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Rainfall Intensity Analysis in the Mount Merak Imogiri Area, as a Data-Based Recommendation for Disaster Mitigation and Drainage Management of Cultural Heritage Sites

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Abstrak

Kawasan Gunung Merak Imogiri di Kabupaten Bantul, DI Yogyakarta, merupakan situs bersejarah dan budaya yang sangat penting. Keberadaannya yang terletak di lereng bukit dengan topografi berundak, menjadikannya rentan terhadap dampak peristiwa hidrometeorologi (seperti hujan ekstrem). Tujuan penelitian ini adalah mengukur dan menganalisis intensitas hujan di kawasan Gunung Merak Imogiri. Memberikan rekomendasi berbasis data untuk strategi mitigasi bencana hidrometeorologi, khususnya terkait dengan pengelolaan drainase dan pencegahan erosi.

Metodologi yang digunakan melibatkan analisis frekuensi terhadap data curah hujan harian maksimum selama 20 tahun (2004–2023) dari Pos Hujan Siluk yang diolah menggunakan perangkat lunak MS Excel. Pemilihan model distribusi terbaik didasarkan pada uji kecocokan Chi-Square dan Smirnov-Kolmogorov, yang menetapkan distribusi Log-Normal sebagai metode yang paling sesuai.

Hasil perhitungan intensitas hujan dengan metode Mononobe dengan mempertimbangkan waktu konsentrasi (Tc) sebesar 4,91 menit. Hasil analisis menunjukkan nilai intensitas hujan untuk kala ulang 2, 5, 10, 20, 50, dan 100 tahun
berturut-turut adalah 15,71; 19,40; 21,66; 23,73; 24,37; dan 26,29 mm/jam. Temuan ini mengindikasikan tingginya risiko limpasan permukaan dalam durasi singkat, sehingga diperlukan desain sistem drainase yang optimal dan penguatan lereng untuk menjaga stabilitas struktur bangunan cagar budaya dari ancaman erosi dan banjir lokal.

Abstract

Mount Merak area in Imogiri Bantul Regency, Yogyakarta Special Region, is a highly important historical and cultural site. Its existence is located on a hillside with a terraced topography, making it vulnerable to the impact of hydrometeorological events (such as extreme rain). The aim of this research is to measure and analyze the intensity of rain in the Mount Merak Imogiri area. Provide data-based recommendations for hydrometeorological disaster mitigation strategies, especially related to drainage management and erosion prevention.

The methodology used involves frequency analysis of maximum daily rainfall data for 20 years (2004–2023) from the Siluk Rain Post which was processed using MS Excel software. The selection of the best distribution model was based on the Chi-Square and Smirnov-Kolmogorov goodness-of-fit tests, which determined the Log-Normal distribution as the most suitable method.

Results of calculating rain intensity using the Mononobe method taking into account the concentration time (Tc) of 4.91 minutes. The analysis results show that the rainfall intensity value for return periods 2, 5, 10, 20, 50 and 100 years respectively is 15.71;
19.40; 21.66; 23.73; 24.37; and 26.29 mm/hour. These findings indicate a high risk of surface runoff in a short duration, so it is necessary to design optimal drainage systems and strengthen slopes to maintain the stability of cultural heritage building structures from the threat of local erosion and flooding.

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INTRODUCTION

The Mount Merak Imogiri area in Bantul Regency, Yogyakarta, is a very important historical and cultural site, attracting thousands of pilgrims and tourists every year. The existence of this tomb complex, which is located on a hillside with terraced topography, makes it vulnerable to the impacts of hydrometeorological events, especially extreme rainfall. The main problem that will be studied is the unavailability of accurate and detailed rainfall intensity data specifically for the Mount Merak Imogiri area. Currently available rainfall data is generally from general stations that are located far away or have too broad a coverage, so they cannot represent the micro conditions and spatial variability of rainfall intensity in the complex Imogiri slope area. This data inaccuracy has implications for the inability to predict potential hydrometeorological threats such as local flooding, surface erosion, and small landslides that could threaten the stability of the tomb's structure, accessibility for visitors, and the safety of the surrounding community. The lack of in-depth understanding of specific rainfall intensity patterns at this location also hampers effective and sustainable disaster mitigation planning.

The aim of this research is measure and analyze rainfall intensity in the Mount Merak Imogiri area. Provide data-based recommendations for hydrometeorological disaster mitigation strategies, particularly related to drainage management and erosion prevention at the cultural heritage site.

The urgency of this research is very high considering several crucial aspects. First, the conservation of cultural heritage sites. The Imogiri area is a priceless cultural heritage and protecting it from the threat of natural disasters is a priority. Damage caused by rainwater can damage the physical structure of the tomb and its supporting infrastructure. Second, the safety of visitors and local communities. The rainy season often brings the risk of puddles, slippery roads, and potential landslides that endanger thousands of pilgrims and residents who carry out activities around the tomb complex Third, the basis for mitigation planning. With accurate rainfall intensity data, local governments and site managers can formulate more targeted, efficient, and effective mitigation action plans, such as optimal drainage system design, slope reinforcement construction, or early warning systems. This research will be a strong scientific foundation for decision making.

This research is a basic knowledge of the characteristics of micro hydrology in complex environments such as terraced slopes which have high conservation value.

While the results of this study have clear practical implications for disaster mitigation, its primary focus is on developing a methodology for measuring and modeling rainfall intensity at the micro scale, which has not been widely explored in similar geographic and topographic contexts in Indonesia. The resulting data and models will form the basis for further applied research, for example the development of early warning systems or the design of specific drainage infrastructure. The selection of this scheme allows for in-depth scientific exploration and contribution to the development of applied hydrological theory and methodology, relevant for the protection of cultural heritage and public safety.

The process of transforming rain into surface flow is determined by several essential properties of rain, namely depth (height), duration (length), intensity, frequency (number of occurrences), and catchment area of rain. Statistically, the relationship between two important parameters, intensity and duration of rainfall, can be related to the frequency of rainfall events expressed in return periods. The return period itself is defined as the hypothetical period during which a certain rainfall quantity is expected to be equaled or exceeded.

The relationship between intensity, duration, and frequency of rainfall is visualized in the form of an Intensity-Duration-Frequency curve (IDF) or often called rain arch. IDF curve analysis requires frequency analysis carried out based on recorded rainfall data. The IDF relationship presentation in the form of a curve is very vital for calculating runoff and peak discharge, especially at certain times of concentration. The IDF curve specifically shows the probability of a certain rainfall intensity occurring for a certain rainfall duration.

Several studies have been conducted on rainfall intensity analysis and the development of IDF curves. For example, (Susilowati & Dyah Indriana Kusumastuti, 2010)(Febriani dkk., 2019) has developed the IDF curve using the Van Breen and Hasper der Weduwen method approaches, and using the Talbot, Sherman, and Ishiguro equations. Surakarta City Region, (Fauziyah dkk., 2013) creating IDF curves with several approximation formulas, including Talbot, Sherman, Ishiguro, and SDR-IDF. Meanwhile, on the Mount Merapi's slopes, (Prayuda, 2015) have also constructed IDF curves using various intensity formulas such as Sherman, Kimijima, Haspers, and Mononobe. Furthermore, (Dewi Ayu Sofia & Nursila, 2019) examine the analysis of intensity, duration, and frequency of rainfall in the Sukabumi area, with the aim of describing the IDF curve and using it to calculate runoff and peak discharge using rational formulas. Their study used the empirical formula of Haspers and Mononobe for intensity calculations (Yohanes I Nyoman Martin Hendriyantha dkk., 2023). The results show that heavy rain generally occurs in short durations, However, there are differences in intensity values between calculations using the Haspers and Mononobe formulas, so this study cannot yet conclude which empirical formula is most suitable for calculating rainfall intensity in the Sukabumi region (Hariati dkk., 2022).

Specifically in the Bantul Regency area, previous research has laid the foundation for understanding regional hydrology. (Nizar Achmad dkk., 2021) conducted a comparative analysis of regional rainfall using the Thiessen and Isohiet Polygon methods, while (Widyasari & Achmad, 2023) focused his study on design rainfall analysis at the district level by identifying the Log-Pearson III distribution as the most appropriate model. However, currently available rainfall data are generally still general stations with broad coverage, so they are not able to represent micro conditions and spatial variability of rainfall intensity in areas with complex topography.

This research fills this knowledge gap by focusing on the micro hydrological characteristics of the Mount Merak Imogiri area. The existence of this cultural heritage site on a hillside with terraced topography makes it very vulnerable to hydrometeorological threats such as surface erosion and small landslides which can threaten the stability of the tomb structure. The novelty of this research lies in the development of a micro-scale rainfall intensity model which has not been widely explored in the context of terraced slope topography which has high conservation value in Indonesia.

The urgency of this research is very high because accurate rain intensity data will be the main scientific foundation in formulating targeted disaster mitigation strategies, starting from optimal drainage system design to efforts to protect priceless cultural heritage. Thus, this research not only contributes to the development of applied hydrology methodology, but also provides practical solutions for public safety and preservation of historic sites.

METHOD

This research was conducted by identifying rainfall data, then determining the watershed rainfall value, and then determining rainfall intensity using a frequency analysis method. The steps in the research process are explained as follows:

Figure 1. Research Flow Diagram

a. Research Location

The research location to be carried out is on Mount Merak Imogiri.

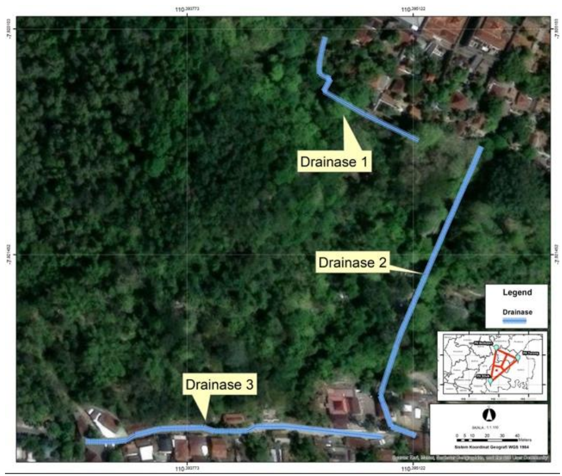

Figure 2. Activity Location

Source: *Googleearth*; Research Results of the Year 2025

b. Required Data

This study uses rainfall data from stations located around Mount Merak, Bantul Regency. Bantul Regency itself is located on the island of Java, stretching between 110°12’34” to 110°31’08” East Longitude and 7°44’04” to 8°00’27” South Latitude.

Information regarding Bantul Regency's map and the rain station coordinates points was obtained from BBWSSO. The rainfall stations observed in this study include Terong, Siluk, dan Bedugan.

The design rainfall analysis is calculated using the MS Excel version of frequency analysis software. The most appropriate selection for data distribution is determined through a goodness-of-fit test. For the chi-square test ($\chi 2$), a distribution is considered to be suitable if the value $\chi 2$ which is calculated to be smaller than $\chi 2$ critic ($\chi 2<\chi$ critic 2), which indicates the hypothesis is accepted. Similarly, in the Smirnov-Kolmogorov test, the hypothesis is accepted if the Dmax value is smaller than Dcritic (Dmax<Dcritic). If a distribution is accepted by both goodness-of-fit tests, then the selection of the best distribution is based on the value $\chi 2$ and the smallest Dmax. Based on the results of the goodness-of-fit test, it was found that the Log-Pearson III distribution is a suitable distribution based on the chi-square test.

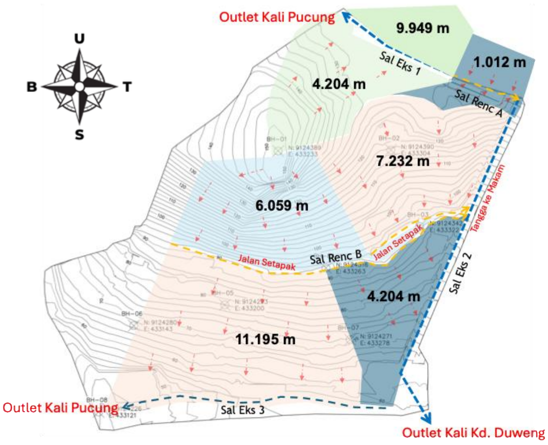

Figure 3. Topography, Channel Network and Water Catchment Area

Source: Research Results in 2025

RESULTS AND DISCUSSION

a. Hydrological Analysis

The hydrology in this data analysis is aimed at seeing the hydrological conditions of the Mount Merak area, Imogiri, Bantul Regency, Data collection to be used in the research consists of primary and secondary data. Primary data consists of a description from conditions of the study area. Secondary data is data obtained from observations or measurements conducted by relevant agencies. Maximum daily rainfall data for the last 20 years obtained from the Meteorology, Climatology and Geophysics Agency / Water Resources Agency / public irrigation / River Basin Organization.

and Topographic maps and land slopes obtained from topographic measurement results

1) Rainfall Analysis

Rainfall conditions and rainfall behavior throughout the year at the study location can be determined by looking at the rainfall pattern around the study location which is recorded at the rain station post (Sukman dkk., 2024). Due to the lack of information on rainfall patterns at the work site, a review is needed to compare rainfall patterns around the site. By examining the relationship between the Mount Merak area, Imogiri, Bantul Regency, and the watershed, a review of the results of the rainfall pattern search at the work site can be conducted.

Rainfall analysis is needed to determine the intensity level used to predict the occurrence of surface flow. The rainfall used in the analysis is the maximum daily rainfall in the last 20 years obtained from the BBWSSO The first step in rainfall analysis is to calculate the average rainfall at the study location from several rainfall recording stations around the river basin. Then, a frequency analysis is carried out to determine the appropriate rainfall distribution for the location. After determining the distribution of rainfall, a suitability test is carried out on the previously selected distribution and this can determine the intensity of rainfall used to predict the occurrence of surface flow.

Based on the results of the rain station inventory obtained from BBWSSO which is located around the planning location, there are 3 (three) rain stations, namely the Siluk Rain Post, Terong Rain Post, and Bedugan Rain Post. By using the Theissen method, the locations that have an influence in the planning area are known, as shown in Figure 4.

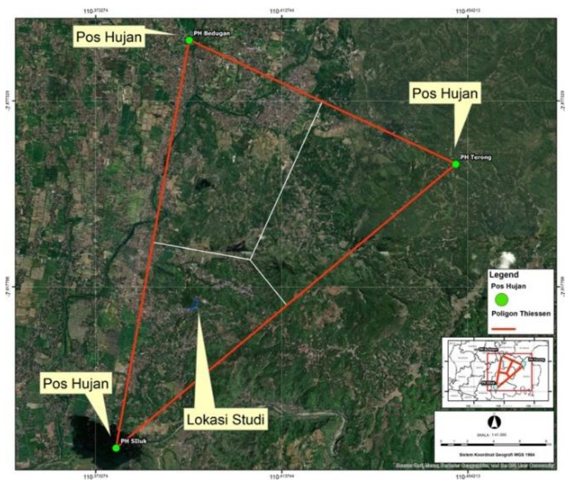

Figure 4. Theissen Polygon at the Plan location

Source: Googleearth; Research Results of the Year 2025

Based on the distribution of the rain stations above, the influential rain post is the Siluk Rain Post. The rainfall data analyzed in this planning is the maximum daily rainfall data from the Siluk Rain Post from 2004 to 2023. From the data above, the maximum daily rainfall value will be used in the calculation.

2) Analysis of Frequency and Probability Calculations

Data series used in frequency analysis is a partial data series, by setting a certain quantity as the lower limit, then all data quantities that are greater than the lower limit are taken and made part of the data series and then analyzed. The lower limit can be taken using a ranking system, where all sufficiently large data quantities are taken, then sorted from largest to smallest. The data taken for further analysis is according to the length of the data, for this analysis the data length used is 20 years (2004-2023).

Hydrological data used in the frequency analysis for the purposes of this rainfall analysis is a series of maximum daily rainfall data obtained from the rainfall post around the location, namely the Siluk Post.

Maximum daily rainfall data is presented in Table 1.

Table 1 Daily Rainfall Data (Maximum)

No	Year	Rr (mm)
1	2023	104,5
2	2022	68,3
3	2021	97,9
4	2020	92,2
5	2019	60,5
6	2018	86,2
7	2017	81,4
8	2016	105,2
9	2015	115,2
10	2014	110,9
11	2013	87,6
12	2012	127,1
13	2011	81,5
14	2010	56,4
15	2009	55,5
16	2008	68,5
17	2007	159,7
18	2006	96,5
19	2005	151,0
20	2004	147,0

Source : Serayu Opak River Basin Organization, 2025

3) Determination of Distribution Type

As an initial analysis to select a frequency distribution that matches the rainfall data, basic statistical parameters are first calculated, namely the average of the rainfall data series (partial series), standard deviation, skewness/asymmetry coefficient and kurtosis coefficient (Bambang Triatmojo, 2010)(Suroso, 2006).

Statistical parameter values of rainfall data are calculated as follows:

- Amount of data (n) = 20
- Average of data series ($\overline{Xrt}$)

$$\overline{X} = \frac{\sum_{i=1}^{n} X_i}{n} \qquad (1)$$

$$\overline{X}_{rt} = 97{,}655$$

- Standard deviation (S)

$$S = \sqrt{\frac{\sum_{i=1}^{n}(X_i - \overline{X}rt)^2}{n-1}} \qquad (2)$$

$$= 30{,}732$$

- Coefficient of variation (Cv)

$$Cs = \frac{n}{(n-1)\times(n-2)\times S_1^{\,3}} \times \sum_{i=1}^{n}(X_i - X\,rt) \qquad (3)$$

$$= 0{,}579$$

- Kurtosis coefficient (Ck)

$$Ck = \frac{n}{(n-1)\times(n-2)\times(n-3)\times S_1^{\,4}} \times \sum_{i=1}^{n}(X_i - Xrt)^4 \qquad (4)$$

$$= -0{,}355$$

The calculation results from the analysis of the largest daily rainfall frequency and the basic values of rainfall statistics at rain stations are presented in Table 2.

Table 2 Rainfall Statistical Analysis Calculation

m	P = m/(N+1)	Tahun	Hujan (mm)	Ln Hujan (mm)
1	0,048	2007	159,700	5,073
2	0,095	2005	151,000	5,017
3	0,143	2004	147,000	4,990
4	0,190	2012	127,100	4,845
5	0,238	2015	115,200	4,747
6	0,286	2014	110,900	4,709
7	0,333	2016	105,200	4,656
8	0,381	2023	104,500	4,649
9	0,429	2021	97,900	4,584
10	0,476	2006	96,500	4,570
11	0,524	2020	92,200	4,524
12	0,571	2013	87,600	4,473
13	0,619	2018	86,200	4,457
14	0,667	2011	81,500	4,401
15	0,714	2017	81,400	4,399
16	0,762	2008	68,500	4,227
17	0,810	2022	68,300	4,224
18	0,857	2019	60,500	4,103
19	0,905	2010	56,400	4,032
20	0,952	2009	55,500	4,016

Source: Analysis results, 2025

4) Data Distribution Testing

- **Chi Square Test (X²)**

Data testing using the Chi-Square method was performed on all distributions to determine whether they met the criteria. Based on the statistical parameters, the distributions met all criteria, as shown in Tables 3 through 6.

Table 3 Chi Square Test (X²)-Normal

Kelas	P(x >= Xm)		Ef	Hujan (mm)	Of	Ef - Of	(Ef-Of)² / Ef
5	,200	0 < P <= ,200	4,000	123,519	4,000	0,000	0,000
	,400	,200 < P <= ,400	4,000	105,441	2,000	2,000	1,000
	,600	,400 < P <= ,600	4,000	89,869	5,000	1,000	0,250
	,800	,600 < P <= ,800	4,000	71,791	4,000	0,000	0,000
	0,999	,800 < P <= 0,999	4,000	2,687	5,000	1,000	0,250
			20,000		20,000	Chi-Kuadrat =	1,500
						DK =	2
Distribusi NORMAL Diterima						Chi-Kritik =	5,991

Source: Analysis results, 2025

Table 4 Chi Square Test (X²)-Log Normal

Kelas	P(x >= Xm)		Ef	Hujan (mm)	Of	Ef - Of	(Ef-Of)² / Ef
5	,200	0 < P <= ,200	4,000	121,441	4,000	0,000	0,000
	,400	,200 < P <= ,400	4,000	100,931	4,000	0,000	0,000
	,600	,400 < P <= ,600	4,000	86,065	5,000	1,000	0,250
	,800	,600 < P <= ,800	4,000	71,530	2,000	2,000	1,000
	0,999	,800 < P <= 0,999	4,000	35,270	5,000	1,000	0,250
			20,000		20,000	Chi-Kuadrat =	1,500
						DK =	2
Distribusi LOG-NORMAL Diterima						Chi-Kritik =	5,991

Source: Analysis results, 2025

Table 5 Chi Square Test (X²)-Gumbel

Kelas	P(x >= Xm)		Ef	Hujan (mm)	Of	Ef - Of	(Ef-Of)² / Ef
5	,200	0 < P <= ,200	4,000	119,765	4,000	0,000	0,000
	,400	,200 < P <= ,400	4,000	99,920	4,000	0,000	0,000
	,600	,400 < P <= ,600	4,000	85,919	5,000	1,000	0,250
	,800	,600 < P <= ,800	4,000	72,422	2,000	2,000	1,000
	0,999	,800 < P <= 0,999	4,000	37,516	5,000	1,000	0,250
			20,000		20,000	Chi-Kuadrat =	1,500
						DK =	2
Distribusi GUMBEL Diterima						Chi-Kritik =	5,991

Source: Analysis results, 2025

Table 6 Chi Square Test (X²)-Log Pearson III

Kelas	P(x >= Xm)		Ef	Hujan (mm)	Of	Ef - Of	(Ef-Of)² / Ef
5	,200	0 < P <= ,200	4,000	121,442	4,000	0,000	0,000
	,400	,200 < P <= ,400	4,000	100,935	4,000	0,000	0,000
	,600	,400 < P <= ,600	4,000	86,069	5,000	1,000	0,250
	,800	,600 < P <= ,800	4,000	71,531	2,000	2,000	1,000
	0,999	,800 < P <= 0,999	4,000	35,257	5,000	1,000	0,250
			20,000		20,000	Chi-Kuadrat =	1,500
						DK =	1
Distribusi LOG-PEARSON III Diterima						Chi-Kritik =	3,841

Source: Analysis results, 2025

Table 7 Selecting the Type of Data Distribution

No	Spread	Condition	Calculation results	information
1	Normal	Cs = 0 Ck =3	Cs = 0,579 Ck = -0,355	rejected
2	Log Normal	Cs/Cv = 3	Cs/Cv = 1,63	accepted
3	Log Person III	Cs = (+) / (-)	Cs = 0,579	accepted
4	Gumbel	Cs = 1,1396 Ck = 5,4002	Cs = 0,579 Ck = -0,355	accepted

Source: Analysis results, 2025

Based on Table 3 to Table 7, all distributions meet the requirements, but the best choice is to use the Log-Normal Distribution.

- **Smirnov Kolmogorov test**

This method of testing is carried out by comparing the data deviation, By data plotting on probability paper with the theoretical line as follows :

$$P\left\{\max\left[P(X)-P(X_i)\right]\right\} \leq \Delta cr \qquad (5)$$

With :

Δcr = From critical table

The Kolmogorov test plotting results are tabulated in Table 9, which shows that all distribution values are accepted.

Table 8 Kolmogorov Chi-test

Hujan (mm)	m	P = m/(N+1)	NORMAL		LOG-NORMAL		GUMBEL		LOG-PEARSON III	
			P(x >= Xm)	Do	P(x >= Xm)	Do	P(x >= Xm)	Do	P(x >= Xm)	Do
159,700	1	0,048	0,022	0,026	0,043	0,004	0,041	0,006	0,043	0,004
151,000	2	0,095	0,041	0,054	0,062	0,033	0,059	0,036	0,062	0,033
147,000	3	0,143	0,054	0,089	0,074	0,069	0,069	0,074	0,074	0,069
127,100	4	0,190	0,169	0,021	0,162	0,029	0,152	0,039	0,162	0,029
115,200	5	0,238	0,284	0,046	0,250	0,012	0,237	0,001	0,250	0,012
110,900	6	0,286	0,333	0,048	0,290	0,004	0,276	0,010	0,290	0,004
105,200	7	0,333	0,403	0,070	0,350	0,017	0,336	0,003	0,350	0,017
104,500	8	0,381	0,412	0,031	0,358	0,023	0,344	0,037	0,358	0,023
97,900	9	0,429	0,497	0,068	0,438	0,009	0,426	0,002	0,438	0,009
96,500	10	0,476	0,515	0,039	0,456	0,020	0,445	0,031	0,456	0,020
92,200	11	0,524	0,570	0,047	0,514	0,010	0,506	0,018	0,514	0,010
87,600	12	0,571	0,628	0,057	0,578	0,007	0,574	0,003	0,578	0,007
86,200	13	0,619	0,645	0,026	0,598	0,021	0,596	0,023	0,598	0,021
81,500	14	0,667	0,700	0,034	0,665	0,001	0,668	0,001	0,665	0,001
81,400	15	0,714	0,702	0,013	0,667	0,048	0,669	0,045	0,667	0,048
68,500	16	0,762	0,829	0,067	0,836	0,074	0,850	0,088	0,836	0,074
68,300	17	0,810	0,830	0,021	0,839	0,029	0,852	0,043	0,839	0,029
60,500	18	0,857	0,887	0,030	0,915	0,058	0,929	0,072	0,915	0,058
56,400	19	0,905	0,910	0,006	0,945	0,040	0,957	0,052	0,945	0,040
55,500	20	0,952	0,915	0,037	0,950	0,002	0,962	0,009	0,950	0,002
DKritik =	0,290			0,089		0,074		0,088		0,074
				Diterima		Diterima		Diterima		Diterima
Ket. :	m =	Peringkat								
	P =	Peluang di lapangan								
	Do =	Selisih peluang lapangan dengan peluang teoritis								

Source: Analysis results, 2025

5) Planned Rain Calculation

Rainfall data for the Mount Merak area in Bantul Regency was collected from rainfall stations near the Mount Merak area in Bantul Regency for analysis purposes. The data was analyzed using probability statistics. The results are presented in Table 10.

Table 9 Design Rain

P(x >= Xm) Probabilitas	T Kala-Ulang	Karakteristik Hujan (mm) Menurut Probabilitasnya NORMAL		LOG-NORMAL		GUMBEL		LOG-PEARSON III	
		X_T	K_T	X_T	K_T	X_T	K_T	X_T	K_T
0,9	1,111	58,271	-1,282	62,288	-1,151	63,84	-1,1	62,287	-1,282
0,5	2,	97,655	0,	93,202	-0,145	92,607	-0,164	93,206	0,
0,2	5,	123,519	0,842	121,441	0,774	119,765	0,719	121,442	0,842
0,1	10,	137,039	1,282	139,459	1,36	137,746	1,305	139,455	1,281
0,05	20,	148,204	1,645	156,337	1,909	154,995	1,866	156,326	1,645
0,02	50,	160,77	2,054	177,788	2,608	177,32	2,592	177,765	2,053
0,01	100,	169,147	2,326	193,701	3,125	194,051	3,137	193,665	2,326
0,001	1000,	192,623	3,09	246,294	4,837	249,332	4,936	246,207	3,089

Source: Analysis results, 2025

Results from the goodness-of-fit test that have been used are that the Chi-Square goodness-of-fit test obtained the best value in the Normal Distribution, while the Smirnov-Kolmogorov goodness-of-fit test obtained the best value in the Log-Normal Distribution. For the decision of the method above, the value is taken from the results of the Log-Normal Distribution.

b. Planned Debit Calculation

1) Concentration Time

Concentration Time, Tc is the time required to flow rainwater from the furthest point to a certain point when viewed from the drainage area.(Asdak, 2023)

The following is the concentration time calculation (tc) based on the following formula:

$tc = 0{,}0195.L^{0{,}77}.S^{-0.385}$

L = 205 m

S = 0,297

tc = 0,0195. 0,205 ^0,77. 0,297^-0.385 = 0,082 hours = 4,91 minute

2) Rain Intensity Calculation

Rain intensity is calculated using the following equation (Mononobe formula):

$$It = \frac{R}{24} \times \left(\frac{24}{Tc}\right)^{2/3} \quad (6)$$

with :

R = duration, design rainfall (mm),

Tc = concentration time (hours),

Rainfall intensity calculation using the Mononobe method produces data such as Table 10 with a return period of 2, 5, 10, 20, 50 and 100 years, therefor the Rain Intensity:

Table 10 Rainfall Intensity Calculation Results

Return Time	R (mm)	I (mm/jam)
2,	93,2	15,71
5,	121,44	19,4
10,	139,46	21,66
20,	156,34	23,73
50,	177,79	24,37
100,	193,7	26,29
1000,	246,29	28,15

Source: Analysis results, 2025

Table 10, the rain intensity value for the 2 year return period is 15.71 mm/hour, which then increases to 21.66 mm/hour at the 10 year return period, and reaches 26.29 mm/hour at the 100 year return period.

The Rain Intensity Curve can be seen in Figure 5.

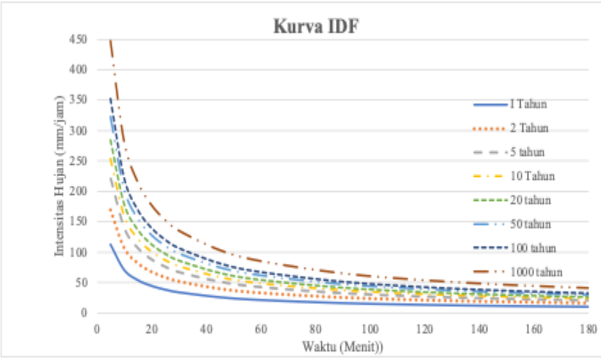

Figure 5. Rain Intensity Curve

This research is in line with (Widyasari & Achmad, 2023) study which identified the frequency distribution in Bantul Regency.

However, this research on Mount Merak provides a more specific contribution at the micro scale by considering the unique stepped topographic parameters of the cultural heritage site, in contrast to the general district analysis. When compared with the results of (Susilowati & Dyah Indriana Kusumastuti, 2010) in Lampung or (Fauziyah dkk., 2013) in Surakarta, the intensity on Mount Merak shows the more dynamic rain characteristics of mountain areas. These findings support (Nizar Achmad dkk., 2021) argument that regional rainfall modeling in Bantul requires high accuracy because of its significant spatial variability.

The rainfall intensity results obtained provide a stronger scientific basis than the general station data currently used. This data allows cultural heritage site managers to design a drainage system that is able to accommodate water loads at an intensity of 26.29 mm/hour for an extreme 100 year scenario, to prevent damage to the physical structure of the tomb due to surface erosion or local flooding.

CONCLUSION

Based on the research results, it is known that:

1. The rainfall intensity in the Mount Merak Imogiri area with a 2-year return period is 15,71 mm/hour, for a 5-year return period of 19,40 mm/hour, for a 10-year return period of 21,66 mm/hour, for a 20-year return period of 23,73 mm/hour, for a 50-year return period of 24,37 mm/hour and for a 100-year return period of 26,29 mm/hour. This intensity value information can be used further to calculate the planned discharge in implementing hydrometeorological disaster mitigation strategies, particularly related to drainage management and erosion prevention at the cultural heritage site;
2. This high intensity characteristic is significantly influenced by the very short concentration time (Tc), namely 4.91 minutes, due to the steep stepped slope topographic conditions;
3. The rainfall intensity value must be used to calculate the planned discharge in order to design optimal drainage channel dimensions to be able to accommodate extreme surface runoff, thus preventing puddles that damage the structure of the grave slopes;
4. The high intensity of rain for a short duration emphasizes the need to strengthen slopes and protect the ground surface to minimize the risk of surface erosion and small landslides that threaten the stability of cultural heritage buildings.

BIBLIOGRAPHY

Asdak, C. (2023). *Hidrologi dan pengelolaan daerah aliran sungai* (revisi). Gadjah Mada University Press.

Bambang Triatmojo. (2010). *Hidrologi Terapan* (Kedua). Beta Offset.

Dewi Ayu Sofia, & Nursila, N. (2019). Analisis Intensitas, Durasi, dan Frekuensi Kejadian Hujan di Wilayah Sukabumi. *JTERA (Jurnal Teknologi Rekayasa)*, *4*(1), 85. https://doi.org/10.31544/jtera.v4.i1.2019.85-92

Fauziyah, S., Sobriyah, & Susilowati. (2013). AnalisisKarakteristik dan Intensitas Hujan Kota Surakarta. *e-Journal Matriks Teknik Sipil*, 82–89.

Febriani, L. A., Wardhani, E., & Halomoan, N. (2019). Analisa Hidrologi Untuk Penentuan Metode Intensitas Hujan Di Wilayah Aerocity X. *Publikasi Riset Orientasi Teknik Sipil (Proteksi)*, *1*(2), 63–70. https://doi.org/10.26740/proteksi.v1n2.p63-70

Hariati, F., Saputra, D., Alimuddin, A., & Yanuarsyah, I. (2022). Dampak Peningkatan Intensitas Hujan dan Tutupan Lahan Terhadap Debit Banjir Puncak Sungai Ciseel. *Jurnal Komposit*, *4*(1), 13–18. https://doi.org/10.32832/komposit.v4i1.3748

Nizar Achmad, Titiek Widyasari, & Mochammad Syaifullah. (2021). Analisis Hujan Wilayah Dengan Metode Poligon Thiessen dan Isohiet di Kabupaten Bantul Menggunakan Software QGIS dan MS Access. *Jurnal Rancang Bangun Teknik Sipil*, *7*(1).

Prayuda, D. D. (2015). Analisis Karakterikstik Intensitas Hujan di Wilayah Lereng Gunung Merapi. *JURNAL REKAYASA INFRASTRUKTUR*, *1*(1), 43.

Sukman, Fatur Rahman Rustan, Yusman, Herman Welem Tanje, Ahmad Syarif Sukri, Muh. Karnoha Amir, Syajruddin, Meny Sriwati, & Ranno Marlany Rachman. (2024). *Hidrologi*. CV. Tohar Media.

Suroso. (2006). Analisis Intensity-Duration-Frequency Kejadian Hujan di Kabupaten Banjarnegara. *Dinamika Rekayasa*, *2*(1), 1–7.

Susilowati & Dyah Indriana Kusumastuti. (2010). Analisa Karakteristik Curah Hujan dan Kurva Intensitas Intensitas Frekuensi (IDF) di Propinsi Lampung. *Jurnal Rekayasa*, *14*(1), 47–56.

Widyasari, T., & Achmad, N. (2023). Kurva Intensitas Durasi Frekuensi Hujan Kabupaten Bantul Dengan Menggunakan Metode Mononobe. *Jurnal Teknik Sipil*, *12*(2).

Yohanes I Nyoman Martin Hendriyantha, Ida Bagus Suryatmaja, & Krisna Kurniari. (2023). Analisis Intensitas Hujan Di Banjar Tuka Dalung Kuta Utara. *JURNAL ILMIAH TEKNIK UNMAS*, *3*(1).