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Flood Frequency Analysis Between Annual Maximum Series (AM) and Peaks-Over-Threshold (POT) Series in Selangor, Malaysia

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Flood Frequency Analysis Between Annual Maximum Series and Peaks-Over-Threshold (POT) Series in Selangor, Malaysia.

By

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ABSTRACT

Flood Frequency Analysis Between Annual Maximum Series (AM) and Peaks-Over-Threshold (POT) Series in Selangor, Malaysia

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Flood Frequency Analysis (FFA) refers to a statistical approach for estimating the probability and magnitude of flood occurrences. Annual Maximum (AM) is the most applied approaches in FFA, it focuses on the most extreme event during the period of time. In fact, it is also crucial to take both smaller and frequent flood events into consideration when performing flood frequency analysis. Therefore, another approach named Peaks-Over-Threshold (POT) method provides a more precise way of computing occurrences of floods by including noteworthy high flow events (even if they are not the most extreme of the year), but it is usually underemployed because of its complexities in threshold selection. This research attempts to compare these two approaches in the flood frequency analysis in Selangor. This study employs the L-moment approach to estimate the parameters of three candidate distributions, which are the generalised Pareto (GPA) distribution, the generalised extreme value (GEV) distribution, and the generalised logistic (GLO) distribution. Then, the L-moment diagram will be implemented to ascertain the optimum distribution for the data series. Additionally, each data series' distribution performance will be evaluated using the goodness-of-fit test and efficiency assessments, namely mean absolute error (MAE), root mean square error

(RMSE) and BIAS. This study aims to determine whether the AM or POT technique associated with one of the three distributions above yields a more dependable and accurate estimate of flood frequency in Selangor. This study can improve the way that flood risk is assessed and managed. It also might help in building infrastructure and flood control solutions, especially for flood-prone regions. Based on the analysis conducted across 13 streamflow stations in Selangor, the POT approach was found to outperform AM in 10 stations, indicating its effectiveness in capturing a broader range of flood events. Among the three candidate distributions, the GPA distribution is being selected at 9 out of 13 stations, particularly due to its lower MAE, RMSE, and Bias values. For instance, POT-GPA combinations at stations like Sg. Bernam At Jam. Skc, Selangor and Sg. Selangor at Rantau Panjang recorded significantly lower MAE, RMSE, and Bias values compared to GLO and GEV. GLO and GEV was selected at 2 stations at 1 station respectively, indicating comparatively less consistent performance. These findings suggest that the POT and GPA combination provides a more reliable and accurate estimate of flood frequency in Selangor. The results of this study are to support improved flood risk assessment and infrastructure planning in Selangor and similar flood-prone areas.

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Declaration

I hereby declare that this final year project report is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UTAR or other institutions.

OOI ZU YAN

Approval Sheet

This final year project report entitled "**Flood Frequency Analysis Between Annual Maximum Series and Peaks-Over-Threshold (POT) Series in Selangor, Malaysia**" was prepared by OOI ZU YAN and submitted as partial fulfilment of the requirements for the degree of Bachelor of Science (Hons) Statistical Computing and Operations Research at Universiti Tunku Abdul Rahman.

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PERMISSION SHEET

It is hereby certified that **OOI ZU YAN** (ID No: **22ADB02279**) has completed this final year project report entitled "**Flood Frequency Analysis Between Annual Maximum Series (AM) and Peaks-Over-Threshold (POT) Series in Selangor, Malaysia**" under the supervision of Dr Nur Amalina Binti Mat Jan (Supervisor) from the Department of Physical and Mathematical Science,

I hereby give permission to the University to upload the softcopy of my final year project report in pdf format into the UTAR Institutional Repository, which may be made accessible to the UTAR community and public.

Yours truly,

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(OOI ZU YAN)

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LIST OF ABBREVIATIONS

AM	Annual Maximum
DID	Drainage and Irrigation Department
FFA	Flood Frequency Analysis
GEV	Generalized Extreme Value
GLO	Generalized Logistics
GPA	Generalized Pareto
LMOM	L-moments
IADA	Integrated Agricultural Development Area
MAE	Mean Absolute Error
PWMs	Probability Weighted Moments
POT	Peaks-Over-Threshold
RMSE	Root Mean Square Error

Chapter 1

Introduction

1.1 Introduction

Flooding is a common natural disaster in Malaysia, as it is happening almost every year in many states (Snu et al., 2018). Factors like rapid urban growth, climate change, and changes in land use have made floods more frequent and severe, especially in Selangor. Floods are among Malaysia's greatest disasters with extensive consequences in terms of their duration, frequency, coverage, and negative impacts on the people and socioeconomic structure (Shah et al., 2017). In some cities like Selangor, the rapid development and poor drainage systems are making the flood become worse, and also damaging homes, roads, and businesses at the same time.

Flood Frequency Analysis (FFA) refers to a statistical method for estimating the magnitude of extreme flood events. It is essential for flood risk management and infrastructure planning. FFA usually fits distribution functions to observe flow data and then estimates the flood quantiles (Pan & Rahman, 2022). From past flood records, FFA can assists engineers and urban planners in designing flood control measures and improving water resource management. An accurate flood prediction is crucial, especially in heavily populated areas, where flooding can cause severe economic losses.

There are two commonly used approaches in FFA, which are the Annual Maximum (AM) series and the Peaks-Over-Threshold (POT) series. The AM method considers only the highest flood event per year, while the POT method includes all significant flood events exceeding a predefined threshold. Each approach has its advantages and limitations, making it important to assess their effectiveness in estimating flood probabilities. The POT approach is not as widely utilised as it might be a lot of work and uncertainty in selecting thresholds (Pan & Rahman, 2022). On the other hand, the AM method is widely adopted due to its simplicity and straightforward data extraction process. However, it might miss smaller but important floods in a year. Therefore, choosing the appropriate and suitable method is important for accurate and responsive flood prediction. By referring to previous studies, it can be observed that most of them are using the top 5% of values. Therefore, the 95th percentile threshold is applied to extract the streamflow data in this analysis.

Flood in Malaysia has caused serious economic and social problems, thus flood risk assessment very important. Using an effective FFA method can help in reducing flood impacts by assisting authorities to design better flood control systems and improve early warning systems. This study compares the AM and POT methods in FFA to find out which one will give more reliable flood predictions for Selangor. The results might be able to help in building infrastructure and lessen the harm to communities from future floods.

1.2 Problem Statement

According to recent research, Malaysia is experiencing an increase in events such as heavy rainfall, which leading to a rise in the frequency of flash floods in heavily populated areas such as Petaling Jaya and Subang (Tee et al., 2024). This extreme weather is causing serious risks to the infrastructures and economic activities. Selecting an appropriate FFA method remains a challenge, therefore, hydrologists strive to improve FFA methods to enable better understanding and prediction of these extreme events. An accurate flood assessment is important for effective urban planning and constructing sustainable water infrastructure (Bezak et al., 2014).

Improper FFA methods may lead to poor hydrological design, thus increasing the infrastructure failure. Furthermore, water may overflow and thus weakening the engineering properties of their structures (Hamzah et al., 2021). These statements show that there is a need for selecting the most suitable FFA approach, so that better management strategies that reduce the impact of extreme weather events can be developed.

1.3 Research Objectives

The main objectives of this study are:

1. To identify the appropriate data frequency for the Peaks-Over-Threshold (POT) and Annual Maximum Series (AM) methods for rivers in Selangor.

2. To develop parameter estimation for Generalized Extreme Value (GEV), Generalized Pareto (GPA), and Generalized Logistics (GLO) distribution of POT and AM and estimate by using L-moments method.
3. To compare performance between the POT and AM methods in three different distributions (GEV, GPA, and GLO) for rivers in Selangor.

1.4 Research Scope

This study is focusing on the flood frequency analysis for 13 river stations in Selangor. It utilises the streamflow data from the year 1960 to 2023. It aims to evaluate both AM and POT approaches in estimating extreme flood events. By comparing these methods, this study provides insights into the more suitable approach for flood risk management in the context of Selangor.

1.5 Research Contribution (Research Gap)

Previous studies by Hamzah (2021) have largely focused on Sungai Langat river basins. This narrow focus somehow limited the exploration of various analytical methods and probability distributions that could potentially offer improved flood predictions. Moreover, a news report on 8 November 2023 revealed that the number of flood victims in Selangor increased from 200 to 792 families. The Drainage and Irrigation Department (DID) also claimed that the water level had exceeded the warning level despite no recorded rainfall (Malay Mail, 2023). This phenomenon has highlighted the need for a more comprehensive flood frequency analysis.

This research expands on past studies by examining a wider geographical area within Selangor and by comparing both the AM and the Peaks-Over-Threshold (POT) methods using multiple probability distributions. By comparing the POT approach alongside with the AM method, this study wish to fill the gaps in current flood analysis and provide better insights for improving flood risk management in Selangor.

1.6 Significance of Study

This study identifies the most suitable approach for FFA in Selangor by comparing the AM and POT methods, which assists in ensuring more reliable flood prediction. It also provides a foundational framework for future flood risk assessment studies, contributing to long-term planning. The findings from evaluating various probability distributions for both AM and POT datasets help researchers and design professionals in selecting appropriate models for flood estimation (Ng et al., 2021). Therefore, this study contributes to improving flood control and infrastructure planning in Selangor by covering more river basins beyond previous research and comparing both AM and POT methods using multiple different distributions.

Chapter 2

Literature Review

2.1 Flood Frequency Analysis

Ahmad et al. (2011) conducted a study on flood frequency analysis (FFA) in Negeri Sembilan, Malaysia. Their study was using the Annual Maximum (AM) method in analysing data from 11 hydrometric stations. They then compared three probability distributions, (GPA, GEV, GPA) to determine the best fit for modelling annual maximum stream flows. They applied the L-moments (LMOM) and the trimmed version called TL-moments (TLMOM1) for parameter estimation. After that, they used the Mean Absolute Deviation Index (MADI) and L-moment ratio diagrams to evaluate the performance of the model. The results showed that the GLO distribution was the most suitable model as it consistently performing better than GEV and GPA across all stations. Although the AM method was found to be simple and effective for modelling extreme floods, the researchers still acknowledged that its limitation of capturing only the highest flood each year that would exclude other significant flood events.

A study that examined flood frequency analysis at the Segamat River streamflow site in Johor, Malaysia was conducted by Badyalina et al. (2021). They applied the Annual Maximum method and the L-moment estimation technique to test five probability distributions, which are Generalized Logistic (GLO), Generalized

Extreme Value (GEV), and Generalized Pareto (GPA), Log-Pearson Type III (PE3), and Log-Normal (LN3). The study is carried out to determine which one best fit the annual peak flows. By using various accuracy measures such as Mean Square Deviation Index (MADI), LMOM and TLMOM1 ratio diagrams, the study found that the LN3 distribution was most effective in fitting the data's right tail, which is crucial for flood risk management. Overall, the researchers concluded that LN3 offers reliable estimates for extreme flood magnitudes, making it a suitable choice for hydrological design and planning in Johor.

2.2 POT and AM Approaches

A study comparing the Peaks Over Threshold (POT) and Annual Maximum (AM) methods by Bezak et al. (2014) has highlighted the strengths and weaknesses of each approach. By using data from the Sava River in Slovenia, they tested different statistical distributions and parameter estimation methods, such as the Method of Moments (MOM), L-moments, and Maximum Likelihood Estimation (MLE). The study showed that the POT method has provided more accurate estimates, especially for higher return periods. This is because it includes multiple flood peaks per year, leading to a larger sample size and more reliable statistical estimates. However, threshold selection and independence criteria were key challenges for POT. In contrast, the AM method, which is relatively simpler, remains widely used but may underestimate extreme flood events. In conclusion, the researchers concluded that the POT method is offering better precision and reliability, making it a stronger choice for detailed flood frequency analysis.

Pan and Rahman (2022) has conducted another study comparing the Peaks Over Threshold (POT) and Annual Maximum (AM) methods for flood frequency analysis (FFA) with the data from 188 gauged stations across southeast Australia. For the POT method, the automated threshold detection techniques are applied, while the Generalized Pareto distribution is used for modelling. On the other hand, the Generalized Extreme Value distribution with the L-moment estimator is used. The results showed that the POT method was more flexible as it considered multiple flood events per year, making it more reliable for lower Annual Recurrence Intervals (ARIs) between 1.01 and 1.75 years. However, the complexity of choosing the threshold and ensuring data independence was a challenge. Meanwhile, the AM method was simpler, but it is having limitations as it only considers the highest flood event each year, which could lead to higher uncertainty, especially in dry areas with irregular rainfall. This is because the loss of valuable flood data due to selecting only a small portion from the original dataset when applying AM method. For higher ARIs, both methods produced similar results, but the POT method still having slightly better accuracy. With this, the study concluded that the POT method is a better choice for detailed flood frequency analysis.

A study conducted by Mostofi Zadeh et al. (2019) has developed a structured approach for pooled flood frequency analysis, which able to compare the Peaks Over Threshold and Annual Maximum Series methods using data from stations across Canada. They grouped similar catchments based on factors like drainage area and mean annual precipitation, then discussed the strengths and weaknesses of both methods. They found out that AM is simple and widely used, and it only considers the highest annual flood, which may overlook other significant events and sometimes might include low flows that affect extreme value analysis. On the other hand, POT includes all flood events above a chosen threshold, which increased the dataset size and thus improved flood estimates for smaller return periods. However, selecting an appropriate threshold and ensuring data independence is always a challenge. The study found that POT generally produced more accurate flood quantile estimates for longer return periods and had lower uncertainties compared to AM.

In short, the AM approach is widely used due to its simplicity. On the other hand, the POT approach is able to capture more flood data, but it also introduces uncertainty in threshold selection. Additionally, different probability distributions may yield varying results when applied to AM and POT datasets. Since previous studies mainly focused on regions like Canada and Australia, this study aims to address the gap in determining the best approach and probability distribution for flood frequency estimation in Selangor, Malaysia.

2.3 Probability Distribution for FFA fitting

In recent years, studies have explored different probability distributions to improve FFA accuracy. Among them, the Generalized Extreme Value (GEV), Generalized Logistic (GLO), and Generalized Pareto (GPA) distribution have been widely applied due to their ability to model extreme hydrological events. The selection of the most appropriate probability distribution is essential for minimizing estimation errors and improving flood risk assessment.

In the study by Ng et al. (2021), the Generalized Extreme Value (GEV) distribution was found to be the best fit for modelling the Annual Maximum Series in the Kelantan River Basin. Its flexibility and ability to capture extreme rainfall events make it well-suited for modelling annual maximum data. This finding is in line with previous guidelines and studies, such as those from the Department of Irrigation and Drainage (DID) Malaysia, which also recommend the GEV distribution for AMS. Additionally, for the Peaks-Over-Threshold method, the Generalized Pareto (GPA) distribution was chosen as the most appropriate because it effectively captures high-frequency events with a long, thick upper tail. These recommendations provide valuable insights for hydrological modelling and flood risk management in regions that frequently experience extreme rainfall events.

In another study on flood frequency analysis (FFA) in the Sungai Langat Basin by Hamzah et al. (2021), they used both the Annual Maximum Series (AM) and the

Partial Duration Series (PDS) methods to assess high-flow events. It is important to note that POT (Peaks-Over-Threshold) and PDS (Partial Duration Series) refer to the same method as they both analysing flood events that exceed a certain threshold rather than just the annual maximum. For the AM data, they found that the Generalized Extreme Value (GEV) distribution was the best model to capture extreme annual flows. In contrast, the POT data that included more frequent high-flow events best described by the Generalized Pareto (GPA) and three-parameter Lognormal (LN3) distributions. The study also showed that the POT approach offers a more accurate estimation of flood magnitudes, especially for events with shorter return periods.

According to another study, which focuses on frequency analysis of maximum daily rainfalls was carried out using the L-moment approach for stations in Selangor and Kuala Lumpur. The research evaluated several probability distributions to identify the best fit for the data, and it found that the generalized logistic distribution (GLO) performed best for modelling extreme rainfall events. This conclusion was supported by performance criteria such as the mean absolute deviation index (MADI), mean square deviation index (MSDI), and the L-moment ratio diagram (Shabri et al., 2009).

Table 2.1: Suggested probability distribution in previous research in Malaysia.

Authors	Location	Best Fit Distribution
Hamzah, Tajudin & Jaafar, 2021	Sungai Langat Basin	GEV (AM) GPA/LN3 (POT)
Ng et al., 2021	Kelantan River Basin	GEV (AM) GPA (POT)
Zakaria et al., 2012	Kampung Lui station	GLO distribution
Ahmad et al., 2011	Negeri Sembilan	GLO (AM)
Shabri et al., 2009	Kuala Lumpur and Selangor	GLO distribution
Zawiah et al., 2009	Peninsular Malaysia	GEV (AM) GPA (POT)

Table 2.1 shows the best fit probability distribution in previous research in Malaysia. With these, the distributions selected for this study are Generalized Extreme Value (GEV), Generalized Logistic (GLO), and Generalized Pareto (GPA) distribution. In this study, a flood frequency analysis (FFA) is conducted for Selangor, Malaysia by utilizing the L-moments method to estimate parameters for three probability distributions: Generalized Extreme Value (GEV), Generalized Pareto (GPA), and Generalized Logistic (GLO). The analysis is based on real data of annual maximum streamflow from multiple stations across Selangor, covering the period from 1960 to 2019. Subsequently, to determine the optimal probability distribution for each streamflow station, the L-moment ratio diagrams and accuracy performance metrics including Root Mean Square Error (RMSE), Mean Absolute Error (MAE), and Bias are applied.

In conclusion, most flood frequency analysis in Malaysia have applied the Annual Maximum method. However, the AM method only considers at the biggest flood each year, thus it might ignore other important flood events. This shows that the importance to explore other methods like the Peaks Over Threshold (POT) approach for FFA in Malaysia. Therefore, this study will compare both AM and POT methods to identify the one with better results for flood prediction in Malaysia.

Chapter 3

Research Methodology

3.1 Research Flow

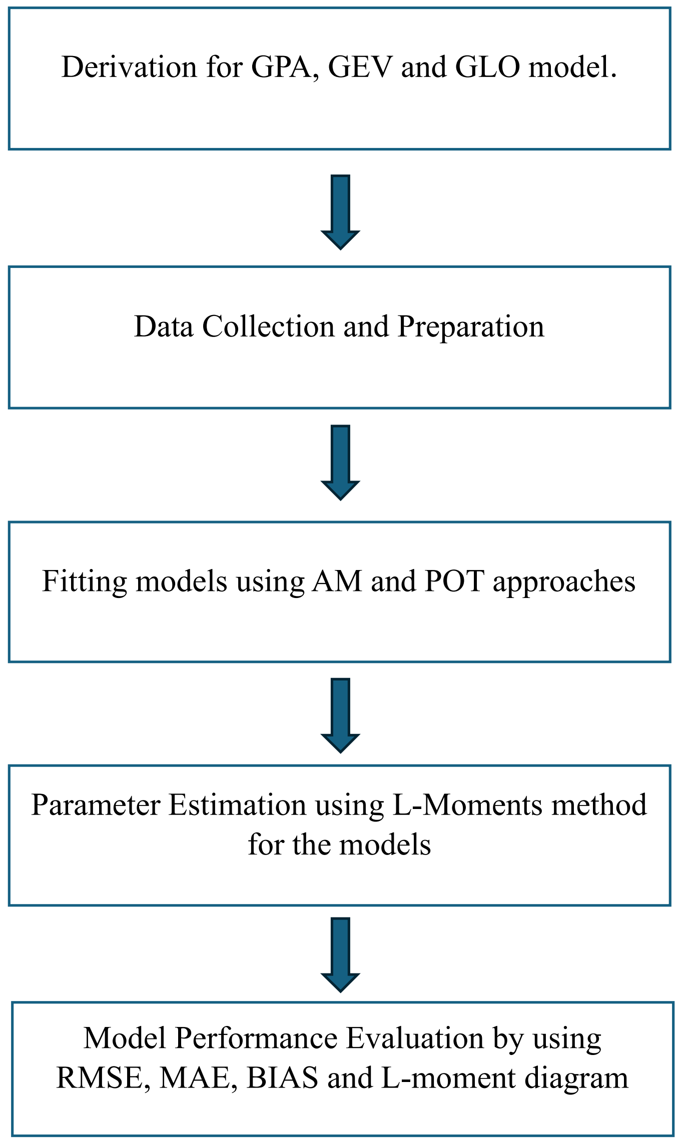

Figure 3.1: Research Flow.

Based on Figure 3.1, flood frequency analysis (FFA) is conducted to compare the performance of the Annual Maximum (AM) and Peaks-Over-Threshold (POT) approaches in estimating flood probabilities for Selangor, Malaysia. The study starts with data collection and preparation, which including handling missing data. Then, the streamflow records from multiple stations are structured into AM and POT datasets. Following this, model development for each method is carried out by defining the AM dataset and selecting an appropriate threshold for the POT method. The L-moments approach is then applied to estimate the parameters of three probability distributions, including Generalized Extreme Value (GEV), Generalized Logistic (GLO), and Generalized Pareto (GPA) for both AM and POT datasets. To assess the accuracy of the models, performance evaluation metrics such as Mean Absolute Error (MAE), Root Mean Square Error (RMSE), and Bias are computed. Finally, the models are compared using L-moment ratio diagrams. The final stage of the study is the selection of the best-fitting distribution and the most suitable flood frequency approach for improved flood risk assessment in Selangor.

3.2 L-moments method

L-moments method is specific linear combination of probability weighted moments (PWMs) and can provides straightforward interpretations of the location, form, and dispersion of sample data (Hamzah et al., 2021). Due to its ease of understanding as a scale and shape measurement of probability distributions, L-moments are thought to be more efficient than other PWMs (Badyalina et al., 2021). Hosking and Wallis (1995) revealed that L-moments have theoretical advantages over as it is able to characterise a wider range of distributions. Additionally, outliers are typically seen in FFA, but L-moments is sufficient robust so that the sample variability has limited impact on it (Hamzah et al., 2021). Moreover, the moment ratio estimators of L-CV and L-skewness do not have bounds that depend on the sample size, which product moment estimators do (Yirba, 2016). Therefore, the L-moments approach is applied in this study since its parameter estimations are more accurate due to the smaller mean-squared error of estimation and are able to compute in an easier way than maximum likelihood estimates (Shabri and Jemain, 2010). Research by Ulrych et al.(2000) has proved that L-moments are less sensitive to extreme values, making them particularly useful in fields like hydrology and geophysics. Their robustness, lower bias, better PDF estimation, and consistency of L-moments give them the potential to improve statistical estimation and inference. Additionally, they can provide more efficient parameter estimates compared to maximum likelihood estimation (Hosking, 1990). These properties make L-moments a strong alternative for fitting probability distributions, especially in hydrological studies.

$$\lambda_1 = \beta_0 \tag{1}$$

$$\lambda_2 = 2\beta_1 - \beta_0 \tag{2}$$

$$\lambda_3 = 6\beta_2 - 6\beta_1 + \beta_0 \tag{3}$$

$$\lambda_4 = 20\beta_3 - 30\beta_2 + 12\beta_1 - \beta_0 \tag{4}$$

Equation 1 to 4 are formulas for the first four L-moments. λ_1 refers to the mean of data, which also known as the L-location. λ_2, which known as L-scale, represents the variability of the data. Moreover, λ_3 and λ_4 are referring to the skewness and kurtosis of the data respectively. These four formulas can be derived by the equations below:

$$\beta_0 = \frac{1}{n}\sum_{j=1}^{n} X_{j:n} \tag{5}$$

$$\beta_1 = \frac{1}{n}\sum_{j=2}^{n} \frac{(j-1)}{(n-1)} X_{j:n} \tag{6}$$

$$\beta_2 = \frac{1}{n}\sum_{j=3}^{n} \frac{(j-1)(j-2)}{(n-1)(n-2)} X_{j:n} \tag{7}$$

Therefore, the formula can be written in general as:

$$\beta_r = \frac{1}{n}\sum_{j=3}^{n} \frac{(j-1)(j-2)L(j-r)}{(n-1)(n-2)L(n-r)} X_{j:n} \tag{8}$$

Where *n* refers to the sample size and *x* refers to the data value.

$$t_r = \frac{\lambda_r}{\lambda_2}, \text{ r} = 3, 4 \tag{9}$$

Equation (9) is the formula for the sample ratio of L-moments. The sample ratios t_3 and t_4 are used in determining the skewness and kurtosis of a sample dataset. Additionally, the coefficient of L variation is represented by

$$t_2 = \frac{\lambda_2}{\lambda_1} \tag{10}$$

Where $|t_r| < 1$ for all $r > 3$.

3.3 Probability Distribution

There are three candidate distributions in this study which are the GLO distribution, GPA distribution and GEV distribution. The L-moments method will be applied in these three distributions. These three distributions are selected because they are expected to fit the dataset well, as discussed in the literature review chapter.

Table 3.1 Probability Distribution Function & LMOM Parameter Estimates.

Distribution	Cumulative Density Distribution	Parameter Estimation
GLO	$X(F) = \xi + \frac{\alpha}{K}\{1 - [\frac{1-F}{F}]^K\}$	$\alpha = \frac{l_2}{\Gamma(1+K)\Gamma(1-K)}$ $\xi = l_1 + \frac{(l_2 - \alpha)}{K}$ $K = -t_3$
GPA	$X(F) = \xi + \frac{\alpha}{K}\{1 - [1-F]^K\}$	$\alpha = l_2[(K+1)(K+2)]$ $\xi = l_1 + l_2(K+2)$ $K = \frac{4}{t_3 + 1} - 3$

GEV	$X(F) = \xi + \frac{\alpha}{K}\{1 - [-ln\ F]^{K}\}$	$\alpha = \frac{l_{2}K}{\Gamma(1+K)\Gamma(1-2^{-K})}$ $\xi = l_{1} + \frac{\alpha(\Gamma(1+K)-1)}{K}$ $K = 7.85890\ C + 2.9554\ C^{2}$ $C = \frac{2}{3+t_{3}} - \frac{ln\ 2}{ln\ 3}$

Table 3.1 shows the probability distribution function and the parameter estimations for the three-parameter probability distributions. For the parameter estimations, ξ refers to the location, while α is representing the scale, along with k that represents the shape.

3.4 Data Description

In Selangor, several key river basins such as Bernam River, Selangor River, Langat River Semenyih River, Lui River, and Tengi River were selected for this study due to their significant hydrological and socio-economic roles. The streamflow data for these rivers in this study were obtained from the Department of Irrigation and Drainage (DID) Malaysia. The Bernam River forms the border between Selangor and Perak. It stretches approximately 200 km with a catchment area of 3,335 km^2. Its eastern region supports rubber and oil palm plantations, while its western regions are supporting the paddy cultivation under the Integrated Agricultural Development Area (IADA) project (Hashim et al., 2021). The second river is the Selangor River that covers about 2,000 km^2 across the Hulu Selangor, Gombak, and Kuala Selangor districts. The basin has undergone extensive land development and land-use changes since 1970s (Bahar et al., 2021). Another major river, the Langat River, with approximately 2,350 km^2 catchment area and length of 141 km. It is situated roughly 40 km east of Kuala Lumpur, between latitudes 2°40'N to 3°16'N and longitudes 101°19'E to 102°1'E. Its key tributaries include Semenyih River, Lui River, and Beranang River, with important streamflow stations located at Kajang, Dengkil, Lui River, and Semenyih River (Langat et al., 2021). Among these, Semenyih River and Lui River were also included in this study. Semenyih River itself covers an area of 266.60 km^2, with 25 catchment valleys and 36 sub-basins ranging from 1.37 to 35.57 km^2. The river is flowing southward through Sepang and Hulu Langat and is located in a humid zone, thus it is receiving about 3000 mm of rainfall annually. It supplies roughly 15% of the treated water to Kuala Lumpur, Selangor, and Putrajaya. However, deforestation, urban expansion, agriculture, and mining have degraded the river's ecological condition (Fawaz et al., 2016). The location of the rivers is shown in Figure 3.2, Figure 3.3, Figure 3.4 and Figure 3.5, while the complete list of selected stations is provided in Table 3.2.

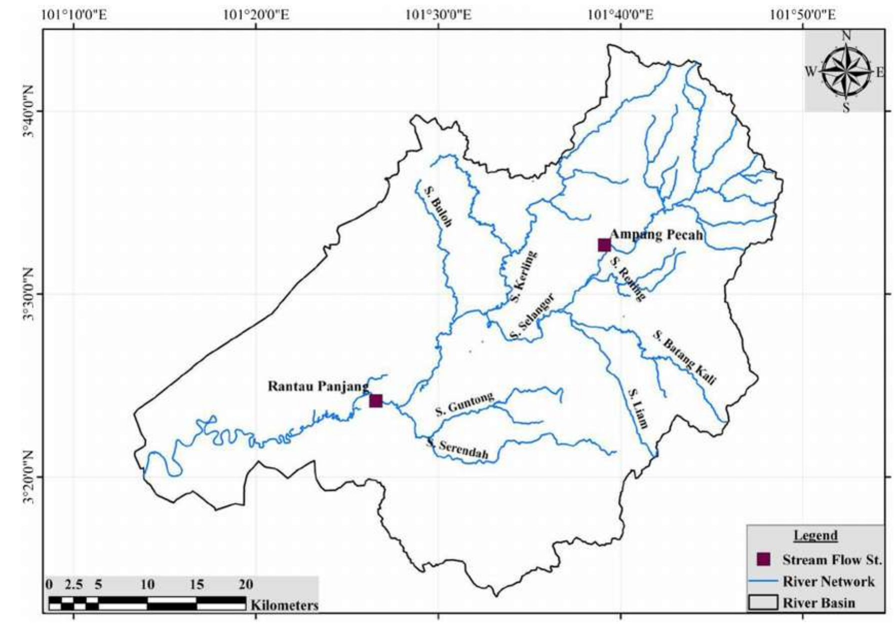

Figure 3.2: Selangor River (Seyam & Othman, 2014).

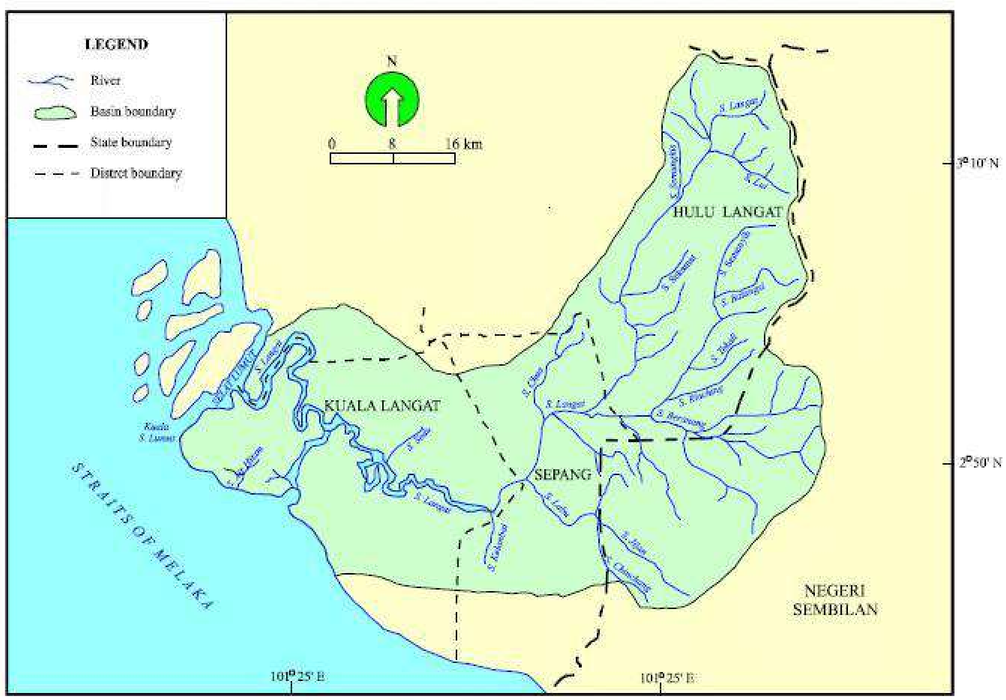

Figure 3.3: Langat River (Roslan et al., 2012).

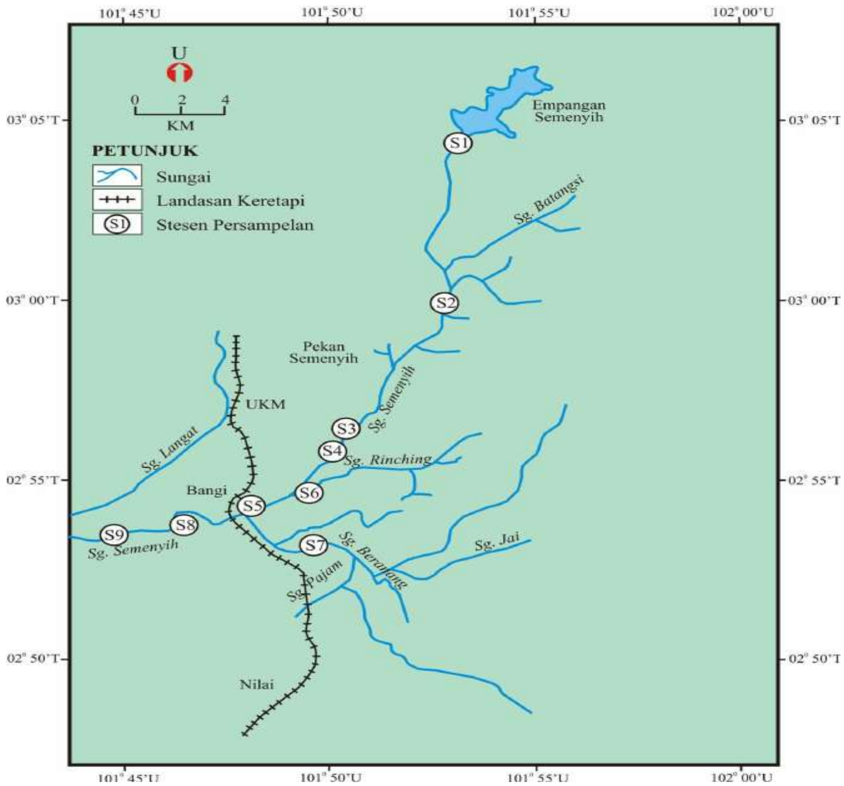

Figure 3.4: Semenyih River (Waseem & Mohsin, 2011).

Figure 3.5: Tengi River. (Source: Google Maps, 2025)

Table 3.2: list of streamflow stations in Selangor.

No.	Station No.	Station Name
1	3615412	SG. BERNAM at TANJUNG MALIM,SELANGOR
2	3414421	SG. SELANGOR at RANTAU PANJANG
3	3813411	SG. BERNAM at JAM.SKC, SELANGOR
4	3516422	SG. SELANGOR at RASA,SELANGOR
5	2816441	SG. LANGAT at DENGKIL,SELANGOR
6	3118445	SG. LUI at KG. LUI,SELANGOR
7	2918401	SG. SEMENYIH at KG.RINCHING, SELANGOR
8	2917401	SG. LANGAT at KAJANG,SELANGOR
9	3516424	SG. SELANGOR at AMPANG PECHAH, S'NGOR
10	3613403	TERUSAN TENGI at HILIR JAM. MERGASTUA
11	2816401	SG. LANGAT at BUKIT CHANGGANG
12	3613402	TERUSAN TENGI at BERNAM HEADWORK
13	3415401	SG. SELANGOR at KG. TIMAH, SELANGOR

3.5 Performance Measurement

3.5.1 MAE, RMSE, BIAS

For the performance measurement of model in this study, MAE, RMSE and BIAS are used to measure the accuracy. Mean Absolute Error (MAE) and Root Mean Square Error (RMSE) are widely used metrics for evaluating model performance (Hodson, 2022). They are used to evaluate the differences and variations between the observed and predicted values. MAE is considered the most intuitive and straightforward measure of average error magnitude, providing an unambiguous assessment of the typical size of errors (Willmott & Matsuura, 2005). This means that MAE easy to understand as it shows the average size of prediction errors without complex assumptions, providing a straightforward measure of how far predictions deviate from actual values. On the other hand, RMSE is a commonly used statistical metric for evaluating model performance in fields such as meteorology, air quality, and climate research (Chai and Draxler, 2014). RMSE is particularly noteworthy as it is one of the most commonly reported yet frequently misinterpreted error metrics in climate and environmental studies (Willmott & Matsuura, 2005). This is because RMSE always reflects average error like MAE does, when in reality, RMSE penalizes larger errors more heavily due to squaring. Bias refers to systematic errors that affect the validity of estimates. Unlike random errors, bias cannot be reduced or eliminated simply by increasing the sample size (Choi & Pak, 1998). Therefore, a better model should have a lower value of bias.

The formulas of MAE, RMSE and Bias are shown as equation 11 to equation 13 below:

$$\text{MAE} = \frac{1}{n}\sum_{i=1}^{n} |F(y_i) - F(\hat{y}_i)| \tag{11}$$

$$\text{RMSE} = \sqrt{\frac{\sum_{i=1}^{n}(F(y_i) - F(\hat{y}_i))^2}{n}} \tag{12}$$

$$\text{BIAS} = \frac{1}{n}\,\frac{\sum_{i=1}^{n}(F(y_i) - F(\hat{y}_i))}{F(y_i)} \tag{13}$$

3.5.2 L-moments diagram

The use of L-moments method and L-moments ratio diagram are increasingly common among hydrologists, as it allows a quick visual assessment of which distribution may best fit the data (Peel., 2001). Numerous authors (Seckin, et al.., 2011; Zakaria al., 2012.; Badyalina, et al, 2021; Mohd Baki et al., 2014; Weerabangsa et al., 2023) have applied L-moment ratio diagrams into their distribution selection process. To plot a L-moment ratio diagrams, L-skewness (τ_3) and L-kurtosis (τ_4) are required, which are calculated using the two equations below:

$$\tau_3 = \frac{L_3}{L_2} \tag{14}$$

$$\tau_4 = \frac{L_4}{L_3} \tag{15}$$

where in L-moments diagram, L_2 refers to the sample L-scale (λ_2), L_3 refers to sample L-skewness (λ_3), and L_4 refers to the sample L-kurtosis (λ_4).

Chapter 4

Result and Discussion

Chapter 4 investigates the outcome of the MAE, RMSE, BIAS and the L-moments diagram. The results are used to find out the most suitable technique for FFA in Selangor, along with the most fitting distributions among the three candidate distributions. Lastly, the quantile estimation is discussed after the three metrics and L-moments diagram.

4.1 Performance Measurement (MAE, RMSE, BIAS)

In this study, the accuracy performance measurement is used to determine the best FFA technique among AM and POT for the streamflow station in Selangor. Table 4.1 shows the value of MAE, BIAS and RMSE at 13 streamflow stations in Selangor. These values are compared to selecting the best model among the six models (GEV_AM, GLO_AM, GPA_AM, GEV_POT, GLO_POT, GPA_POT). Lower values of these metrics indicate a better model for the streamflow station. In Table 4.1 the lowest set of values is bolded for a better view.

Table 4.1: Result of MAE, RMSE, BIAS for 13 stations.

Stations	Distribution	MAE	RMSE	BIAS
Sg. Bernam At Tanjung Malim, Selangor	GEV_AM	29.360	40.800	29.030
	GLO_AM	29.790	42.810	29.630
	GPA_AM	27.200	35.260	26.530
	GEV_POT	32.800	35.560	24.400
	GLO_POT	**25.860**	31.160	24.370
	GPA_POT	26.110	**30.970**	**23.270**

Table 4.1: Result of MAE, RMSE, BIAS for 13 stations.

Sg. Selangor At Rantau Panjang	GEV_AM	144.830	161.580	144.830
	GLO_AM	148.620	169.490	148.620
	GPA_AM	134.130	145.330	134.130
	GEV_POT	20.740	24.130	5.840
	GLO_POT	27.380	32.260	12.920
	GPA_POT	**13.190**	**14.940**	**4.730**
Sg. Bernam At Jam.Skc, Selangor	GEV_AM	91.702	116.443	70.080
	GLO_AM	96.544	122.729	71.010
	GPA_AM	81.275	100.918	68.902
	GEV_POT	70.080	84.596	36.489
	GLO_POT	71.010	86.023	37.866
	GPA_POT	**68.902**	**80.436**	**30.746**
Sg. Selangor At Rasa, Selangor	GEV_AM	30.053	35.557	28.487
	GLO_AM	32.032	36.762	30.556
	GPA_AM	**25.989**	33.754	24.384
	GEV_POT	28.615	33.532	28.615
	GLO_POT	28.837	34.621	28.837
	GPA_POT	26.107	**26.345**	**14.989**
Sg. Langat At Dengkil,Selangor	GEV_AM	262.187	330.080	151.616
	GLO_AM	266.556	336.876	151.623
	GPA_AM	248.042	306.071	143.942
	GEV_POT	171.794	199.269	171.794
	GLO_POT	**143.293**	**157.333**	**140.397**
	GPA_POT	147.049	171.004	143.293
Sg. Lui At Kg. Lui,Selangor	GEV_AM	15.675	16.994	15.675
	GLO_AM	15.908	17.420	15.908
	GPA_AM	14.850	15.841	14.850
	GEV_POT	8.315	9.037	8.315
	GLO_POT	7.654	8.763	7.654
	GPA_POT	**7.586**	**8.369**	**7.586**
Sg. Semenyih At Kg.Rinching, Selangor	GEV_AM	9.616	12.928	9.616
	GLO_AM	10.460	14.628	10.460
	GPA_AM	**8.156**	**10.741**	**8.156**
	GEV_POT	15.580	18.708	13.220
	GLO_POT	15.952	19.416	13.564
	GPA_POT	14.426	16.993	12.087

Table 4.1: Result of MAE, RMSE, BIAS for 13 stations.

Sg. Langat At Kajang,Selangor	GEV_AM	142.141	215.585	71.962
	GLO_AM	141.548	214.008	69.462
	GPA_AM	140.748	213.719	76.372
	GEV_POT	**48.818**	**63.008**	**47.117**
	GLO_POT	53.601	68.268	53.601
	GPA_POT	58.113	68.078	58.113
Sg. Selangor At Ampang Pechah, S'ngor	GEV_AM	8.354	12.001	8.354
	GLO_AM	8.960	12.487	8.952
	GPA_AM	7.460	11.413	7.460
	GEV_POT	7.651	9.129	6.142
	GLO_POT	9.083	9.922	9.083
	GPA_POT	**6.482**	**7.390**	**5.742**
Terusan Tengi At Hilir Jam. Mergastua	GEV_AM	4.749	6.794	4.749
	GLO_AM	5.302	7.053	5.302
	GPA_AM	**4.291**	**6.473**	**4.291**
	GEV_POT	10.858	13.011	9.254
	GLO_POT	11.521	13.859	9.890
	GPA_POT	9.699	11.781	8.128
Sg. Langat At Bukit Changgang	GEV_AM	29.645	35.358	16.890
	GLO_AM	32.175	36.547	19.092
	GPA_AM	26.184	33.552	14.322
	GEV_POT	34.366	37.385	-17.442
	GLO_POT	**25.301**	**32.776**	**6.297**
	GPA_POT	31.184	32.917	20.669
Terusan Tengi At Bernam Headwork	GEV_AM	11.079	12.466	11.079
	GLO_AM	12.057	13.515	12.057
	GPA_AM	**9.698**	**11.233**	**9.698**
	GEV_POT	15.205	18.153	12.960
	GLO_POT	15.876	19.160	13.607
	GPA_POT	13.765	16.368	11.509
Sg. Selangor At Kg. Timah, Selangor	GEV_AM	67.776	102.142	58.335
	GLO_AM	67.979	101.861	57.138
	GPA_AM	65.277	98.551	59.162
	GEV_POT	60.986	66.159	60.986
	GLO_POT	50.845	57.391	50.845
	GPA_POT	**50.570**	**52.516**	**50.570**

As shown in Table 4.1, the POT approach is observed to be better, with 10 out of 13 stations in Selangor having lower values compared to the AM approach. The 10 stations are Sg. Bernam At Tanjung Malim, Sg. Selangor At Rantau Panjang, Sg. Bernam At Jam.Skc, Sg. Selangor At Rasa, Sg. Langat At Dengkil, Sg. Lui At Kg. Lui, Sg. Semenyih At Kg.Rinching, Sg. Langat At Kajang, Sg. Selangor At Ampang Pechah, Terusan Tengi At Hilir Jam. Mergastua, Sg. Langat At Bukit Changgang, Terusan Tengi At Bernam Headwork, Sg. Selangor At Kg. Timah. For Sg. Bernam At Tanjung Malim And Sg. Selangor At Rasa, the RMSE and BIAS are the lowest, while the MAE is the second lowest, with only a slight difference compared to the lowest. Therefore, POT still being considered as the better method for these stations, as 2 out of 3 metrics are the lowest. For the remaining three stations, AMs stand out as a better approach for their FFA. Therefore, based on the overall results, the POT approach can be identified as the more reliable method for flood frequency analysis in Selangor.

4.2 L-Moment Diagrams

The AM and POT data at different streamflow stations were plotted in the L-moment diagram that are shown in Figure 4.1 to Figure 4.13 below.

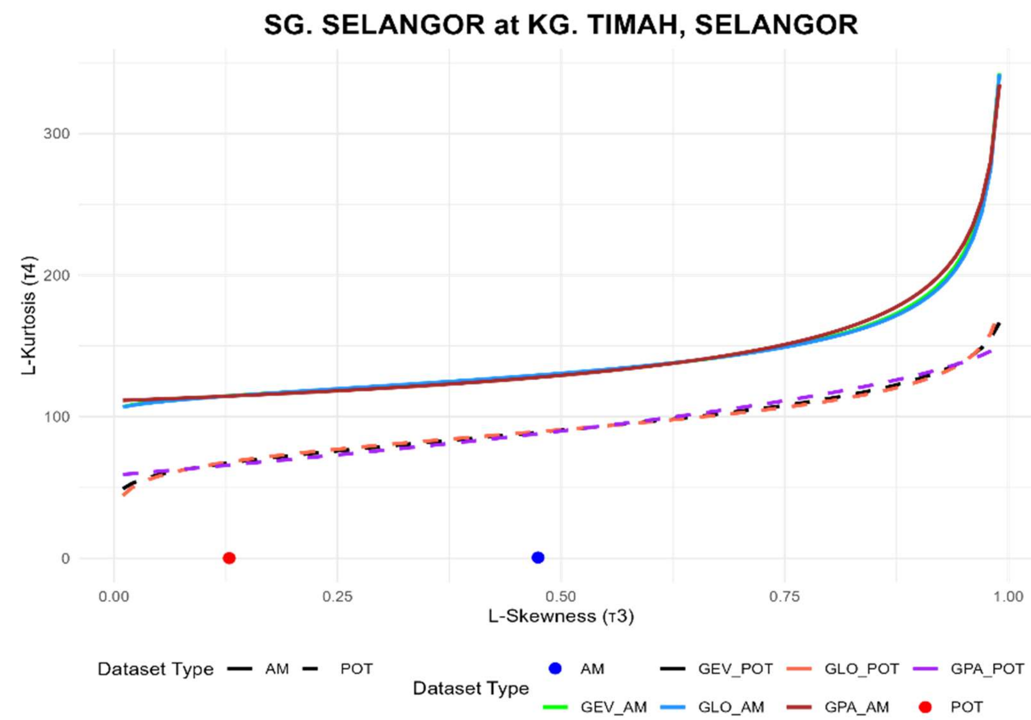

Figure 4.1: L-Moment Diagrams for Sg. Selangor At Kg. Timah, Selangor.

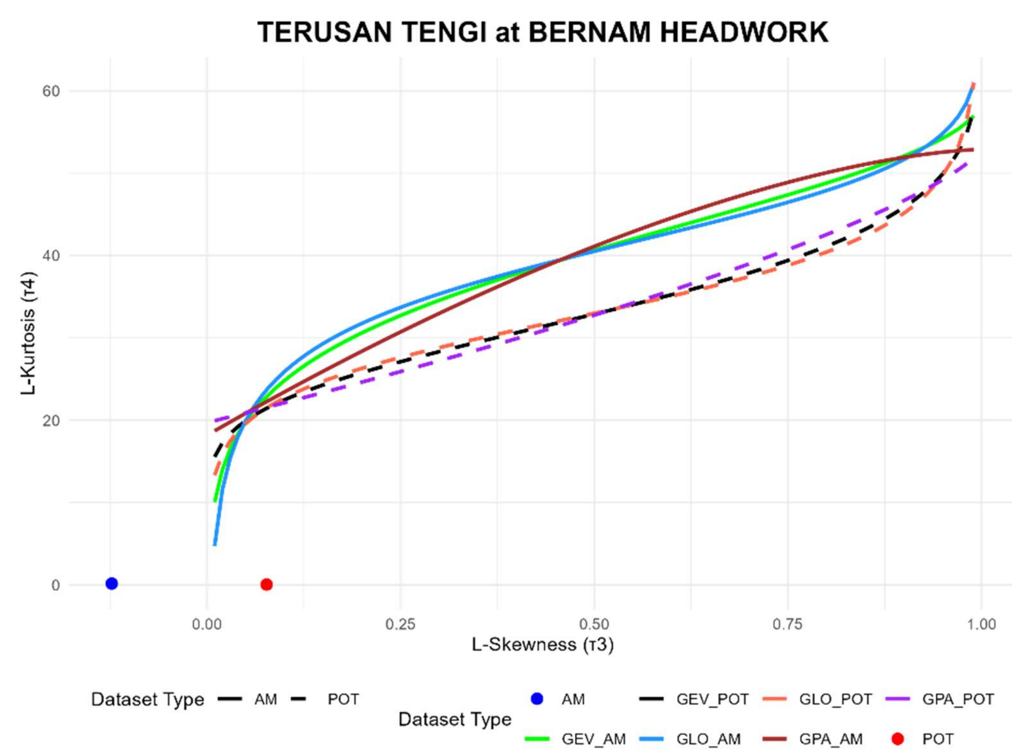

Figure 4.2: L-Moment Diagrams for Terusan Tengi At Bernam Headwork.

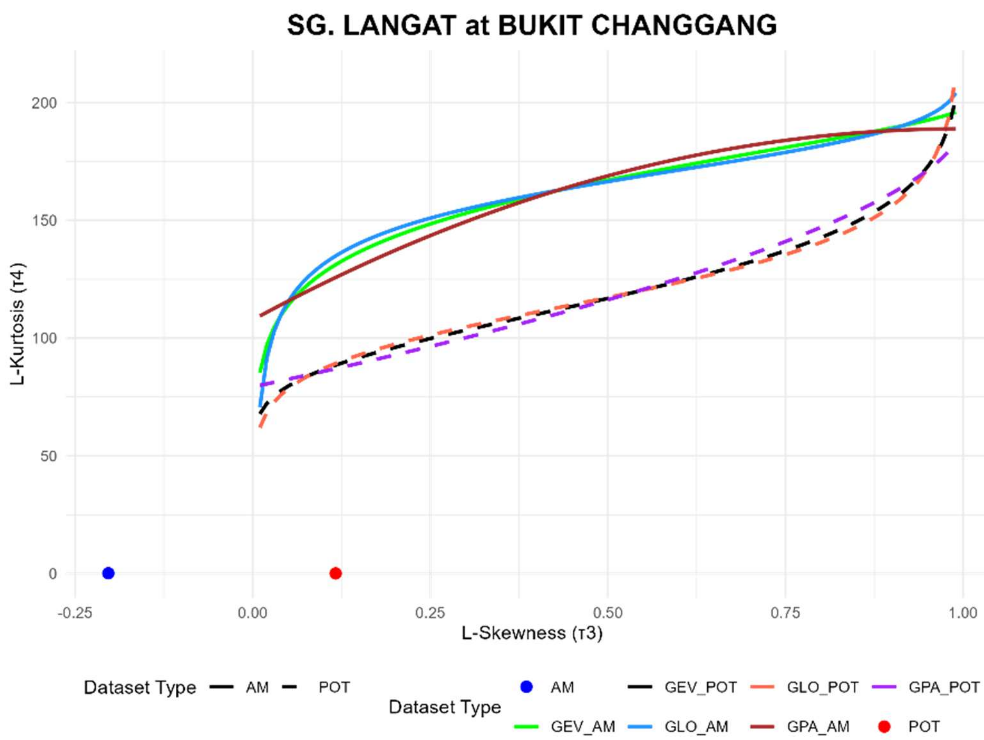

Figure 4.3: L-Moment Diagrams for Sg. Langat At Bukit Changgang.

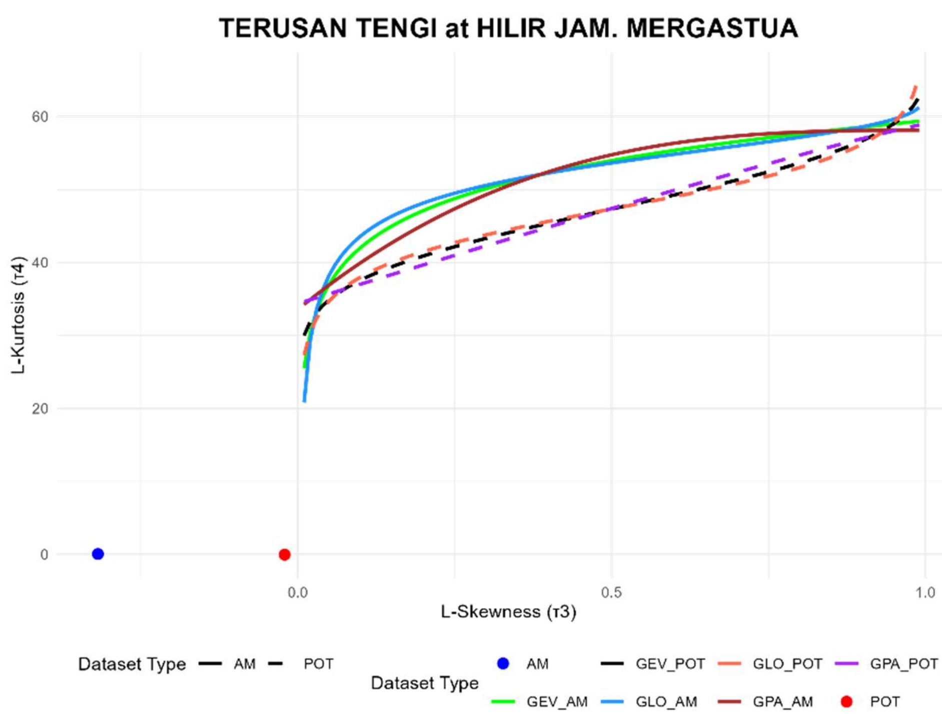

Figure 4.4: L-Moment Diagrams for Terusan Tengi At Hilir Jam. Mergastua.

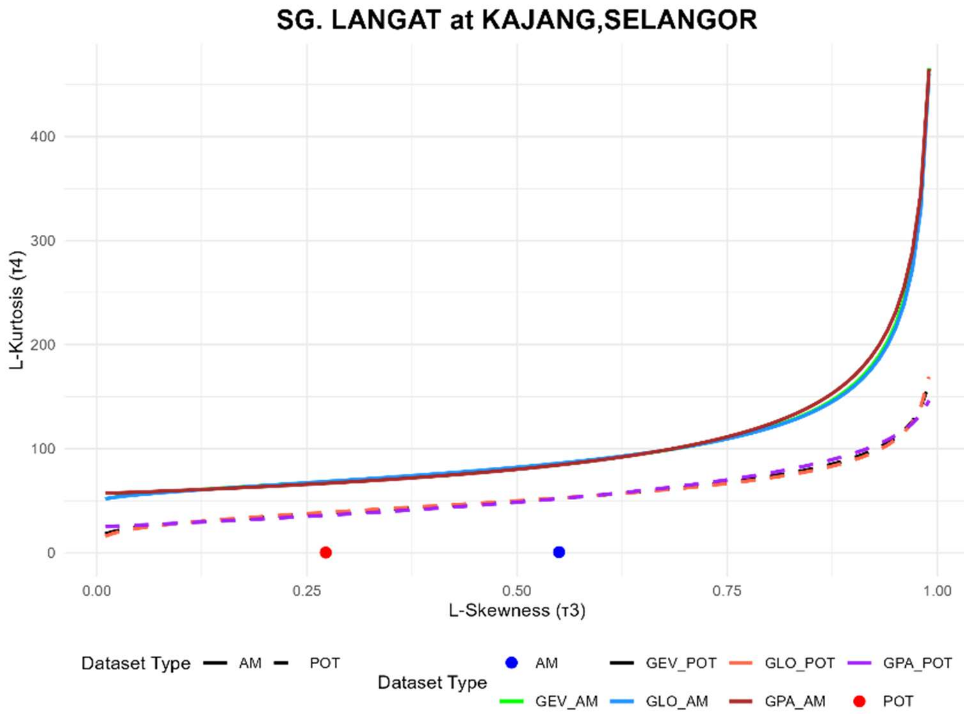

Figure 4.5: L-Moment Diagrams for Sg. Langat At Kajang, Selangor.

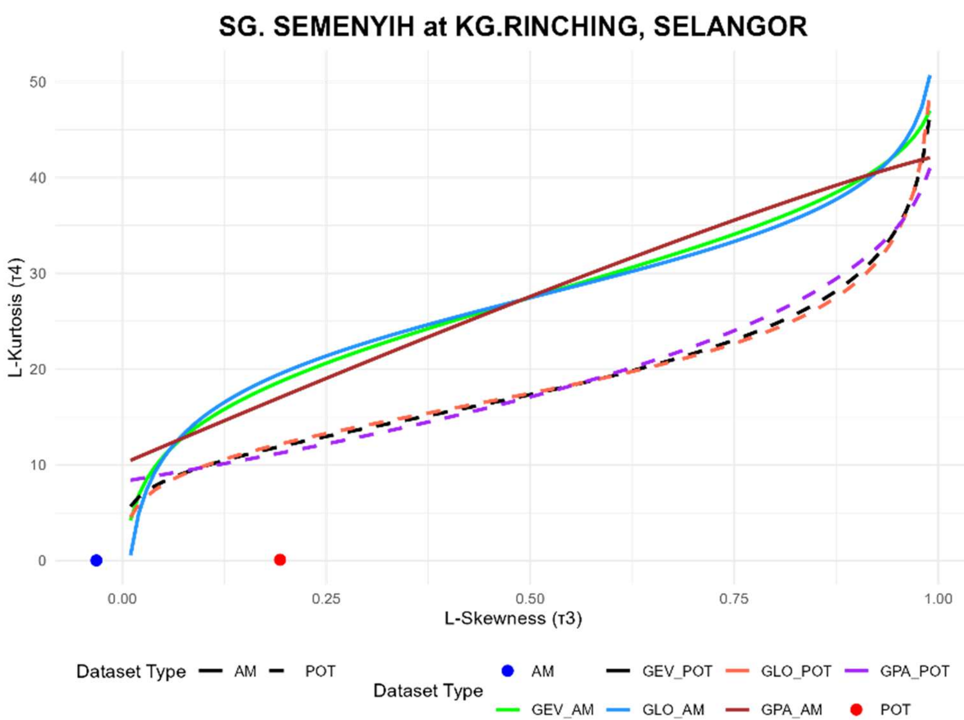

Figure 4.6: L-Moment Diagrams for Sg. Semenyih At Kg. Rinching, Selangor.

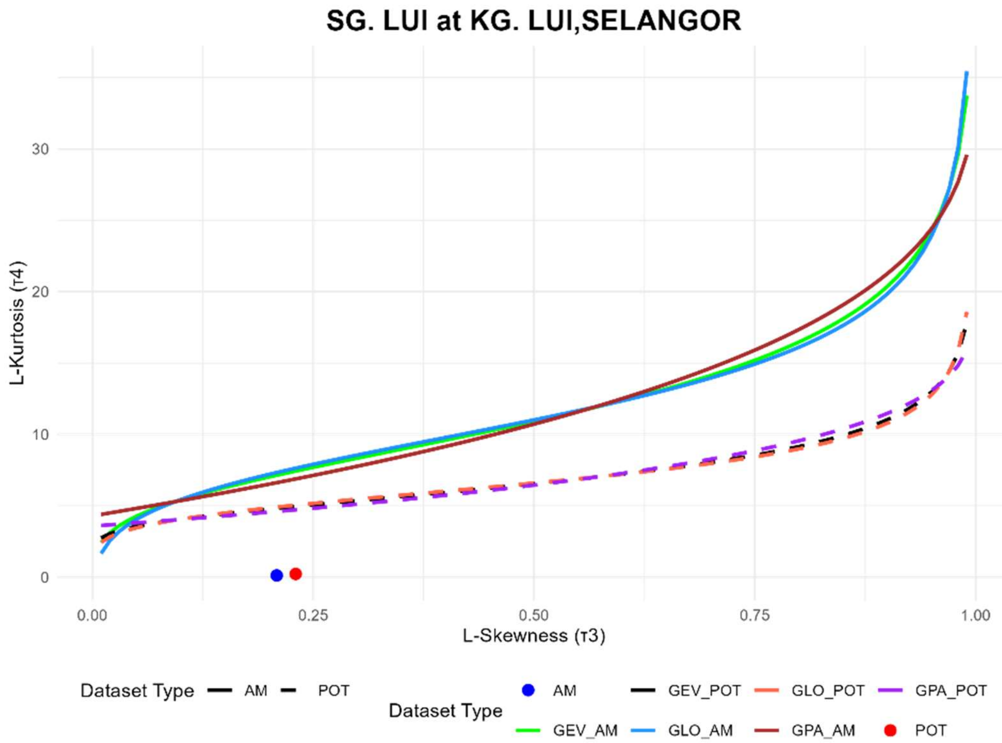

Figure 4.7: L-Moment Diagrams for Sg. Lui At Kg. Lui, Selangor.

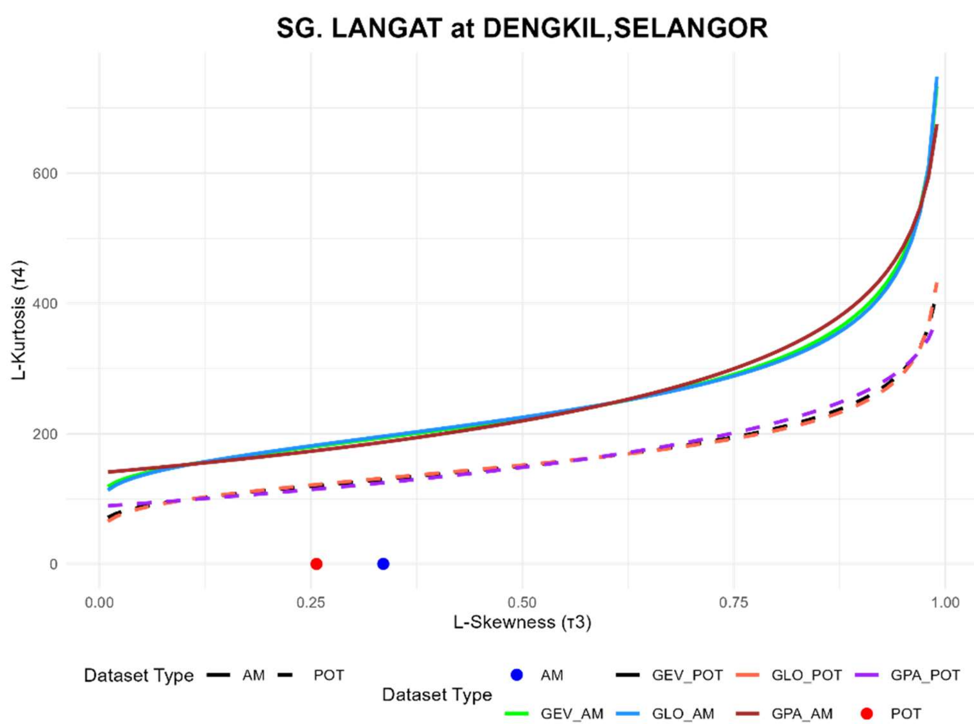

Figure 4.8: L-Moment Diagrams for Sg. Langat At Dengkil, Selangor.

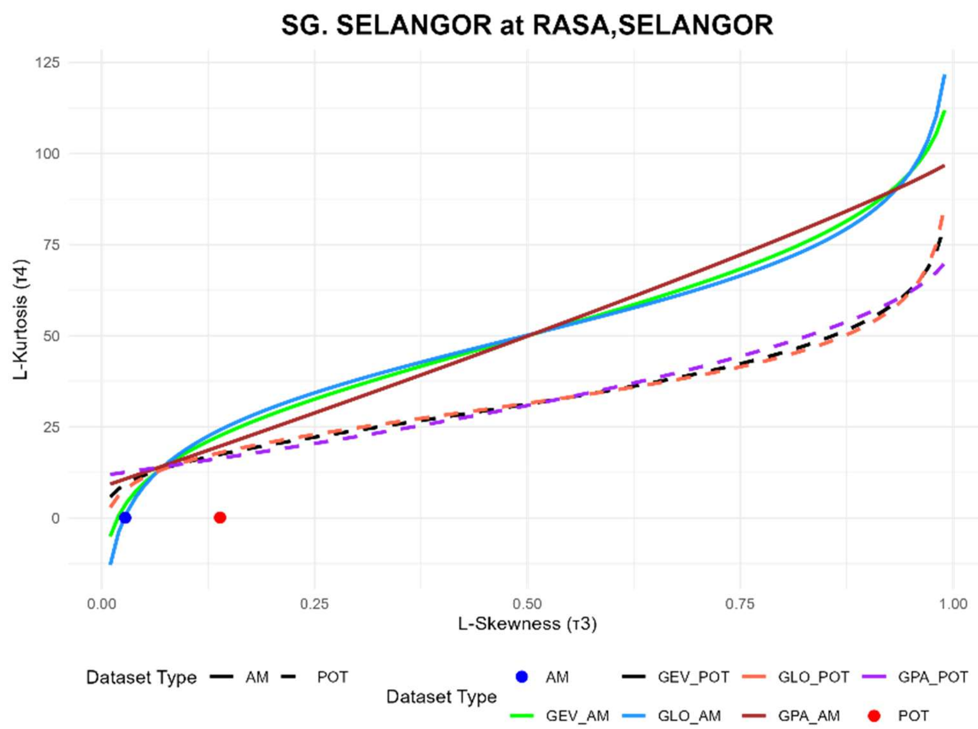

Figure 4.9: L-Moment Diagrams for Sg. Selangor At Rasa, Selangor.

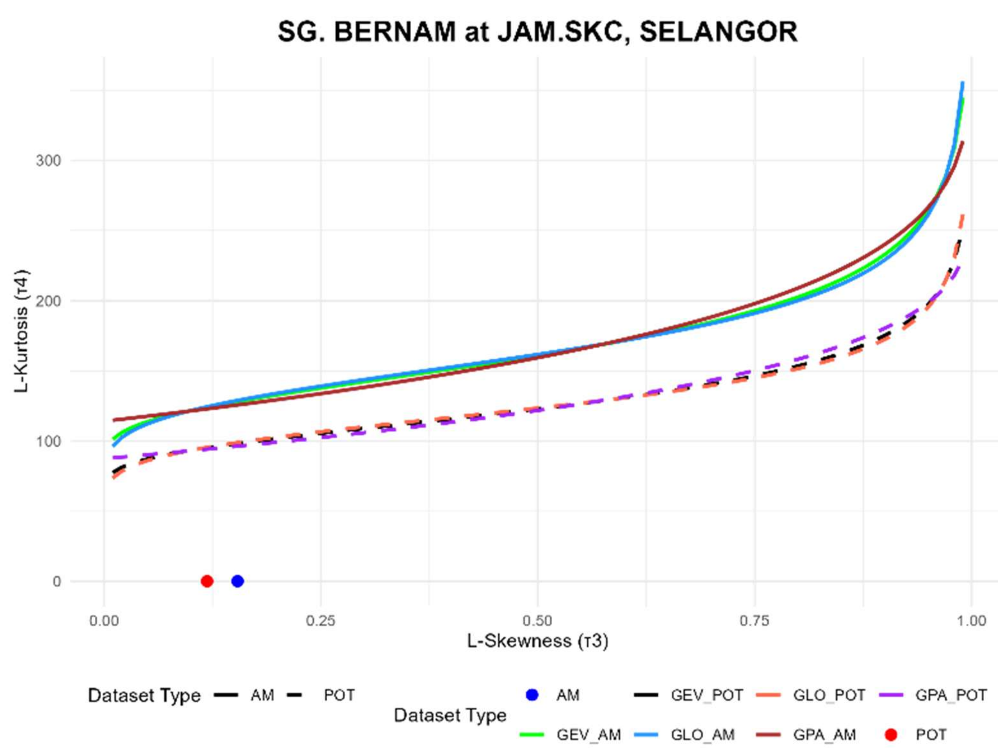

Figure 4.10: L-Moment Diagrams for Sg. Bernam At Jam. Skc, Selangor.

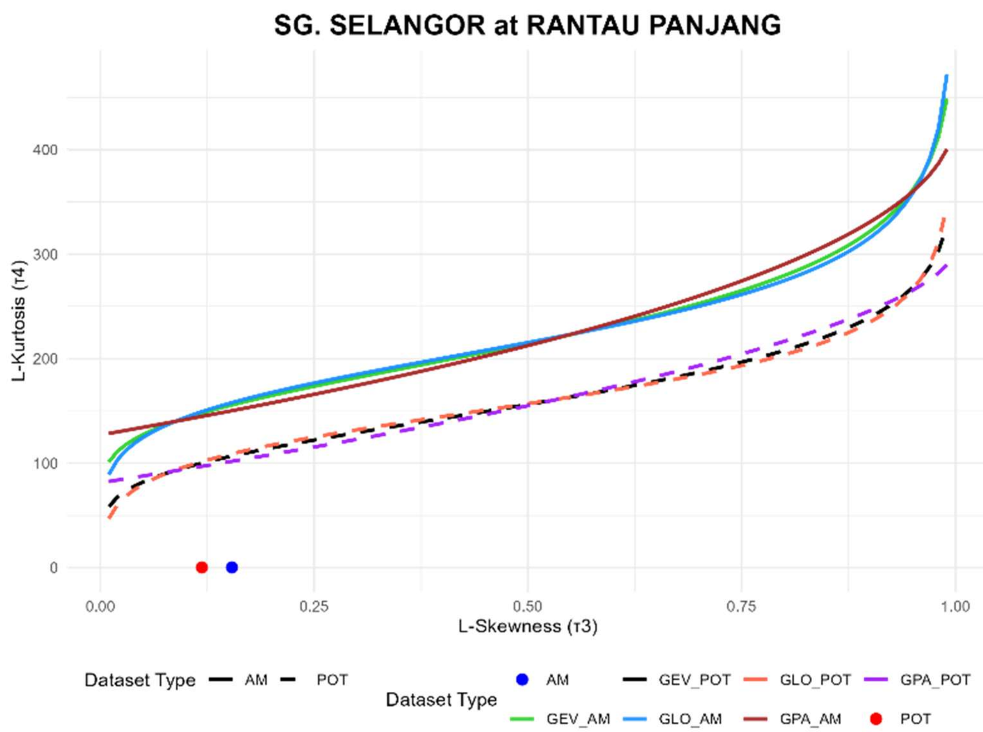

Figure 4.11: L-Moment Diagrams for Sg. Selangor At Rantau Panjang.

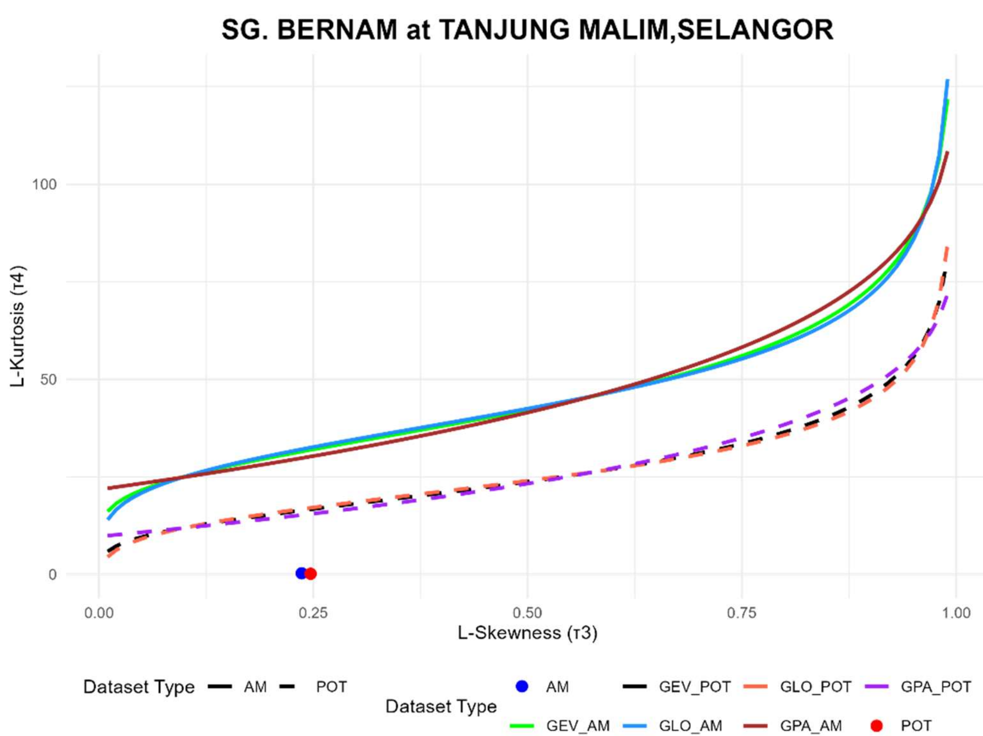

Figure 4.12: L-Moment Diagrams for Sg. Bernam At Tanjung Malim, Selangor.

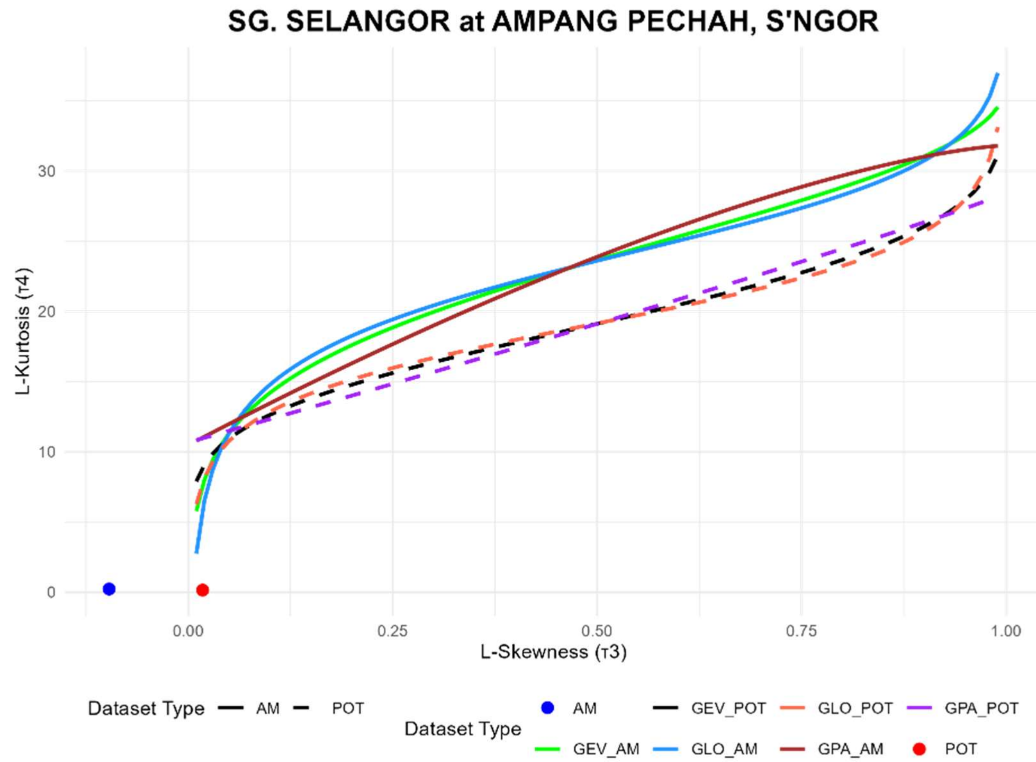

Figure 4.13: L-Moment Diagrams for Sg. Selangor At Ampang Pechah, Selangor.

Table 4.2: Best Fitting Distribution.

Station Name	Best Distribution (POT)
SG. BERNAM at TANJUNG MALIM,SELANGOR	GPA
SG. SELANGOR at RANTAU PANJANG	GPA
SG. BERNAM at JAM.SKC, SELANGOR	GPA
SG. SELANGOR at RASA,SELANGOR	GPA
SG. LANGAT at DENGKIL,SELANGOR	GLO
SG. LUI at KG. LUI,SELANGOR	GPA
SG. SEMENYIH at KG.RINCHING, SELANGOR	GPA
SG. LANGAT at KAJANG,SELANGOR	GPA
SG. SELANGOR at AMPANG PECHAH, S'NGOR	GPA
TERUSAN TENGI at HILIR JAM. MERGASTUA	GPA
SG. LANGAT at BUKIT CHANGGANG	GLO
TERUSAN TENGI at BERNAM HEADWORK	GPA
SG. SELANGOR at KG. TIMAH, SELANGOR	GPA

From Figure 4.1-4.13, the data point for each selected method (AM or POT) was visually compared with the three theoretical distribution curves on the L-moment ratio diagram. For example, if the AM data point aligned closely with the GEV_AM curve, it indicated that the GEV distribution was the most suitable for that station under the AM method. Since only one method was selected for each station in the previous evaluation stage, only its corresponding data point was considered for comparison. Each point was evaluated against its three distribution curves.

Based on these results, the GPA distribution is observed as the most fitting in overall, with 11 out of 13 stations showing alignment with the GPA curve. These stations are Sg. Bernam At Tanjung Malim, Sg. Selangor At Rantau Panjang, Sg. Bernam At Jam.Skc, Sg. Selangor At Rasa, Sg. Lui At Kg. Lui, Sg. Semenyih At Kg. Rinching, Sg. Langat At Kajang, Sg. Selangor At Ampang Pechah, Terusan Tengi At Hilir Jam. Mergastua, Terusan Tengi At Bernam Headwork, And Sg. Selangor At Kg. Timah. Meanwhile, GLO distribution was found to be more suitable for SG. Langat At Dengkil And SG. Langat At Bukit Changgang.

This result indicates that due to variations in data series among the rivers in Selangor, it is difficult to recommend one suitable distribution for all stations. This is because the variability in annual peak flow is likely influenced by climate change and the increasing unpredictability of weather patterns (Badyalina et al., 2021).

4.3 Flood Quantile Estimation

Table 4.3 below shows the estimated flood discharge of each model in different quantiles for the 13 streamflow stations in Selangor.

Table 4.3: Estimated Flood Discharge (m^3/s) for each return period (years).

Stations	Return Periods (years)	GEV_AM	GLO_AM	GPA_AM	GEV_POT	GLO_POT	GPA_POT
SG. BERNAM at TANJUNG MALIM,SELANGOR	2	42.152	42.494	41.477	23.756	23.997	23.272
	10	73.467	71.790	76.574	45.898	44.722	48.127
	20	87.094	85.760	88.048	55.724	54.749	56.518
	100	121.865	126.944	108.469	81.259	84.692	71.908
SG. SELANGOR at RANTAU PANJANG	2	214.422	215.517	212.558	156.203	156.983	154.999
	10	321.886	315.918	330.904	239.696	235.064	245.978
	20	361.632	358.568	360.139	268.380	266.617	265.615
	100	449.033	472.133	400.585	327.467	347.102	289.821
SG. BERNAM at JAM.SKC, SELANGOR	2	160.982	161.769	159.429	122.970	123.542	121.869
	10	233.004	229.147	240.155	175.358	172.522	180.437
	20	264.381	261.307	266.597	197.515	195.399	198.700
	100	344.529	356.179	313.743	252.575	261.600	229.810
SG. SELANGOR at RASA,SELANGOR	2	49.999	50.178	49.920	31.267	31.495	30.892
	10	85.118	83.276	86.762	54.387	53.102	56.245
	20	94.935	94.997	92.064	62.675	62.087	62.164
	100	111.886	121.764	96.782	80.402	85.575	69.963
SG. LANGAT at DENGKIL,SELANGOR	2	223.709	225.384	219.910	150.803	151.901	148.575
	10	388.300	380.452	406.160	251.564	246.258	261.830
	20	473.899	465.175	486.841	297.101	292.534	301.221
	100	732.966	747.892	675.267	417.496	432.427	375.520
SG. LUI at KG. LUI,SELANGOR	2	10.912	11.014	10.718	6.541	6.590	6.446
	10	20.365	19.850	21.262	11.029	10.787	11.470
	20	24.267	23.904	24.417	12.959	12.772	13.081
	100	33.746	35.454	29.592	17.831	18.578	15.898
SG. SEMENYIH at KG.RINCHING, SELANGOR	2	27.461	27.464	27.587	17.343	17.477	17.097
	10	39.595	39.012	39.889	29.785	29.101	30.931
	20	42.523	42.759	41.180	34.766	34.321	34.860
	100	47.006	50.727	42.089	46.534	48.907	41.009

Table 4.3: Estimated Flood Discharge (m^3/s) for each return period (years).

SG. LANGAT at KAJANG, SELANGOR	2	81.779	82.205	80.195	49.499	49.950	48.563
	10	161.441	159.455	169.490	91.192	89.030	95.515
	20	219.241	215.429	230.848	110.587	108.618	112.623
	100	465.686	461.060	465.255	163.291	169.005	146.352
SG. SELANGOR at AMPANG PECHAH, S'NGOR	2	23.660	23.603	23.881	19.112	19.143	19.109
	10	31.041	30.740	31.017	26.046	25.686	26.346
	20	32.538	32.842	31.517	27.938	27.970	27.337
	100	34.538	36.981	31.784	31.143	33.123	28.186
TERUSAN TENGI at HILIR JAM. MERGAS TUA	2	53.965	53.631	54.754	47.324	47.335	47.396
	10	58.560	58.606	58.083	56.717	56.257	56.985
	20	59.008	59.645	58.112	59.048	59.199	58.055
	100	59.363	61.228	58.116	62.697	65.536	58.843
SG. LANGAT at BUKIT CHANGGANG	2	167.088	166.433	168.874	116.860	117.245	116.269
	10	189.242	188.753	188.088	158.452	156.145	161.557
	20	192.500	194.338	188.670	172.674	171.816	171.246
	100	195.927	204.044	188.854	201.849	211.680	183.103
TERUSAN TENGI at BERNAM HEADWORK	2	40.662	40.525	41.120	32.895	32.996	32.768
	10	52.108	51.685	51.936	45.881	45.172	46.702
	20	54.264	54.844	52.568	49.951	49.805	49.227
	100	56.983	60.875	52.866	57.695	61.037	51.920
SG. SELANGOR at KG. TIMAH, SELANGOR	2	130.316	130.695	129.201	90.464	90.814	89.905
	10	181.902	180.136	187.434	126.868	124.846	129.703
	20	215.418	212.619	222.069	139.646	138.797	138.640
	100	342.505	341.902	334.744	166.466	174.822	150.033

Sg. Bernam at Tanjung Malim is a significant upstream station located at the border between Selangor and Perak. For this station, the estimated 100-year peak discharge is 121.87 m^3/s under the GEV_AM model, while the GPA_POT model estimates a notably lower value of 71.38 m^3/s., indicating a significant variation between AM and POT approaches. Meanwhile, the 100-year return flood is estimated at 289.82 m^3/s by GPA_POT at Sg. Selangor at Rantau Panjang.

For Sg. Langat at Dengkil, which lies in a more urbanized catchment, the estimated discharge for a 100-year event is 732.97 m^3/s by the GEV_AM model and 275.92 m^3/s by GPA_POT, suggesting that the POT approach provides more conservative estimates. This pattern can also be seen at Sg. Semenyih at Kg. Rinching, where the 100-year discharge ranges from 47.00 m^3/s (GEV_AM) to 41.09 m^3/s (GPA_POT). For Terusan Tengi at Hilir Jam. Mergastua, the 100-year return period peak is estimated at 59.36 m^3/s (GEV_AM) and 58.84 m^3/s (GPA_POT), showing less deviation than in some upstream sites.

According to Cheah et al. (2019), the increased flood flow in Selangor is largely attributed to urbanization. Urban development like houses, shops, and factories increases the amount of water that runs off during heavy rain. The expansion of residential, commercial, and industrial land significantly raises the runoff potential by reducing infiltration and accelerating peak discharge during storm events. Additionally, hard surfaces like roads and buildings stop water from flowing into the ground.

4.4 Summary of findings

Table 4.4 below has summarised the results for this study. It includes the most fitting method and distributions for easier comparison.

Table 4.4 Summary of Findings.

No.	Station No.	Station Name	Method	Distribution
1	3615412	Sg. Bernam At Tanjung Malim,Selangor	POT	GPA
2	3414421	Sg. Selangor At Rantau Panjang	POT	GPA
3	3813411	Sg. Bernam At Jam.Skc, Selangor	POT	GPA
4	3516422	Sg. Selangor At Rasa,Selangor	POT	GPA
5	2816441	Sg. Langat At Dengkil,Selangor	POT	GLO
6	3118445	Sg. Lui At Kg. Lui,Selangor	POT	GPA
7	2918401	Sg. Semenyih At Kg.Rinching, Selangor	AM	GPA
8	2917401	Sg. Langat At Kajang,Selangor	POT	GEV
9	3516424	Sg. Selangor At Ampang Pechah, Selangor	POT	GPA
10	3613403	Terusan Tengi At Hilir Jam. Mergastua	AM	GPA
11	2816401	Sg. Langat At Bukit Changgang	POT	GLO
12	3613402	Terusan Tengi At Bernam Headwork	AM	GPA
13	3415401	Sg. Selangor At Kg. Timah, Selangor	POT	GPA

In summary, among the 13 streamflow stations in Selangor, the POT approach was observed to be the method with better performance at 10 stations, while the Annual Maximum (AM) method was preferred at 3 stations. Among the three probability distributions, the Generalized Pareto (GPA) distribution was most frequently selected, then it is followed by Generalized Logistic (GLO) and Generalized

Extreme Value (GEV). This suggests that the POT approach, especially when pairing with the GPA distribution, seems to be generally more effective for flood frequency analysis in Selangor.

Chapter 5

Conclusion

This study applied the Flood Frequency Analysis (FFA) for selected streamflow stations across Selangor, Malaysia. FFA is important in national planning efforts, as it enables authorities to improve urban and infrastructure planning and hydrological risk assessments in preparation for future flood events. In this study, both the Annual Maximum (AM) and Peaks-Over-Threshold (POT) approaches were compared for evaluating flood occurrences using historical streamflow data from 13 stations in Selangor.

In this study, three widely used probability distributions (GEV, GLO, GPA) were fitted to the streamflow data using the L-moments method for parameter estimation. The analysis started from the development of AM and POT datasets, followed by parameter estimation and model accuracy evaluation using (MAE, BIAS, RMSE)

To determine the most suitable method and distribution for each station, the performance metrics were compared along with the L-moment ratio diagram. Based on the evaluation, the POT approach was observed to outperform the AM method in 10 out of 13 stations. These results indicate its strength in capturing more detailed flood behavior for rivers in Selangor. Furthermore, the GPA distribution is selected as the best-fitting distribution, while GLO distribution is selected for the remaining two stations.

The findings highlight that there might not be a universal distribution or method applicable to all locations. However, this study helps to identify the approach and distribution that generally perform better in the context of Selangor. It can provide insights into flood risk prediction in Selangor by examining both AM and POT approaches and finding the best-fitting distributions at selected stations.

This limitation of this study is that it only focuses on three probability distributions and only applies the L-moments method for parameter estimation. As a recommendation for future research, it might be more insightful to have a test on more distributions and also apply other estimation methods such as LH-moments or Maximum Likelihood Estimation (MLE) to improve the model comparison and its result accuracy.

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Appendices

Appendix A

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Programme / Course	BACHELOR OF SCIENCE (HONOURS) STATISTICAL COMPUTING and OPERATIONS RESEARCH
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Date: 27/04/25

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Appendix B

Flood Frequency Analysis Between Annual Maximum Series (AM) and Peaks-Over-Threshold (POT) Series in Selangor, Malaysia.

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