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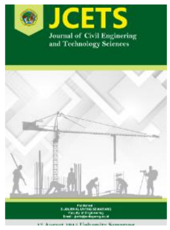

Hydrological Analysis of Water Treatment Plan (WTP) in Karian Dam Upstream

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Abstract

Rainfall or discharge data is obtained from the river basin authority by conducting hydrological analysis using the Nakayashu Synthetic Unit Hydrograph method to obtain the peak flood discharge and performing a dependable flow analysis (Q80%) using probability equations. On January 2, 2020 there was a flash flood that destroyed at least 1,410 houses, 30 bridges and hydraulic buildings located in the ciberang river flow among them is the PDAM row water intake structure. The need for hydrological studies to predict flood discharge as data needed in planning the stability of hydraulic building structures and determining the water surface elevation for intake operations. The results of the hydrological study of the Ciberang watershed obtained the design flood discharge values for specific return period of Q2 = 205,1 m3/s, Q5 = 340,5 m3/s, Q10 = 406,4 m3/s, Q25 = 475,6 m3/s, Q50 = 518,1 m3/s, Q100 = 549,6 m3/s. The estimated historical flash flood discharge that occurred in early 2020 in the ciberang river upstream of the Karian reservoir based on the testimony of residents as high as 8 meters is equivalent to the design discharge for Q25, which is 475.6 m³/s. The results of the dependable discharge (Q80%) calculations for the Ciberang watershed indicate that the minimum discharge occurs in September at 7.22 m³/s, while the maximum discharge occurs in February at 37.0 m³/s.

Keywords: Hidrolog; Rainfall Plan; Flood Discharge Plan; Dependable Discharge.

1 Introduction

The flow rate in a river depends on the intensity of rainfall in the surrounding area as well as that generated from the upstream regions of the river. The factors that determine the water table level in a River Basin (DAS) include rainfall, topography, land slope, soil type, infiltration, land use, vegetation, land cover, river channel capacity, hydrogeological conditions, climate change, drainage systems, water management, and others. Rainfall or discharge data is obtained through the river management agency by conducting hydrological analysis using the Nakayasu Synthetic Unit Hydrograph method to determine peak flood discharge [1], [2], [5], [7], [10], [13], [14], [16]. The existing condition of the SPAM IKK Cipanas has a drinking water treatment system with a raw water source from the Ciberang River. The system uses a free intake type without a sluice gate, with intake channels and wells but without soil retaining wall (SRW) structures. On January 2, 2020, a flash flood occurred, destroying at least 1,410 homes, 30 bridges, and several sections of roads that collapsed. The

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intake structure located in the upstream Ciberang River near the Karian Reservoir was also swept away by the river's current as a result of the incident. The need for a hydrology study to predict flood discharge as essential data for planning the stability of hydraulic structures along the Ciberang River's flow and for the design of intake service facilities. This study will analyze the design flood discharges for return periods of 2, 5, 10, 25, 50, and 100 years and will consider the flash flood discharge that occurred at the beginning of 2020 in the upstream Ciberang River near the Karian Reservoir. Based on the analysis of these design discharges and reliable discharges aims to determine the lowest water level in the river.

2 Literature Review

A study on the design discharge for natural rivers involves hydrological analysis steps, including rainfall data calculation, the computation of synthetic unit hydrographs using the Nakayasu method, and determining the reliable discharge (Q80%) using the Weibull method.

The rainfall intensity [1], [2], [5], [7], [10], [13], [14], [16] can be expressed using the Mononobe equation as follows:

$$I = \frac{R_{24}}{24}\left(\frac{24}{t}\right)^{2/3} \quad (1)$$

Where I is the rainfall intensity (mm/hour), t is the time (hours), and R24 is the designed 24-hour rainfall depth (mm).

[1], [2], [5], [7], [10], [13], [14], [16] use the Nakayasu synthetic unit hydrograph for the calculation of design flood discharge with the following formula:

$$Qp = \frac{A.Ro}{3{,}6(0{,}3T_P+T_{0,3})} \quad (2)$$

Where Qp is the peak flood discharge ($m^3/s/mm$), A is the watershed area up to the outlet (km^2), Ro is the unit rainfall (mm), Tp is the time lag from the start of rainfall to the peak of the unit hydrograph (hours), and T0.3 is the time required for the discharge to decrease from the peak discharge to 30% of the unit hydrograph's peak discharge (hours), as illustrated in the figure below:

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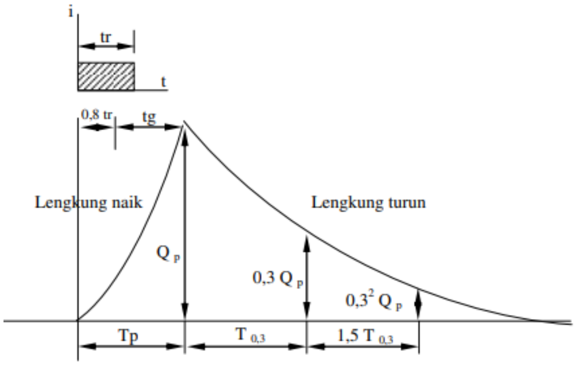

Figure 1. Nakayasu Synthetic Unit Hydrograph

[3], [4], [6], [8], [9], [11], [12], [15] use the Weibull method for the calculation of the reliable discharge (Q80%) with the following formula:

$$P = \frac{m}{(n+1)} \times 100\% \tag{3}$$

Where P is the probability (m³/s), n is the total number of data, and m is the rank or order of the data, starting from 1 up to the total number of data (n), with monthly discharge data arranged from the largest value to the smallest value.

3 Research Method

The research process involves collecting secondary data, including eleven years of rainfall data. The analysis begins with testing the consistency of the rainfall data, followed by regional rainfall analysis using the Thiessen Polygon method, probability distribution analysis, design rainfall analysis, and Intensity-Duration-Frequency (IDF) analysis. Additionally, the Synthetic Unit Hydrograph (HSS) analysis is conducted. For raw water supply needs, the reliable discharge (Q80%) is utilized, based on sufficient discharge data collected over the 11-year study period. Monthly discharge data is arranged in descending order from the largest value to the smallest. The Weibull method is applied to calculate the Q80%. If no data reaches the 80% threshold, interpolation is performed to estimate the reliable discharge value.

4 Research Data

The data used in this study consists of rainfall data from 2013 to 2023, obtained from O&P I of the Cidanau – Ciujung – Cidurian River Basin Agency.

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Table 1. Recapitulation of Maximum Rainfall at Rainfall Stations

Years	Maximum Rainfall (mm)				
	Sta. Pasir Ona	Sta. Cimarga	Sta. Ciminyak/ Cilaki	Sta. Banjar Irigasi	Curah Hujan (mm)
2013	142,00	82,00	131,00	77,00	47,34
2014	82,00	115,00	84,00	60,00	36,89
2015	48,00	82,00	104,00	30,00	18,45
2016	149,00	98,00	100,00	115,00	70,71
2017	107,00	88,00	96,00	103,00	63,33
2018	102,00	93,00	97,00	178,00	109,44
2019	58,00	107,00	63,00	186,00	114,36
2020	75,00	83,00	172,00	150,00	92,23
2021	193,00	152,00	108,00	144,00	88,54
2022	92,00	111,50	173,00	146,00	89,77
2023	70,00	76,00	86,00	107,00	65,79
Average					**72,44**

Table 2. Recapitulation of Ciberang River Discharge Data

NO	YEARS	MOUNTH											
		JAN	FEB	MAR	APR	MEI	JUN	JUL	AGT	SEP	OKT	NOV	DEC
1	2013	232,22	36,97	144,10	36,26	21,53	24,72	32,35	40,59	34,47	26,63	26,84	46,62
2	2014	179,78	85,47	25,62	23,05	22,76	20,97	29,23	39,65	14,41	21,43	25,32	22,67
3	2015	114,43	57,03	27,67	40,37	34,00	34,00	0,89	16,41	5,23	20,49	16,92	56,91
4	2016	27,86	37,21	31,82	68,82	54,50	19,50	21,33	24,78	17,68	18,74	63,24	10,93
5	2017	109,21	166,27	22,67	45,85	40,96	26,13	24,33	11,90	99,95	52,41	61,19	106,30
6	2018	54,10	46,57	25,36	30,89	59,72	18,94	13,98	5,56	16,27	17,30	22,07	56,47
7	2019	52,72	51,47	20,53	43,97	60,31	17,54	13,81	12,32	10,20	11,90	8,92	16,51
8	2020	78,68	44,08	33,74	23,45	61,32	39,79	16,51	28,03	19,80	21,65	24,32	117,59
9	2021	37,41	56,45	19,73	27,46	37,66	49,72	14,65	43,44	54,71	67,52	45,28	41,11
10	2022	13,83	33,31	30,71	17,59	26,24	41,49	38,73	32,69	38,10	35,79	15,46	57,09
11	2023	68,76	57,39	61,29	54,07	24,84	17,23	15,93	13,19	4,59	-	-	0,51

5 Research Data

The stations used for rainfall data collection are the Banjar Irigasi Rainfall Station, Cimarga Rainfall Station, Ciminyak/Cilaki Rainfall Station, and Pasir Ona Rainfall Station, with the highest coefficient recorded at the Banjar Irrigation Rainfall Station. The data obtained consists of daily rainfall records over eleven years. From this daily data, the maximum daily rainfall for each month is selected. After obtaining the monthly maximum rainfall for each month, the highest value among the twelve months is chosen as the annual rainfall (see Table 1). Subsequently, this daily rainfall data will be

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processed into design rainfall data (see Table 3), which will then be used to calculate the design flood discharge.

Table 3. Design Rainfall of Cipanas

No	Kala Ulang Tr (th)	Hujan Rancangan (mm)
1	2	68,31
2	5	103,48
3	10	126,77
4	25	156,19
5	50	178,025
6	100	199,69

Rainfall intensity is the amount of rainfall that occurs over a specific period during which the water is concentrated. It is denoted by the letter I and is measured in units of mm/hour. In the design flood calculation, input in the form of design rainfall distributed into hourly rainfall (hyetograph) is required. To convert design rainfall into hourly rainfall, the hourly rainfall distribution pattern must first be determined. This distribution pattern can be obtained by observing significant rainfall events. By averaging the observed rainfall distribution pattern, an average distribution pattern is derived, which is then assumed to represent the design rainfall conditions as hourly rainfall values.

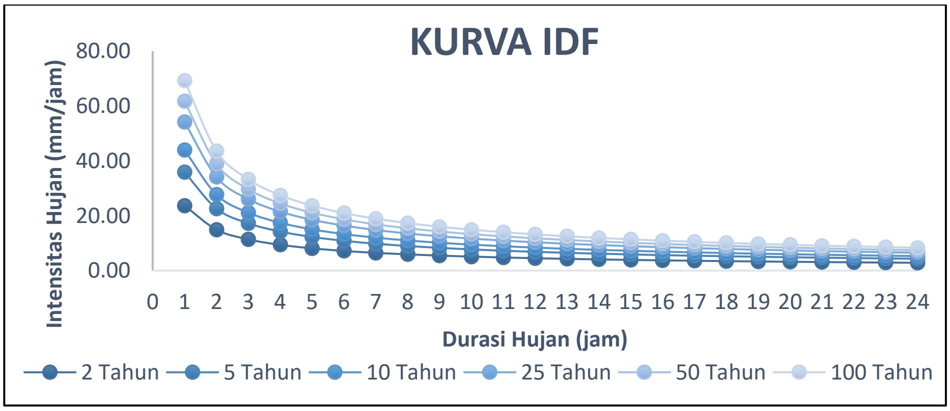

Figure 2. Hourly Hyetograph of Design Rainfall

To compare the design flood discharge obtained from discharge data analysis with that derived from rainfall data analysis, an empirical calculation is necessary. The analysis of design flood discharge is carried out using appropriate methods, depending on data availability and their suitability for the

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study area, while ensuring that the resulting flood hydrograph aligns with field conditions (providing reasonable and acceptable hydraulic results). The method used in this study is the Nakayasu Synthetic Unit Hydrograph method.

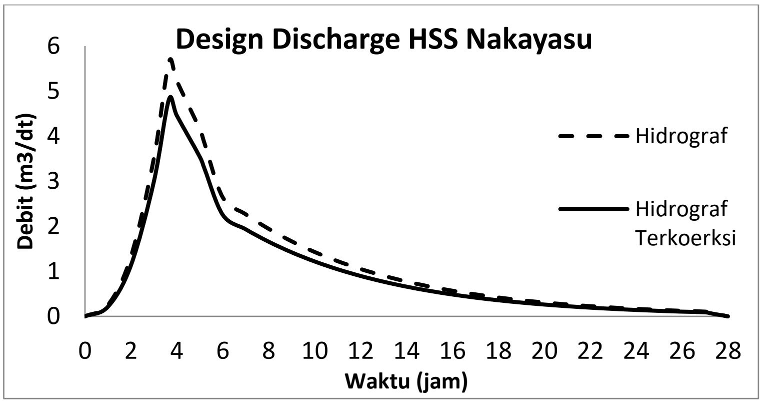

Figure 3. HSS Nakayashu

With the same design rainfall and hourly rainfall intensity (see Figure 3), the resulting flood hydrograph for the Ciberang PDA DTH is obtained as shown in the figure below (see Figure 4).

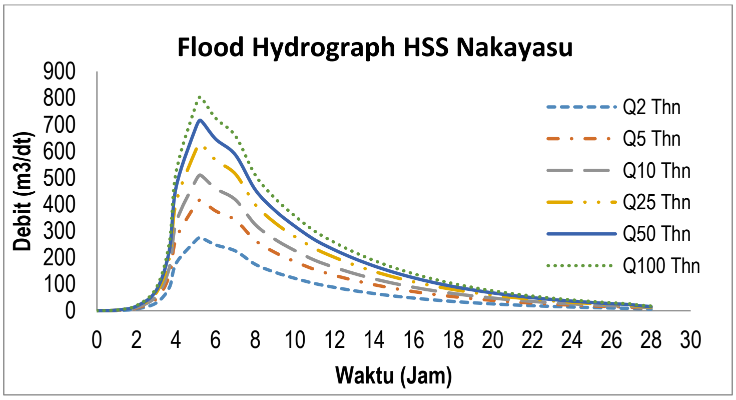

Figure 4. Nakayasu Method Flood Hydrograph

A comparison can be made between the Nakayasu Synthetic Unit Hydrograph (HSS) calculations using rainfall data and the calculations using flood discharge data, as shown in the table below (see Table 4).

Table 4. Recapitulation of Design Discharge

No	Kala Ulang Tr (th)	Hujan Rancangan (mm)	Debit Rancangan (m3/det)
1	2	68,31	205,1
2	5	103,48	340,5

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3	10	126,77	406,4
4	**25**	**156,19**	**475,6**
5	50	178,025	518,1
6	100	199,69	549,6

It can be concluded that the design flood discharge analysis using the Nakayasu Synthetic Unit Hydrograph method closely approximates and is acceptable compared to the design flood discharge obtained from actual flood discharge data. Furthermore, to determine the lowest water level in the Ciberang River, the dependable discharge (Q80%) is analyzed using the Weibull method.

Table 5. Interpolation of Q80%

Bulan	Discharge (m3/sec)
Januari	31,68
Februari	37,07
Maret	21,39
April	23,21
Mei	23,59
Juni	18,10
Juli	13,88
Agustus	12,07
September	7,22
Oktober	14,06
November	11,54
Desember	13,16

By interpolating the reliable discharge Q80% (see Table 5), the resulting graph is created as shown in the figure below (see Figure 5).

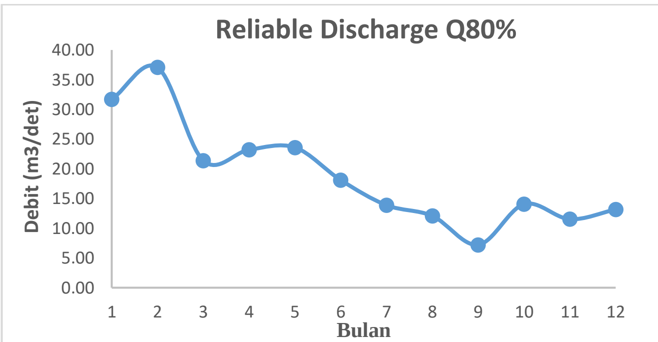

Figure 5. Grafik Reliable Discharge (Q80%)

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From the graph shown above, it can be concluded that the minimum reliable discharge occurs in September at 7.22 m³/s, while the maximum reliable discharge occurs in February at 37.07 m³/s. The predicted discharge during the flash flood event at the beginning of 2020, based on the existing hydraulic cross-section of the Ciberang River, is as follows:

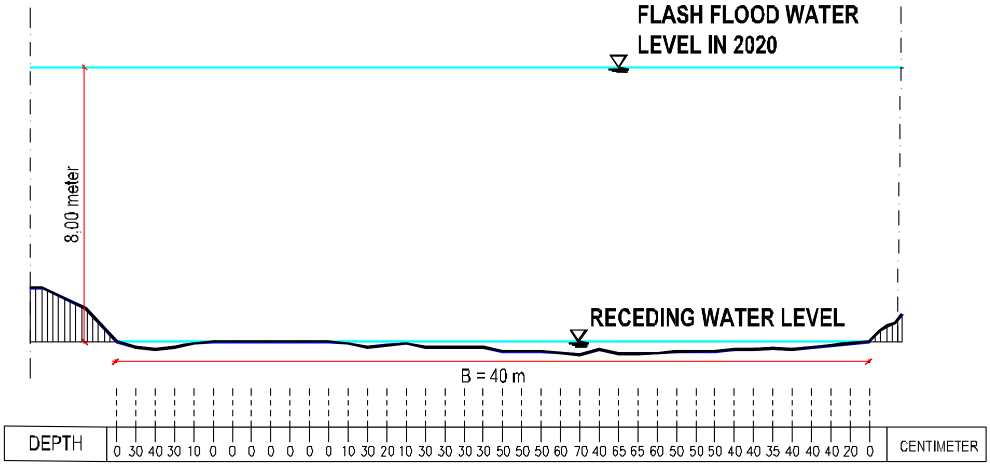

Figure 6. Sketch of the Ciberang River Flash Flood in 2020

The results of the hydrological analysis of the Ciberang River flash flood history, using a flood height parameter of 8 meters obtained from interviews with residents living near the Ciberang River, are as follows:

Measured River Width (B)	: 40 meter
Flood Water Level (h)	: 8 meter
Receding Water Level (h)	: 0,5 meter
Cros-sectional Area (A)	: 320 m^2
Flow Vecolity (V)	: 1,3664 m/s
Flood Discharge History (Q)	: 475,6 m^3/s (Equevalent to Q_{25})

6 Conclusion

The results of the design flood discharge calculation using the Nakayasu method are acceptable for the design flood discharge. The design flood discharges are as follows: Q2 = 205.1 m³/s, Q5 = 340.5 m³/s, Q10 = 406.4 m³/s, Q25 = 475.6 m³/s, Q50 = 518.1 m³/s, and Q100 = 549.6 m³/s. The estimated discharge of the flash flood that occurred at the beginning of 2020 in the Ciberang River upstream of the Karian Reservoir, based on witness testimony indicating a flood height of 8 meters, is equivalent to the design flood discharge Q25, which is 475.6 m³/s. The results of the reliable discharge analysis for

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the Ciberang watershed indicate that the minimum reliable discharge occurred in September, at 7.22 m^3/s, while the maximum reliable discharge occurred in February at 37.0 m^3/s.

7 Reference

[1] Andayani, R., & Umari, Z. F. (2022). *DEBIT BANJIR RANCANGAN DAS SELABUNG DENGAN HSS NAKAYASU* (Vol. 7, Issue 1).

[2] Ari Wulandari, D. (2022). *PREDIKSI UMUR WADUK GUNUNGROWO SETELAH PENGERUKAN*.

[3] Arrazy, M., Liany, S., Hendratta, A., Halim, F., Teknik, F., Sipil, J., Sam, U., & Manado, R. (2018). ANALISIS ANGKUTAN SEDIMEN DI SUNGAI AIR KOLONGAN KABUPATEN MINAHASA UTARA. Jurnal Sipil Statik, 6(12), 1043–1054.

[4] Basri, H., Nilai, R., Ketersesiaan, E., Air, H., Daerah, S., & Sungai, A. (2012). NILAI EKONOMI KETERSEDIAAN HASIL AIR DARI SUB DAERAH ALIRAN SUNGAI (DAS) KRUENG JREU KABUPATEN ACEH BESAR.

[5] Dewi, R., Limantara, L. M., & Soetopo, W. (2016). *ANALISIS PARAMETER ALFA HIDROGRAF SATUAN SINTETIK NAKAYASU DI SUB DAS LESTI*.

[6] Destiany, A., Fauzi, M., & Handayani, Y. L. (2019). ANALISIS DEBIT ANDALAN SUNGAI BATANG LUBUH POS DUGA AIR PASIR PENGARAIAN. In Jurnal Teknik (Vol. 13).

[7] Fu, H., Shan, Y., Yang, K., Guo, Y., & Liu, C. (2024). Stage–discharge relationship in an erodible compound channel with overbank floods. *Journal of Hydrology*, *635*. https://doi.org/10.1016/j.jhydrol.2024.131181

[8] Indra, Z., Jasin, M. I., Binilang, A., & Mamoto, J. D. (2012). ANALISIS DEBIT SUNGAI MUNTE DENGAN METODE MOCK DAN METODE NRECA UNTUK KEBUTUHAN PEMBANGKIT LISTRIK TENAGA AIR. In Jurnal Sipil Statik (Vol. 1, Issue 1).

[9] Kementerian PUPR, Modul Alokasi Air, Jakrta, 2014

[10] Krisnayanti, D. S. (2020). *PERBANDINGAN DEBIT BANJIR RANCANGAN DENGAN METODE HSS NAKAYASU, GAMA I DAN LIMANTARA PADA DAS RAKNAMO*. https://www.researchgate.net/publication/348580501

[11] Osly, P. J., Ihsani, I., Ririhena, R. E., & Araswati, F. D. (2018). ANALISIS KEBUTUHAN DAN KETERSEDIAAN AIR KABUPATEN MANOKWARI DENGAN MODEL MOCK (Analysis of water demand and supply in Kabupaten Manokwari with Mock Model). In J.Infras (Vol. 5, Issue 2).

[12] Sejati, W., & Akbar, T. T. (2023). Optimization Study of Cropping Pattern in the Klakah Irrigation Area, Lumajang Regency, Using Linear Programming. ADI Journal on Recent Innovation (AJRI), 5(2), 136–145. https://doi.org/10.34306/ajri.v5i2.999

[13] Sudrajad, I., Sutopo, Y., Sutarto, D. A., & Sipil, J. T. (2020). *Pengaruh Pemilihan Kala Ulang Debit Banjir Rancangan Metode HSS Nakayasu Terhadap Dimensi Sand Pocket di Gunung Merapi*. *5*(1), 80–89. https://jurnal.unitri.ac.id/index.php/rekabuana

[14] Sutapa, W. (2005). *KAJIAN HIDROGRAF SATUAN SINTETIK NAKAYASU UNTUK PERHITUNGAN DEBIT BANJIR RANCANGAN DI DAERAH ALIRAN SUNGAI KODINA*.

[15] Syafrudin Mopangga. (2019). ANALISIS NERACA AIR DAERAH ALIRAN SUNGAI BOLANGO. In Analisis Neraca Air Daerah Aliran Sungai Bolango (Vol. 7, Issue 2).

[16] Trilita, M. N., Suryandari, W., & Handajani, N. (2020). Study of Hidrology Nunukan Raw Water Retention Basin in North Kalimantan. *Journal of Physics: Conference Series*, *1569*(4). https://doi.org/10.1088/1742-6596/1569/4/042045

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