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Frequency Analysis Of Rainfall In Johor State Using Probability Distribution

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Abstract
Since the 1950s, extreme precipitation frequency has increased and produced more rain in many parts of the world. The threat of flooding is the most immediate effect of heavy rain. This danger is magnified in cities, where impermeable pavements compel water to flow swiftly into sewer systems. In this study, the extreme value Type 1 (Gumbel), Normal, and Log-Pearson Type III probability distributions have been utilized to perform flood frequency analysis on the peak annual series discharge data of 16 stations at Johor state for the water years 2010 to 2020. The predicted design floods for the return periods of 2 years, 5 years, 10 years,50 years, 100 years, and 1000 years were obtained and compared. Our results indicate that the Gumbel type 3 distribution predicted larger discharge values in most of the stations.

Keywords: Frequency, Flood, Return-period, Rainfall, Gumbel, Normal, Log-Pearson.

1.0 INTRODUCTION
Malaysia has an equatorial climate. It frequently experiences the effects of the Northeast and Southwest monsoons, as well as persistently high temperatures and excessive humidity. Extreme precipitation events have become more frequent and have produced greater rain in various places of the world since the 1950s.A. Z. Ismail, Z. Yusop et al, (2015). Malaysia is a tropical nation, and changes in rainfall patterns have a significant impact on its hydrological systems.B. K. Sathe, M. v Khire et al,(2012). C. Buonocore et al, (2021). Numerous research studies indicate that climate change has increased Malaysia's rainfall quantity and severity. The most noticeable immediate result of heavy rain is the risk of flooding. This risk is increased in urban areas because impermeable pavement forces water to flow quickly into sewage systems.F. Policelli, A. Hubbard,et al,(2019), J. Kraus, A. Rakhmat Trihamdani et al,. Along with flooding, landslides are also more likely to occur during periods of heavy rainfall. When excessive precipitation rises, the water table saturates the ground, causing a landslide. Therefore, slopes can become unstable. By lowering water quality, excessive precipitation can also have an adverse effect on ecosystems and human health.L. Lin et al,(2016). Stormwater runoff has the potential to contaminate bodies of water M. Farooq, M. Shafique et al,(2018). Natural disasters like flooding are something that this modern tropical nation still must contend with. It is one of the most important problems Malaysia deals with each year. Understandably, flood records show a consistent tendency to increase the frequency of flood incidents, given the annual expectation for high rainfall.M. Vernon, P. N. Halpin et al,(2005). To find the trend of precipitation and the optimal distribution model for daily maximum rainfall series, it is necessary to make an effort.N. Farehah, B. Abdullah et al,(2015). For flood prevention and mitigation, it is crucial to understand the factors that contribute to exces-

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sive precipitation and their hydrometeorological relationships with floods, particularly considering the threat posed by global climate change.F. Policelli, A. Hubbard et al,(2009). Extreme precipitation and floods have typically been monitored using in situ measurements.N. Nadrah, A. Tukimat et al,(2012). On the other hand, different hydrological and meteorological retrievals are made possible through remote sensing at various temporal and spatial resolutions.Q. Yang et al,(2019). It is anticipated that using remote sensing data alone or in combination with modeling techniques will enhance flood monitoring and modeling capabilities, facilitating decision-making.Q. Yang et al,(2019) S. N. MOHAMED, I. TARMIZI et al,(2019). To create more effective flood prevention and control systems, it is critically necessary to improve extreme precipitation monitoring, modeling, and forecasting methods.F. Policelli, A. Hubbard et al,(2019). Based on frequency analyses conducted at several locations in the state of Johor, the primary goal of this study was to determine the trend of extreme rainfall. Extreme value type 1 (Gumbel) Log Pearson Type, Normal Distribution, and Distribution come under 3 probability distributions that are taken into consideration in the study. The main study objective is to use the three-distribution method to calculate the design rainfall depth for return periods T=2, 3, 10, 50, and 100 years for 16 stations near the Johor River basin in Johor state and for selecting a distribution method that is suitable for data among the three listed (Normal, Log-Pearson and Gumbel Extreme value). In particular, when the climate has changed, the selection of design rainfalls, which are highly important inputs for the design of water infrastructure projects, is influenced by the frequency analysis of extreme precipitation. In addition, it's essential to improve flood management and defenses by conducting evaluations of excessive precipitation.

2.0 METHODOLOGY

Study Area

Johor is the southern state of Peninsular Malaysia, and has a total size of about 19,210 square kilometers. It has the fifth-largest land area among the states. It is the most southern state on Peninsular Malaysia. Its latitudes are between 1°20″N and 2°35″N. All year long, it rains in Johor and the other Peninsular Malaysian states that are close by. S. Rehman, M. Sayeed et al,(2021). The temperature of Johor is affected by both the north-east monsoon, which happens from the month of November to the month of February, and the south-west monsoon, which happens from May to August. S. Rehman, M. Sayeed et al,(2021), S. Richard Chikabvumbwa and D. Worku (2017).

Fig 1.
Peninsular Malaysia's Johar state

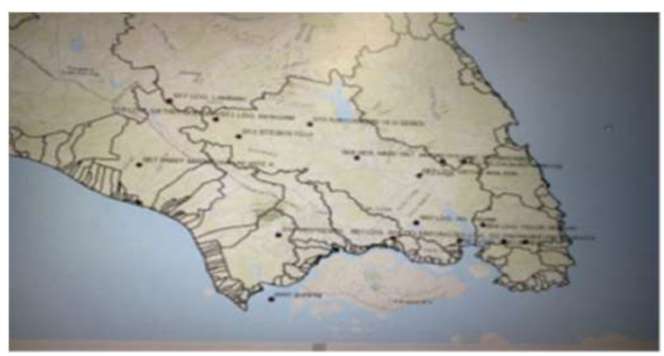

Fig 2.
Sixteen rainfall stations of Johor state

Data Collection and Data Analysis

NAHRIM (National Water Research Institute of Malaysia) provided the most recent rainfall data, which covers the period from 2010 to

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2030. Four alternative data formats—hourly, daily, weekly, and annual—were gathered for everyday precipitation data at 16 rainfall stations in Johor from 2010 to 2030. Daily data can be converted to weekly, monthly, or annual data, but this study's calculation employs daily data. Using Microsoft Excel, the daily yearly maximum rainfall depth for the 16 rainfall stations in the research area was calculated by analysing and organising the daily rainfall depths.

Gumbel's Distribution Method

If you had a list of the highest levels of a river for the last ten years, you could use this distribution to show how they are spread out. It helps figure out if a big earthquake, flood, or other natural disaster is likely. W. H. A. Wan Deraman, N. J. Abd Mutalib et al,(2017). The PDF of the Gumbel distribution with a position parameter of and a scale parameter of is

$$f(x) = \frac{1}{\beta} \exp\left[-\left(\frac{x-\mu}{\beta} + \exp\left(-\frac{x-\mu}{\beta}\right)\right)\right.$$

$\beta > 0$. Cumulative Density Function (CDF) is

$$F(x) = \exp\left[-\left(\exp\left(-\frac{x-\mu}{\beta}\right)\right)\right]$$

Gumbel distribution's inverse is

$$F^{-1}(p) = \mu - \beta \ln(-\ln p)$$

Where, the standard Gumbel distribution is the case where $\mu = 0$ and $\beta = 1$.

The Gumbel distribution is often referred to as the double exponential distribution; however, the word "exponential distribution" is more commonly associated with the Laplace distribution.

If x follows a Weibull distribution, then the distribution of -ln(x) will follow a Gumbel.

Mean + Median +ln 2 Mode

Deviation from the mean 6 Skewness, about 1.14, and Kurtosis 2.4

Here is the Euler-Mascheroni constant, and its value is −0(1). This represents the negative of the digamma function when it is set to 1 (for more information, see MLE Fitting Gamma Distribution), and its value is roughly equivalent to 0.

NORMAL DISTRIBUTION

In this symmetric distribution, the majority of

Mean	+
Median	+ln 팩 2 ( )
Mode	
Standard deviation	$\sqrt{6}$
Skewness	1.14 approx.
Kurtosis	2.4

Table 1: Descriptive Statistics of Maximum Rainfall Data

the values are centered and have long tails to the left and right. There are no gaps between the values, making it a continuous distribution. The analyses will be carried out using Excel, and the following formulas will be used for the analyses on all the stations.

> The mean and standard deviation of the maximum flood in mm/hr will be computed by using the formulas.

> Compute the values of Z, W, and P using the formulas below.

$$K = w - \frac{2.515517+0.802853w+0.010328}{1+1.432788w+0.189269w^2+0.0013}$$

$$w = \left[ln\left(\frac{1}{p^2}\right)\right]^{\frac{1}{2}}$$

$$p = \frac{1}{T}$$

Compute the values of Maximum rainfall depth $X_{T=}$ + $K_T S_X$, plot the graph of X_t and Z.

Log Pearson Type III Distribution

333 After the statistics for the river spot are figured out. They can be used to make a frequency distribution. The graph can be used to figure out how likely floods of different sizes are. With this method, numbers can be estimated for events that don't happen as often as the floods that have been seen.

3.0 RESULTS AND DISCUSSION

Descriptive Statistics:

The average, standard deviation, skewness, and the most rain that fell at each place. The average amount of rain at each station over the last 20 years has been between 26.5 mm and 47.5 mm

Station ID	Station name	Mean (mm)	Standard deviation (mm)	Skewness	Max amount (mm)
1732004	Parit Madirono	41.37	29.65	0.90	156.60
1737001	Sek Men Bkt Besar	37.76	14.85	-0.25	74.58
1738131	Ldg Getah Malaya	42.94	12.77	-0.11	66.23
1739003	Ldg Permatang	47.49	18.50	0.60	107.77
1933121	Ldg Getah See Sun & di Sg. Rengam	29.31	6.37	0.28	43.54
1834001	Stesen Tele	26.96	5.65	0.69	40.35
1836001	Rncgn Ulu Sebol	31.07	7.93	0.01	50.20
1933151	Ldg Lambak	28.62	7.88	0.54	54.41
1538117	Ldg Sg Pelentong	36.28	11.35	-0.14	63.07
1539134	Ldg Sg Tiram	32.66	8.48	0.10	55.36
1539136	Ldg Lim Lim Bhd	40.07	13.48	0.38	73.57
1540135	Ldg Telok Sengat	40.24	18.18	0.82	87.37
1541137	Ldg Sg Papan	40.86	15.60	0.163	84.72
1541139	Johor Silicia	45.39	17.69	0.085	89.79
1737127	Felda Bkt Waha	43.40	14.99	0.82	83.83
1834001	Stesen Ulu Remis	29.92	6.54	0.47	44.01

Table 2:
Average rainfall, standard deviation, skewness, and maximum daily rainfall for 17 rain stations over the past 20 years.

per day, with station 1739003 having the highest average at 47.49 mm per day and station 1834001 having the lowest average at 26.96 mm per day. For all seventeen sites, the standard variation ranges from 5.5 mm per day to 29.7 mm per day. With a figure of 29.65 mm per day, the standard deviation for Parit Madirono is the biggest, while the standard deviation for Stesen Ulu Remis is only 5.65 mm per day. The coefficient of skewness is used to check how much a distribution around the mean is skewed. The numbers of skewness fall between -0.1 and 0.9. The station with the highest skewness value is Parit Madirono, which has a value of 0.896. The station with the lowest skewness value is Ldg Getah Melaya, which has a value of -0.106. The largest amount of rain that can fall in a day ranges from 40 mm to 157 mm. Parit Madirono gets the most rain, with a maximum of 156.6 mm per day, while Ldg Permatang gets the least, with a maximum of 107.77 mm per day. On the other hand, Stesen Ulu Remis gets the least amount of rain, which is 40.35 mm per day. In the Table below, you can see a summary of how the distribution's data set is made up.

Probability Distributions:
Three probability distributions were used in this study. The parameters of probability distributions are given in Table 4.3. The Table shows that the Gumbel type 1 distribution fits best as it provided maximum values for stations Sek Men Bkt Besar, Ldg Getah Melaya, Ldg Getah See Sun & di Sg. Rengam, Stesen Tele, Rncgn Ulu Sebol, Ldg Lambak, Ldg Sg Pelentong, Ldg Sg Tiram, Ldg Lim Lim Bhd, Ldg Sg Papan, Johor Silicia and Stesen Ulu Remis, while Log Pearson type 3 comes as

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the second best fit, providing maximum values for stations, Parit Madirono, Ldg Permatang, Ldg Telok Sengat and Felda Bkt Waha. Moreover, table 2.1

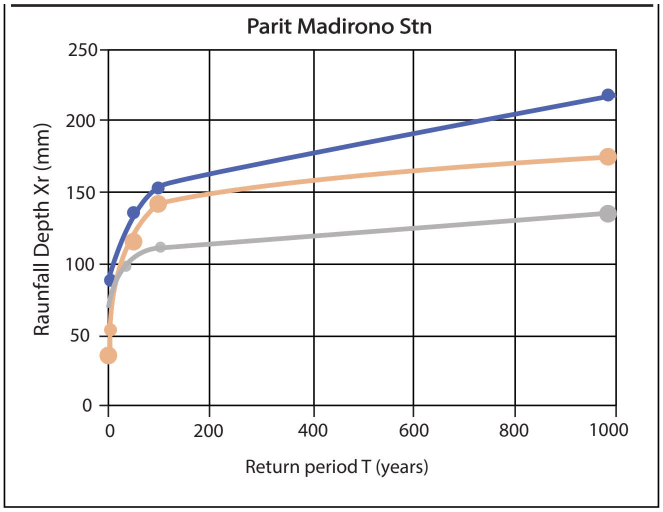
Station Id	Station Name	Rainfall design (mm)	Return period					
			2	5	10	50	100	1000
1732004	Parit Madirono	Gumbel Type 1	37	68	89	135	154	218
		Normal	`41	66	79	102	110	133
		Log Pearson Type 3	34	52	67	115	142	274
1737001	Sek Men Bkt Besar	Gumbel Type 1	36	51	62	85	94	126
		Normal	21	33	40	51	56	67
		Log Pearson Type 3	36	48	55	70	76	93
1738131	Ldg Getah Malaya	Gumbel Type 1	41	55	64	83	92	119
		Normal	42	53	58	68	71	81
		Log Pearson Type 3	41	53	61	76	82	101
1739003	Ldg Permatang	Gumbel Type 1	45	64	77	106	118	158
		Normal	47	63	71	86	91	105
		Log Pearson Type 3	43	58	70	98	112	167
1933121	Ldg Getah See Sun & di Sg. Rengam	Gumbel Type 1	28	35	40	49	54	67
		Normal	29	35	37	42	44	49
		Log Pearson Type 3	28	34	38	46	49	60
1834001	Stesen Tele	Gumbel Type 1	26	32	36	45	48	61
		Normal	27	32	34	39	40	44
		Log Pearson Type 3	26	31	35	43	47	60
1836001	Rncgn Ulu Sebol	Gumbel Type 1	30	38	44	56	61	78
		Normal	31	38	41	47	50	56
		Log Pearson Type 3	30	37	41	50	54	65
1933151	Ldg Lambak	Gumbel Type 1	27	36	41	53	59	76
		Normal	29	35	39	45	47	53
		Log Pearson Type 3	27	34	38	49	53	70
1538117	Ldg Sg Pelentong	Gumbel Type 1	35	47	55	72	80	104
		Normal	36	46	51	60	63	71
		Log Pearson Type 3	35	45	51	63	68	84
1539134	Ldg Sg Tiram	Gumbel Type 1	31	40	46	59	65	83
		Normal	33	40	44	50	52	59
		Log Pearson Type 3	32	39	43	53	57	70
1539136	Ldg Lim Lim Bhd	Gumbel Type 1	38	52	62	83	91	120
		Normal	40	51	57	68	71	82
		Log Pearson Type 3	38	50	57	72	79	100
1540135	Ldg Telok Sengat	Gumbel Type 1	38	57	70	98	110	149
		Normal	40	56	64	78	83	96
		Log Pearson Type 3	35	50	63	98	117	200
1541137	Ldg Sg Papan	Gumbel Type 1	39	55	66	90	100	134
		Normal	41	54	61	73	77	89
		Log Pearson Type 3	38	51	60	81	91	124
1541139	Johor Silicia	Gumbel Type 1	43	62	74	101	113	151
		Normal	45	60	68	82	87	100
		Log Pearson Type 3	42	57	67	90	100	135
1737127	Felda Bkt Waha	Gumbel Type 1	41	57	68	91	101	133
		Normal	43	56	63	74	78	90
		Log Pearson Type 3	40	52	62	86	99	149
1834001	Stesen Ulu Remis	Gumbel Type 1	28	35	39	50	54	68
		Normal	29	34	37	42	44	49
		Log Pearson Type 3	28	34	38	47	51	66

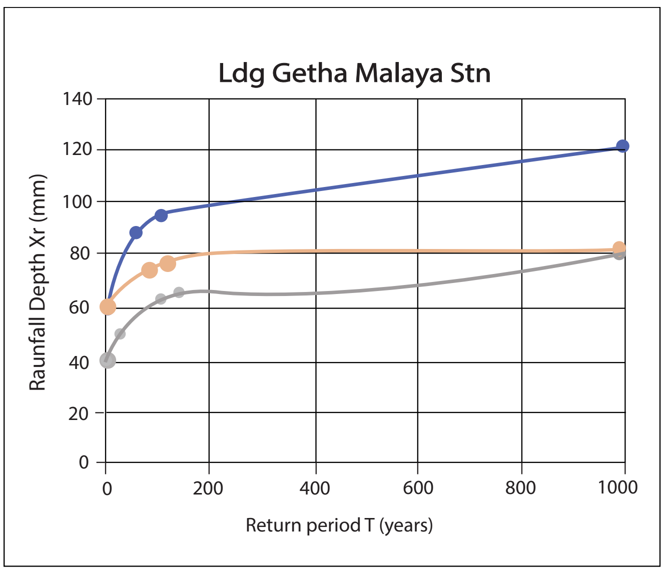
Table 3:
Comparison of Rainfall Design for Various Station

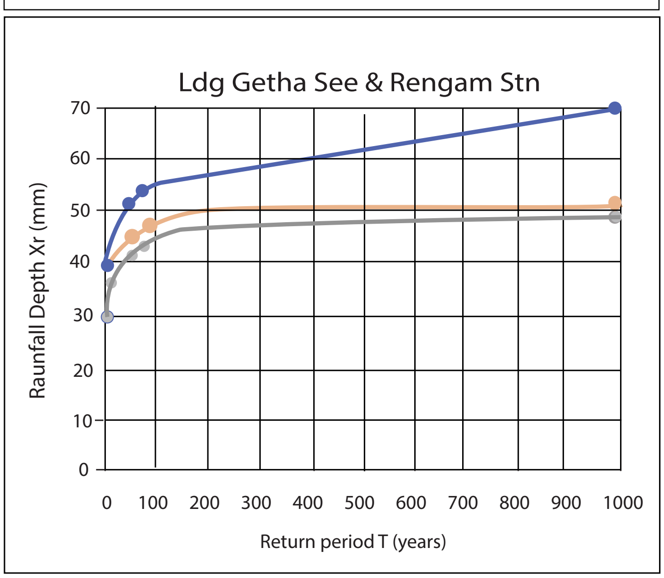
indicates that the Normal distribution fits poorly for the extreme rainfall analysis at Johor state since it provided the minimum values for the stations.

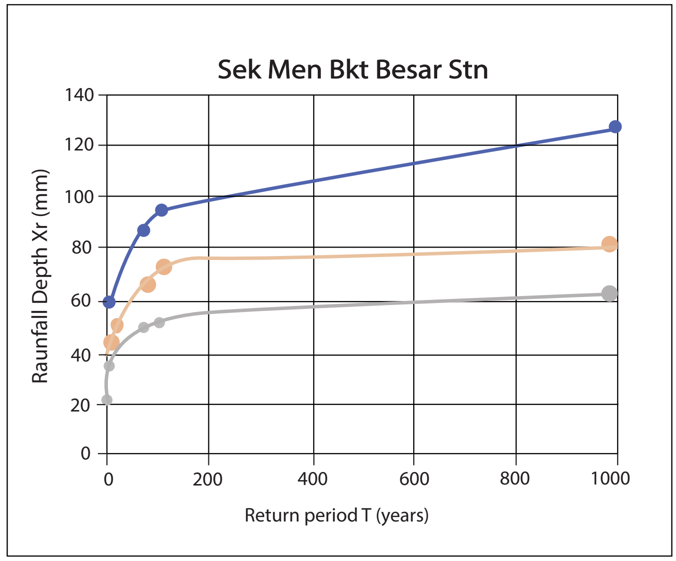
Comparison of rainfall frequency analysis

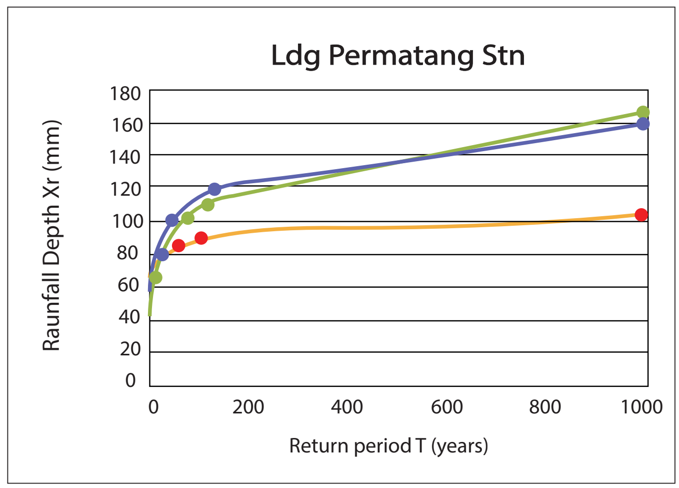
The Comparison of rainfall frequency analysis can be seen as illustrated by the lines on the graphs, which shows that most of the stations predicted higher values of precipitation for Gumbel Type 1, while the Log Pearson Type III

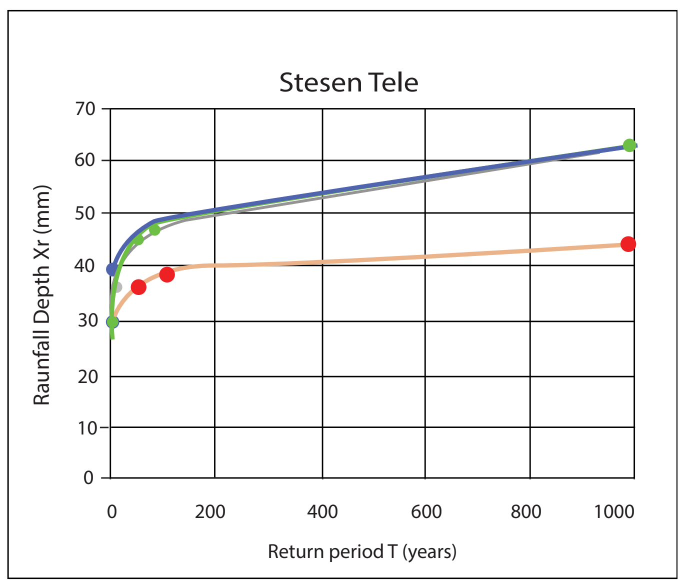












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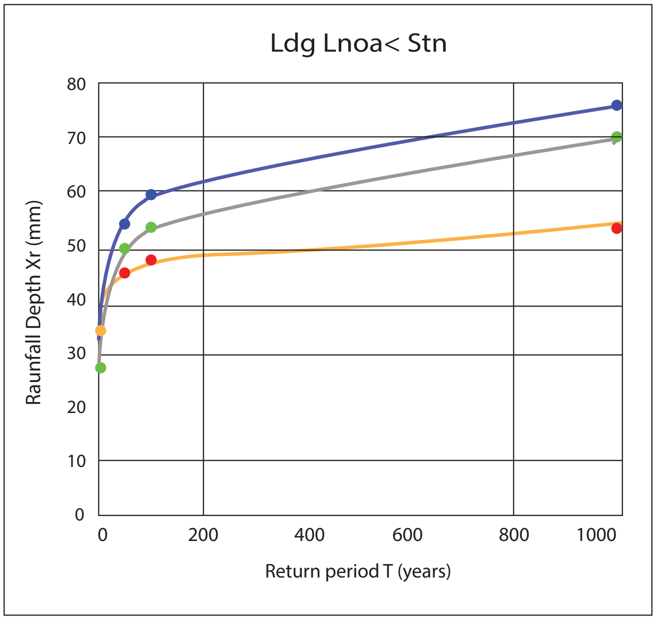

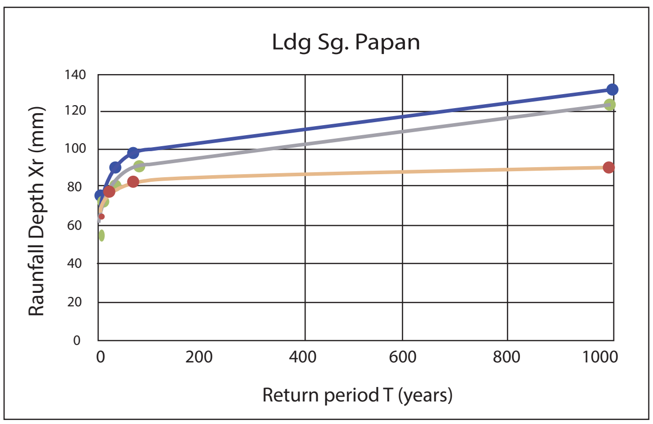

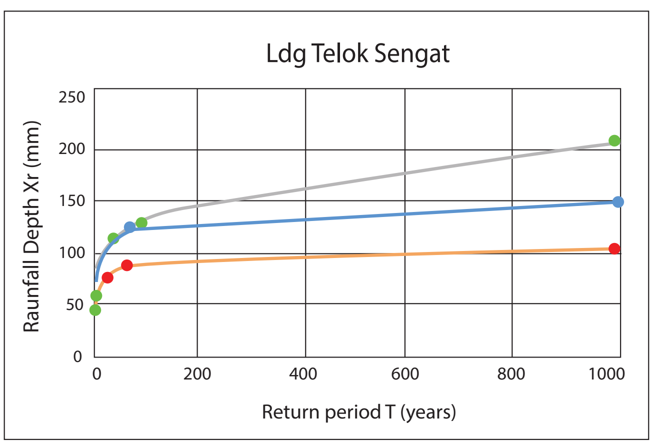

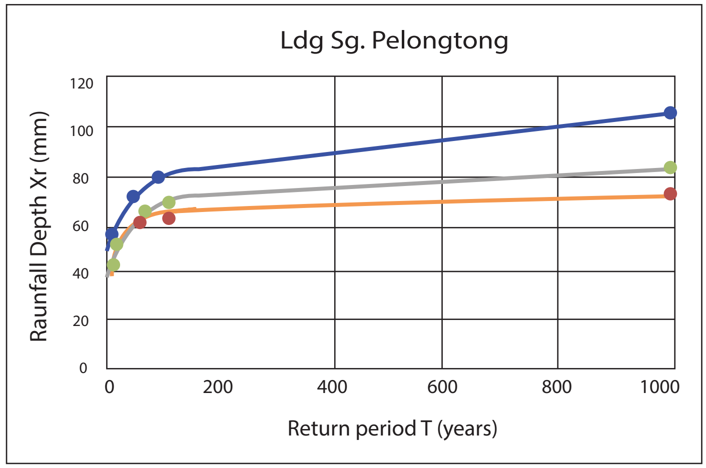

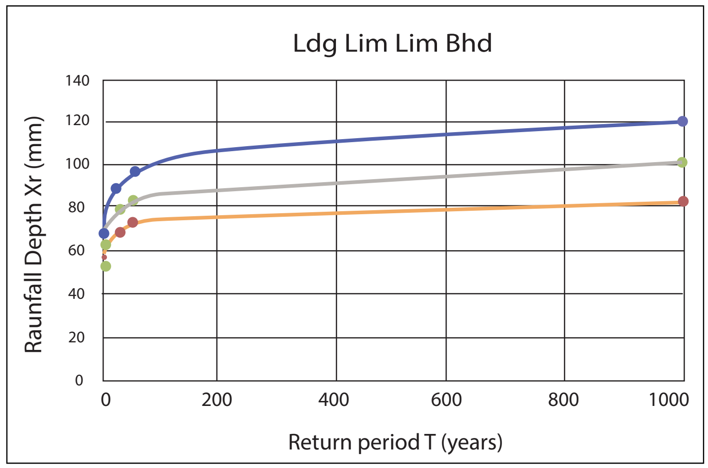

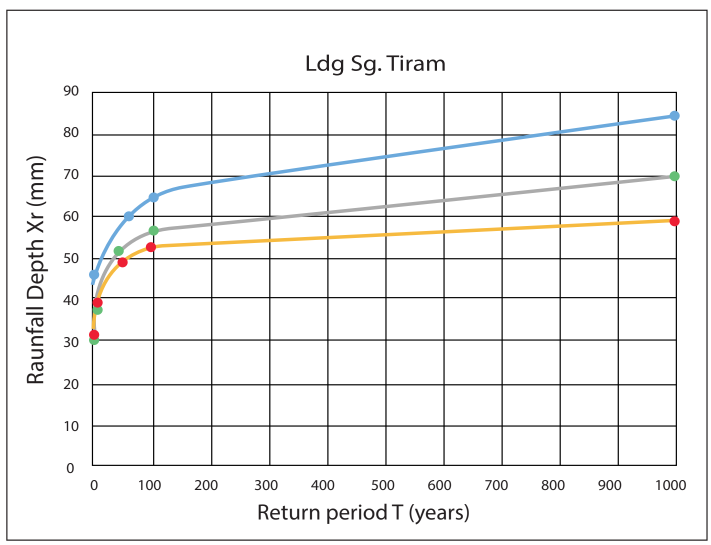

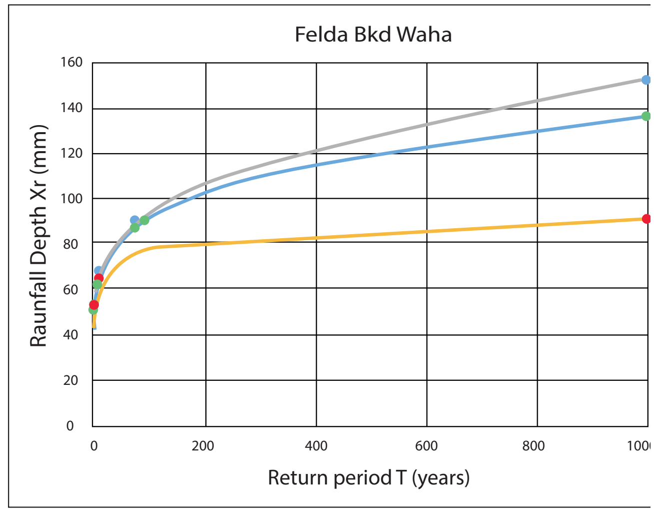

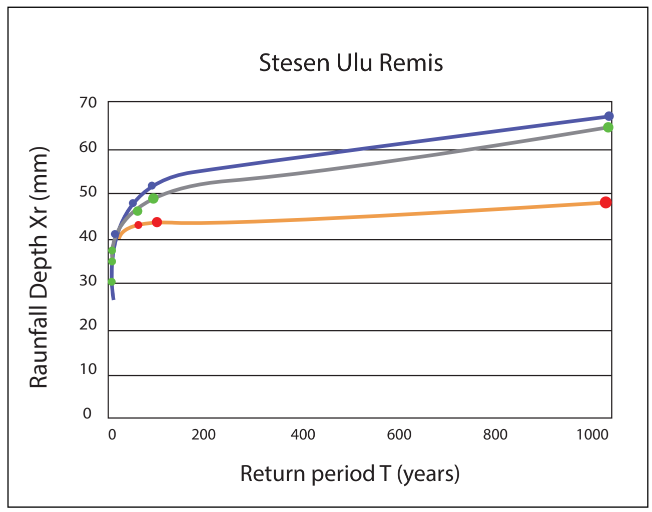

predicted the 2nd highest values and Normal Distribution predicting the least values for all the stations. The results of the three probability distributions for each location, generated from the Table above are illustrated in the graphs below.

4.0 CONCLUSION

Malaysia has a tropical climate with a large variability in rainfall. Extreme rainfall events are frequently associated with natural disasters; hence it is critical that an adequate rainfall model be used to generate reliable rainfall series. This research is useful for determining which probability distributions are most compatible with data from Johor's rain gauges. Using three different probability distributions, the maximum values of the rainfall estimates were computed and compared. Most of the stations' discharge levels were projected to be greater using the Log Pearson type III distribution. The severe rainfall in Johor state may be best predicted using the Gumbel type 1 distribution. Depending on the return duration (2, 5, 10, 50, 100, or 1000 years), the rain values used in the design process might be anywhere from 21 mm to 274 mm.

Recommendation

This study executed the rainfall depth for return periods T-2, 5, 10, 50, 100, and 1000 years for 16 rainfall stations near the Johor River basin in Johor State using the three-distribution method and determined the best fit among the three

(Normal, Log-Pearson and Gumbel Extreme Value). However, the data will not accommodate the design for non-rainfall stations. Thus, it is recommended for future studies to investigate regional frequency analysis for non-rainfall stations.

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