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REGIONAL RAINFALL FREQUENCY ANALYSIS FOR SAMARAHAN RIVER BASIN

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REGIONAL RAINFALL FREQUENCY ANALYSIS FOR SAMARAHAN RIVER BASIN

DAYANG NAZIHAH BINTI ABANG UTHMAN

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Masters	
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ABSTRACT

In the planning to mitigate flood, it is essential for engineers to determine the magnitude and frequency of rainfall. The rainfall frequency and magnitude can be achieved by using rainfall frequency analysis. In this study, a regional rainfall frequency of Samarahan River Basin is analysed. There are 12 rainfall stations in Samarahan River Basin area. However, only 11 rainfall stations are selected in this study due to inadequate number of data. The rainfall frequency analyses of each individual station in Samarahan River Basin are conducted using Gumbel distribution and Weibull plotting position formula. The curves that close to each other are grouped into the same region. Other factors such as topography, station elevation, type of rainfall distribution and isohyet are also considered in designing the region. Subsequently, a regional rainfall frequency map of Samarahan River Basin is established. The findings show that Samarahan River Basin can be divided into three homogenous regions. In comparison to previous research, there are changes in grouping the rainfall stations selected into regions due to different years of data used and number of rainfall stations selected. Nevertheless, the dissimilarity outcomes also may cause by other factors such as the changing of nature over time.

ABSTRAK

Dalam perancangan untuk mengurangkan banjir, adalah penting bagi jurutera untuk menentukan magnitud dan kekerapan hujan. Kekerapan dan magnitud hujan boleh dicapai dengan menggunakan analisis frekuensi hujan. Dalam kajian ini, kekerapan hujan serantau Lembangan Sungai Samarahan dianalisis. Terdapat 12 stesen hujan di kawasan Lembangan Sungai Samarahan. Walau bagaimanapun, hanya 11 stesen hujan yang dipilih dalam kajian ini kerana bilangan data tidak mencukupi. Analisis kekerapan hujan untul setiap stesen di Lembangan Sungai Samarahan dijalankan menggunakan taburan Gumbel dan formula penempatan plot Weibull. Lengkung yang berdekatan antara satu sama lain dikelompokkan ke rantau yang sama. Faktor-faktor lain seperti topografi, ketinggian stesen, jenis taburan hujan dan isohyet juga dipertimbangkan dalam merekabentuk rantau ini. Selepas itu, peta frekuensi hujan serantau Lembangan Sungai Samarahan dihasilkan. Hasil kajian menunjukkan bahawa Lembangan Sungai Samarahan boleh dibahagikan kepada tiga kawasan. Berbanding dengan penyelidikan sebelumnya, terdapat perubahan dalam mengelompokkan stesen hujan yang terpilih ke dalam kawasan-kawasan kerana datatahunan dan bilangan stesen hujan yang digunakan berbeza. Walau bagaimanapun, dapatan perbezaan analisis juga boleh disebabkan oleh faktor-faktor lain seperti perubahan alam dari semasa ke semasa.

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LIST OF ABBREVIATIONS

ADMR	-	Average Daily Maximum Rainfall
DID	-	Department of Irrigation and Drainage
DMR	-	Daily Maximum Rainfall
EVI	-	Extreme Value Type I
EVII	-	Extreme Value Type II
EVIII	-	Extreme Value Type III
GEV	-	Generalized Extreme Value
HP 26	-	Hydrological Procedure No. 26
SHYB	-	Sarawak Hydrological Year Book

CHAPTER 1

INTRODUCTION

1.1 Research Background

Kota Samarahan is one of the divisions in Sarawak with a total area of 508 km^2. It is situated about 30 kilometres from the capital, Kuching and officially become the main education centre for the state with the construction of Universiti Malaysia Sarawak (UNIMAS), Universiti Teknologi Mara (UITM) and Tun Abdul Razak Institute of Teacher Education. The map of Malaysia is as shown in **Figure 1.1**.

Figure 1.1: Map of Malaysia

(Source: http://motherearthtravel.com/malaysia/map.htm)

Flood has frequently happened in Kota Samarahan and causing a lot of concern from people. The latest flood that hit this area is on February 2016 that involves thousands of families as stated in New Strait Times Online (2016). According to the Department of Irrigation and Drainage Sarawak, the recorded flood events in Sarawak are mostly in February to March. Recently, drought also regularly occurs in Samarahan for this few years. In July 2012, Borneo Post Online (2012) reported that a total of 203 cases of water shortage happened in Kuching that involving Kota Samarahan area with the worst hit divisions for Betong and Miri. Thus, Samarahan is very vulnerable for both disasters.

1.2 Problem Statement

For Samarahan basin, the regional rainfall frequency curve and map have been updated until 2007 in previous research by Ahmad (2009). In the study, 6 rainfall stations are selected which are Kampung Semilang, Ketup, Semonggok, Paya Paloh, Kota Samarahan and Asajaya using rainfall data of 11 years from 1997 to 2007. **Figure 1.2** below shows the Trendlines of DMR/ADMR versus Reduced Variate for all rainfall stations in Samarahan basin by Ahmad (2009). Subsequently, the curves are delineate into regions as shown in **Figure 1.3** and then interpreted into a map as presented in **Figure 1.4**. As a result, three homogeneous regions are formed. Region 1 consists of Kampung Semilang whereas Ketup, Semonggok, Paya Paloh and Kota Samarahan station are grouped into Region 2. For Asajaya station, it is located in Region 3.

In the preparation of mitigate drought and flood, it is crucially important for the engineers to determine the magnitude and frequency of rainfall data. The data plays the main role for designing the hydrologic structures such that it is one of ways to disaster prevention. In order to obtain the data, rainfall frequency analysis can be used. Subsequently, the analysis can be developed to form a regional rainfall frequency analysis map by using the consideration of homogeneity factor.

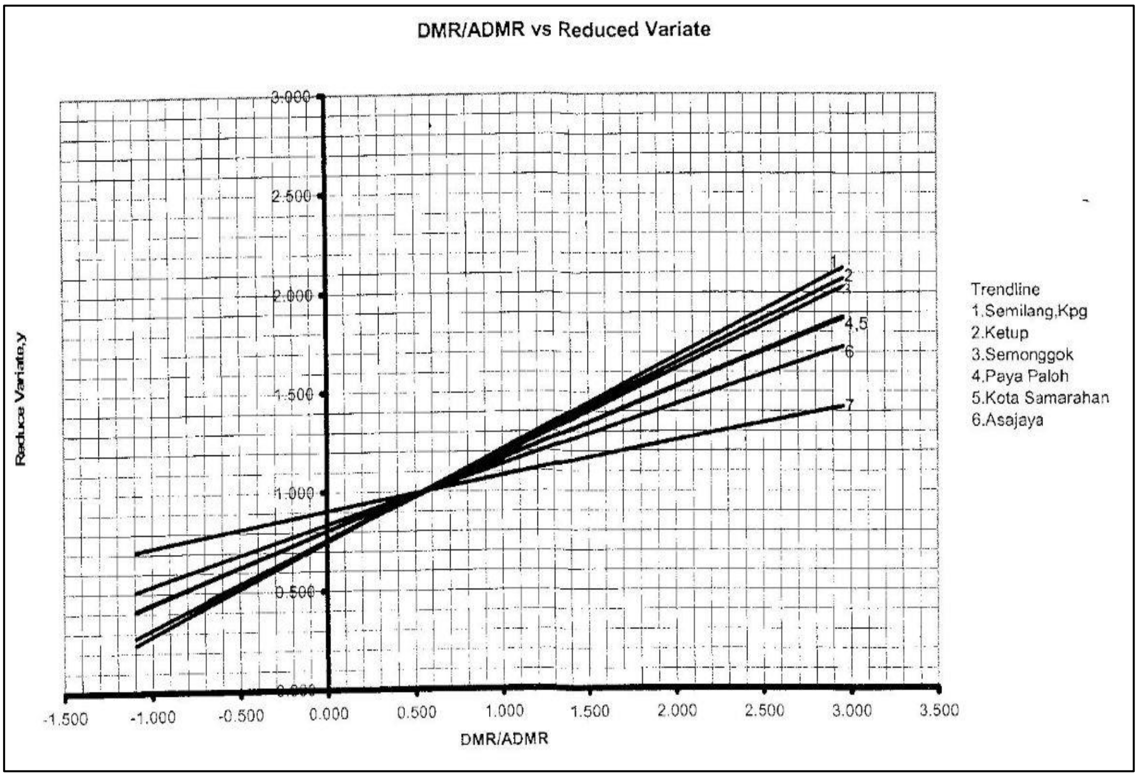


Figure 1.2: Trendlines of DMR/ADMR versus Reduced Variate for all rainfall stations in Samarahan basin by Ahmad (2009)

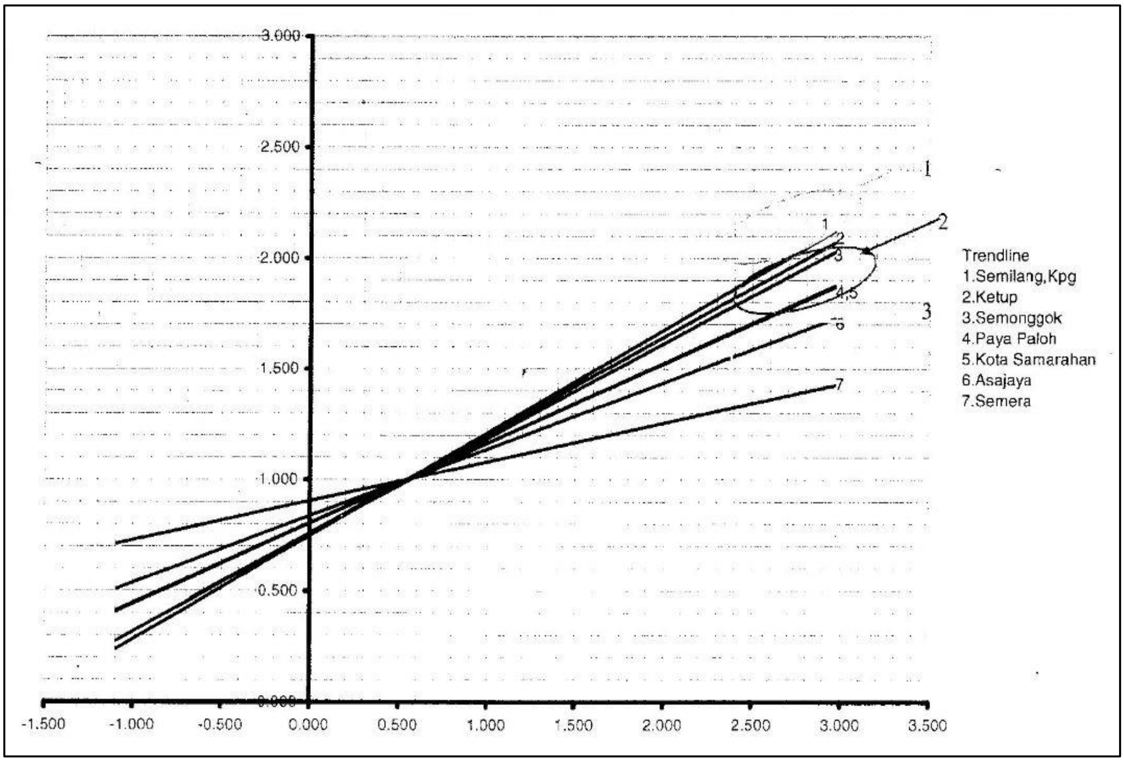


Figure 1.3: Extreme Rainfall Region for Samarahan basin by Ahmad (2009)

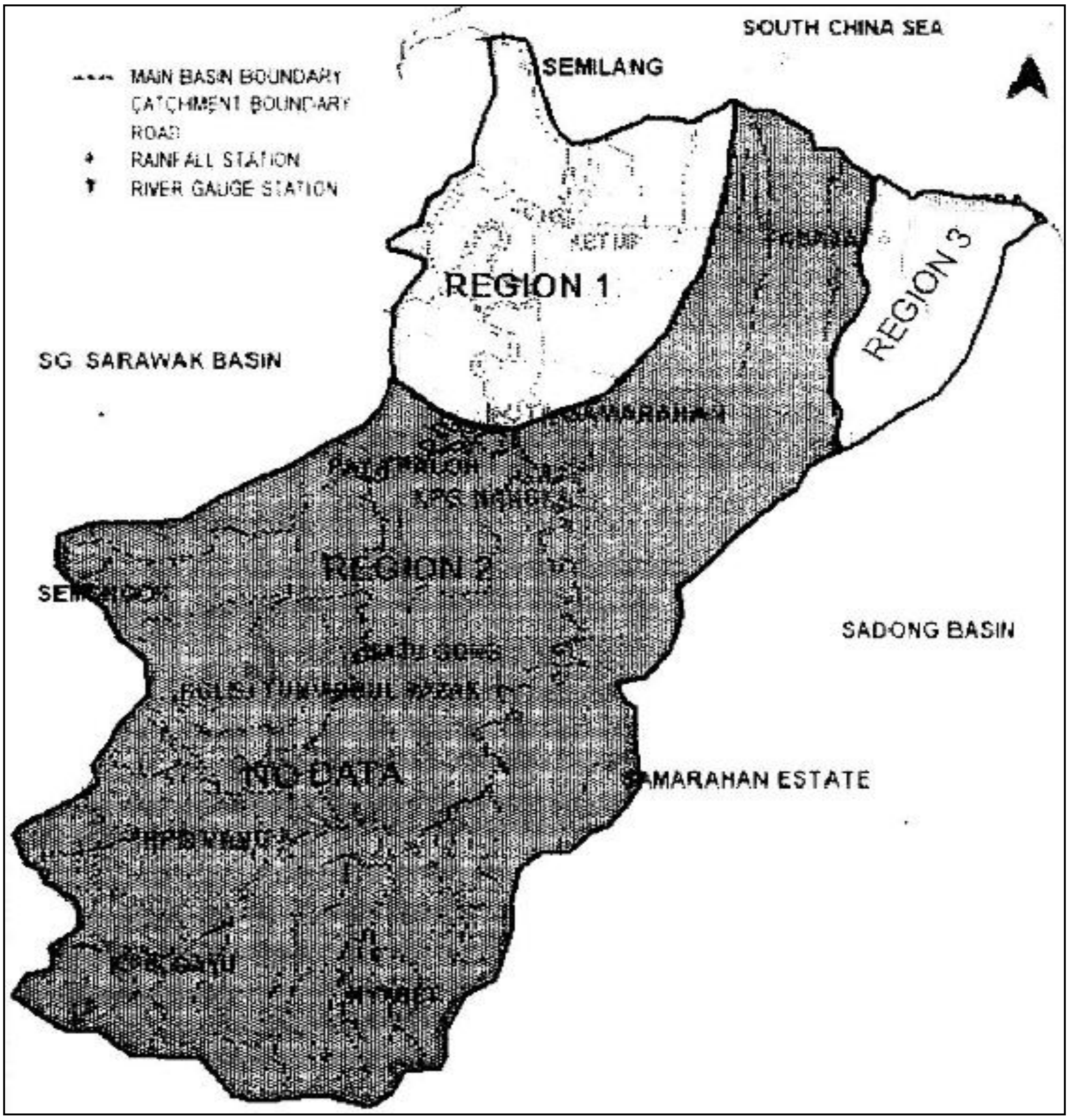


Figure 1.4: Rainfall region map for Samarahan basin by Ahmad (2009)

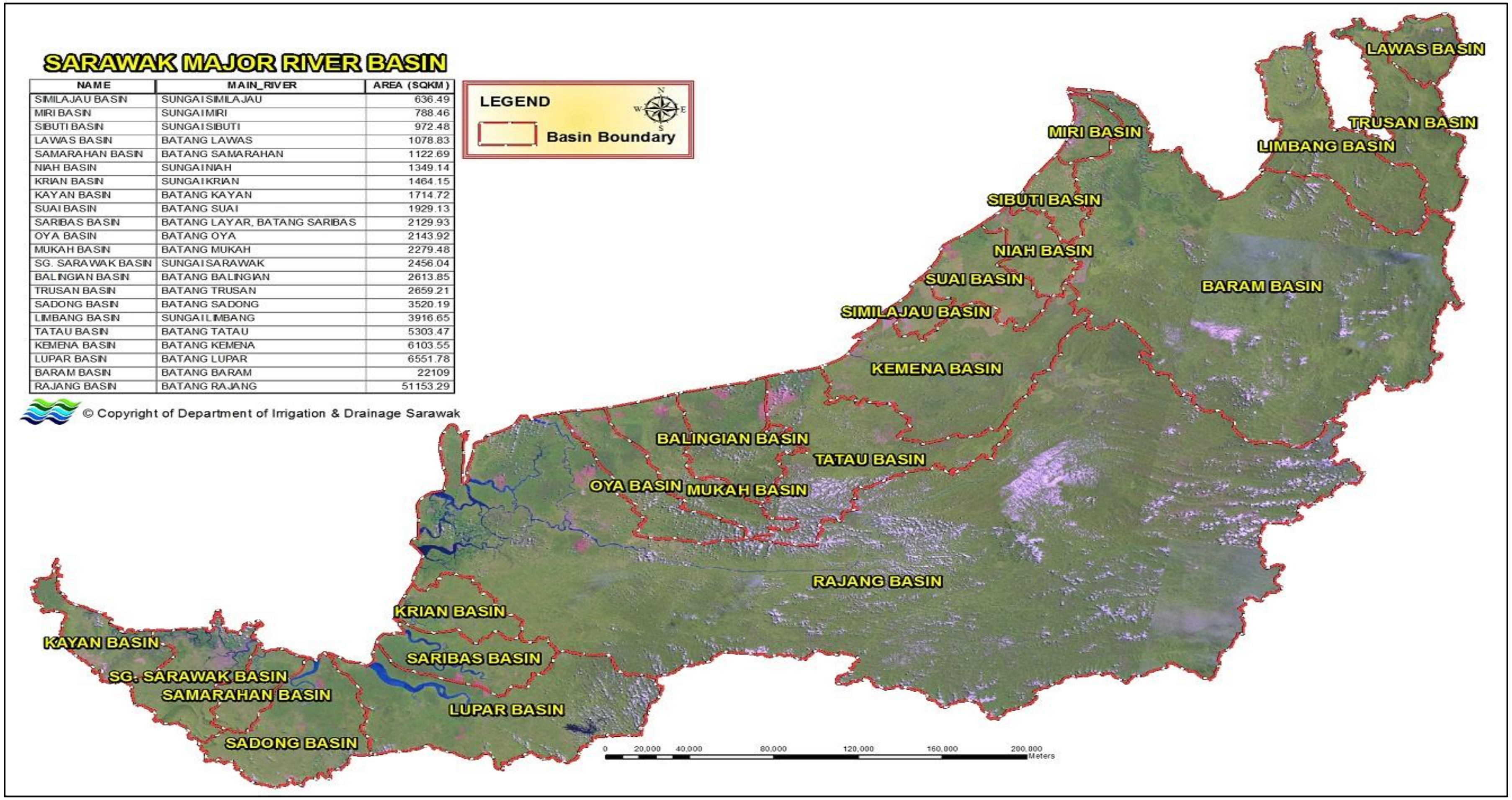
1.3 Objective of the Study

The main purposes of this study are to perform and update the existing regional rainfall analysis for Samarahan River Basin by

i. Developing regional rainfall frequency curves of Samarahan River Basin
ii. Developing regional rainfall frequency map of Samarahan River Basin
iii. Comparing the analysis obtained with the previous research

1.4 Scope of Study

The selected area of this study is Samarahan river basin which is one of the 22 major river basins in Sarawak. There are 12 rainfall stations in Samarahan river basin which are Semera, Asajaya, Ketup, Kampung Baru, Kampung Similang, Kampung Gayu, JPS Samarahan, Paya Palah, Semongok, Samarahan Estate, Plaman Nyabet and Dragon School. All the location of stations in Samarahan basin and major river basin in Sarawak can be refer in **Figure 1.5** and **Figure 1.6**. There are several methods that can be used to plot the rainfall data analysis such as Geiger, California, Hazen, Gringerton and etc. However, for this study the method used will focus on Gumbel distribution and Weilbull plotting position only.



NAME	MAIN_RIVER	AREA (SQKM)
SIMILAJAU BASIN	SUNGAI SIMILAJAU	636.49
MIRI BASIN	SUNGAI MIRI	788.46
SIBUTI BASIN	SUNGAI SIBUTI	972.48
LAWAS BASIN	BATANG LAWAS	1078.83
SAMARAHAN BASIN	BATANG SAMARAHAN	1122.69
NIAH BASIN	SUNGAI NIAH	1349.14
KRIAN BASIN	SUNGAI KRIAN	1464.15
KAYAN BASIN	BATANG KAYAN	1714.72
SUAI BASIN	BATANG SUAI	1929.13
SARIBAS BASIN	BATANG LAYAR, BATANG SARIBAS	2129.93
OYA BASIN	BATANG OYA	2143.92
MUKAH BASIN	BATANG MUKAH	2279.48
SG. SARAWAK BASIN	SUNGAI SARAWAK	2456.04
BALINGIAN BASIN	BATANG BALINGIAN	2613.85
TRUSAN BASIN	BATANG TRUSAN	2659.21
SADONG BASIN	BATANG SADONG	3520.19
LIMBANG BASIN	SUNGAI LIMBANG	3916.65
TATAU BASIN	BATANG TATAU	5303.47
KEMENA BASIN	BATANG KEMENA	6103.55
LUPAR BASIN	BATANG LUPAR	6551.78
BARAM BASIN	BATANG BARAM	22109
RAJANG BASIN	BATANG RAJANG	51153.29

Figure 1.5: Sarawak Major River Basin

(Source: http://www.did.sarawak.gov.my

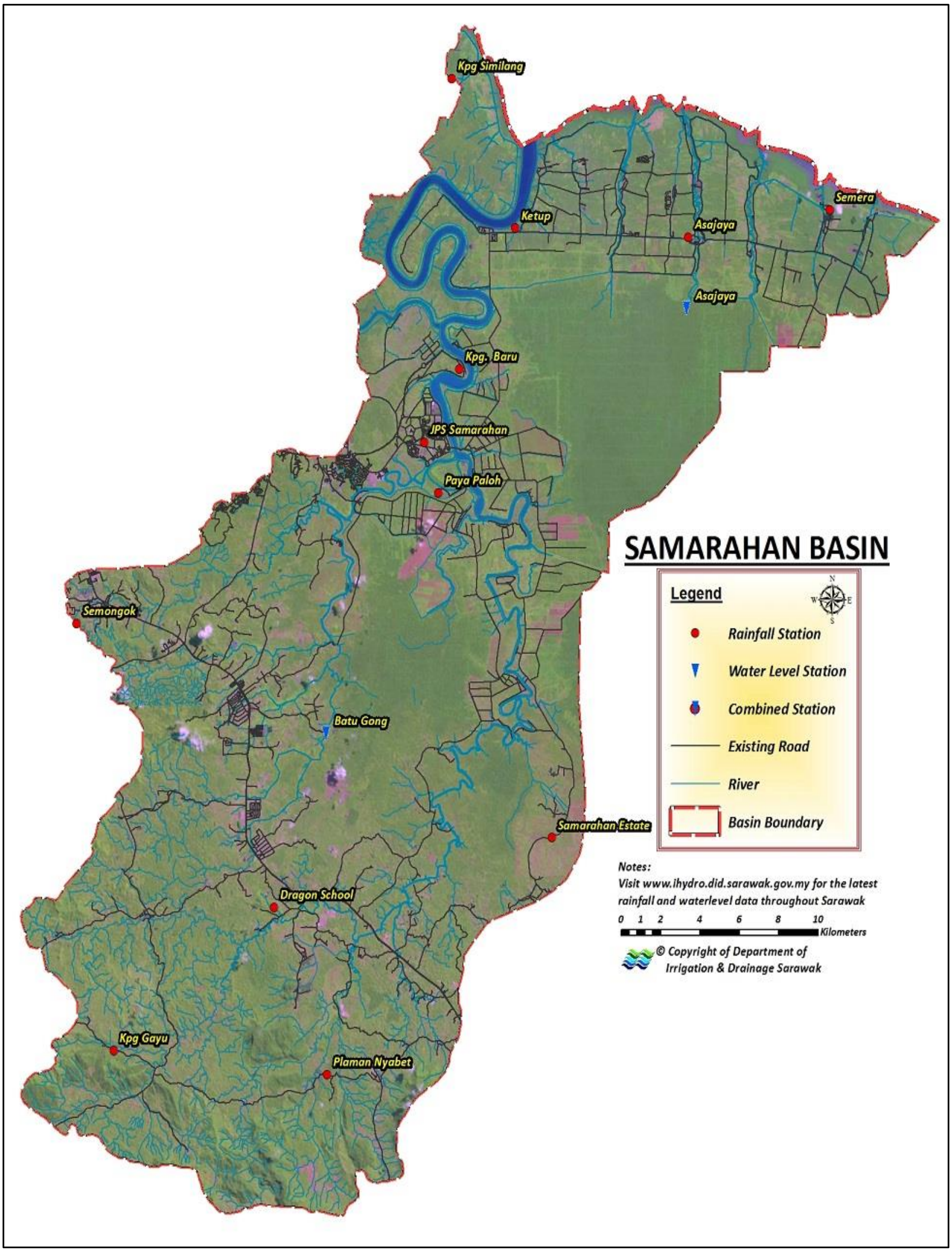


Figure 1.6: Rainfall Stations in Samarahan River Basin

(Source: http://www.did.sarawak.gov.my)

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In this chapter, a complete review for rainfall estimation using selected regionalization technique is presented. At the beginning of the chapter, **Section 2.2** provides the idea of frequency analysis. Since rainfall frequency analysis can be analyse by two main methods, **Section 2.3** is subdivided into two subsections in which **Section 2.3.1** and **Section 2.3.2** will explain on probability distribution and plotting position to be applied. The regional rainfall frequency analysis is then elaborated in the following **Section 2.4**.

2.2 Frequency Analysis

Hosking and Wallis (2005) defined frequency analysis as the evaluation on the rate of occurrence for a particular event. As stated by National Institute of Hydrology, Roorkee (n.d.), frequency analysis or known as probabilistic modelling is the first and most popular application to be used in hydrological statistics. It also articulated that by evaluating the observations from the analysis, hydrologic processes such as rainfall, snowfall, floods and drought can be examined. Several researches regarding hydrologic processes are elaborated in the next paragraphs.

According to Karimi and Shahedi (2013), the phenomenon of drought is the unusual shortage of rainfall within a long period of time. In their research on hydrological drought analysis of Karkheh River Basin in Iran, threshold level method has been applied with the application of frequency analysis. Daily discharges of 13 hydrometric stations which located on the main tributaries of the river basin are collected from Water Resources Management Organization of Iran. The period of maximum and minimum length of existing data used are 54 and 20 years for all stations. From the overall outcomes, it can be concluded that the entire stations in Karkheh River basin experienced to hydrological drought with the numerous and least occurrence in station 21-169 and station 21-157.

Another example of hydrologic process is rainfall. A study in verifying the rainfall patterns with related changes using frequency analysis are done by Hasan, Chowdhury and Ahmed (2014). The study area is situated at the north-eastern part of Bangladesh which mainly focused in Sylhet city. Heavy rainfall that likely to happen in Bangladesh regularly will cause flood. This is due to most of its parts are a low-lying plain of 144,000 km^2 located on deltas of large rivers flowing from Himalayas and experiencing a sub-tropical humid weather with wide seasonal variations (Hasan et. al, 2014). Hence, the study is important and useful as the researchers managed to identify the significant changes of rainfall that occurred. The daily, monthly, yearly and seasonal variation data of rainy days starting from year 1957 to 2006 has been used for the research.

Since flood cause severe damage to society and environment, it has become one of the hydrologic processes that need to be aware of. Analyses regarding to it should be carried out continuously in order to mitigate the flood. One of the frequency analysis studies is done by Mujiburrehman (2013) based on Narmada River. The flood data of Gardeshwar station within the periods of year 1949 to 1979 is used to evaluate the maximum monthly flood data. Mujiburrehman (2013) stated that the outcomes of following research can be utilized for flood forecasting management.

To the same extent, a thesis regarding seasonal snowfall in Southern Interior of British Columbia is done by Martin (2015). The study area is chosen due to it complex precipitation patterns and verified to be the best location for studying extreme rainfall and snowfall. The first procedure adopted in the study is by using the frequency analysis approach as it turns out to be a common technique in analyzing extreme events among engineers and hydrologists.

In conclusion, it is proved that frequency analysis is very helpful in engineering study especially hydrologic procedures. Thus, this method is suitable to be used for this research.

2.3 Rainfall Frequency Analysis

Rainfall frequency analysis is essential to evaluate big events and their possibility to happen (Adlouni and Ouarda, 2010). It is then stated that the analysis is beneficial for engineering purposes such as hydraulic design and landslide risk assessment (Testik, 2010). Since the trend of rainfall is able to be interpreted from the analysis, it is possible to perform flood mitigation as well. As a whole, the analysis does contribute to the problem solving of society and environment.

The probability of rainfall occurrence can be classified into three main aspects in term of maximum, minimum and mean evaluation. This can be justified as stated by McCuen, (2002) that "the variable could also be the mean annual rainfall, the peak discharge, the 7-day low flow or a water quality parameter" which referring to frequency analysis that applied for rainfall data. According to McCuen (2002), the development of low flow discharges for rainfall data is to utilize in water quality control. Meanwhile, Rao and Kao (2006) explained that the purpose of extreme rainfall analysis is to design storm water management systems and to evaluate the flood possibility of variety storm events. The mean evaluation is then to determine the average rainfall receives within a month or year for any region. Hence, all of the three evaluations are important to be used.

According to Raes (2013), the estimation of rainfall depths or return period needed for any design can be attained. It is also stated that frequency analysis includes the collecting of historical data over an adequate number of years are as follows:

1. Rank the data and select plotting positions by evaluating the possibility of exceedance with one or another method.
2. Choose a distributional assumption and plot the data in a probability plot.
3. Identify the goodness of the selected distribution. Another distribution has to be selected or the data must be transformed if it is unsatisfactory.

4. Determine rainfall depths (X_p) that can be expected for selected probabilities or return period from the probability plot.

Raes (2013) elaborated more that in rainfall frequency analysis, the primary step is to rank the rainfall data. Subsequently, a serial number (r) ranging from 1 to n (number of observations) is assigned. The probability is then determined and assigned to each of the rainfall depths. The corresponding of rainfall depth probability assumed to be exceeded if the data are ranked in descending order. Thus, when data are ranked begin with the lowest to the highest value, the probability considered as non-exceedance. The estimation of probabilities exceedance by a method is needed since these probabilities are unknown. Basically, all the steps mentioned are to estimate the probability of exceedance that may occur. **Table 2.1** below shows several methods to be used for the estimation.

Table 2.1 Methods for estimating probabilities of exceedance or non-exceedance of ranked data, where r is that rank number and n the number of observations by Raes (2013)

Method	Estimate of probability of exceedance or non-exceedance
California (California State Department, 1923)	$\frac{r}{n}100$
Hazen (Hazen, 1930)	$\frac{(r-0.5)}{n}100$
Weibull (Weibull, 1939)	$\frac{r}{(n+1)}100$
Gringorten (WMO, 1983)	$\frac{(r-0.44)}{(n+0.12)}100$
Sevruk and Geiger (Sevruk and Geiger, 1981)	$\frac{(r-3/8)}{(n+1/4)}100$

Later, a plot of the rainfall depths versus their probabilities of exceedance should be done. It is further explained that “when the data are plotted on arithmetic paper, where both axes have a linear scale, the data are not likely to be on a straight line but to follow a S-shaped curve” Raes (2013). The plot is known as percentage ogive and as example; the probability plot of the total annual rainfall for Bombay is shown in **Figure 2.1**.

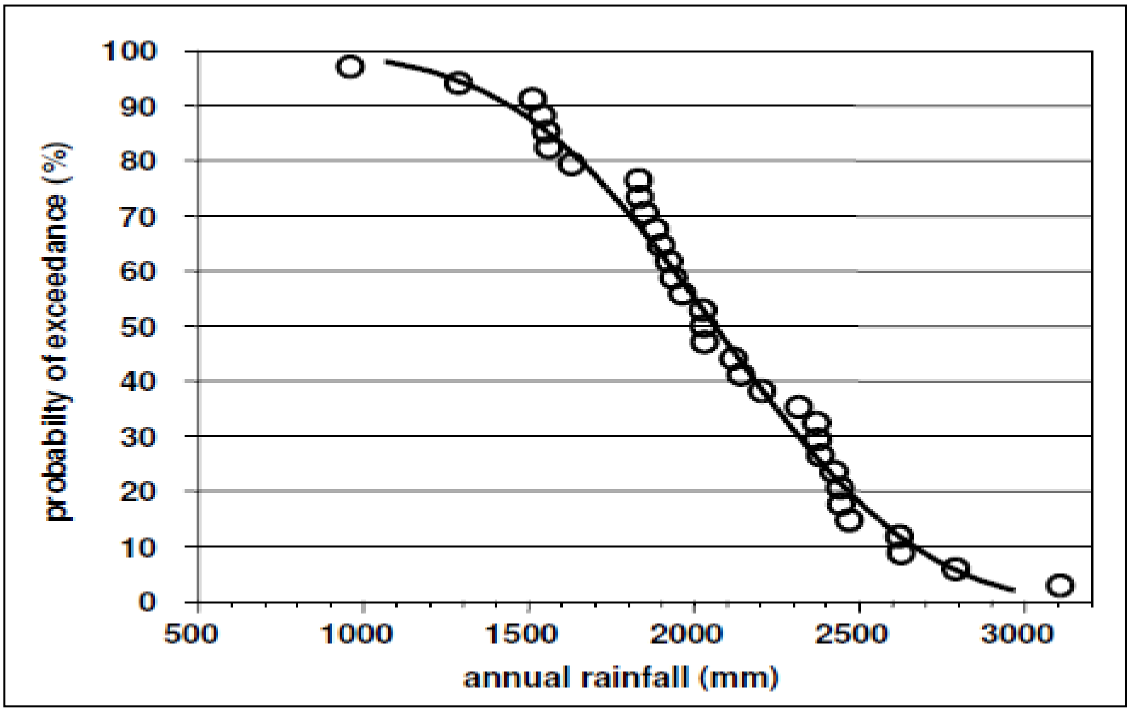


Figure 2.1: Probability plot of the total annual rainfall for Bombay by using linear scales for both axes by Raes (2013)

The vertical axis of the probability plot is then rescaled by selecting a probability distribution in order that the data to fall on a straight line. The cumulative distribution of the total population is then fall on the straight line on probability paper gives the goodness of selected distribution easier to verify. Hence, the most excellent graphical technique to test distributional assumptions is probability plotting (Raes, 2013). The two main methods to analyse rainfall frequency analysis; probability distribution and plotting position are elaborated in the following subsections.