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ANALYSIS OF RAINFALL CHARACTERISTICS IN BALIKPAPAN CITY BASED ON DATA FROM BALIKPAPAN METEOROLOGICAL STATION

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ABSTRACT

This study objected to finding the best-fit probability distribution method using four distributions: Normal Distribution, Gumbel Distribution, Log Normal Distribution, and Log Pearson Type III Distribution. According to the score of the goodness-of-fit test, Log Pearson Type III was selected as the best-fit probability distribution. Design rainfall and rainfall intensity were also calculated for the return period of 2 years, 5 years, 10 years, 15 years, and 25 years. In relation to the rainfall intensity, the IDF curve was created. The IDF curve shows higher intensity in the first 5 hours of rainfall, and then the trend decreases gradually. Moreover, it shows that the higher the return period, the higher the rainfall intensity. The movement of curves is essential for designing drainage, flood intensity, and planting period.

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Keywords: Design Rainfall, Frequency Analysis, Probability Distributions, Rainfall Intensity

INTRODUCTION

The accurate estimation of rainfall depth and its return period for several applications in water resources engineering depends on historical data. A proper database is required to evaluate water availability. Balikpapan is one of the cities in Indonesia that exhibits appropriate rainfall data and is stored by the Balikpapan Meteorological Station.

According to Balikpapan Meteorological Station, there is occurrence of fluctuations in rainfall intensity. The rainfall duration of 1.5 hours has the same intensity is the same as rain for 12 days. Compared to 2020, there is more rainfall occurence in 2021. The occurrence of rain in 2020 was for 230 days, whereas in 2021 there was 265 days (KLHS RPJMD Kota Balikpapan, 2021a). The climate in Balikpapan is equatorial, hot, humid, and rainy all year round. In 2021, the highest precipitation was recorded in August with 446,0 mm. Meanwhile, the lowest precipitation was recorded in February with 135,4 mm (BPS Kota Balikpapan, 2022). According to the Annual Rainfall Map of Balikpapan referring to MIROC Model RCP45 Period 2021-2025, there is an increase in the potential accident in Balikpapan, especially in the North Balikpapan district. Several factors that increase the danger of flooding are due to high rainfall intensity in certain months, namely December, January, March, and April (KLHS RPJMD Kota Balikpapan, 2021b).

Based on the analysis of carrying capacity of regulatory services prevention and protection from floods, West Balikpapan District, Balikpapan Kota and North Balikpapan are areas that have a high risk against the flood disaster in Balikpapan City.

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Even though when compared to 2020, there has been a decrease in flooding cases in 2021 from 88 cases to 20 cases in 2020 (DLH Kota Balikpapan, 2021). The decrease in flood cases is due to the more optimum drainage channel capacity and the dams for flood control in accordance with the Drainage Master Plan. So, planning and normalizing drainage channel is one of the solution to prevent flooding.

A frequency analysis of design rainfall must be carried out to observe the impact of climate changes on extreme weather events and flood risks in Balikpapan. Examples of situations where rainfall serves as a crucial input to design and modeling include the estimation of flood in irrigation planning, drainage designing, and planting season (Chang et al., 2013). The present study aims to evaluate the rainfall intensity for different return periods and ascertain the type of probability distribution that best fits the rainfall.

LITERATURE REVIEW

Oldeman criteria is a classification of climate based on the months of the year, classified into wet, humid, and dry months. Wet months can be analyzed when rainfall is above 200 mm, and dry months are indicated when rainfall intensity is below 100 mm (Elma Sofia & Maya Amalia, 2017). These criteria are used to see the potential month for planting in the agricultural sector. Rainfall intensity can be calculated by using rainfall frequency analysis. The analysis is a technique to predict the depth of rainfall intensity for a return period. The output data is necessary for agriculture and designing irrigation and drainage (El Adlouni & Ouarda, 2013).

Several methods are commonly used to create rainfall frequency analysis data, such as; Normal Distribution, Gumbel Distribution, Log-Normal, and Log Pearson Type III. These methods need historical data to be used as input data to estimate the projected rainfall intensity. However, those four methods must be tested and analyzed with two goodness of fit test, which is the Chi-Square and Smirnov-Kolmogorov test. Both tests must be done to all distribution methods to see the consistency of the data to estimate the rainfall intensity.

Rainfall intensity measures the highest depth of collected water within a period of rainfall. Historical data will provide rainfall intensity projection using Mononobe empirical formula (Upomo & Kusuma-wardani, 2016). Based on the output data of Mononobe calculation, rainfall-intensity-frequency (IDF) curves can be created since it is essential to see the relationship between rainfall intensity (mm), duration (hours), and return period (years). The IDF curves cover the rainfall intensity from 1 to 24 hours, with a return period of 2, 5, 10, 15, and 25 years. These data are typically used to see the requirement of rainfall intensity for most applications, such as water management and engineering application (Martel et al., 2021).

METHODS

In this study, the variable was the rainfall data obtained from Balikpapan Meteorological Station from 2012 to 2021. The rainfall is then recapitulated to get monthly rainfall data and rainfall classification according to Oldeman Method. The steps of this research method are as follows:

1. Perform a frequency analysis for determining design rainfalls with various return periods. Several probability distributions can be used, such as the Normal Distribution method, Gumbel Distribution, Log Normal Distribution, and Log-Person Type III Distribution. Of the four methods, the best-fit probability distribution method is selected by conducting several tests.
2. Perform the Chi-Square and Smirnov-Kolmogorov test (The goodness-of-fit test)
3. Calculate design rainfall for the return period of 2 years, 5 years, 10 years, 15 years, and 25 years.
4. Determine the intensity of rainfall using the Mononobe formula
5. Create IDF (intensity-duration-frequency) curve of rainfall based on the rainfall intensity

In the frequency analysis, several statistical parameters such as standard deviation (Sd), skewness coefficient (Cs), and kurtosis coefficient (Ck) were calculated. The calculation of Sd (Roa, 2018), Cs (Ahmed & Ali, 2016), and Ck (Kementerian Pekerjaan Umum dan Perumahan Rakyat, 2018) is written as follows.

$$Sd = \sqrt{\frac{\sum_{i=1}^{n}(X_i - \bar{X})^2}{n}} \quad (1)$$

$$Cs = n\frac{\sum_{i=1}^{n}(X_i - \bar{X})^3}{(n-1)(n-2)Sd^3} \quad (2)$$

$$Ck = \frac{\frac{1}{n}\sum_{i=1}^{n}(X_i - \bar{X})^4}{Sd^4} \quad (3)$$

Where *n* is the amount of rainfall data; *Xi* is rainfall data at *i* year; *X* is the mean value of rainfall for n years, and *Sd* is the standard deviation. For the subsequent calculation of Sd, Cs, and Ck, the equation (1), (2), and (3) can be used.

Normal Distribution

The maximum value of design rainfall corresponding to t years return period was defined by the equation (4) (Amin et al., 2016).

$$X_t = \bar{X} + k_t.Sd \quad (4)$$

Where *Xt* is the maximum value of design rainfall for t years return period (mm); $\bar{X}$ is the mean value; K_t is the frequency factor; and *Sd* is standard deviation.

Gumbel Distribution

Gumbel probability distribution is commonly used for extreme value analysis of hydrological data like floods and maximum rainfalls. The calculation of design rainfall corresponding to t years return period was defined by the equation (5) (Rochyani, 2017).

$$X_t = \bar{X} + \frac{Sd}{Sn}(Y_t - Y_n) \quad (5)$$

Where *Xt* is value of design rainfall for t years return period (mm); $\bar{X}$ is the mean value; *Sd* is standard deviation; *Sn* is standard deviation of reduced variated; *Yt* is reduced variated; and *Yn* is mean of reduced variated.

Log Normal Distribution

The log-normal distribution is a distribution of random variables with a normally distributed logarithm. The value of design rainfall corresponding to t years return period is defined by the equation (6) (Amin et al., 2016).

$$X_t = 10^{Log\,\bar{X} + k_t.Sd} \quad (6)$$

Where *Xt* is the value of design rainfall for t years return period (mm); $\bar{X}$ is the mean value; K_t is frequency factor; and *Sd* is standard deviation.

Log Pearson Type III Distribution

Design rainfall calculation for return period is affected by the *Kt* value, which depends on the skewness coefficient and probability. The analysis of the design rainfall return period is defined by equation (7) (Harahap et al., 2018).

$$X_t = 10^{Log\,\bar{X} + k_t.Sd} \quad (7)$$

Where *Xt* is the value of design rainfall for t years return period (mm); $\bar{X}$ is the mean value; K_t is frequency factor for Log Pearson Type III distribution; and *Sd* is standard deviation.

Chi-square Test

The Chi-square test is commonly used to test the goodness-of-fit of empirical data to specific theoretical distribution with the following formula (Arvind et al., 2017).

$$X^2 = \sum_{i=1}^{k}\frac{(O_i - E_i)^2}{E_i} \quad (8)$$

Where *Oi* is observed frequency; *Ei* is expected frequency; and *i* is number of observations (1, 2, …….k). The x^2 distribution has a degree of freedom with the following formula (Sabarish et al., 2017).

$$Degree\ of\ freedom = N - h - 1 \quad (9)$$

Where *N* is the total number of sample data; *h* is number of parameters. The commonly used value of the level of significance is 5%. The critical values of the chi-square test ($X_{critical}$) for a particular degree of freedom and at a specific significance level can be obtained from the Chi-square distribution table. The hypothesis is accepted if the value meets the criteria as shown below (Baghel et al., 2019).

$$X^2 < X_{critical} \quad (10)$$

RESULTS AND DISCUSSION

The rainfall data from 2012-2021 from Balikpapan Metrological Station is shown in the following table.

Table 1. Rainfall Data from 2012-2021

Mnth	Rainfall Intensity (mm)										Avrg (mm)
	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	
1	254.2	190	199.6	267.9	67.8	221	254.4	291.5	158.1	250.4	215.49
2	293.5	519.9	98	329.1	172.3	104	217.7	75.4	316.7	135.4	226.20
3	244.2	36.8	256.1	182.8	189.6	340	412.2	159.1	196.8	167	218.46
4	181.8	205	271.5	220.5	101	195	117.1	149.6	337.3	159.8	193.86
5	483.4	259.4	146.8	199.7	202.1	535	381.7	166	287.6	260.5	292.22
6	230.2	191.2	246.3	509.8	92	251	222	636.6	545.6	176.6	310.13
7	361.8	205.3	242.2	114.5	243.9	326	319.2	243.2	521.7	148.6	272.64
8	165.6	328.7	187.3	69.1	44.8	430	151.4	63.7	263.5	446	215.01
9	76.9	165.1	21.2	-*	141	267	18.5	97.2	473.9	421	186.87
10	203	146.6	164.3	37.5	202.6	116	212.8	242.2	257.6	357.3	193.99
11	243.8	442.4	145.8	111.8	288	282	120.2	89	315.4	306.8	234.52
12	176	220.4	421.9	112.7	538.4	272	367.4	115.5	280.6	233	273.79
Total	2914.4	2910	2401	2155	2283	3339	2794	2329	3954	3062	2833.
Avrg	242.9	242.6	200.1	195.9	190.3	278.3	232.9	194.1	329.6	255.2	236.17

Information: 1=January, 2=February, 3=March, 4=April, 5=May, 6=June, 7=July, 8=August, 9=September, 10=October, 11=November, 12=December; Avrg=Average; Source: Balikpapan Meteorological Station; *Data is not available

From **Table 1**, according to the Oldeman method, it is shown that there are 9 wet months (January, February, March, May, June, July, August, November, December) and 3 dry months (April, September, October). The results of frequency analysis calculation using several probability distribution methods is shown as follows in **Table 2**.

Table 2. Frequency Analysis Result

Distribution Method	Standard	Results	Conclusion
Normal Distribution	$Cs \approx 0$ $Ck = 3$	$Cs \approx 1{,}139$ $Ck = 2{,}896$	Rejected
Gumbel Distribution	$Cs \leq 1{,}1396$ $Ck \leq 5{,}4002$	$Cs = 1{,}139$ $Ck = 2{,}896$	Accepted
Log Normal Distribution	$Cs = 3Cv + Cv^2 = 3$ $Ck = 5{,}383$	$Cs = 0{,}736$ $Ck = 2{,}352$	Rejected
Log Pearson Type III Distribution	$Cs \neq 0$	$Cs = 0{,}736$	Accepted

The Gumbel distribution and Log Pearson Type III Distribution provided a relevant result compared to the standard. However, Log Pearson Type III was chosen because the Gumbel distribution does not account directly for the computed skew of the data. In the Gumbel distribution, the peak flow series is not distributed using the double-exponential distribution equation, as shown by the fact that the total curve fit is not significantly better than that obtained using the normal distribution (Odunuga & Raji, 2014). After that, the Log Pearson Type III Distribution method was subjected to a goodness-of-fit test (Chi-square test and Smirnov- Kolmogorov test).

The chi-square test defines whether there is a major difference between the expected and observed frequencies in several categories (Coronado-Hernández et al., 2020). The chi-square value corresponds to the degree of freedom of 1 with the 5% level of significance found to be 3,84, while the calculated chi-square is 3,6, which is less than the table value. This indicates that the Log Pearson Type III is accepted, as explained in Equation 10. Result of Chi-square Test with Log Pearson Type III data presented in **Table 3**.

Table 3. Result of Chi-square Test with Log Pearson Type III data

Number	Interval	E_i	O_i	$O_i - E_i$	$(O_i - E_i)^2$	$\frac{(O_i - E_i)^2}{E_i}$
1	$x < 225{,}11$	2.5	4	1.5	2.25	0.9
2	$225{,}11 < x < 259{,}53$	2.5	4	1.5	2.25	0.9
3	$259{,}53 < x < 294{,}75$	2.5	1	-1.5	2.25	0.9
4	$294{,}75 < x < 329{,}57$	2.5	1	-1.5	2.25	0.9
	Total	10	10	0	9	3.6

Smirnov-Kolmogorov test was used to analyze and ensure the fit test of this study. The result of this test will be examined to investigate the relationship between calculated data and expected value (Akpen et al., 2019). The Log Pearson Type III distribution was a selected model to estimate Balikpapan's rainfall intensity. The calculated standard deviation and maximum values of 0.078 and 0.912, respectively. The critical value (Δx) was taken from the Smirnov-Kolmogorov table based on a 5% confidence interval with 10 sample data results of 0.409. It can be seen that the maximum value does not fit the critical value, resulting in not matching data. It can be concluded that the Smirnov-Kolmogorov test showed that the chosen method Log Pearson III is not suitable for rainfall intensity projection.

The rainfall intensity can be calculated using the Mononobe empirical formula based on the rainfall projection data, as defined by Equation (11) (Chalid & Prasetya, 2020). The rainfall intensity shows the depth of accumulation water (mm) within a period of time.

$$I = \frac{R_{24}}{24} (\frac{24}{t})^{2/3} \quad (11)$$

The calculation of the above equation results in rainfall intensity by using rainfall projection data (R_{24}) in duration time (t). Rainfall Intensity with Return Period presented in **Table 4**.

Table 4. Rainfall Intensity with Return Period

Rainfall Duration (Hour)	Rainfall Intensity with Return Period (mm/hour)				
	RP=2 years	RP= 5 years	RP=10 years	RP=15 years	RP=25 years
1	78.05	92.24	101.28	105.05	113.01
2	49.17	58.11	63.80	66.18	71.19
3	37.52	44.34	48.69	50.50	54.33
4	30.98	36.61	40.19	41.69	44.85
5	26.69	31.55	34.64	35.93	38.65
6	23.64	27.94	30.67	31.81	34.22
7	21.33	25.21	27.68	28.71	30.88
8	19.51	23.06	25.32	26.26	28.25
9	18.04	21.32	23.41	24.28	26.12
10	16.82	19.87	21.82	22.63	24.35
11	15.78	18.65	20.48	21.24	22.85
12	14.89	17.60	19.32	20.04	21.56
13	14.12	16.68	18.32	19.00	20.44
14	13.44	15.88	17.44	18.08	19.45
15	12.83	15.17	16.65	17.27	18.58
16	12.29	14.53	15.95	16.54	17.80
17	11.81	13.95	15.32	15.89	17.09
18	11.36	13.43	14.75	15.29	16.45

Rainfall Duration (Hour)	Rainfall Intensity with Return Period (mm/hour)				
	RP=2 years	RP= 5 years	RP=10 years	RP=15 years	RP=25 years
19	10.96	12.95	14.22	14.75	15.87
20	10.59	12.52	13.75	14.26	15.34
21	10.25	12.12	13.31	13.80	14.85
22	9.94	11.75	12.90	13.38	14.39
23	9.65	11.41	12.52	12.99	13.97
24	9.38	11.09	12.17	12.63	13.58
Total	489	578	635	658	708

The calculation of rainfall intensity by using Mononobe is presented in **Table 4**. It shows the rainfall intensity in the return period of 2, 5, 10, 15, and 25 years with 95% confidence interval. The rainfall intensity will be expected in the range of 489-708 mm, with the highest rainfall intensity found in 25 year return period. Based on Handajani et al. (2021), rainfall intensity in Surakarta City, Central Java, will increase with the more extended return period. Suharyanto, (2016) found that rainfall intensity increase gradually from 2 to 25 years return period (95.2 mm to 155.3 mm). This phenomenon happens because the probability of the highest rainfall intensity will occur at least once within the 25 year return period. However, it can also be explained that maximum rainfall intensity will occur at least once every return period. Therefore, rainfall intensity and return period can be used to estimate flood occurrence in the future.

The Intensity-Duration-Frequency(IDF) curves are a graph that shows the probability of rainfall intensity over a period of time. The IDF curves describe the relationship between rainfall intensity, duration, and return period (Elsebaie, 2012). The Intensity-Duration-Frequency (IDF) curves are plotted from resulted data of the Log Pearson Type III method.

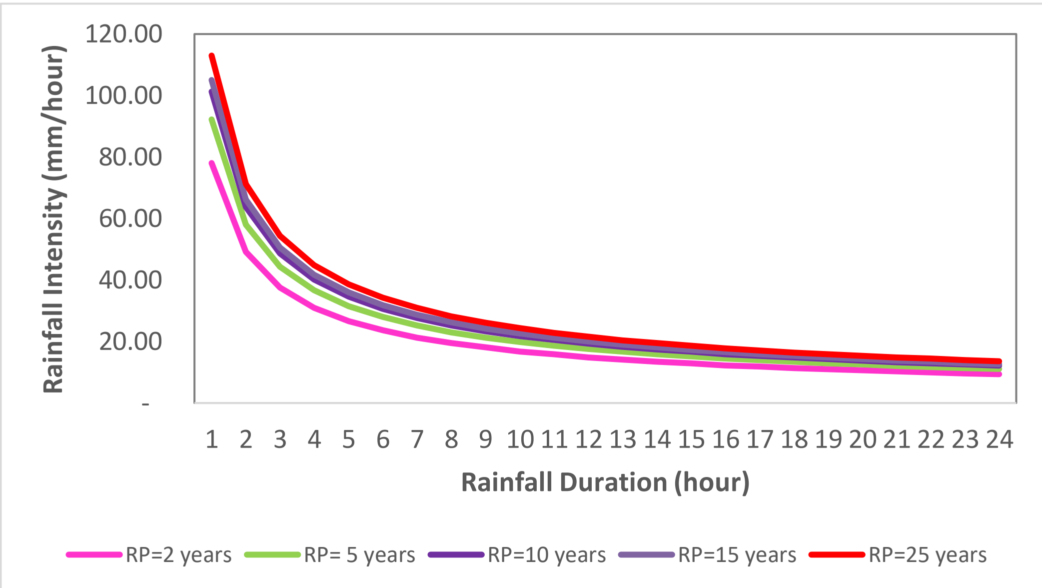

Figure 1. Intensity-Duration-Frequency Curves

As shown in **Figure 1**, the graph shows IDF curves of Balikpapan rainfall intensity with 95% confidence interval. It means all rainfall intensity can adjust between 5% upper or lower. Considering 2 years return period will be predicted 20 mm rainfall intensity while it also has a probability to change from 15 mm to 25 mm. Higher rainfall intensity is found in the first 5 hours of rainfall, and the trend decreases gradually. This situation indicates that the storms will last for a short duration. However, an increase in the return period increases rainfall intensity, therefore higher probability of heavy storms will occur with a higher return period (Tfwala et al., 2017). Mahdi and Mohamedmeki (2020) have found that the IDF curves of Baghdad City obtained similar distributions where the rainfall intensity will decrease with the increase of rainfall duration when an increment of rainfall intensity follows the return period increment. It can be concluded that the rainfall intensity is inversely proportional to time while it is symmetrical to the return period. The movement of curves is essential for the base of designing drainage, flood intensity, and planting period (Sheereen et al., 2022).

CONCLUSION

In comparison to other distribution methods, Log Pearson Type III distribution shows the most suitable value according to the Chi-square test. It can be used to estimate the design rainfall and intensity for the return period of up to 25 years. The findings of rainfall intensity are essential for the development of forecasting techniques as well as agricultural planning in the context of changing climatic circumstances.

Author's declaration

Authors' contributions and responsibilities

The authors made substantial contributions to the conception and design of the study. The authors took responsibility for data analysis, interpretation and discussion of results. The authors read and approved the final manuscript.

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All data are available from the authors.

Competing interests

The authors declare no competing interest.

REFERENCES

Ahmed, R., & Ali, S. (2016). Modelling of intensity-duration-frequency curves for Lahore City using frequency analysis. *Sustainable Development and Planning VIII*, *1*(June), 725–733. https://doi.org/10.2495/sdp160611

Akpen, G. D., Aho, M. I., & Musa, A. A. (2019). Rainfall intensity-duration-frequency models for Lokoja Metropolis, Nigeria. *Global Journal of Pure and Applied Sciences*, *25*(1), 81. https://doi.org/10.4314/gjpas.v25i1.11

Amin, M. T., Izwan, M., & Alazba, A. A. (2016). A best-fit probability distribution for the estimation of rainfall in northern regions of Pakistan. *Open Life Sciences*, *11*(1), 432–440. https://doi.org/10.1515/biol-2016-0057

Arvind, G., Ashok Kumar, P., Girish Karthi, S., & Suribabu, C. R. (2017). Statistical Analysis of 30 Years Rainfall Data: A Case Study. *IOP Conference Series: Earth and Environmental Science*, *80*(1). https://doi.org/10.1088/1755-1315/80/1/012067

Baghel, H., Mittal, H. K., Singh, P. K., Yadav, K. K., & Jain, S. (2019). Frequency Analysis of Rainfall Data Using Probability Distribution Models. *International Journal of Current Microbiology and Applied Sciences*, *8*(06), 1390–1396. https://doi.org/10.20546/ijcmas.2019.806.168

BPS Kota Balikpapan. (2022). *Kota Balikpapan Dalam Angka*. https://www.ptonline.com/articles/how-to-get-better-mfi-results

Chalid, A., & Prasetya, B. (2020). Utilization of a pond in East Jakarta for a sustainable urban drainage system model. *IOP Conference Series: Earth and Environmental Science*, *437*(1). https://doi.org/10.1088/1755-1315/437/1/012018

Chang, H. K., Tan, Y. C., Lai, J. S., Pan, T. Y., Liu, T. M., & Tung, C. P. (2013). Improvement of a drainage system for flood management withassessment of the potential effects of climate change. *Hydrological Sciences Journal*, *58*(8), 1581–1597. https://doi.org/10.1080/02626667.2013.836276

Coronado-Hernández, Ó. E., Merlano-Sabalza, E., Díaz-Vergara, Z., & Coronado-Hernández, J. R. (2020). Selection of hydrological probability distributions for extreme rainfall events in the regions of Colombia. *Water (Switzerland)*, *12*(5), 1–12. https://doi.org/10.3390/W12051397

DLH Kota Balikpapan. (2021). *Dokumen Informasi Kinerja Pengelolaan Lingkungan Hidup Daerah Kota Balikpapan Tahun 2021*.

El Adlouni, S., & Ouarda, T. B. M. J. (2013). Frequency Analysis of Extreme Rainfall Events. *Rainfall: State of the Science*, *January*, 171–188. https://doi.org/10.1029/2010GM000976

Elma Sofia, & Maya Amalia. (2017). ANALISIS KARAKTERISTIK CURAH HUJAN DI KOTA BANJARBARU BERDASARKAN DATA STASIUN KLIMATOLOGI BANJARBARU. *Jurnal Konstruksia*, *7*(1), 13–14.

Elsebaie, I. H. (2012). Developing rainfall intensity–duration–frequency relationship for two regions in Saudi Arabia. *Journal of King Saud University - Engineering Sciences*, *24*(2), 131–140. https://doi.org/10.1016/j.jksues.2011.06.001

Handajani, N., Zainab, S., & Trilita, M. N. (2021). Analysis of Intensity, Duration, Frequency for Groundsill Planning in the Lower Bengawan Solo River Basin. *IOP Conference Series: Materials Science and Engineering*, *1125*(1), 12015. https://doi.org/10.1088/1757-899X/1125/1/012015

Harahap, R., Jeumpa, K., & Hadibroto, B. (2018). Flood Discharge Analysis with Nakayasu Method Using Combination of HEC-RAS Method on Deli River in Medan City. *Journal of Physics: Conference Series*, *970*(1), 0–11. https://doi.org/10.1088/1742-6596/970/1/012011

Kementerian Pekerjaan Umum dan Perumahan Rakyat. (2018). *Analisis Hidrologi dan Sedimentasi*. https://bpsdm.pu.go.id/center/pelatihan/uploads/edok/2019/03/740a8_6._MODUL-3_ANA LISIS_HIDROLOGI_DAN__SEDIMEN.pdf

KLHS RPJMD Kota Balikpapan. (2021, a). *Wali kota balikpapan*.

KLHS RPJMD Kota Balikpapan. (2021, b). *Wali kota balikpapan*.

Mahdi, E. S., & Mohamedmeki, M. Z. (2020). Analysis of rainfall intensity-duration-frequency (IDF) curves of Baghdad city. *IOP Conference Series: Materials Science and Engineering*, *888*(1), 0–9. https://doi.org/10.1088/1757-899X/888/1/012066

Martel, J.-L., Brissette, F. P., Lucas-Picher, P., Troin, M., & Arsenault, R. (2021). Climate Change and Rainfall Intensity–Duration–Frequency Curves: Overview of Science and Guidelines for Adaptation. *Journal of Hydrologic Engineering*, *26*(10), 1–18. https://doi.org/10.1061/(asce)he.1943-5584.0002122

Odunuga, S., & Raji, S. A. (2014). Flood Frequency Analysis and Inundation Mapping of Lower Ogun River Basin. *Journal of Water Resource and Hydraulic Engineering Sept*, *3*(3), 48–59.

Roa, G. S. (2018). Frequency analysis of rainfall data. In *Ilocos Sur Polytechnic State College* (Vol. 57, Issue 1). https://doi.org/10.1051/matecconf/20165703013

Rochyani, N. (2017). Study of acid mine drainage management with evaluating climate and rainfall in East Pit 3 West Banko coal mine. *AIP Conference Proceedings*, *1903*(May). https://doi.org/10.1063/1.5011525

Sabarish, R. M., Narasimhan, R., Chandhru, A. R., Suribabu, C. R., Sudharsan, J., & Nithiyanantham, S. (2017). Probability analysis for consecutive-day maximum rainfall for Tiruchirapalli City (south India, Asia). *Applied Water Science*, *7*(2), 1033–1042. https://doi.org/10.1007/s13201-015-0307-x

Sheereen, Z., Ganie, M., & Rout, S. (2022). *A Study on the Influence of Rainfall on Agriculture using IDF curve A Study on the Influence of Rainfall on Agriculture using IDF curve*. *June*.

Suharyanto, A. (2016). Prediction of Flood Area Based on the Occurrence of Rainfall Intensity. *GMSARN International Journal*, *10*, 129–136.

Tfwala, C. M., van Rensburg, L. D., Schall, R., Mosia, S. M., & Dlamini, P. (2017). Precipitation intensity-duration-frequency curves and their uncertainties for Ghaap plateau. *Climate Risk Management*, *16*(May), 1–9. https://doi.org/10.1016/j.crm.2017.04.004

Upomo, T. C., & Kusumawardani, R. (2016). Pemilihan Distribusi Probabilitas Pada Analisa Hujan Dengan. *Jurnal Teknik Sipil & Perencanaan*, *18*(2), 139–148.