FREQUENCY ANALYSIS OF RIVERFLOW IN SABAH AND SARAWAK

by

AWANG AZFAR B AWANG ALI BAHAR

Submitted to the Civil Engineering Programme
in Partial Fulfillment of the Requirements
for the Degree
BACHELOR OF ENGINEERING (Hons)
(CIVIL ENGINEERING)

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CERTIFICATION OF APPROVAL

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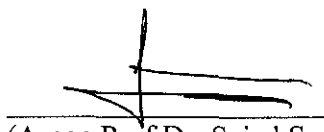
Approved by,



(Assoc Prof Dr. Saied Saeidi)

UNIVERSITI TEKNOLOGI PETRONAS
TRONOH, PERAK
JUN 2007

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

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AWANG AZFAR B AWANG ALI BAHAR

ABSTRACT

Design flood estimation is an important task that is required planning and design of many civil engineering projects. In this study, the flood records of 37 stations in Sabah and 5 stations in Sarawak are examined using six probability distributions mostly used in Flood Frequency Analysis which are Weibull Plotting Position, Log-Pearson III, Gumbel Type I, Log-Normal 2, Log Normal 3 and Pearson III. This is a continuation project of Frequency Analysis in Peninsular Malaysia made by Miss Nabila Abu Bakar, to complete the study on Frequency Analysis for Malaysia. The primary objective of frequency analysis is to relate the magnitude of occurrence, flood in this case through the use of probability distributions. To ease the process, software called DISTRIB which developed by A.P Dr Saied Saiedi (1989) is used to obtain more accurate result. A best fit distribution with the lowest error is subsequently developed for each station. The results presented herein are useful for reference for practicing engineers and will be used to predict high streamflow on any return period.

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CHAPTER 1
INTRODUCTION

1.1 Project Background

Flood is an unusual high stage in a river which overtops the natural or artificial banks in any reach of a river. Floods are produced when the capacity of the river channel is inadequate to carry off the abnormal quantity of water arising from heavily rainfall. Since the flood plain is a desirable location for man and its activities, it is important that floods can be controlled so that the damage does not exceed an acceptable limit. The knowledge of flood prediction is very important in order to reduce damage caused by high flow of water. It will be used to design structures which are prone to floods such as dams and bridges.

This project is based on statistical method to obtain the frequency analysis of flood occurring in a specified period of time. Statistical methods are utilized to organize, present and reduced observed data to a form that facilitates their interpretation and evaluation.

There are many distributions used in Malaysia to obtain the return period of floods of rivers. The distributions are subjected to some amount of error which will reduce the effectiveness of the design. Recently, there has been no study on the best distribution that could be used in Malaysia. This project is a continuation of previous project in obtaining the frequency of flood occurring in Malaysia. The previous project area was in Peninsular Malaysia done by Miss Nabilah bt. Abu Bakar, and this project area will be focus in Sabah and Sarawak.

1.2 Problem Statement

The accurate estimation of design floods remains one of the major challenges for many engineers and planners who are involved in project design. The purpose of design flood estimation is to make predictions on the magnitude of flood discharges at a particular section of a river of interest corresponding to a risk level that is acceptable to the design structures. With sufficient length of flow observations at a particular site of interest, one can make statistical inference on the flood discharges corresponding to various acceptable risk levels. Moreover, the magnitude of the design flood directly affects the dimensions and the cost of the structure.

While there are general recommendations over the best choice in method for frequency analysis, the designer and engineers should rely on the specific data of the river and the best method to suit the data. Currently, there is little available study and report on flood frequency analysis for Malaysia. Many practicing engineers in Malaysia are adopted to use Gumbel Type I distribution suggested in the Hydrological Procedure No. 4 (HP 4) for flood frequency analysis recommended by Department of Irrigation and Drainage (DID), Malaysia.

However, the accuracy of frequency analysis is dependent on the amount of input data available from the river gauging station. Sometimes the designer has to work on a limited amount of data to obtain the discharge at a specified return period. This will significantly decrease the accuracy of the flood prediction.

1.3 Objectives

The main objectives of this project are:

- River data collection for Sabah and Sarawak
- Check streamflow data for discrepancy
- Flood frequency analysis for rivers in Sabah and Sarawak
- Appraisal of flood frequency of the common distributions as applied to Malaysian rivers

1.4 Scope of Study

In this project the scope of the study is limited to:

- Maximum annual (yearly) flood rivers in Sabah and Sarawak
- Rivers with more than 10 annual floods data are included
- Six distributions are evaluated, which are:
    i. Weibull Plotting Position
    ii. Log-Pearson III
    iii. Gumbel Type I
    iv. Log-Normal 2
    v. Log-Normal 3
    vi. Pearson III

CHAPTER 2
LITERATURE REVIEW

2.1 Distributions in Flood Frequency Analysis

Flood frequency study is a statistical approach for the prediction of many hydrologic processes including flood flows and rainfall. The standard procedure to determine probabilities of flood flows consists of fitting the observed stream flow record to specific probability distributions. However, this procedure only works for basins that have 'long enough' streamflow records (minimum 10 years) to warrant statistical analysis.

Kite (1988) discussed eight frequency distributions for the flood frequency analysis. They are discrete distributions, normal distribution, two-parameter lognormal distribution, three-parameter log-normal distribution, type I extremal distribution, Pearson type III distribution, log- Pearson type III distribution and type III extermal distribution. For every distribution, the parameters and standard error are determined using method of moments, maximum likelihood method and other approximation methods. He then compared the frequency distributions of annual maximum daily flows of St. Mary's River at Stillwater, Nova Scotia over the period 1915 to 1986, to find the best fitting distribution using the standard error. From the analysis, type I extermal (Gumbel Type I) distribution has the lowest standard error as compared to other distributions. However, this result is not applicable to rivers in other parts of the world due to difference in data sample.

Subramanya (1984) discussed on several methods for estimating the magnitude of flood peak of rivers, which are the rational method, empirical method, unit hydrograph technique and flood frequency studies. The use of a particular method depends upon the desired objective, the available data and the importance of the projects. For flood frequency analysis which uses statistical method, he studied on three methods of distributions which are plotting position (Weibull formula), Gumbel Type I method and Log-Pearson type III distribution. He uses a direct approach to come out with the estimated flood for various return periods. Weibull formula for plotting position is a simple empirical technique to arrange the given annual extreme series in descending order of magnitude and to assign an order number. There are several other empirical formulae available to calculate the probability of occurrence. Gumbel's extreme value distribution and log Pearson type III method are two commonly used analytical method discussed. Gumbel defined a flood as the largest of the 365 daily flows and the annual series of flood flows constitute a series of largest values of flows. Gumbel Type I method used a special Gumbel probability paper to graph its distribution. A Gumbel distribution will plot a straight line on a Gumbel probability paper. This property can be used for extrapolation, whenever necessary. Log- Pearson type III distribution is widely used in the USA for projects sponsored by the US Government. In this, the variate is first transformed into logarithmic form (base 10) and the transformed data is then analysed. This distribution takes into account the skewness (degree of the symmetrical of distribution to the left or right) of the distribution.

2.2 Publications by Department of Irrigation and Drainage Malaysia

Since early 1970's, the Department of Irrigation and Drainage (DID) has published a total of 26 *Hydrological Procedures* (HP) and 20 *Water Resources Publications* (WRP). These HP's and WRP's have been widely used by engineers, hydrologists, field hydrological personnel and other professionals in projects related to hydrology and water resources. Hydrological Procedure No. 4 describes a flood estimation technique (peak discharge) based on regional analysis. Frequency analysis was carried out on available runoff data of

61 stations using Gumbel Extremal Type I theory. To extend the results of the gauged catchments to ungauged areas, regional dimensionless flood frequency curves and regional regression equations relating mean annual flood to the catchment characteristics (area and annual rainfall) were developed. Estimating flood magnitudes for a given return period can be easily done offer knowing the location of the catchment with respect to the defined flood regions and the catchment areas and annual rainfall. This procedure is applicable to catchment areas greater than 20 km^2. Nonetheless, this flood estimation technique is not used in this project. However, this paper shows that Gumbel Extermal Type I method is widely used in Malaysia and is recommended by DID.

The discharge data are obtained from DID publications, 'Streamflow and River Suspended Sediment Records'. The book is published for data of every 5 years of duration, for all river stations in Malaysia. The available publications for this project are from year 1975 to 1990 (15 years). All river stations are numbered according to its location, and classified within each state. By referring to the latest publication, there are all together 100 river stations in the whole of Malaysia, of which 83 are located in Peninsular Malaysia and the remaining 17 are at Sabah and Sarawak. For each river, a detailed description of data is provided, including the location, catchment area and elevation, catchment characteristic and water utilization upstream of the river. Water utilization includes the amount of extraction by Public Works Department for water supply and by Department of Irrigation and Drainage for padi cultivation. The summary of discharges (unit m^3/s) includes annual and monthly mean, maximum and minimum streamflow data. The annual maximum of river discharge is the absolute maximum water discharge for each year, and is used for this project. Information on the flow- duration analysis for 5 years duration of each river stations is also included in this publication. These sets of data are used for the estimation of flood using the frequency analysis. After year 1975, DID provided river suspended sediment records for all its river stations. However, this information is not relevant to the study of this project.

2.3 Influence of Urbanization to Floods in Malaysia

Highland forests, often referred to as 'water sponges', are able to absorb a significant amount of water from rainfall. It will then causes variation to the rate of flow and volume of water into a river. Wetlands are able to take up excess water from a river system and acts as natural flood control mechanism. Sedimentation of rivers is largely attributed to deforestation in the highlands and large- scale land clearing for urban and agricultural development along the course of a river.

According to Krishnan *et al.* (2001), it is evident that the rapid economic development in Malaysia in recent decades has also been associated with adverse effects upon the environment. One of the undesirable effects is an aggravation of floods, particularly urban areas in the lowlands. Highland forests and wetlands have a strong link to floods in the lowlands. The destruction of the ecosystem for economic exploitation is important element in increasing of floods. Generally, rainfall in the highlands is more uniform spread throughout the year but there are evidences to suggest that slight increases in rainfall occur from the height of 400 m to 1,000 m above sea level, according to Abdul Rahim Nik (1996). Studies have shown that total water yield is affected by conversion and clearance of highland forests to other land uses.

Flooding characteristics are definitely affected by the removal of forest cover. According to Abdul Rahim Nik & Zulkifli Yusop (1999), there is scientific evidence which support the link between deforestation and flooding but only at local level within catchment of less than 50,000 ha. Increased landslides and flashfloods occurrences have been associated with widespread removal of natural forest cover in the highlands for the purpose of land use transformation. In most cases, flood flow increase is actually caused by soil compaction and reduces infiltration rather than vegetation removal (Balamurugan G. & Mohd Rizal Mohd Razali, 1999). Gassim *et al.* (1994) mentioned that flooding in Kota Kinabalu was due to two factors; the morphology of the area and rapid growth development around the city, especially in the coastal area. Yaziz and Wan Nor Azmin (1984) reported that the frequency of flood peaks has increased with rapid urbanization in the Sungai Batu Catchment in Kuala Lumpur and Sungai Klang Catchment in Klang.

2.4 Flood Frequency Analysis in Malaysia

Design flood estimation is an important task that is required in the planning and design of many civil engineering projects. Its purpose is to predict the magnitude of flood discharges of a river corresponding to a risk level that is acceptable to the design of structures. The risk is normally taken to be a probability of annual recurrence interval (return period). Many practicing engineers rely on rainfall intensities to generate flood peaks using a simple classical method called the rational method for flood estimations. The rational method is intended for very small basins, but it is common to be applied in some large basins without any modification. This poses a problem as the method does not take the pattern of any relation of physical law or forecasting or a hydrology cycle.

Lim and Lye (2003) uses index- flood procedure based on L- moments for regional flood estimation of ungauged basins in Sarawak, Malaysia. Two homogeneous regions were identified and the Generalized Extreme Value and the Generalized Logistic distributions are found to describe the distribution of extreme flood events appropriately within the respective regions. A regional growth curve is subsequently developed for each of the regions. These curves can be used for the estimation of design floods in ungauged basins in Sarawak.

West Malaysia experience wet season beginning from October to the middle of January annually and usually flooding may occur within this period especially in low- lying areas. According to Muhammad Barzani *et al.* (1996), the flooding phenomenon has not only been restricted to the wet season and their frequency of occurrence has tended to increase. The monsoon, with wind dominantly from the south west and north east reaches West Malaysia resulting in heavy precipitation in the foothill regions and gradually change in precipitation intensity towards the coast in the south west. The moisture laden south westerly winds prevail from May to September, an inter- monsoonal period from late September to early November, and from November to March the north east monsoon sets in, followed by a second inter- monsoonal period until early May (Wong, 1974).

Flood frequency analysis of Semenyih Basin, Selangor was done using only 12 years of annual data, from 1969 to 1981. Flooding occur almost annually in the Hulu Langat area from 1951 to 1990. The highest big flood occurred in January 1971 which is classified as a catastrophic flood based on 15 years of frequency analysis. Influence of regional monsoon is most likely a more important factor for the occurrence of the 1971 flood in Semenyih Basin. Based on the return period of 15 years, the next big flood event would occur, but in 1986 most Asian countries were influenced by drought associated with the El- Nino phenomenon. No particular distribution is specified for the frequency analysis of Semenyih and Beranang Basin. However, plotted graphs of peak discharge versus the recurrence interval indicate that Weibull Plotting Position is used for the frequency analysis. The result could be used for construction of dams and other structures within the catchment area.

CHAPTER 3
FLOOD FREQUENCY ANALYSIS

3.1 Introduction to Flood Frequency Analysis

Flood frequency analysis is used to predict design floods for sites along a river. The technique involves using observed annual peak flow discharge data to calculate statistical information such as mean values, standard deviations, skewness, and recurrence intervals. These statistical data are then used to construct frequency distributions, which are graphs and tables that tell the likelihood of various discharges as a function of recurrence interval or exceedence probability.

3.2 Return Period

The recurrence interval of flood is called return period which is defined as:

$$T = 1 / P$$
$$= P^{-1} \qquad (1)$$

Where, T = Return Period

P = Probability of recurrence of flood whose magnitude equal to or greater than specified magnitude, X

This represents the average intervals between the occurrence of flood of magnitude equal or greater than X. Thus if is stated that the return periods of a flood is 500 m^3/s is 30

years at a certain station, it implies that on an average, the streamflow magnitude equal or greater than 500 m^3/s occurs once in 30 years. However, it does not mean that every 30 years one such event is likely to occur. It is just a method of predicting. This concept is widely used for representation of flood frequency distribution.

3.3 Hydrological Frequency Distributions

Chow (1951) has shown that most frequency- distribution functions applicable in hydrologic studies can be expressed in the following equation known as the general equation of hydrologic frequency analysis:

$$x_T = \bar{x} + K\sigma \tag{2}$$

Where x_T = value X of a random hydrologic series with a return period T,

$\bar{x}$ = mean of the variate,

σ = standard deviation of the variate,

K = frequency factor which depends upon the return period, T and the assumed frequency distribution

Standard error of estimate is defined as:

$$S = \left[\frac{\sum_{i=1}^{n} (x_i - \hat{x}_i)^2}{n} \right]^{\frac{1}{2}} \tag{3}$$

Where $\hat{x}_i$ = computed estimate of recorded event x_i

The values of the annual maximum flood from a given catchment area for large number of years are called the annual series. This series is used to calculate the magnitude of flood that will occur in the projected years. For this study, the frequency distributions used will be limited to only six, which are:

- Weibull Plotting Position
- Log- Pearson III
- Gumbel Type I
- Log Normal 2
- Log Normal 3
- Pearson III

3.3.1 Weibull Plotting Position

This method ranked the order of the data in order to plot a graph. The data is arranged in descending order (from high magnitude to the lowest) and the probability, P, of each event being equaled or exceeded is calculated using the plotting position formula:

$$P = \frac{m}{N+1} \tag{4}$$

Where,

M = order or number

N = total number of events

Using the Weibull formula, the recurrence interval, T;

$$T = \frac{1}{P} = \frac{(N+1)}{m} \tag{5}$$

Using probability paper, graph Q vs T is plotted of the above equation. The plotted point is then fitted to a best- fitting curve and the extrapolation is used to estimate the flood

magnitude of a specific return period. However, when large extrapolations of T are involved, the projected magnitude of flood will have high inaccuracy.

3.3.2 Log- Pearson III

If the logarithms, ln x, of a variable x are distributed as a Pearson III variate, then the variable x will be distributed as a log- Pearson III with probable density function:

$$p(x) = \frac{1}{\alpha\Gamma(\beta)}\left[\frac{\ln x - \gamma}{\alpha}\right]^{\beta-1} e^{-\left[\frac{\ln x-\gamma}{\alpha}\right]} \qquad (6)$$

Where α, β, γ = parameters

$\Gamma(\beta)$ = gamma function

To simplify the equation, this method will use equation as the basis equation. In this, the variate is first transformed into logarithmic form and then analyzed.
The series of z variate, where

$$z = \log x \qquad (7)$$

Where x = variate of random hydrologic series

For this z series, for any recurrence interval T, the basic equation elaborate by Chow (1951) gives,

$$z_T = \mu_z + K_z\sigma_z \qquad (8)$$

Where K_z = frequency factor which is a function of recurrence interval T and coefficient of skew, γ_1

= f (γ_1, T)

σ_z = standard deviation of z variate sample

γ_1 = skew coefficient of variate z

$$= \frac{N\sum(z-\mu_z)^3}{(N-1)(N-2)(\sigma_z)^3} \qquad (9)$$

μ_z = mean of z

N = number of years of record

The variations of K_z are given in Table 3-1

Table 3-1: Frequency Factors for Use in Log Pearson III Distribution

Coefficient of Skew	Cumulative Probability, P, %					
γ_1	50	80	90	95	98	99
	Corresponding Return Period, T, Years					
	2	5	10	20	50	100
0.0	0.0000	.8416	1.2816	1.6448	2.0537	2.3264
0.1	-.0167	.8363	1.2917	1.6728	2.1070	2.3997
0.2	-.0333	.8303	1.3009	1.6996	2.1595	2.4727
0.3	-.0499	.8234	1.3089	1.7254	2.2112	2.5453
0.4	-.0664	.8157	1.3159	1.7501	2.2619	2.6172
0.5	-.0828	.8072	1.3218	1.7735	2.3117	2.6884
0.6	-.0990	.7980	1.3267	1.7958	2.3603	2.7588
0.7	-.1151	.7880	1.3304	1.8168	2.4078	2.8283
0.8	-.1310	.7773	1.3330	1.8366	2.4541	2.8968
0.9	-.1467	.7659	1.3345	1.8551	2.4991	2.9641
1.0	-.1621	.7537	1.3349	1.8723	2.5428	3.0303
1.1	-.1772	.7409	1.3342	1.8881	2.5851	3.0952
1.2	-.1921	.7275	1.3324	1.9026	2.6260	3.1588
1.3	-.2067	.7134	1.3295	1.9157	2.6653	3.2209
1.4	-.2209	.6987	1.3255	1.9274	2.7031	3.2816
1.5	-.2347	.6834	1.3204	1.9378	2.7394	3.3406
1.6	-.2482	.6676	1.3143	1.9467	2.7740	3.3981
1.7	-.2612	.6513	1.3072	1.9543	2.8070	3.4538
1.8	-.2738	.6344	1.2990	1.9604	2.8383	3.5078
1.9	-.2860	.6171	1.2897	1.9651	2.8678	3.5600
2.0	-.2977	.5993	1.2795	1.9684	2.8956	3.6103

*Source: Kite. 1988

3.3.3 Gumbel Type I

This extreme value distribution was introduced by Gumbel (1941) and is known as Gumbel's distribution. It is one of the most widely used probability-distribution functions for extreme values in hydrologic studies. According to his theory, the probability of occurrence of an event equal to or larger than a value x_0 is

$$P(X \geq x_0) = 1 - e^{-e^{-y}} \tag{10}$$

in which y is a dimensionless variable given by

$$y = \alpha(x - a) \tag{11}$$

$$a = \mu_x - 0.45005\sigma_x \tag{12}$$

$$\alpha = 1.2825/\sigma_x \tag{13}$$

$$y = \frac{1.2825(x - \mu_x)}{\sigma_x} + 0.577 \tag{14}$$

Where μ_x = mean of maximum streamflow values, X

σ_x = standard deviation of the variate X

Rearranging Gumbel's equation, the value of the variate X with a return period T is

$$x_T = \mu_x + K\sigma_{x-1} \tag{15}$$

Where σ_{n-1} =standard deviation of the sample size N

$$K = \frac{y_T - \overline{y_n}}{S_n} \tag{16}$$

$$y_T = -\left[\ln . \ln \frac{T}{T-1}\right] \tag{17}$$

$\overline{y_n}$ = reduced mean, a function of sample size N and given in Table 3-2

S_n = reduced standard deviation, a function of sample size N and given in Table 3-2

Table 3-2: Reduced Mean $\overline{y_n}$ and Standard Deviation S_n in Gumbel's Extreme Value Distribution

SAMPLE SIZE, N	MEAN, $\overline{y_n}$	STANDARD DEVIATION, S_n
10	0.4952	0.9496
15	0.5128	1.0206
20	0.5236	1.0628
25	0.5309	1.0914
30	0.5362	1.1124
35	0.5403	1.1285
40	0.5436	1.1413
45	0.5463	1.1518
50	0.548	1.1607
55	0.5504	1.1682
60	0.5521	1.1747
65	0.5535	1.1803
70	0.5548	1.1854
75	0.5559	1.1898
80	0.5569	1.1938
85	0.5578	1.1974
90	0.5586	1.2007
95	0.5593	1.2037
100	0.5600	1.2065

*Source: Kite, 1988

3.3.4 Log- Normal 2

Murray R.Speigel (1999) defined if the logarithms ln x, of a variable x are normally distributed, then the variable x is said to be logarithmic- normally distributed such that

$$p(x) = \frac{1}{x\sigma_y\sqrt{2\pi}} e^{\frac{[\ln x - \mu_y]^2}{2\sigma_y^2}} \tag{18}$$

Where μ_y = mean of natural logarithms of x

σ_y = standard deviation of natural logarithms of x

If y = ln x is normally distributed, Eq. (3.2) can be written in terms of logarithms as:

$$\ln x_T = y_T = \mu_y + t\sigma_y \tag{19}$$

Where t = standard normal deviate

Alternatively to avoid computation of the mean and standard deviation of logarithms, equation above can be modified:

$$e^{y_T} = e^{\mu_y + \sigma_y^2/2}\left[1 + K\left(e^{\sigma_y^2} - 1\right)^{\frac{1}{2}}\right] \tag{20}$$

Where K $= \dfrac{e^{\sigma_y t - \sigma_y^2/2} - 1}{\left(e^{\sigma_y^2} - 1\right)^{\frac{1}{2}}}$ (21)

3.3.5 Log- Normal 3

Just as the log- normal distribution represents the normal distribution of the logarithms of the variable x, log- normal 3 represents the normal distribution of the logarithms of the reduced variable (x-a) where a is a lower boundary. (Murray R.Speigel, 1999) The probability density distribution is then given by:

$$p(x) = \frac{1}{(x-a)\sigma_y\sqrt{2\pi}} e^{\frac{[\ln(x-a)-\mu_y]^2}{2\sigma_y^2}} \tag{22}$$

Where μ_y = mean of natural logarithms of (x-a)

σ_y = standard deviation of natural logarithms of (x-a)

If the lower boundary, a, is known then the reduced variable (x-a) can be used together with the procedures described for log- normal 2 distribution.

Condie (1973) has described a simple graphical method of determining the parameter a, which is applicable, provided that:

i. At least one of the graph scales, vertical or horizontal, is logarithmic

ii. The curvature of the best fitting line is gradually decreasing

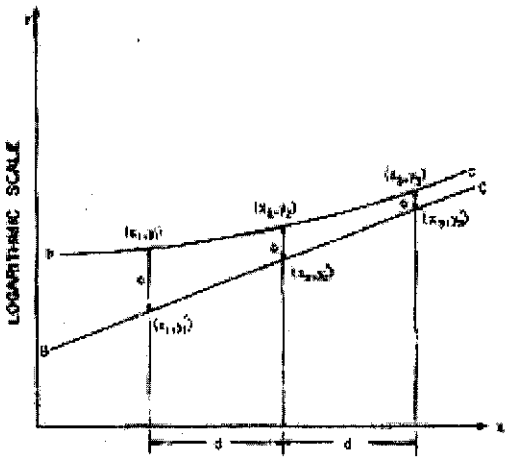

Figure 3-1: Graphical Technique of Estimating Parameter a

Referring to Figure 3-1, (*source: Kite, 1988), (x_1, y_1), (x_2, y_2), (x_3, y_3) are three points on the best-fitting line through the plotted event magnitudes (b-c) such that:

$$(x_3 - x_1) = (x_2 - x_3) \tag{23}$$

$$a = \frac{y_1 y_2 - y_3^{\,2}}{y_1 + y_2 - 2y_3} \tag{24}$$

The T- year event, x_T, is

$$x_T = a + e^{\mu_y + t\sigma_y} \tag{25}$$

3.3.6 Pearson III

The probability density distribution of Pearson III distribution is of the form

$$p(x) = \frac{1}{\alpha\Gamma(\beta)}\left[\frac{x-\gamma}{\alpha}\right]^{\beta-1} e^{-\left[\frac{x-\gamma}{\alpha}\right]} \tag{26}$$

Where α, β, γ = parameters

$\Gamma(\beta)$ = gamma function

If the substitution $y = (x-\gamma)/\alpha$ is made, the equation 3.18 simplifies to

$$p(y) = \frac{y^{\beta-1}e^{-y}}{\Gamma(\beta)} \tag{27}$$

Which is a one parameter gamma distribution described in many statistical texts.

For the sample mean, μ, standard deviation, σ, and coefficient of skew, γ_1, the parameters α, β and γ can be determined. Then,

$$\beta = (2/\gamma_1) \tag{28}$$

$$\alpha = \sigma/\sqrt{\beta} \tag{29}$$

$$\gamma = \mu - \sigma\sqrt{\beta} \tag{30}$$

CHAPTER 4
RAINFALL AND RIVERS IN SABAH AND SARAWAK

4.1 Rainfall in Sabah and Sarawak

Due to its more north-easterly location, Sabah is drier than Sarawak. The north-east coast suffers higher precipitation from December to January, whereas heavy rainfall occurs May to November on the west coast. The annual average rainfall is 2630 mm for Sabah and 3830 mm for Sarawak, with heavier precipitation recorded in the east coast of Peninsular Malaysia and the coastal regions of Sabah and Sarawak. The North-East Monsoon blows approximately from November to April bringing heavy rain to the east coast. From statistics, Sabah encounters rain half the number of days in a year. Most of the rains are of tropical rainstorms due to extremely high evaporation rate.

The seasonal variation of rainfall in Sabah and Sarawak can be divided into five main types:

a) The coastal areas of Sarawak and northeast Sabah experience a rainfall regime of one maximum and one minimum. While the maximum occurs during January in both areas, the occurrence of the minimum differs. In the coastal areas of Sarawak, the minimum occurs in June or July while in the northeast coastal areas of Sabah, it occurs in April. Under this regime, much of the rainfall is received during the northeast monsoon months of December to March. In fact, it accounts for more than half of the annual rainfall received on the western part of Sarawak.

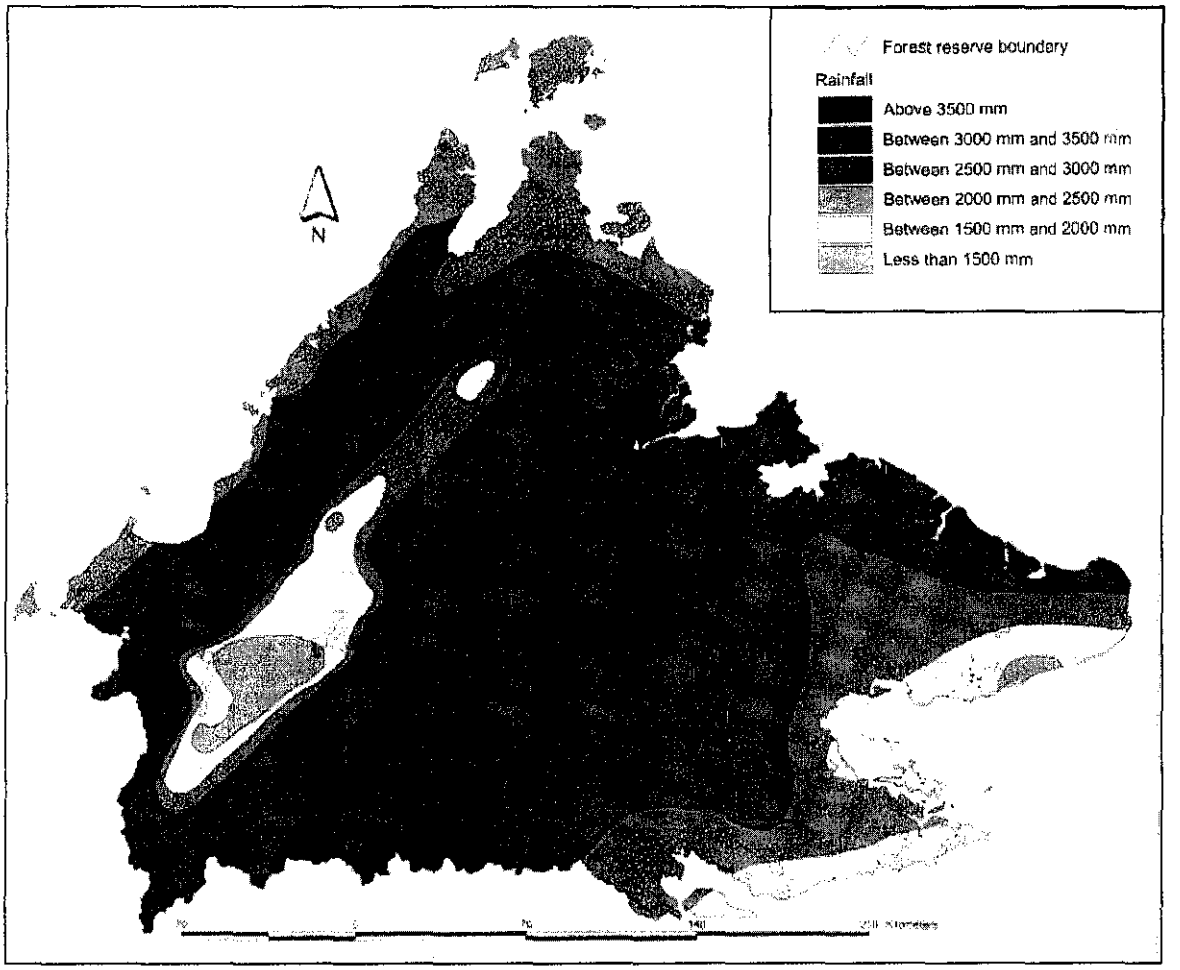

Figure 4-1: Average Monthly Fall in Sabah

*Source: The internet

In Sabah the rainfall intervals is 500 mm from 1000 mm to above 3500 mm, a fairly clear pattern of mean annual rainfall subjected to the geographic position and topographic features of Sabah can be found.

Generally, Sabah receives about 2500–3500 mm of rainfall annually. However, some localities obtained much lower or beyond this range due to influenced of coastal and in shadowed to large land-mass or ranges. The highest rainfall ranges, which is above 3500 mm, estimated only to cover 1% of the state. The ranges distributed on small localised area of Mt. Kinabalu and Crocker Range (Ulu Moyog), north-eastern of Labuk Highlands and low-lying area in south-eastern of Klias plain. However, it may also believe to cover on other high elevated ground such as along peaks of mountain ranges and highlands.

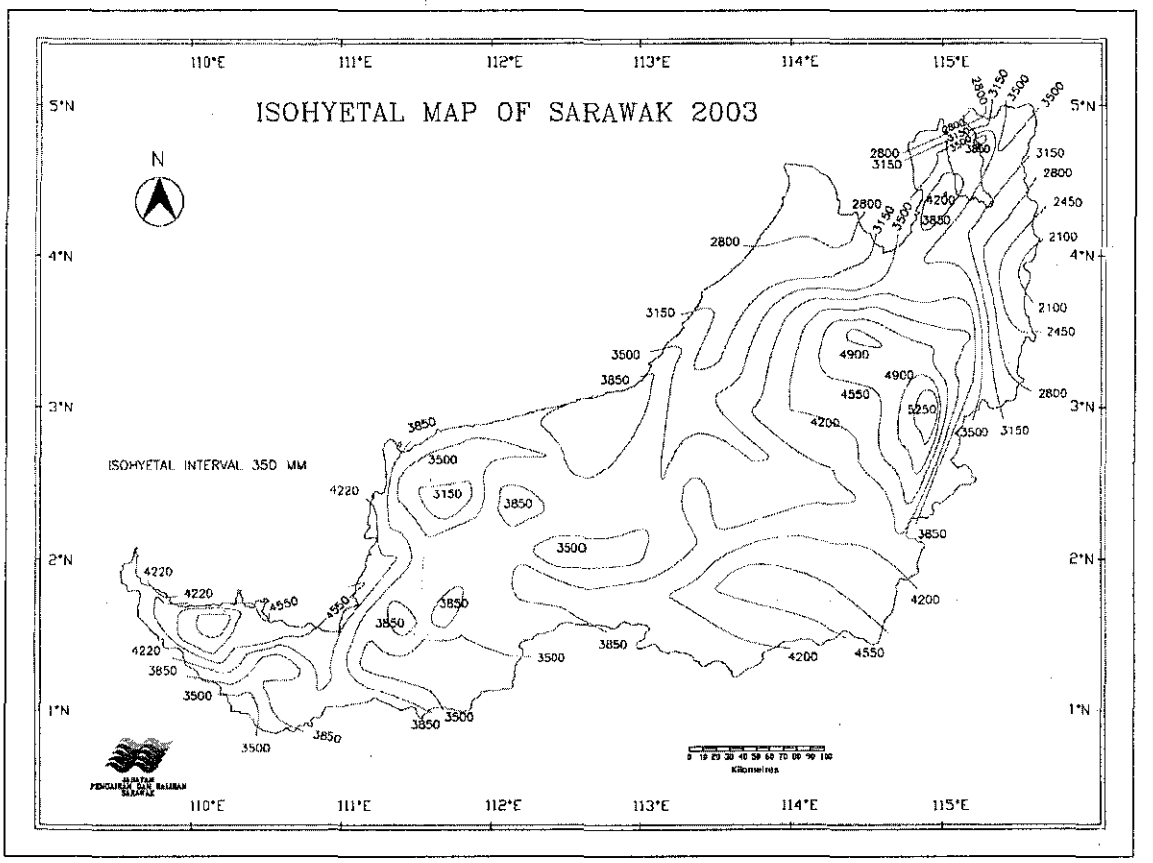

Figure 4-2: Isohyetal Map of Sarawak 2003

*Source: DID, Sarawak

In Sarawak, the total monthly rainfall varied from much below normal to much above normal. Sarawak, with an average rainfall of 5000 mm per year, is an expansive network of rivers, rainforests, mangroves, swamp forests and mountains. Annual rainfall varies between 3300 mm to 4600 mm for the greater part of the country.

Generally, Kuching, Samarahan, Sri Aman, Betong and Sarikei divisions would get more rain than the other areas of Sarawak while Miri and Limbang divisions would get the least amount of rain comparatively. Over Miri and Limbang divisions, more rain would be expected during the inter-monsoon periods than the southwest monsoon period. This is because more frequent and heavier convective rain would occur in the afternoon and evening during the inter-monsoon period.

4.2 Rivers in Sabah and Sarawak

There are 176 total numbers of rivers in Sabah and Sarawak. Each state (Sabah and Sarawak) manages rivers in their respective states. The rivers consist of the main and tributaries. The Rajang River is the longest river in Sarawak and Malaysia with a length of 760km located in northwest of Borneo. The Kinabatangan River (Sungai Kinabatangan) is the longest rivers in Sabah and it is the second longest river in Malaysia, with a length of 560 kilometers from its headwaters in the mountains of southwest Sabah, to its outlet at the Sulu Sea, east of Sandakan.

Table 4-1: Rivers in Sabah and Sarawak

State	Total Rivers
Sabah	64
Sarawak	112
Total	**176**

4.2.1 Sabah

There are 64 river systems in Sabah with 16 classified as major rivers in Sabah. There are 16 river basins in Sabah, with the Kinabatangan River basin on the East Coast as the largest basin, covering an area of 15,385 km². The Padas river basin on the West Coast covers an area of about 8,726 km^2. Most of the other basins cover comparatively smaller areas. In the table 4-2 next page shows 16 major rivers in Sabah and in the figure 4-3 shows a map of Sabah Rivers which includes the major rivers in each district, obtained from River Engineering of DID, Sabah

Table 4-2: 16 major rovers of Sabah in different district

	Name of rivers	District
1	Sg. Bengkoka	Kudat
2	Sg. Kadamaian	Kota Belud
3	Sg. Wario	Kota Belud
4	Sg. Segama	Lahad Datu
5	Sg. Sugut	Beluran
6	Sg. Kinabatangan	Kinabatangan
7	Sg. Papar	Papar
8	Sg. Padas	Beaufort
9	Sg. Membakut / Mawao	Membakut
10	Sg. Mesapol	Sipitang
11	Sg. Nabawan	Nabawan
12	Sg. Kalumpang	Kunak
13	Sg. Babagon	Penampang
14	Sg. Pensiangan	Pensiangan
15	Sg. Kiulu	Tamparuli/Tuaran
16	Sg. Tamparuli	Tamparuli/Tuaran

*Source: Department of Fisheries, Sabah

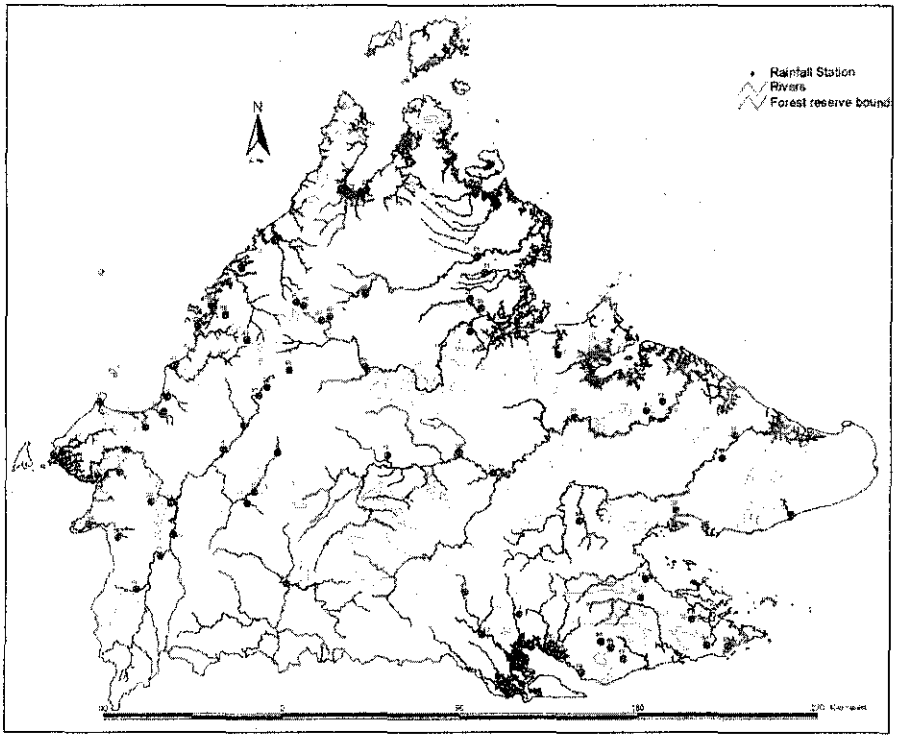

Figure 4-3: Map of rivers in Sabah

*Source: DID, Sabah

4.2.2 Sarawak

There are 112 river systems in Sarawak. The 760 km long Sungai Rejang is the longest river in the country. The river flows approximately 760 km to the South China Sea. The upper part of Rajang River is also known as Batang Balui by the Orang Ulu. Malaysia largest and tallest (160m) hydro electric project, Bakun Hydro Electric Dam Project, is located on Batang Balui narrow Bakun Fall.

There are basically 22 basins in Sarawak. The biggest basins are upper Rajang Basin located in the Kapit division. Kapit division is well known as hilly areas and the stream flow is very turbulence.

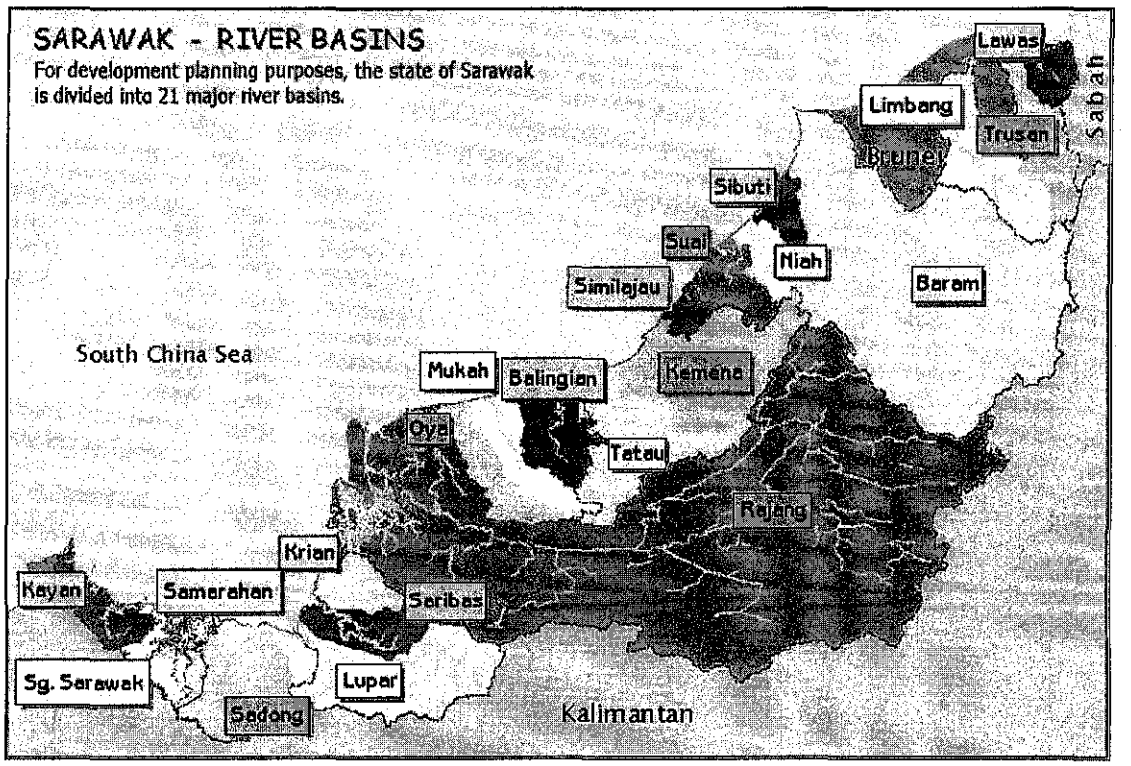

Figure 4-4: Main rivers and basins in Sarawak

Table 4-3: Main Rivers and basins in Sarawak

NO.	BASINS	AREA (KM^2)	NAME OF MAIN RIVER	TOTAL COMBINED LENGTH OF MAIN RIVER(S) (KM)
1	KAYAN	1,645	BATANG KAYAN	125
2	SG. SARAWAK	2,375	SUNGAI SARAWAK	120
3	SAMARAHAN	1,090	BATANG SAMARAHAN	115
4	SADONG	3,550	BATANG SADONG	150
5	LUPAR	6,510	BATANG LUPAR	275
6	SARIBAS	2,200	BATANG SARIBAS	160
7	KRIAN	1,500	SUNGAI KRIAN	120
8	RAJANG Lower / Upper	47,880	BATANG RAJANG	760
9	OYA	2,195	BATANG OYA	240
10	MUKAH	2,275	BATANG MUKAH	205
11	BALINGIAN	2,510	BATANG BALINGIAN	160
12	TATAU	5,260	BATANG TATAU	270
13	KEMENA	6,100	BATANG KEMENA	190
14	SIMILAJAU	660	SUNGAI SIMILAJAU	65
15	SUAI	1,540	BATANG SUAI	130
16	NIAH	1,280	SUNGAI NIAH	105
17	SIBUTI	1,020	SUNGAI SIBUTI	80
18	BARAM	22,930	BATANG BARAM	635
19	LIMBANG	3,950	SUNGAI LIMBANG	275
20	TRUSAN	2,615	BATANG TRUSAN	205
21	LAWAS	1,050	BATANG LAWAS	75

*Source: DID, Sarawak

CHAPTER 5
FLOOD IN SABAH AND SARAWAK

Malaysia has along history of flooding, the country being exposed to monsoon winds and heavy conventional rainfall all year round rendering more than about 10% of the country being flood-prone. The annual average rainfall is 2,630 mm for Sabah and 3,830 mm for Sarawak, with heavier precipitation recorded in the coastal regions of Sabah and Sarawak. Bulk of population in Sarawak and Sabah is concentrated in towns and villages in river valleys and coastal plains, hence prone to flood damages.

5.1 Flood event in Sabah

In Sabah, floods are not a common occurrence because the average annual precipitation in the state is only 2,630 mm and is not widespread. Northern Sabah receives an annual rainfall of 2,800 mm and between 2,000 mm and 2,800 mm of rain falls at the foothills. The West and East Coasts of Sabah receive the most rainfall. Floods usually occur after a downpour in the low plains.

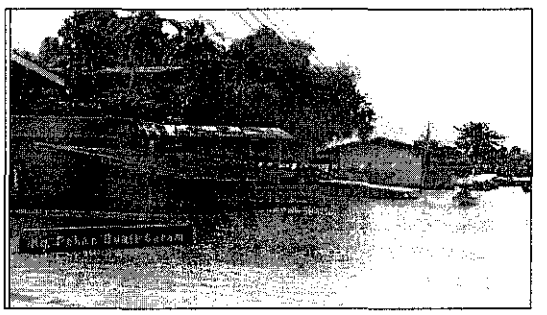

Figure 5-1: Flood in Kinabatangan, Sabah (1998)*

*Source: The internet – Flood in Sabah

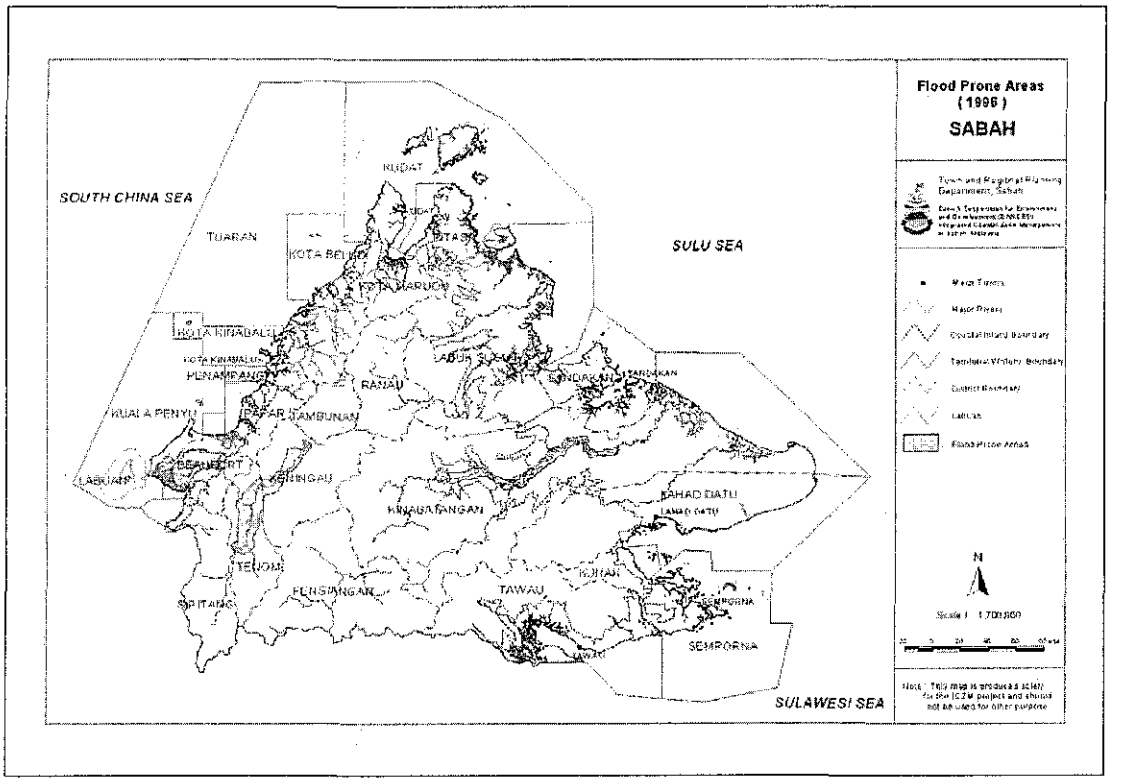

Figure 5-2: Flood prone areas in Sabah, Malaysia*

*Source: Civil Engineering Program, School of Engineering & Information Technology, Universiti Malaysia Sabah

Flood prone areas in Sabah are shown in Figure 5-2. As shown in the figure, virtually every district in Sabah is affected by flooding to some extent but areas most affected are mostly in the West Coast with the exception of the Kinabatangan River in the East Coast. The severity of flooding in these areas varies from year to year and from river to river. The Department of Irrigation and Drainage monitor flood in the low-lying areas and compile annual records of such floods.

5.1.1 Flood Related Disaster in Sabah

Table 5-1: Flood related disaster in Sabah*

No	Area	Date	Incidence
1	**Beaufort** -Kampung Suasa -Kampung Logo	Jan,2007	The total victims was 210 affected two villages, Kampung Suasa (129 families) and Kampung Lago (81 families), in Beaufort. 1 people died drown in the tragedy. The government had allocated RM120 million to repair all damages.
2	**Kinabatangan**	Feb,06	16 villages along Sg. Kinabatangan were affected by the big flood. 411 families were evacuated to temporary shelters. It is considered the worst flood as the water level was 3 meter above dangerous level.
2	**Kudat** -Kudat town -Sikuati	Dec,2006	Flood took place in some part of Kudat town .110 families from three kampungs in Sikuati, Kudat, had to be sheltered at Sekolah Kebangsaan Lok Yuk in Sikuati
3	**Kota Marudu**	Dec,2006	194 families from four villages in Kota Marudu and Pitas were evacuated to flood relief centres in the districts
4	**Kota Kinabalu** -Tuaran -Karambunai	July,2005	2,793 families were affected by the big floods in Karambunai, Tuaran and Kota Kinabalu . Total of RM1,402,500 worth of cash and food assistance were used to help the victims and repairing the utilities
5	**Southwest Sabah** -Penampang -Papar -Beaufort	Oct,2001	Heavy rains on 8th October 2001 over the west coast of Sabah, Brunei and the northeastern coast of Sarawak caused flooding over low-lying areas of the districts of Beaufort, Papar and Penampang in southwest Sabah. Hundreds

			of families were affected by the floods which caused several roads to be below 1 to 2 feet of water and disrupted rail services.
6	**Kinabatangan**	Feb, 2000	Continuous heavy rain for several days caused severe floods affecting 20 villages in **Kinabatangan** district, Sabah. About 4000 residents from 870 families were evacuated to safety while at least two people were drowned; nine houses were washed away while 14 others were badly damaged. According to the report, this was the worst flood since 1996.
7	57 areas in seven districts were affected, the **Penampang** district leading with **22** affected areas, followed by **Kota Kinabalu** with **12** areas, **Papar 10**, **Kota Belud 7**, **Tuaran 5**, **Beaufort 3** and **Keningau** 3.	Jan,1999	The worst ever flood to hit Sabah happened on 6th January 1999. More than 2,000 residents in seven districts were evacuated to temporary shelters. The heavy rain fell non-stop for ten hours resulting in a huge flood. Penampang was worst hit by the flood.
8	**Keningau** Other affected areas included **Tuaran**, **Papar**, **Kota Kinabalu**, **Penampang**, **Tawau** and **Sandakan**.	Dec,1996	Storm Greg resulted in a huge flood in Keningau at the northeastern part of Sabah resulting in the loss of many lives. Many of those who died were Indonesians working in that area.

*Source: Unusual weather events in Malaysia (2000)
Daily Express, Sabah (2006)

There is estimated RM 130 million financial losses and 200 reported deaths, in December 1996 flood event (see to Table 5-2) (Chan, 1997). Prior to this situation, Sabah has played a part in the preparation of guidelines for developments, known as the 'Sabah Water Resources Master Plan', in the year 1995

Table 5-2: Official flood loss estimates for selected floods in Malaysia

Flood event (Year)	(Place)	Damage ($ million at 1993 prices)	Deaths	Persons evacuated
1967	Kelantan R. Basin	199.3	38	320,000
1967	Perak R. Basin	154.5	0	280,000
1967	Terengganu R. Basin	40.2	17	78,000
1971	Pahang R. Basin	93.1	24	153,000
1971	Kuala Lumpur	84.7	24	NA
1979	Peninsular Malaysia	NA	7	23,898
1982	Peninsular Malaysia	NA	8	9,893
1983	Peninsular Malaysia	NA	14	60,807
1984	Batu Pahat R. Basin	20.3	0	8,400
1986	Peninsular Malaysia	NA	0	40,698
1988	Peninsular Malaysia	NA	37	100,755
1988	Kelantan R. Basin	33.0	19	36,800
1988	Sabah	NA	1	NA
1991	Peninsular Malaysia	NA	11	NA
1992	Peninsular Malaysia	NA	12	NA
1993	Peninsular Malaysia	NA[a]	22	17,000
1995	Peninsular Malaysia	NA	0	14,900
1996	Sabah (June)	NA	1	9,000
1996	Sabah (December)	130.0[b]	200[c]	15,000

Notes:
NA = not available
[a] In the state of Kelantan, a total of 200 schools were closed during the 1993 flood resulting in 113,000 students missing school for a total of between six to 11 days
[b] The Sabah government estimated that damage to roads, bridges, schools, power lines, government offices and other public utilities would need at least RM130 million to restore (*The Star*, 1 January 1997). If private properties, industries, businesses, corps, livestock, shipping vessels and other privately owned assests were taken into account, the damage figures would have been at least many million Ringgits higher. More than 4,552 houses were destroyed during this event
[c] Another 104 people were still missing nearly a week after the event

*Source: DID Malaysia, Malaysia National Security Council and local newspaper

5.2 Flood Event in Sarawak

In Sarawak flood season is known as "Landas". Most part of Sarawak affected by flood especially those located along big rivers. Sarawak experiences high rainfall of about 3850 mm annually and total annual surface water runoff is about 306 billion m^3. River courses are relatively short with steep gradients in upper stretches and comparatively flat and meandering stretches in the lower reaches. Flood flows are transient in upper reaches in duration and intensity towards the coastal plains.

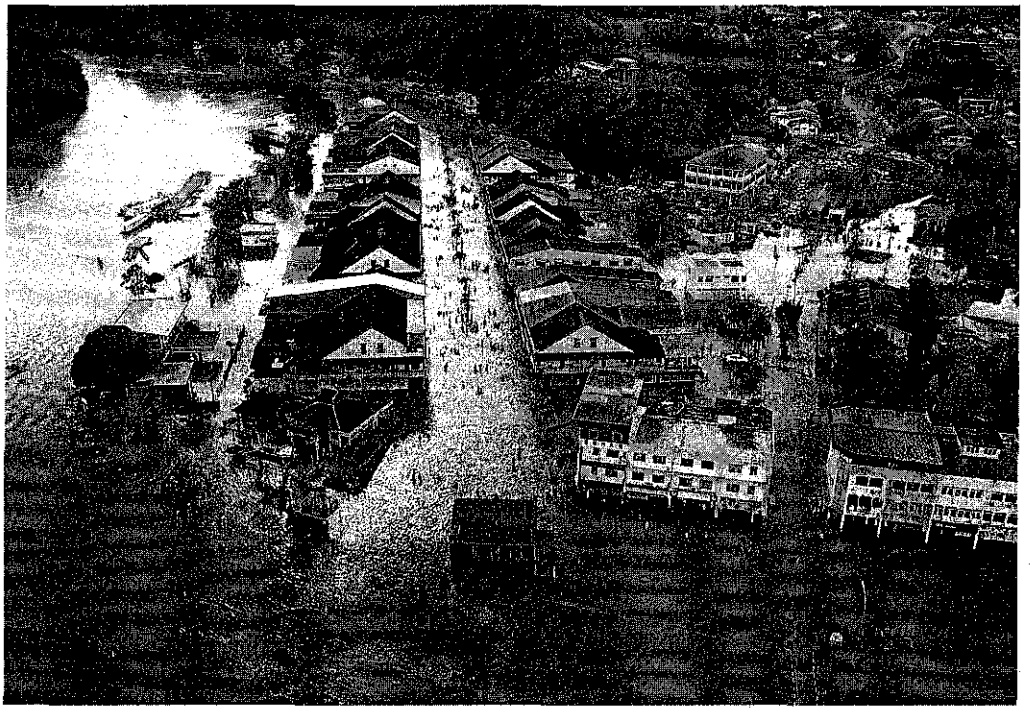

Figure 5-3: Flood in Sibu

*Source: Sibu Municipal Council (SMC)

Many parts of Sarawak experienced the most severe floods in recorded history during January and February 1963. During this period, the state experienced rainfall in amounts far greater than the normally high total for this time, and this was the major cause of the flooding. The long duration of rainfall and their high intensity contributed significantly to the seriousness of the flood situation.

Flood Duration:

- 5 - 10 days in Kuching Division
- 3 - 10 days in Limbang & Lawas Divisions
- 10 - 30 days in Bintulu, Baram, Miri and Btg. Kemena regions
- 10 days in Mukah region
- 40 days in Sibu (2 events, one with duration of 1 month and the other about 10 days)

Flooding did not occur simultaneously throughout the country. Flood Damages Reported:

- 800 longhouses badly damaged and destroyed.
- 35,600 persons affected.
- 4 persons died.

Recently, major floods of February 2003 and January 2004 that claimed to be the worst floods in 50 years in Sarawak, had Bau and surrounding area flood-stricken. Thousands of people were affected, and a lot of property damages.

Being a flood-hit area, Department of Irrigation & Drainage (D.I.D.) Sarawak is the regulating body that monitoring the hydrological data in the Sarawak Kanan River system. There are 2 river gauging stations in Sarawak Kanan River, namely Buan Bidi station and Siniawan Station.

Buan Bidi gauging station is located upstream of Sarawak Kanan River, measuring the water level and indirect river flow through a developed rating curve equation. Siniawan gauging station is downstream, measuring only the water level. In between these two stations laid the town of Bau and several kampongs with approximate population of about 42,000. The area is left with little hydrological information to ponder with, thus indicated a need to reconstruct past flood events to have a better representation of the flooding scenarios in the mentioned area.

CHAPTER 6
METHODOLOGY

6.1 Type of Data

According to Kite (1988), there are two ways in which data may be used in frequency analysis. The first method, direct frequency analysis, is to select from the total data only that information which is required in the design process, which is the maximum discharge in each year (annual series). The second method is to design mathematical model which will describe the observed hydrograph. This model can then be used to generate many sets of data to be abstracted.

For this project, the method used is direct frequency analysis, using annual maximum series of data ranging from 1965 to 2006. The annual series takes one extreme event from each year of the record. A major disadvantage of this technique is that the second or third highest event in a particular year maybe higher than the maximum event in another year, but is disregarded. But none the less, this method is used as it is very simple and requires direct application of data provided by Department of Irrigation and Drainage (DID) Malaysia.

6.2 Data Collection

The first step in carrying out flood frequency analysis is to obtain the data series that is annual maximum discharge. The annual maximum series should be as long as the record allows. The greater the length of record the more certainty can be attached to the prediction of average recurrence interval.

The source of data is obtained from Hydrological Department, DID in both area that are Sabah and Sarawak. DID which responsible for all collection river discharge provides means for designers, researchers to obtain data easily from their database. To facilitate any river data, one has to fill a form either on-line or by personally come to office and no fee will be charged. On 7th February 2006, a letter of application for Softcopy streamflow data from earliest years available and the list of all related publications was faxed and send to both DID Sabah and Sarawak.

A reply was received from DID, Sarawak through email on 24th February 2006 attached with Water level data for 6 stations in Sarawak. On 28th of February 2006, the author received Discharge Rating Curves for 29 stations in Sarawak through fax for discharge calculation.

On 7th March 2006 an email from DID, Sabah was received indicating that the author had to fax his application for the data using the form provided in their website. Furthermore, in the email includes the list of publication. On 21st March 2006, an email attached with softcopy data in term of daily mean discharge was received. The range of data applied is from 1965-2005. A letter was received on 3rd April 2006 from DID, Sabah indicates that all of the application had been approved and an attachment of a list of station in Sabah.

With the aim of more comprehensive and good analysis, more data is taken from publications by DID, Sabah. However, published data is very limited starting from 1963-1975. Any published data after 1975 were obtained from Hydrological Data published by DID, Malaysia though the number of Sabah and Sarawak stations in the publication were limited. The publications used for this project are:

1. Hydrologic Records of Sabah to 1968
2. Hydrological Records for Sabah 1969-1975
3. Hydrological Data- Streamflow Records 1975-1980
4. Hydrological Data- Streamflow Records 1980-1985
5. Hydrological Data- Streamflow Records 1985-1990

After making some comparisons, the author found that there's a large different of value for maximum discharge. Thus, on 27th April 2007, an email has been sent for data clarification. A reply was received through email on 30th April 2007 specify that the discharge values in the book were in term of maximum instantaneous and should not be compared with maximum values in the softcopy as the reading is for daily means. Thus, on 3rd May 2007, a complete set of data for instantaneous maximum, minimum and average from earliest available until 2006 had been received through email. In this case, Mr. Ho Tsun Lin, Assistant Director for Hydrological and Survey Department in DID, himself advised the author to used the softcopy data for analysis.

The streamflow data are then place into Microsoft Excel for analysis. The graph of time (in year) versus discharge is then plotted. A sample of graph for station Sg. Padas at Kemabong, Sabah is shown in figure 6-1 below:

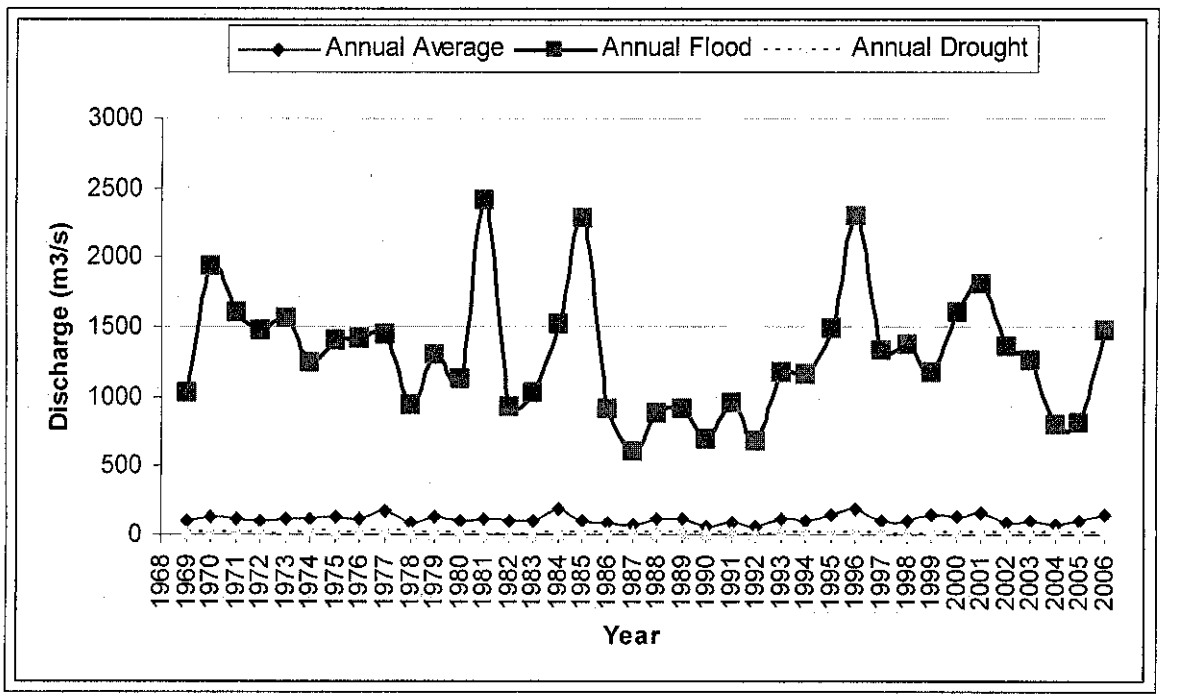

Figure 6-1: Graph of Time versus Discharge for Sg. Padas at Kemabong (1969-2006)

For each river station, the detail of description obtained from the publications by DID is extracted and included as part of the research (refer figure 6-1 for station at Sungai Padas

at Kemabong, Sabah). It includes the location of the site, its catchment area, elevation and catchment characteristics (shape, topography, vegetation, soil cover and rock type).

Station No. 4959401

SUNGAI PADAS AT KEMABONG

Gauging site:- 130m cableway

Longitude & Latitude: - 115°55'15" E 04°55'00'' N.

Catchment Area:- 3185km2

Elevation above mean sea level:- 183 m

Catchment characteristics:-

(a) **Shape**:- The maximum length and breadth of the catchment are 90 km and 55 km respectively

(b) **Topography**:- Mountainous with elevation up to 2000m

(c) **Vegetation** :- Virgin and secondary jungle with some shifting cultivation

(d) **Soil Cover**:- Sandy loams 204m deep

(e) **Rock Type**: - East side of catchment: sandstone, mudstone. West side of catchment: siltstone shale, massive sandstone.

Ranged of observations:- The range of river stages observed is from 18.93m to 26.42m

Figure 6-2: Description of river station (Sungai Padas at Kemabong, Sabah) provided by DID

All of information regarding mean annual discharge, average maximum and minimum and absolute maximum and minimum discharge is summarized in a table.

Table 6-1: Information on discharge of river station - Sg. Padas at Kemabong

Name	Sungai Padas at Kemabong
Area (km^2):	3185
Elevation (m):	183
Average Rainfall (mm)	
Water Use	
Total Mean yearly (m^3/s):	113.77
Mean of "Min"s yearly (m^3/s)	13.0
Mean of "Max"s yearly (m^3/s):	1296.3
Absolute Min, yearly (m^3/s):	2.74
Absolute Max yearly (m^3/s):	2404.2
Source	Hydrological Records for Sabah, 1968-1975, DID Sabah Softcopy, Annual Average. Instantaneous Minimum and Maximum, DID, Sabah

The table includes the catchment area, elevation, average rainfall and water use (provided by DID) and other information on rivers discharge. Table 6-1 is available in Appendix for all river station analysed.

6.3 Choice of Stations

In the figure 6-3 next page, shows the location of river stations in Sabah. In the first figures location of all river stations exist in Sabah. The pink circle represents the river stations chosen for the analysis while the blue triangle indicates the river stations not analysed due to insufficient data. In the figure 6-4 shows water level stations in Sabah. Most of water level stations in Sarawak located at the south of the state and only 5 stations have a sufficient and reliable data for the analysis.

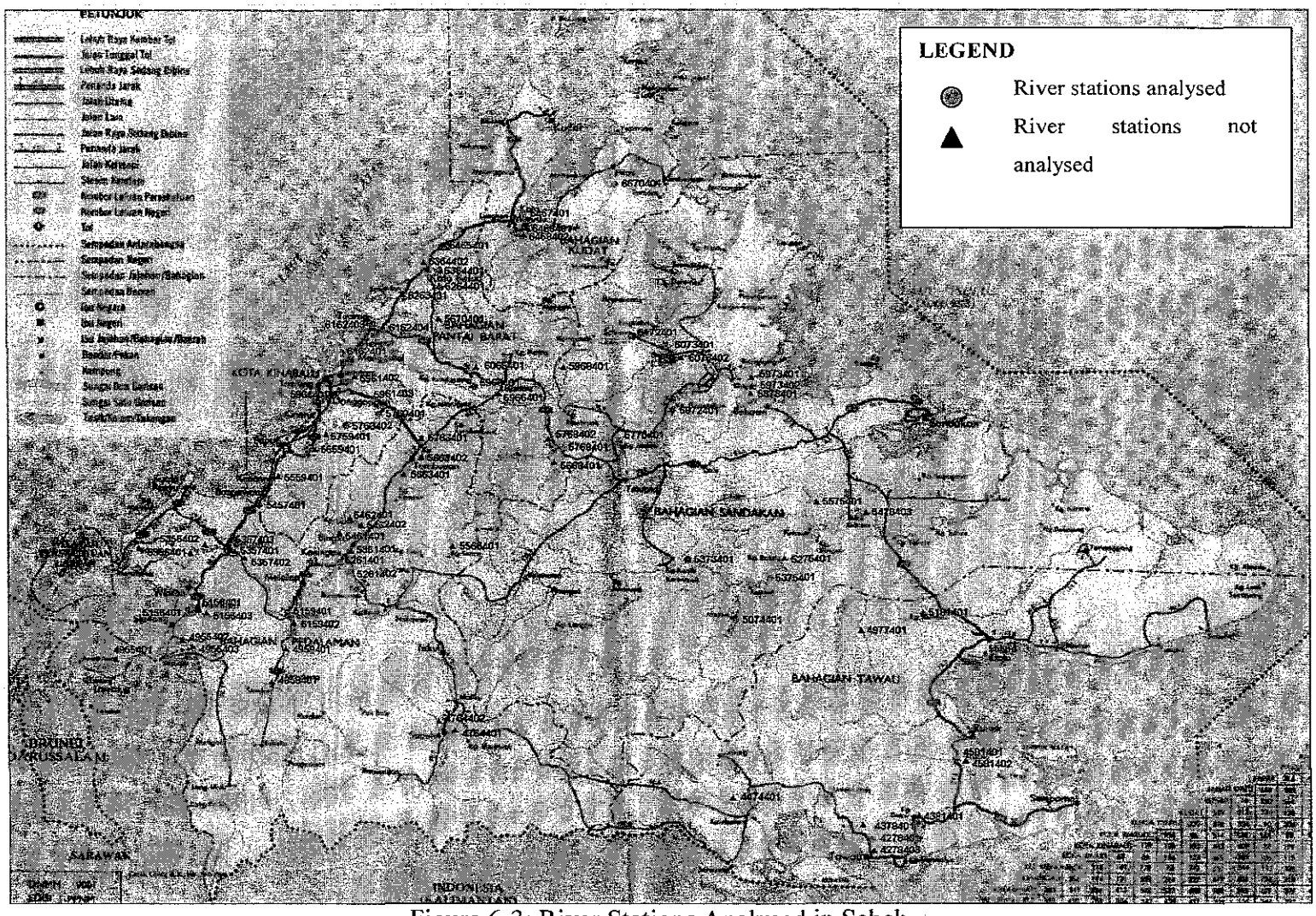

Figure 6-3: River Stations Analysed in Sabah

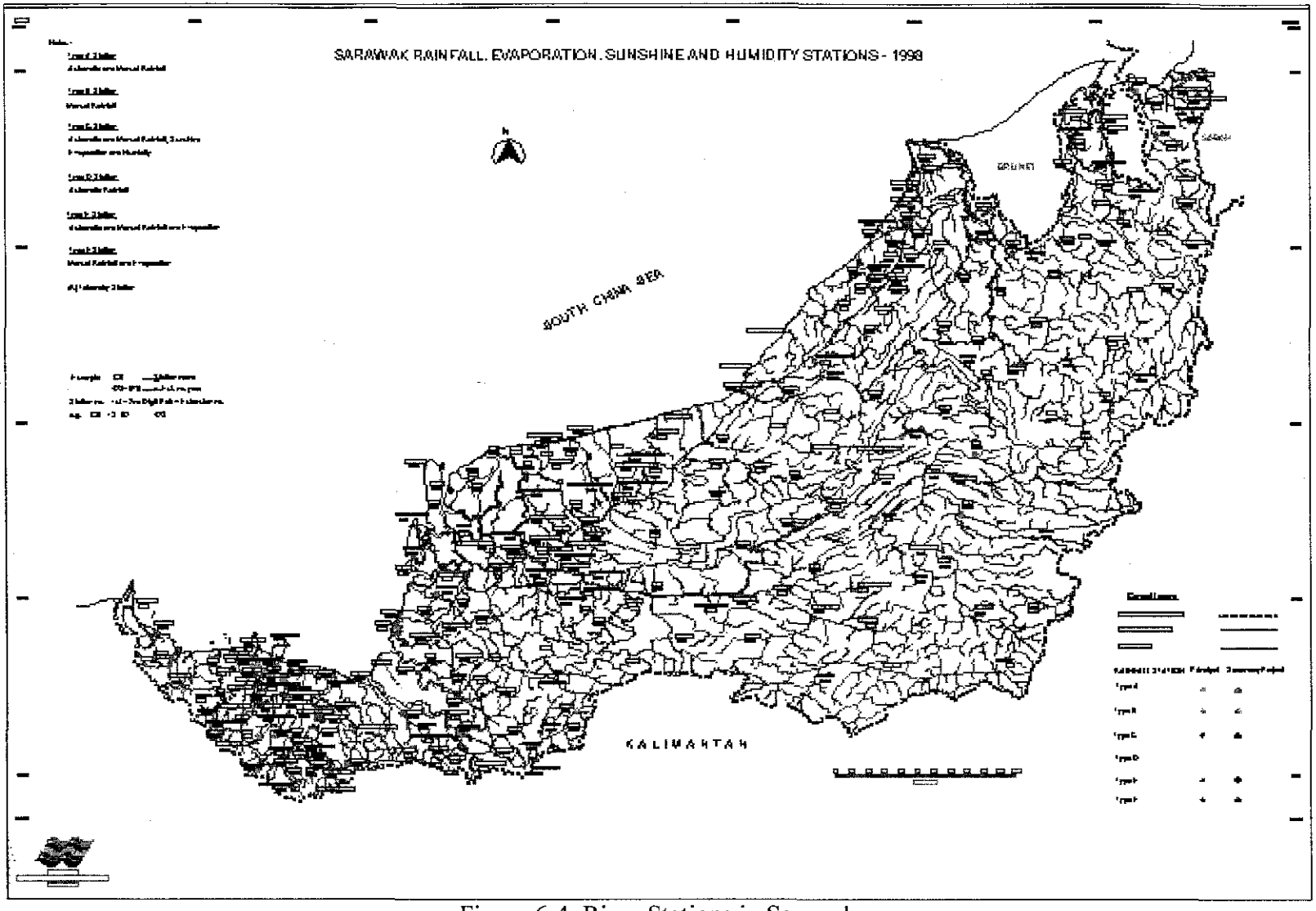

Figure 6-4: River Stations in Sarawak

Table 6- 2: Number of stations in Sabah and Sarawak

State	No. of Station	Station Analysed
Sabah	44	37
Sarawak	79	5
Total	**123**	**42**

Overall only 34% of stations in Sabah and Sarawak have been analysed. For Sabah, the total numbers of stations are 44 and there are 37 stations with sufficient data to be analysed. All of the annual data are obtained from softcopy. 7 more stations are not included in analysis due to insufficient amount of annual data from the stations. The reasons for the lack of data are mechanical failure of the gauge, inaccessibility, flood, damage to the recorder and human error. In order to obtain good result for flood frequency analysis, the minimum amounts of data required are 10 years which is equivalent to 10 maximum streamflow or flood data. Such stations with more than 10 years should produce more accurate result and the probability to obtain the highest flood magnitude for the duration will be larger.

There are 79 water level stations in Sarawak. Since all of the data provided by the authority are in term of water level, calculation is required to convert them into discharge. The authority provides specific Rating-Curve for each station. Only 29 stations in Sarawak do have rating curve and only 5 stations are usable for the analysis. The flood stages for these 5 stations are still in the effective range of the Rating-Curve. For other remain stations, most of the flood stages are out of effective range of the Rating-Curve given thus flood flow are unable to determine. The list of stations with Rating Curves is shown in the appendix B.

The annual discharges are taken from available data from 1965-2006. Though, there are no stations with complete 40 annual data the annual maximum data available are 38. Some of the data are incomplete which has some unknown values in particular year. This will cause inaccuracy in the result as the years with no flood data may have the highest flood of the study period (40 years). The number of river stations for both states in Sabah and Sarawak with specific amount of data is shown in Figure 6-5:

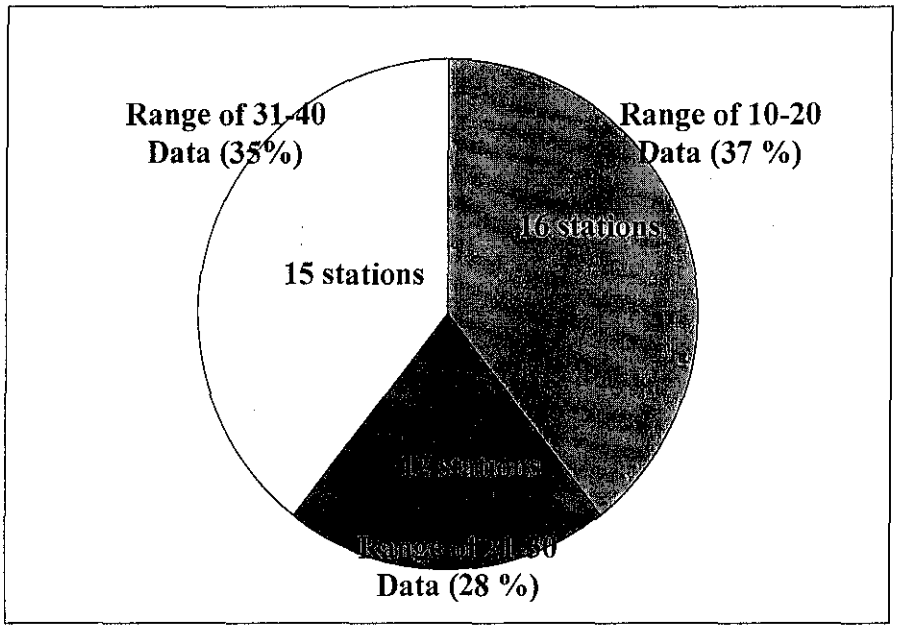

Figure 6-5: No of stations with range Yearly Data

6.4 Analysis of Annual Maximum Discharge Data

Flood frequency analysis is a statistical method to analyse flood data, which involves many formulas and graph. To enhance the misunderstanding of frequency analysis, manual calculations are done to calculate the return period of discharge for some stations. After proper understanding, it will be easier to analyse the data. To ease the process, software called *DISTRIB* is used to obtain a more accurate result. This software was developed by Dr. Saied Saiedi (1989), which uses QBasic to obtain the streamflow for many return periods.

Users are required to enter the type of data, number of data to be analyzed, the return period required and the streamflow data as the input of the programme. *DISTRIB* will then compute the sum, mean, standard deviation, skew coefficient and variation coefficient of the data and the log of the data (for log- type distributions). The output of the programme will be the projected streamflow for the specified return period. The distributions computed by *DISTRIB* are the normal distribution, log- normal 2, Gumbel type I, log- Pearson III, log- normal 3, Pearson III and plotting position formula (Weibull). The analysis includes the standard error of each distribution, which is taken as the basis to choose the two best fit distribution of the result. A sample of *DISTRIB* output is attached in the Appendix B, for Sungai Tawau at Kuhara, Sabah. Note that for this project, the distributions used are limited to Log-Normal 2, Gumbel Type I, Log-Pearson III, Log-Normal 3, Pearson III and Weibull Plotting Position.

DISTRIB could analyze a minimum of 10 data. Thus, stations of less than 10 years maximum streamflow data will be disregard. Out of the 44 river stations, only 39 stations have the significant number of data, ranging from 10 to 40 years of annual maximum flow.

Two best- fit distributions will be chosen based on the computation of the distribution standard error. The distributions with two lowest errors are taken as the two best fit distributions to be further analyzed in the discussion.

CHAPTER 7
RESULTS

7.1 Description of results

Table 7-1 and 7-2 in the next page shows stations with streamflow data received by the authority for both states. The detailed information on the river is described in table 7-3 and 7-4 for Sabah and Sarawak. It contains the catchment characteristic and information run off of the river station.

The results of flood frequency analysis are summarized in table 7-5 and 7-6 for Sabah and Sarawak. This table describes the river name along with the total mean (m^3/s), the estimated flood for selected return periods from 5 to 10,000 years and the two best fit distributions from the analysis. The table is crucial in analyzing the result of findings.

A short summary of each river (location and characteristic) is described in the Appendix C. The summary is given by DID Sabah. The graphs of annual discharge of each river are plotted on streamflow discharge (m^3/s) vs. time (year) axis. The second graph is the frequency analysis of annual floods of the river. After the data had been run in *DISTRIB*, the result obtained is plotted in a graph to describe the differences in the output data. The distributions are plotting position (Weibull), Log- Pearson, Gumbel Type I, Log- Normal 2, Log- Normal 3 and Pearson III.

able 7-1 Summary of River Stations in Sabah

STN. NUMBER	NAME OF STATION	PERIOD OF DATA	REMARKS	NOTES
4278402	SG. TAWAU di KUHARA	1983 - 2006		ANALYSED
4278403	SG. TAWAU di JAMBATAN PUTIH	1994 - 1999	closed	NOT ANALYSED
4378401	SG. TAWAU di LADANG IMAM	2000 - 2006		NOT ANALYSED
4381401	SG. BALUNG di BALUNG BRIDGE	1992 - 11/2006		ANALYSED
4474401	SG. KALABAKAN di KALABAKAN	1986 - 11/2006		ANALYSED
4581401/ 2	SG. KALUMPANG di MOSTYN BRIDGE	1969 - 09/2006		ANALYSED
4764401	SG. SAPULUT di SAPULUT	1990 - 2006		ANALYSED
4764402	SG. TALANKAI di LOTONG	1993 - 2006		ANALYSED
4955403	SG. MENGALONG di SINDUMIN	1983 - 2006		ANALYSED
4959401	SG. PADAS di KEMABONG	1969 - 2006		ANALYSED
5074401	SG. KUAMUT di ULU KUAMUT	1969 - 2006		ANALYSED
5156403	SG. LAKUTAN di MESAPOL	1994 - 2006		ANALYSED
5159401	SG. PADAS di TENOM	1969 - 1985	closed	ANALYSED
5181401	SG. SEGAMA di LIMKABONG	1978 - 10/2006		ANALYSED
5261401	SG. PEGALAN di ANSIP	1969 - 2006		ANALYSED
5261402	SG. SOOK di BIAH	1969 - 2006		ANALYSED
5275401	SG. KINABATANGAN di PAGAR	1986 - 2006		ANALYSED
5357403	SG. PADAS di BEAUFORT JPS	1981 - 2006		ANALYSED
5373401	SG. MILIAN di TANGKULAP	1969 - 2006		ANALYSED
5375401	SG. KINABATANGAN di BALAT	1978 - 2006		ANALYSED
5461401	SG. BAIAYO di BANDUKAN	1993 - 2006		ANALYSED
5462402	SG. APIN-APIN di WATERWORKS	1996 - 2006		ANALYSED
5465401	SG. LABAU di SINUA	1993 - 2006		ANALYSED
5668401	SG. KEGIBANGAN di TAMPIAS P.H.	1997 - 2006		ANALYSED
5760401	SG. PAPAR di KAIDUAN	1969 - 2006		ANALYSED
5760402	SG. PAPAR di KOGOPON	1969 - 2006		ANALYSED
5768401	SG. LABUK di TAMPIAS	1977 - 2000	closed	ANALYSED
5768402	SG. LIWAGU di MARINGKAN	1997 - 2006		ANALYSED
5872401	SG. LABUK di POROG	1969 - 2000	No gauging after 2000	ANALYSED
5872402	SG. LABUK di TELUPID	2001 - 2006		NOT ANALYSED
5961401/ 3	SG. MOYOG di PENAMPANG	1969 - 2006		ANALYSED
6065401	SG. LIWAGU di KINABALU PARK	1993 - 2006		ANALYSED
6073401/ 2	SG. TUNGUD di BASAI	1969 - 2006		ANALYSED
6162401	SG. TUARAN di MALANGGANG	1969 - 1982	closed	ANALYSED
6162403	SG. TUARAN di P.H. NO.1	1982 - 2001	closed	ANALYSED
6162404	SG. TUARAN di TAMPARULI	2001 - 2006		NOT ANALYSED
6172401	SG. SUGUT di BUKIT MONDOU	1984 - 2006		ANALYSED
6264401	SG. KADAMAIAN di TAMU DARAT	1969 - 2006		ANALYSED
6364401	SG. WARIU di BRIDGE NO.2	1969 - 2006		ANALYSED
6468402	SG. BONGAN di TIMBANG BATU	1988 - 2006		NOT ANALYSED
6670401	SG. BENGKOKA di KOBON	1972 - 2006		ANALYSED
5966401	SG. LIWAGU di BEDUKAN	1970 - 1980		ANALYSED
5770401	SG. LABUK di TOMBOLOI	1969 - 1976		NOT ANALYSED
6467401	SG. BANDAU di SIMPANGAS	1969 - 1976		NOT ANALYSED
			Total Stations	44
			Total Stations Analysed	37

Table 7-2: Station with Data received by DID, Sarawak

No	Stn Number	Station Name	River Name	River Basin	Period of Data
1	1004438	Krusen	Kayan Sungai	Sadong	1983-2006
2	1005447	Meringgu	Ketup	Sadong	1981-2006
3	1006403	Sg. Bedup	Bedup	Sadong	1977-1985
4	1018401	Lubok Antu	Al	Lupar	1977-2006
5	1105401	Serian	Sadong	Sadong	1962-2006
6	1108401	Sabal Kruin	Sabal Kruin	Sadong	1988-2006
7	1114415	Sg. Entulang	Entulang	Lupar	1984-1985
8	1114422	Entulang D	Entulang	Lupar	1980-2006
9	1204441	Ma'ang	Serin	Samarahan	1983-1991
10	1210401	Tuba	Sebuyau	Lupar	1987-2000
11	1301426	Boring	Sarawak	Sungai Sarawak	1970-1997
12	1301427	Buan Bidi	Sarawak Kanan	Sungai Sarawak	1981-2006
13	1302428	Git	Sarawak Kiri	Sungai Sarawak	1975-2006
14	1304439	Batu Gong	Tuang	Samarahan	1976-2006
15	1310401	Mintu, Kuala	Mintu	Lupar	1995-2006
16	1316401	Entaban	Skrang	Lupar	1988-2006
17	1415401	Lubau , Nanga	Layar	Saribas	1990-2006
18	1601401	Rayu, Sg.	Rayu	Sungai Sarawak	1992-2006
19	1714402	Wong Bernet	Krian	Krian	1982-2006
20	1813401	Sebatan	Sebatan	Krian	1983-2006
21	1826401	Mukeh, Ng.	Katibas	Lower Rajang	1979-2001
22	1932408	Telok Buing	Balleh	Upper Rajang	1984-2001
23	2130405	Benin, Nanga	Rajang	Upper Rajang	1981-2005
24	2421401	Stapang	Oya	Oya	1988-2005
25	2737413	Belaga	Rajang	Upper Rajang	1975-2005
26	2837401	Sg. Belaga	Belaga	Upper Rajang	1984
27	3152408	Lio Matu	Baram	Baram	1975-2005
28	3231401	Sibiu ATC	Sibiu	Kemena	1983-2002
29	3541410	Jegan, Long	Tinjar	Baram	1967-2005
30	3946411	Terawan, Long	Tutuh	Baram	1982-2005
31	4448420	Insungai, Nanga	Limbang	Limbang	1977-2005
32	4450401	Lubok Lalang	Lalang	Limbang	1989-1996

Table 7-3: Detailed Information of Rivers in Sabah

Number		Geographical Characteristic		Catchment Characteristic			Data		Runoff Info							Rainfall Info Annual Pavg(mm)
No	St. No	Name of Station	Name of River	Length of River (km)	Elevation (m)	Catchment Area (km2)	No of Data	Year	Annual Flood, Q (m3/s)					Std Deviation	Coeff of Variation (%)	
									Total Mean	Mean of "Min"s	Mean of "Max"s	Absolute Min	Absolute Max			
1	4278401	Sg. Tawau at Kuhara	Sg. Tawau	-	12	104	32	69-06	3.28	1.03	27.02	0.13	62.3	15.23	56	1500
2	4278403	Sg. Tawau at Jambatan Putih	Sg. Tawau	-	-	-	6	94-99	2.94	0.58	40.8	0.4	110.14	37.65	92	1500
3	4378401	Sg. Tawau at Ladang Imam	Sg. Tawau	-	-	-	7	00-06	4.42	1.83	47.84	0.81	62.3	8.27	17	1500
4	4381401	Sg. Balung at Balung Bridge	Sg. Balung	-	-	-	15	94-06	3.93	0.52	83.48	0.06	213.19	50.27	60	3000
5	4474401	Sg. Kalabakan at Kalabakan	Sg. Kalabakan	-	-	-	21	86-06	32.63	1.69	695.56	0.53	1401.2	398.46	57	2500
6	4581401	Sg. Kalumpang at Mostyn Bridge	Sg. Kalumpang	-	55	544	37	69-06	22.37	4.02	681.78	0.1	1820.1	458.32	67	2500
7	4764401	Sg. Sapulut at Sapulut	Sg. Sapulut	-	-	-	17	90-06	76.67	11.78	900.31	4.89	1836.6	340.7	38	3500
8	4764402	Sg. Talankai at Lotong	Sg. Talankai	-	-	-	14	93-06	21.48	4.19	349.72	0.75	581.78	141.14	40	3500
9	4955403	Sg. Mengalong at Sindumin	Sg. Mengalong	-	-	-	23	83-06	27.21	2.2	552.35	0.14	889.98	249.62	45	3500
10	4959401	Sg. Padas at Kemabung	Sg. Padas	-	183	3185	38	69-06	113.77	13	1296.53	2.74	2404.2	438.97	34	3000
11	5077401	Sg. Kuamut at Ulu Kuamut	Sg. Kuamat	-	30	2950	38	69-06	122.66	8.2	1956.92	2.31	4121.3	856.1	44	3000
12	5156403	Sg. Lakutan at Mesapol	Sg. Lakutan	-	10	316	21	69-06	9.45	1.08	434.62	0.2	1388.3	267.69	62	3000
13	5159401	Sg. Padas at Tenom	Sg. Padas	-	168	7718	17	69-85	182.33	25.63	1633.2	4.95	4730.1	1204.98	73	2000
14	5181401	Sg. Segama at Limkabung	Sg. Segama	-	-	2450	29	78-06	101.86	14.11	977.73	1.53	2063.3	414.05	42	2500
15	5261401	Sg. Pegalan at Ansip	Sg. Pegalan	-	230	2175	38	69-06	52.03	10.78	400.57	1.96	1379.6	236.9	59	3000
16	5261402	Sg. Sook at Biah	Sg. Sook	-	260	1684	38	69-09	24.53	2.25	180.72	0.39	357.49	73.61	41	3000
17	5275401	Sg. Kinabatangan at Pagar	Sg. Kinabatangan	-	-	-	21	86-06	352.41	35.64	1510.87	4.25	2004	335.71	22	3000

Table 7-3: Detailed Information of Rivers in Sabah

Number		Geographical Characteristic		Catchment Characteristic			Data		Runoff Info							Rainfall Info Annual Pavg(mm)
No	St No	Name of Station	Name of River	Length of River (km)	Elevation (m)	Catchment Area (km2)	No of Data	Year	Annual Flood, Q (m3/s)					Std Deviation	Coeff of Variation (%)	
									Total Mean	Mean of "Min"s	Mean of "Max"s	Absolute Min	Absolute Max			
18	5357403	Sg. Padas at Beaufort JPS	Sg. Padas	-	-	-	16	81-06	220.43	24.13	960.29	1.04	1535.4	256.03	27	3500
19	5373401	Sg. Milian at Tangkulap	Sg. Milian	-	25	5730	38	69-06	227.55	24.09	1085.3	2.79	2413.6	355.91	33	3500
20	5375401	Sg. Kinabatangan at Balat	Sg. Kinabatangan	563	23	10800	29	78-06	406.17	48.37	1681.52	7.49	3611.6	571.55	34	3500
21	5461401	Sg. Baiayo at Bandukan	Sg. Baiayo	-	-	-	14	93-06	5.95	1.48	55.15	0.08	92.39	22.11	40	3000
22	5462402	Sg. Apin- Apin at Waterworks	Sg. Apin-Apin	-	-	-	11	96-06	4.14	0.8	89.98	0.22	160.62	41.88	47	3000
23	5465401	Sg. Labau at Sinua	Sg. Labau	-	-	-	14	93-06	5.52	0.87	254.51	0.3	538.28	114.22	45	2500
24	5668401	Sg. Kegibangan at Tampias	Sg. Kegibangana	-	-	-	10	97-06	44.12	8.49	568.19	2.4	709.92	71.65	13	3000
25	5760401	Sg. Papar at Kaiduan	Sg. Papar	-	91	357	37	69-06	24.24	3.48	438.24	0.86	1550.6	251.44	57	3000
26	5760402	Sg. Papar at Kogopon	Sg. Papar	-	24	536	37	69-06	43.18	6.48	814.13	1.33	2477	389.07	48	3000
27	5768401	Sg. Labuk at Tampias	Sg. Labuk	-	168	2010	24	77-00	105.65	21.37	1270.34	1.77	2882.9	672.87	53	3500
28	5768402	Sg. Liwagu at Maringkan	Sg. Liwagu	-	-	-	10	97-06	37.05	8.09	284.64	2.4	395.68	77.01	31	3500
29	5770401	Sg. Labug at Tomboloi	Sg. Labuk	-	98	2460	8	69-76	118.2	21.61	1404.81	11.8	2774	684.21	49	3000
30	5872401	Sg. Labuk at Porog	Sg. Labuk	-	17	3240	32	69-00	185.76	37.16	1806.34	4.1	3534.4	836.5	46	3000
31	5872402	Sg. Labuk at Telupid	Sg. Labuk	-	-	-	6	2000-2006	125.82	28.63	1037.2	24.79	1497.2	279.2	27	3000
32	5961401	Sg. Moyog at Penampang	Sg. Moyog	-	-	-	38	69-00	14.9	1.3	295.76	0.21	507.28	81.09	27	2500
33	5966401	Sg. Liwagu at Bedukan	Sg. Liwagu	-	430	440	11	70-80	4.96	0.49	82.55	0.01	298.67	80.46	95	2500
34	6065401	Sg. Liwagu at Kinabalu Park	Sg. Liwagu	-	-	-	14	93-06	0.57	0.12	22.32	0.06	91.34	22.23	100	2500
35	6073401	Sg. Tungud at Basai	Sg. Tungud	-	24	700	38	69-06	43	4.37	782.24	0.89	1516.8	359.73	46	3000
36	6162401	Sg. Tuaran at Malanggang	Sg. Tuaran	-	45	546	14	69-82	43.48	4.69	1202.45	0.16	3040.2	681.21	57	2000
37	6162403	Sg. Tuaran at P.H No.1	Sg. Tuaran	-	45	639	20	82-01	34.05	3.75	427.6	0.81	902.89	183.57	43	2000

Table 7-3: Detailed Information of Rivers in Sabah

Number		Geographical Characteristic		Catchment Characteristic			Data		Runoff Info							Rainfall Info Annual Pavg(mm)
No	St. No	Name of Station	Name of River	Length of River (km)	Elevation (m)	Catchment Area (km2)	No of Data	Year	Annual Flood, Q (m3/s)					Std Deviation	Coeff of Variation (%)	
									Total Mean	Mean of "Min"s	Mean of "Max"s	Absolute Min	Absolute Max			
38	6162404	Sg. Tuaran at Tamparuli	Sg. Tuaran	-	-	-	6	2001-2006	5.59	1.37	63.02	0.75	92.39	27.39	43	2000
39	6172401	Sg. Sugut at Bukit Mundou	Sg. Sugut	-	50	2150	23	84-06	79.88	11.47	966.14	1.18	1796.1	430.31	45	2000
40	6264401	Sg. Kedamaian at Tamu Darat	Sg. Kedamaian	-	52	338	38	69-06	32.4	3.28	855.14	0.72	1574.2	348.23	41	2500
41	6364401	Sg Wariu at Bridge no.2	Sg. Wariu	-	37	243	38	69-06	18.58	2.66	551.95	0.63	1457.7	185.36	34	2000
42	6467401	Sg. Bandau at Simpangas	Sg. Bandau	-	40	228	8	69-75	11.24	0.95	1097.33	0.2	2333	637.05	58	2500
43	6468402	Sg. Bongan at Timbang Batu	Sg. Bongan	-	-	-	19	88-06	15.08	2.48	470.4	0.81	1996.2	500.85	106	2500
44	6670401	Sg. Bengkoka at Kobon	Sg. Bengkoka	-	-	-	38	69-06	24.48	2.53	602.99	0.11	1631.3	398.45	66	2500

Table 7-4: Detailed information of Rivers in Sarawak

		GEOGRAPHICAL CHARACTERISTIC			CATCHMENT CHARACTERISTIC		DATA		RUNOFF INFO							Rainfall Info
									Annual Flood, (m^3/s)					Std	Coeff Variation (%)	Annual Pavg(mm)
No. Stn	Stn No	Name of station	Name of river	Length of river (km)	Elevation (m)	Catchment Area (km^2)	No of data	Year	Total Mean	Mean of "Min"s	Mean of "Max"s	Absolute Min	Absolute Max			
1	1005447	Meringgu at Sg. Ketup	Sg. Ketup	-	-	338.2	24	81-05	19.94	3.57	78.99	0.31	119.61	14.01	18	4220
1	1006403	Sg Bedup at Bedup	Sg. Bedup	-	-	46	9	77-85	3.13	0.65	32.86	0.43	60.56	14.47	24	3850
2	1018401	Batang Ai at Lubok Antu	Sg. Ai	-	26	1304.7	29	77-05	124.52	27.78	425.86	1.39	682.77	135.45	32	3850
3	1105401	Serian at Batang Sadong	Sg. Ketup	150	-	950.5	42	62-05	56.81	5.25	266.49	0.33	392.04	62.29	23	3850
4	1114415	Batang Entulang at Entulang	Sg. Entulang	-	50	43.8	2	84-85	131.05	12.75	2482.55	1	4784	1187.79	48	3150
	1210401	Tuba at Sg. Sebuyau	Sg. Sebuyau	-	-	28.5	24	87-00	2.69	0.75	7.88	2.64	10.39	1.55	20	3500
5	1301426	Sg. Pedil at Boring	Sg. Pedil	-	-	123	9	77-85	15.98	1.97	384.59	0.17	589.1	94.58	16	3850
6	1301427	Sg. Sarawak Kanan at Pekan Buan Bidi	Sg. Sarawak Kanan	120	16.74	217	5	81-85	182.33	2.47	274.91	2.47	390.1	1204.98	73	4220
7	1302428	Sg. Sarawak Kiri at Kg. Git	Sg. Sarawak Kiri	120	-	425	13	77-90	33.01	8.18	468.81	0.06	866.33	187.58	40	4220
8	1813401	Sg. Sebatan at Sebatan	Sg. Sebatan	-	50	33	5	81-85	1.06	0.04	9.97	0.01	13.76	3.57	36	3500
9	2130405	Sg. Rajang at Ng Benin	Sg. Rajang	760	50	21192	9	81-90	1429.53	113.15	4329.53	1.61	6385.64	2256.95	35	3850
10	2737413	Sg. Rajang at Belaga	Sg. Rajang	760	50	18190	5	81-85	1343.5	203.46	6147.9	146.79	7610.5	913.8	12	3850
11	2837401	Sg. Belaga at Long Bangan	Sg. Belaga	-	50	2503	1	84-85	-	-	-	-	-	-	-	4200
12	3946411	Sg. Tutoh at Long Terawan	Sg. Tutoh	-	18.3	3210	6	82-87	214.98	44.41	636.44	2.6	961.52	252.85	40	4200

Table 7-5 Summary of Results Obtained From Flood Frequency Analysis of Annual Flood in Sabah

No	Name of Station	Area (km^2)	Total Mean (m^3/s)	No of Yearly Data	Coeff. of Variation (%)	Return Period (year)							Two Best Fit Distributions	
						5	10	20	50	100	1000	10000		
						Estimated Floods (m^3/s)								
1	Sg. Tawau at Kuhara	104	3	38	56	40	51	60	73	83	115	146.52	Gumbel Type I	Log-Pearson III
2	Sg. Balung at Balung Bridge		4	15	60	116	149	182	224	256	364	475	Pearson III	Log-Pearson III
3	Sg. Kalabakan at Kalabakan		33	21	57	1060	1290	1472	1661	1772	1955	2123	Log Pearson III	Gumbel Type I
4	Sg. Kalumpang at Mostyn Bridge	544	22	38	67	942	1242	1528	1900	2178	3098	4016	Gumbel Type I	Log-Pearson III
5	Sg. Sapulut at Sapulut		77	17	38	1187	1465	1731	2074	2328	3182	4042	Gumbel Type I	Log-Pearson III
6	Sg. Talankai at Lotong		21	14	40	464	532	585	642	678	775	848	Pearson III	Log-Pearson III
7	Sg. Mengalong at Sindumin		27	23	45	775	883	963	1045	1094	1215	1297	Pearson III	Log-Pearson III
8	Sg. Padas at Kemabung	3185	114	38	34	1661	1974	2222	2577	2843	3722	4600	Gumbel Type I	Log-Pearson III
9	Sg. Kuamut at Ulu Kuamut	2950	123	38	44	2688	3226	3761	4454	4973	6687	8399	Gumbel Type I	Log-Normal 2
10	Sg. Lakutan at Mesapol	316	9	21	62	573	762	963	1240	1460	2236	3074	Pearson III	Log-Normal 2
11	Sg. Padas at Tenom	7718	182	17	73	1438	2144	2946	4116	5058	8610	12654	Pearson III	Log-Normal 2
12	Sg. Segama at Limkabung	2450	102	29	42	1331	1607	1871	2213	2470	3316	4161	Gumbel Type I	Log-Normal 2
13	Sg. Pegalan at Ansip	2175	52	38	59	520	673	845	1112	1351	2441	4199	Log-Pearson III	Pearson III
14	Sg. Sook at Biah	1684	25	38	41	242	290	336	395	440	587	735	Gumbel Type I	Pearson III
15	Sg. Kinabatangan at Pagar		352	21	22	1457	1721	1947	2208	2388	2914	3372	Pearson III	Gumbel Type I
16	Sg. Padas at Beaufort JPS		220	16	27	1182	1354	1518	1732	1892	2420	2947	Gumbel Type I	Log-Pearson III
17	Sg. Milian at Tangkulap	5730	228	38	33	1380	1613	1835	2123	2388	3052	3763	Gumbel Type I	Log-Normal 2
18	Sg. Kinabatangan at Pulat	10800	406	29	34	2044	2424	2803	3306	3690	4992	6338	Pearson III	Gumbel Type I

No	Name of Station	Area (km^2)	Total Mean (m^3/s)	No of Yearly Data	Coeff. of Variation (%)	Return Period (year)							Two Best Fit Distributions	
						5	10	20	50	100	1000	10000		
						Estimated Floods (m^3/s)								
19	Sg. Baiayo at Bandukan		6	14	40	71	88	105	126	142	179	195	Gumbel Type I	Pearson III
20	Sg. Apin- Apin at Waterworks		4	11	47	100	126	152	184	209	290	372	Gumbel Type I	Log-Normal 2
21	Sg. Labau at Sinua		6	14	45	340	430	517	630	713	992	1273	Gumbel Type I	Log-Normal 2
22	Sg. Kegibangan at Tampias		44	10	13	614	650	682	719	743	817	884	Log-Pearson III	Pearson III
23	Sg. Papar at Kaiduan	357	24	37	57	574	751	935	1189	1388	2089	2842	Pearson III	Log-Pearson III
24	Sg. Papar at Kogopon	536	43	37	48	1023	1297	1582	1977	2286	3374	4544	Pearson III	Log-Pearson III
25	Sg. Labuk at Tampias	2010	106	24	53	1858	2313	2750	3314	3738	5136	6533	Gumbel Type I	Pearson III
26	Sg. Liwagu at Maringkan		37	10	31	310	366	418	490	538	707	876	Gumbel Type I	Log-Pearson III
27	Sg. Labuk at Porog	3240	186	32	46	2513	3065	3595	4280	4794	6491	8185	Gumbel Type I	Pearson III
28	Sg. Moyog at Penampang		15	38	27	364	418	470	535	585	750	914	Gumbel Type I	Pearson III
29	Sg. Liwagu at Bedukan	440	5	11	95	129	202	289	427	550	1082	1826	Log-Pearson III	Gumbel Type I
30	Sg. Liwagu at Kinabalu Park		1	14	100	33	50	65	90	109	176	249	Pearson III	Gumbel Type I
31	Sg. Tungud at Basai	700	43	38	46	1086	1286	1506	1649	1775	2108	2347	Log-Pearson III	Pearson III
32	Sg. Tuaran at Malanggang	546	43	14	57	1817	2331	2826	3464	3933	5521	7120	Gumbel Type I	Log-Normal 2
33	Sg. Tuaran at P.H No.1	639	34	20	43	593	720	842	999	1117	1508	1898	Gumbel Type I	Pearson III
34	Sg. Kedamaian at Tamu Darat		6	6	43	1124	1303	1455	1630	1750	1999	2372	Pearson III	Log-Pearson III
35	Sg. Wariu at Bridge no.2	2150	80	23	45	754	912	1064	1261	1408	1895	2381	Gumbel Type I	Log-Normal 2
36	Sg. Bongan at Timbang Batu		15	19	106	782	1132	1491	1981	2362	3685	5089	Pearson III	Log-Normal 2
37	Sg. Bengkoka at Kobon		24	38	66	940	1186	1422	1727	1956	2711	3466	Gumbel Type I	Pearson III

Table 7-6: Summary of Results Obtained From Flood Frequency Analysis of Annual Flood in Sarawak

No	Name of Station	Area (km^2)	Total Mean (m^3/s)	No of Yearly Data	Coeff. of Variation (%)	Return Period (year)							Two Best Fit Distributions	
						5	10	20	50	100	1000	10000		
						Estimated Floods (m^3/s)								
1	Lubok Antu at Batang Ai	1304.7	125	29	32	542	606	662	726	770	900	1013	Pearson III	Log-Pearson III
2	Meringgu at Sg. Ketup	338.2	20	24	60	92	101	111	122	132	161	191	Gumbel Type I	Log-Pearson III
3	Serian at Batang Sadong	950.5	124	21	23	361	437	510	607	680	923	1172	Pearson III	Gumbel Type I
4	Tuba at Sg. Sebuyau	28.5	3	24	38	9	10	12	13	14	17	21	Gumbel Type I	Log-Pearson III
5	Git at Sg. Sarawak Kiri	425	33	13	40	640	805	964	1170	1320	1831	2346	Gumbel Type I	Pearson III

CHAPTER 8
DISCUSSION

In Sabah, the maximum, minimum and mean discharge plotted for year 1960 – 1965, 1982- 1984 and 1995- 1997 were relatively high. This is due to the great flood that occurred in early 1960's, in the middle of 1980's and Greg Storm on 1996. Storm Greg resulted in a huge flood in Keningau at the northeastern part of Sabah. In Sarawak, flood occurred almost every year during December to January.

8.1 Curve Fitting of the Distributions

The best distributions are chose based on the least standard error obtained from the analysis. Curve fitting is then done on the distributions, to obtain the regression constant and R^2. The summary of the curve fittings using logarithmic trend is presented on the table next page. The curves which the curve fittings are based on are shown in figure 8-1 to 8-17. The numbers located at the end of each station name on the graph indicates the number of flood data for each station.

Table 8-1: Curve fitting Using Logarithmic Functions

No. Stn	District	Hydro Region	Name of Station	Name of Best Fit Distribution	Equation = aLn(x) + b	a	b	R2	Refer to Figure
1	Tawau		Sg. Tawau at Kuhara	Gumbel Type I	y = 14.118Ln(x) + 17.425	14.118	17.425	0.9994	8-1
2			Sg. Balung at Balung Bridge	Pearson III	y = 47.211Ln(x) + 39.447	47.211	39.449	0.9999	
3			Sg. Kalabakan at Kalabakan	Log-Pearson III	y = 164.98Ln(x) + 886.66	164.98	886.66	0.8514	
4			Sg. Kalumpang at Mostyn Bridge	Gumbel Type I	y = 408.92Ln(x) + 281.97	408.92	281.97	0.9992	
5			Sg. Segama at Limkabung	Gumbel Type I	y = 373.88Ln(x) + 629.87	373.88	629.87	0.9989	
6	Sandakan		Sg. Kuamut at Ulu Kuamut	Gumbel Type I	y = 762.37Ln(x) + 1437.6	762.37	1437.6	0.9992	8-2
7			Sg. Kinabatangan at Pagan	Pearson III	y = 270.16Ln(x) + 1065.5	270.16	1065.5	0.9692	
8			Sg. Kinabatangan at Balat	Pearson III	y = 561.97Ln(x) + 1119.5	561.97	1119.5	0.9998	
9			Sg. Milian at Tangkulap	Gumbel Type I	y = 316.94Ln(x) + 869.12	316.94	869.12	0.9992	
10			Sg. Labuk at Porog	Gumbel Type I	y = 754.45Ln(x) + 1295.6	754.45	1295.6	0.9992	
11			Sg. Tungud at Basai	Log-Pearson III	y = 183.19Ln(x) + 849.12	183.19	849.12	0.9423	
12	Kudat		Sg. Bongan at Timbang Batu	Pearson III	y = 557.17Ln(x) -156.16	557.17	-156.16	0.9982	8-3
13			Sg. Bengkoka at Kobon	Gumbel Type I	y = 336.05Ln(x) + 397.58	336.05	397.58	0.9992	
14	Interior		Sg. Sapulut at Sapulut	Gumbel Type I	y = 384.37Ln(x) + 570.19	384.37	570.19	0.9995	8-4
15			Sg. Talankai at Lotong	Pearson III	y = 56.717Ln(x) + 389.57	56.717	389.57	0.9189	
16			Sg. Mengalong at Sindumin	Pearson III	y = 79.966Ln(x) + 676.13	79.966	676.13	0.8708	
17			Sg. Padas at Kemabung	Gumbel Type I	y = 390.91Ln(x) + 1030.2	390.19	1030.2	0.9992	
18			Sg. Lakutan at Mesapol	Pearson III	y = 320.72Ln(x) + 23.632	320.72	26.632	0.9957	
19			Sg. Padas at Tenom	Pearson III	y = 1403.7Ln(x) - 1086.8	1403.7	-1086.8	0.9852	

Table 8-1: Curve fitting Using Logarithmic Functions

No. Stn	District	Hydro Region	Name of Station	Name of Best Fit Distribution	Equation = aLn(x) + b	a	b	R2	Refer to Figure
20			Sg. Pegalan at Ansip	Log-Pearson III	y = 428.59Ln(x) - 388.67	428.59	-388.67	0.9264	8-4
21	Interior		Sg. Sook at Biah	Gumbel Type I	y = 65.552Ln(x) + 136.06	65.552	136.06	0.9992	8-5
22			Sg. Padas at Beaufort JPS	Gumbel Type I	y = 234.92Ln(x) + 802.63	234.92	802.63	0.9992	
23			Sg. Baiayo at Bandukan	Gumbel Type I	y = 23.355Ln(x) + 33.766	23.355	33.766	0.9995	
24			Sg. Apin- Apin at Waterworks	Gumbel Type I	y = 36.057Ln(x) + 42.273	36.057	42.273	0.9995	
25			Sg. Labau at Sinua	Gumbel Type I	y = 123.72Ln(x) + 140.59	123.78	140.59	0.9995	
26			Sg. Kegibangan at Tampias	Log-Pearson III	y = 37.707Ln(x) + 559.64	37.707	559.64	0.9745	
27	West Coast		Sg. Papar at Kaiduan	Pearson III	y = 291.86Ln(x) + 77.019	291.86	77.019	0.9968	8-6
28			Sg. Papar at Kogopon	Pearson III	y = 452.88Ln(x) + 251.87	452.88	251.87	0.9967	
29			Sg. Labuk at Tampias	Gumbel Type I	y = 621.83Ln(x) + 854.49	621.83	854.49	0.9992	
30			Sg. Liwagu at Maringkan	Gumbel Type I	y = 75.175Ln(x) + 184.49	75.175	184.49	0.9992	
31			Sg. Moyog at Penampang	Gumbel Type I	y = 73.135Ln(x) + 246.25	73.135	246.25	0.9992	
32			Sg. Liwagu at Bedukan	Log-Pearson III	y = 202.31Ln(x) - 284.02	202.31	-284.02	0.9444	8-7
33			Sg. Liwagu at Kinabalu Park	Pearson III	y = 27.56Ln(x) - 14.025	27.54	-14.025	0.9953	
34			Sg. Tuaran at Malanggang	Gumbel Type I	y = 702.12Ln(x) + 688.81	702.12	688.81	0.9995	
35			Sg. Tuaran at P.H No.1	Gumbel Type I	y = 173.58Ln(x) + 312.84	173.58	312.84	0.9992	
36			Sg. Kedamaian at Tamu Darat	Pearson III	y = 179.89Ln(x) + 866.86	179.89	866.86	0.9672	
37			Sg Wariu at Bridge no.2	Gumbel Type I	y = 216.48Ln(x) + 404.48	216.48	404.48	0.9992	

Table 8-2: Curve Fitting Using Logarithmic Functions for Sarawak

No. Stn	District	Hydro Region	Name of Station	Name of Best Fit Distribution	Equation = aLn(x) + b	a	b	R2	Refer to Figure
1	**Sri Aman**		Lubok Antu at Batang Ai	Pearson III	y = 66.386Ln(x) + 445.44	14.118	17.425	0.9704	**8-8**
2	**Samarahan**		Meringgu at Sg. Ketup	Gumbel Type I	y = 13.299Ln(x) + 70.132	47.211	39.449	0.9992	
3	**Serian**		Serian at Batang Sadong	Pearson III	y = 106.84Ln(x) + 187.17	164.98	886.66	0.9999	
4	**Kuching**		Git at Sg. Sarawak Kiri	Gumbel Type I	y = 408.92Ln(x) + 281.97	408.92	281.97	0.9992	
5	**Sri Aman**		Tuba at Sg. Sebuyau	Gumbel Type I	y = 1.5208Ln(x) + 6.8946	1.5208	6.8946	0.9992	

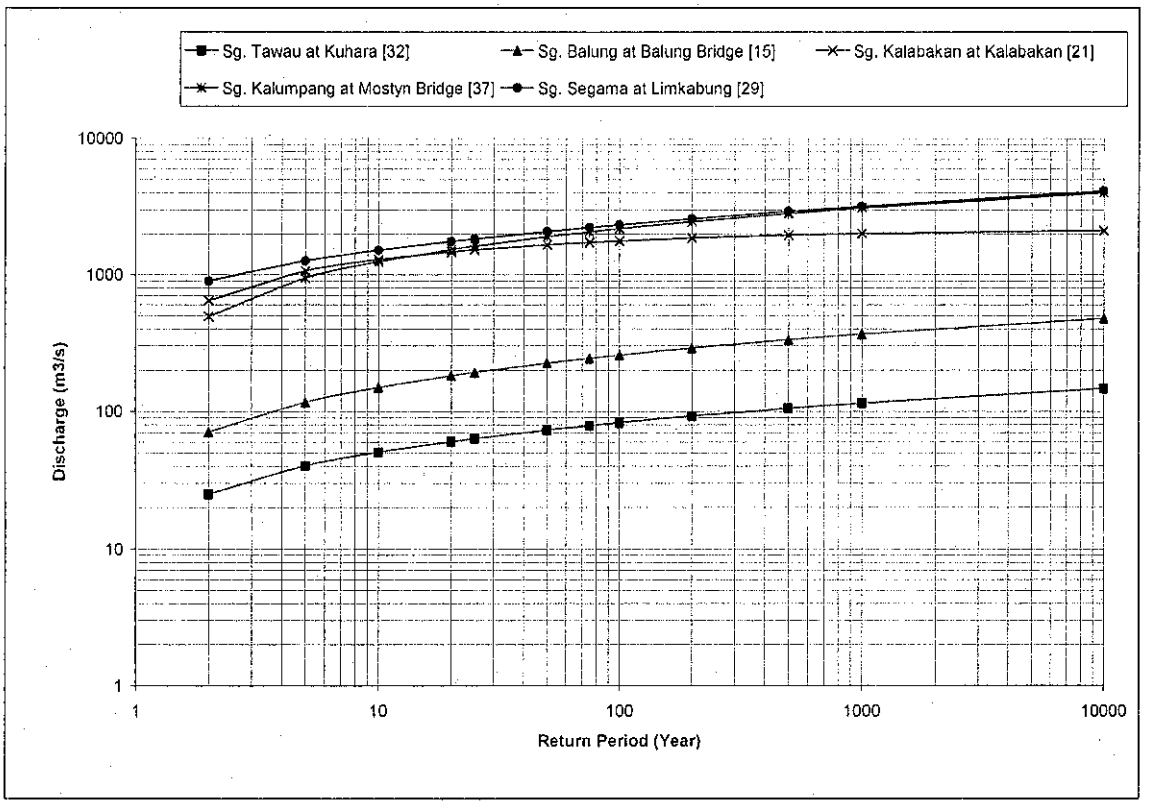

Figure 8-1: The Best Distributions for River Stations in Tawau, Sabah

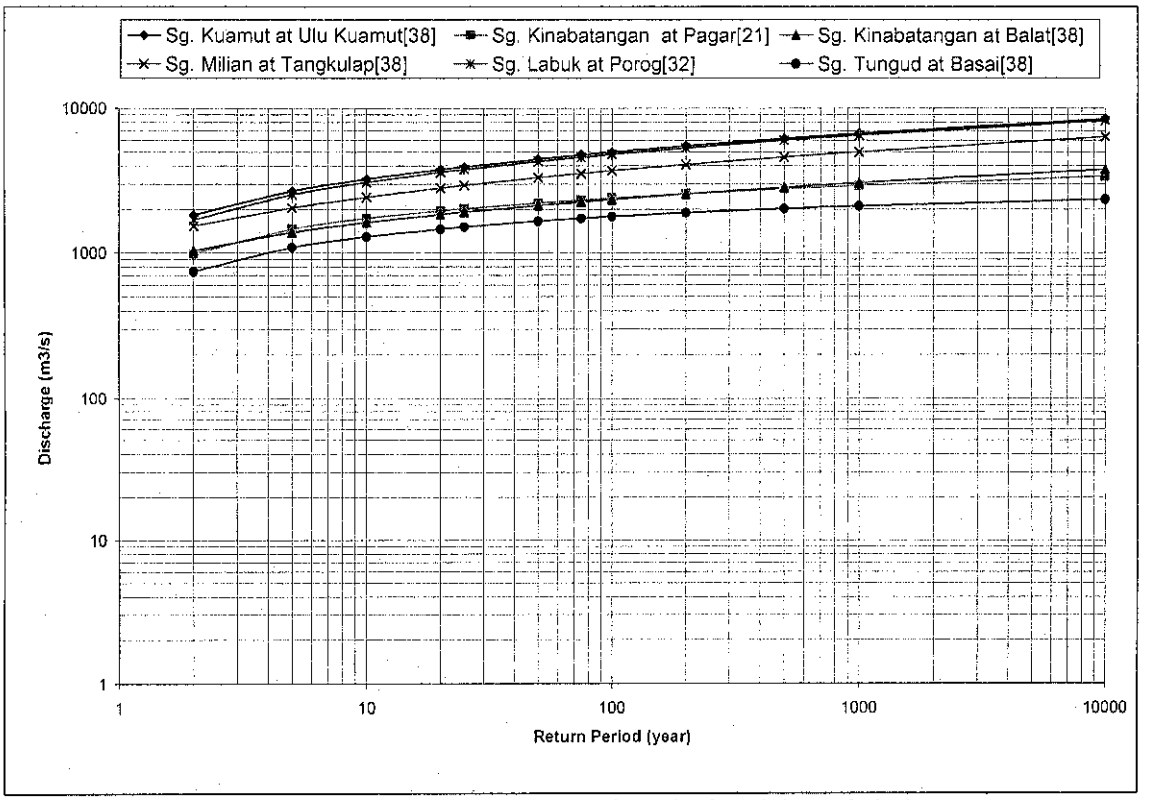

Figure 8-2: The Best Distributions for River Stations in Sandakan, Sabah

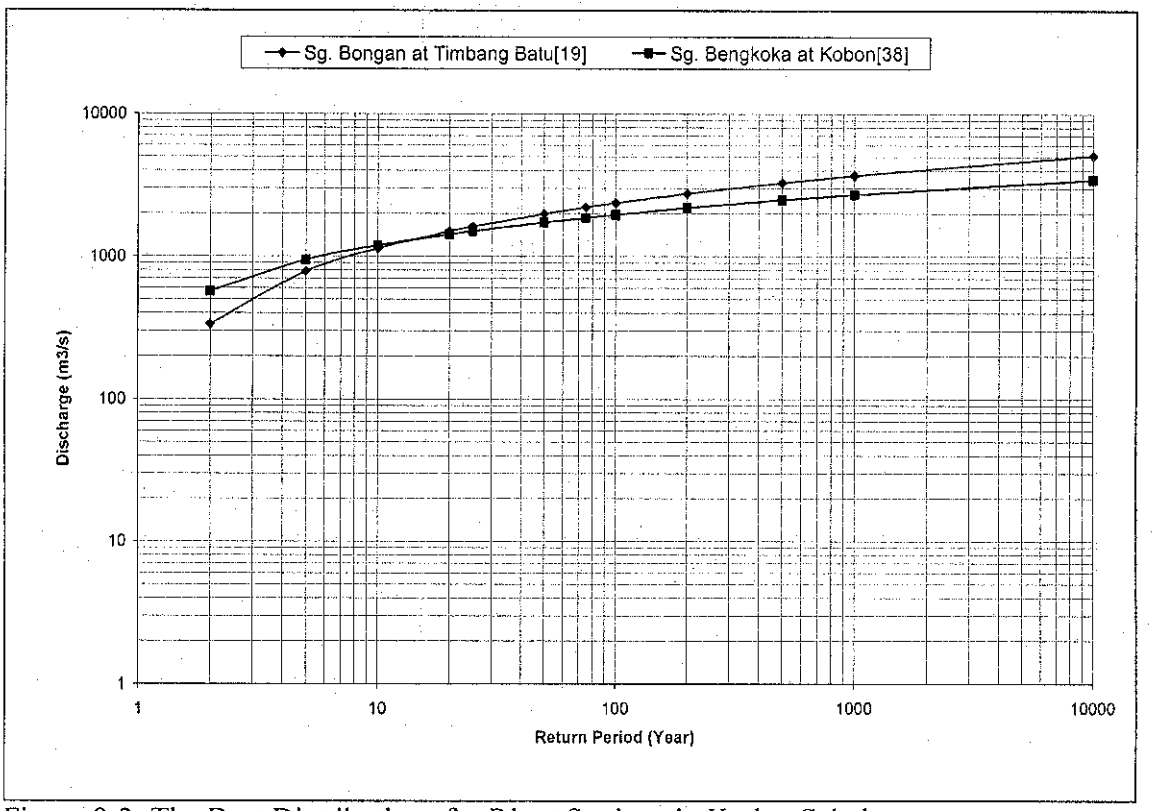

Figure 8-3: The Best Distributions for River Stations in Kudat, Sabah

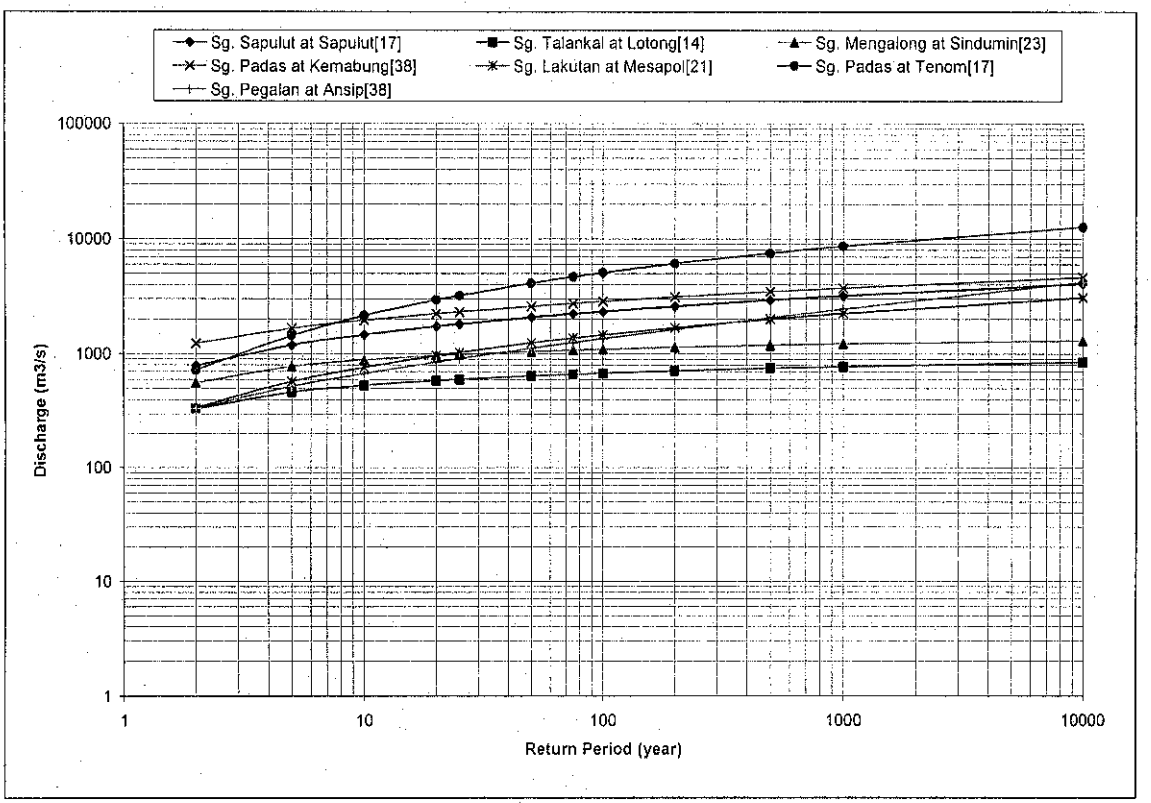

Figure 8-4: The Best Distributions for River Stations in Interior (1), Sabah

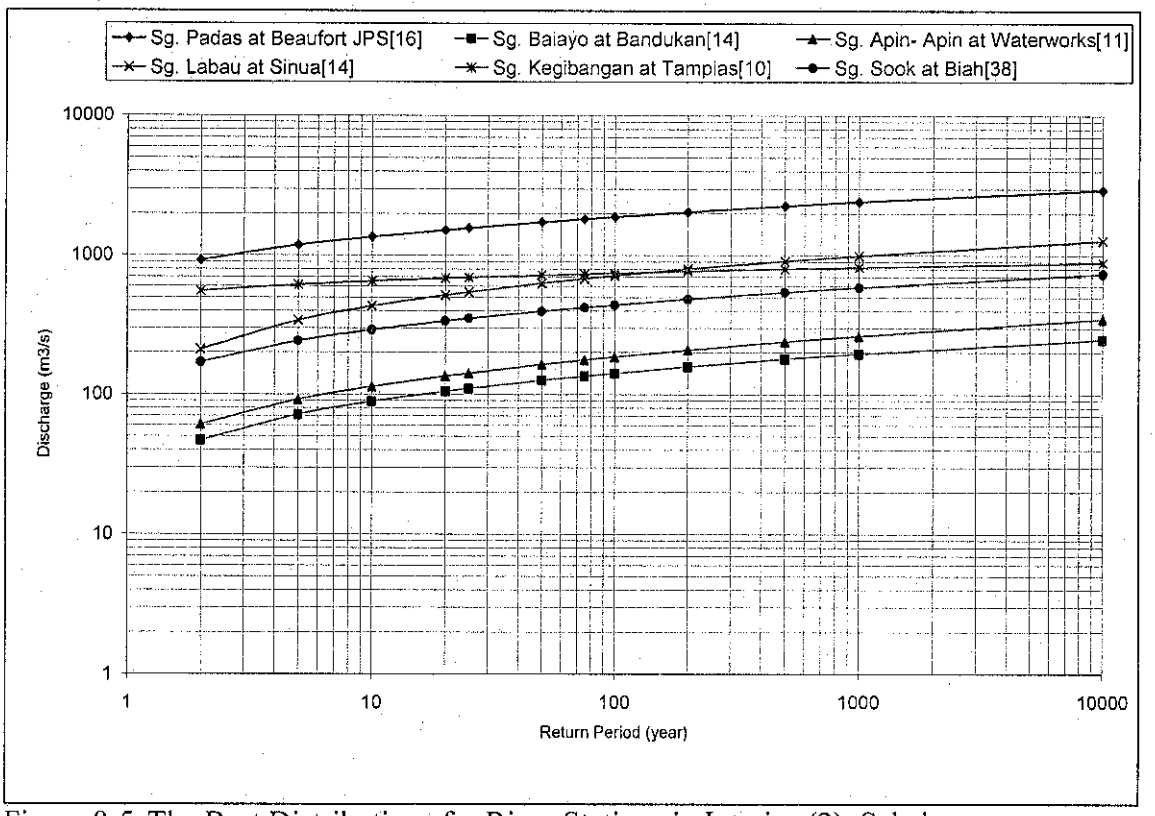

Figure 8-5: The Best Distributions for River Stations in Interior (2), Sabah

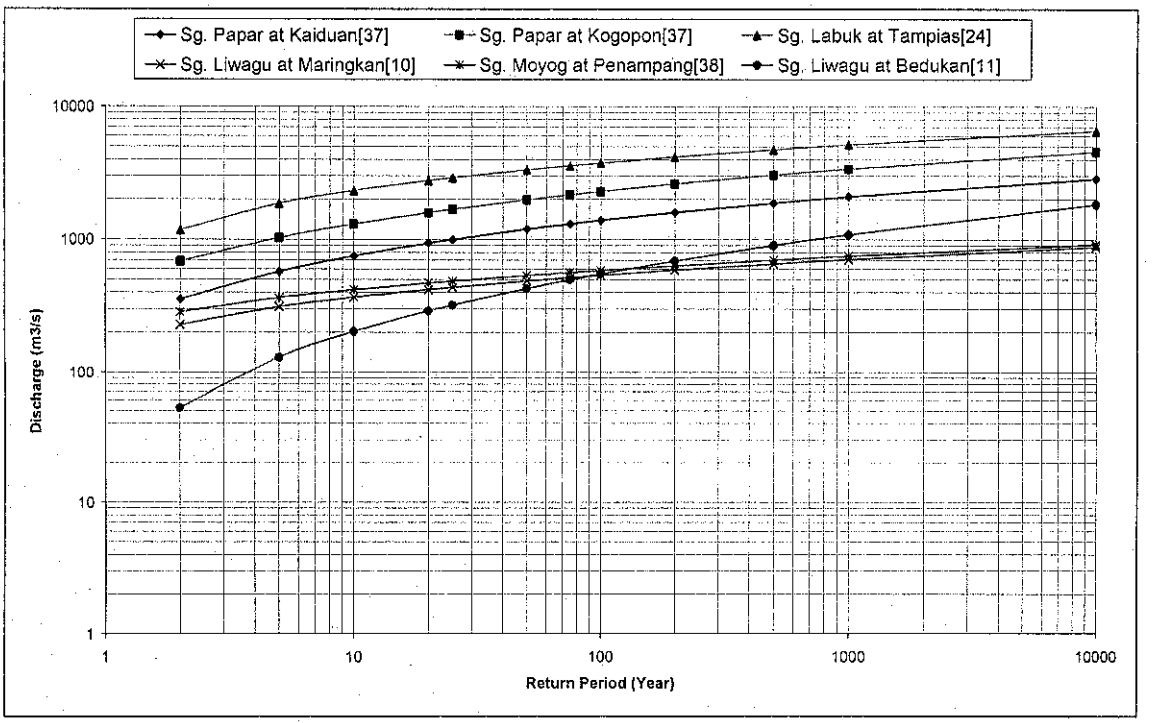

Figure 8-6: The Best Distributions for River Stations in West Coast (1), Sabah

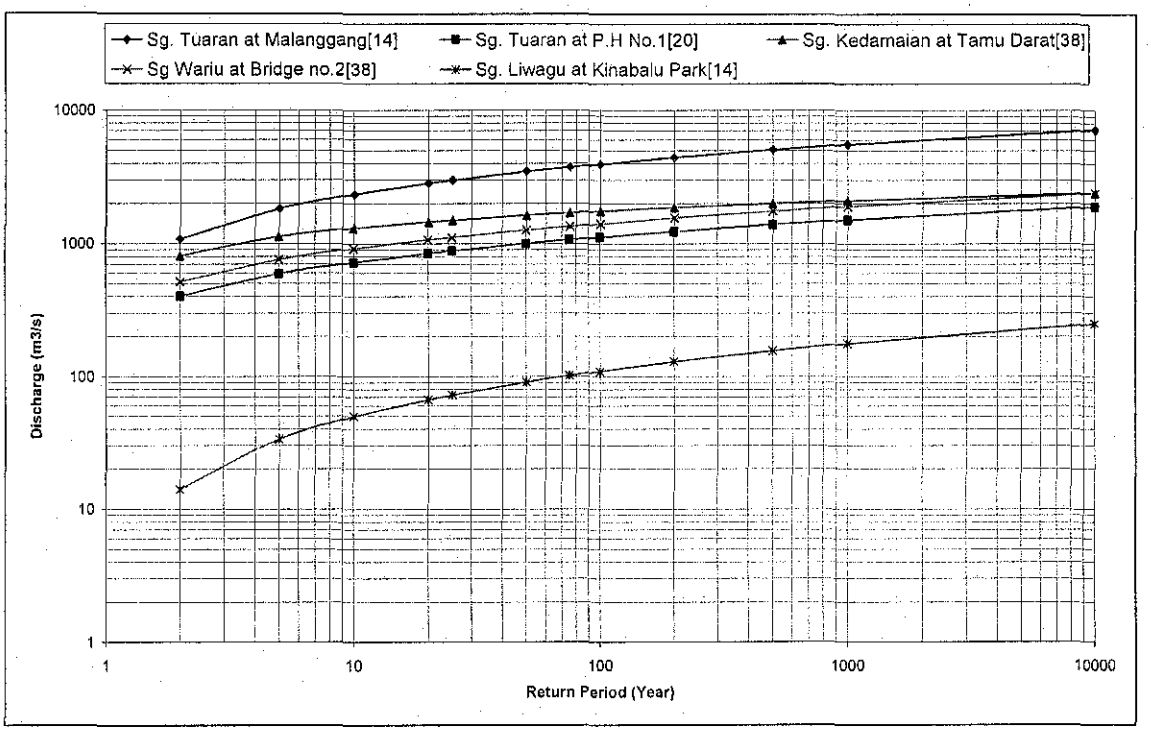

Figure 8-7: The Best Distributions for River Stations in West Coast (2), Sabah

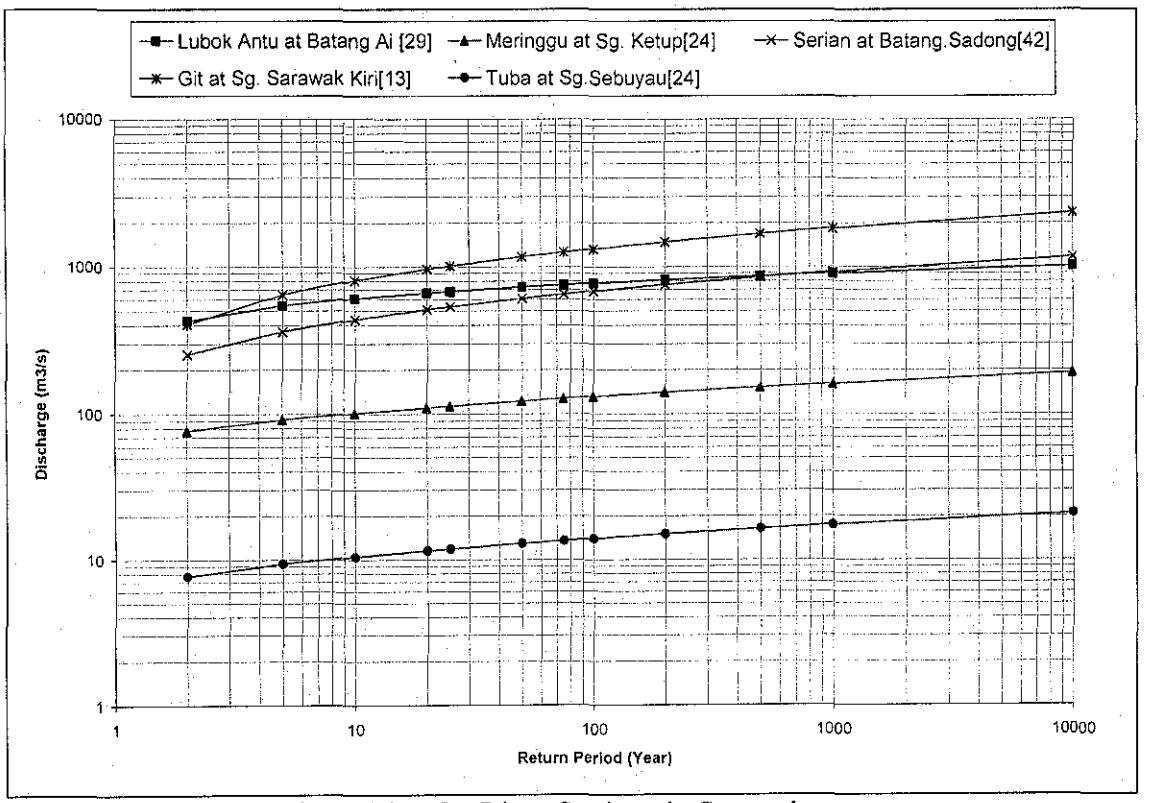

Figure 8-8: The Best Distribution for River Stations in Sarawak

8.2 Best Distributions

There are 64 rivers in Sabah 44 gauging stations in Sabah. Among all of the data received only 37 had been analyzed. For Sarawak the total numbers of water level gauging stations are 79 and only 5 stations had been analyzed due to some difficulties (Refer to Appendix B).Based on Flood Frequency Analysis, the two distributions with the least standard error are taken as best-fit distribution for the station analysed.

Best-fit distribution specifies the distribution for each station with least amount of standard error. Two best fit-distributions show the two distributions with minimum standard error. As an example, for station of Sg. Tawau at Kuhara, Tawau (refer Appendix B), the two best-fit distributions are Gumbel Type I and Log-Pearson III. The Gumbel Type I method has the least standard error of 2.45 and Log-Pearson III has the second least standard error of 2.87.

In short, the most common distributions analysed with least error are Gumbel Type I, Pearson III and Log-Pearson III. Other distributions such as Log-Normal 2, Log, Normal 3 and Weibull Plotting Position have large error thus will not be included in the analysis.

From the analysis done Predicted Discharge of Various Return Periods graph are plotted. Log-Normal 3 distributions have the highest discharge for a specified return period, while Log-Pearson III and Pearson III yield the least discharge. Thus, the selection for the best distribution for analysis is very important as it will decide the cost of the structure design, construction and drainage system.

8.2.1 Whole of Sabah

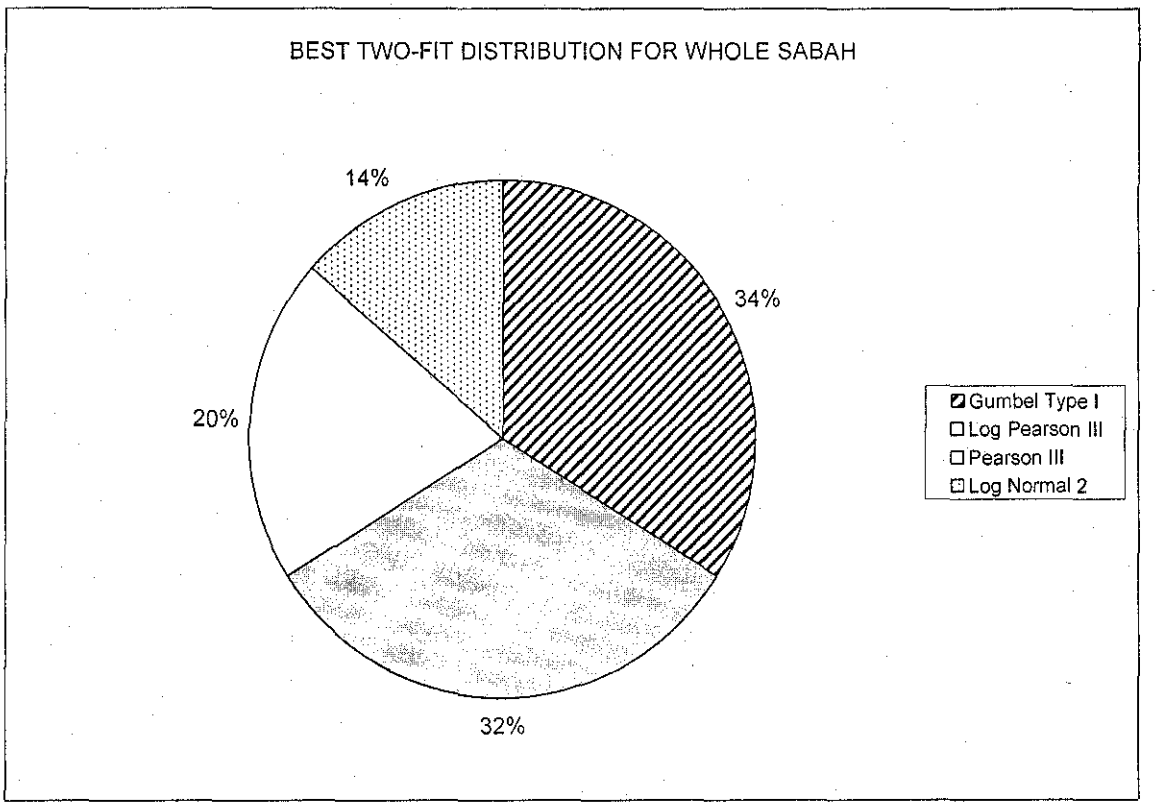

Figure 8-9: The First Two Best-Fit Distributions for the whole Sabah

From the pie chart above, the first best two-fit distribution are Gumbel Type I (34 %) and Log- Pearson III (32%) followed by Pearson III (20%) and Log- Normal II (14 %). When it is said that 40 percent of the first two distributions are Gumbel Type I, it means that Gumbel Type I distributions is one of the two distributions with least standard error for 34 percent from the total 74 analyse. Thus, this shows that Gumbel Type I is generally the best distribution to be used for Sabah followed by Pearson III, Log-Pearson III and Log Normal 2.

8.2.2 Tawau

Tawau is situated on the South-East Coast of Sabah. It is facing the interior mountain ranges on the west and the Celebes Sea on the east. Overall Tawau has 11 rivers and 8 river gauging stations. Tawau receives about 2000-2500 mm rainfall annually.

For Tawau, there are 5 stations had been analysed. The two best-fit distributions are Log Pearson III (40%), Gumbel Type I (40 %), Pearson III (10%) and Log-Normal 2 (10 %). Most of the stations have a mean flood less than 50m3/s except for station in Sg. Segama at Limkabung. Sg. Segama is located in Lahad Datu area 110 km from Tawau town.

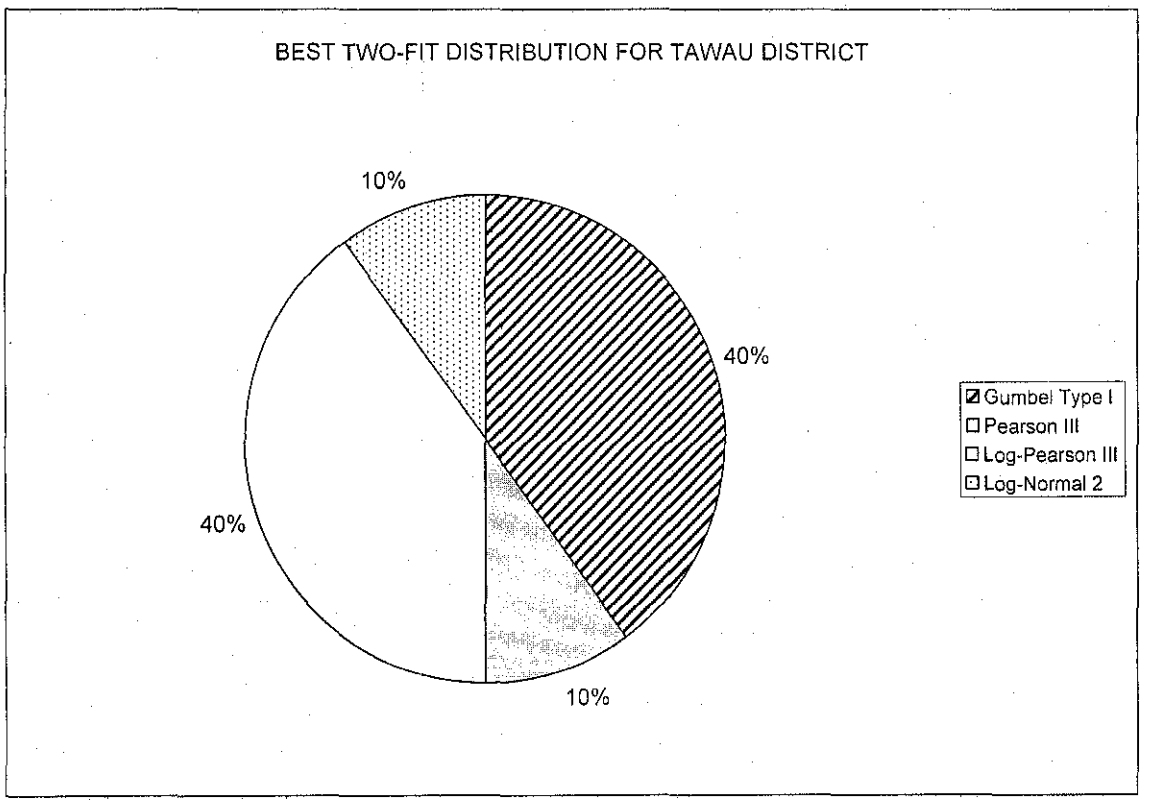

Figure 8-10: The First Two Best Fit Distribution for Tawau District

The best distribution to be used in Tawau District is Gumbel Type I or Log-Pearson III, followed by Pearson III and Log-Normal 2

8.2.3 Sandakan

Sandakan is situated on the East coast of Sabah. The longest river in Sabah is located in Kinabatangan, Sandakan Sabah. There are 14 river gauging stations in Sandakan. Sandakan receives 3000-3500 mm annual rainfall in the interior Kinabatangan and Tangkulap area and 2000-2500 mm at the coastal area. There are 5 stations had been analysed in Sandakan. The two best-fit distributions are Gumbel Type I (33%), Log-Pearson III (25 %), Pearson III (25%) and Log-Normal 2 (17 %). Most of the rivers in Sandakan has a big mean flow which is more than $100m^3/s$ especially Sungai Kinabatangan which has total mean flow of $406m^3/s$.

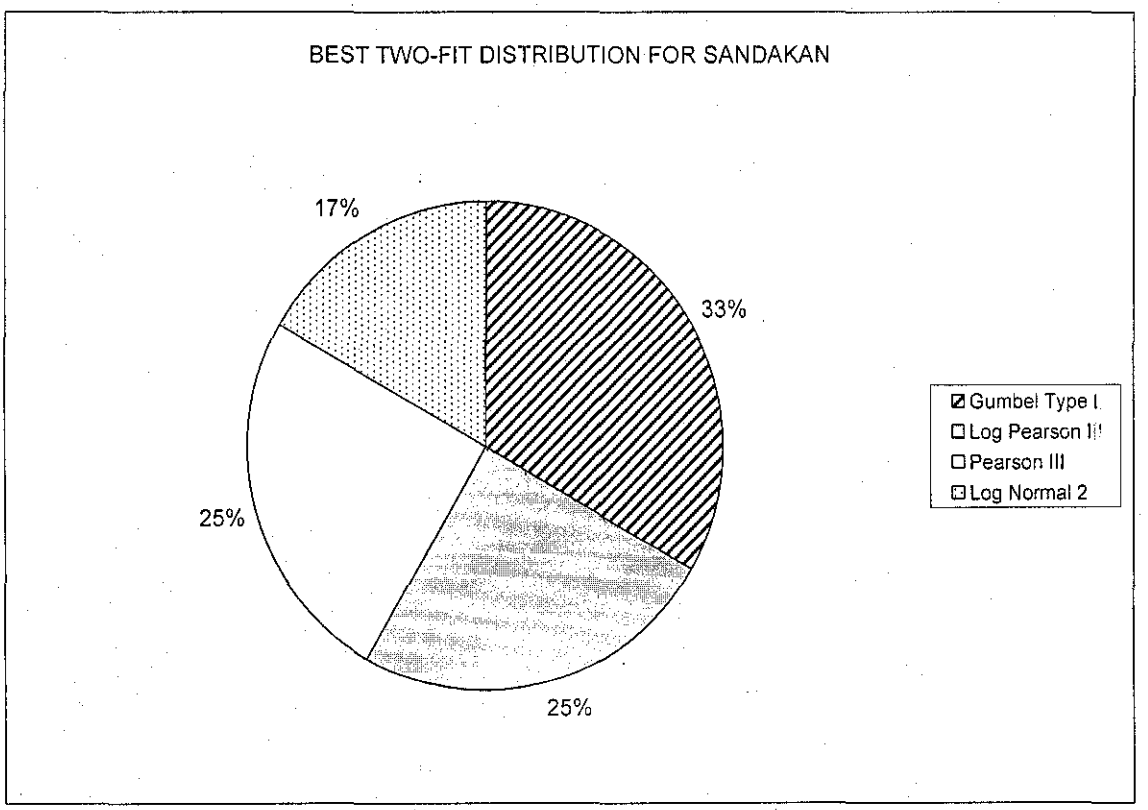

Figure 8-11: The First Two Best Fit Distribution for Sandakan District

The best distributions to be used in Sandakan are Gumbel Type I, followed by Pearson III, Log-Pearson III and Log-Normal 2

8.2.4 Kudat

Kudat is situated in the northernmost part of Sabah. On the west, it faces the South China Sea and on the east the Sulu Sea. It serves as the division administrative centre for the Kudat Division, which includes Kudat, Pitas, Kota Marudu and some islands. There are only 4 river gauging stations in Kudat area.

Kudat receives about 2000-2500 mm of rainfall annually. For Kudat, The two best-fit distributions are Gumbel Type I (40%), Log-Pearson III (20 %), Pearson III (20%) and Log-Normal 2 (20 %). Most of the rivers in Sandakan have a mean flow of less than $50m^3/s$ which shows that the river flows is quite low.

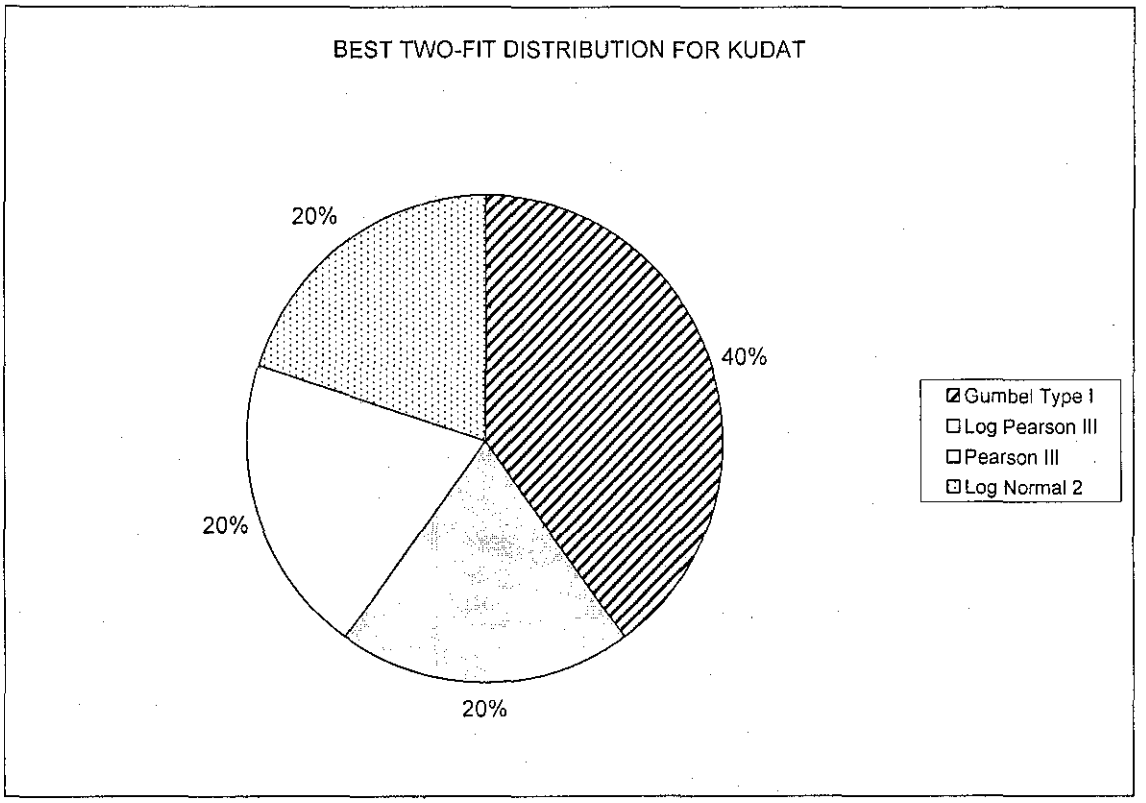

Figure 8-12: The First Two Best Fit Distribution for Kudat District

The best distributions to be used in Kudat are Gumbel Type I, followed by Pearson III, Log-Pearson III and Log-Normal 2

8.2.5 West Coast

The west coast of Sabah has the largest number of stations covered compared to other districts. There are 23 river gauging stations in West Coast areas. Most of the places with high population such as villages and towns located along the rivers in West Coast.

The two best-fit distributions are Pearson III (32%), Gumbel Type I (27%), Log-Pearson III (23 %), and Log-Normal 2 (18 %).

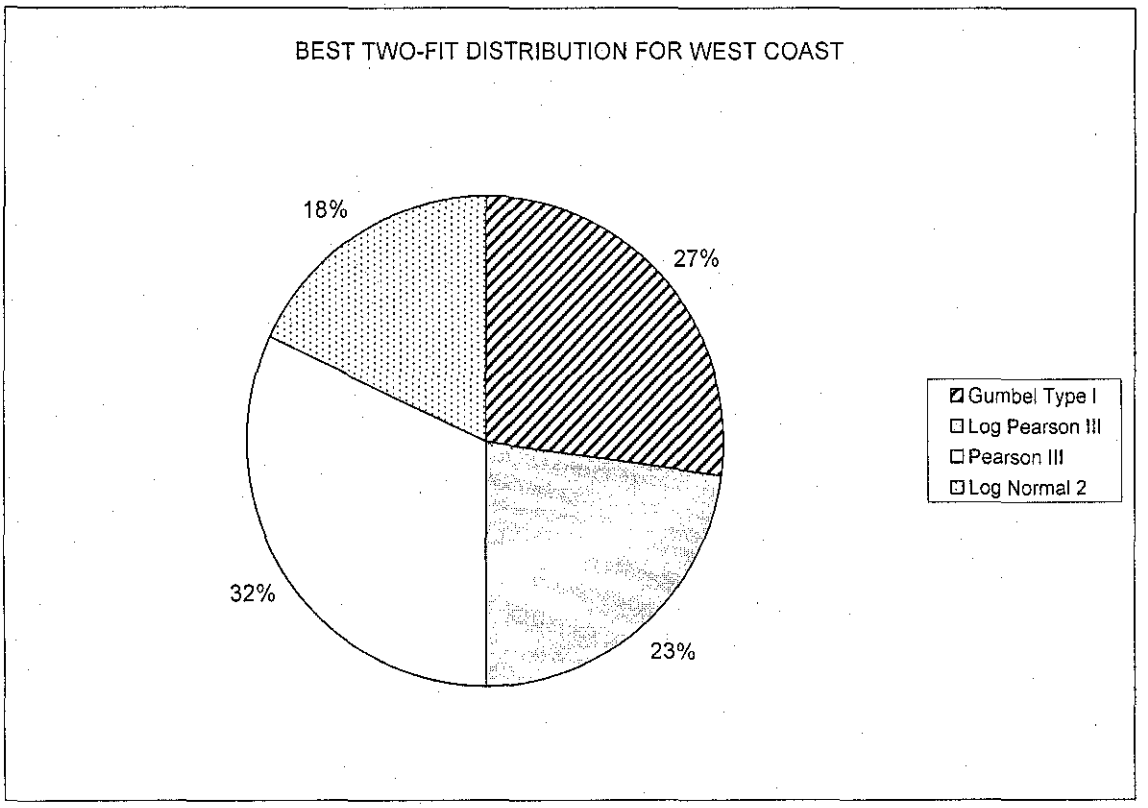

Figure 8-13: The First Two Best Fit Distribution for West Coast District

The best distributions to be used in West Coast are Pearson III, followed by Gumbel Type I, Log-Pearson III and Log-Normal 2

8.2.6 Interior

For Interior District, Gumbel Type I is the best distributions for 31 percent of the total of 26 analyse, followed by Log-Pearson III 27 percent, Pearson III 27 percent and log-Normal 2. Most places in Interior Sabah consider the driest place in Sabah but there are some places in the district such as Tenom located in the flood plain.

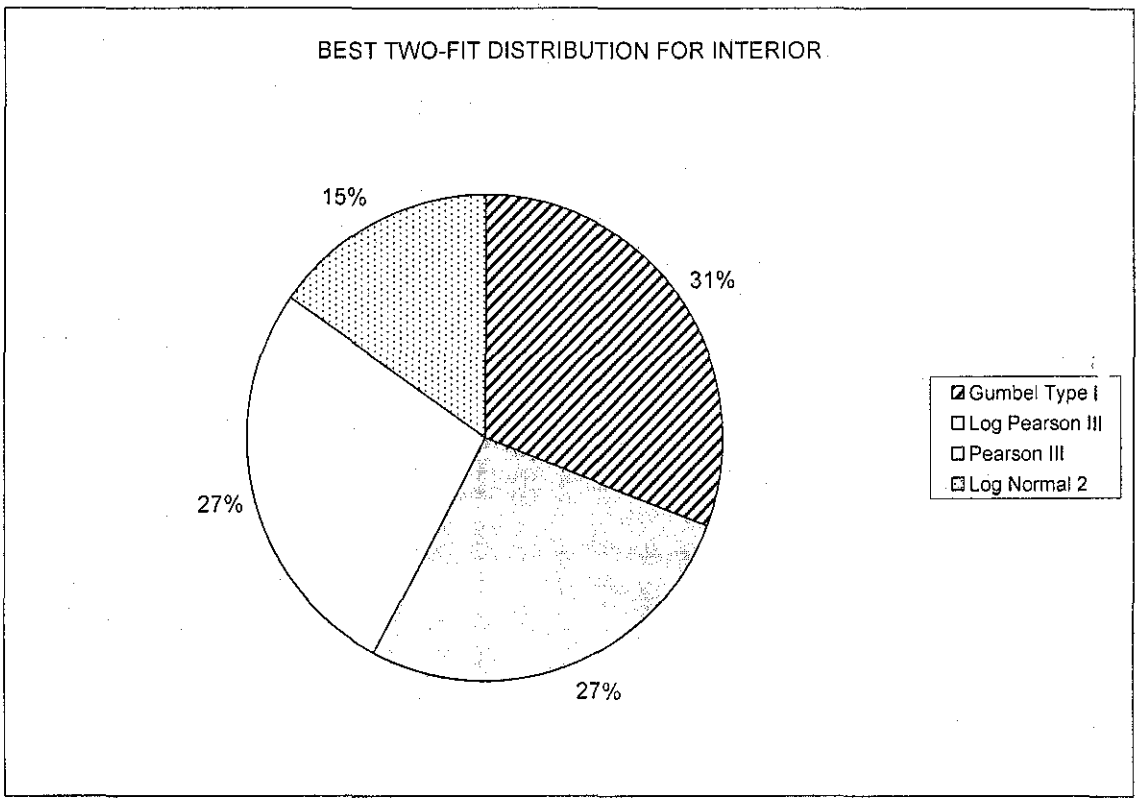

Figure 8-14: The First Two Best Fit Distribution for Interior District

Generally, the best distributions to be used in Interior are Gumbel Type I, followed by Log-Pearson III, Pearson III and Log-Normal 2.

8.2.7 Sarawak

As the total number of stations analyzed for Sarawak is 5 only, it is not right to conclude the best-two fit distribution for the state. The best-two fit distributions stated below are based on 5 stations that had been analysed. All of the stations located at the south of Sarawak. Base on the analysis, it is still true that Gumbel Type I and Log-Pearson III are the best distributions to be used.

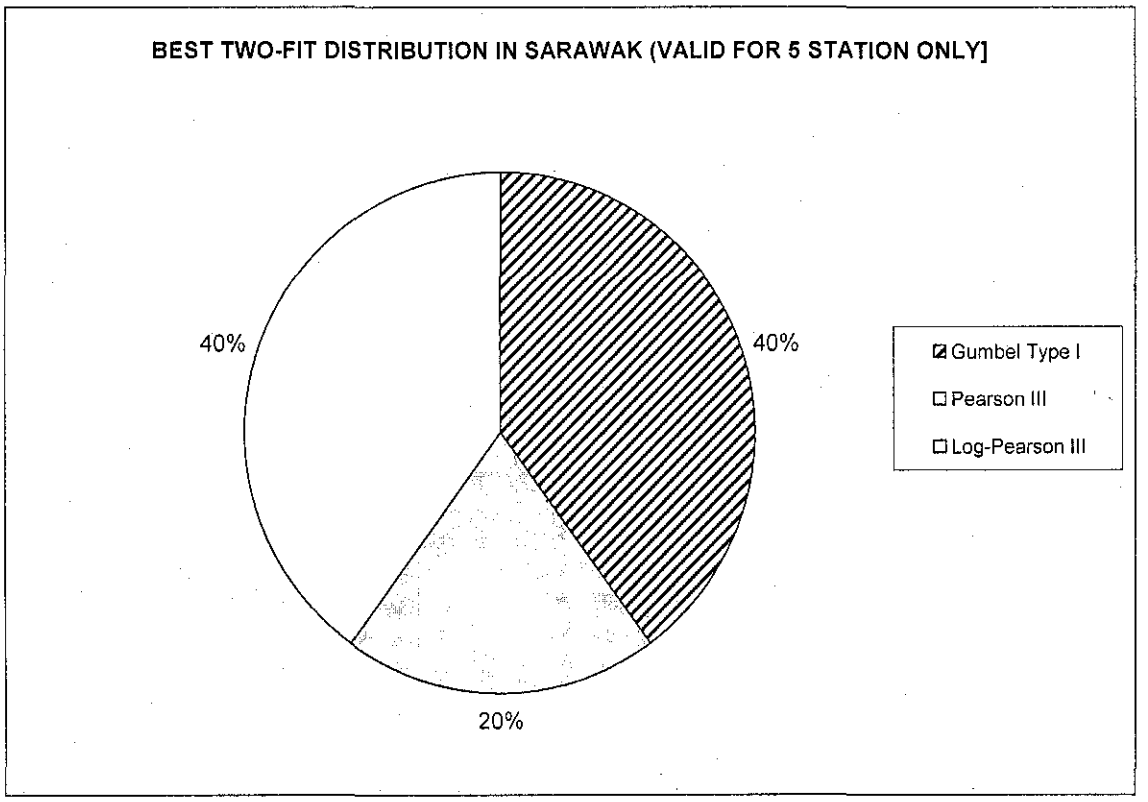

Figure 8-15: The First Two Best Fit Distribution for Sarawak (valid for 5 stations only)

8.3 Correlation between Catchment Area and Average Discharge

Theoretically, the average discharge of a river is largely dependent on its catchment area hence the larger the catchment area, the higher the average discharge of the river. This is true as the increasing in area will result to a higher volume of precipitation (height x area).

In this project for the river analysis, the relationship between the average discharge and its catchment area is determined using a graph of total mean versus its catchment area. The first graph plotted is the graph of total mean versus the catchment area of the whole rivers analysed (Figure 8-16). The best fit line does not consider the points outside the range of average data. Based on the graph, the total means increases with the catchment area. This is true for most of the rivers in Sabah and Sarawak.

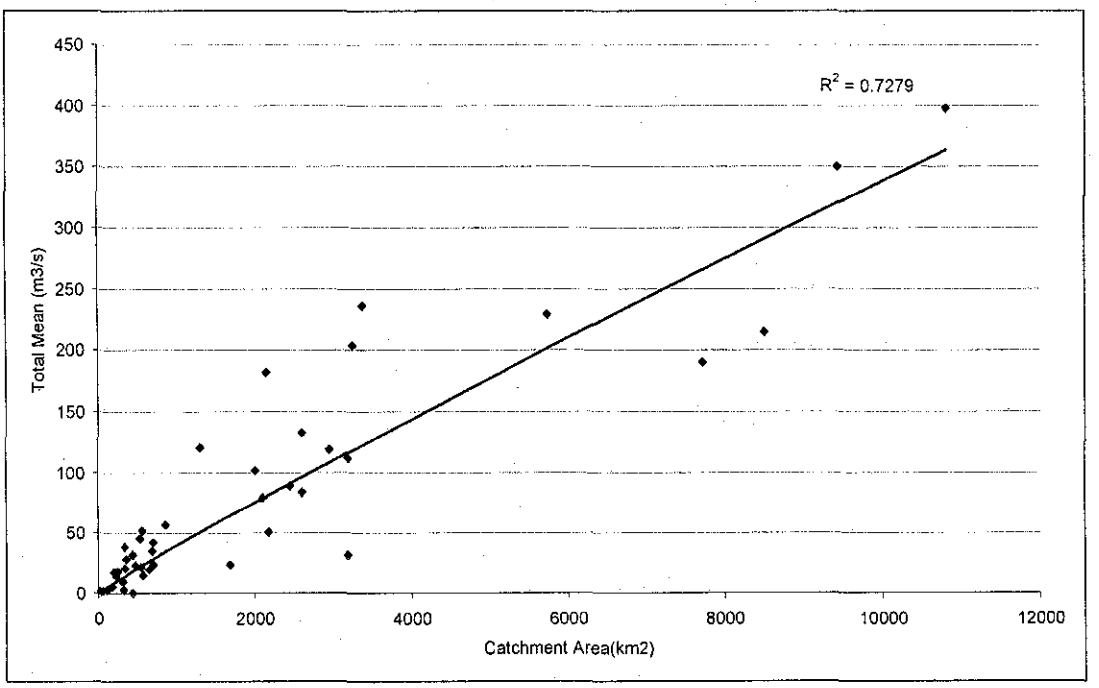

Figure 8-16: Total Mean Discharge versus Catchment Area for Sabah and Sarawak

In the figure 8-17 below, shows the total mean discharge versus catchment area for areas less than 1000 km^2, while Figure 8-18 shows the total mean discharge versus catchment area for areas larger than 1000 km^2, for Sabah and Sarawak. Both graphs illustrate that as the catchment area increases, the total mean discharge also increase

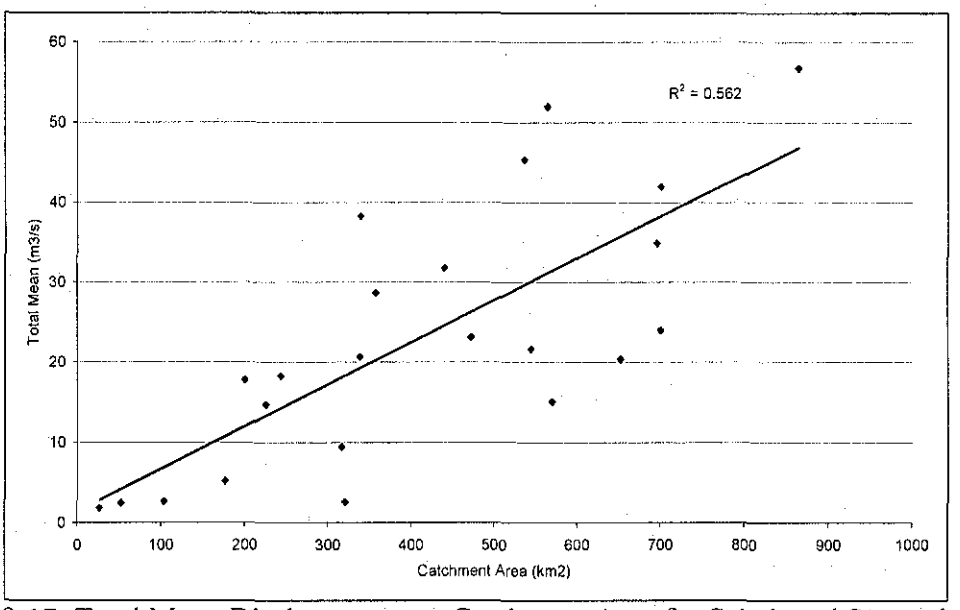

Figure 8-17: Total Mean Discharge versus Catchment Area for Sabah and Sarawak

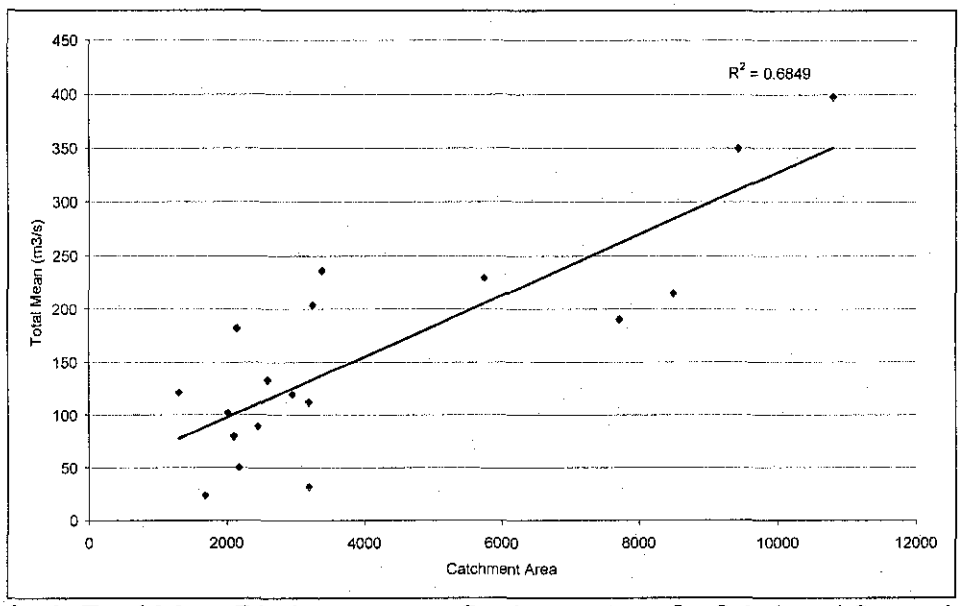

Figure 8-18: Total Mean Discharge versus Catchment Area for Sabah and Sarawak (More than 1000 $km^{2)}$

CHAPTER 9

CONCLUSION AND RECOMMENDATION

9.1 Conclusion

A practical flood frequency analysis for Sabah and Sarawak has been presented. Streamflow data had been collected for Sabah from 1965 – 2006 and Sarawak 1965-2005. The streamflow are mainly obtained from Hydrology and Survey Department, Department of Drainage and Irrigation in Sabah and Sarawak. Most of the data obtained in form of softcopy. The total numbers of stations analysed are 37 out of 44 total numbers of river gauging stations in Sabah and 5 out of 79 stations in Sarawak. The data were put into database and frequency analysis of the data is done using software.

From the result obtained, it can be concluded that in general the best distributions to be used for frequency analysis in Sabah are Gumbel Type I and Log-Pearson III. The result is in conforming to the recommendation by Department of Irrigation and Drainage (DID) Malaysia for flood prediction in manual provided (H.P 4) which uses Gumbel Type I. For Sarawak, the best distributions for 5 stations analysed are Gumbel Type I and Log-Pearson III.

9.2 Recommendation

Investigation is needed in order to identify the development and changes in water intake at each river analyse. A river diversion project may cause the streamflow to reduce significantly after a specified year. Besides, any urbanization process occurs at the upstream may disturbed the streamflow in other words urbanization may reduce the permeable layer of soil and increases the streamflow. Thus a detail investigation should be made to ensure the data used for prediction of flood is accurate and reliable.

For a more comprehensive result, the river stations in Sabah should be increased. However, as the river gauging stations is specified by the Department of Irrigation and Drainage Malaysia and the number is fixed, it is very difficult to obtain more stations for analysis.

The analysis of river stations in Sarawak should be continued to be conducted. An extra task and initiative should be made to any person doing the research as DID, Sarawak do not have any reliable source of determining flood discharge for all of the rivers in the state. According to Yeo Howe Lim (2003) in his paper it difficult to estimate flood in mostly place in Sarawak as the states facing problems such as many rivers remain ungauged, shortness of records and inaccuracy of flow rating curves. There should be more rating curve for rivers.

In Sabah and Sarawak both states are not using Hydrology region as use in the Peninsular Malaysia thus, it is difficult to see the relationship between the distributions and the regions. A specific rainfall study should be made in Sabah order to relate rainfall magnitude and flood in Sabah.

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APPENDICES

APPENDIX A
CORRESPONDENCE ON DATA COLLECTION

UNIVERSITI
TEKNOLOGI
PETRONAS

Saied Saiedi, Assoc. Prof., Ph.D.,
Civil Engng., Dept., University Technology PETRONAS (UTP)
31750 Tronoh, Perak, MALAYSIA
Ph. + 605 368 7284 Fax: +605 365 6716
E-mail: saiedsaiedi@petronas.com.my

)irector,
Attention: Assistant Director
Wong Wen Ho),
)rainage and Irrigation Department Sarawak,
Hydrology and Water Resources,
)th and 10th Floors,
Wisma Saberkas,
Jln Tun Abg Haji Openg, P.O Box 1230,
)3626, Kuching, Sarawak

27 April 2007

Tel: +6082-421506 Fax: +6082-426400

)ear Sir,

I have a final year student, Mr. Awang Azfar b. Awang Ali Bahar, working on his final year thesis "*Frequency* Analysis *of floods in* Sabah and Sarawak". My student and I have had correspondence and visits with your counterpart Mr. Thomas Lau and other colleagues of your department such as Mrs. Hidayati, and Mr. Lo Hong Min who have kindly assisted by providing some data for some river stations (water level data for 17 stations) and the rating curves of some (28) stations in Sarawak.

My student is at the final stage of his research and he requires some supplementary data that include:

- Updated rating curves of the stations. I remember Mr. Lo was working on them early last year.
- Flood data (water level or discharge) of the river stations up to 2006.

Sincerely,

Saied Saiedi

cc. Mrs Hidayati Tel:082 662135, Fax: 082 662019
Mr Lo Hong Min " " " """ " " " """ " " " """ " " " """ " " "

UNIVERSITI
TEKNOLOGI
PETRONAS

Saied Saiedi, Assoc. Prof., Ph.D.,
Civil Engng., Dept., University Technology PETRONAS (UTP)
31750 Tronoh, Perak, MALAYSIA
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E-mail: saiedsaiedi@petronas.com.my

Mr. Ho Tsun Lin
Hydrology and Water Resources
Department of Irrigation and Drainage,
Level 5, Wisma Pertanian, Jalan Tasik Luyang,
Off Jalan Maktab Gaya, Locked Bag 2052,
88767 Kota Kinabalu, Sabah

Tel: +60 88-430689 Fax: +60 88-432780

2nd March 200

Dear Sir,

Mr Awang Azfar B Awang Ali Bahar is a final year civil engineering student at UTP workin on his Final Project on *"Frequency* Analysis *of rainfall and runoff in* Sabah and Sarawak under my supervision. The Final Year Project Course covers two semesters and he is at th beginning of the first semester. I would appreciate if you could instruct your colleagues t assist us in obtaining the following information needed for our research.

1) "Streamflow Records" from the earliest years available until late 2005, both softcopy an hard copy.

2) The list of all related publications by DID Sabah.

Sincerely,

Saied Saiedi

Assoc. Prof. Dr. Saied Saiedi
Lecturer
Civil Engineering Programme
Universiti Teknologi PETRONAS
31750 Tronoh
Perak Darul Ridzuan, MALAYSIA.

Ps. this is the second correspondence for the same request. The first was directed to the Assistant Director on 28 Feb. Later, my student told me that a new letter is to be directed to Mr. Ho Tsun Lin.

JABATAN PENGAIRAN DAN SALIRAN
INANAM
Bahagian Hidrologi dan Ukur
Lorong Burung Keleto
89350, Inanam, Kota Kinabalu
Sabah, Malaysia

Telefon : 088-430689
No. Faks : 088-432780
Email : jpsssi1@tm.net.my

RUJ KAMI : JPS(H&U)/1/2/4/5 Pt.3(19)

TARIKH : 20 Mac 2006

Encik Awang Azfar B. Awang Ali Bahar
Village 5A, L-4-3-2
University Technology PETRONAS (UTP)
31750 Tronoh
PERAK

Tuan

Permohonan Data Hidrologi

Dengan segala hormatnya, borang permohonan data tuan bertarikh 08 Mac 2006 dan surat sokongan daripada Assoc. Prof. Dr. Saied Saiedi diterima pada 13 Februari 2006 dan 06 Mac 2006 masing-masing mengenai dengan perkara di atas adalah dirujuk.

2. Bersama-sama ini dibekalkan data luah purata harian bagi stesen-stesen sungai seperti yang disenaraikan dalam Lampiran melalui emel untuk tindakan tuan selanjutnya.

3. Tiada sebarang bahagian data berkenaan dibenarkan untuk disalin atau dicetakkan untuk tujuan lain dan haruslah diguna semata-mata untuk projek yang dimaksudkan atas budibicara sendiri.

Sekian, harap maklum.

"BERKHIDMAT UNTUK NEGARA DENGAN BERSIH, CEKAP DAN AMANAH"

Saya yang menurut perintah

(HO TSUN LIN)
Penolong Pengarah Kanan
Bahagian Hidrologi Dan Ukur
b.p. Pengarah Pengairan Dan Saliran Negeri Sabah
KOTA KINABALU

s.k. Assoc. Prof. Dr. Saied Saiedi
Lecturer
Civil Engineering Department
University Technology PETRONAS (UTP)
31750 Tronoh
PERAK

'BERJIMAT DAN MENABUNG AMALAN MULIA'
'JAYAKAN PERKHIDMATAN SEMPURNA'

From: "Dos Saguman" <Dos.Saguman@sabah.gov.my> View Contact Details

To: "Saied Saiedi (UTP)" <saiedsaiedi@petronas.com.my>, "Awang Azfar" <awgazfar_aab@yahoo.com>

CC: "Ho Tsun Lin" <TsunLin.Ho@sabah.gov.my>

Subject: Flow Data - Min and Max Instantaneous Value.

Date: Thu, 3 May 2007 15:12:01 +0800

aied Saiedi, Assoc Prof Dr
ivil Engineering Dept, University Technology PETRONAS (UTP)
1750 Tronoh, Perak, Malaysia

ear Sir

s directed, i am sending you the above mentioned data for your attention.

lease do not hesitate to enquire if in case you have any question regarding this matter.

hank you

ours Sincerely

os Saguman
nit Prosesan Data Hidrologi
ahagian Hidrologi dan Ukur
PS Inanam.

Plain Text Attachment [Scan and Save to Computer]

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~~ NIWA Tideda ~~~ JPS Sabah                    3-MAY-2007
3:29
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ubject: data clarification for Sabah rivers
ate: Fri, 27 Apr 2007 18:39:45 +0800
rom: "Saied Saiedi (UTP)" <saiedsaiedi@petronas.com.my> View Contact Details
o: TsunLin.Ho@sabah.gov.my
C: LeeYun.Chin@sabah.gov.my, Dos.Saguman@sabah.gov.my, awgazfar_aab@yahoo.com

o: Senior Assistant Director Ho Tsun Lin,
Hydrology and Survey Section,
Department of Irrigation and Drainage,
Lorong Burung Keleto,
89350, Inanam, Kota Kinabalu, Sabah

el: 088-280520 Fax: 088-432780

ear Sir,

eferring to the flood data that are already provided by your colleagues for the research work of my student *Ir. Awang Azfar b. Awang Ali Bahar*), I would like to ask for a clarification:

the book entitled "Hydrological records for Sabah , 1969-1975" (as an example) the discharges are totally fferent from the data given by your good colleague Mrs Chin Lee Yun through correspondence in the past. or example, for "site 4959401 SG. PADAS at KEMABONG" in 1971, the maximum flood is 2199.6 while in the oftcopy it is 739.3. The difference is usually huge. Other river stations and other years have the same oblem. It may well be because of different rating curves used or ....

s we are at the end of the data analysis and we should decide about which one to choose, I would like to ask ou to kindly tell your colleagues to give **some explanation to be considered before finalizing the choice of ie data**.

Truly yours,
Saied Saiedi, Assoc Prof Dr
Civil Engineering Dept, University Technology PETRONAS (UTP)
31750 Tronoh, Perak , Malaysia
Tel: 05-368 7284 , Fax: 05-365 6716

Appendix A: Correspondence from DID, Sarawak

A.1 Introduction

On 4th May 2007, the author had faxed a letter to Mr. Wong Wen Ho, Assistant Director of Hydrology and Survey Department (082-424400) also sending copy to Mrs. Hidayati, Engineer and Mr. Lo Hong Min to request new water level data and new rating curves. The following memo will explain the situation after had a phone conversation with the authority.

A.2 Water Level Data

All of data provided and received by Drainage and Irrigation Department, (DID) Sarawak were in term of water level. As this study is using discharge the author has to convert the water level into discharge to ease the analysis. Thus, in order to convert them, the author have to make some calculation based on rating curves given by the DID.

On last year, we received rating curves formula based on Sarawak Hydrological Year Book 2001. There were 29 rating curves for 29 stations out of 79 stations in Sarawak. The rating curves provided had an effective range. Most of the flood and big flow condition were out of the range. Any calculations more than effective range are not valid in term of discharge.

A.2 Explanation from the authority

On 10th May 2007, the author had a phone conversation with Mrs. Hidayati, Engineer (082-662135) in Hydrology and Survey Department for further explanation and enquiry. In the phone conversation, the author raise some question about nature of data provide by DID Sarawak were different from other states. In the previous project done by Miss Nabila, and data obtained from DID, Sabah for this project, all of the data received from

each DID states were in term of discharge. Mrs. Hidayati explained that the author should not doubt on the nature of data they have. The data they had provided had been used for a very long time and established. Any further process such as discharge conversion should be made by any person himself for his own use.

Besides, in her further explanation for flood condition the rating curves should not be used as the water level is out of effective range. They will not provide any rating curves for bigger range. The person or any researcher himself should produce his own rating curves in order for them to obtain the discharge. In addition, they had provided such enough data for any researcher .Furthermore, she explained that it is hard for them to obtain rating curves for other river as her department has a few employees only and should not be blame for their handicapped. In this phone conversation as well she added that there were no new rating curves available. Any calculation should base on Rating Curves Formula published in Sarawak Hydrological Year Book 2001 (the latest that available).

A.4 Discharge reading in Hydrological Data (1975-1990)

In the publication Hydrological Data, River Discharge and Suspended Sediment Records (1975-1990) published by DID, Malaysia, there were 14 Sarawak stations in the book and the reading were in discharge. As I have some water level data in softcopy I had calculate them into discharge and compare them with the publication. The readings were totally different. Regarding this I called Mr. Kevin, Engineer (082-662135) in the Hydrology and Survey Department to explain more about the condition. In the phone conversation Mr. Kevin makes clear that I should not compare the value in the book and compare them with the recent calculation. The value in the book only valid during the time their gauge it and obviously they have different effective range and rating curves formula on that time.

SUNGAI TAWAU AT KUHARA, TAWAU, SABAH

STATION NUMBER: 4278401
Note : In 31 periods, you have 0 Unknown value(s) AND 1 Zero(s)

Sum of	X=	845.49	Sum of	LN(X)=	96.08
Mean of	X=	27.27	Mean of	LN(X)=	3.20
Standard Dev. of	X=	15.61	Standard Dev. of	LN(X)=	0.54
Skew Coef. of	X=	0.71	Skew Coef. of	LN(X)=	-0.01
Variation Coef. of	X=	0.57	Variation Coef. of	LN(X)=	0.17

return period (year) :	2	5	10	20	25	50	75	100	200	500	1000	10000	standard erro
NORMAL :	27.27	40.12	47.06	52.77	54.39	59.19	61.71	63.43	67.36	72.11	75.41	85.30	4.03
LOG - NORMAL 2 par. (M) :	23.65	36.71	46.48	56.49	59.69	70.35	76.70	81.33	93.08	109.51	122.63	172.12	3.34
LOG - NORMAL 2 par. (L) :	24.60	38.31	48.56	59.07	62.43	73.62	80.28	85.14	97.47	114.71	128.49	180.43	26.74
GUMBEL Type I (M) :	24.93	40.18	50.51	60.43	63.48	73.26	78.84	82.79	92.45	105.12	114.63	146.52	2.45
GUMBEL Type I (L) :	24.69	38.40	47.69	56.60	59.35	68.14	73.15	76.71	85.38	96.77	105.32	133.99	2.78
LOG - PEARSON III (M) :	24.63	38.32	48.52	58.96	62.28	73.34	79.92	84.71	96.84	113.75	127.22	177.76	2.87
LOG - NORMAL 3 par. (M) :	22.97	29.44	36.90	47.18	51.02	66.14	76.76	85.32	110.28	153.13	194.38	411.02	8.89
LOG - NORMAL 3 par. (L) :	24.15	38.31	49.38	61.09	64.90	77.79	85.59	91.35	106.16	127.32	144.54	211.70	2.92
PEARSON III (M) :	25.46	39.25	47.77	55.42	57.69	64.70	68.56	71.25	77.64	85.75	91.65	110.68	3.00
PEARSON III (L) :	24.10	38.66	49.21	59.57	62.78	73.13	79.06	83.29	93.63	107.30	117.63	152.78	2.60
PLOTTING POSITION FORMULA :	23.68	41.67	53.66	60.68	61.54	-	-	-	-	-	-	-	-

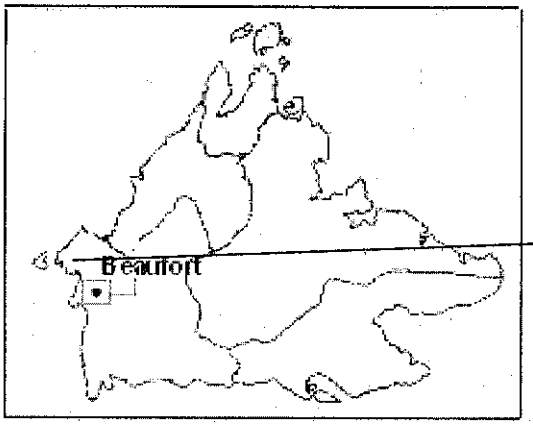
(M) : Moments Method
(L) : Maximum Likelihood Method

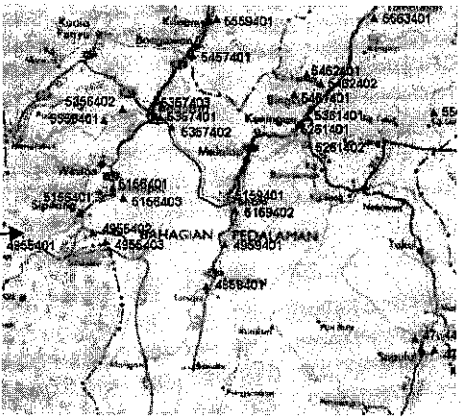
APPENDIX C
DETAIL OF RIVER STATIONS ANALYSED

SABAH

SUNGAI PADAS AT KEMABONG

Location





Description by DID, SABAH

Station No. 4959401

SUNGAI PADAS AT KEMABONG

Gauging site:- 130m cableway

Longitude & Latitude: - 115°55'15" E 04°55'00" N.

Catchment Area:- 3185km^2

Elevation above mean sea level:- 183 m

Catchment characteristics:-

(f) **Shape**:- The maximum length and breadth of the catchment are 90 km and 55 km respectively

(g) **Topography**:- Mountainous with elevation up to 2000m

(h) **Vegetation** :- Virgin and secondary jungle with some shifting cultivation

(i) **Soil Cover**:- Sandy loams 204m deep

(j) **Rock Type**: - East side of catchment: sandstone, mudstone. West side of catchment: siltstone shale, massive sandstone.

Ranged of observations:- The range of river stages observed is from 18.93m to 26.42m

Summary of Data

Name	Sungai Padas at Kemabong
Area (km^2):	3185
Elevation (m):	183
Average Rainfall (mm)	
Water Use	
Total Mean yearly (m^3/s):	113.77
Mean of "Min"s yearly (m^3/s)	13
Mean of "Max"s yearly (m^3/s):	1296.53
Absolute Min, yearly (m^3/s):	2.74
Absolute Max yearly (m^3/s):	2404.2
Source	Hydrological Records for Sabah, 1968-1975, DID Sabah Streamflow and River Suspended Sediment Records,1975-1990, DID, Malaysia

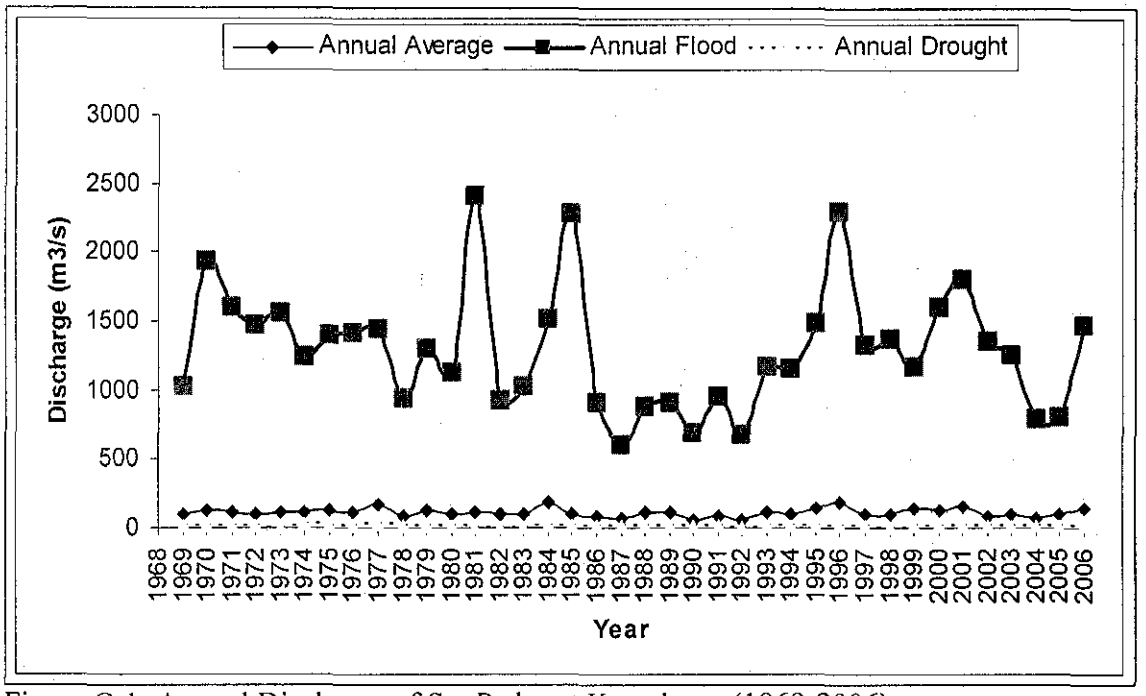


Figure C-1: Annual Discharge of Sg. Padas at Kemabong (1969-2006)

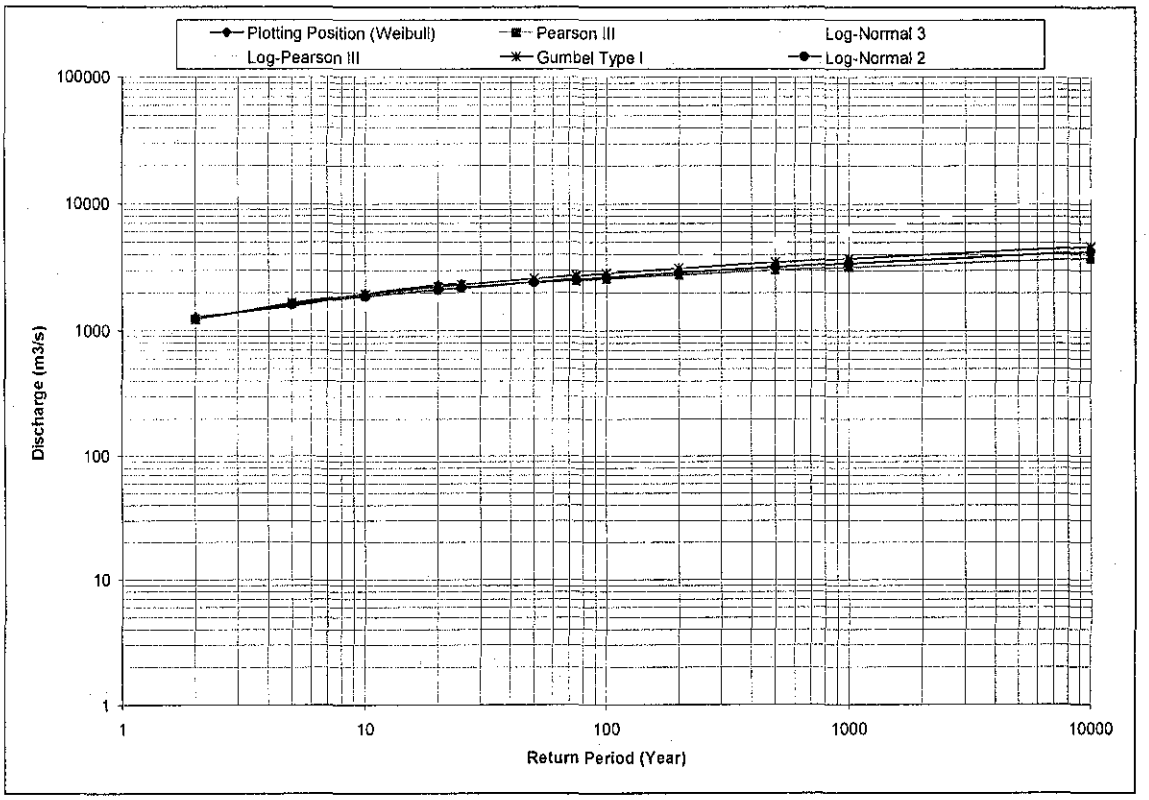
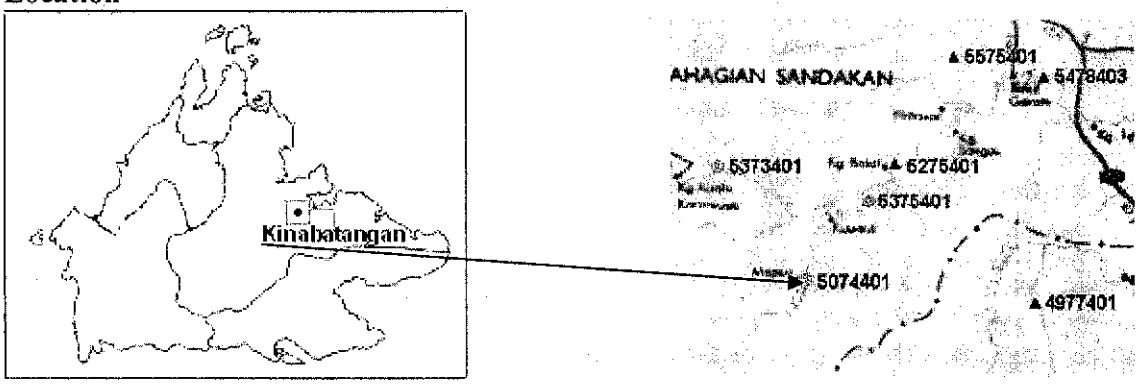


Figure C-2: Frequency Analysis of Annual Floods in Sg Padas at Kemabong (1969-2006)

SUNGAI KUAMUT AT ULU KUAMUT

Location



Description by DID, SABAH

Station No. 5074401

SUNGAI KUAMUT AT ULU KUAMUT

Gauging site:- Gauging by boat

Longitude & Latitude: - 117°26'30" E 05°04'55" N.

Catchment Area:- 2950 km^2

Elevation above mean sea level:- 30 m

Catchment characteristics:-

(a) **Shape**:- The maximum length and breadth of the catchment are 90 km and 50 km respectively

(b) **Topography**:- Hills and mountainous with elevation up to 1500m

(c) **Vegetation** :- Virgin jungle

(d) **Soil Cover**:- Sandy to clayey soils of 1-3m deep

(e) **Rock Type**: - Sandstone, mudstone and some chert and basalt in upper catchment.

Ranged of observations: - The range of river stages observed is from 12.45m to 28.99m. Discharge measurements have been taken between 12.44 and 18.63 m.

Summary of Data

Name	Sg. Kuamut at Ulu Kuamut
Area (km^2):	2950
Elevation (m):	30
Average Rainfall (mm)	
Water Use	
Total Mean yearly (m^3/s):	122.66
Mean of "Min"s yearly (m^3/s)	8.2
Mean of "Max"s yearly (m^3/s):	1956.92
Absolute Min, yearly (m^3/s):	2.31
Absolute Max yearly (m^3/s):	4121.3
Source	Hydrological Records for Sabah, 1968-1975, DID Sabah Streamflow and River Suspended Sediment Records,1975-1990, DID, Malaysia

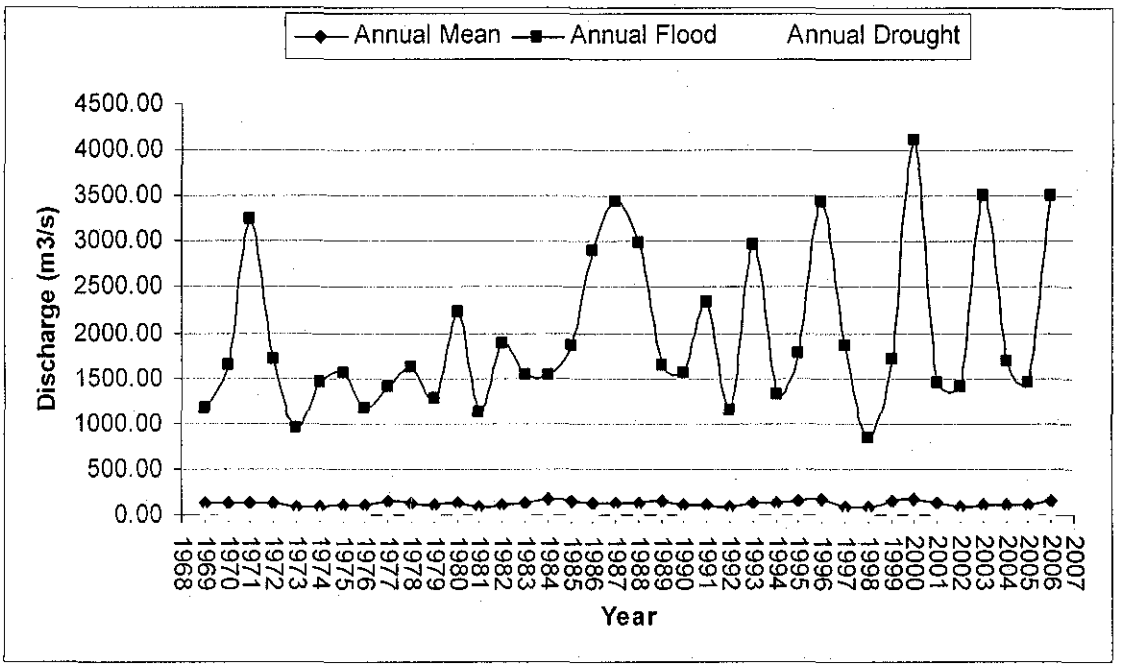


Figure C-3: Annual Discharge at Sungai Kuamut at Ulu Kuamut

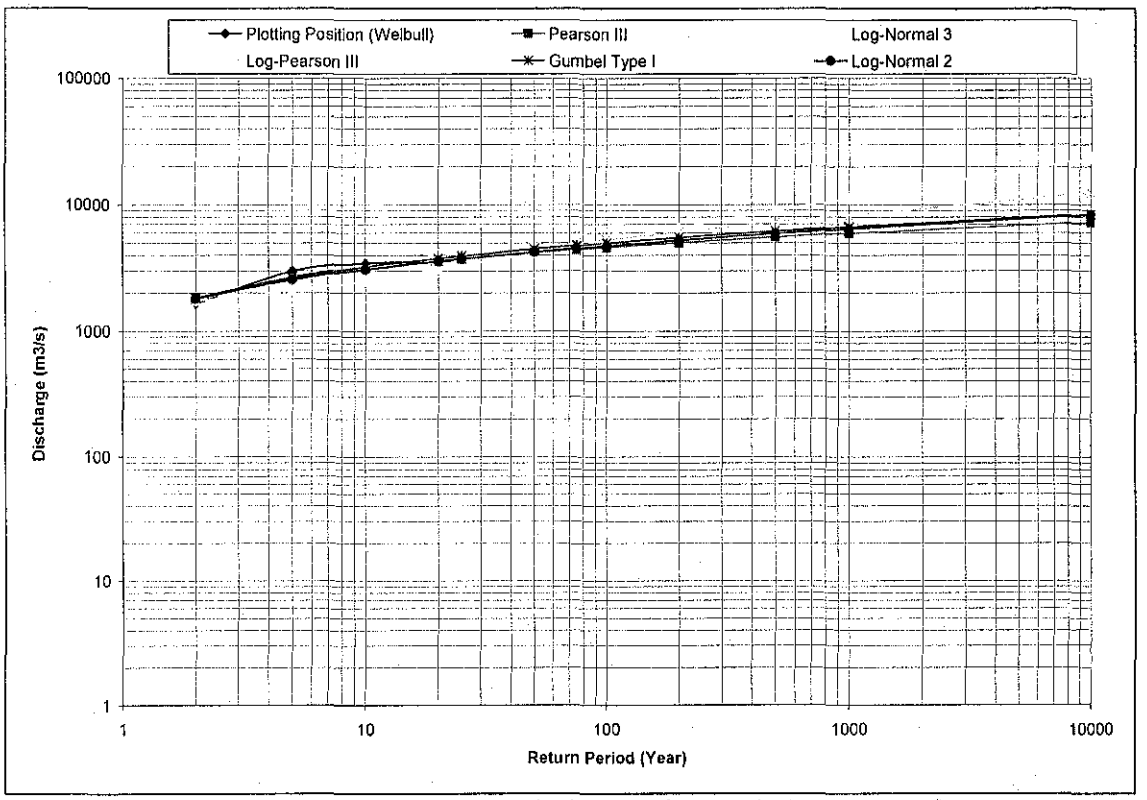
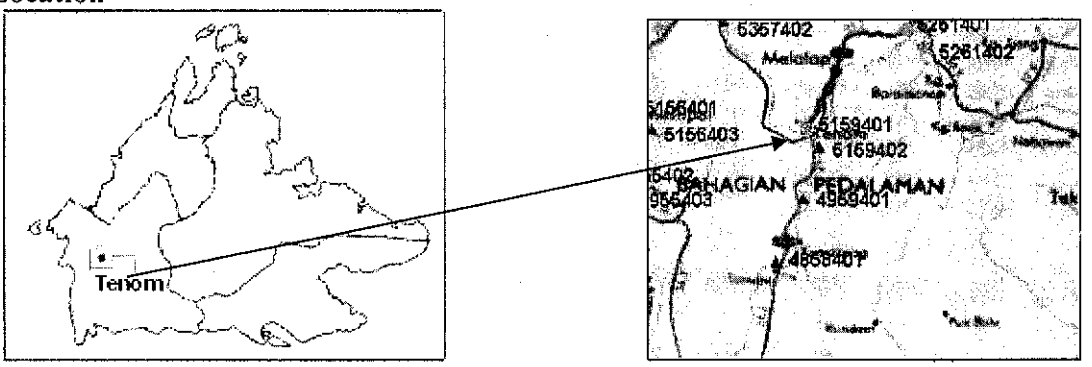


Figure C-4: Frequency Analysis of Annual Floods of Sungai Kuamut at Ulu Kuamut, (1969-2006)

SUNGAI PADAS AT TENOM

Location



Description by DID, SABAH

Station No. 5159401

SUNGAI PADAS AT TENOM

Gauging site:- Gauging by boat

Longitude & Latitude: - 115°55'50" E 05°07'00" N.

Catchment Area:- 7718 km^2

Elevation above mean sea level:- 168 m

Catchment characteristics:-

(a) **Shape**:- The maximum length and breadth of the catchment are 60 km and 200 km respectively

(b) **Topography**: - 20% ALLUVIAL valley with elevation 200-600m. 60% hills (1000m) and 20% mountains with elevation up to 2600m.

(c) **Vegetation** :- Padi and various other crops, grassland rubber trees, virgin and secondary jungle

(d) **Soil Cover**: - Sandy loams 204m deep. Mountains: Sandy loam of 1-2 m deep. Alluvium: Various textures in layers of 10-20 m deep. Fine to coarse sand, loam of 2-5 m deep.

(e) **Rock Type**: - East side of catchment: Sandstone, mudstone West side of catchment: Siltstone shale, massive sand stone. Sandstone and mudstone predominant in upper catchment: South side of catchment: Sandstone, mudstone. North side of catchment: Alluvial gravel

Ranged of observations:- The range of river stages observed is from 19.6 m to 27.64m

Summary of Data

Name	Sg. Padas at Tenom
Area (km^2):	7718
Elevation (m):	168
Average Rainfall (mm)	
Water Use	
Total Mean yearly (m^3/s):	182.33
Mean of "Min"s yearly (m^3/s)	25.63
Mean of "Max"s yearly (m^3/s):	1633.2
Absolute Min, yearly (m^3/s):	4.95
Absolute Max yearly (m^3/s):	4730.1
Source	Hydrological Records for Sabah, 1968-1975, DID Sabah Streamflow and River Suspended Sediment Records,1975-1990, DID, Malaysia

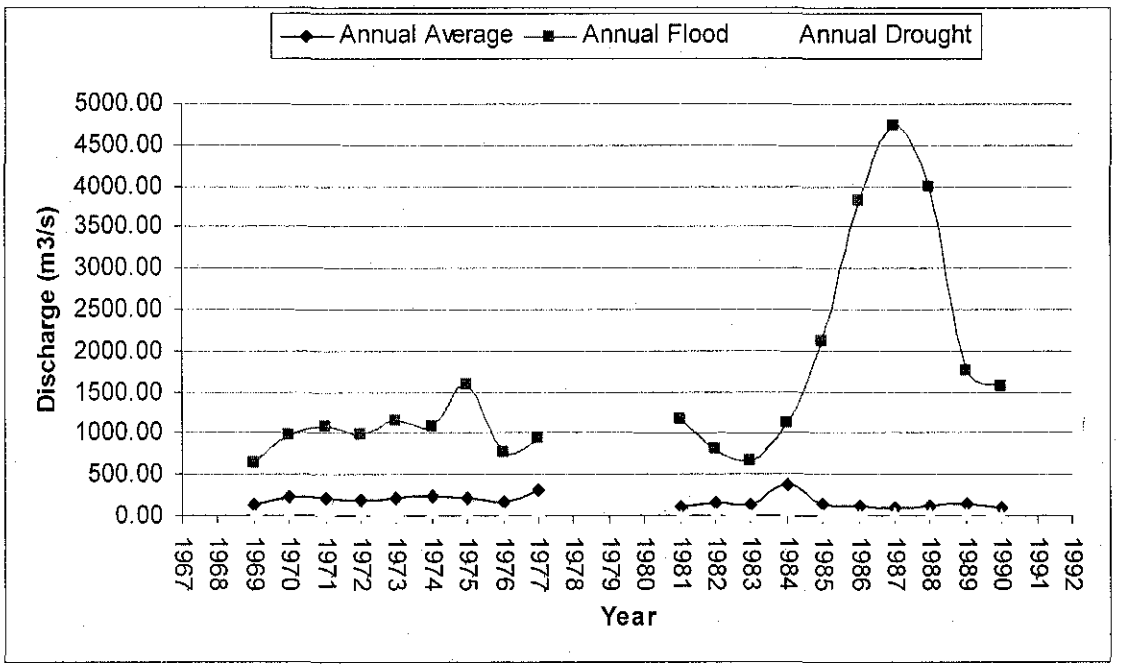


Figure C-5: Annual Discharge of Sg. Padas at Tenom (1969-2006)

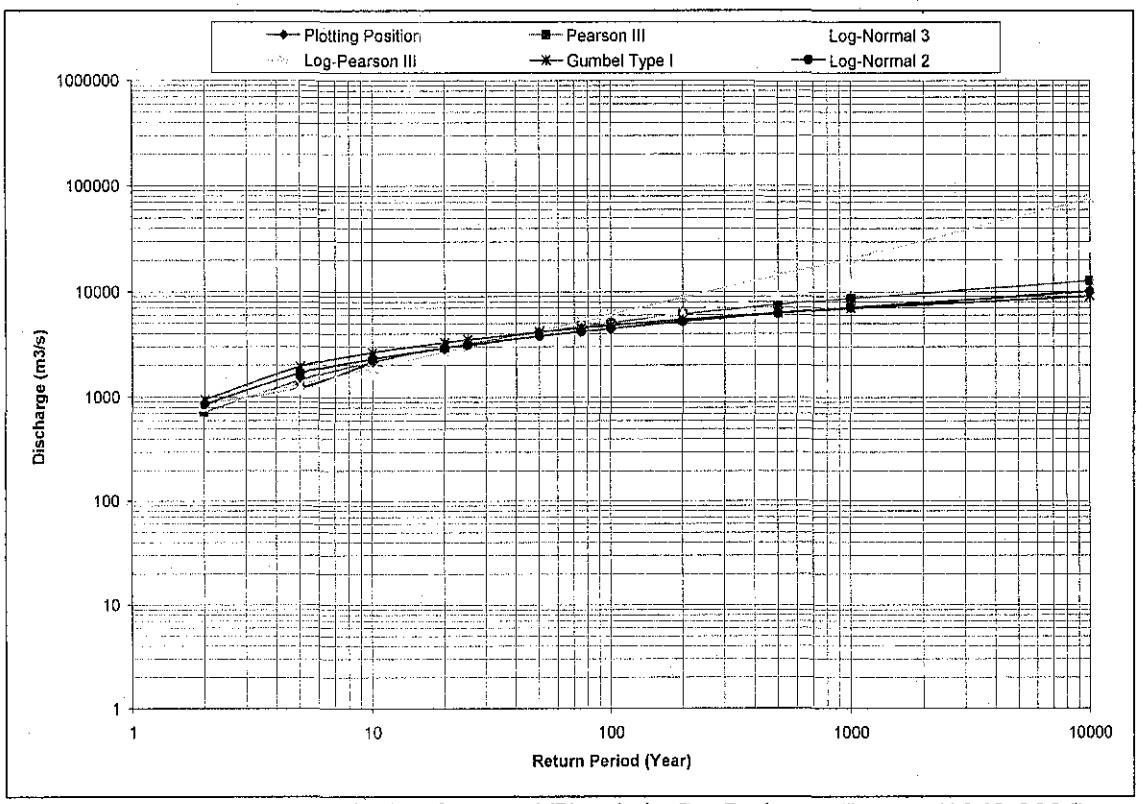
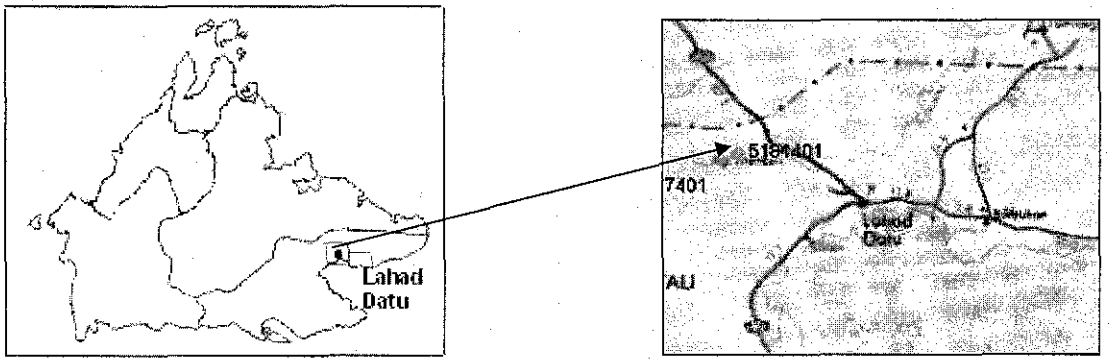


Figure C-6: Frequency Analysis of Annual Floods in Sg. Padas at Tenom (1969-2006)

SUNGAI SEGAMA AT LIMKABUNG

Location



Description by DID, SABAH

Station No. 5181401

SUNGAI SEGAMA AT LIMKABUNG

Gauging site:- Gauging by boat

Longitude & Latitude: - 118°07'50" E 05°07'25" N.

Catchment Area:- 2450 km^2

Elevation above mean sea level:- 168 m

Catchment characteristics:-

(a) **Shape**:- The maximum length and breadth of the catchment are 85 km and 48 km respectively

(b) **Topography**: - Low undulating hills predominate with some mountain in the upper catchment.

(c) **Vegetation** :- Virgin and secondary jungle and shifting cultivation and other crops

(d) **Soil Cover**: - Ferric, chromic and orthic Lewisol, eutric cambisol lithosol.

(e) **Rock Type**: - Southern part of catchment: Basic and intermediate igneous rock. Northern part of catchment: Mudstone and sandstone. Upper catchment: Mudstone and Sandstone

Ranged of observations: - The range of river stages observed is from 14.93 m to 22.91m. Discharge measurements have been taken between 15.09m and 20.61m

Summary of Data

Name	Sg. Segama at Limkabung
Area (km^2):	2450
Elevation (m):	168
Average Rainfall (mm)	
Water Use	
Total Mean yearly (m^3/s):	101.86
Mean of "Min"s yearly (m^3/s)	14.11
Mean of "Max"s yearly (m^3/s):	977.73
Absolute Min, yearly (m^3/s):	1.53
Absolute Max yearly (m^3/s):	2063.3
Source	Hydrological Records for Sabah, 1968-1975, DID Sabah Streamflow and River Suspended Sediment Records,1975-1990, DID, Malaysia

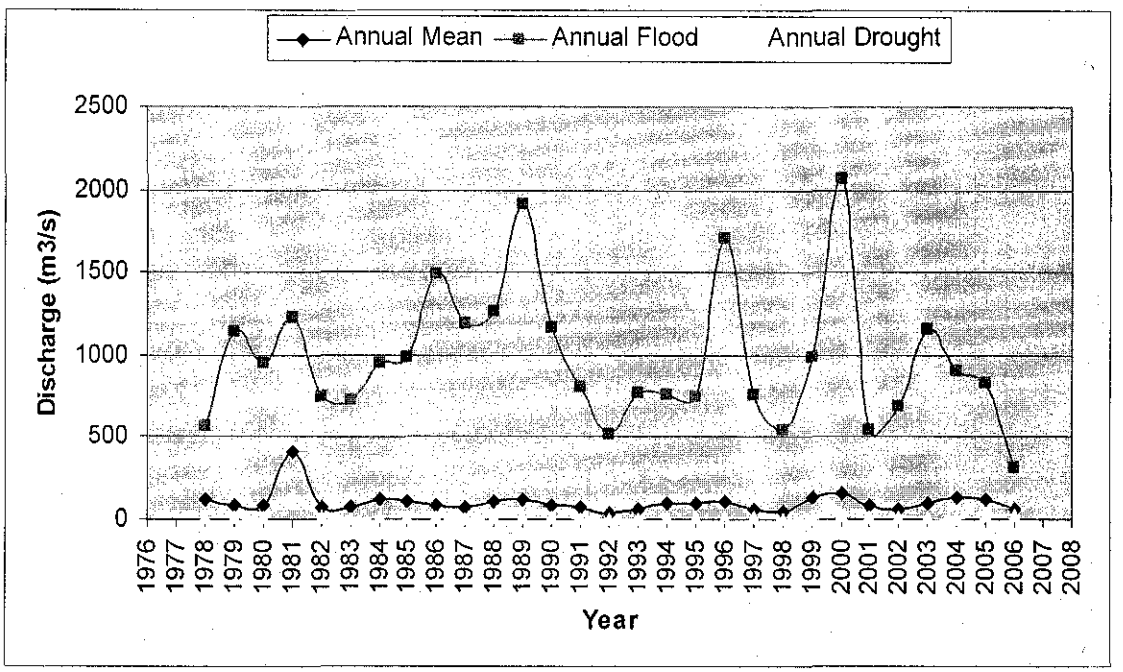


Figure C-7: Annual Discharge of Sg. Segama at Limkabung (1978-2006)

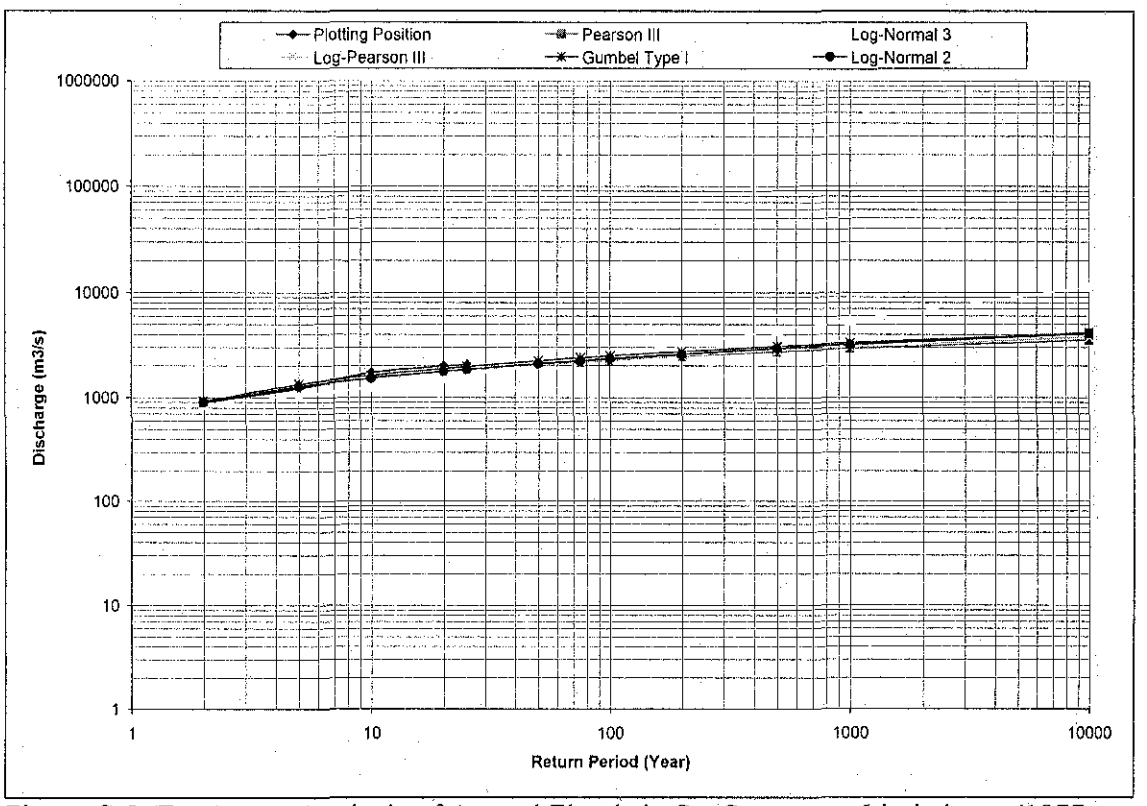
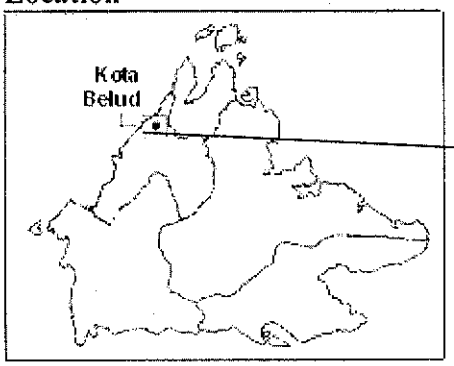
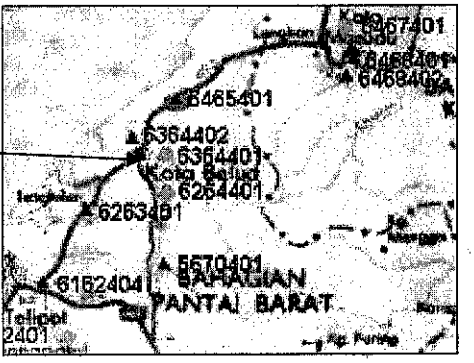


Figure C-8: Frequency Analysis of Annual Floods in Sg. Segama at Limkabung (1977-2006)

SUNGAI WARLU AT JAMBATAN NO.2

Location





Description by DID, SABAH

Station No. 6364401

SUNGAI WARLU AT JAMBATAN NO.2

Gauging site:- Gauging by boat

Longitude & Latitude: - 116°29'00" E 06°19'20" N.

Catchment Area:- 243 km^2

Elevation above mean sea level:- 37 m

Catchment characteristics:-

(a) **Shape:-** The maximum length and breadth of the catchment are 25 km and 12 km respectively

(b) **Topography**: - 30% undulating hills and 70% mountainous with elevations up to 3000 m

(c) **Vegetation**: - Rubber trees, grassland, secondary jungle and upland vegetation.

(d) **Soil Cover**: - Shallow granitic soil in the mountains with sand and loam of 2-3m deep in the hills

(e) **Rock Type**: - Sandstone and shale with shump breccia in the lower catchment and ultrabasic granite in the upper catchment

Ranged of observations:- The range of river stages observed is from 25.06 m to 36.03m. Discharge measurements taken between 25.78m and 26.51 m

Summary of Data

Name	Sungai Warlu at Jambatan no.2
Area (km^2):	243
Elevation (m):	37
Average Rainfall (mm)	
Water Use	
Total Mean yearly (m^3/s):	18.58
Mean of "Min"s yearly (m^3/s)	2.66
Mean of "Max"s yearly (m^3/s):	551.95
Absolute Min, yearly (m^3/s):	0.63
Absolute Max yearly (m^3/s):	1457.7
Source	Hydrological Records for Sabah, 1968-1975, DID Sabah Streamflow and River Suspended Sediment Records,1975-1990, DID, Malaysia

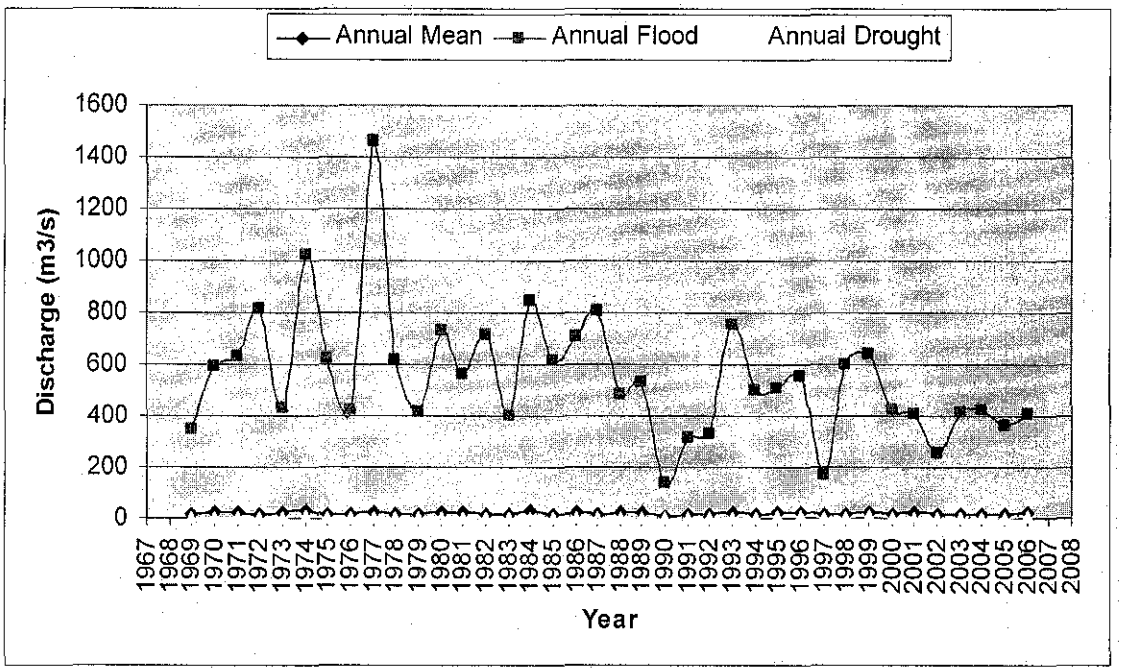


Figure C-9: Annual Discharge of Sg. Warlu at Bridge no.2 (1969-2006)

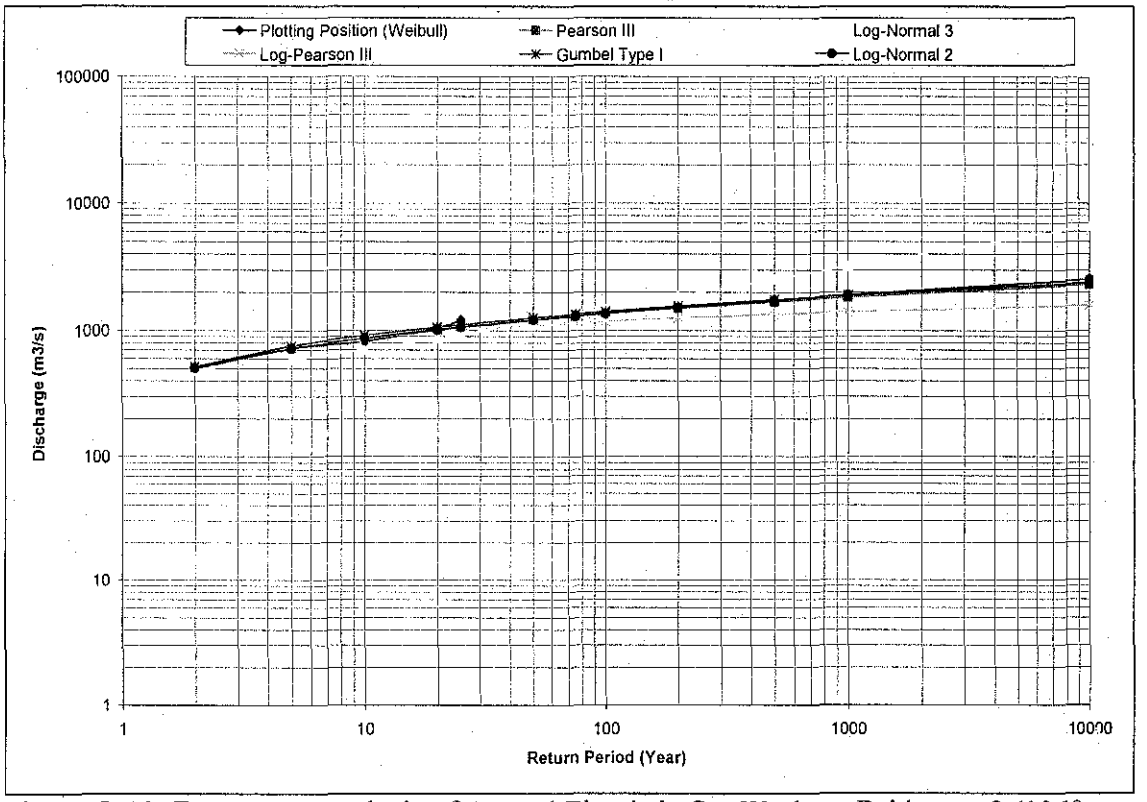
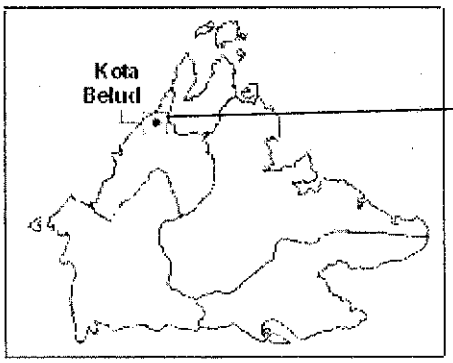
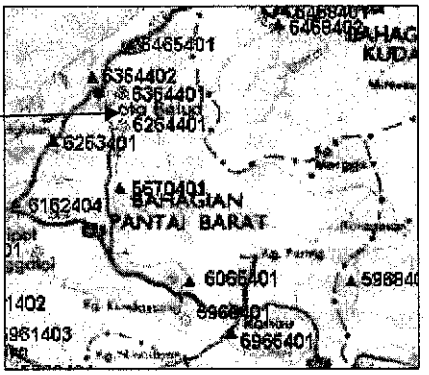


Figure C-10: Frequency Analysis of Annual Floods in Sg. Warlu at Bridge no.2 (1969-2006)

SUNGAI KEDAMAIAN AT TAMU DARAT

Location





Description by DID, SABAH

Station No. 6264401

SUNGAI KEDAMAIAN AT TAMU DARAT

Gauging site:- 190 m Cableway

Longitude & Latitude: - 116°27'10" E 06°15'50" N.

Catchment Area:- 338 km^2

Elevation above mean sea level:- 52 m

Catchment characteristics:-

(a) **Shape**:- The maximum length and breadth of the catchment are 25 km and 15 km respectively

(b) **Topography**: - 10% undulating hills and 90% mountainous with elevations up to 4000 m

(c) **Vegetation**: - Padi, rubber trees, grassland, secondary jungle and highland altitude vegetation.

(d) **Soil Cover**: - Shallow granite and granitic soil in the mountains with sand and loam of 2.3m deep in the hills

(e) **Rock Type**: - Sandstone, shale with shump breccia in the upper catchment, ultrabasic

Ranged of observations: - The range of river stages observed is from 23.70 m to 27.08m. Discharge measurements taken between 23.75m and 25.51 m

Summary of Data

Name	Sg. Kedamaian at Tamu Darat
Area (km^2):	338
Elevation (m):	52
Average Rainfall (mm)	
Water Use	
Total Mean yearly (m^3/s):	32.4
Mean of "Min"s yearly (m^3/s)	3.28
Mean of "Max"s yearly (m^3/s):	855.14
Absolute Min, yearly (m^3/s):	0.72
Absolute Max yearly (m^3/s):	1574.2
Source	Hydrological Records for Sabah, 1968-1975, DID Sabah Streamflow and River Suspended Sediment Records,1975-1990, DID, Malaysia

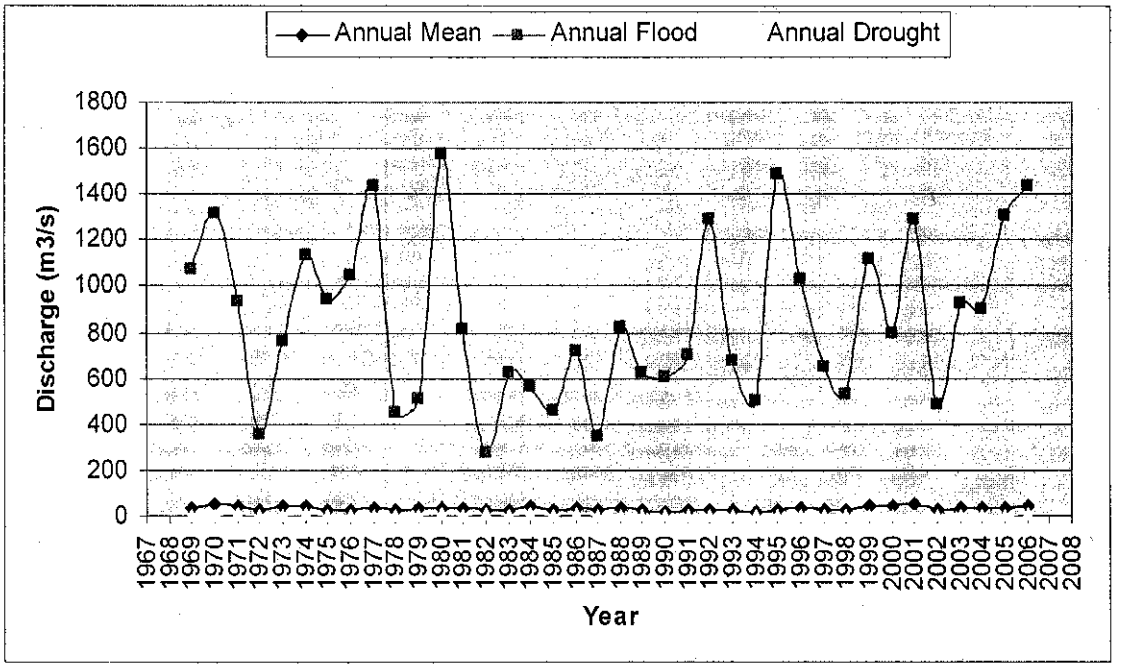


Figure C-11: Annual Discharge of Sg. Kedamaian at Tamu Darat (1969-2006)

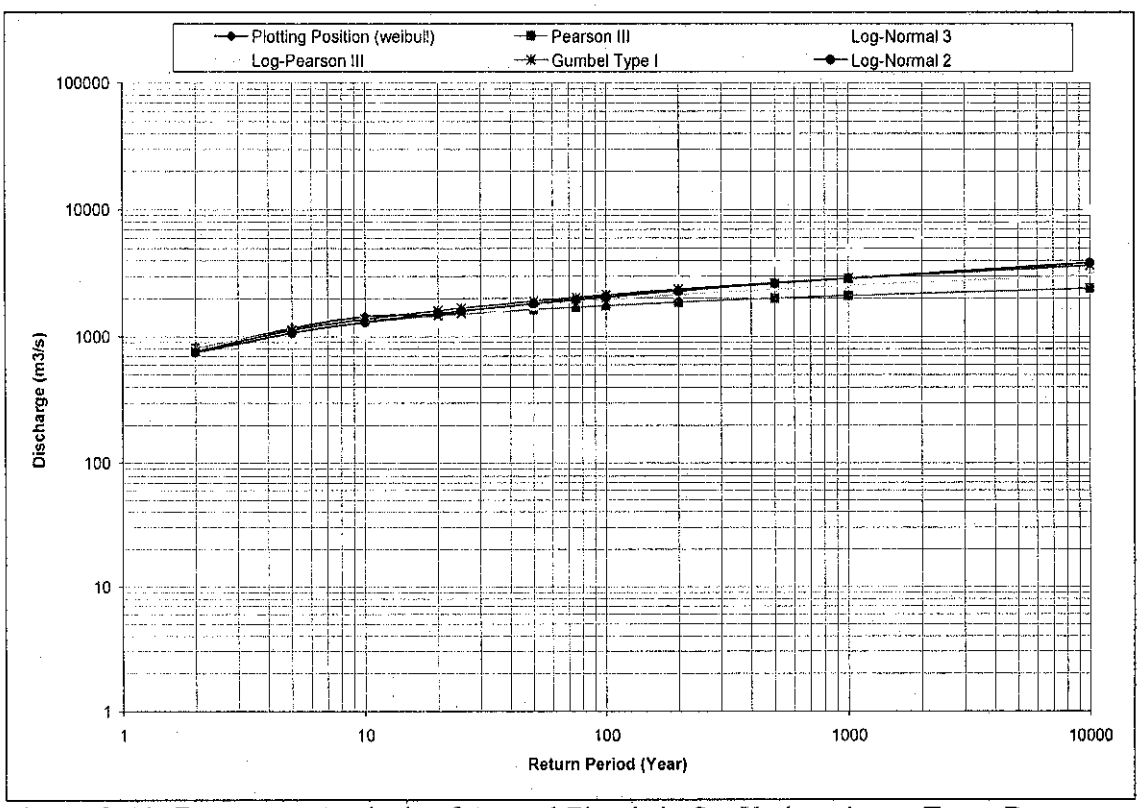
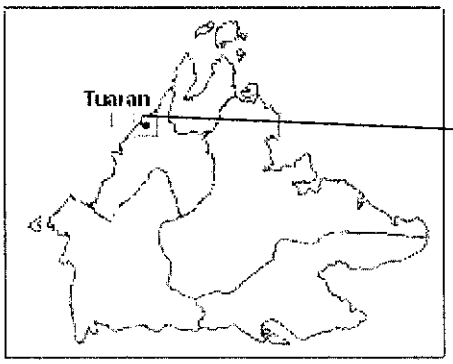
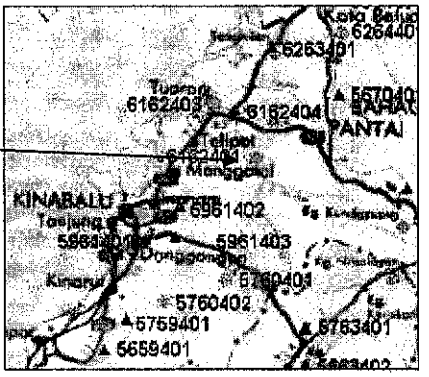


Figure C-12: Frequency Analysis of Annual Floods in Sg. Kedamaian at Tamu Darat (1969-2006)

SUNGAI TUARAN AT MALANGGANG

Location





Description by DID, SABAH

Station No. 6162401

SUNGAI TUARAN AT MALANGGANG

Gauging site:- 85 m Cableway

Longitude & Latitude: - 116°16'20" E 06°06'10" N.

Catchment Area:- 564 km^2

Elevation above mean sea level:- 45 m

Catchment characteristics:-

(a) **Shape:-** The maximum length and breadth of the catchment are 35 km and 30 km respectively

(b) **Topography:** - Mostly mountainous with elevations of up to 1660m

(c) **Vegetation:** - Padi, rubber trees, secondary jungle and shifting cultivations

(d) **Soil Cover:** - Sandy to clayey loams of 1-3 m deep

(e) **Rock Type:** - Sandstone and shale

Ranged of observations:- The range of river stages observed is from 28.46 m to 34.47m

Summary of Data

Name	Sg Tuaran at Malanggang
Area (km^2):	564
Elevation (m):	45
Average Rainfall (mm)	
Water Use	
Total Mean yearly (m^3/s):	43.48
Mean of "Min"s yearly (m^3/s)	4.69
Mean of "Max"s yearly (m^3/s):	1202.45
Absolute Min, yearly (m^3/s):	0.16
Absolute Max yearly (m^3/s):	3040.20
Source	Hydrological Records for Sabah, 1968-1975, DID Sabah Streamflow and River Suspended Sediment Records,1975-1990, DID, Malaysia

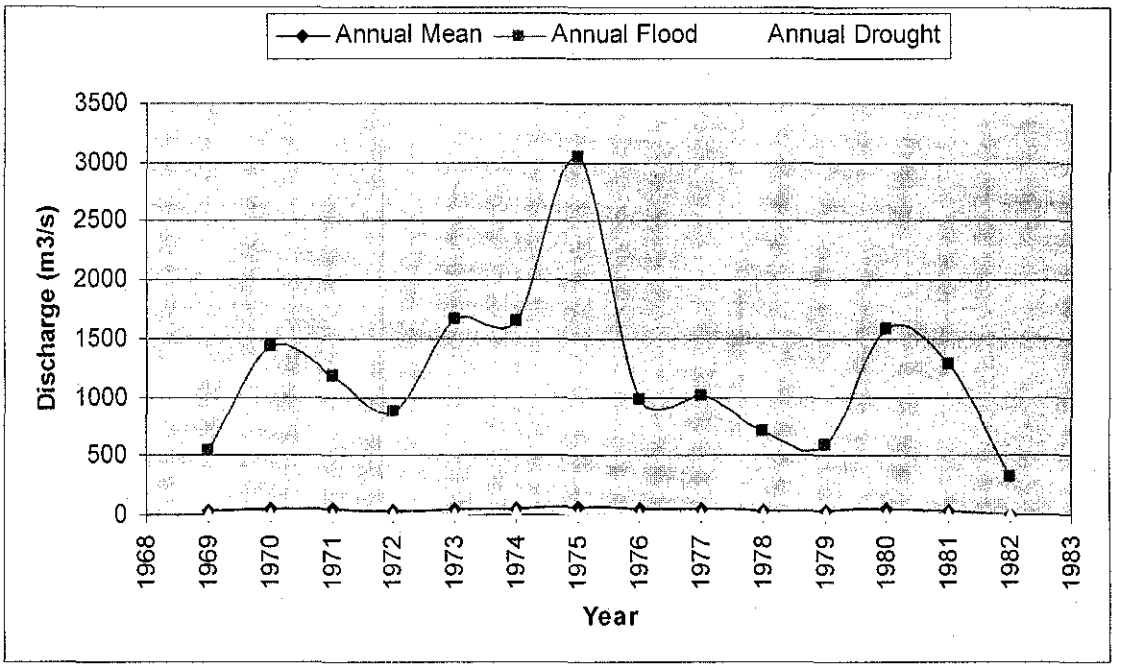


Figure C-13: Annual Discharge of Sg. Tuaran at Malanggang (1969-1982)

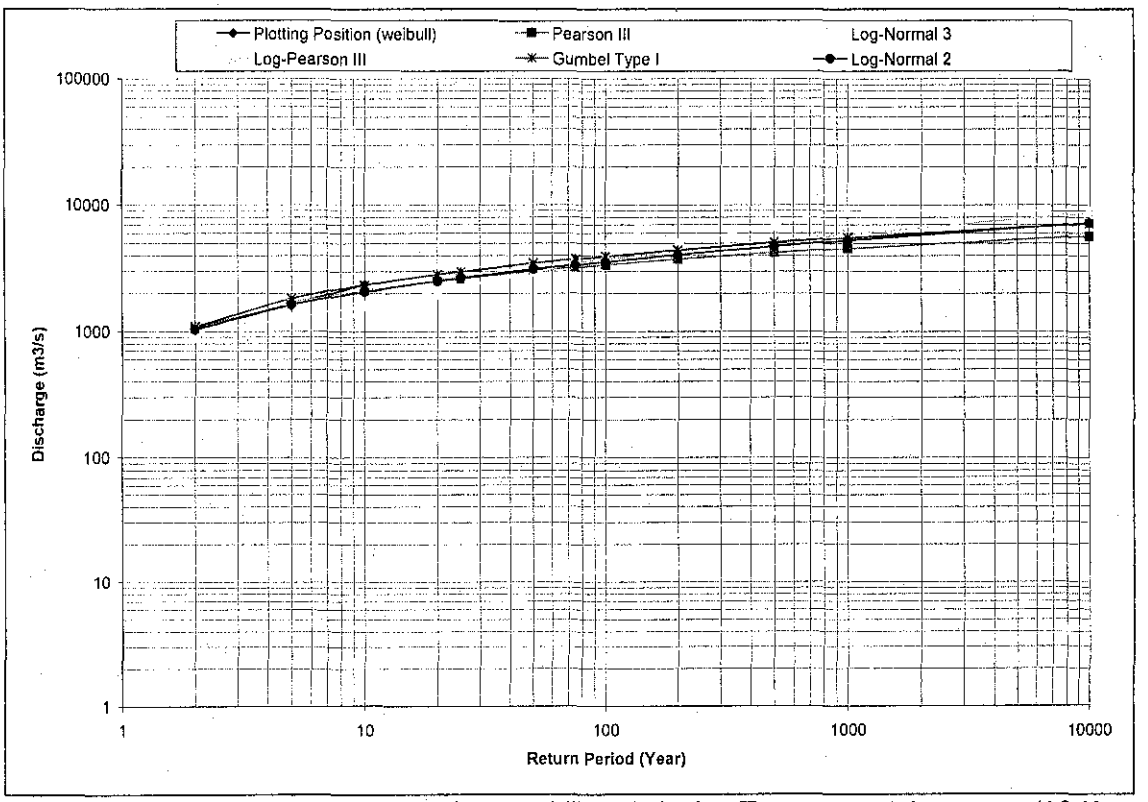
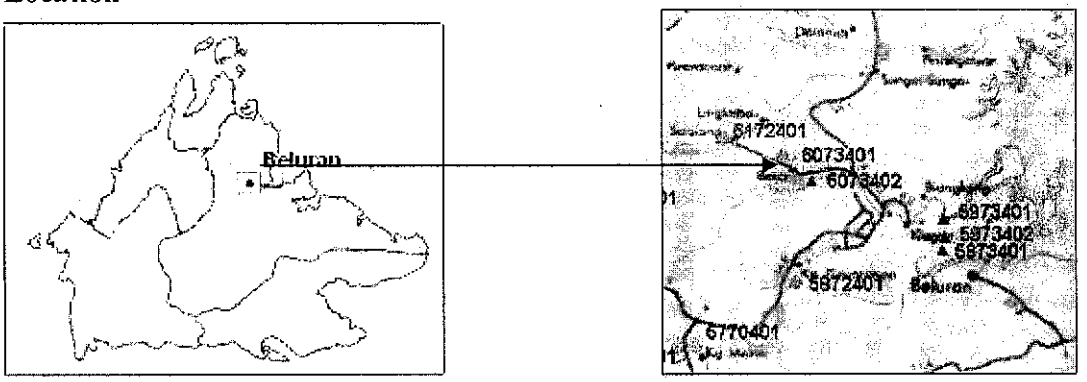


Figure C-14: Frequency Analysis of Annual Floods in Sg. Tuaran at Malanggang (1969-1982)

SUNGAI TUNGUD AT BASAI

Location



Description by DID, SABAH

Station No. 6073401

SUNGAI TUNGUD AT BASAI

Gauging site: - Gauging by boat.

Longitude & Latitude: - 117°18'30" E 06°03'00" N.

Catchment Area:- 564 km^2

Elevation above mean sea level:- 24 m

Catchment characteristics:-

(a) **Shape**:- The maximum length and breadth of the catchment are 50 km and 20 km respectively

(b) **Topography**: - Hills with elevation up to 400m.

(c) **Vegetation**: - Virgin and secondary jungle with some shifting cultivations

(d) **Soil Cover**: - Clayey loams of 2-3 m deep

(e) **Rock Type**: - Sandstone and mudstone in the north side of the catchment and in the south side of catchment the gabbro, chert and basalt.

Ranged of observations: - The range of river stages observed is from 22.15 m to 86.89m. Discharge measurements have been taken between 22.19m and 23.81m

Summary of Data

Name	Sg. Tungud at Basai
Area (km^2):	564
Elevation (m):	24
Average Rainfall (mm)	
Water Use	
Total Mean yearly (m^3/s):	43.0
Mean of "Min"s yearly (m^3/s)	4.37
Mean of "Max"s yearly (m^3/s):	782.24
Absolute Min, yearly (m^3/s):	0.89
Absolute Max yearly (m^3/s):	1516.8
Source	Hydrological Records for Sabah, 1968-1975, DID Sabah Streamflow and River Suspended Sediment Records,1975-1990, DID, Malaysia

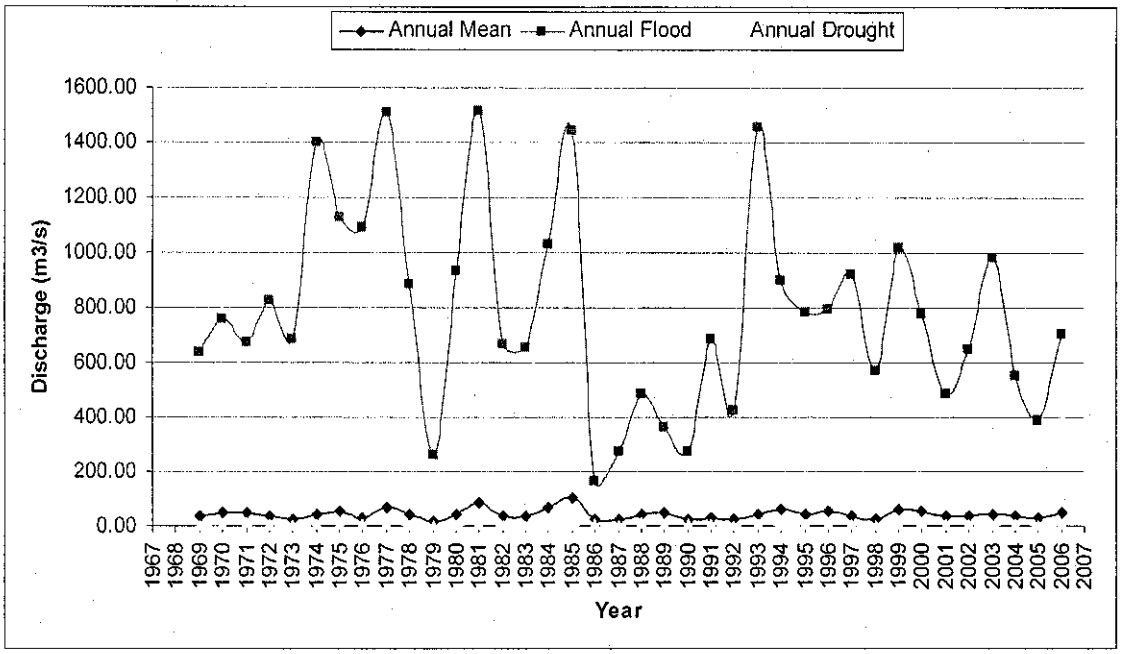


Figure C-15: Annual Discharge of Sg. Tungud at Basai (1969-2006)

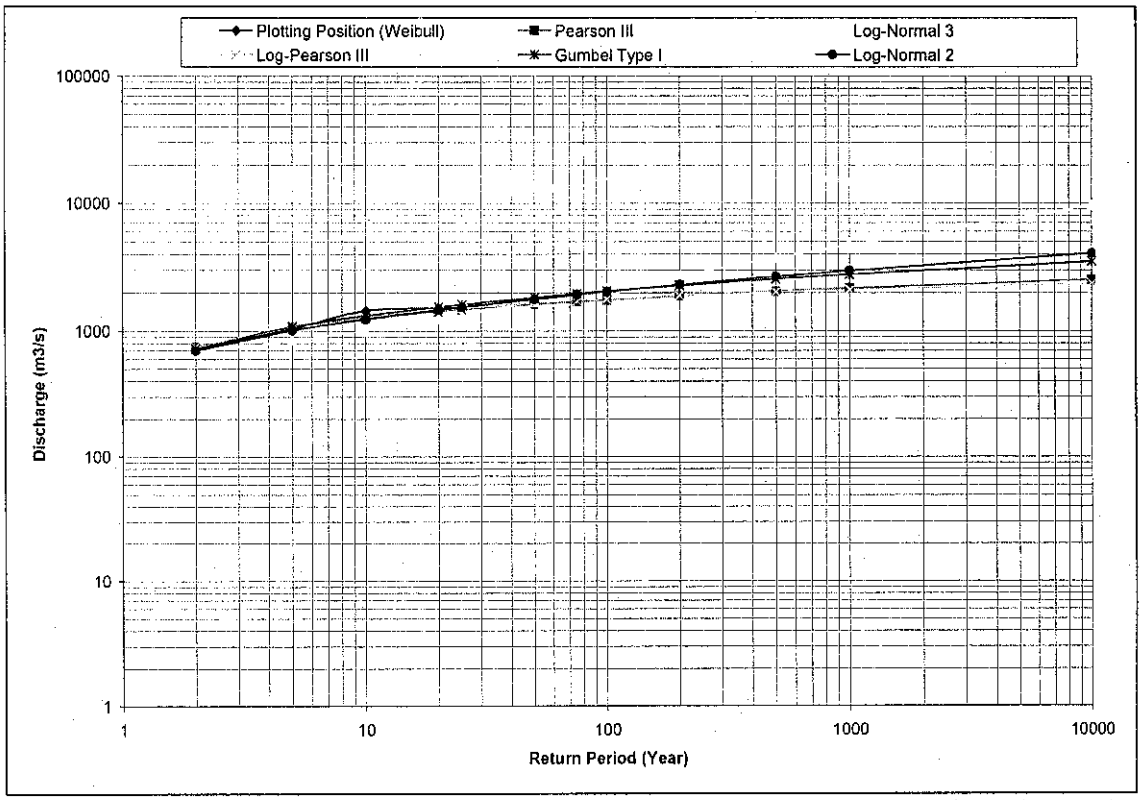
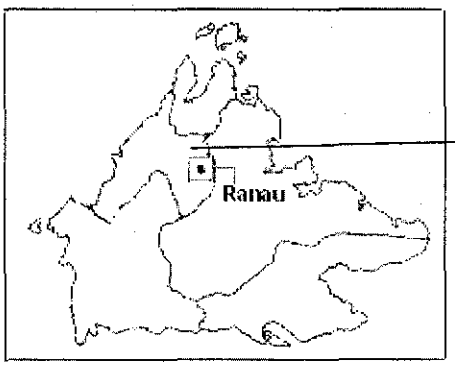
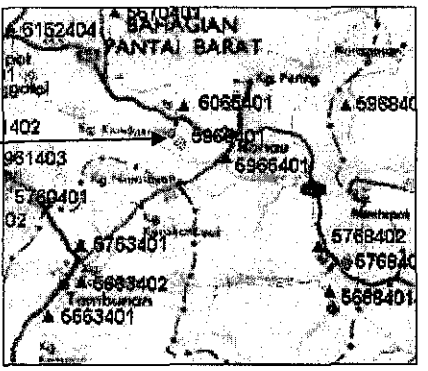


Figure C-16: Frequency Analysis of Annual Floods in Sg. Tungud at Basai (1969-2006)

SUNGAI LIWAGU AT BEDUKAN

Location





Description by DID, SABAH

Station No. 5966401

SUNGAI LIWAGU AT BEDUKAN

Gauging site:- Gauging by boat

Longitude & Latitude: - 116°39'10" E 05°55'00" N.

Catchment Area:- 440 km^2

Elevation above mean sea level:- 430 m

Catchment characteristics:-

(a) **Shape:-** The maximum length and breadth of the catchment are 20 km and 30 km respectively

(b) **Topography:** - Mountainous with elevations of up to 4000m

(c) **Vegetation:** - Padi and various other crops, virgin and secondary jungle

(d) **Soil Cover:** - Sandy loam in varying depths and in the upper catchment, shallow granitic soils.

(e) **Rock Type:** - Sandstone and shale and in the upper catchment, ultrabasic and granite

Ranged of observations:- The range of river stages observed is from 26.52 m to 30.59m

Summary of Data

Name	Sg. Liwagu at Bedukan
Area (km^2):	440
Elevation (m):	430
Average Rainfall (mm)	
Water Use	
Total Mean yearly (m^3/s):	4.96
Mean of "Min"s yearly (m^3/s)	0.49
Mean of "Max"s yearly (m^3/s):	87.55
Absolute Min, yearly (m^3/s):	0.01
Absolute Max yearly (m^3/s):	298.67
Source	Hydrological Records for Sabah, 1968-1975, DID Sabah Streamflow and River Suspended Sediment Records,1975-1990, DID, Malaysia

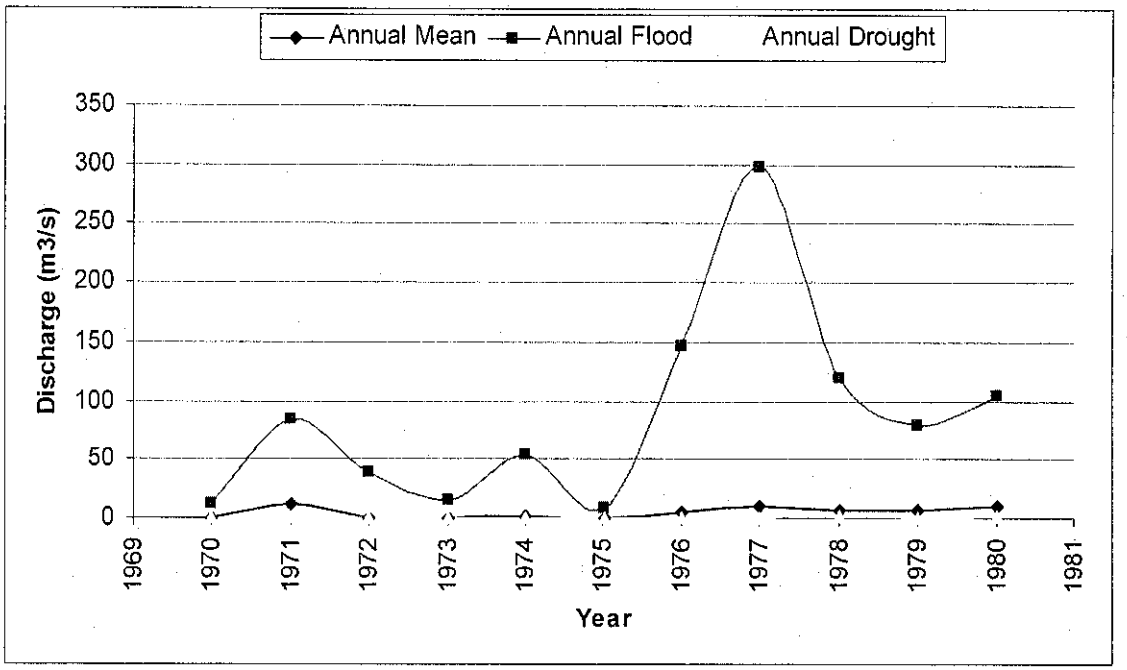


Figure C-17: Annual Discharge of Sg. Liwagu at Bedukan (1970-1980)

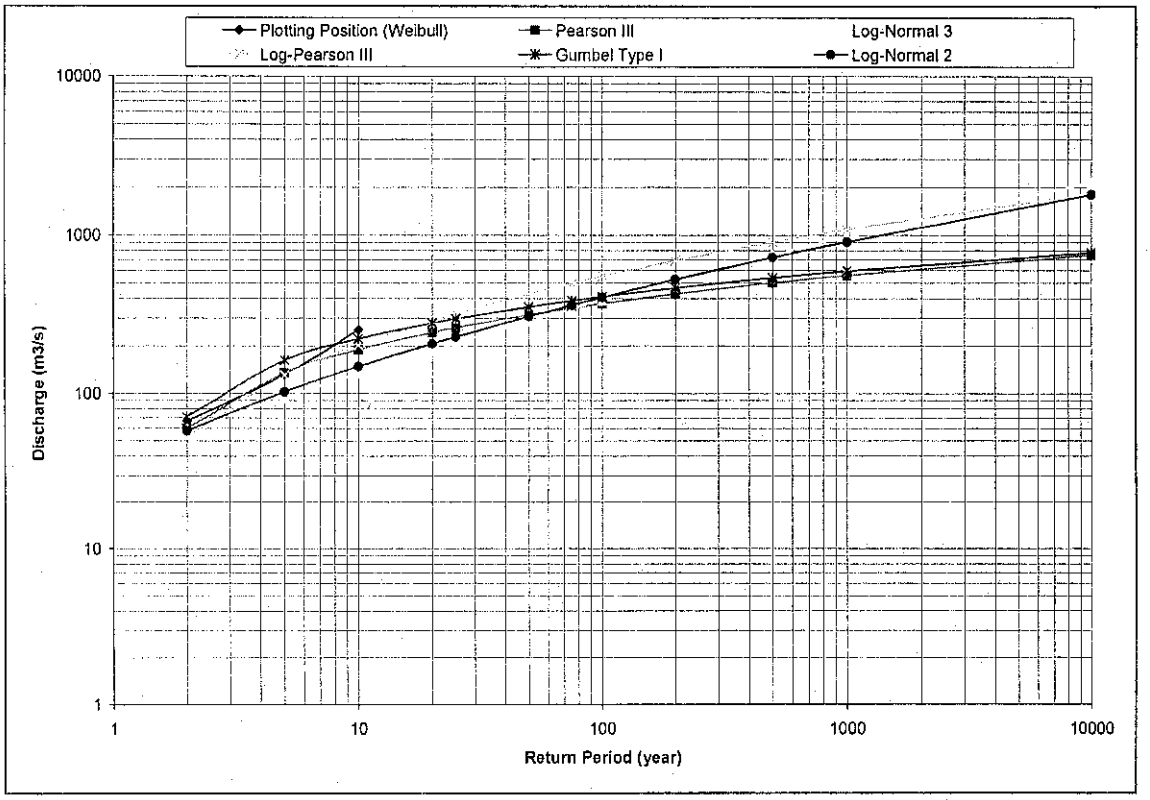
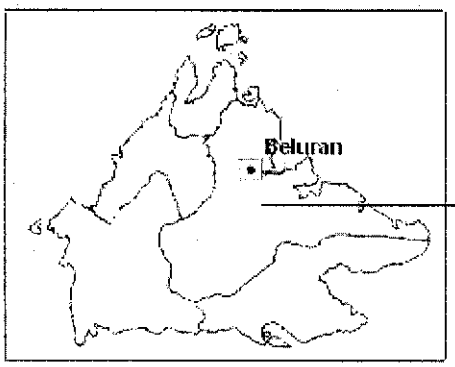
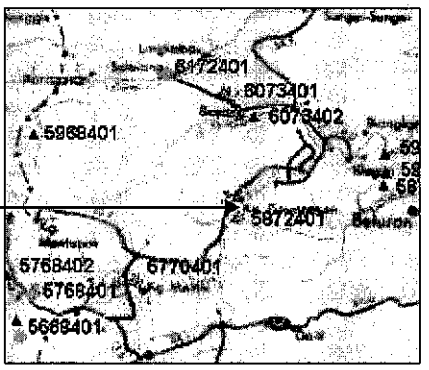


Figure C-18: Frequency Analysis of Annual Floods in Sg. Liwagu at Bedukan (1970-1980)

SUNGAI LABUG AT POROG

Location





Description by DID, SABAH

Station No. 5872401

SUNGAI LABUK AT POROG

Gauging site:- Gauging by boat

Longitude & Latitude: - 117°13'40" E 05°51'15" N.

Catchment Area:- 3240 km^2

Elevation above mean sea level:- 17 m

Catchment characteristics:-

(a) **Shape**:- The maximum length and breadth of the catchment are 95 km and 60 km respectively

(b) **Topography**: - 10% undulating hills with elevations around 200m. 50% hills with elevations around 4000m.

(c) **Vegetation**: - Padi and various other crops and also virgin and secondary jungle rubber trees, secondary jungle and shifting cultivations

(d) **Soil Cover**: - Sandy to clayey loams of 1-3 m deep

(e) **Rock Type**: - Sandstone and shale

Ranged of observations:- The range of river stages observed is from 28.46 m to 34.47m

Summary of Data

Name	Sg. Labuk at Porog
Area (km^2):	3240
Elevation (m):	17
Average Rainfall (mm)	
Water Use	
Total Mean yearly (m^3/s):	185.76
Mean of "Min"s yearly (m^3/s)	37.16
Mean of "Max"s yearly (m^3/s):	1806.34
Absolute Min, yearly (m^3/s):	4.1
Absolute Max yearly (m^3/s):	3534.4
Source	Hydrological Records for Sabah, 1968-1975, DID Sabah Streamflow and River Suspended Sediment Records,1975-1990, DID, Malaysia

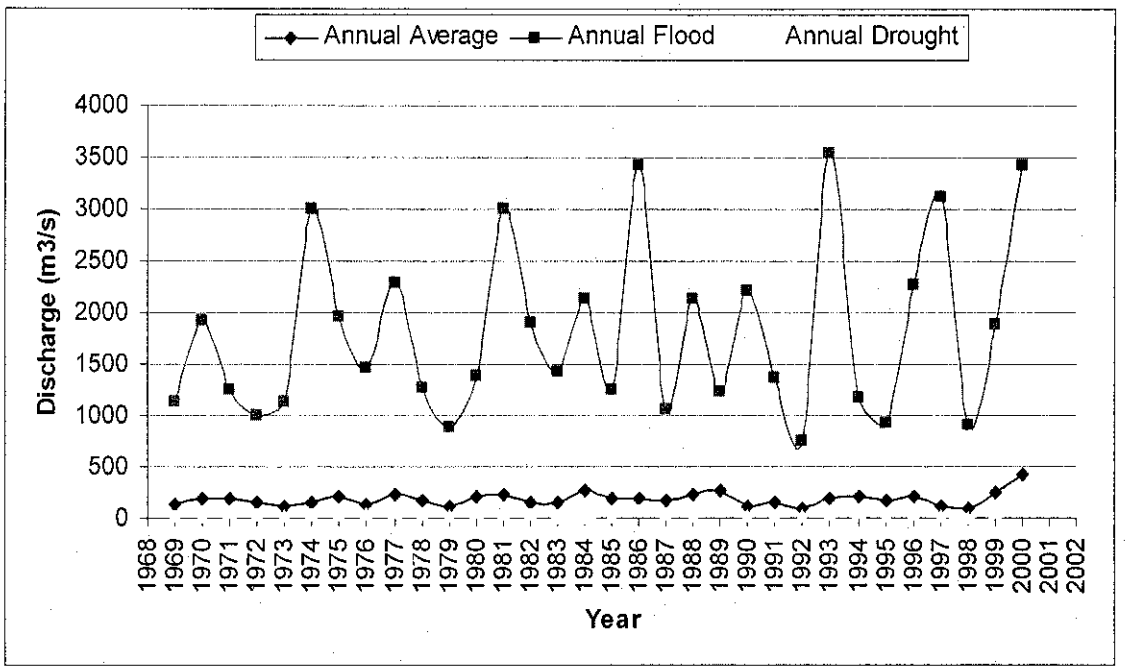


Figure C-19: Annual Discharge of Sg. Labug at Porog (1969-2006)

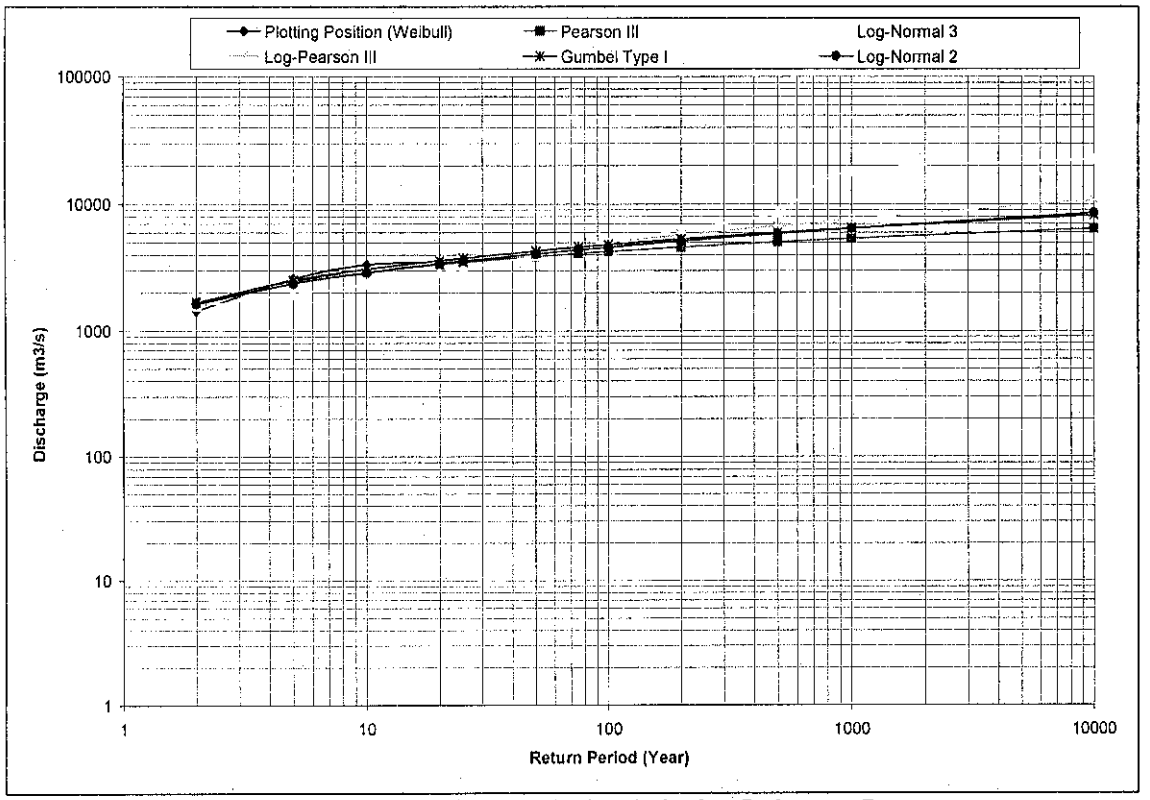
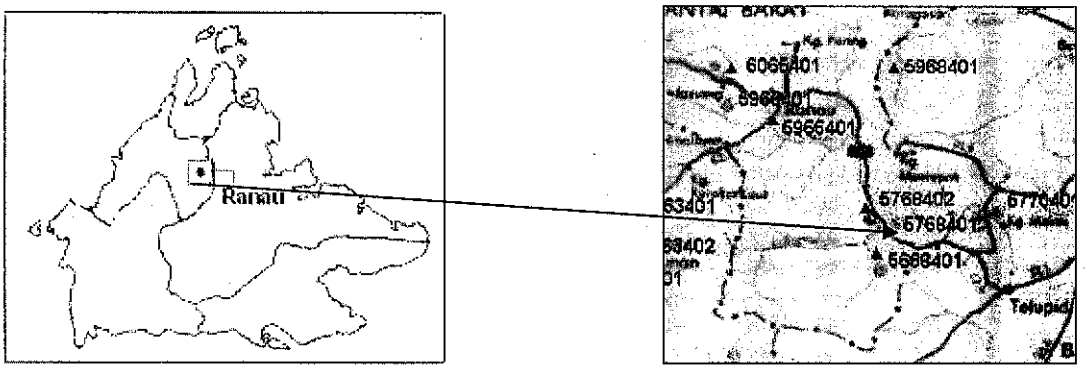


Figure C-20: Frequency Analysis of Annual Floods in Sg. Labug at Porog

SUNGAI LABUK AT TAMPIAS

Location



Description by DID, SABAH

Station No. 5768401

SUNGAI LABUK AT TAMPIAS

Gauging site:- Gauging by boat

Longitude & Latitude: - 116°51'35" E 05°43'05" N.

Catchment Area:- 2010 km^2

Elevation above mean sea level:- 168 m

Catchment characteristics:-

(a) **Shape:-** The maximum length and breadth of the catchment are 58 km and 52 km respectively

(b) **Topography**: - Mountainous with elevations of up to 4000m in the upper catchment.

(c) **Vegetation**: - Padi with various other crops and shifting cultivation. Virgin and secondary jungle

(d) **Soil Cover**: - Sandy loams of varying depths and in the upper catchments, shallow granitic soil

(e) **Rock Type**: - Sandstone, shale and in the upper catchment, ultrabasic and granite

Ranged of observations: - The range of river stages observed is from 0.78 m to 11.91m. Discharge measurements taken between 6.83m and 7.15 m

Summary of Data

Name	Sg. Labuk at Tampias
Area (km^2):	2010
Elevation (m):	168
Average Rainfall (mm)	
Water Use	
Total Mean yearly (m^3/s):	106.65
Mean of "Min"s yearly (m^3/s)	21.37
Mean of "Max"s yearly (m^3/s):	1270.34
Absolute Min, yearly (m^3/s):	1.77
Absolute Max yearly (m^3/s):	2882.9
Source	Hydrological Records for Sabah, 1968-1975, DID Sabah Streamflow and River Suspended Sediment Records,1975-1990, DID, Malaysia

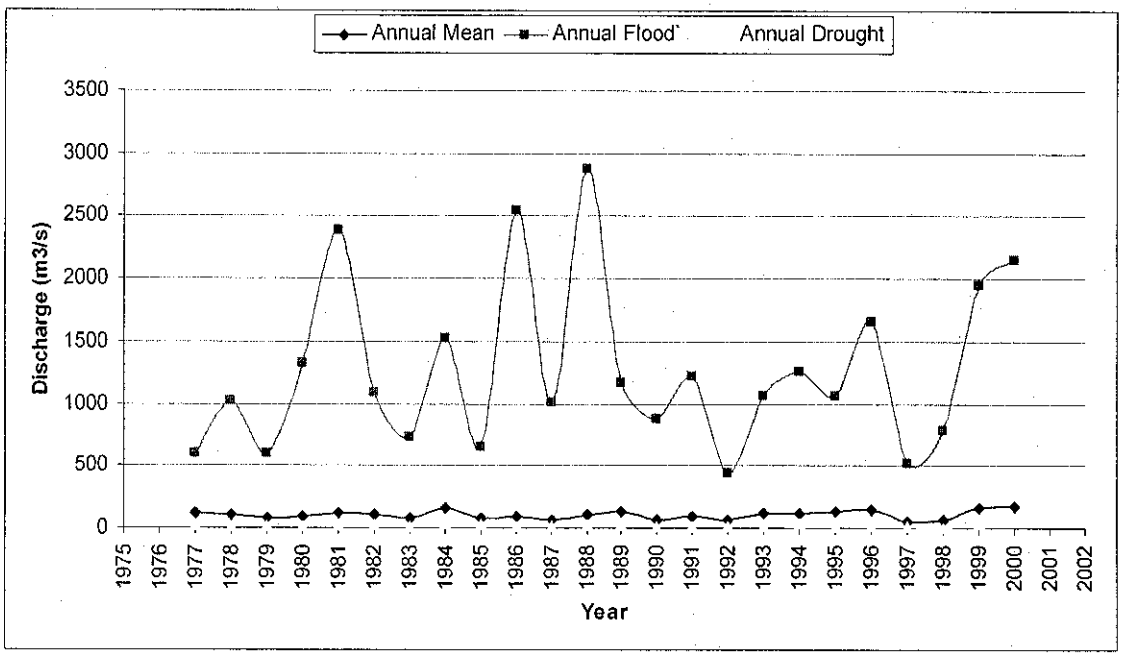


Figure C-21: Annual Discharge of Sg. Labuk at Tampias (1977-2006)

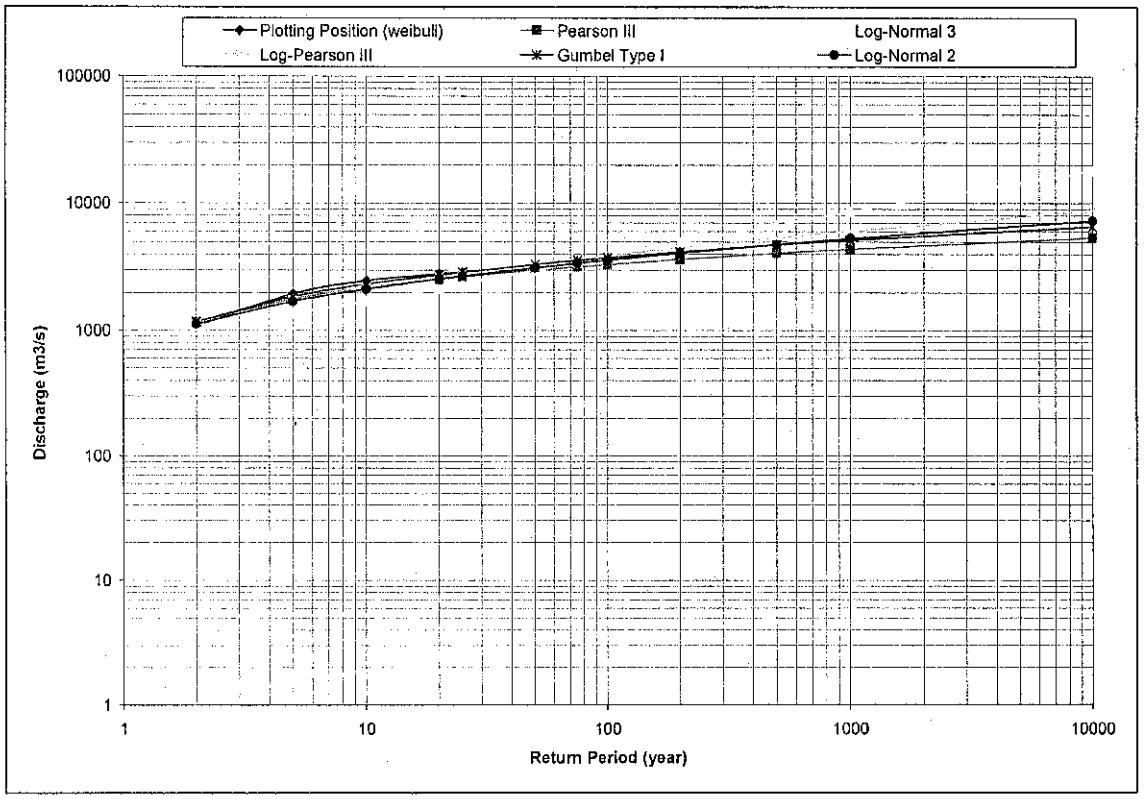
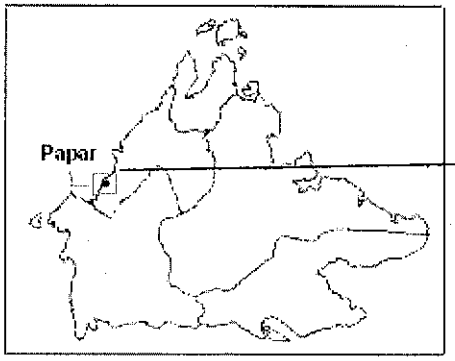
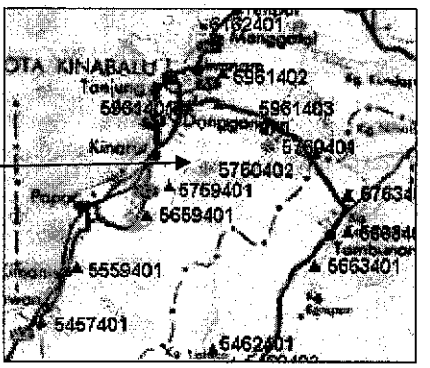


Figure C-22: Figure Frequency Analysis of Annual Floods in Sg. Labuk at Tampias (1977-2006)

SUNGAI PAPAR AT KOGOPON

Location





Description by DID, SABAH

Station No. 5760401

SUNGAI PAPAR AT KOGOPAN

Gauging site:- 76 m Cableway

Longitude & Latitude: - 116°05'30" E 05°46'10" N.

Catchment Area:- 357 km^2

Elevation above mean sea level:- 91 m

Catchment characteristics:-

(a) **Shape**:- The maximum length and breadth of the catchment are 25 km and 20 km respectively

(b) **Topography**: - Mostly mountainous with elevations of up to 1500m

(c) **Vegetation**: - Secondary jungle and shifting cultivations

(d) **Soil Cover**: - Sandy to clayey loams of 1-3 m deep

(e) **Rock Type**: - Sandstone and shale

Ranged of observations:- The range of river stages observed is from 25.91 m to 30.29m. Discharge measurements taken between 25.91m and 26.95 m

Summary of Data

Name	Sg. Papat at Kogopon
Area (km^2):	357
Elevation (m):	91
Average Rainfall (mm)	
Water Use	
Total Mean yearly (m^3/s):	24.24
Mean of "Min"s yearly (m^3/s)	3.48
Mean of "Max"s yearly (m^3/s):	438.24
Absolute Min, yearly (m^3/s):	0.86
Absolute Max yearly (m^3/s):	1550.6
Source	Hydrological Records for Sabah, 1968-1975, DID Sabah Streamflow and River Suspended Sediment Records,1975-1990, DID, Malaysia

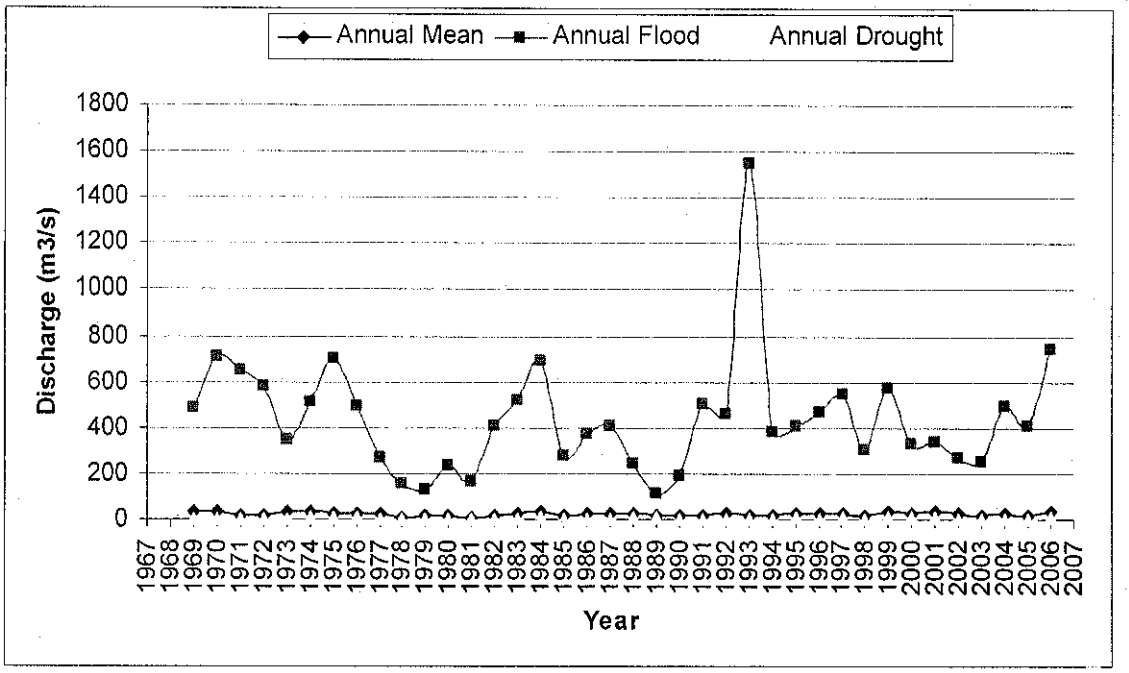


Figure C-23: Annual Discharge of Sg. Papar at Kogopan (1969-2006)

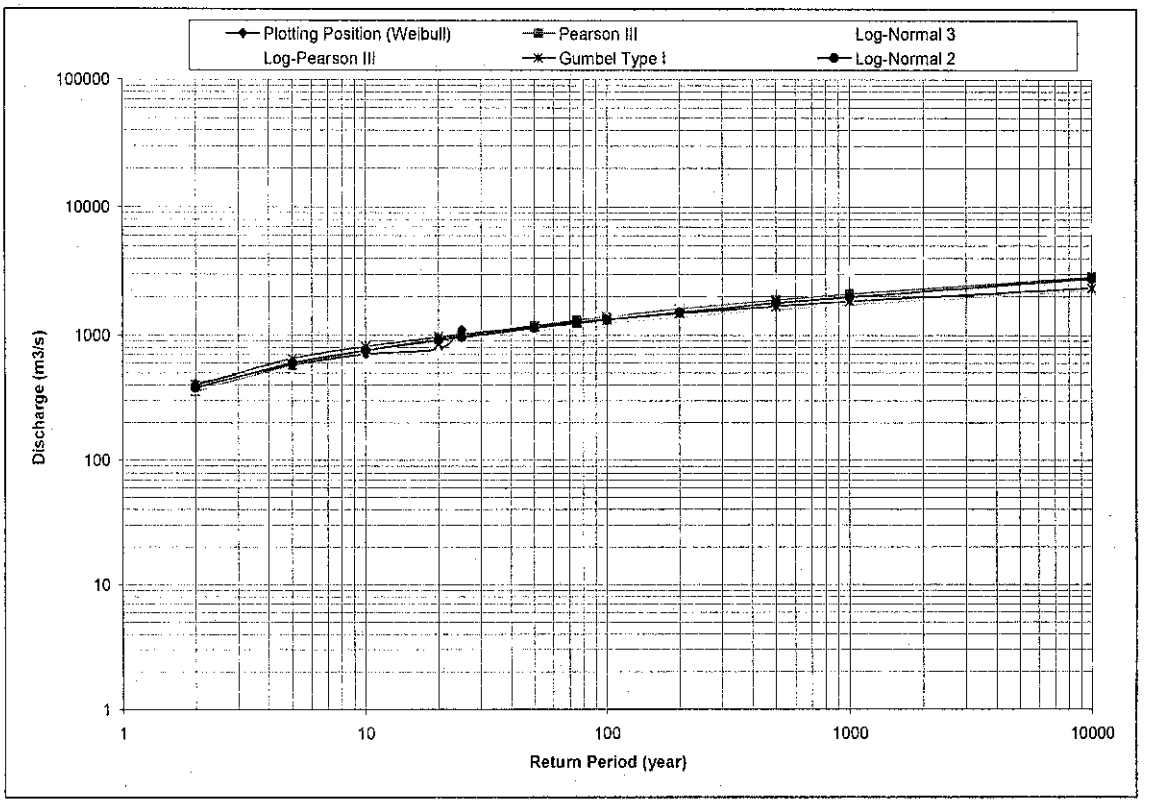
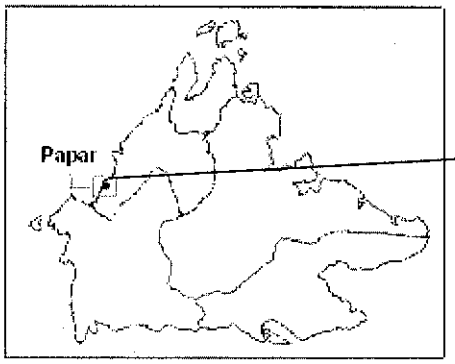
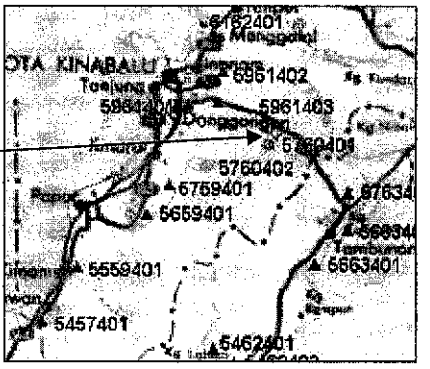


Figure C-24: Frequency Analysis of Annual Floods in Sg. Papar at Kogopan (1969-2006)

SUNGAI PAPAR AT KAIDUAN

Location





Description by DID, SABAH

Station No. 5760402

SUNGAI PAPAR AT KAIDUAN

Gauging site:- 116 m Cableway

Longitude & Latitude: - 116°02'10" E 05°42'30" N.

Catchment Area:- 536 km^2

Elevation above mean sea level:- 24 m

Catchment characteristics:-

(a) **Shape**:- The maximum length and breadth of the catchment are 35 km and 20 km respectively

(b) **Topography**: - Mountainous with elevations of up to 1500m

(c) **Vegetation**: - Secondary jungle, shifting cultivations and rubber trees.

(d) **Soil Cover**: - Sandy to loams of 1-3 m deep

(e) **Rock Type**: - Sandstone and shale

Ranged of observations:- The range of river stages observed is from 25.14 m to 30.72m. Discharge measurements have been taken between 25.83m and 27.20m.

Summary of Data

Name	Sungai Papar at Kaiduan
Area (km^2):	536
Elevation (m):	24
Average Rainfall (mm)	
Water Use	
Total Mean yearly (m^3/s):	43.18
Mean of "Min"s yearly (m^3/s)	6.48
Mean of "Max"s yearly (m^3/s):	814.13
Absolute Min, yearly (m^3/s):	1.33
Absolute Max yearly (m^3/s):	2477
Source	Hydrological Records for Sabah, 1968-1975, DID Sabah Streamflow and River Suspended Sediment Records,1975-1990, DID, Malaysia

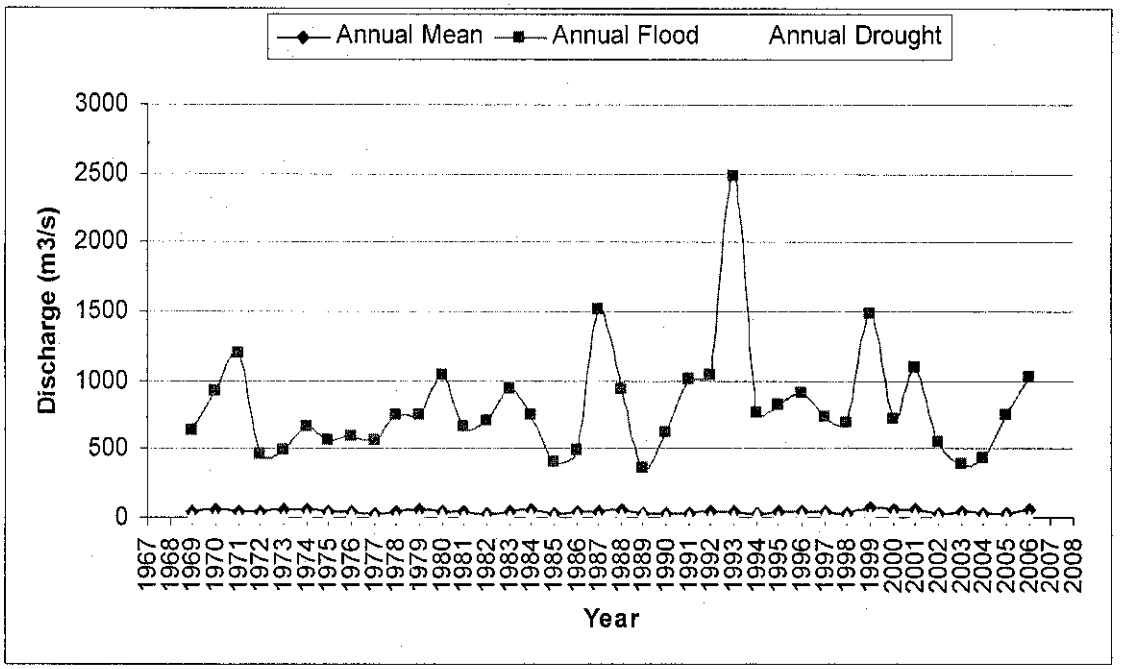


Figure C-25: Annual Discharge of Sg. Papar at Kaiduan (1969-2006)

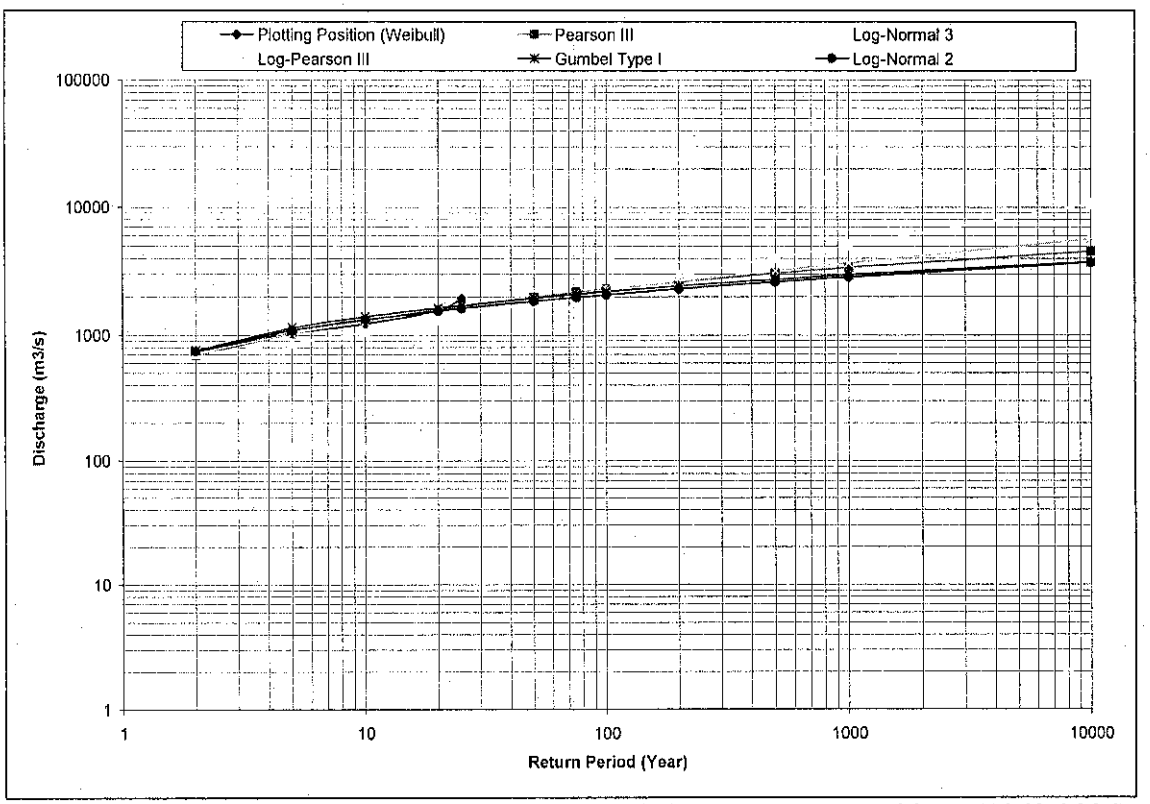
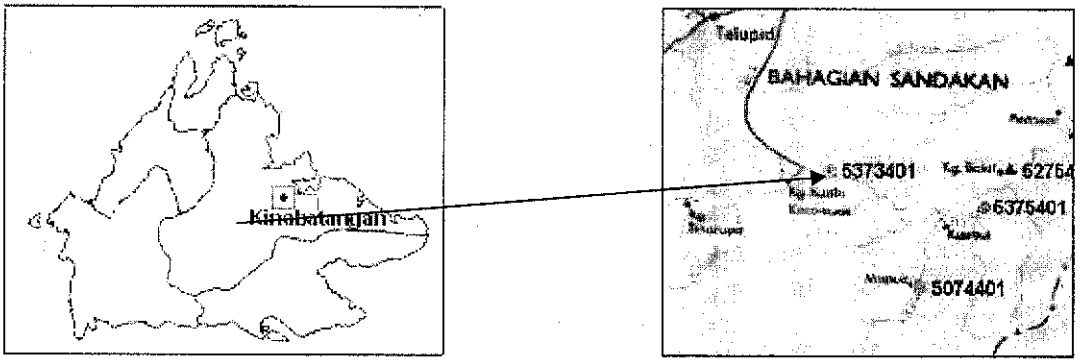


Figure C-26: Frequency Analysis of Annual Floods in Sg. Papar at Kaiduan (1969-2006)

SUNGAI MILIAN AT TANGKULAP

Location



Description by DID, SABAH

Station No. 5373401

SUNGAI MILIAN AT TANGKULAP

Gauging site:- Gauging by boat

Longitude & Latitude: - 117°19'05" E 05°18'15" N.

Catchment Area:- 5730 km^2

Elevation above mean sea level:- 25 m

Catchment characteristics:-

(a) **Shape**:- The maximum length and breadth of the catchment are 95 km and 80 km respectively

(b) **Topography**: - 80% hill with elevations around 600m and 20% mountainous with elevation up to 2600m

(c) **Vegetation**: - Virgin and secondary jungle with some shifting cultivation.

(d) **Soil Cover**: - Hills, covered with sandy loam of 1-3 M deep. Mountains covered with fine to coarse sand and shallow in depth

(e) **Rock Type**: - Mudstone, sandstone, and in the north side of the catchment, chert, basalt and gabbro

Ranged of observations: - The range of river stages observed is from 12.32 m to 26.68m. Discharge measurements have been taken between 12.40m and 23.08m

Summary of Data

Name	Sungai Millian at Tangkulap
Area (km^2):	5730
Elevation (m):	25
Average Rainfall (mm)	
Water Use	Nil
Total Mean yearly (m^3/s):	227.55
Mean of "Min"s yearly (m^3/s)	24.09
Mean of "Max"s yearly (m^3/s):	1085.3
Absolute Min, yearly (m^3/s):	2.79
Absolute Max yearly (m^3/s):	2413.6
Source	Hydrological Records for Sabah, 1968-1975, DID Sabah Streamflow and River Suspended Sediment Records,1975-1990, DID, Malaysia

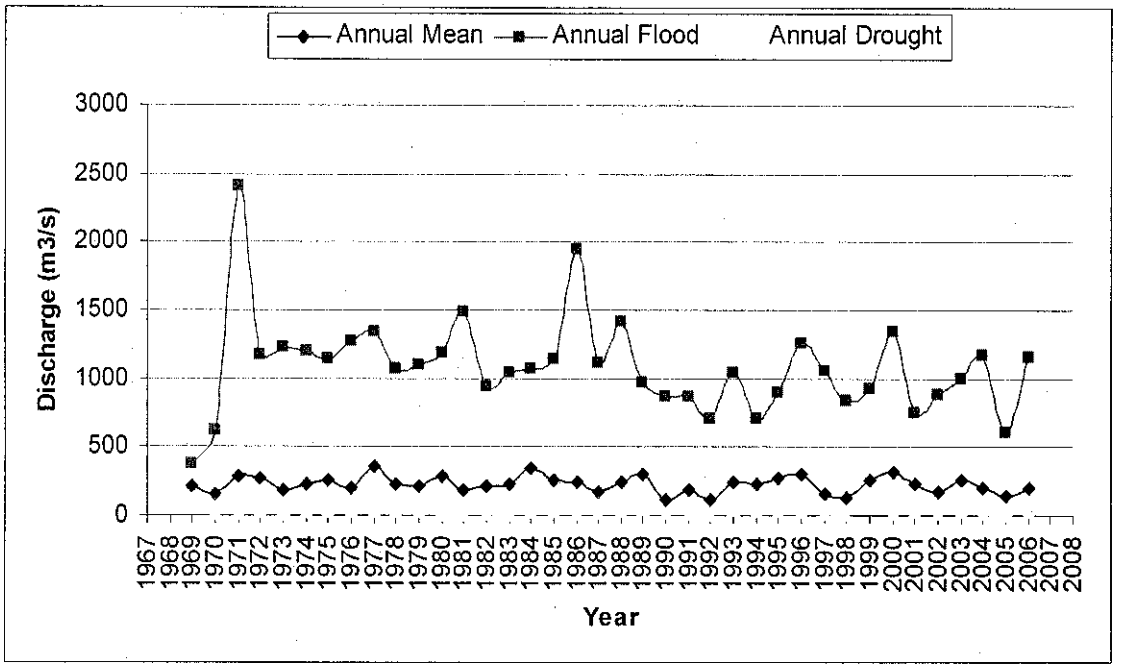


Figure C-27: Annual Discharge of Sg. Milian at Tangkulap (1969-2006)

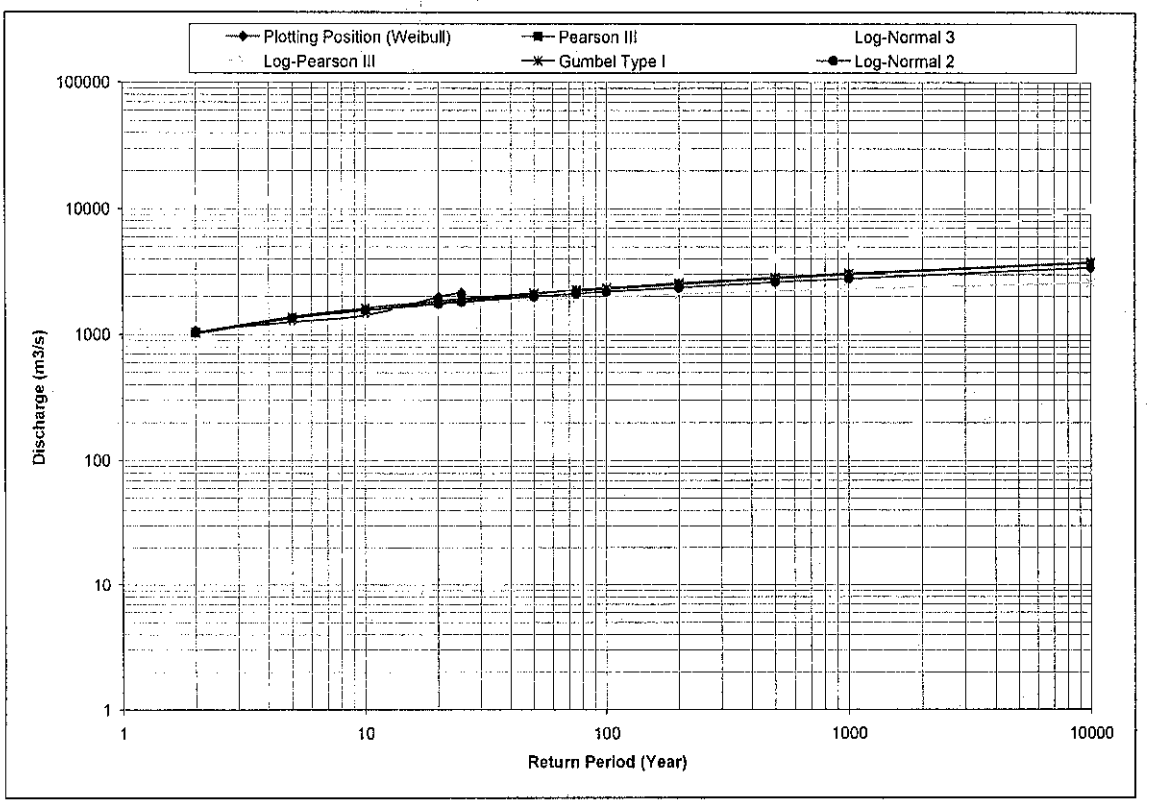
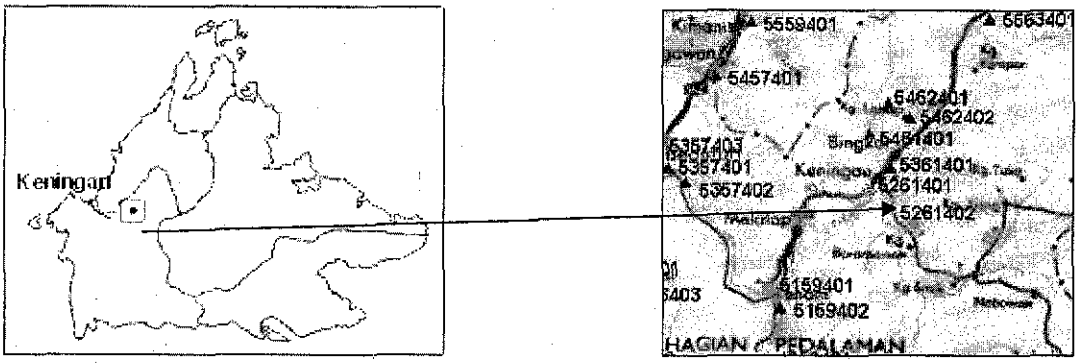


Figure C-28: Frequency Analysis of Annual Floods in Sg. Milian at Tangkulap (1969-2006)

SUNGAI SOOK AT BIAH

Location



Description by DID, SABAH

Station No. 5261402

SUNGAI SOOK AT BIAH

Gauging site:- 45 m Cableway

Longitude & Latitude: - 116°08'25" E 05°15'25" N.

Catchment Area:- 1684 km^2

Elevation above mean sea level:- 260 m

Catchment characteristics:-

(a) **Shape**:- The maximum length and breadth of the catchment are 45 km and 75 km respectively

(b) **Topography**: - Terraces with elevations around 500m and some mountains with elevation of up to 1500m.

(c) **Vegetation**: - Grassland, virgin and secondary jungle with some shifting cultivations and rubber trees.

(d) **Soil Cover**: - Find to coarse sand, loam of 2-5 m deep

(e) **Rock Type**: - South side of the catchment : Sandstone mudstone, North side of catchment : Alluvial gravel

Ranged of observations:- The range of river stages observed is from 25.46 m to 29.30m

Summary of Data

Name	Sungai Sook at Biah
Area (km^2):	1684
Elevation (m):	260
Average Rainfall (mm)	
Water Use	Nil
Total Mean yearly (m^3/s):	24.53
Mean of "Min"s yearly (m^3/s)	2.25
Mean of "Max"s yearly (m^3/s):	180.72
Absolute Min, yearly (m^3/s):	0.39
Absolute Max yearly (m^3/s):	357.49
Source	Hydrological Records for Sabah, 1968-1975, DID Sabah Streamflow and River Suspended Sediment Records,1975-1990, DID, Malaysia

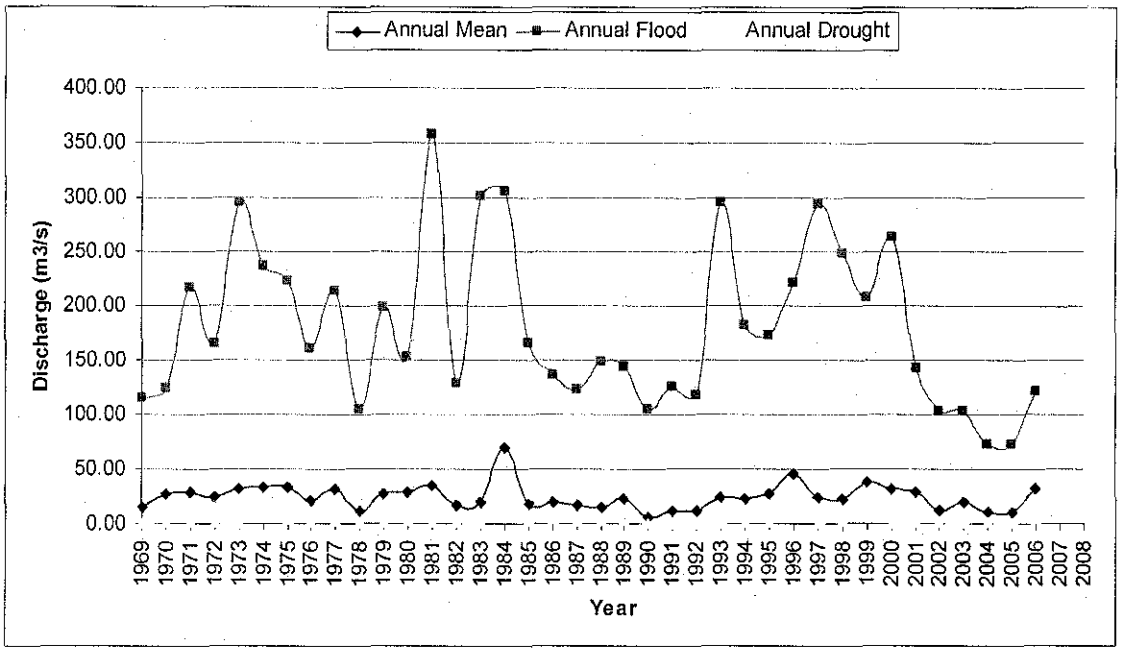


Figure C-29: Annual Discharge of Sg. Sook at Biah (1969-2006)

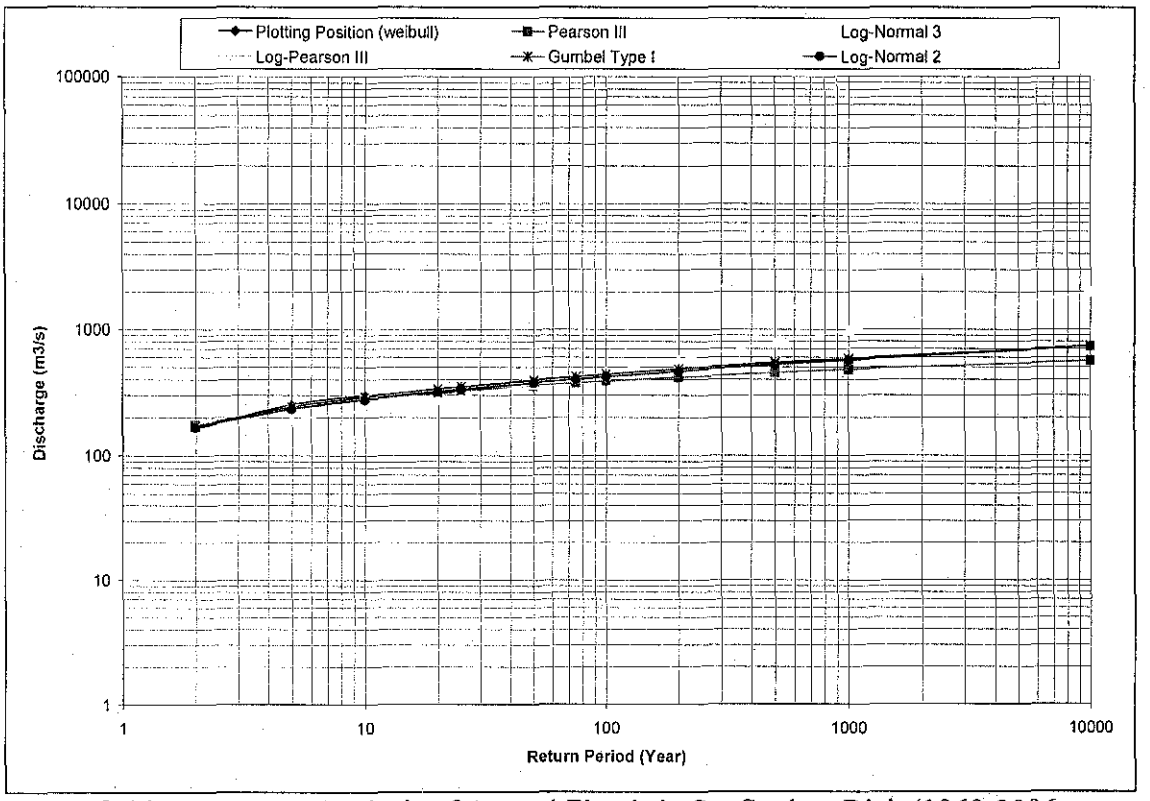
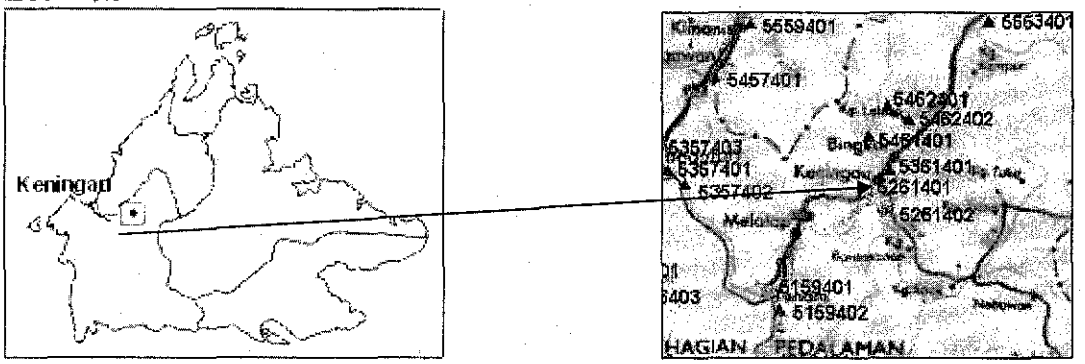


Figure C-30: Frequency Analysis of Annual Floods in Sg. Sook at Biah (1969-2006

SUNGAI PEGALAN AT ANSIP

Location



Description by DID, SABAH

Station No. 5261401

SUNGAI PEGALAN AT ANSIP

Gauging site:- 60 m Cableway

Longitude & Latitude: - 116°06'25" E 05°16'55" N.

Catchment Area:- 2175 km^2

Elevation above mean sea level:- 230 m

Catchment characteristics:-

(a) **Shape**:- The maximum length and breadth of the catchment are 70 km and 45 km respectively

(b) **Topography**: 30% Alluvial Valley with elevation of 400-600 m and 70% mountainous with elevation up to 2600m

(c) **Vegetation**: - Padi and various other crops, grassland virgin and secondary jungle

(d) **Soil Cover**: - Mountainous: Sandy loam of 1-2m deep. Alluvium: Various textures in layers of 10-20 m deep.

(e) **Rock Type**: - Sandstone, mudstone and mudstone predominant in the upper catchment.

Ranged of observations:- The range of river stages observed is from 17.21 m to 25.30m

Summary of Data

Name	Sungai Pegalan at Ansip
Area (km^2):	2175
Elevation (m):	230
Average Rainfall (mm)	
Water Use	0.86 Ml/day 1.30 Ml/day
Total Mean yearly (m^3/s):	52.03
Mean of "Min"s yearly (m^3/s)	10.78
Mean of "Max"s yearly (m^3/s):	400.57
Absolute Min, yearly (m^3/s):	1.96
Absolute Max yearly (m^3/s):	1379.6
Source:	Hydrological Records for Sabah, 1968-1975, DID Sabah Streamflow and River Suspended Sediment Records,1975-1990, DID, Malaysia

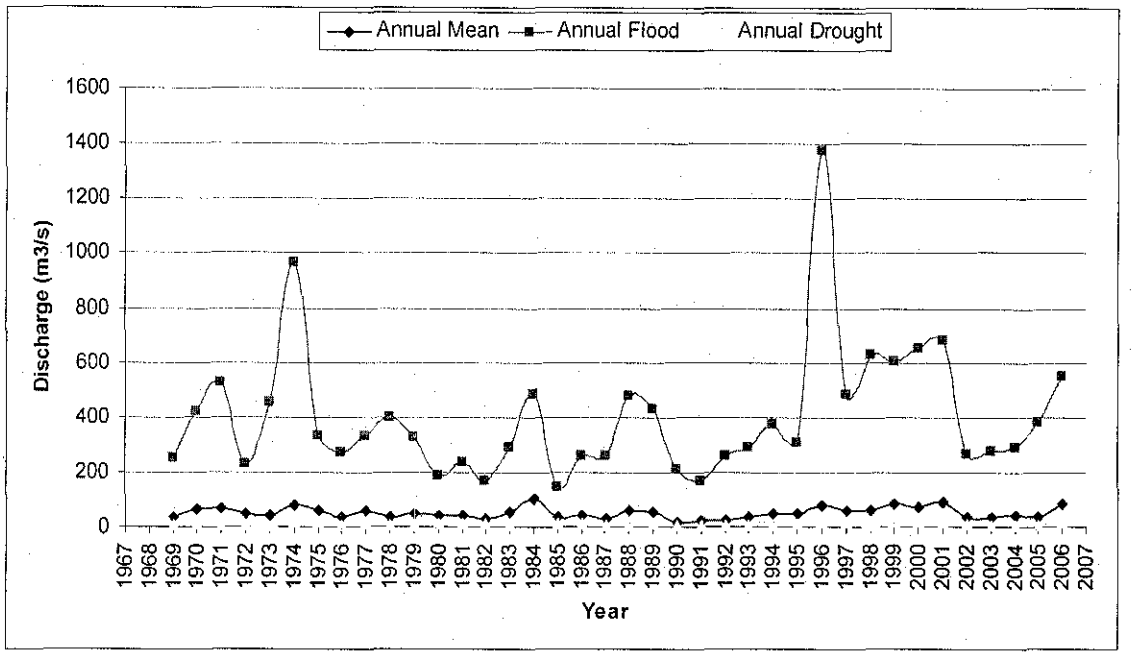


Figure: C-31: Annual Discharge of Sg. Pegalan at Ansip (1969-2006)

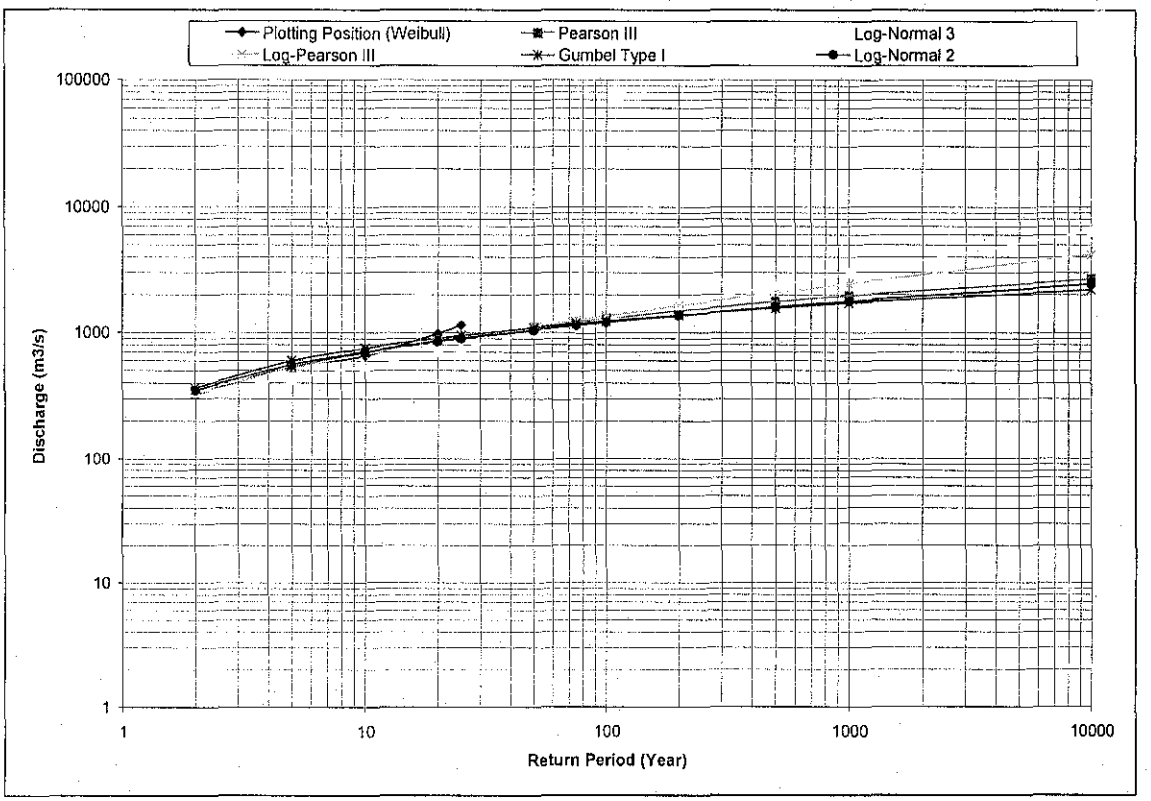
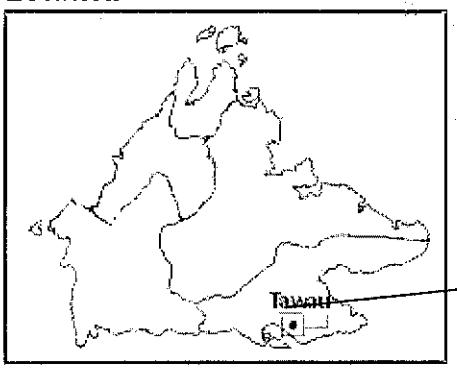
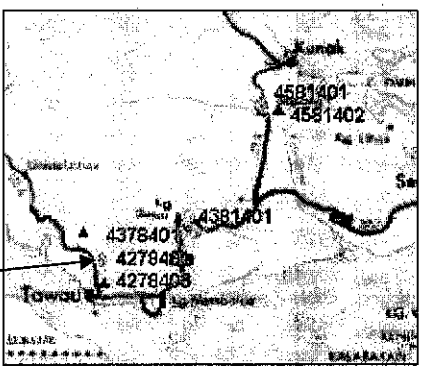


Figure C-32: Frequency Analysis of Annual Floods in Sg. Pegalan at Ansip (1969-2006)

SUNGAI TAWAU AT KUHARA

Location





Description by DID, SABAH

Not Available

Summary of Data

Name	Sungai Tawau at Kuhara
Area (km^2):	104
Elevation (m):	-
Average Rainfall (mm)	-
Water Use	
Total Mean yearly (m^3/s):	3.28
Mean of "Min"s yearly (m^3/s)	1.03
Mean of "Max"s yearly (m^3/s):	27.02
Absolute Min, yearly (m^3/s):	0.13
Absolute Max yearly (m^3/s):	62.30
Source:	Softcopy Streamflow Data 1969-2006, DID, Sabah, Malaysia

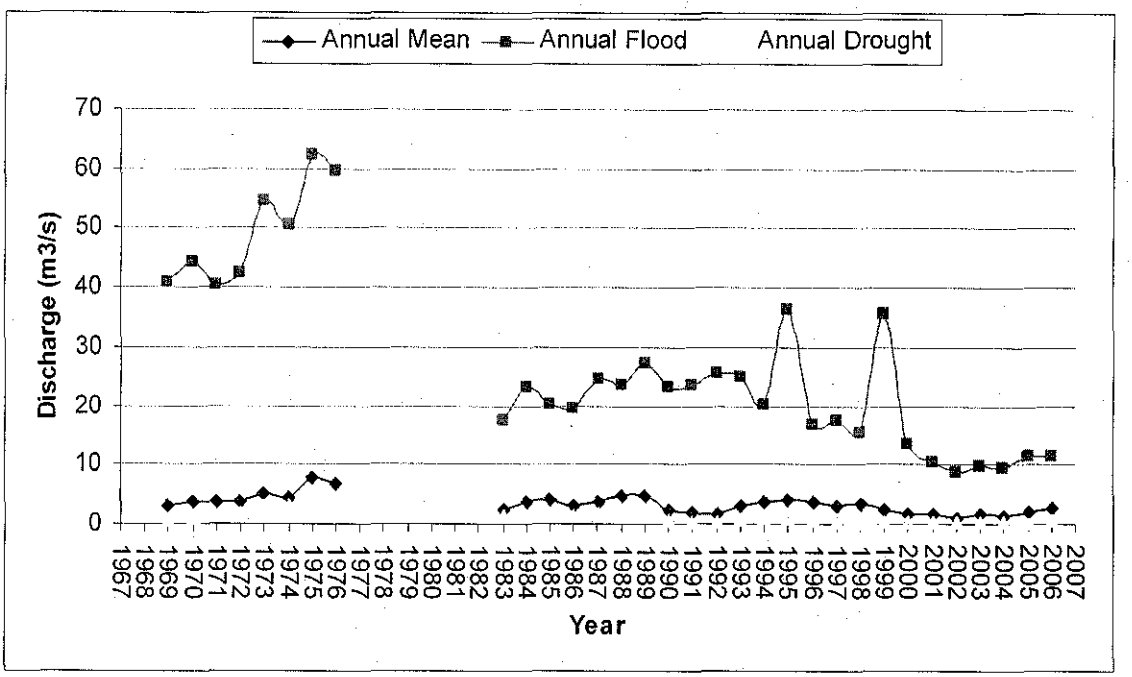


Figure C-33: Annual Discharge of Sg. Tawau at Kuhara (1969-2006)

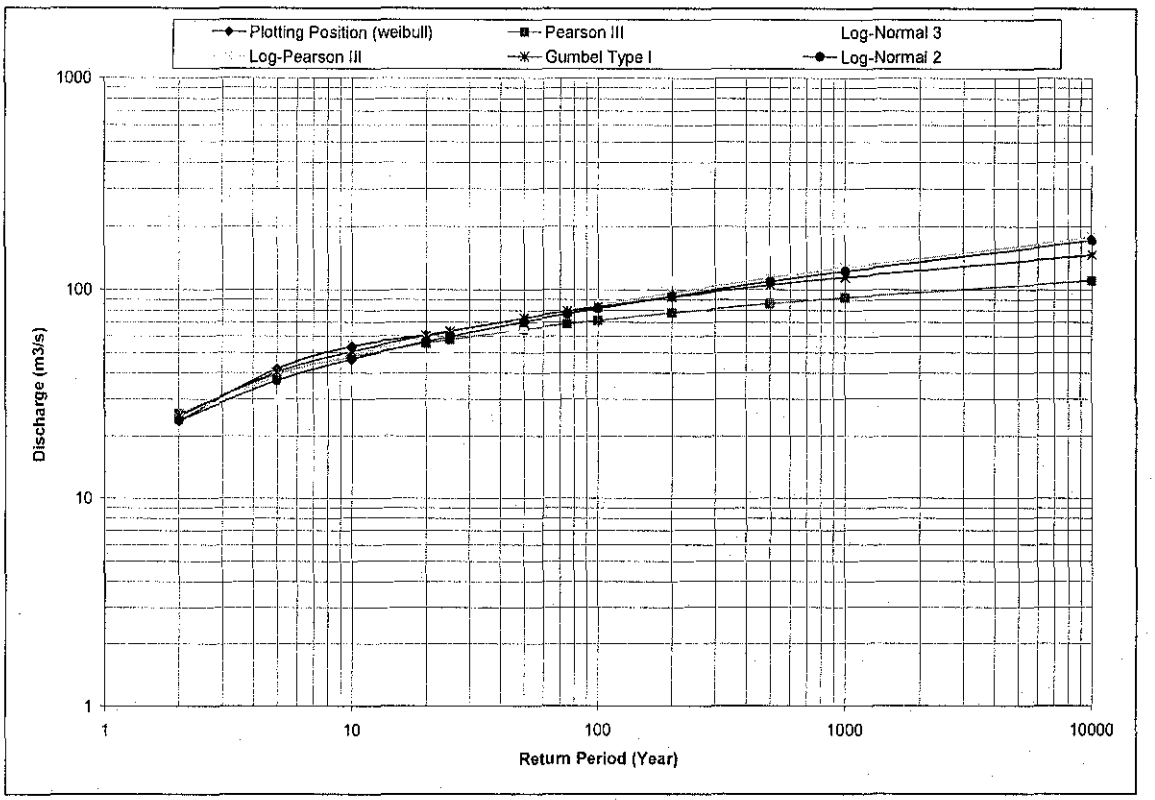
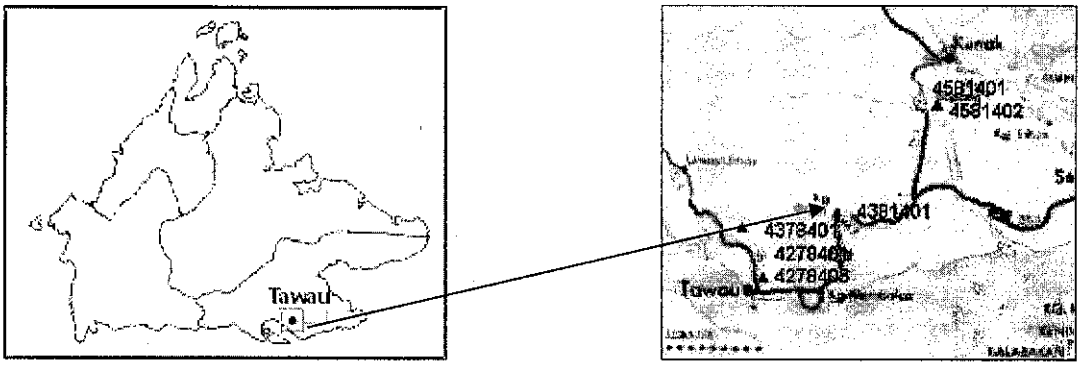


Figure C-34: Frequency Analysis of Annual Floods in Sg. Tawau at Kuhara (1969-2006)

SUNGAI BALUNG AT BALUNG BRIDGE

Location



Description by DID, SABAH

Not Available

Summary of Data

Name	Sungai Balung at Balung Bridge
Area (km^2):	2175
Elevation (m):	230
Average Rainfall (mm)	
Water Use	0.86 Ml/day 1.30 Ml/day
Total Mean yearly (m^3/s):	3.93
Mean of "Min"s yearly (m^3/s)	0.52
Mean of "Max"s yearly (m^3/s):	83.48
Absolute Min, yearly (m^3/s):	0.06
Absolute Max yearly (m^3/s):	213.19
Source:	Softcopy Streamflow Data 1969-2006, DID, Sabah, Malaysia

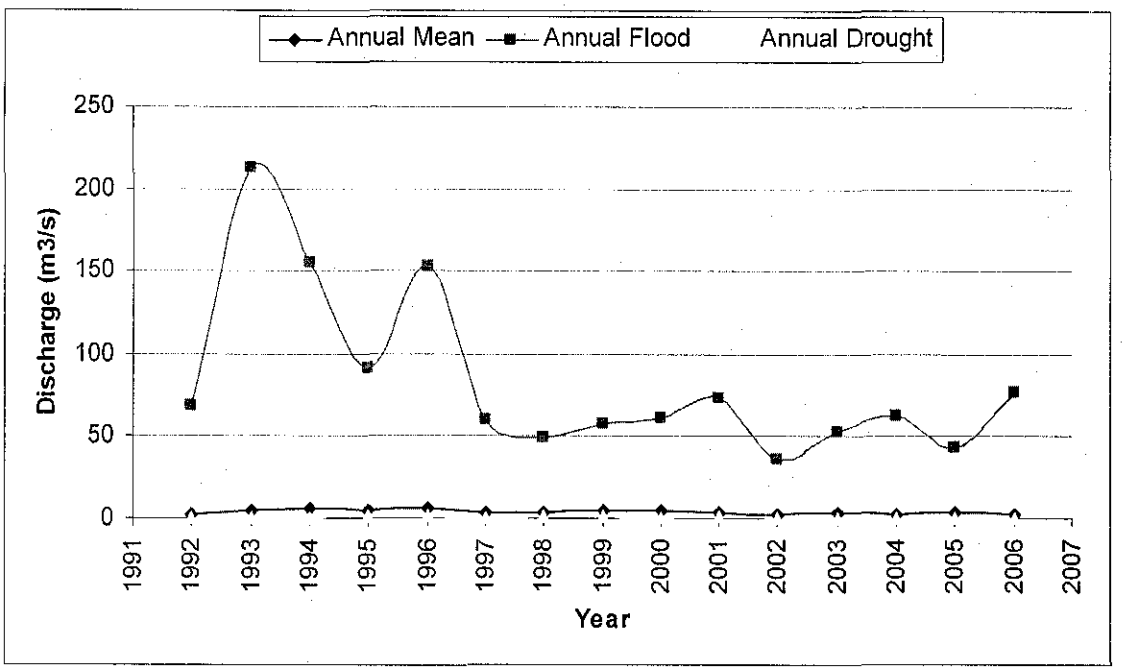


Figure C-35: Annual Discharge of Sg. Balung at Balung Bridge (1992-2006)

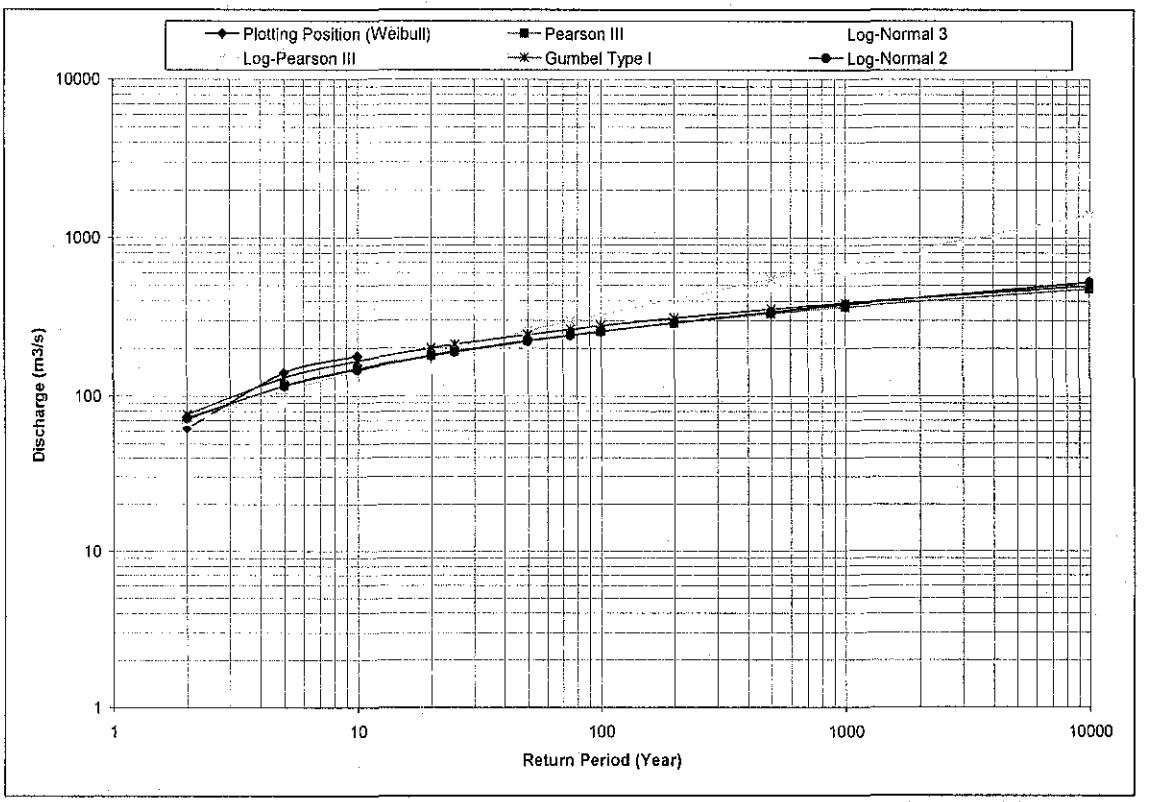
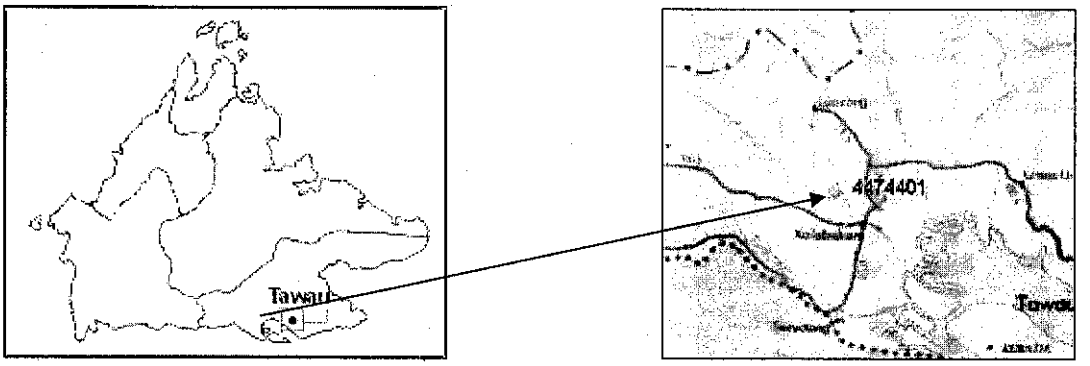


Figure C-36: Frequency Analysis of Annual Floods in Sg. Balung at Balung Bridge (1992-2006)

SUNGAI KALABAKAN AT KALABAKAN

Location



Description by DID, SABAH

Not Available

Summary of Data

Name	Sungai Kalabakan at Kalabakan
Area (km^2):	1150
Elevation (m):	-
Average Rainfall (mm)	
Water Use	
Total Mean yearly (m^3/s):	32.63
Mean of "Min"s yearly (m^3/s)	1.69
Mean of "Max"s yearly (m^3/s):	695.56
Absolute Min, yearly (m^3/s):	0.53
Absolute Max yearly (m^3/s):	1401.2
Source:	Softcopy Streamflow Data 1969-2006, DID, Sabah, Malaysia

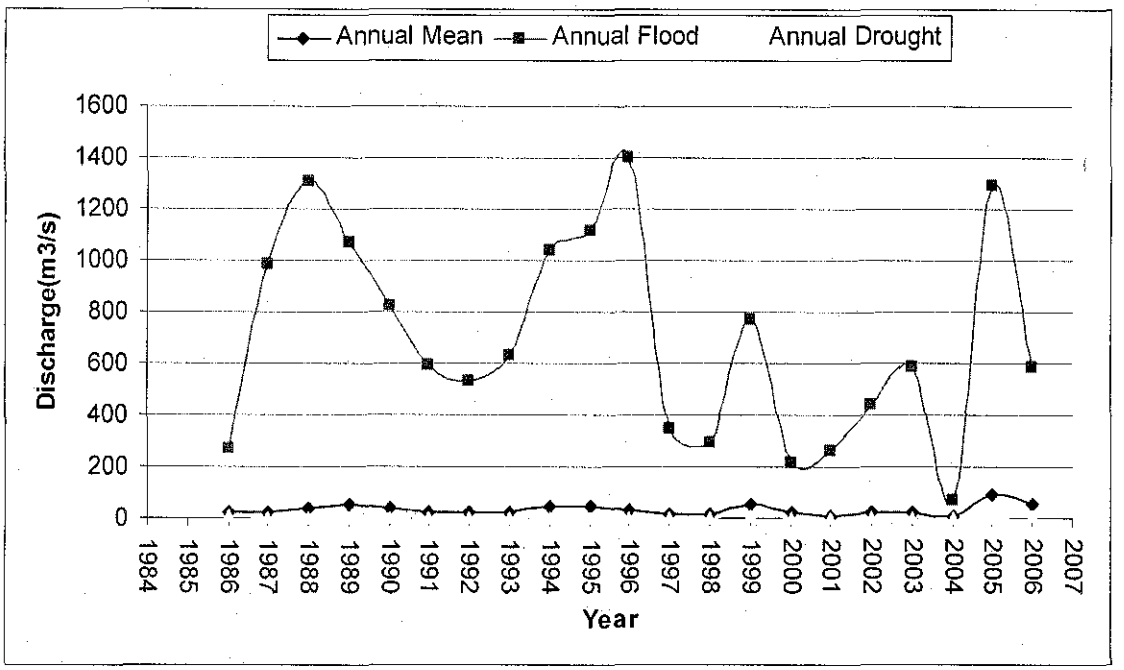


Figure C-37: Annual Discharge of Sg. Kalabakan at Kalabakan (1986-2006)

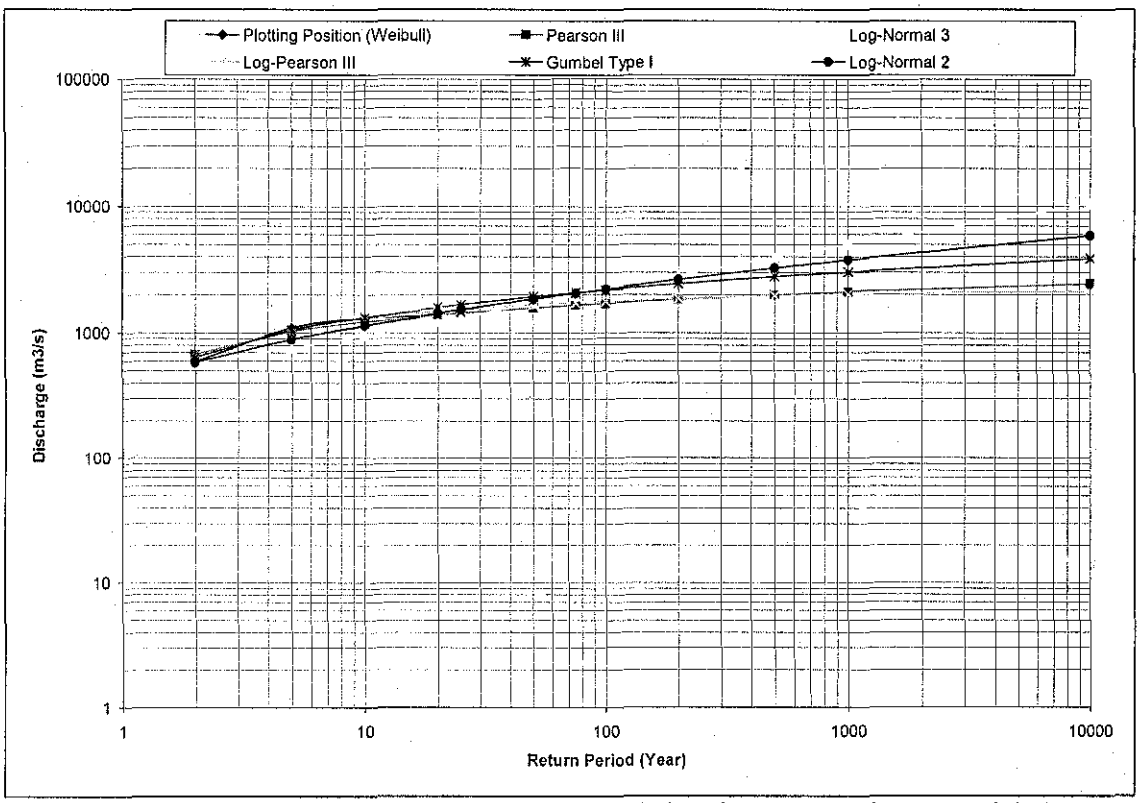
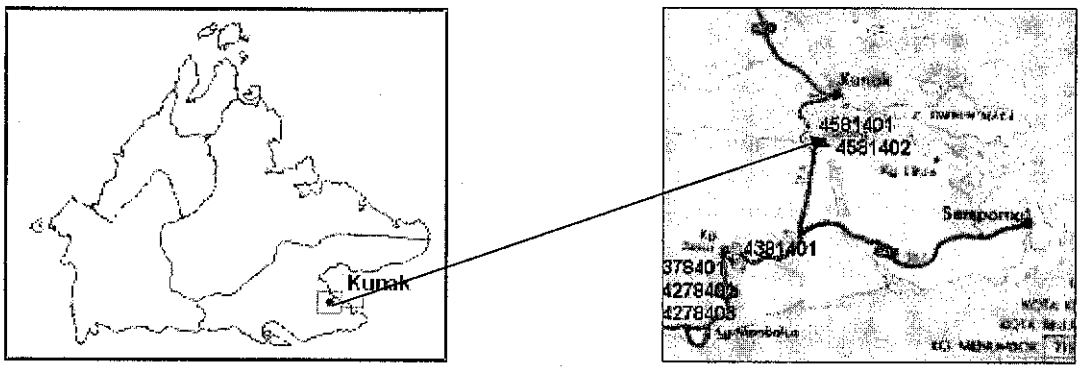


Figure C-38: Frequency Analysis of Annual Floods in of Sg. Kalabakan at Kalabakan (1986-2006)

SUNGAI KALUMPANG AT MOSTYN BRIDGE

Location



Description by DID, SABAH

Not Available

Summary of Data

Name	Sungai Kalumpang at Mostyn Bridge
Area (km^2):	565
Elevation (m):	-
Average Rainfall (mm)	
Water Use	
Total Mean yearly (m^3/s):	22.37
Mean of "Min"s yearly (m^3/s)	4.02
Mean of "Max"s yearly (m^3/s):	681.78
Absolute Min, yearly (m^3/s):	0.1
Absolute Max yearly (m^3/s):	1820.1
Source:	Softcopy Streamflow Data 1969-2006, DID, Sabah, Malaysia

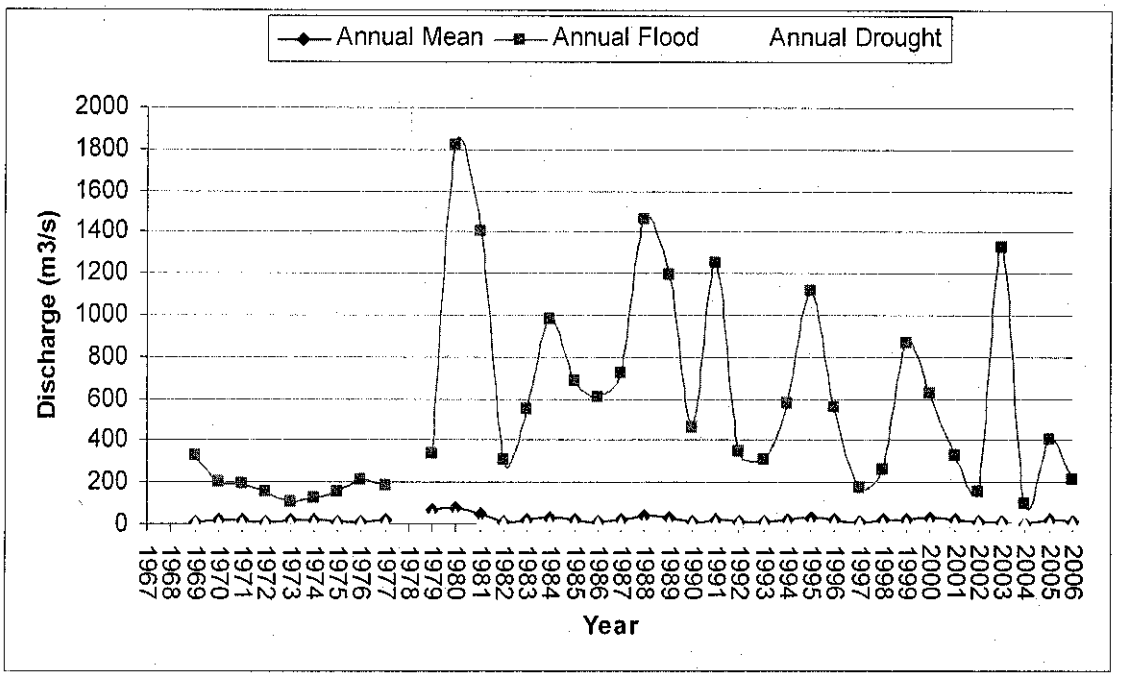


Figure C-39: Annual Discharge of Sg. Kalumpang at Mostyn Bridge (1969-2006)

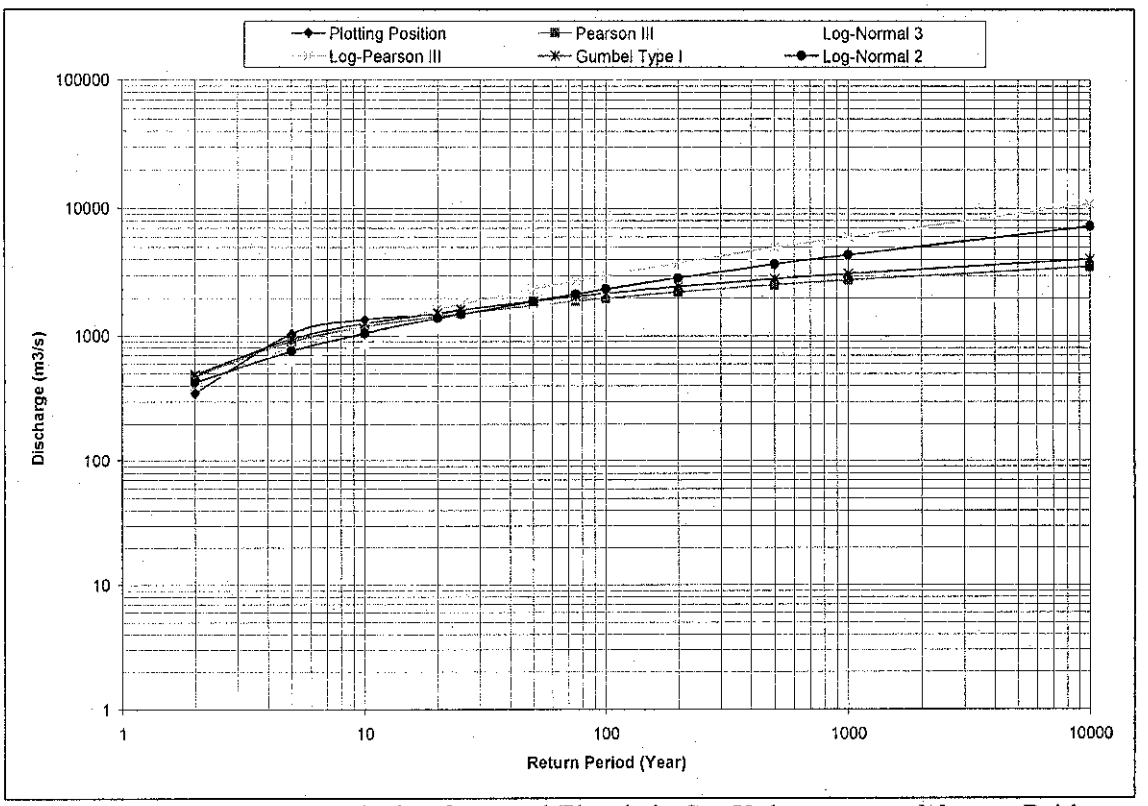
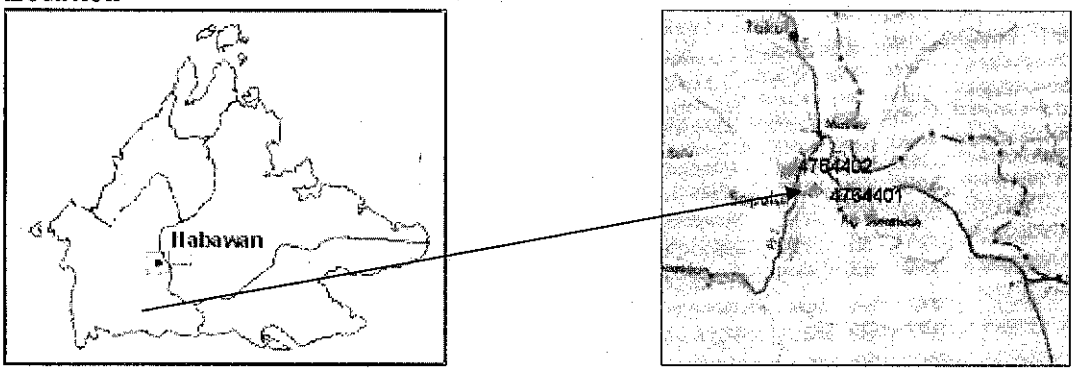


Figure c-40: Frequency Analysis of Annual Floods in Sg. Kalumpang at Mostyn Bridge (1969-2006)

SUNGAI SAPULUT AT SAPULUT

Location



Description by DID, SABAH

Not Available

Summary of Data

Name	Sungai Sapulut at Sapulut
Area (km^2):	2599
Elevation (m):	-
Average Rainfall (mm)	
Water Use	
Total Mean yearly (m^3/s):	76.67
Mean of "Min"s yearly (m^3/s)	11.78
Mean of "Max"s yearly (m^3/s):	900.31
Absolute Min, yearly (m^3/s):	4.89
Absolute Max yearly (m^3/s):	1836.6
Source:	Softcopy Streamflow Data 1969-2006, DID, Sabah, Malaysia

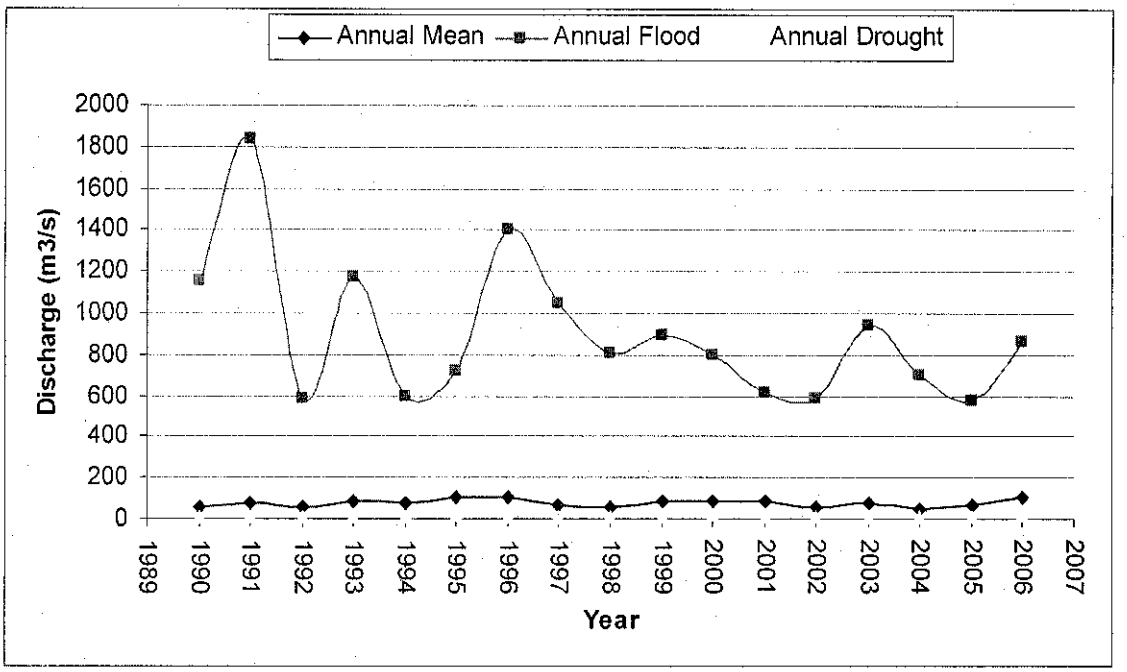


Figure C-41: Annual Discharge of Sg. Sapulut at Sapulut (1990-2006)

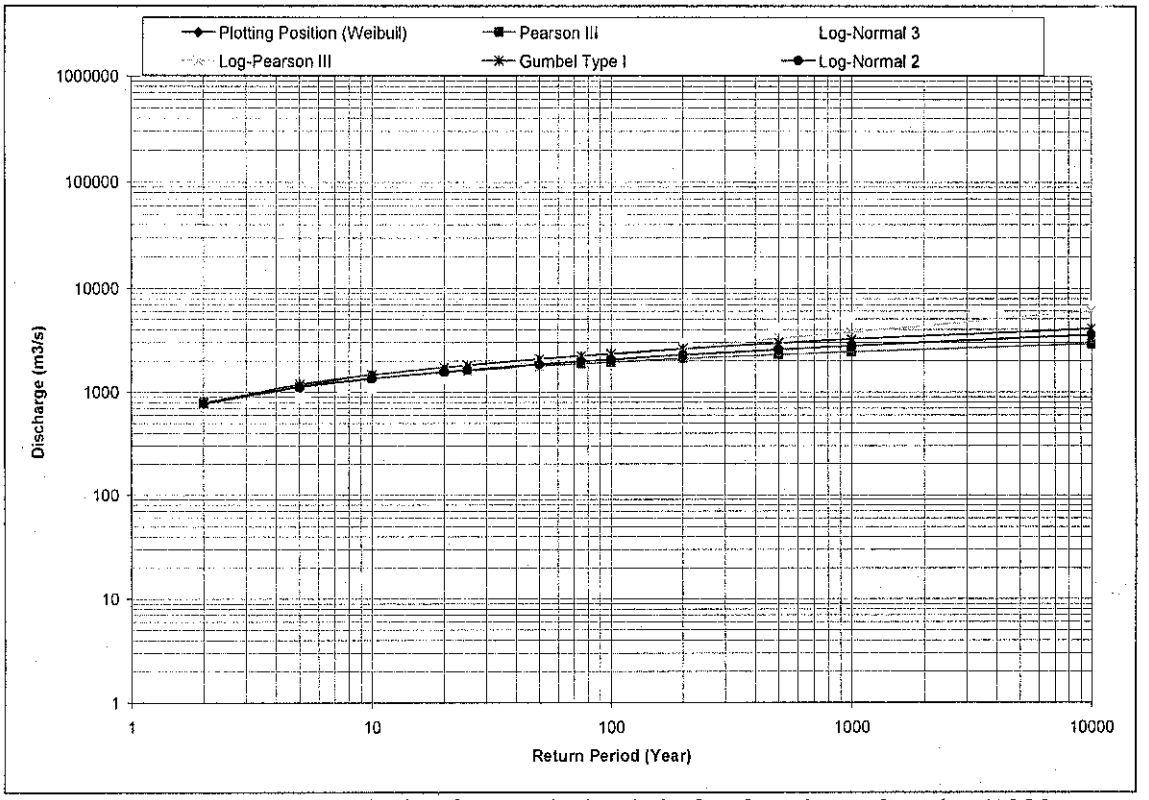
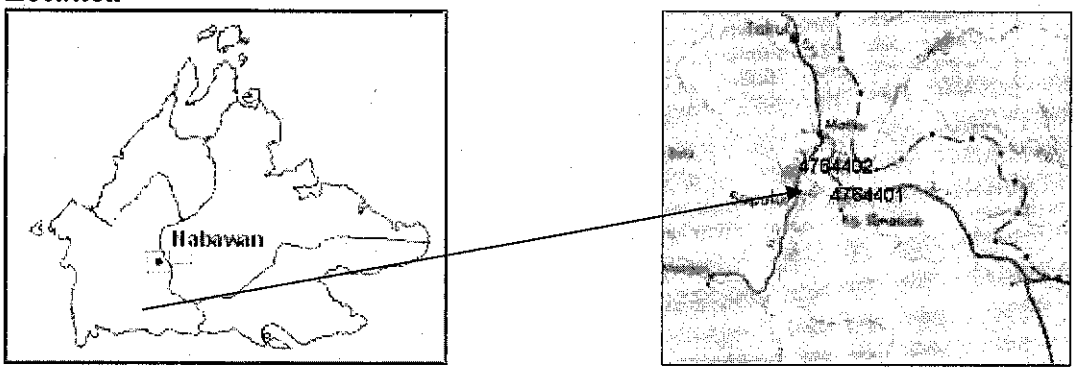


Figure C-42: Frequency Analysis of Annual Floods in Sg. Sapulut at Sapulut (1990-2006)

SUNGAI TALANKAI AT LOTONG

Location



Description by DID, SABAH

Not Available

Summary of Data

Name	Sungai Talankai at Lotong
Area (km^2):	652
Elevation (m):	-
Average Rainfall (mm)	
Water Use	
Total Mean yearly (m^3/s):	21.48
Mean of "Min"s yearly (m^3/s)	4.19
Mean of "Max"s yearly (m^3/s):	349.72
Absolute Min, yearly (m^3/s):	0.75
Absolute Max yearly (m^3/s):	581.78
Source:	Softcopy Streamflow Data 1969-2006, DID, Sabah, Malaysia

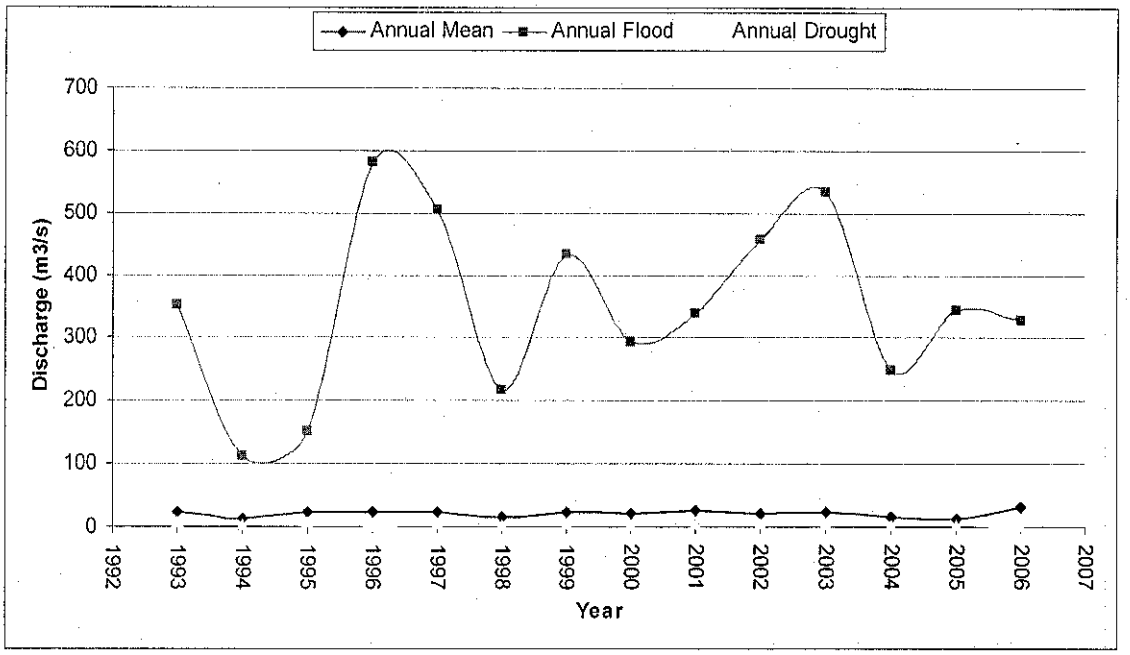


Figure C-43: Annual Discharge of Sg. Talankai at Lotong (1993-2006)

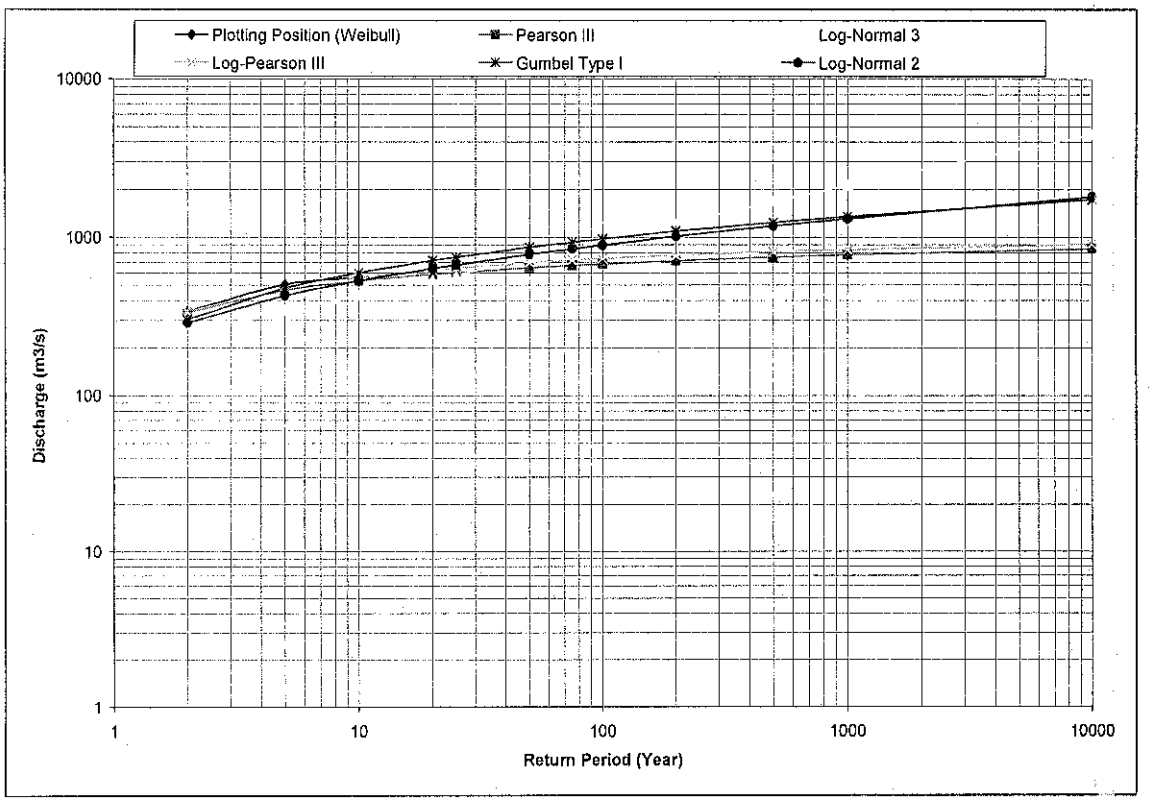
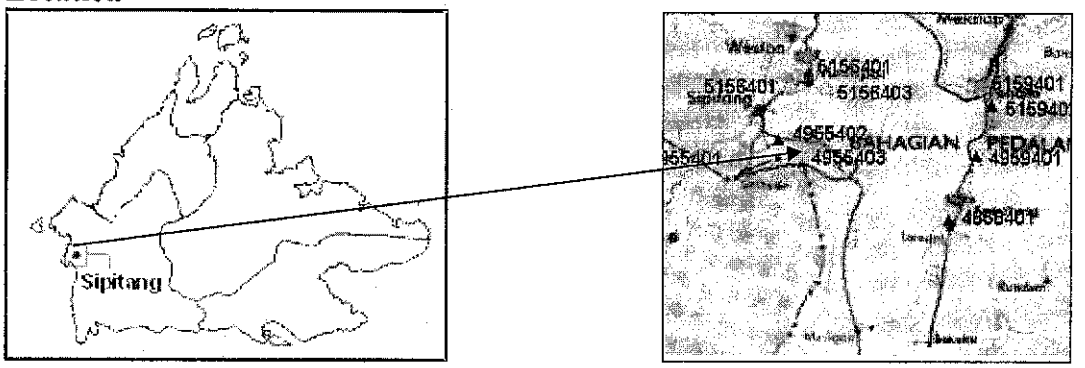


Figure C-44: Frequency Analysis of Annual Floods in Sg. Talankai at Lotong (1993-2006)

SUNGAI MENGALONG AT SINDUMIN

Location



Description by DID, SABAH

Not Available

Summary of Data

Name	Sungai Mengalong at Sindumin
Area (km^2):	472
Elevation (m):	-
Average Rainfall (mm)	
Water Use	
Total Mean yearly (m^3/s):	27.21
Mean of "Min"s yearly (m^3/s)	2.2
Mean of "Max"s yearly (m^3/s):	552.35
Absolute Min, yearly (m^3/s):	0.14
Absolute Max yearly (m^3/s):	889.98
Source:	Softcopy Streamflow Data 1969-2006, DID, Sabah, Malaysia

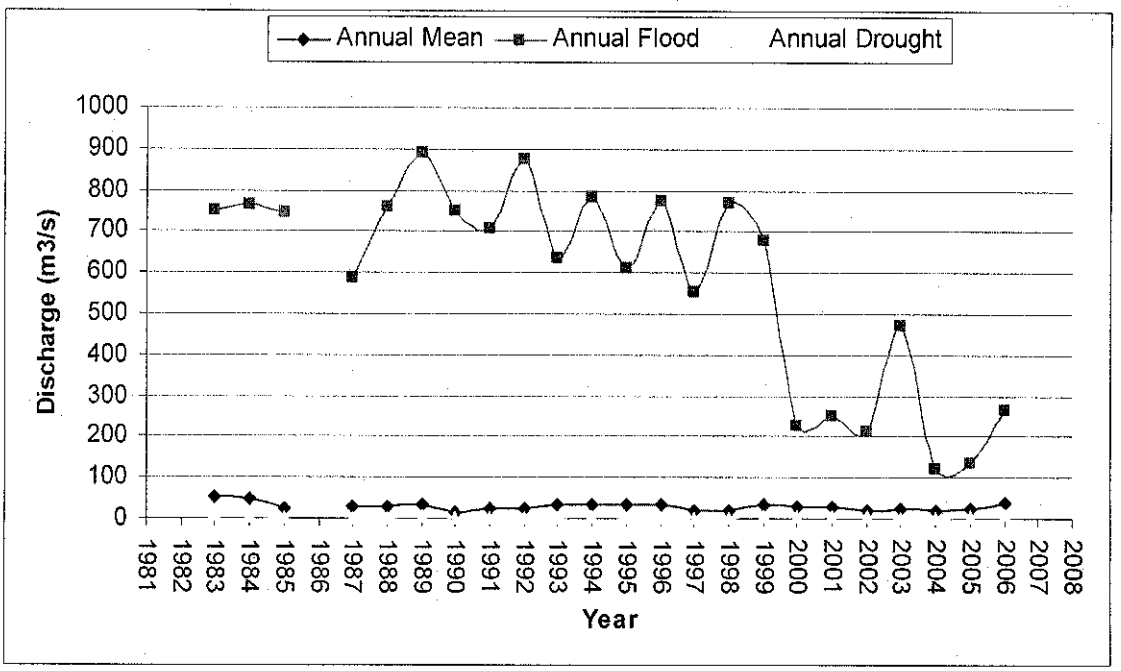


Figure C-45: Annual Discharge of Sg. Mengalong at Sindumin (1982-2006)

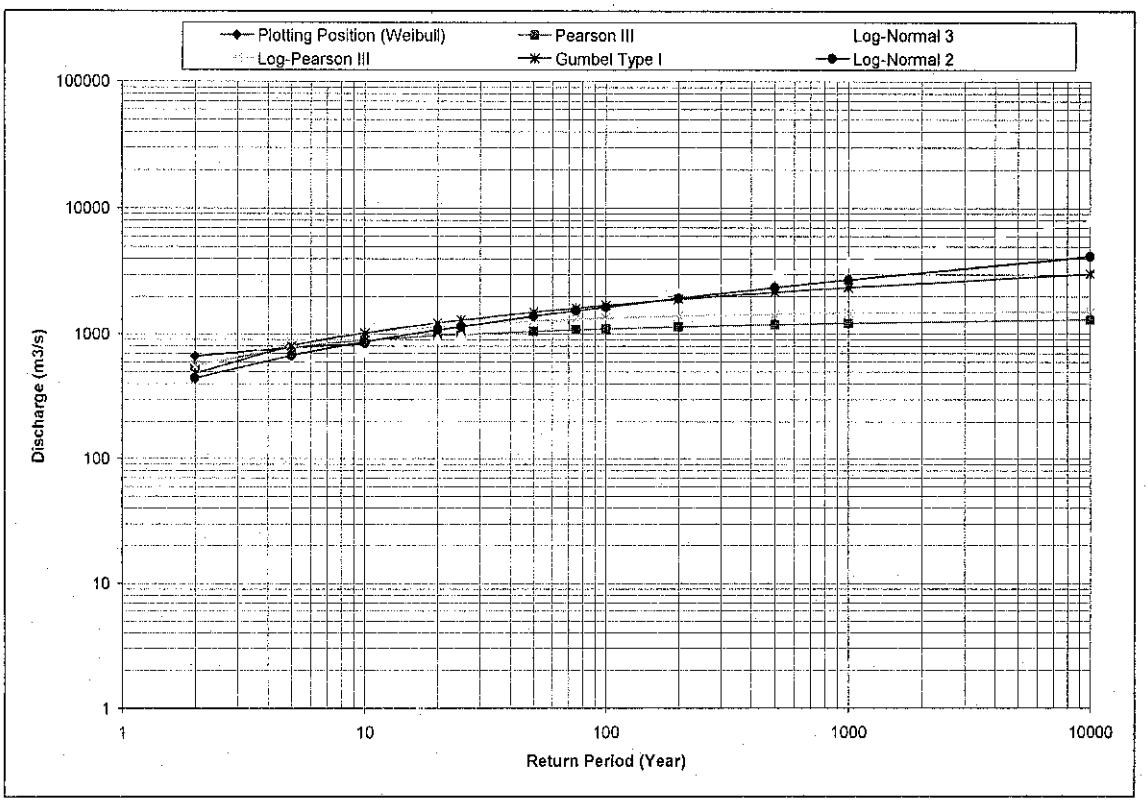
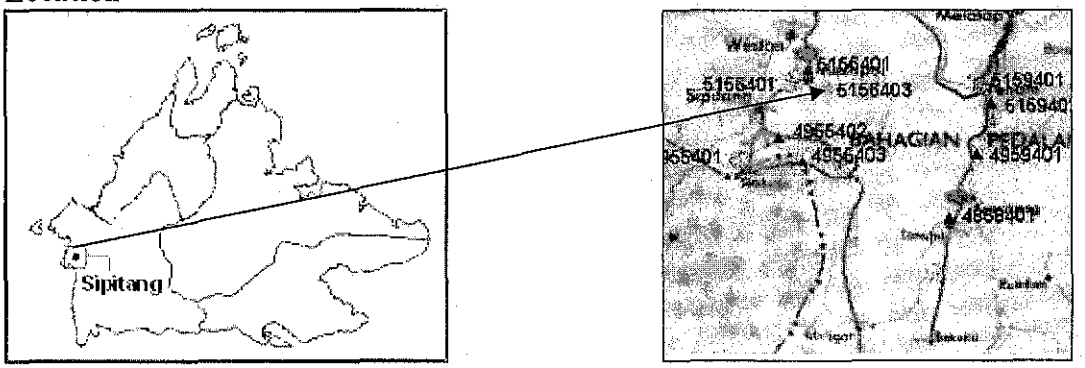


Figure C-46: Frequency Analysis of Annual Floods in Sg. Mengalong at Sindumin (1982-2006)

SUNGAI LAKUTAN AT MESAPOL

Location



Description by DID, SABAH

Not Available

Summary of Data

Name	Sungai Lakutan at Mesapol
Area (km^2):	173
Elevation (m):	-
Average Rainfall (mm)	
Water Use	
Total Mean yearly (m^3/s):	9.45
Mean of "Min"s yearly (m^3/s)	1.08
Mean of "Max"s yearly (m^3/s):	434.62
Absolute Min, yearly (m^3/s):	0.2
Absolute Max yearly (m^3/s):	1388.3
Source:	Softcopy Streamflow Data 1969-2006, DID, Sabah, Malaysia

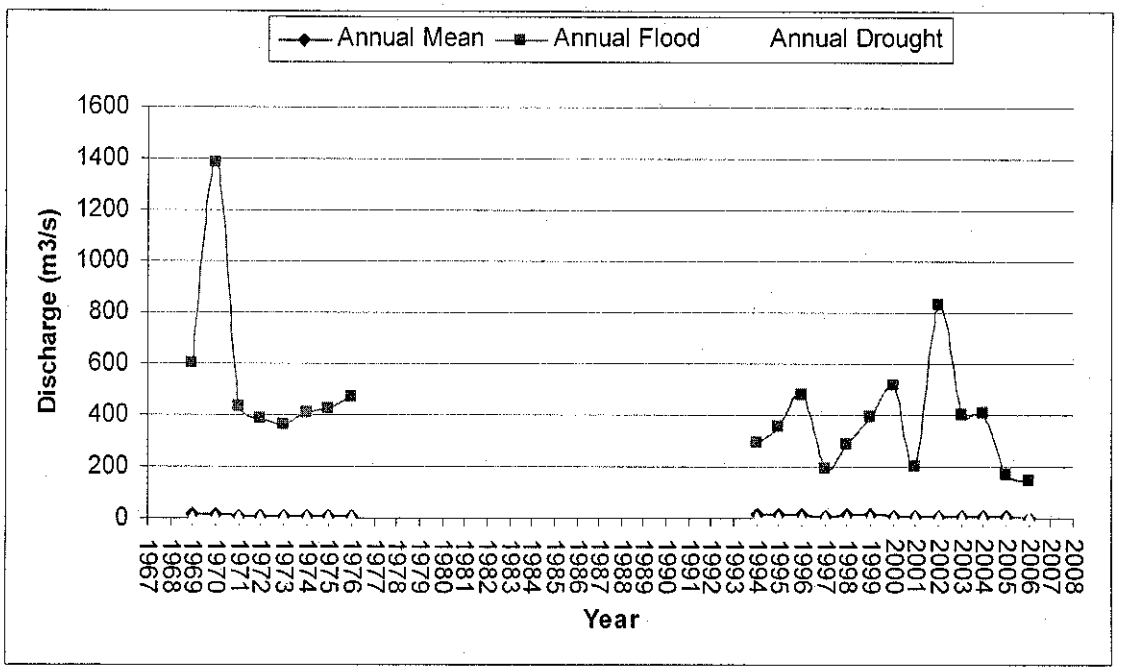


Figure C-47: Annual Discharge of Sg. Lakutan at Mesapol (1969-2006)

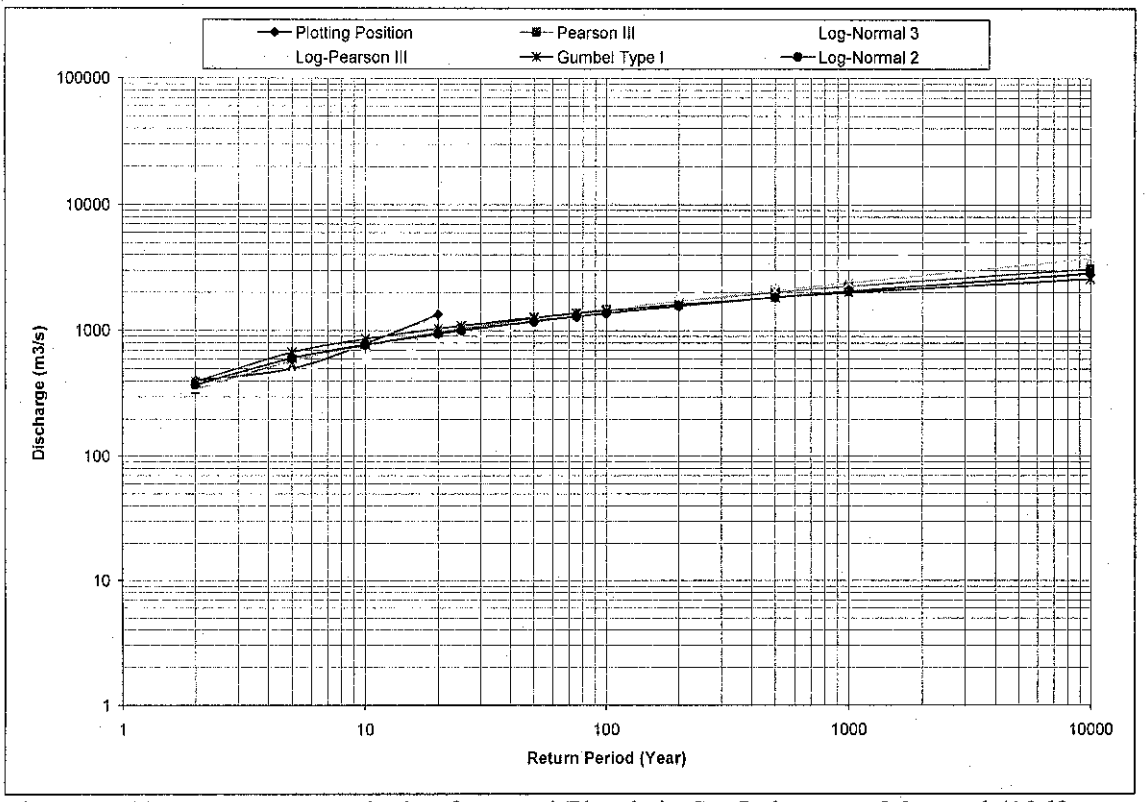
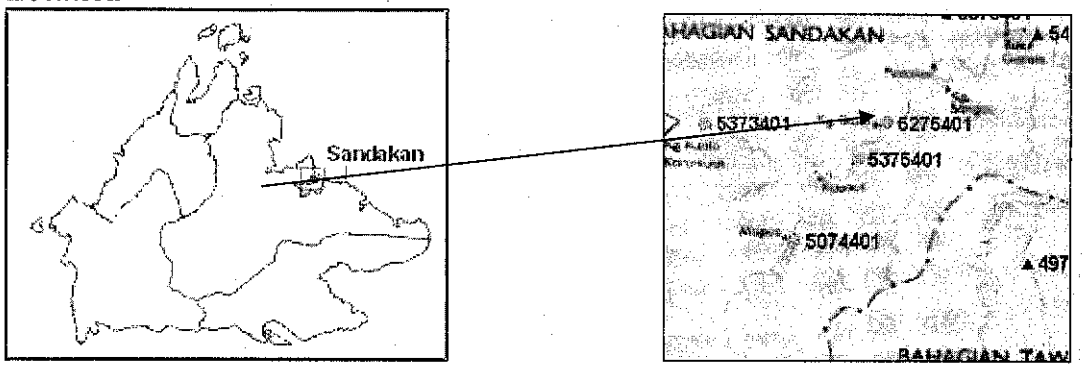


Figure C-48: Frequency Analysis of Annual Floods in Sg. Lakutan at Mesapol (1969-2006)

SUNGAI KINABATANGAN AT PAGAR

Location



Description by DID, SABAH

Not Available

Summary of Data

Name	Sungai Kinabatangan at Pagar
Area (km^2):	9430
Elevation (m):	-
Average Rainfall (mm)	
Water Use	
Total Mean yearly (m^3/s):	352.41
Mean of "Min"s yearly (m^3/s)	35.64
Mean of "Max"s yearly (m^3/s):	1510.87
Absolute Min, yearly (m^3/s):	4.25
Absolute Max yearly (m^3/s):	2004
Source:	Softcopy Streamflow Data 1969-2006, DID, Sabah, Malaysia

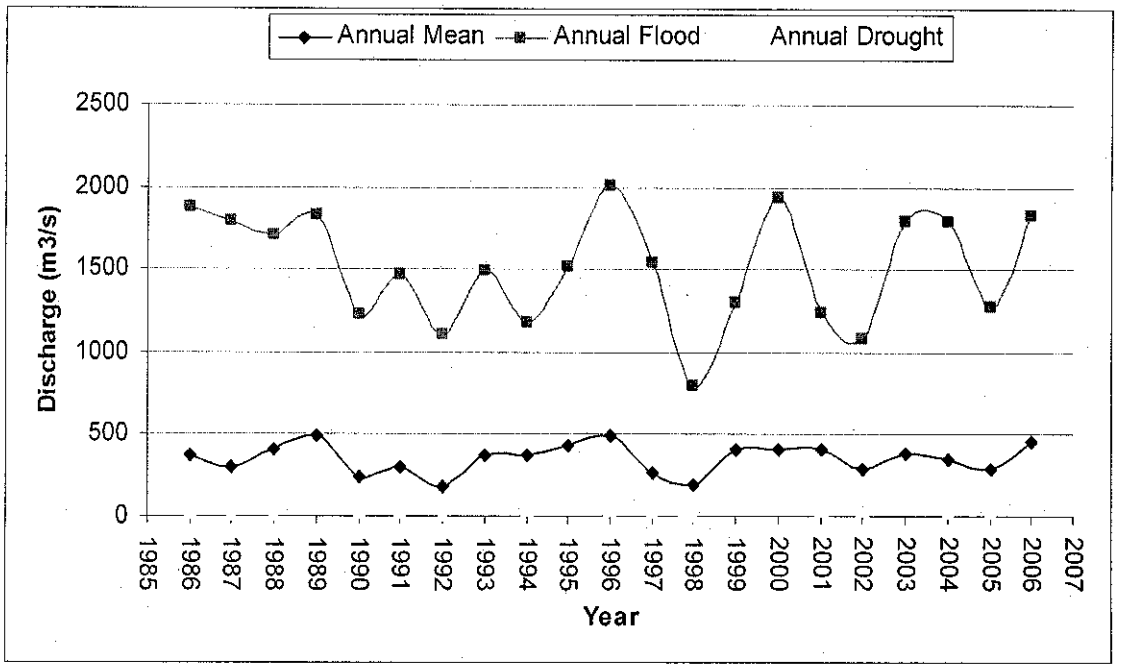


Figure C-49: Annual Discharge of Sg. Kinabatangan at Balat (1986-2006)

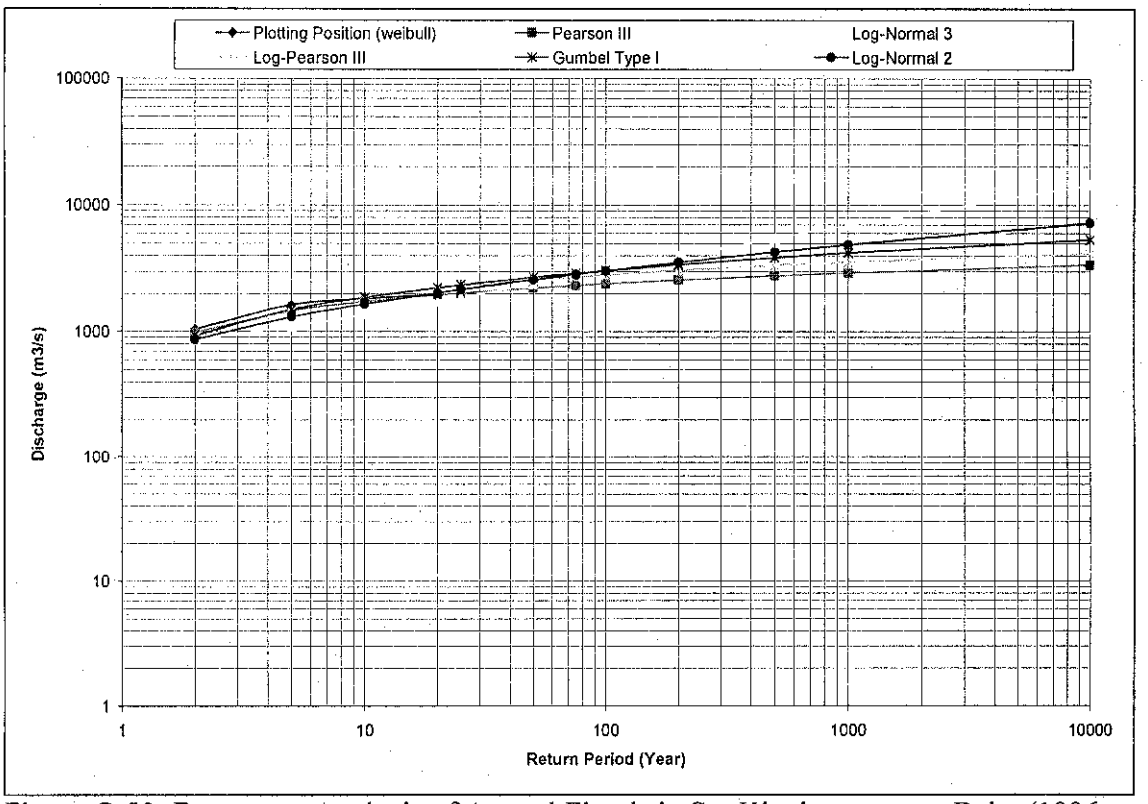
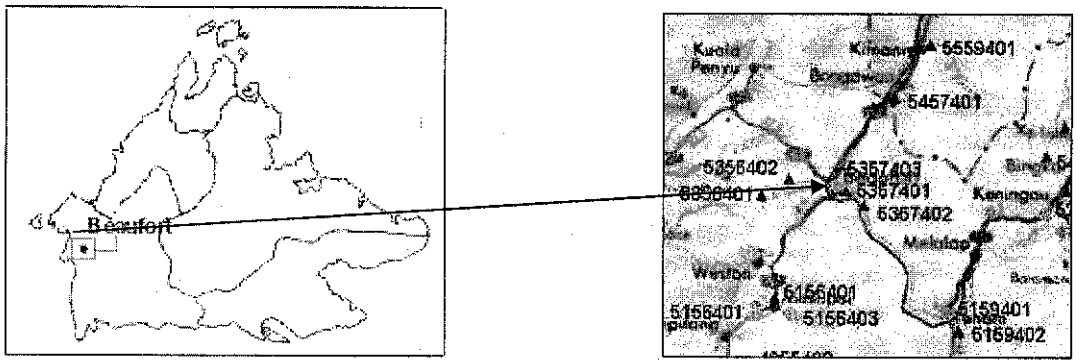


Figure C-50: Frequency Analysis of Annual Floods in Sg. Kinabatangan at Balat (1986-2006

SUNGAI PADAS AT BEAUFORT JPS

Location



Description by DID, SABAH

Not Available

Summary of Data

Name	Sungai Padas at Beaufort JPS
Area (km^2):	8500
Elevation (m):	-
Average Rainfall (mm)	
Water Use	
Total Mean yearly (m^3/s):	220.43
Mean of "Min"s yearly (m^3/s)	24.13
Mean of "Max"s yearly (m^3/s):	960.29
Absolute Min, yearly (m^3/s):	1.04
Absolute Max yearly (m^3/s):	1535.4
Source:	Softcopy Streamflow Data 1969-2006, DID, Sabah, Malaysia

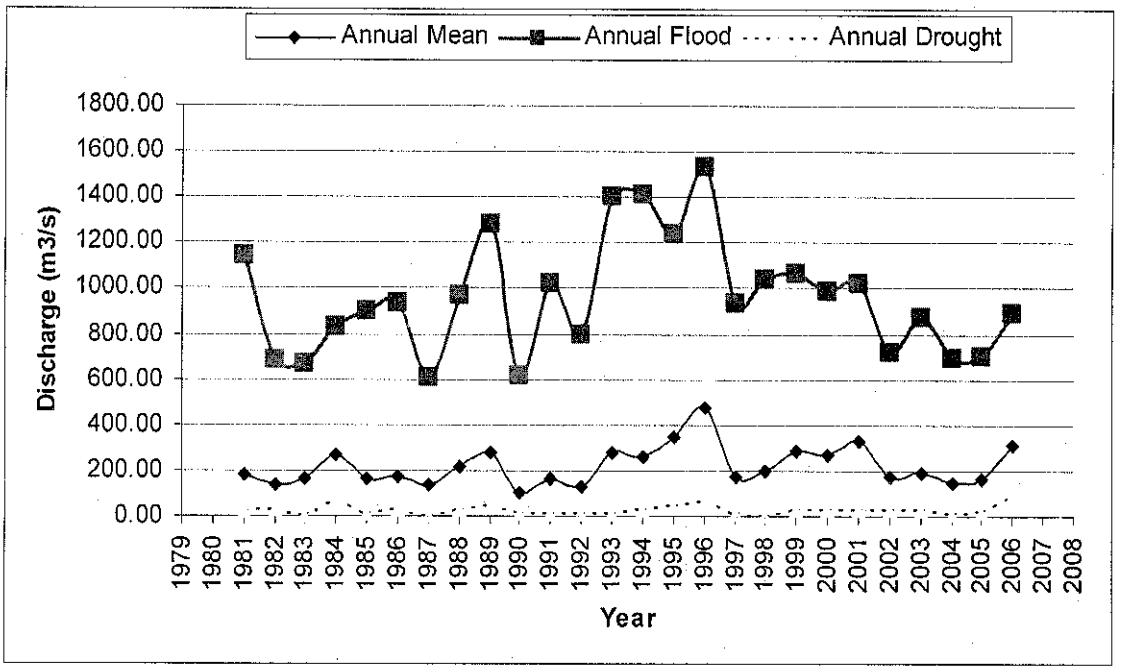


Figure C-51: Annual Discharge of Sg. Padas at Beaufort JPS (1980-2006)

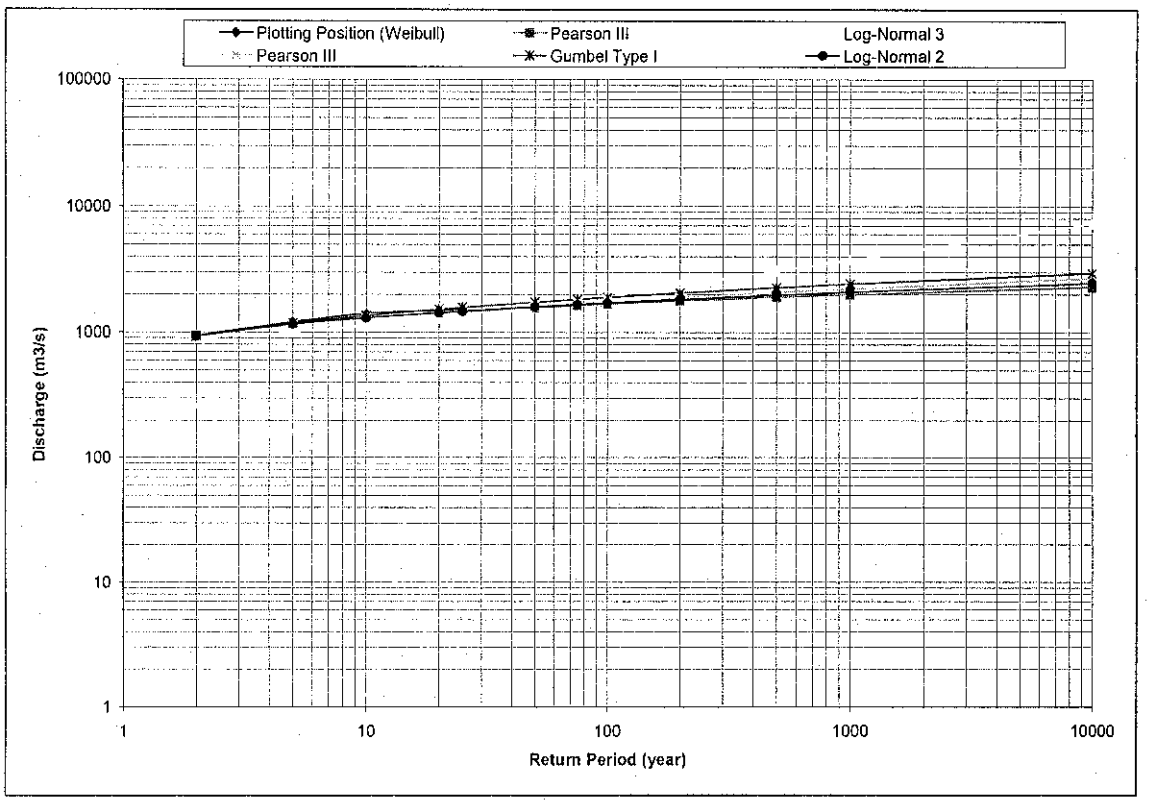
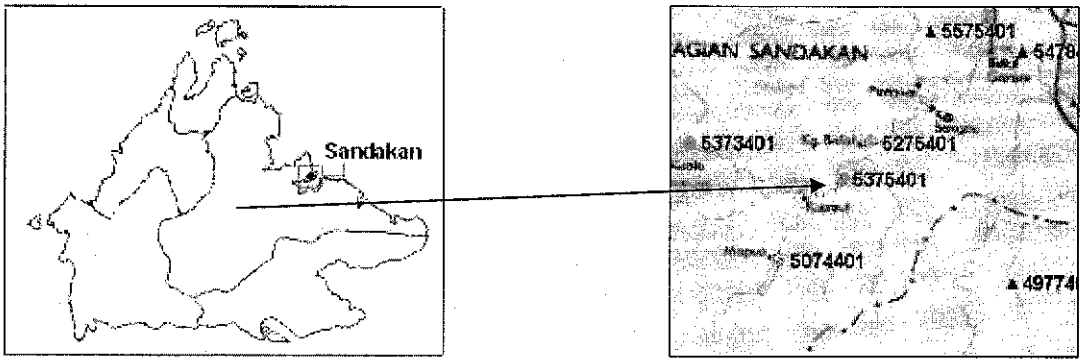


Figure C-52: Frequency Analysis of Annual Floods in Sg. Padas at Beaufort JPS (1980-2006)

SUNGAI KINABATANGAN AT BALAT

Location



Description by DID, SABAH

Not Available

Summary of Data

Name	Sungai Kinabatangan at Balat
Area (km^2):	10800
Elevation (m):	-
Average Rainfall (mm)	
Water Use	
Total Mean yearly (m^3/s):	406.17
Mean of "Min"s yearly (m^3/s)	48.37
Mean of "Max"s yearly (m^3/s):	1681.52
Absolute Min, yearly (m^3/s):	7.49
Absolute Max yearly (m^3/s):	3611.6
Source:	Softcopy Streamflow Data 1969-2006, DID, Sabah, Malaysia

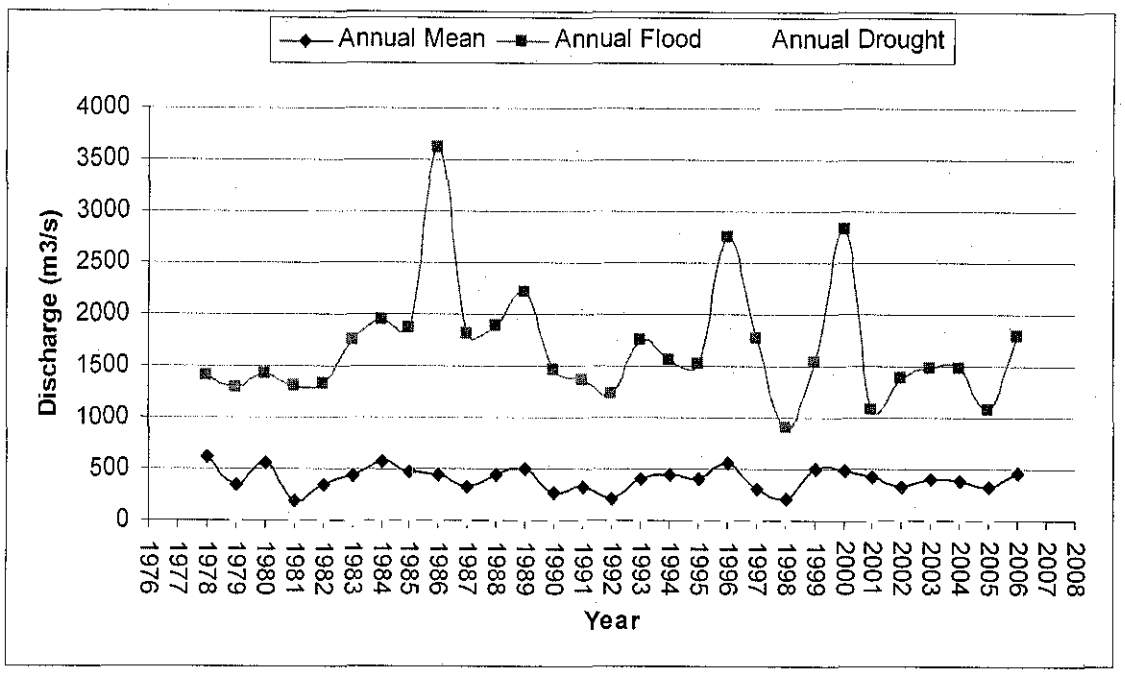


Figure C-53: Annual Discharge of Sg. Kinabatangan at Balat (1978-2006)

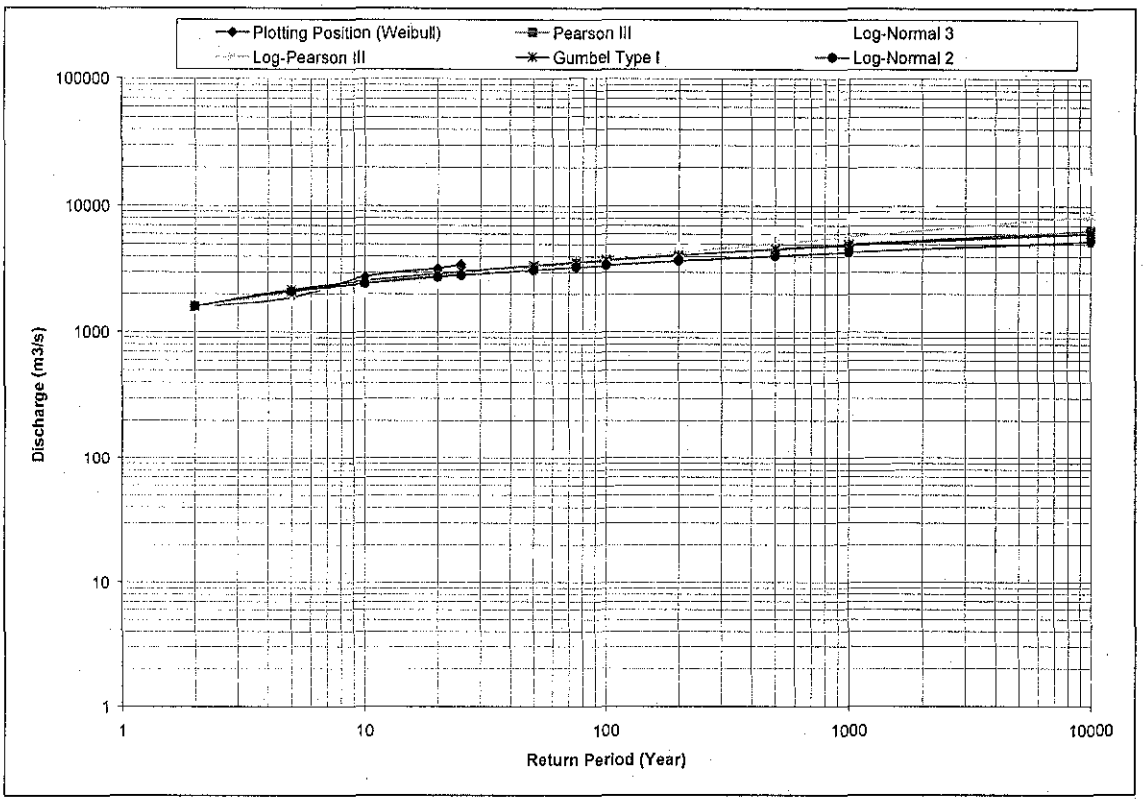
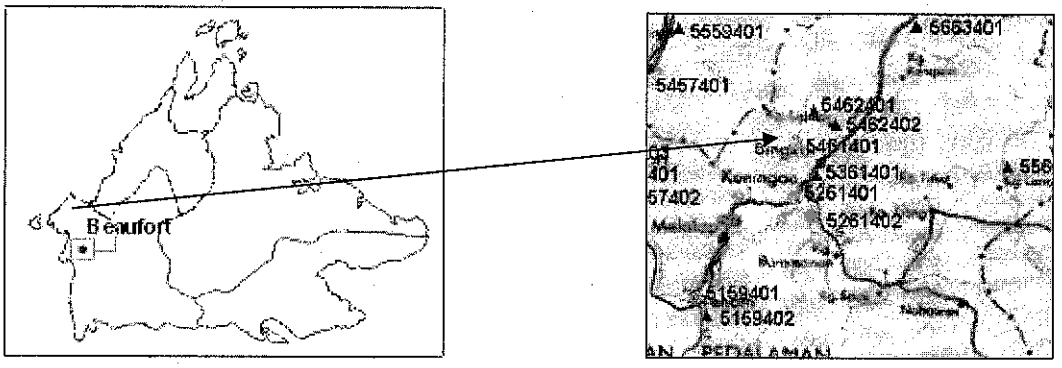


Figure C-54: Frequency Analysis of Annual Floods in Sg. Kinabatangan at Balat (1978-2006)

SUNGAI BAIAYO AT BEDUKAN

Location



Description by DID, SABAH

Not Available

Summary of Data

Name	Sungai Baiayo at Bedukan
Area (km^2):	176
Elevation (m):	-
Average Rainfall (mm)	
Water Use	
Total Mean yearly (m^3/s):	5.95
Mean of "Min"s yearly (m^3/s)	1.48
Mean of "Max"s yearly (m^3/s):	55.15
Absolute Min, yearly (m^3/s):	0.08
Absolute Max yearly (m^3/s):	92.39
Source:	Softcopy Streamflow Data 1969-2006, DID, Sabah, Malaysia

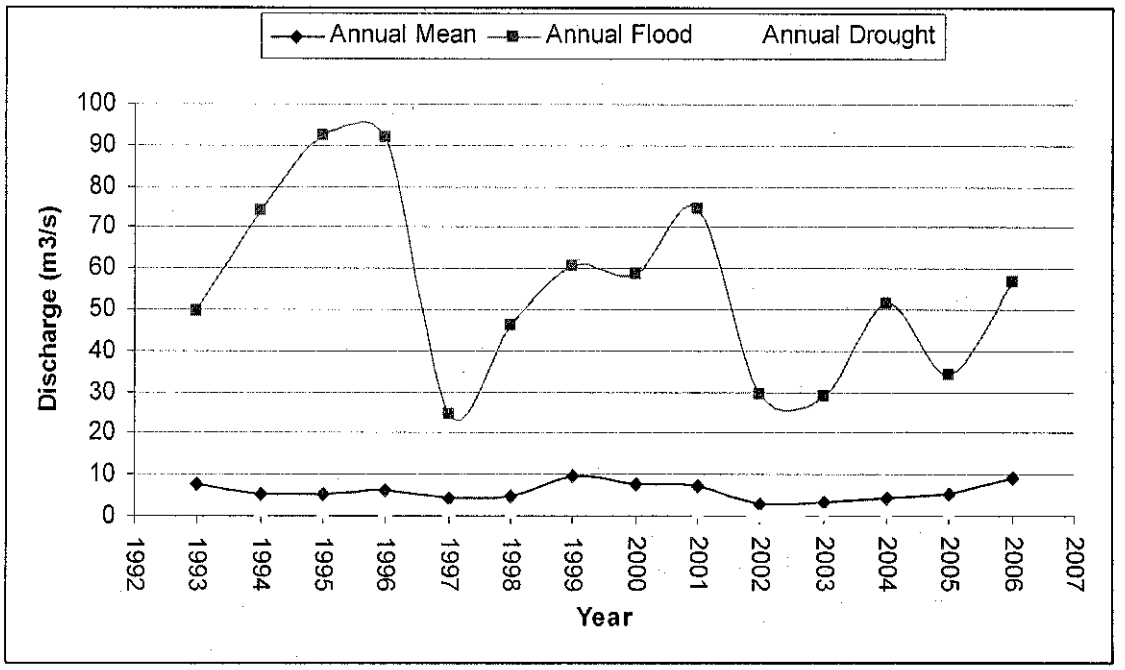


Figure C-55: Annual Discharge of Sg Baiayo at Bedukan (1993-2006)

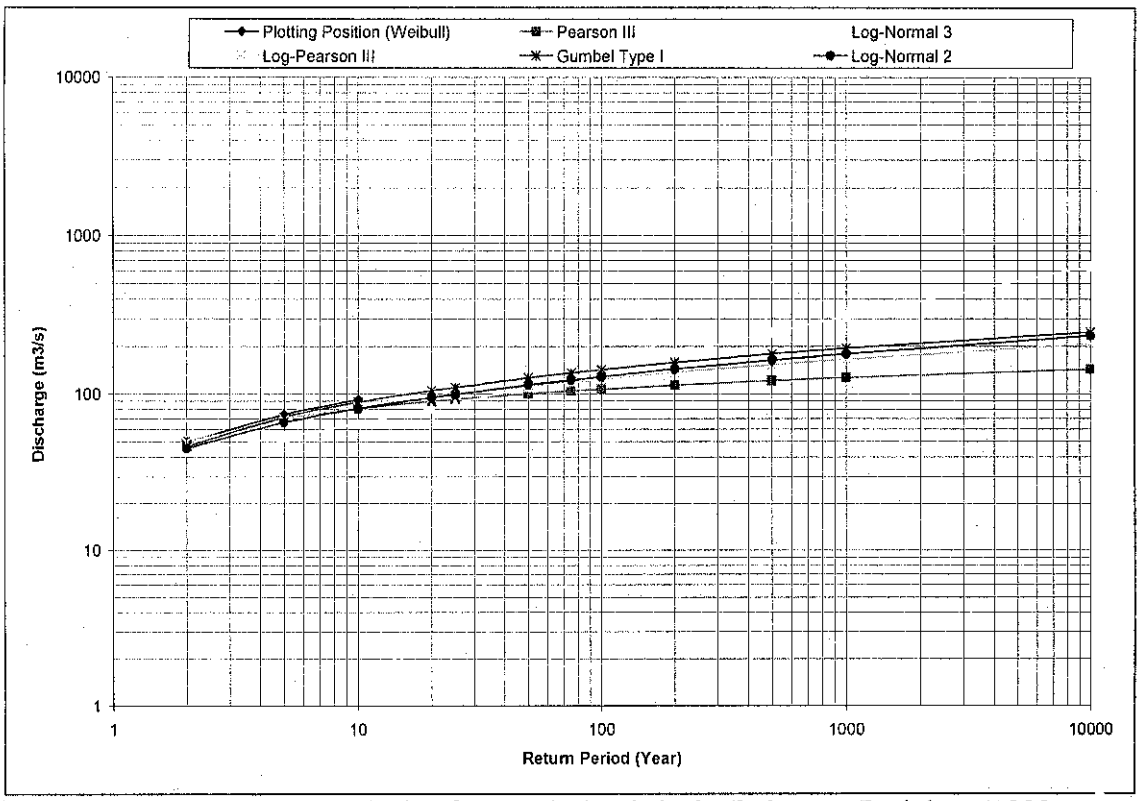
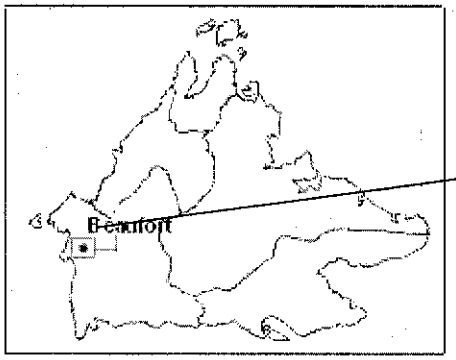
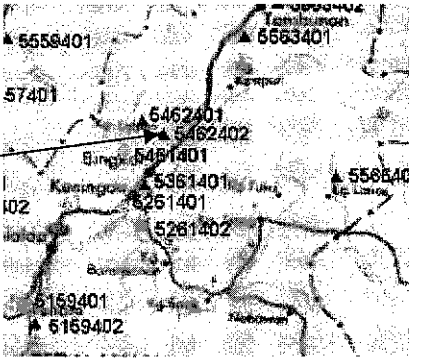


Figure C-56: Frequency Analysis of Annual Floods in Sg Baiayo at Bedukan (1993-2006)

SUNGAI APIN-APIN AT WATERWORKS

Location





Description by DID, SABAH

Not Available

Summary of Data

Name	Sungai Apin-Apin at Waterworks
Area (km^2):	133
Elevation (m):	-
Average Rainfall (mm)	
Water Use	
Total Mean yearly (m^3/s):	4.14
Mean of "Min"s yearly (m^3/s)	0.8
Mean of "Max"s yearly (m^3/s):	89.98
Absolute Min, yearly (m^3/s):	0.22
Absolute Max yearly (m^3/s):	160.62
Source:	Softcopy Streamflow Data 1969-2006, DID, Sabah, Malaysia

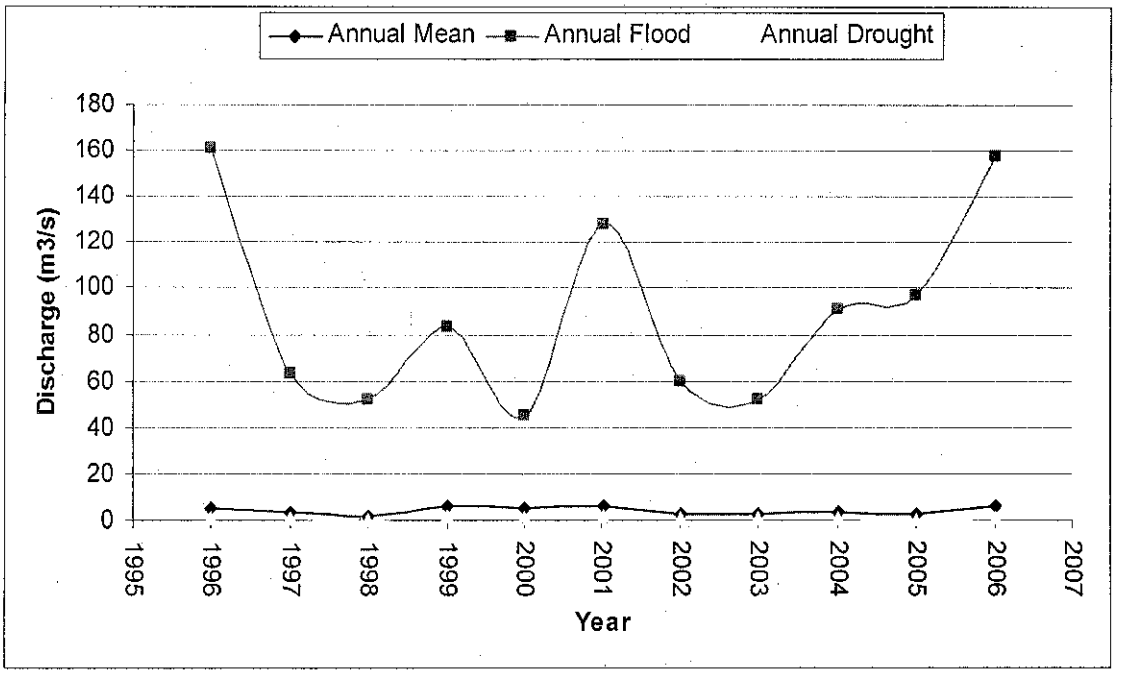


Figure C-57 : Annual Discharge of Sg. Apin-Apin at Waterworks (1996-2006)

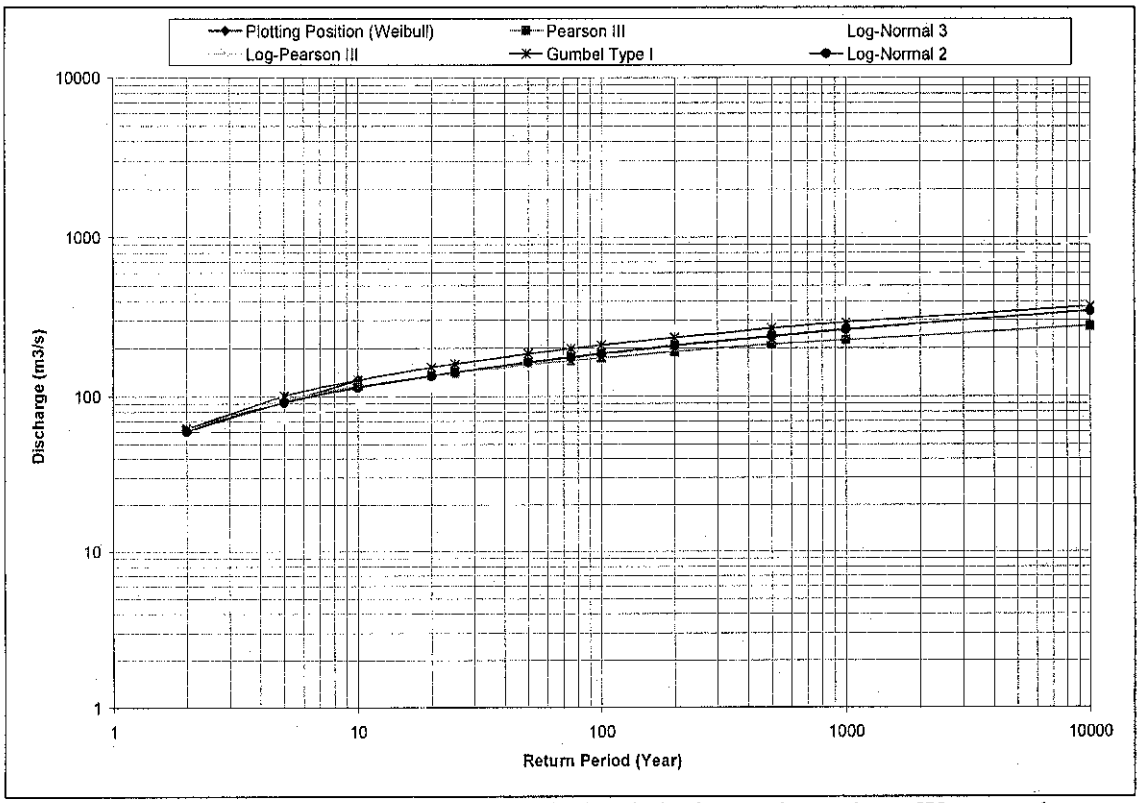
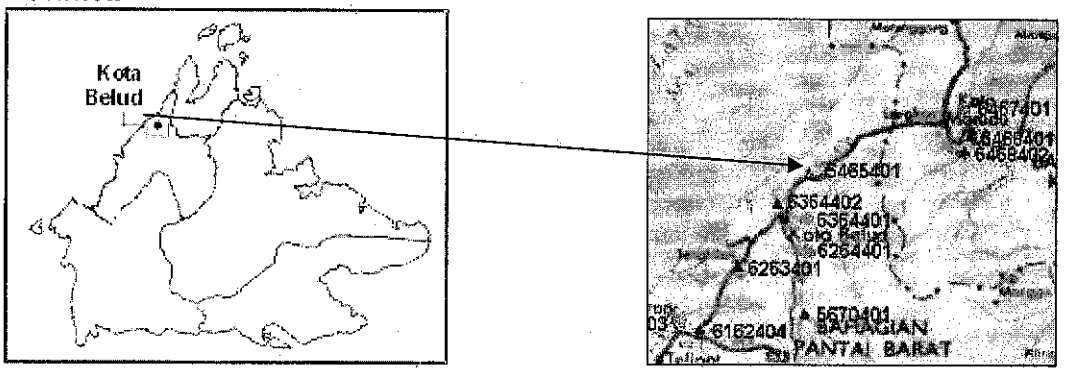


Figure C-58: Frequency Analysis of Annual Floods in Sg. Apin-Apin at Waterworks (1996-2006)

SUNGAI LABAU AT SINUA

Location



Description by DID, SABAH

Not Available

Summary of Data

Name	Sungai Labau at Sinua
Area (km^2):	-
Elevation (m):	-
Average Rainfall (mm)	
Water Use	
Total Mean yearly (m^3/s):	5.52
Mean of "Min"s yearly (m^3/s)	0.87
Mean of "Max"s yearly (m^3/s):	254.51
Absolute Min, yearly (m^3/s):	0.3
Absolute Max yearly (m^3/s):	538.28
Source:	Softcopy Streamflow Data 1969-2006, DID, Sabah, Malaysia

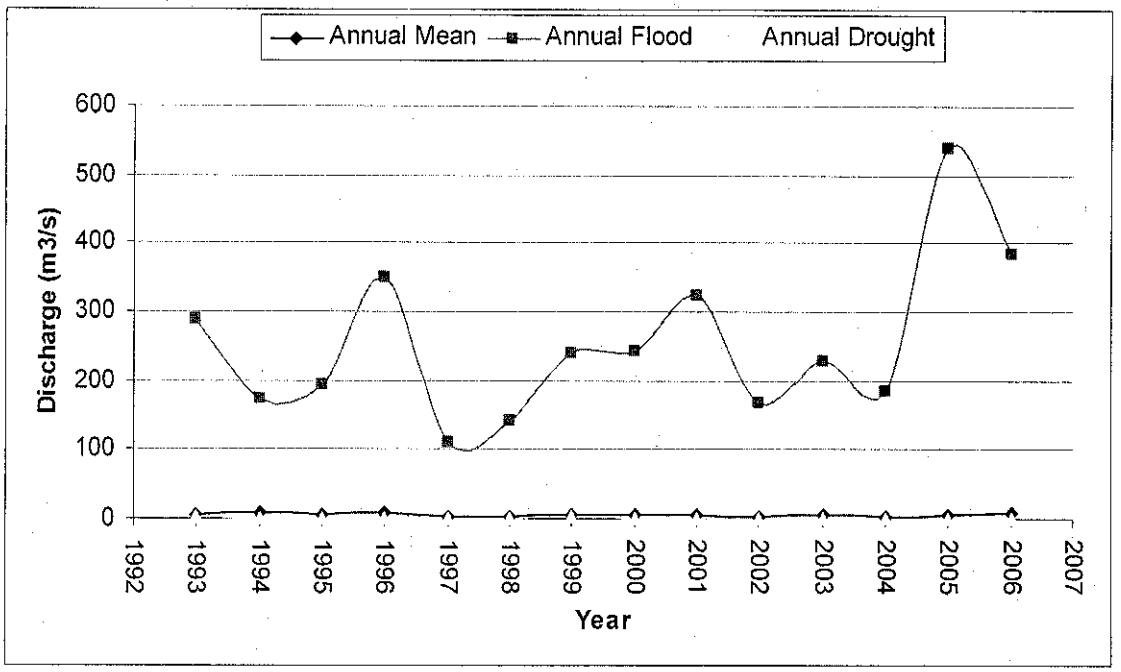


Figure C-59: Annual Discharge of Sg. Labau at Sinua (1993-2006)

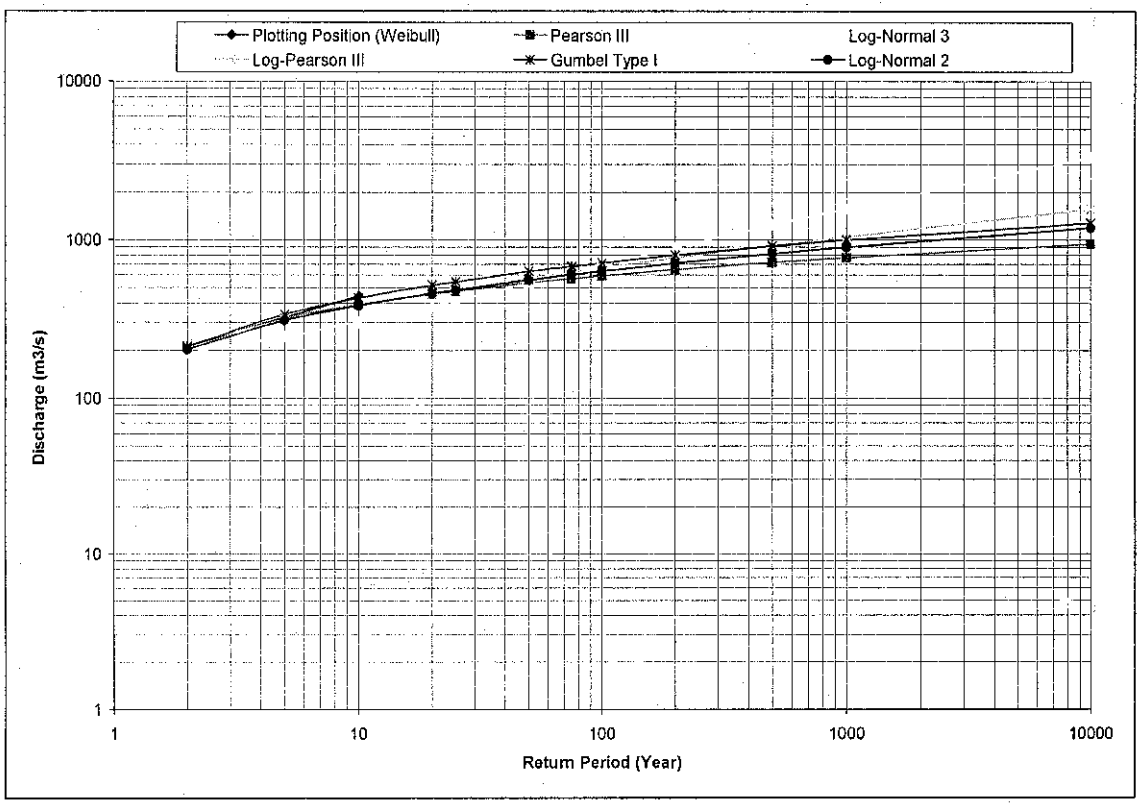
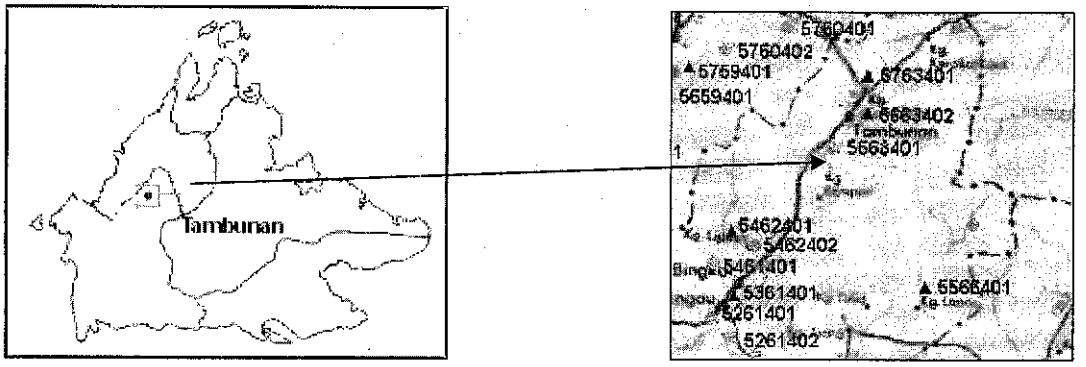


Figure C-60: Frequency Analysis of Annual Floods in Sg. Labau at Sinua (1993-2006)

SUNGAI KEGIBANGAN AT TAMPIAS

Location



Description by DID, SABAH

Not Available

Summary of Data

Name	Sungai Kegibangan at Tampias
Area (km^2):	800
Elevation (m):	-
Average Rainfall (mm)	
Water Use	
Total Mean yearly (m^3/s):	44.12
Mean of "Min"s yearly (m^3/s)	8.49
Mean of "Max"s yearly (m^3/s):	568.19
Absolute Min, yearly (m^3/s):	2.4
Absolute Max yearly (m^3/s):	709.92
Source:	Softcopy Streamflow Data 1969-2006, DID, Sabah, Malaysia

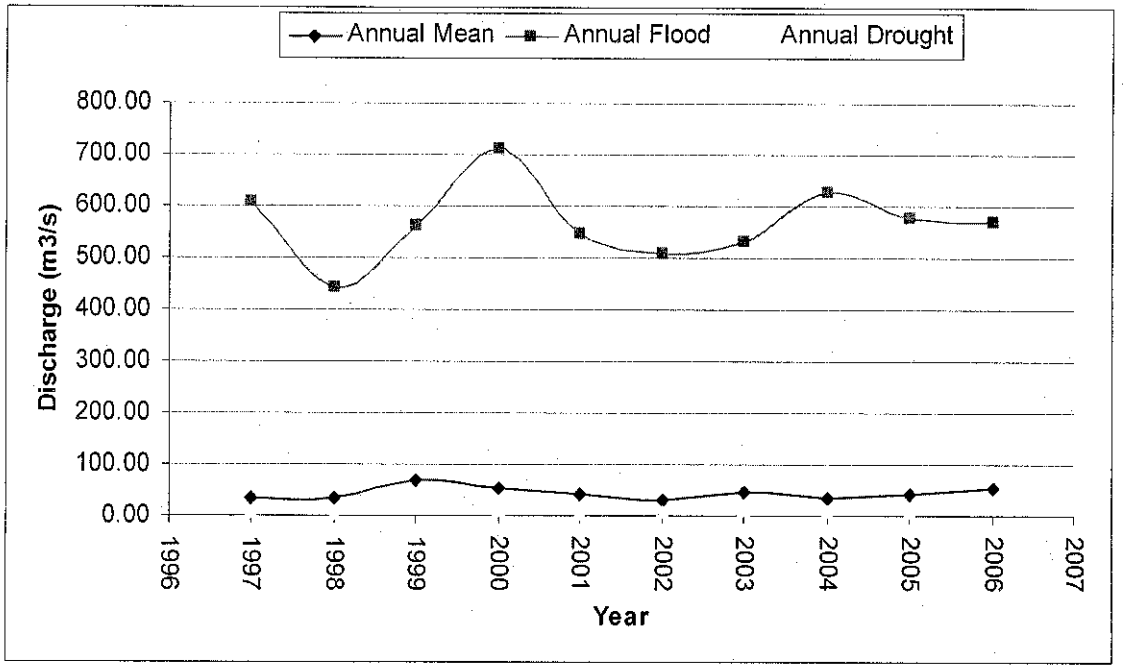


Figure C-61: Annual Discharge of Sg. Kegibangan at Tampias (1997-2006)

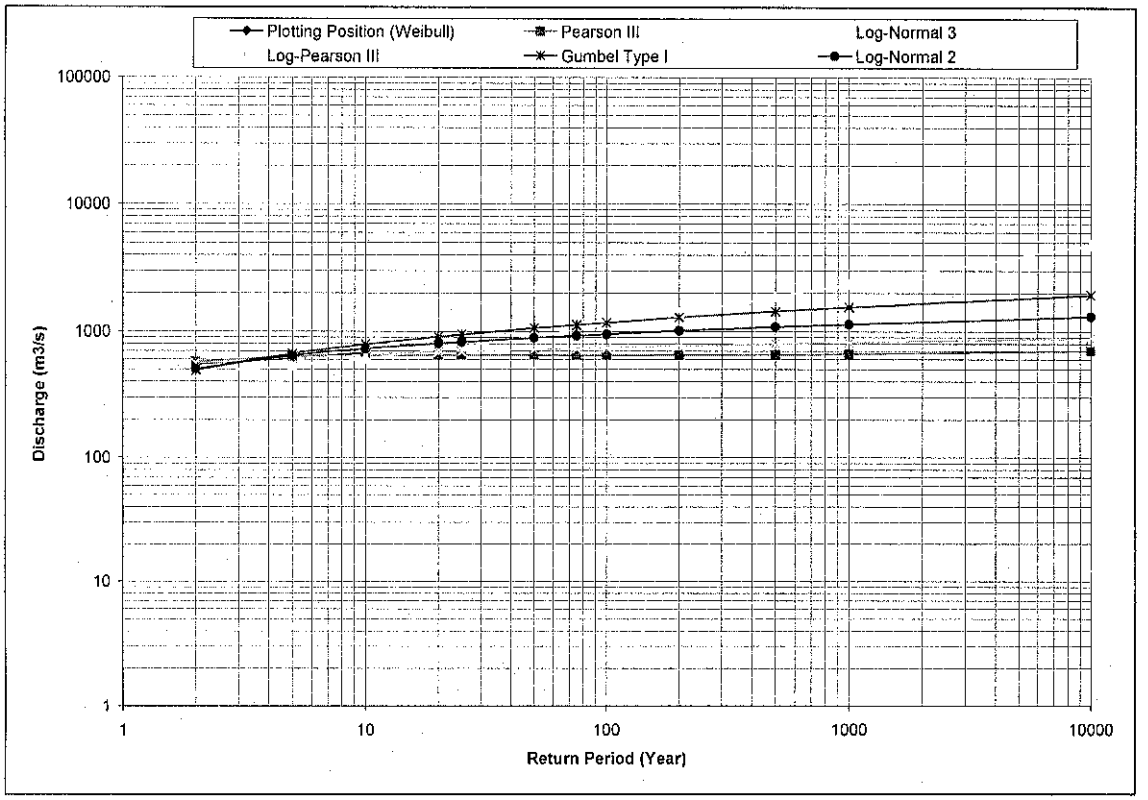
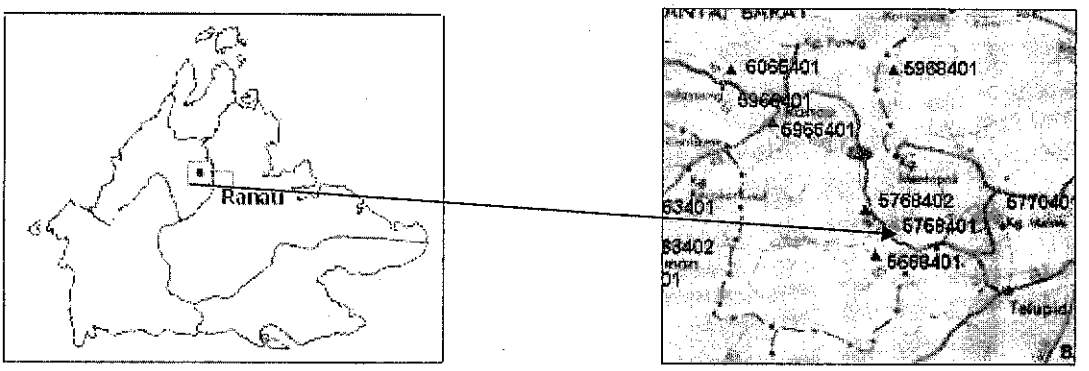


Figure C-62: Frequency Analysis of Annual Floods in Sg. Kegibangan at Tampias (1997-2006)

SUNGAI LIWAGU AT MARINGKAN

Location



Description by DID, SABAH

Not Available

Summary of Data

Name	Sungai Liawagu at Maringkan
Area (km^2):	2000
Elevation (m):	
Average Rainfall (mm)	
Water Use	
Total Mean yearly (m^3/s):	37.05
Mean of "Min"s yearly (m^3/s)	8.09
Mean of "Max"s yearly (m^3/s):	284.64
Absolute Min, yearly (m^3/s):	2.4
Absolute Max yearly (m^3/s):	395.68
Source:	Softcopy Streamflow Data 1969-2006, DID, Sabah, Malaysia

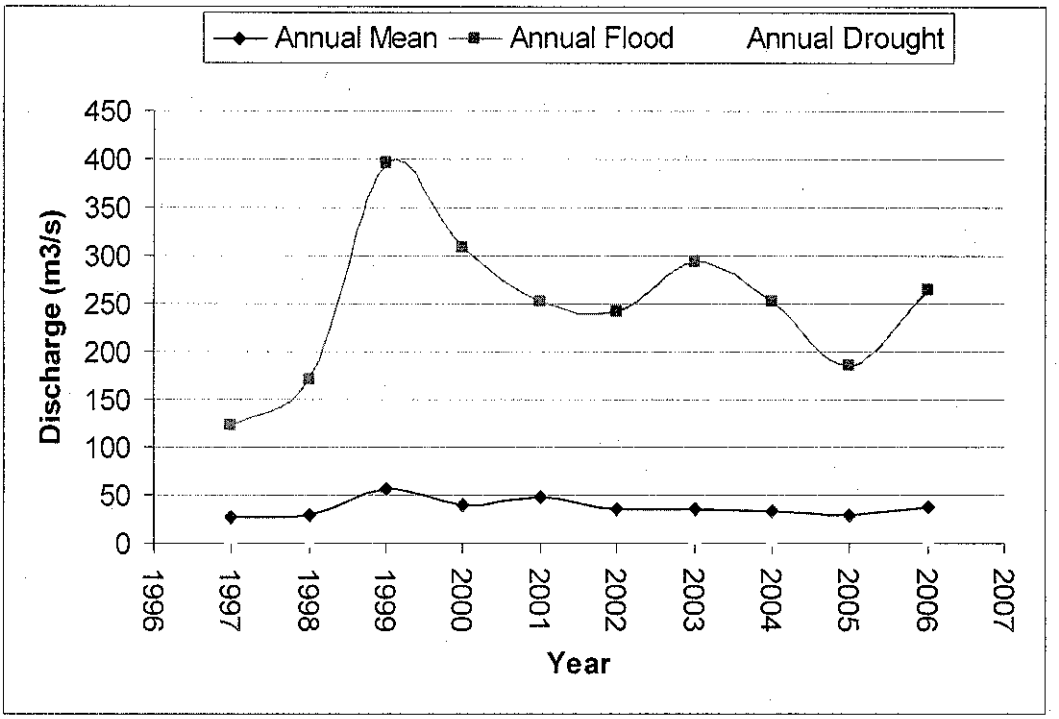


Figure C-63: Annual Discharge of Sg. Liwagu at Maringkan (1997-2006)

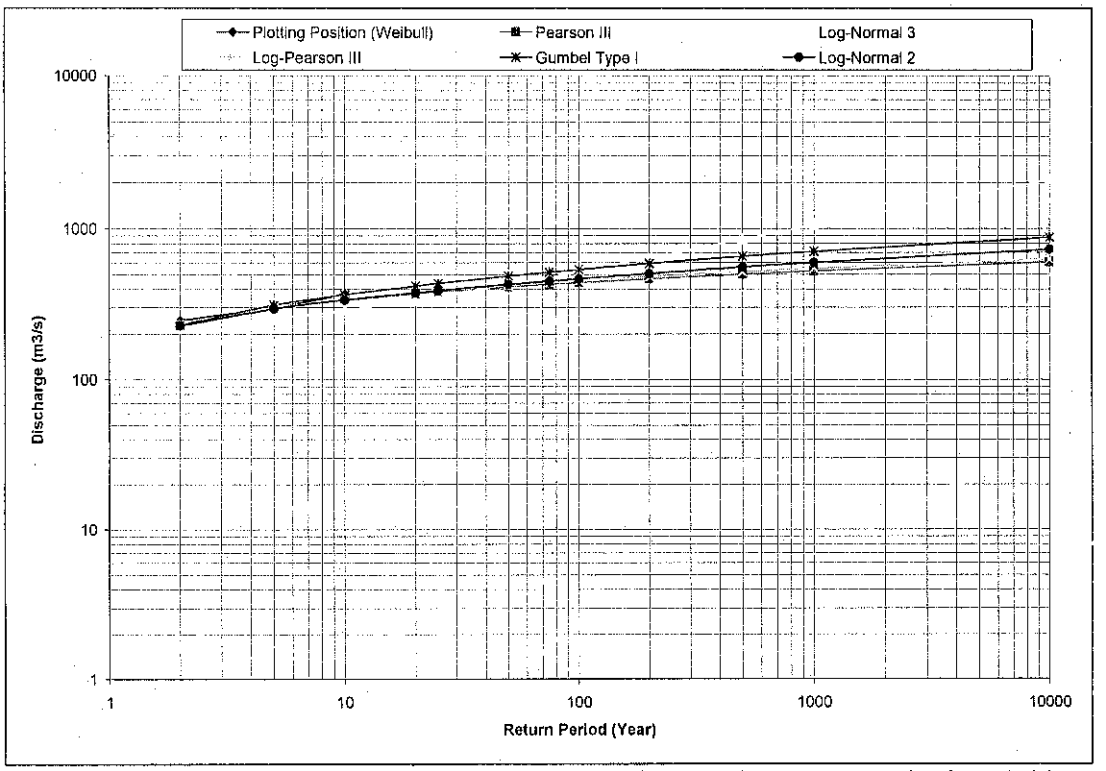
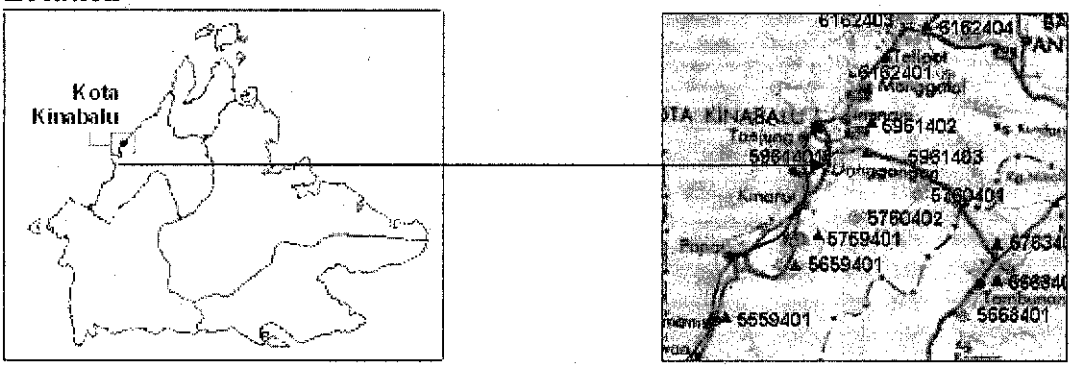


Figure C-64: Frequency Analysis of Annual Floods in Sg. Liwagu at Maringkan (1997-2006)

SUNGAI MOYOG AT PENAMPANG

Location



Description by DID, SABAH

Not Available

Summary of Data

Name	Sungai Moyog at Penampang
Area (km^2):	191
Elevation (m):	
Average Rainfall (mm)	
Water Use	
Total Mean yearly (m^3/s):	14.9
Mean of "Min"s yearly (m^3/s)	1.3
Mean of "Max"s yearly (m^3/s):	295.76
Absolute Min, yearly (m^3/s):	0.21
Absolute Max yearly (m^3/s):	507.28
Source:	Softcopy Streamflow Data 1969-2006, DID, Sabah, Malaysia

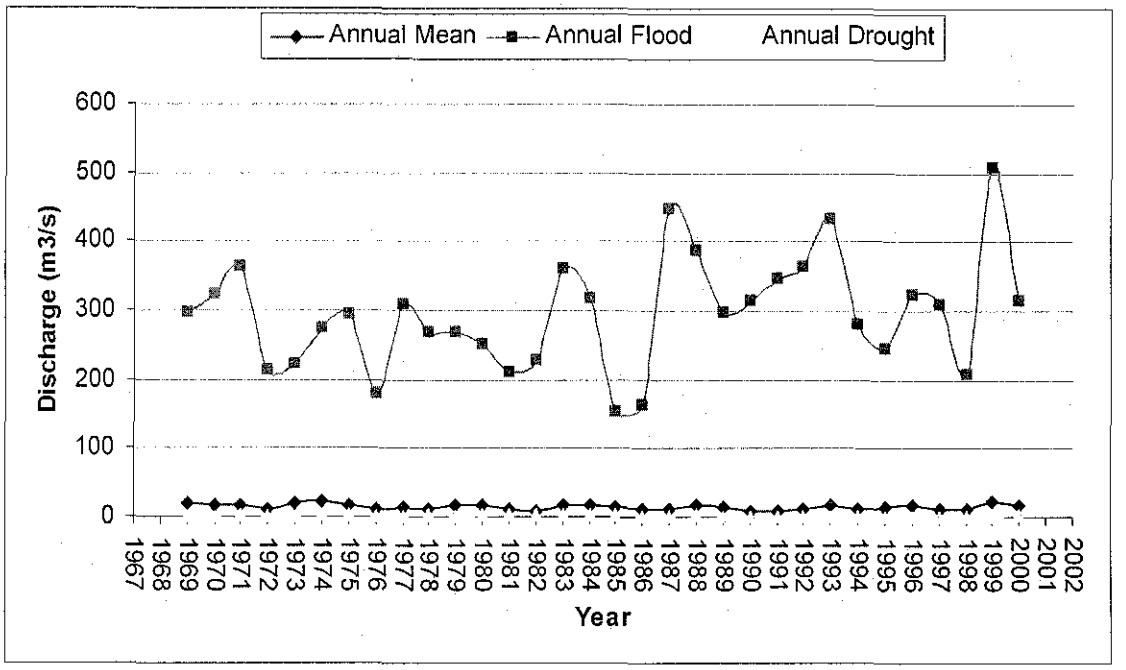


Figure C-65: Annual Discharge of Sg. Moyog at Penampang(1969-2006)

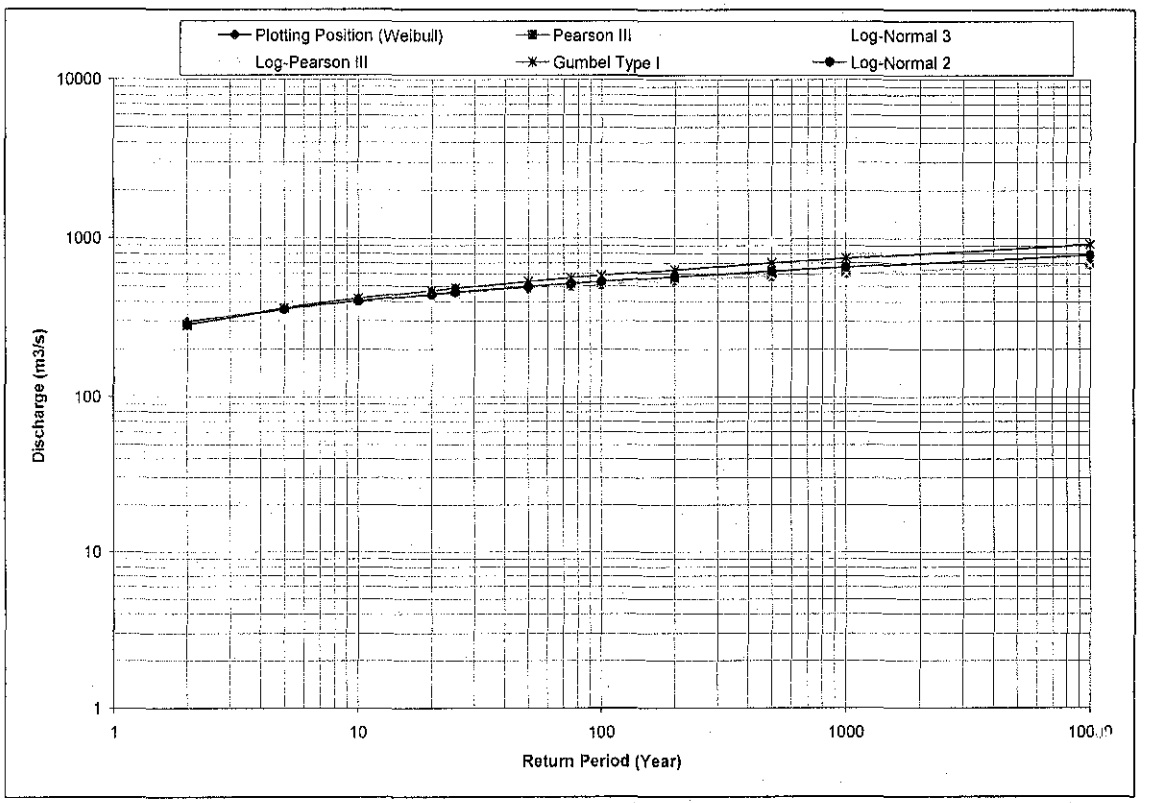
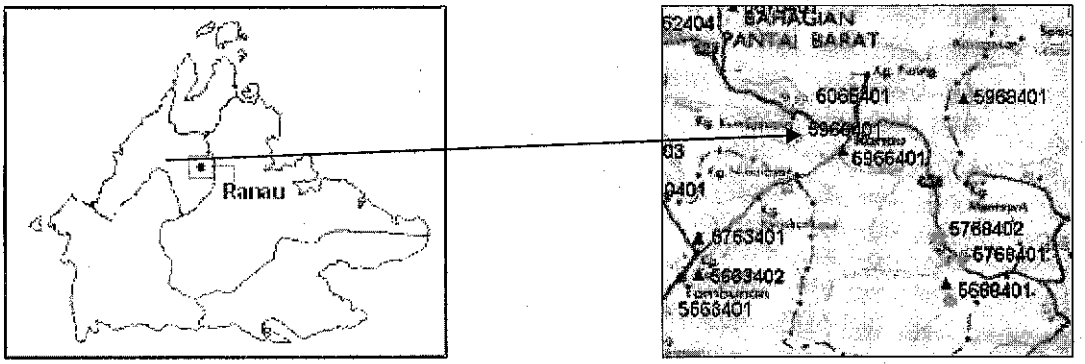


Figure C-66: Frequency Analysis of Annual Floods in Sg. Moyog at Penampang(1969-2006)

SUNGAI LIWAGU AT KINABALU PARK

Location



Description by DID, SABAH

Not Available

Summary of Data

Name	Sungai Liwagu at Kinabalu Parl
Area (km^2):	11
Elevation (m):	-
Average Rainfall (mm)	
Water Use	
Total Mean yearly (m^3/s):	0.57
Mean of "Min"s yearly (m^3/s)	0.12
Mean of "Max"s yearly (m^3/s):	22.32
Absolute Min, yearly (m^3/s):	0.06
Absolute Max yearly (m^3/s):	91.34
Source:	Softcopy Streamflow Data 1969-2006, DID, Sabah, Malaysia

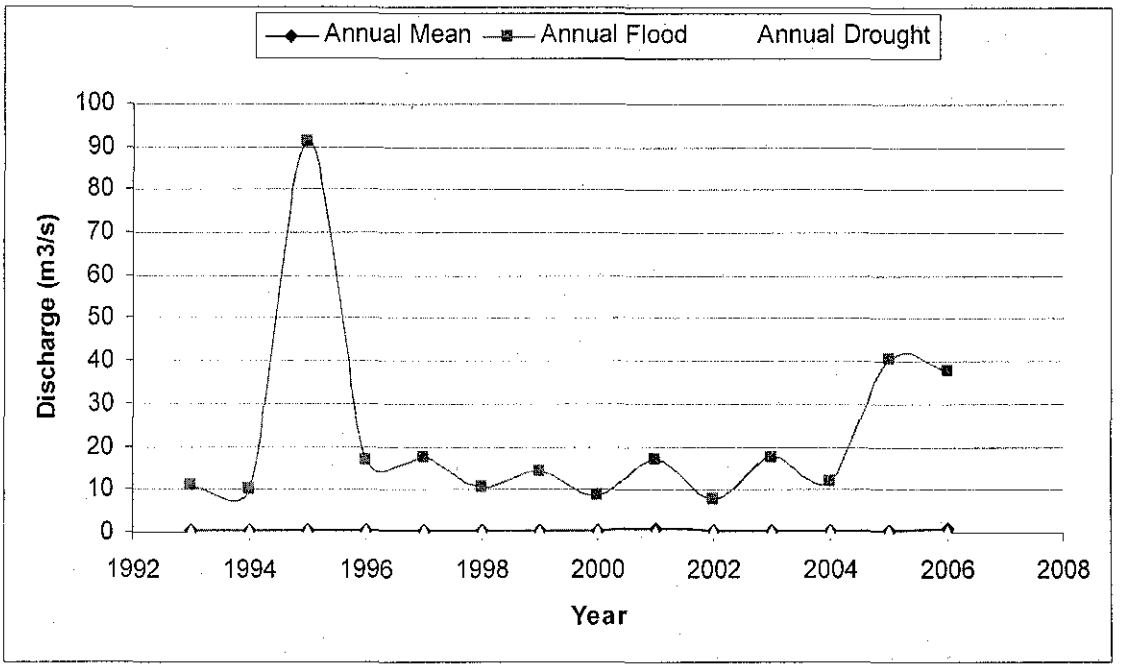


Figure C-67: Annual Discharge of Sg. Liwagu at Kinabalu Park (1993-2006)

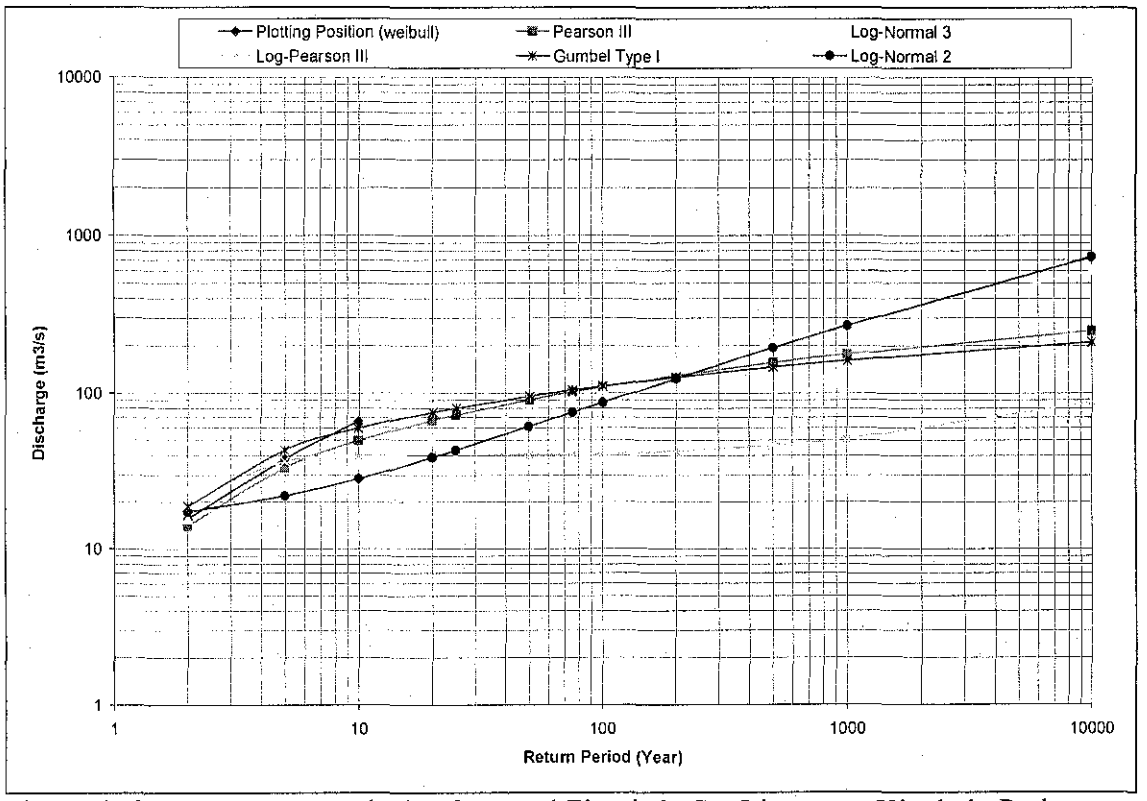
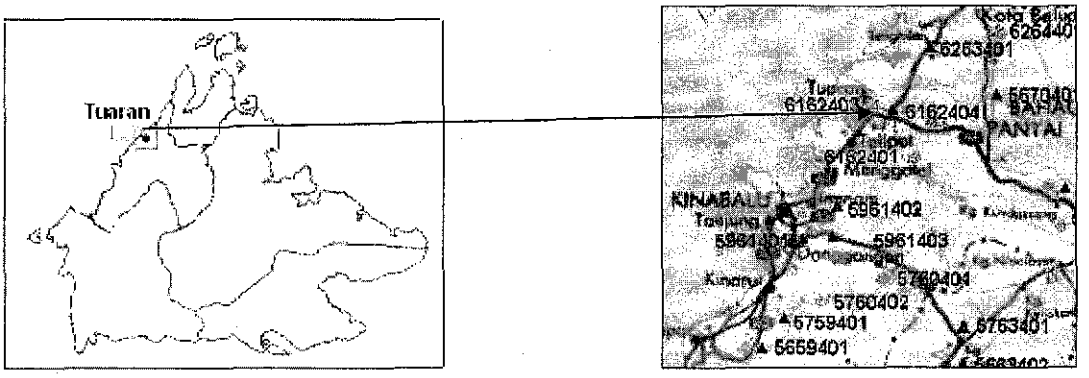


Figure C-68: Frequency Analysis of Annual Floods in Sg. Liwagu at Kinabalu Park (1993-2006)

SUNGAI TUARAN AT P.H NO.1

Location



Description by DID, SABAH

Not Available

Summary of Data

Name	Sungai Tuaran at P.H No.1
Area (km^2):	695
Elevation (m):	-
Average Rainfall (mm)	
Water Use	
Total Mean yearly (m^3/s):	34.05
Mean of "Min"s yearly (m^3/s)	3.75
Mean of "Max"s yearly (m^3/s):	427.6
Absolute Min, yearly (m^3/s):	0.81
Absolute Max yearly (m^3/s):	902.89
Source:	Softcopy Streamflow Data 1969-2006, DID, Sabah, Malaysia

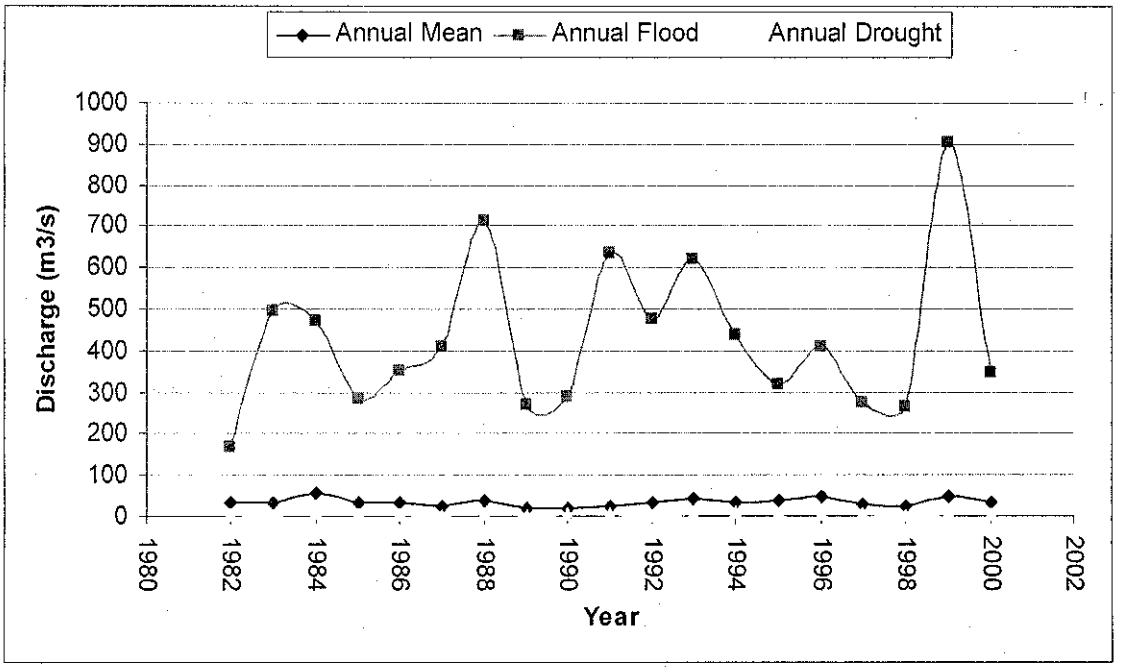


Figure C-69: Annual Discharge of Sg. Tuaran at P.H no. 1 (1982-2000)

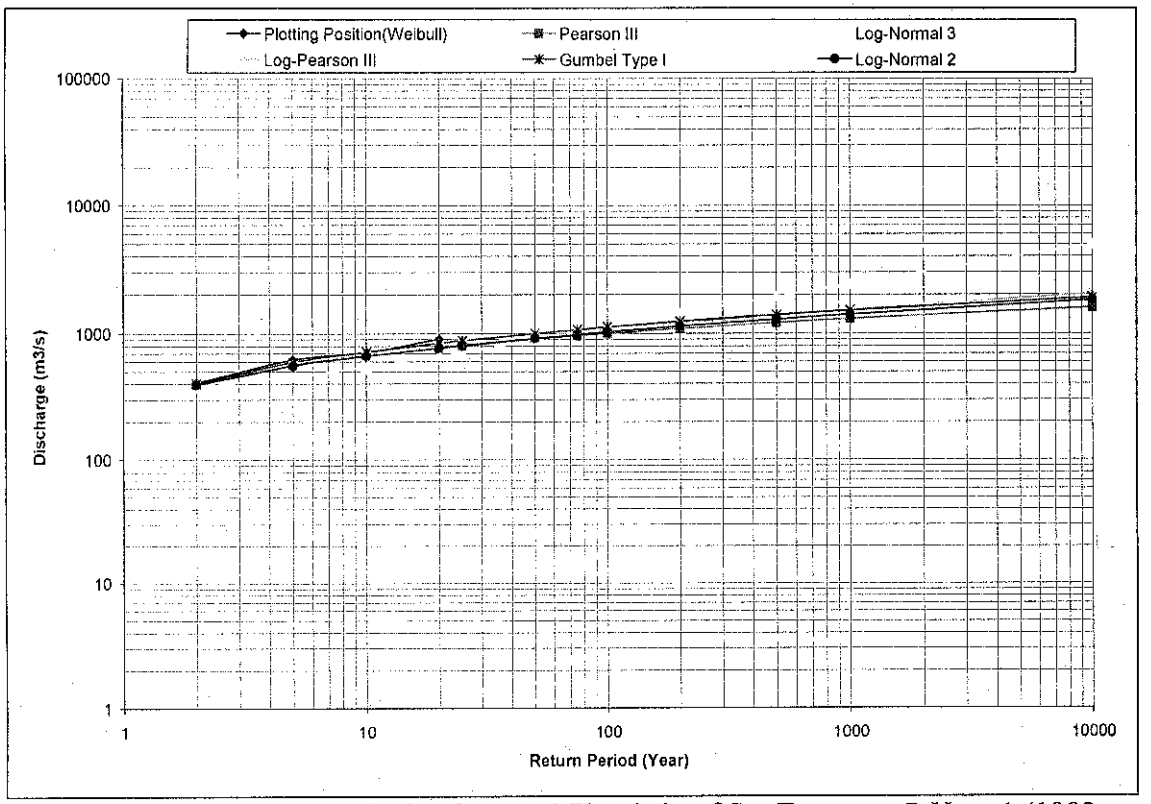
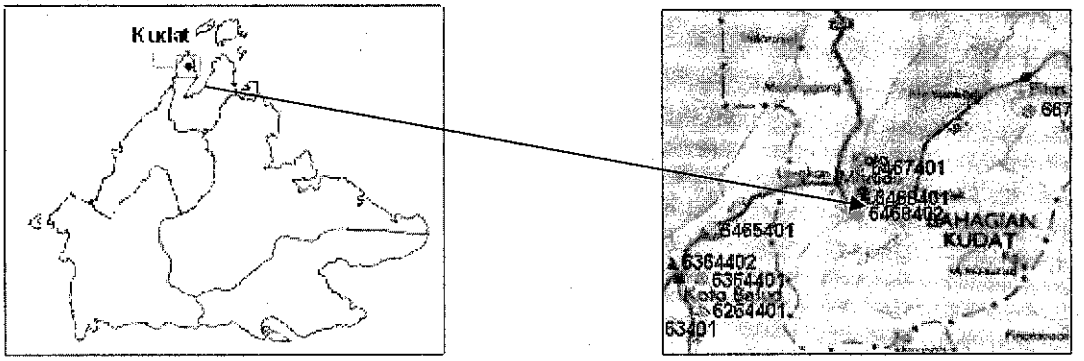


Figure C-70: Frequency Analysis of Annual Floods in of Sg. Tuaran at P.H no 1 (1982-2000)

SUNGAI BONGAN AT TIMBANG BATU

Location



Description by DID, SABAH

Not Available

Summary of Data

Name	Sungai Bongan at Timbang Batu
Area (km^2):	570
Elevation (m):	-
Average Rainfall (mm)	
Water Use	
Total Mean yearly (m^3/s):	15.08
Mean of "Min"s yearly (m^3/s)	2.48
Mean of "Max"s yearly (m^3/s):	470.4
Absolute Min, yearly (m^3/s):	0.81
Absolute Max yearly (m^3/s):	1996.2
Source:	Softcopy Streamflow Data 1969-2006, DID, Sabah, Malaysia

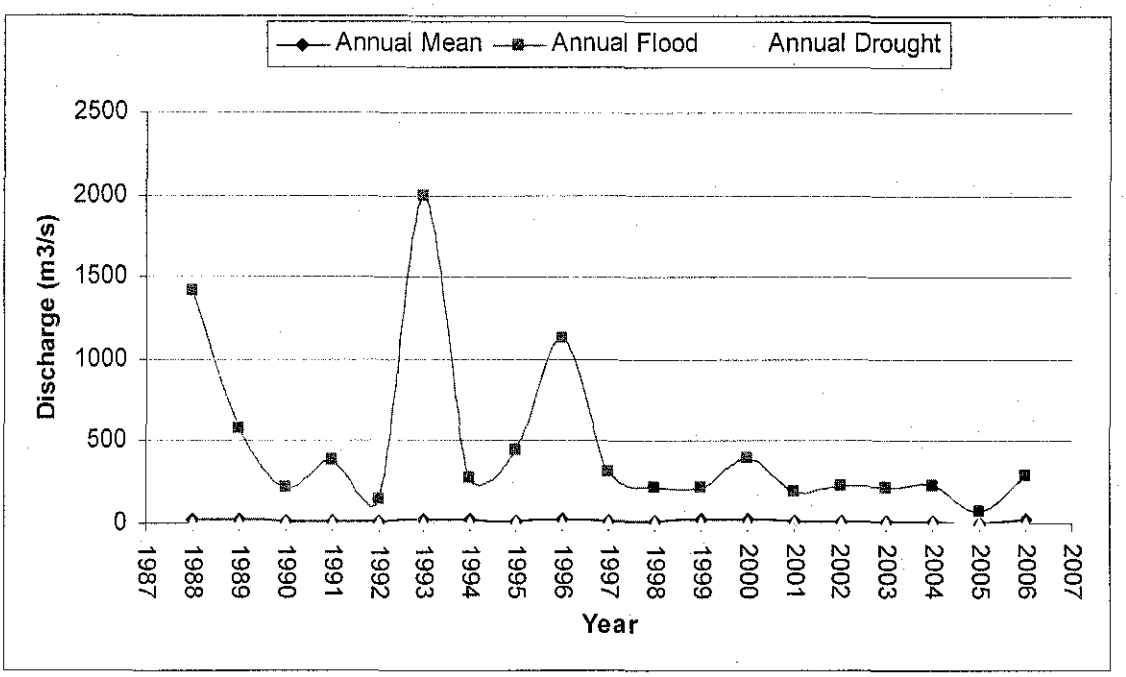


Figure C-71: Annual Discharge of Sg. Bongan at Timbang Batu (1988-2006)

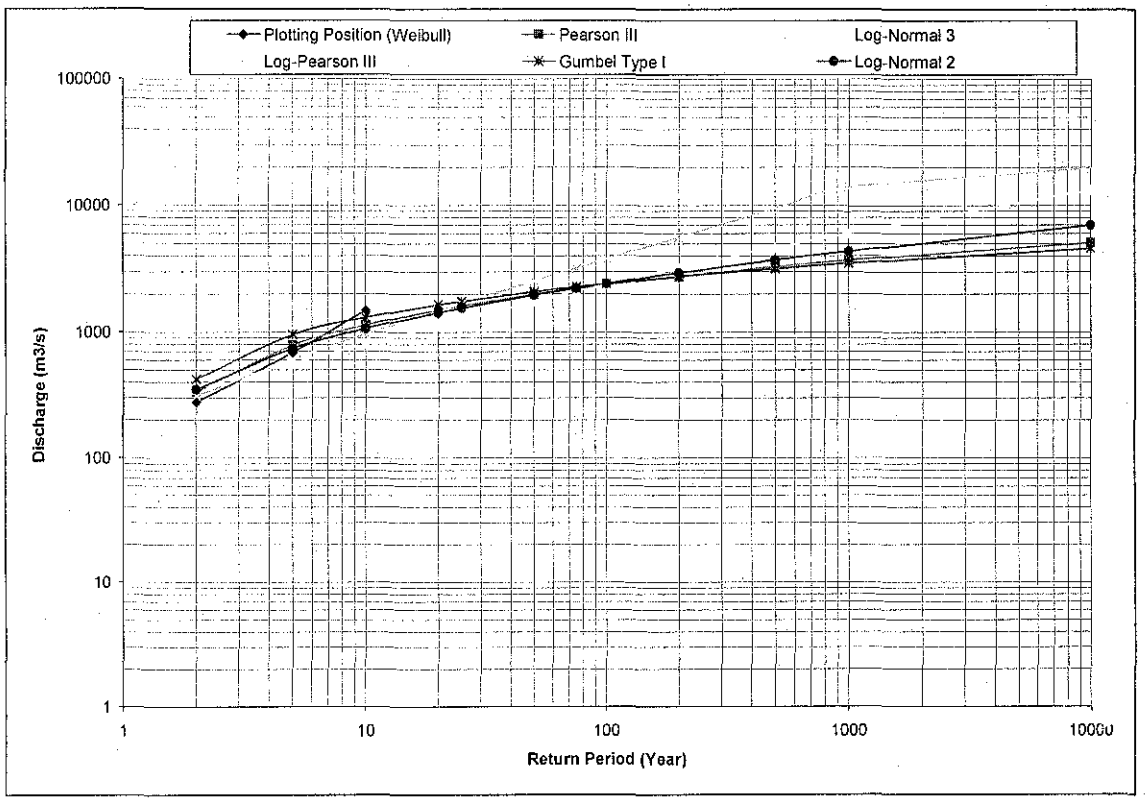
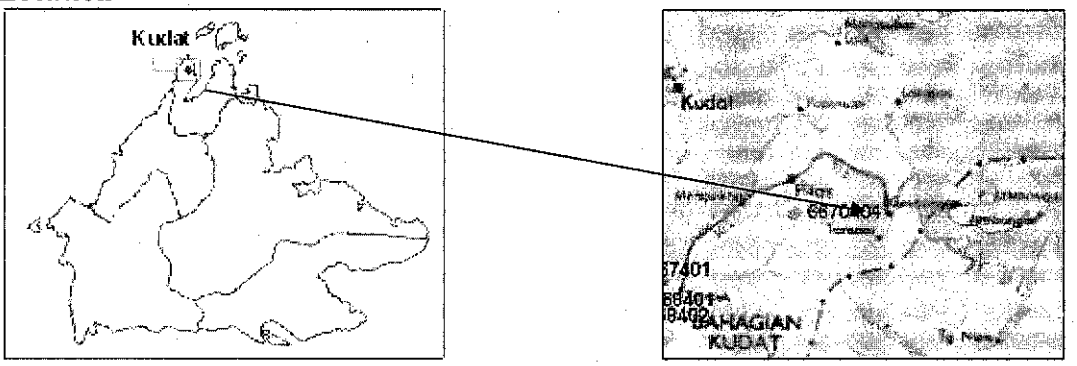


Figure C-72: Frequency Analysis of Annual Floods in Sg Bongan at Timbang Batu (1988-2006)

SUNGAI BENGKOKA AT KOBON

Location



Description by DID, SABAH

Not Available

Summary of Data

Name	Sungai Bengkoka at Kobon
Area (km^2):	700
Elevation (m):	
Average Rainfall (mm)	
Water Use	
Total Mean yearly (m^3/s):	24.48
Mean of "Min"s yearly (m^3/s)	2.53
Mean of "Max"s yearly (m^3/s):	602.99
Absolute Min, yearly (m^3/s):	0.11
Absolute Max yearly (m^3/s):	1631.3
Source:	Softcopy Streamflow Data 1969-2006, DID, Sabah, Malaysia

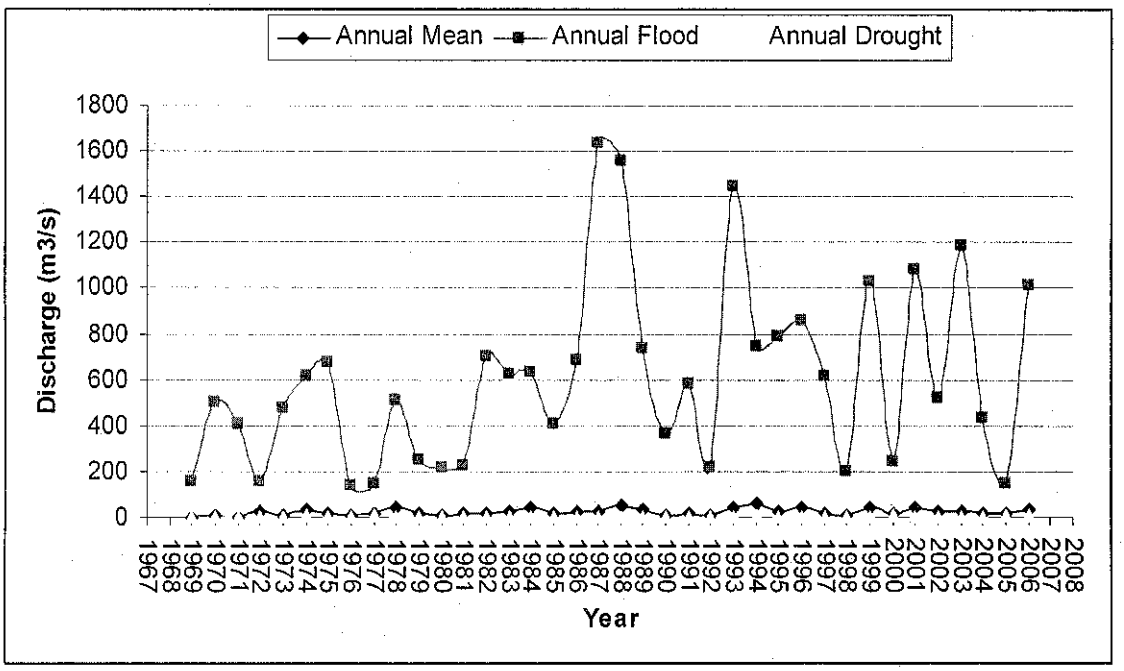


Figure C-73: Annual Discharge of Sg. Bengkoka at Kobon (1969-2006)

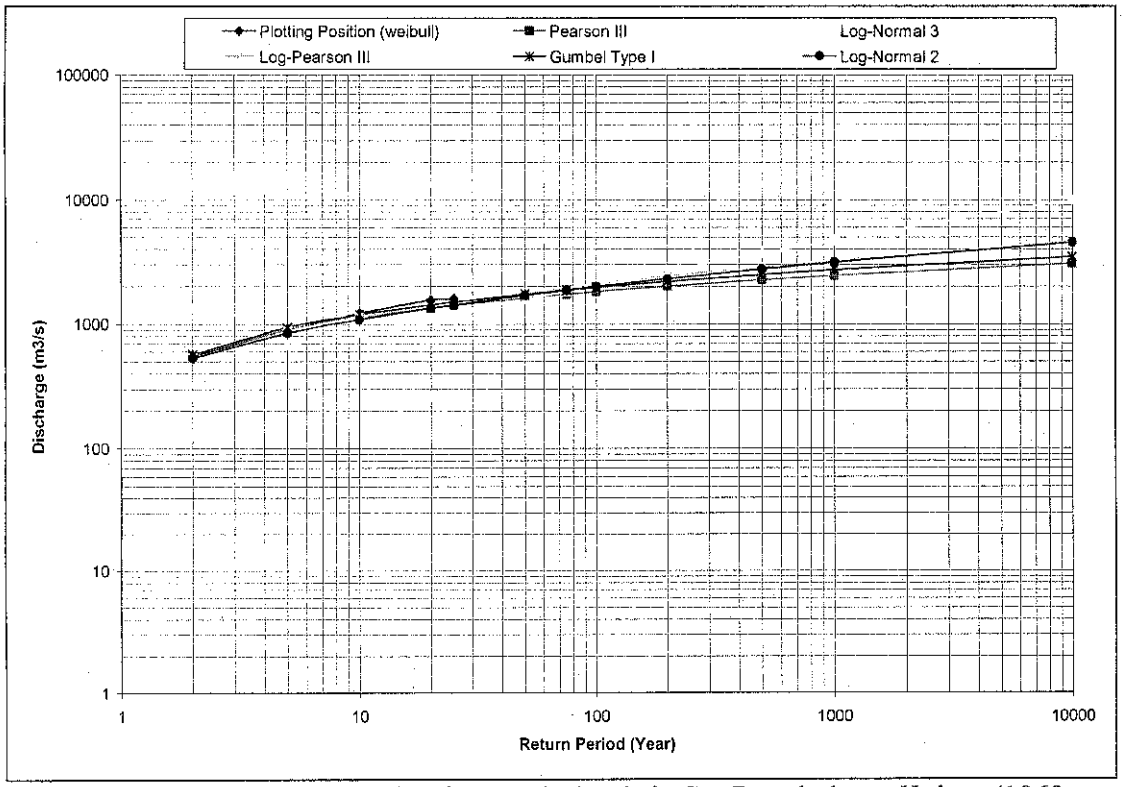
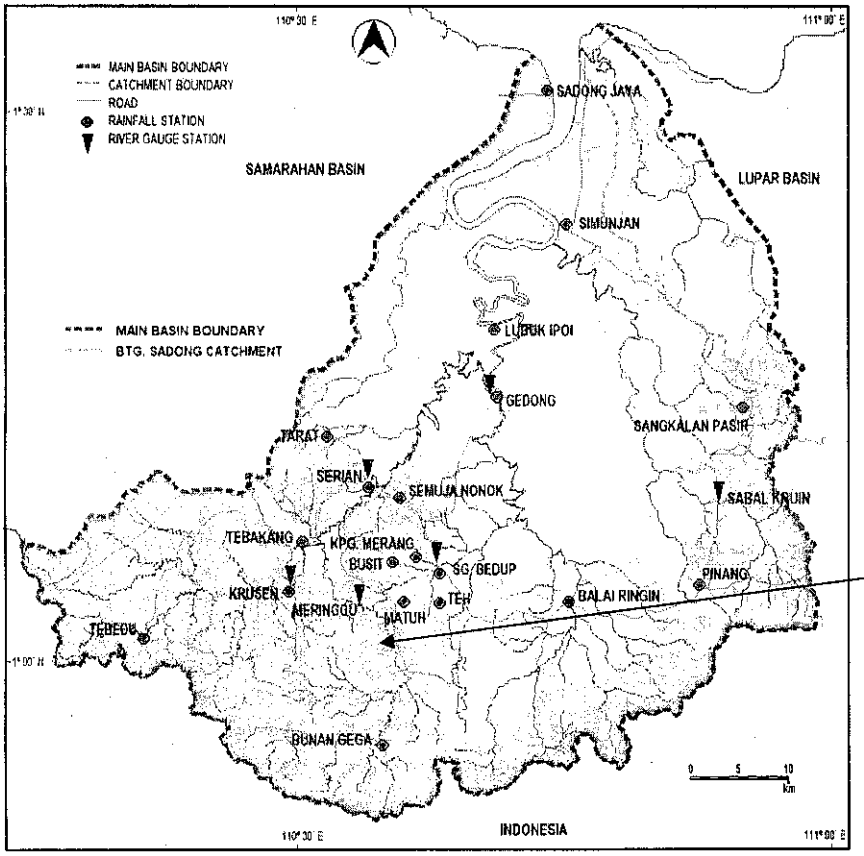


Figure C-74: Frequency Analysis of Annual Floods in Sg. Bengkoka at Kobon (1969-2006)

SARAWAK

MERINGGU AT SUNGAI KETUP

SADONG BASIN



Sg Ketup at Meringgu

Description by DID, SARAWAK

NOT AVAILABLE

Summary of Data

Name	Sungai Ketup At Meringgu
Area (km^2):	338.2
Elevation (m):	
Average Rainfall (mm)	
Water Use	
Total Mean yearly (m^3/s):	19.94
Mean of "Min"s yearly (m^3/s)	3.57
Mean of "Max"s yearly (m^3/s):	78.99
Absolute Min, yearly (m^3/s):	0.31
Absolute Max yearly (m^3/s):	119.61
Source	Softcopy Waterlevel Data, 1981-2005, DID, Sarawak

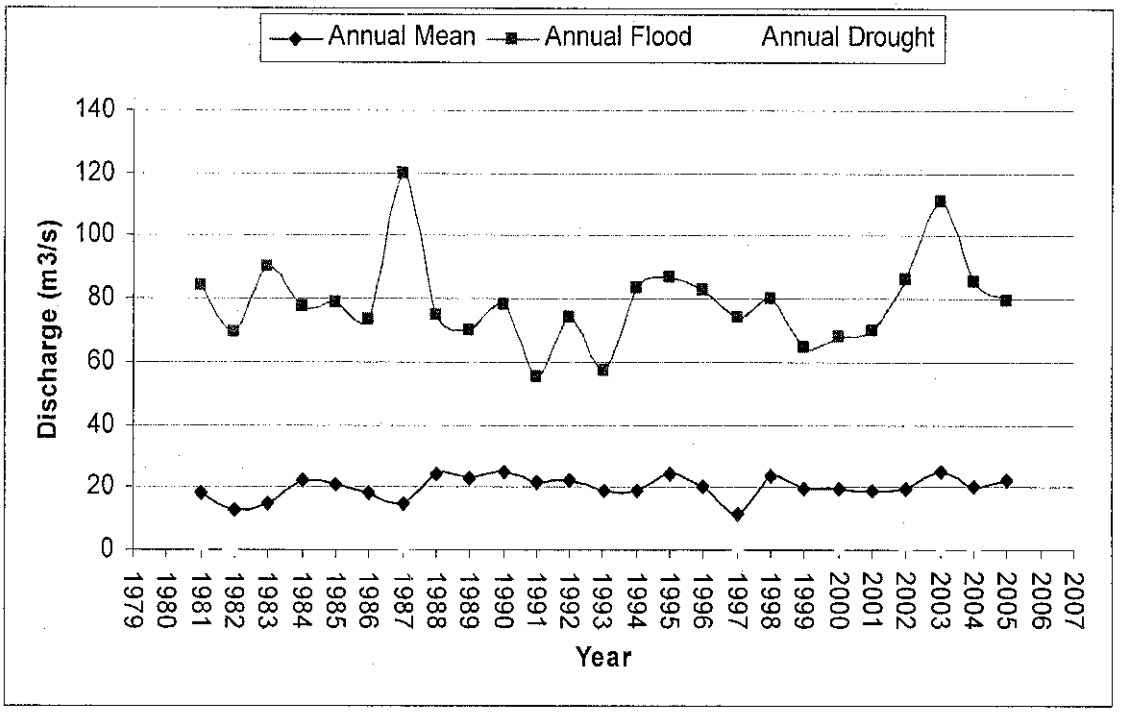


Figure C-75: Annual Discharge of Sungai Ketup at Meringgu (1981-2005)

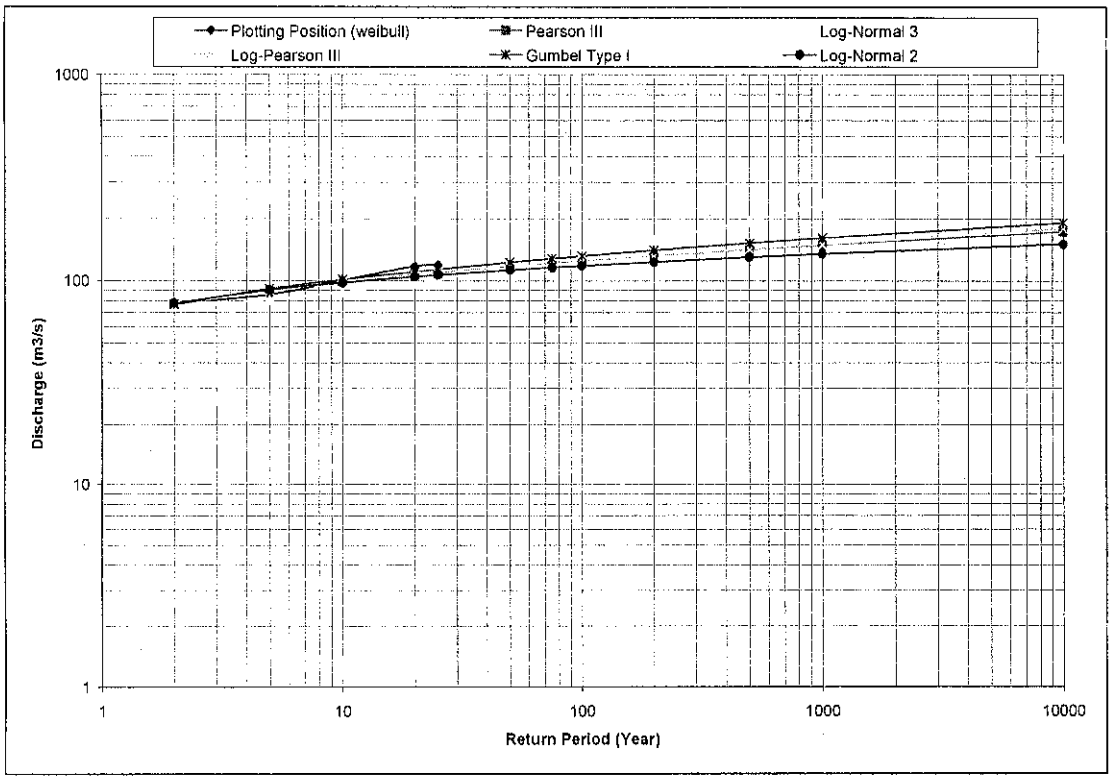
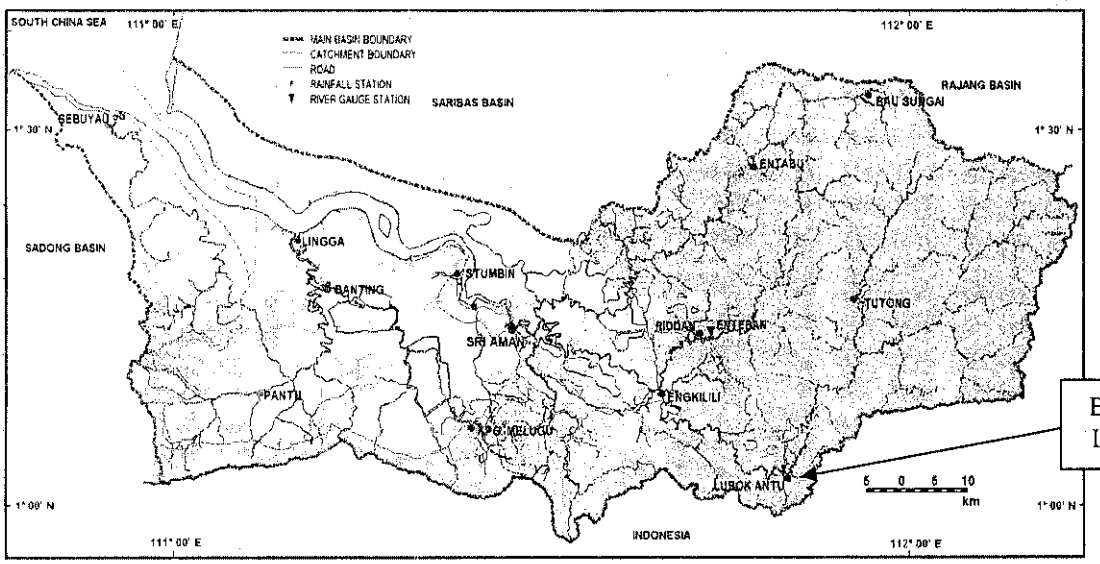


Figure C-76: Frequency Analysis of Annual Floods of Sungai Ketup at Meringgu (1981-2005)

BATANG AI AT LUBOK ANTU

LUPAR BASIN



Description by DID, SABAH

Station No. 1018401

BATANG AI AT LUBOK ANTU

Gauging site:-

Longitude & Latitude: - 111°49'35" E 01°02'35" N.

Catchment Area:- 1300 km^2

Elevation above mean sea level:- 26 m

Catchment characteristics:-

(k) **Shape**:- The maximum length and breadth of the catchment are 62 km and 33 km respectively

(l) **Topography**:- Gently sloping to steep land

(m) **Vegetation** :- Mainly Forest

(n) **Soil Cover**:- Skeletal Soils and Red Yellow Podzolic Soil

(o) **Rock Type**: - Sands, clays, sedimentary and metamorphic.

Ranged of observations:- The range of river stages observed is from 20.46m to 25.61m while discharge measurements have been taken between 20.92m and 23.77m above mean sea level.

Summary of Data

Name	Batang Ai at Lubok Antu
Area (km^2):	1300
Elevation (m):	26
Average Rainfall (mm)	
Water Use	
Total Mean yearly (m^3/s):	124.52
Mean of "Min"s yearly (m^3/s)	27.78
Mean of "Max"s yearly (m^3/s):	425.86
Absolute Min, yearly (m^3/s):	1.39
Absolute Max yearly (m^3/s):	682.77
Source	Softcopy Waterlevel Data, 1981-2005, DID, Sarawak Streamflow and River Suspended Records, 1975-1990

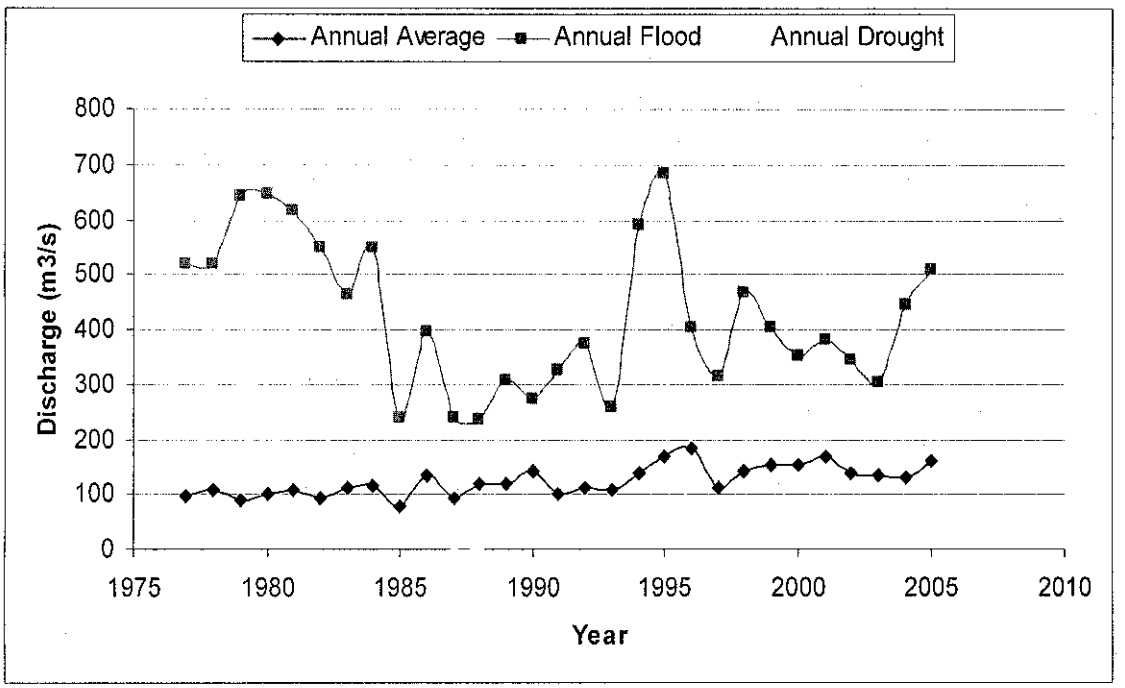


Figure C-77: Annual Discharge of Batang Ai at Lubok Antu , Sarawak (1977-2005)

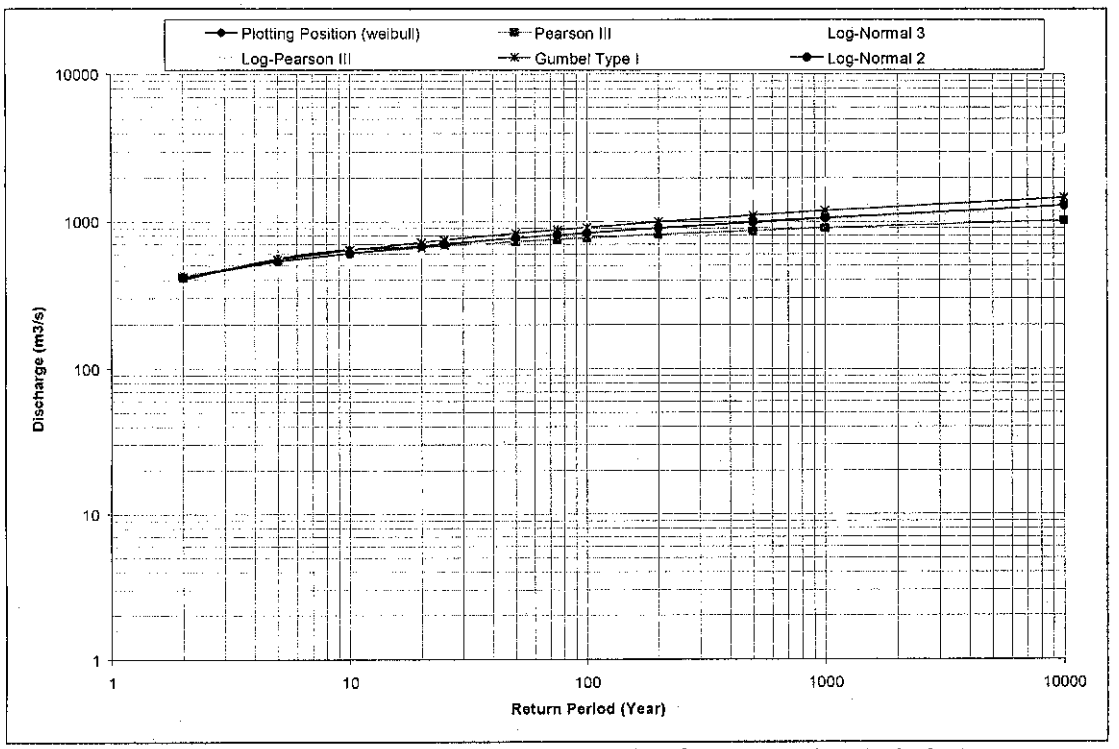
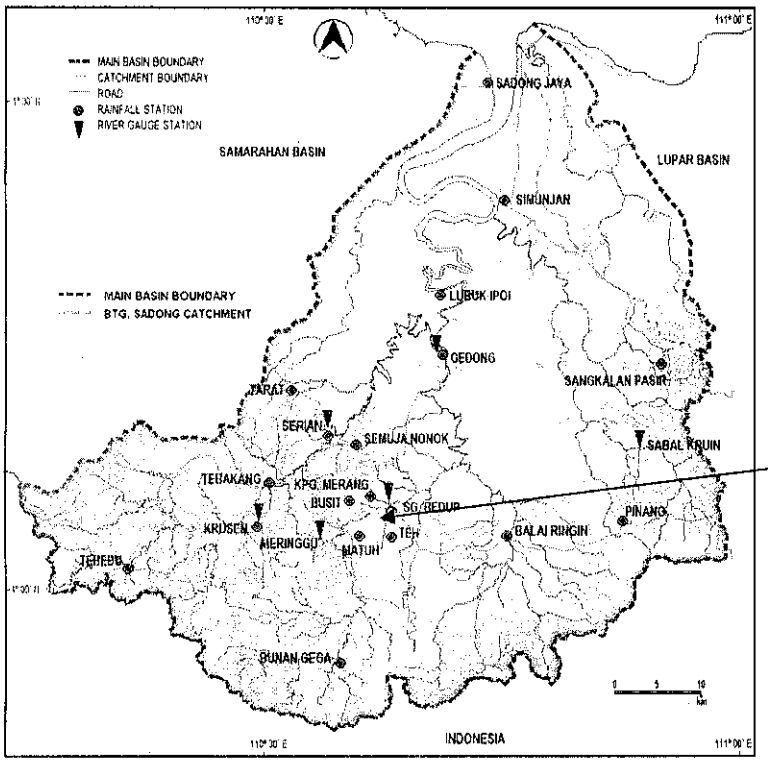


Figure C-78: Frequency Analysis of Annual Floods of Batang Ai at Lubok Antu , Sarawak (1977-2005)

SUNGAI SADONG AT SERIAN

SADONG BASIN



Description by DID, SABAH

Station No. 1018401

SUNGAI SADONG AT SERIAN

Gauging site:-

Longitude & Latitude: - 110°34'00" E 01°09'35'' N.

Catchment Area:- 941 km^2

Elevation above mean sea level:-

Catchment characteristics:-

(p) **Shape**:- The maximum length and breadth of the catchment are 41 km and 49 km respectively

(q) **Topography**:- Moderately steep to undulating land

(r) **Vegetation** :- Mainly Forested areas

(s) **Soil Cover**:- Gley soils with poorly drained sands and clay

(t) **Rock Type**: - Mainly sedimentary rocks

Ranged of observations:- The range of river stages observed is from 2.10 m to 9.76 m while discharge measurements have been taken between 2.66 m and 9.76 m above mean sea level.

Summary of Data

Name	Sungai Sadong at Serian
Area (km^2):	941
Elevation (m):	
Average Rainfall (mm)	
Water Use	
Total Mean yearly (m^3/s):	56.81
Mean of "Min"s yearly (m^3/s)	5.25
Mean of "Max"s yearly (m^3/s):	266.49
Absolute Min, yearly (m^3/s):	0.33
Absolute Max yearly (m^3/s):	392.04
Source	Softcopy Waterlevel Data, 1981-2005, DID, Sarawak Streamflow and River Suspended Records, 1975-1990

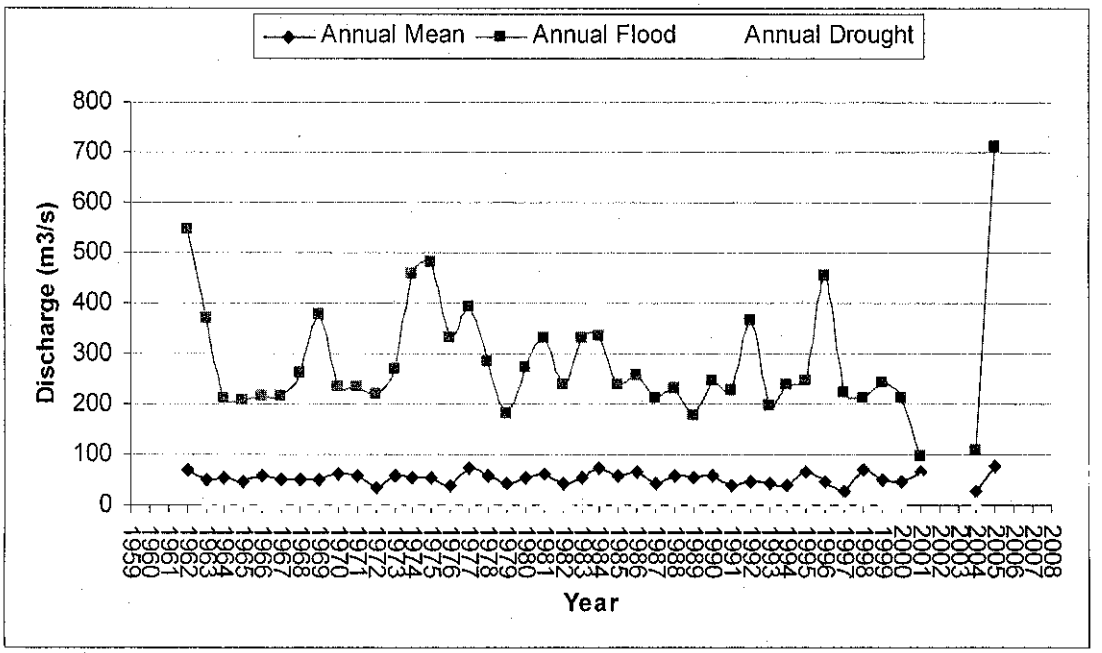


Figure C-79: Annual Discharge of Sungai Sadong at Serian, Sarawak (1968-2005)

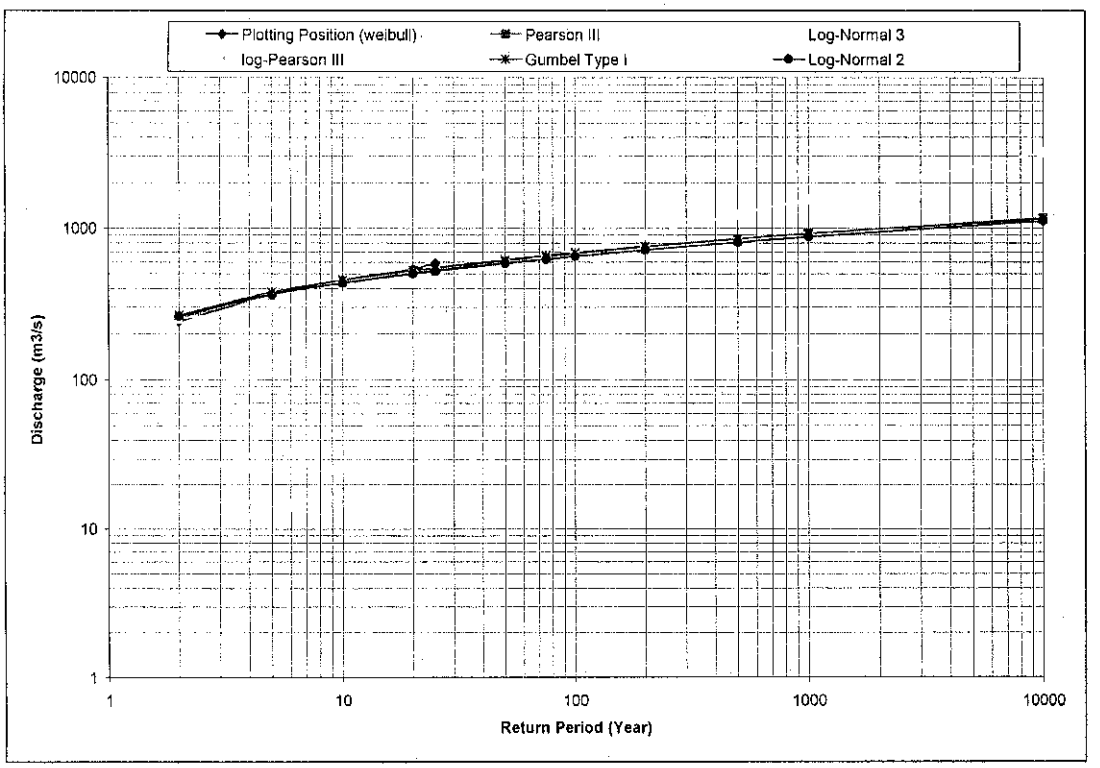
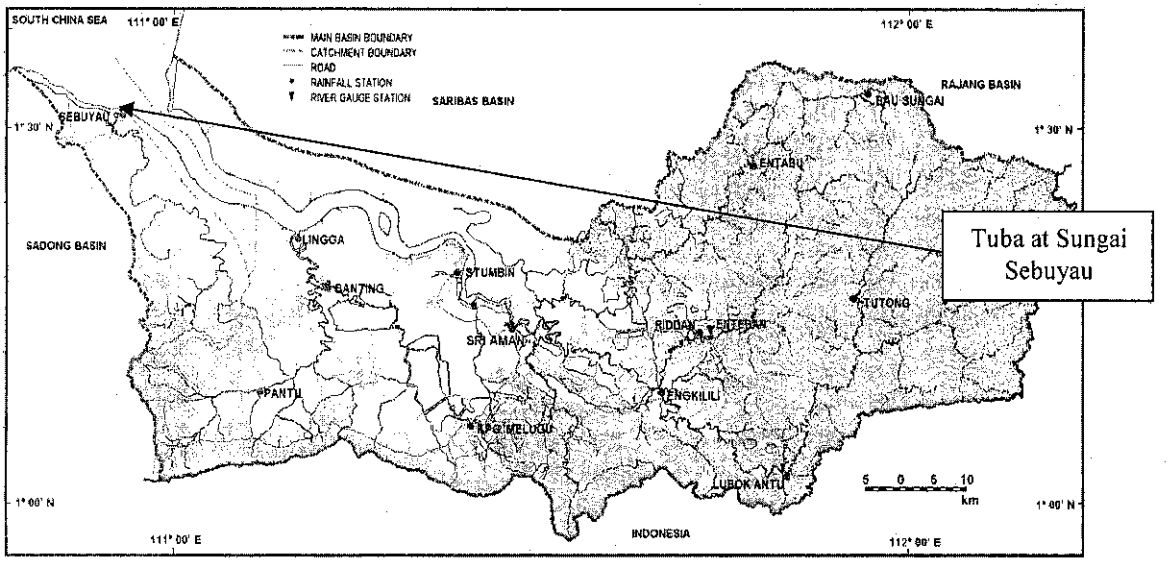


Figure C-80: Frequency Analysis of Annual Floods of Sungai Sadong at Serian, Sarawak (1968-2005)

TUBA AT SUNGAI SEBUYAU

LUPAR BASIN



Description by DID, SABAH

NOT AVAILABLE

Summary of Data

Name	Sungai Tuba at Sebuyau
Area (km^2):	28.5
Elevation (m):	
Average Rainfall (mm)	
Water Use	
Total Mean yearly (m^3/s):	2.69
Mean of "Min"s yearly (m^3/s)	0.75
Mean of "Max"s yearly (m^3/s):	7.88
Absolute Min, yearly (m^3/s):	2.64
Absolute Max yearly (m^3/s):	10.39
Source	Softcopy Waterlevel Data, 1987-2000, DID, Sarawak

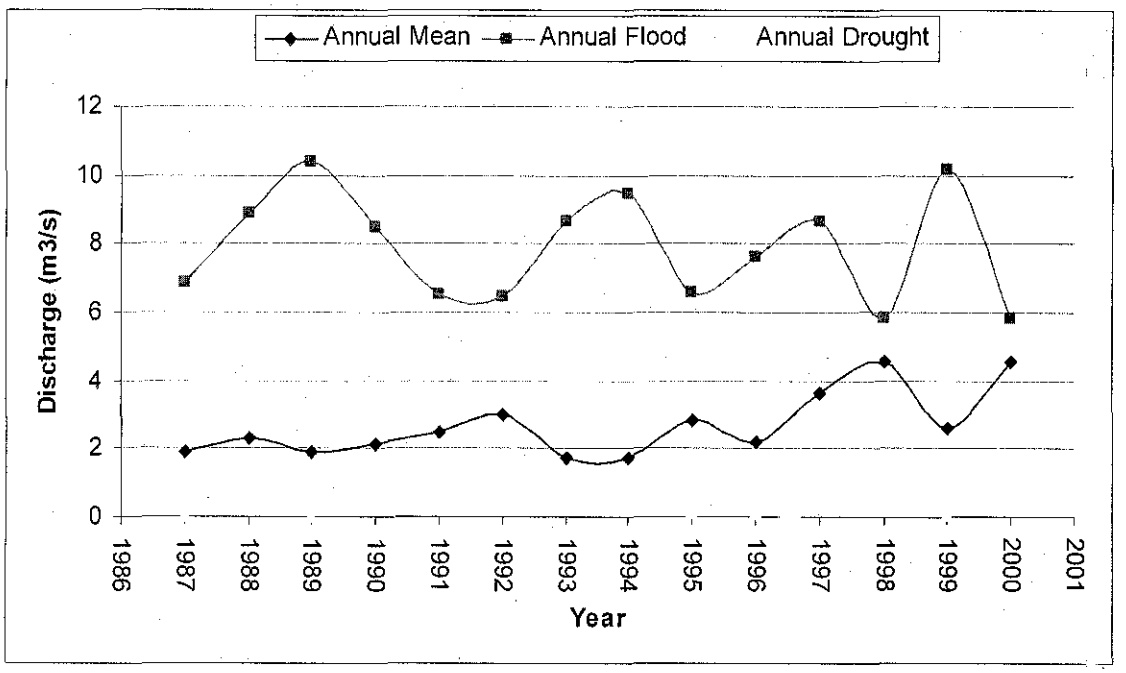


Figure C-81: Annual Discharge of Sungai Tuba at Sebuyau, Sarawak (1987-2000)

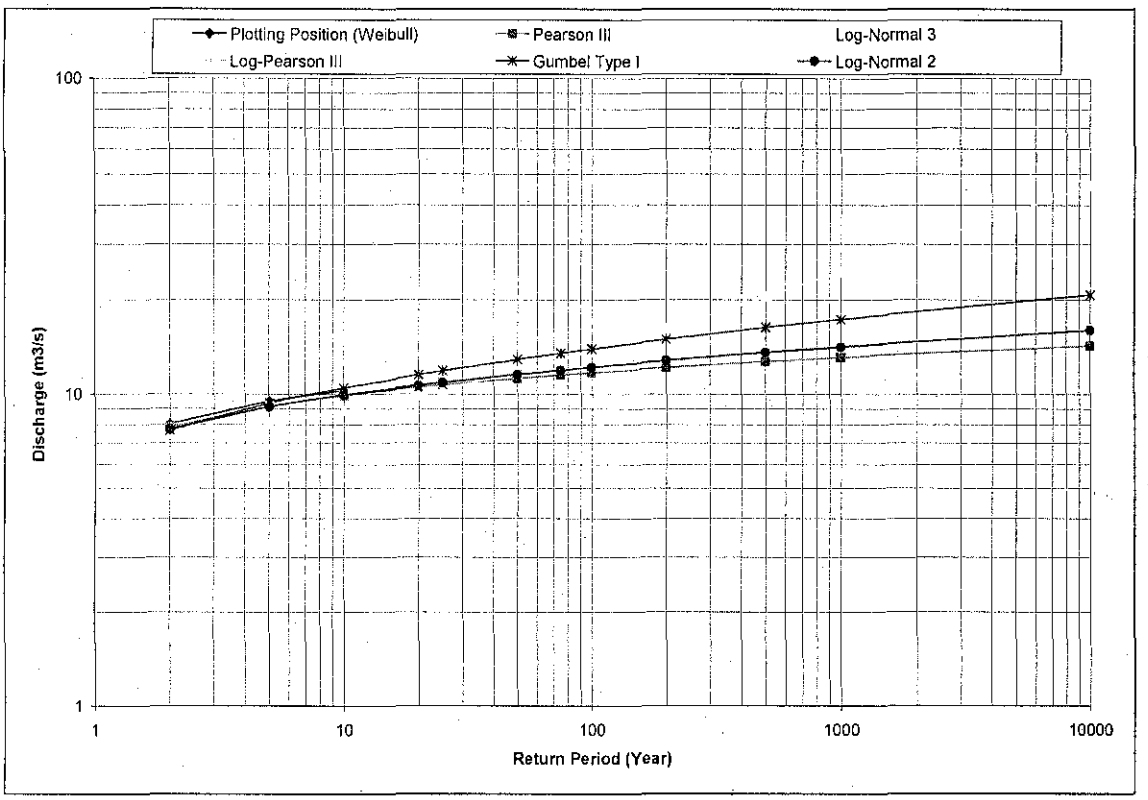
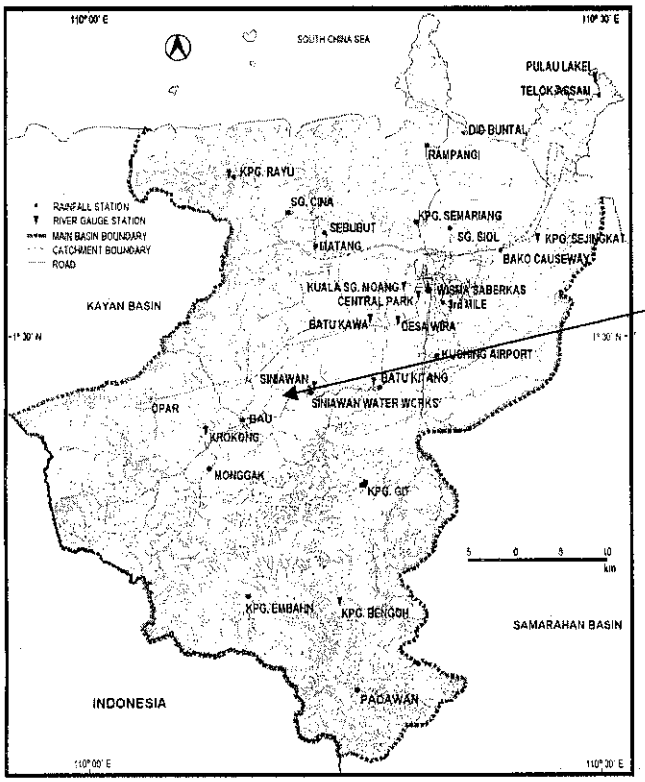


Figure C-82: Frequency Analysis of Annual Floods of Sungai Tuba at Sebuyau, Sarawak (1987-2000)

SUNGAI SARAWAK KIRI AT GIT

Sarawak Basin



Sg Sarawak Kanan at Buan Bidi, Kuching

Description by DID, SABAH

NOT AVAILABLE

Summary of Data

Name	Sungai Sarawak Kanan at Buan Bidi
Area (km^2):	425
Elevation (m):	
Average Rainfall (mm)	
Water Use	
Total Mean yearly (m^3/s):	33.01
Mean of "Min"s yearly (m^3/s)	8.18
Mean of "Max"s yearly (m^3/s):	468.81
Absolute Min, yearly (m^3/s):	0.6
Absolute Max yearly (m^3/s):	866.33
Source	Softcopy Waterlevel Data, 1987-2000, DID, Sarawak

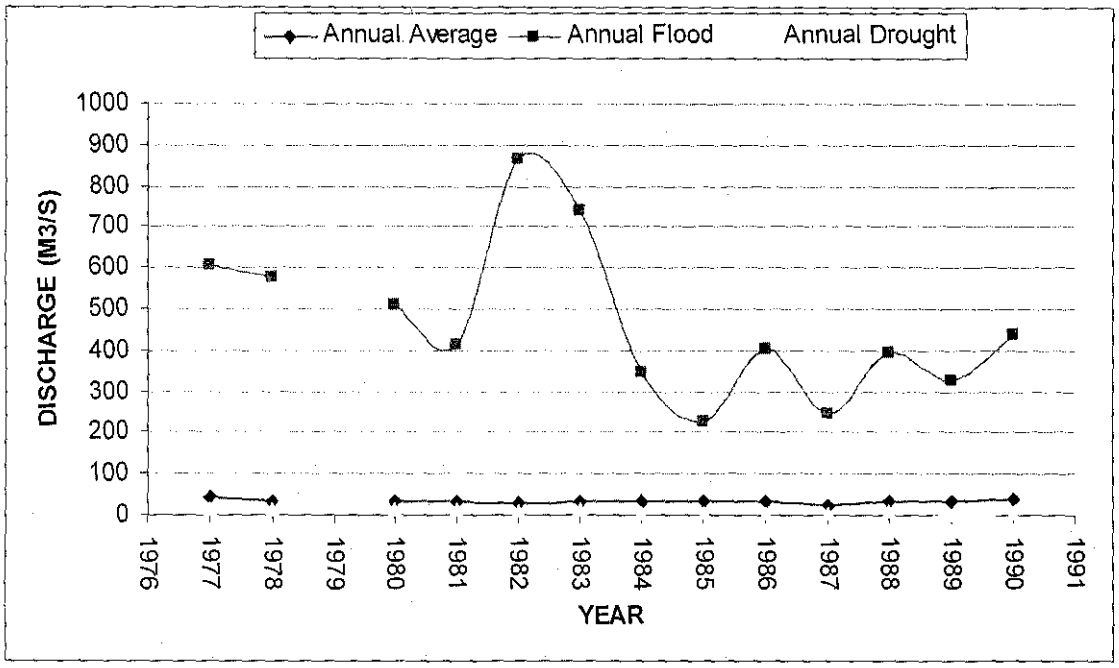


Figure C-83: Annual Discharge of Sungai Sarawak at Kg. Git, Sarawak (1977-1990)

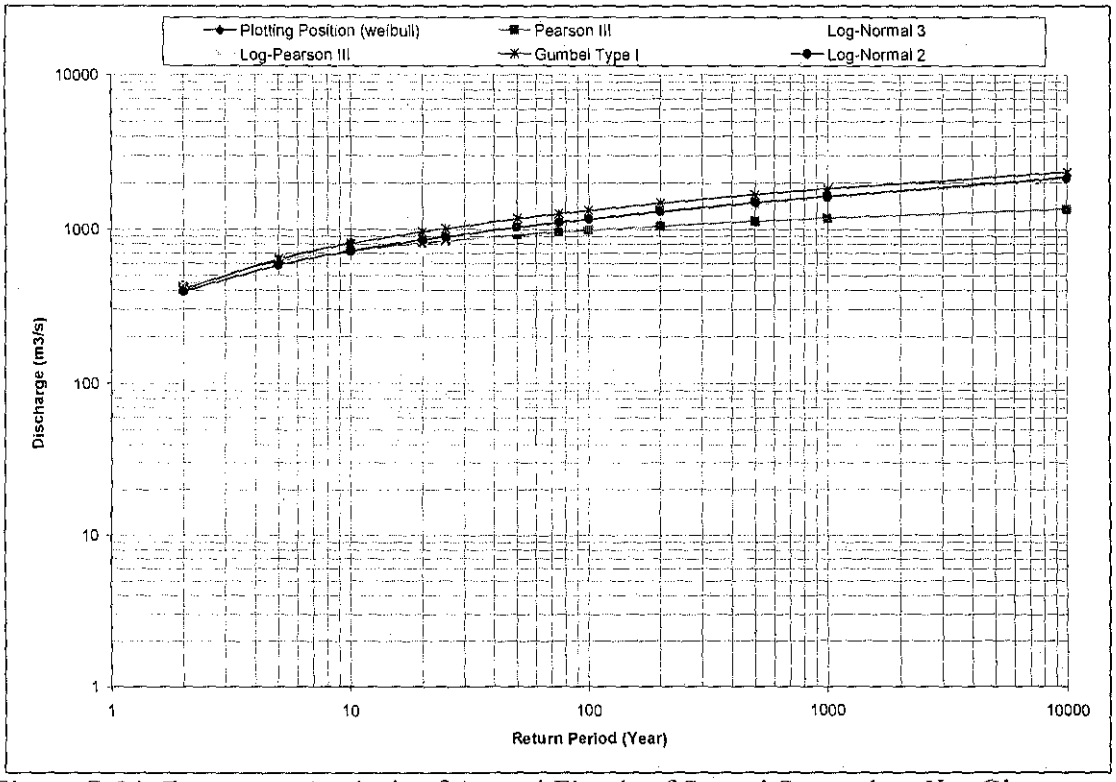


Figure C-84: Frequency Analysis of Annual Floods of Sungai Sarawak at Kg. Git, Sarawak (1987-2000)