3rd five minutes, the cumulative percentage is 100%.

Table 4.3 (c): Analysis using WRRI for 3rd Quartile of 60 minutes rainfall events of JKR Gambang

		Depth																
3rd Q	%Cum	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	33.33	0.7	1.5	4.6	1.4	3.9	0.5	0.3	6.8	3.7	7	2.8	0.3	0.1	1.4	7.5	1.8	3.6
5	66.67	0.4	0.1	2.4	0.4	0.9	0.2	0.2	3.9	1.4	4.8	0.7	0.2	0.1	1.3	3.3	1.3	0.1
5	100	0.2	0.1	1.8	0.3	0.1	0.2	0.1	2.6	1.1	1.4	0.3	0.2	0.1	0.4	2.1	0.5	0.1

From the analysis above by using Water Resources Research Institute method for the 3rd quartile of 60 minutes rainfall events of JKR Gambang, the average rainfall intensity are calculated. For the 1st five minutes, the average rainfall intensity calculated is 2.82mm. For the 2nd five minutes, the average rainfall intensity recorded is 1.28mm. Next, for the 3rd five minutes, the average rainfall intensity obtained is 0.682mm.

Furthermore, the percentage of the average rainfall intensity need to be calculated. For the 1st five minutes, the percentage calculated is 58.97%. For the 2nd five minutes, the percentage recorded is 26.77%. Next, for the 3rd five minutes, the percentage obtained is 14.26%.

Last but not least, the cumulative percentage are calculated as the data need to be included for developing the curve of Rainfall Temporal Pattern. So, for the 1st five minutes, the cumulative percentage calculated is 58.97%. For the 2nd five minutes, the cumulative percentage recorded is 85.74%. Next, for the 3rd five minutes, the cumulative percentage is 100%.

Table 4.3 (d): Analysis using WRRI for 4th Quartile of 60 minutes rainfall events of JKR Gambang

4th Q	%Cum	Depth																
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	33.33	0.1	0.1	0.7	0.2	0.1	0.1	0.1	0.5	0.5	0.2	0.1	0.2	0.1	0.2	0.8	0.4	0.1
5	66.67	0.1	0.1	0.2	0.2	0.1	0.1	0.1	0.2	0.3	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.1
5	100	0.1	0.1	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.1

Average	Percentage	Cumulative %
0	0	0
0.265	51.16	51.16
0.141	27.22	78.38
0.112	21.62	100
0.518		

From the analysis above by using Water Resources Research Institute method for the 4th quartile of 60 minutes rainfall events of JKR Gambang, the average rainfall intensity are calculated. For the 1st five minutes, the average rainfall intensity calculated is 0.265mm. For the 2nd five minutes, the average rainfall intensity recorded is 0.141mm. Next, for the 3rd five minutes, the average rainfall intensity obtained is 0.112mm.

Furthermore, the percentage of the average rainfall intensity need to be calculated. For the 1st five minutes, the percentage calculated is 51.16%. For the 2nd five minutes, the percentage recorded is 27.22%. Next, for the 3rd five minutes, the percentage obtained is 21.62%.

Last but not least, the cumulative percentage are calculated as the data need to be included for developing the curve of Rainfall Temporal Pattern. So, for the 1st five minutes, the cumulative percentage calculated is 51.16%. For the 2nd five minutes, the cumulative percentage recorded is 78.38%. Next, for the 3rd five minutes, the cumulative percentage is 100%.

Table 4.4 (a): Analysis using WRRI for 1st Quartile of 120 minutes rainfall events of JKR Gambang

1st Q	%Cum	Depth										
		1	2	3	4	5	6	7	8	9	10	11
0	0	0	0	0	0	0	0	0	0	0	0	0
5	16.67	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
5	33.33	0.1	0.2	0.1	0.1	0.1	0.1	0.2	0.1	0.1	0.1	0.1
5	50	0.1	0.2	0.1	0.1	0.1	0.2	0.2	0.1	0.2	0.1	0.2
5	66.67	0.1	0.2	0.1	0.1	0.1	0.3	0.3	0.1	0.2	0.1	0.2
5	83.33	0.1	0.2	0.1	0.1	0.1	0.7	0.3	0.1	0.4	0.1	0.2
5	100	0.1	0.3	0.1	0.1	0.1	0.9	0.4	0.1	0.5	0.1	0.2

From the analysis above by using Water Resources Research Institute method for the 1st quartile of 120 minutes rainfall events of JKR Gambang, the average rainfall intensity are calculated. For the 1st five minutes, the average rainfall intensity calculated is 0.1mm. For the 2nd five minutes, the average rainfall intensity recorded is 0.118mm. Next, for the 3rd five minutes, the average rainfall intensity obtained is 0.145mm. For the 4th five minutes, the average rainfall intensity calculated is 0.164mm. For the 5th five minutes, the average rainfall intensity recorded is 0.218mm. Next, for the 6th five minutes, the average rainfall intensity obtained is 0.264mm.

Furthermore, the percentage of the average rainfall intensity need to be calculated. For the 1st five minutes, the percentage calculated is 9.91%. For the 2nd five minutes, the percentage recorded is 11.69%. Next, for the 3rd five minutes, the percentage obtained is 14.37%. For the 4th five minutes, the percentage calculated is 16.25%. For the 5th five minutes, the percentage recorded is 21.61%. Next, for the 6th five minutes, the percentage obtained is 26.16%.

Last but not least, the cumulative percentage are calculated as the data need to be included for developing the curve of Rainfall Temporal Pattern. So, for the 1st five minutes, the cumulative percentage calculated is 9.91%. For the 2nd five minutes, the cumulative percentage recorded is 21.6%. Next, for the 3rd five minutes, the cumulative percentage is 35.97%. For the 4th five minutes, the cumulative percentage calculated is 52.22%. For the 5th five minutes, the cumulative percentage recorded is 73.83%. Next, for the 6th five minutes, the cumulative percentage obtained is 100%.

Table 4.4 (b): Analysis using WRRI for 2nd Quartile of 120 minutes rainfall events of JKR Gambang

2nd Q	%Cum	Depth										
		1	2	3	4	5	6	7	8	9	10	11
0	0	0	0	0	0	0	0	0	0	0	0	0
5	16.67	0.1	0.4	0.2	0.1	0.2	1.1	0.5	0.1	0.7	0.1	0.3
5	33.33	0.1	1	0.5	0.1	0.2	1.3	0.6	0.1	0.8	0.5	0.5
5	50	0.1	1.2	1.4	0.1	0.3	1.6	0.7	0.2	1.5	0.6	0.6
5	66.67	0.1	1.9	2.7	0.1	0.4	3.8	0.8	0.2	1.8	1.2	0.7
5	83.33	0.1	3.2	3.4	0.3	0.6	10.2	1.2	0.4	3	1.4	1.3
5	100	0.2	4.5	4.1	0.4	0.6	12.8	1.4	3.3	4.4	3.6	2.8

From the analysis above by using Water Resources Research Institute method for the 2nd quartile of 120 minutes rainfall events of JKR Gambang, the average rainfall intensity are calculated. For the 1st five minutes, the average rainfall intensity calculated is 0.345mm. For the 2nd five minutes, the average rainfall intensity recorded is 0.518mm. Next, for the 3rd five minutes, the average rainfall intensity obtained is 0.754mm. For the 4th five minutes, the average rainfall intensity calculated is 1.245mm. For the 5th five minutes, the average rainfall intensity recorded is 2.282mm. Next, for the 6th five minutes, the average rainfall intensity obtained is 3.464mm.

Furthermore, the percentage of the average rainfall intensity need to be calculated. For the 1st five minutes, the percentage calculated is 4.01%. For the 2nd five minutes, the percentage recorded is 6.02%. Next, for the 3rd five minutes, the percentage obtained is 8.76%. For the 4th five minutes, the percentage calculated is 14.46%. For the 5th five minutes, the percentage recorded is 26.51%. Next, for the 6th five minutes, the percentage obtained is 40.24%.

Last but not least, the cumulative percentage are calculated as the data need to be included for developing the curve of Rainfall Temporal Pattern. So, for the 1st five minutes, the cumulative percentage calculated is 4.01%. For the 2nd five minutes, the cumulative percentage recorded is 10.03%. Next, for the 3rd five minutes, the cumulative percentage is 18.79%. For the 4th five minutes, the cumulative percentage calculated is 33.25%. For the 5th five minutes, the cumulative percentage recorded is 59.76%. Next, for the 6th five minutes, the cumulative percentage obtained is 100%.

Table 4.4 (c): Analysis using WRRI for 3rd Quartile of 120 minutes rainfall events of JKR Gambang

3rd Q	%Cum	Depth										
		1	2	3	4	5	6	7	8	9	10	11
0	0	0	0	0	0	0	0	0	0	0	0	0
5	16.67	0.2	3.9	3.8	0.3	0.6	11.5	1.3	0.4	3.2	2.1	1.4
5	33.33	0.1	2	2.7	0.2	0.4	4	1.1	0.2	2.8	1.3	0.9
5	50	0.1	1.5	1.7	0.1	0.3	1.8	0.8	0.2	1.5	0.9	0.7
5	66.67	0.1	1.1	0.6	0.1	0.3	1.4	0.6	0.1	1	0.5	0.6
5	83.33	0.1	0.9	0.3	0.1	0.2	1.3	0.6	0.1	0.8	0.1	0.4
5	100	0.1	0.4	0.2	0.1	0.2	1	0.4	0.1	0.6	0.1	0.2

From the analysis above by using Water Resources Research Institute method for the 3rd quartile of 120 minutes rainfall events of JKR Gambang, the average rainfall intensity are calculated. For the 1st five minutes, the average rainfall intensity calculated is 2.609mm. For the 2nd five minutes, the average rainfall intensity recorded is 1.427mm. Next, for the 3rd five minutes, the average rainfall intensity obtained is 0.873mm. For the 4th five minutes, the average rainfall intensity calculated is 0.582mm. For the 5th five minutes, the average rainfall intensity recorded is 0.445mm. Next, for the 6th five minutes, the average rainfall intensity obtained is 0.309mm.

Furthermore, the percentage of the average rainfall intensity need to be calculated. For the 1st five minutes, the percentage calculated is 41.78%. For the 2nd five minutes, the percentage recorded is 22.85%. Next, for the 3rd five minutes, the percentage obtained is 13.98%. For the 4th five minutes, the percentage calculated is 9.32%. For the 5th five minutes, the percentage recorded is 7.13%. Next, for the 6th five minutes, the percentage obtained is 4.95%.

Last but not least, the cumulative percentage are calculated as the data need to be included for developing the curve of Rainfall Temporal Pattern. So, for the 1st five minutes, the cumulative percentage calculated is 41.78%. For the 2nd five minutes, the cumulative percentage recorded is 64.63%. Next, for the 3rd five minutes, the cumulative percentage is 78.61%. For the 4th five minutes, the cumulative percentage calculated is 87.93%. For the 5th five minutes, the cumulative percentage recorded is 95.06%. Next, for the 6th five minutes, the cumulative percentage obtained is 100%

Table 4.4 (d): Analysis using WRRI for 4th Quartile of 120 minutes rainfall events of JKR Gambang

4th Q	%Cum	Depth										
		1	2	3	4	5	6	7	8	9	10	11
0	0	0	0	0	0	0	0	0	0	0	0	0
5	16.67	0.1	0.2	0.1	0.1	0.1	0.8	0.4	0.1	0.5	0.1	0.2
5	33.33	0.1	0.2	0.1	0.1	0.1	0.6	0.3	0.1	0.4	0.1	0.2
5	50	0.1	0.2	0.1	0.1	0.1	0.2	0.2	0.1	0.2	0.1	0.2
5	66.67	0.1	0.2	0.1	0.1	0.1	0.2	0.2	0.1	0.2	0.1	0.1
5	83.33	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
5	100	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1

From the analysis above by using Water Resources Research Institute method for the 4th quartile of 120 minutes rainfall events of JKR Gambang, the average rainfall intensity are calculated. For the 1st five minutes, the average rainfall intensity calculated is 0.245mm. For the 2nd five minutes, the average rainfall intensity recorded is 0.209mm. Next, for the 3rd five minutes, the average rainfall intensity obtained is 0.145mm. For the 4th five minutes, the average rainfall intensity calculated is 0.136mm. For the 5th five minutes, the average rainfall intensity recorded is 0.1mm. Next, for the 6th five minutes, the average rainfall intensity obtained is 0.1mm.

Furthermore, the percentage of the average rainfall intensity need to be calculated. For the 1st five minutes, the percentage calculated is 26.2%. For the 2nd five minutes, the percentage recorded is 22.35%. Next, for the 3rd five minutes, the percentage obtained is 15.51%. For the 4th five minutes, the percentage calculated is 14.55%. For the 5th five minutes, the percentage recorded is 10.7%. Next, for the 6th five minutes, the percentage obtained is 10.7%.

Last but not least, the cumulative percentage are calculated as the data need to be included for developing the curve of Rainfall Temporal Pattern. So, for the 1st five minutes, the cumulative percentage calculated is 26.2%. For the 2nd five minutes, the cumulative percentage recorded is 48.55%. Next, for the 3rd five minutes, the cumulative percentage is 64.06%. For the 4th five minutes, the cumulative percentage calculated is 78.61%. For the 5th five minutes, the cumulative percentage recorded is 89.31%. Next, for the 6th five minutes, the cumulative percentage obtained is 100%

4.5 Data Analysis at Station JKR Gambang for WRRI

At the station of JKR Gambang, there were 17 events recorded for the period of 60 minutes. Analyzation was made and shown below. The lowest curve plotted was in the second quartile while the highest is in the third quartile. The curves plotted represented at JKR Gambang is in an hour period of time by using Huff Time Distribution Method are as shown in Figure 4.3.

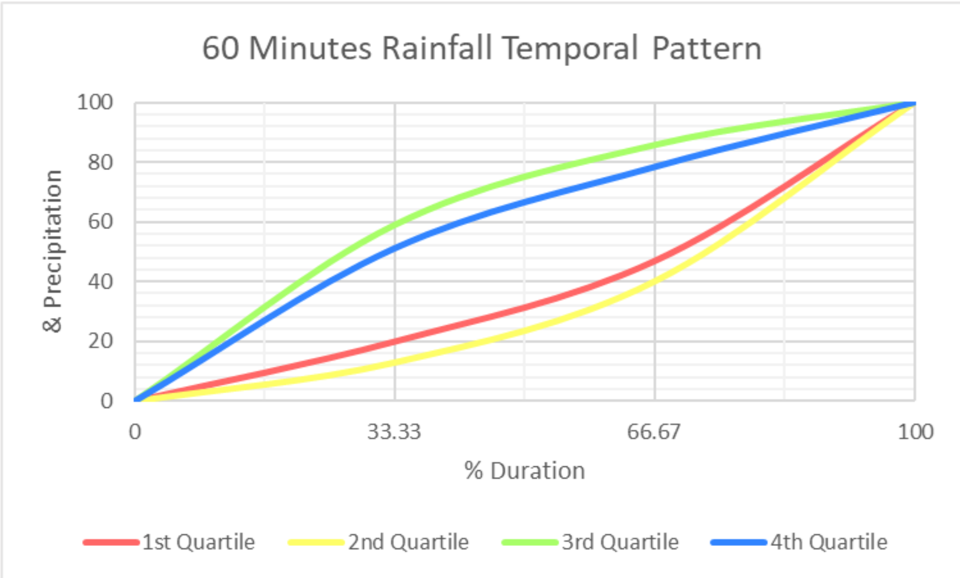

Figure 4.3: 60 minutes graph using WRRI method

For a 120 minutes period of time curve, here were 11 events of precipitation are recorded at Station JKR Gambang. The lowest curve plotted is in the second quartile while the highest curve is in third quartile. The curves plotted represented at JKR Gambang is in 120 period of time by using Water Resources Research Institute are as shown in Figure 4.4.

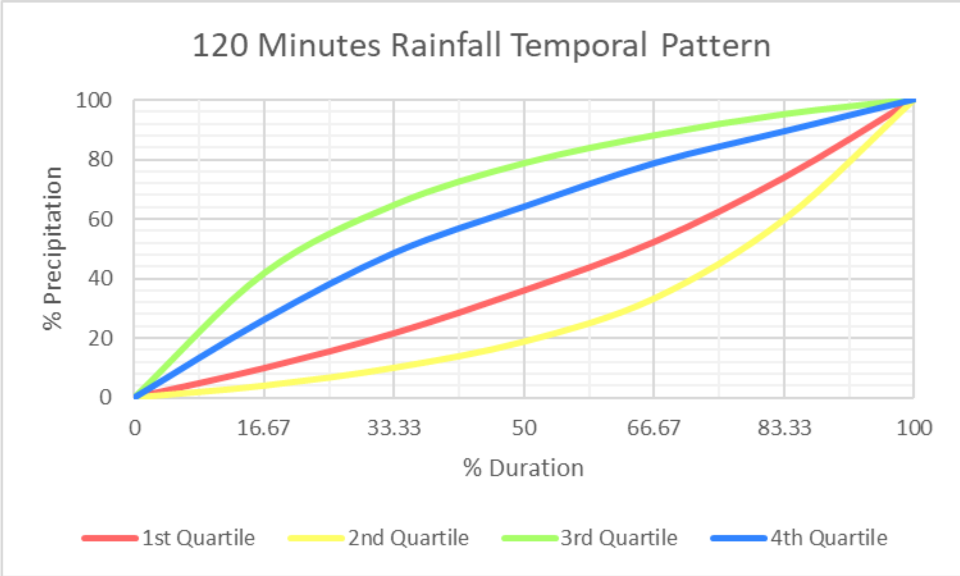

Figure 4.4: 120 minutes graph using WRRI method

4.6 Comparison

Both Huff Time Distribution and Water Resources Research Institute used rainfall event of 60 minutes and 120 minutes as comparison. All of the four curve produce are represented each quartile which is first, second, third and fourth respectively. In order to compare the result from both methods, the difference are calculated in term of percentage are plotted.

Table 4.5 for (a), and (b) shows the comparison of 60 minutes and 120 minutes rainfall event respectively for JKR Gambang. For 60 minutes rainfall event, the third quartile has the lowest percentage in difference while the first quartile has the highest percentage in difference. For 120 minutes rainfall event, the highest percentage in difference is in first quartile and the lowest is in third quartile.

Table 4.5 (a): Comparison of 60 minutes rainfall event between Huff Time Distribution Method (HTDM) and Water Resources Research Institute

60 Minutes			
Quartile	**HTDM**	**WRRI**	**Difference %**
1st Quartile	36.8	5.48	74.08
2nd Quartile	30.02	51.53	26.38
3rd Quartile	23.86	38.78	23.82
4th Quartile	9.32	4.2	37.87

Table 4.5 (b): Comparison of 120 minutes rainfall event between Huff Time Distribution Method (HTDM) and Water Resources Research Institute

120 Minutes			
Quartile	**HTDM**	**WRRI**	**Difference %**
1st Quartile	35.67	6	71.2
2nd Quartile	24.31	51.25	35.66
3rd Quartile	26.21	37.18	17.31
4th Quartile	13.81	5.57	42.52

CHAPTER 5

CONCLUSION

5.1 Introduction

In this study, the objectives were to create temporal rainfall pattern utilizing HTDM and WRRI Method and to compare about the result of the two method. The study was at Universiti Malaysia Pahang which close to the station JKR Gambang. The precipitation events of an hour and 120 minutes were extricated so as to continue on the investigation. The study were done through and displayed regarding plotting of graph of depth versus duration cumulatively. The graphs plotted delivered curves of quartile. The quartile from HTDM were then compared to the quartile from WRRI. Both method were thought about in term of percentage differences. The differences are obtained from the cumulative precipitation depth of the two methods and from that, the highest and least range can be observed.

5.2 Conclusion

The rainfall temporal pattern of Universiti Malaysia Pahang were created utilizing Huff Time Method and WRRI Method and curves of all the four quartile were obtained. Thereafter, the curves from both were compared about and percentage differences in each point were likewise obtained. From that, this study figure out to discover the percentage differences and which quartile produce the highest and least range in differences.

Based on the result, the rainfall temporal pattern are developed by HTDM and WRRI method, the differences in each graph plotted changes from about 17.31% to 74.08%. It can also be seen that the 3rd Quartile has the lowest range in difference for 60 minutes rainfall events with 23.82% while 1st Quartile has the highest range in difference for 60 minutes rainfall events with 74.08%. On the other hand, the highest range is in 1st

Quartile for 120 minutes event with 71.20% and 3rd Quartile has the lowest range in difference with 17.31%. From the analyzation, there are various pattern of graph between quartile and method itself. All the differences recognized may contributed to high percent of differences. This is because the data taken for this study are the raw data that are collected and obtained by the Department of Irrigation and Drainage (DID). Thus, various of curve are obtained. Other than that, maybe due to poor maintenance of station which resulting in losses of data in that particular station contributed to vary curve. Thus, there are maybe inaccuracy of data obtained and that could possibly affected the result.

In conclusion, this study have achieve the objective to develop the rainfall temporal pattern by using Huff Time Distribution Method and Water Resources Research Institute method and to compared the result from both method.

5.3 Recommendation

There are a few recommendation that can be done to improvise the result of this study. Such recommendations are as follow;

- Develop the rainfall temporal pattern using other method and compared with MSMA2.
- Testing the temporal pattern with real hydraulic and hydrology design and compared the result with both method.
- To have more study to which method are best to use and describe the rainfall temporal pattern.

REFERENCES

Adler, R. F., Negri, A.J. (1988). A satellite infrared technique to estimate tropical convective and stratiform rainfall. *Journal of Applied Meteorology*, 30-51.

Alharty, H. (2006). *Design Storm*. Retrieved from www.ce.utexas.edu/prof/maidment/GradHydro2010/Visual/DesignStorms.ppt

Anagnostou, E. N., Negri, A.J., Adler, R.F. (1999). A satellite infrared technique for diurnal rainfall variability studies. *Journal of Geophysical Research*, 31477-31488.

Ba, M. B., and Nicholson, S. E. (1998). Analysis of convective activity and its relationship to the rainfall over the Rift Valley lakes of East Africa during 1983-90 using the Meteosat infrared channel. *Journal of Applied Meteorology*, 1250-1264.

Brandes, E. (1975). Optimizing Rainfall Estimates with the Aid of Radar. *Journal of Applied Meteorology*, 1339-1345.

Bustami, R.A, Rosli, N.A, Adam, J.H, and Li, K.P. (2012). *Development of Rainfall Temporal Pattern for Southern Region of Sarawak*. Retrieved from http://ir.unimas.my/2990/1/a16%20jan.pdf

C. Duchon, C. Biddle. (2010). Undercatch of Tipping-bucket Gauges In High Rain Rate Events. *Adv. Geosci.*, 11-15.

Department of Irrigation and Drainage. (2012). *Urban Stormwater Management Manual for Malaysia Second Edition (MSMA2).*

E. Habib, W. Krajewski, A. Kruger. (2001). Sampling Errors of Tipping-Bucket Rain Gauge Measurement. *Journal of Hydrol. Eng.*, 159-166.

El-Sayed. (2017). Development of synthetic rainfall distribution for Sinai area. In El-Sayed. Ain Shams Eng J.

Freedman, D. (2005). *Statistical Models.* Cambridge: Cambridge University Press.

Golkar, F., Farahmand, A. (2009). Rainfall Temporal Pattern of Some Climatic Types Of Iran. *12 International River Symposium*, (pp. 21-24). Brisbane Australia.

Griffith, C. G., Woodley, W. L., Grube, P. G., Martin, D.W., Stout, J., and Sikdar, D.N. . (1978). Rain estimation from geo synchronous satellite imagery - Visible and infrared studies. *Monthly Weather Review*, 1153-1171.

Habets, F., LeMoigne, P., and Noilhan, J. (2004). The utility of operational precipitation forecasts to served as input for streamflow forecasting. *Journal of Hydrology*, 270–288.

J. Creutin, G. Delrieu, T. Lebel. (1988). Rain Measurement by Raingage- Radar Combination: A Geostatistical Approach. *Journal of Atmos. Ocean. Tech.*, 102-115.

J. Garcia-Pintado, G. Barbera, M. Erena, V. Casttillo. (2009). RAinfall Estimation By Rain Gauge-Radar Combination: A Concurrent Multiplicative-Additive Approach. *Water Resour. Res.*

J. Joss, J.C. Thams, A. Waldvogel. (1970). *The Accurracy of Daily Rainfall Measurements by Radar*. Zurich: ETH.

J. Testud, E. Le Bouar, E. Obligis, M. Ali-Mehenni. (2000). The rain profilling algorithm applied to polimetric weather radar. *Journal of Atmosphere and Oceanic Technology*, 332-356.

J. Wang, B. Fisher, D. Wolff. (2008). Estimating Rain Rates Determination from Tipping-Bucket Rain Gauge Measurement. *Journal of Atmos. Ocean. Tech.*, 903-934.

Krajewski, W. (1987). Cokriging radar-rainfall and raingage data. *Journal of Geophys. Res.*, 9571-9580.

L. Sieck, S. Burges, M. Steiner. (2007). Challenges in Obtaining Reliable Measurements of Point Rainfall. *Water Resour. Res.*

M. Savina, B. Schappi, P. Molnar, P. Burlando, B. Sevruk. (2012). Comparison of a tipping-bucket and electronic weighing precipitation gage for snowfall. In *Atmos. Res. vol. 103* (pp. 45-51).

Marsalek, J. (1981). Calibration of the tipping-bucket raingage. *Journal of Hydrology*, 343-354.

Nakakita, E. (2002). Radar Hydrology Precipitation and Water Resources. *Textbook for 12th IHP Training Course, HyARC Nagoya University and UNESCO*, 111-129.

Rogers, R.R., Yau, M.K. . (1988). A Short Course in Cloud Physics. *Butterworth-Heinemann*.

S. Tengeleng, N. Armand. (2014). Performance of Using Cascade Forward Back Propagation Neural Networks for Estimating Rain Parameters with Rain Drop Size Distribution. *Atmosphere*, 454-472.

Smith, A. (2010). *Hydrological Theory*. Retrieved from http://www.alanasmith.com/theory-Derivation-Huff-Storm.htm

Todd, M. C., Kidd, C., Kniveton, D., and Bellerby, T.J. (2001). A combined satellite infrared and passive microwave technique for estimation of small-scale rainfall. *Journal of Atmospheric and Oceanic Technology*, 742-755.

van Hees, R.M., Lelieveld, J., Collins, W.D. (1999). Detecting tropical convection using AVHRR satellite data. *Journal of Geophysical Research*, 9213–9228.

Viessman, W. Jr. and Lewis L. G. (2003). *Introduction To Hydrology.* London: Pearson Education Inc.

X. Liu, T. Gao, L. Liu. (2013). A comparison of rainfall measurements from multiple instruments. In *Atmos. Meas. vol. 6, no. 7* (pp. 1585-1595).