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 <https://doi.org/10.55463/issn.1674-2974.50.7.9>

Surface Water Balance Based on the Water District Analysis in Lamong Watershed, East Java Province, Indonesia

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Received: April 8, 2023 / Revised: May 4, 2023 / Accepted: June 2, 2023 / Published: July 31, 2023

Abstract: The Kali Lamong Watershed is an area administratively located in Gresik, Lamongan, Mojokerto Regencies, and Surabaya City. The Kali Lamong is one of the water resources in these regions. Nowadays, the Kali Lamong is used for raw water, industry, and agriculture, so it has an essential value for society in this region. The average yearly rainfall in the Kali Lamong is 1,700 mm, however, the hydrology conditions in the Kali Lamong Watershed are critical. It is seen from the discharge condition in the rainy season that is moreover the river capacity, but in the dry season it experiences drought. This research intends to determine the solution to the problem with the Kali Lamong Watershed. There is a need for good understanding related to the condition of the Kali Lamong about water availability that is used for the ecosystem demand in this watershed. Therefore, this study aims to conduct the water balance analysis in the Kali Lamong Watershed depending on the water district. The methodology is based on water availability analysis in each water district and water demand analysis for domestic, agricultural, and industrial sectors. The water availability analysis is carried out through two approaches 1) based on the estimation of the discharge data record in one of the water recorders, and 2) using rainfall-runoff modeling. The water balance analysis result in each water district revealed a water deficit in the Lamong Hulu and Kalitemu water districts, where there are only two months periods of water surplus.

Keywords: watershed, water balance, water district, Kali Lamong.

基于印度尼西亚东爪哇省拉蒙流域水区分析的地表水平衡

摘要：卡利拉蒙流域是一个行政区域，位于格雷西克、拉蒙甘、莫佐克托县和泗水市。卡利拉蒙河是这些地区的水资源之一。如今，卡利拉蒙河被用于原水、工业和农业，因此对该地区的社会具有重要价值。卡利拉蒙流域年平均降雨量为 1700 毫米，但卡利拉蒙流域的水文条件十分严峻。从雨季的流量情况看，也是河流的容量，但在旱季却遭遇干旱。这项研究旨在确定卡利拉蒙流域问题的解决方案。需要充分了解卡利拉蒙河的状况以及用于满足该流域生态系统需求的水的可用性。因此，本研究旨在根据水区对卡利拉蒙流域进行水平衡分析。该方法基于每个水区的

水资源可用性分析以及家庭、农业和工业部门的用水需求分析。水可用性分析通过两种方法进行：1) 基于对其中一台水记录器中的流量数据记录的估计，2) 使用降雨径流模型。各水区水平衡分析结果显示，拉蒙乌鲁水区和卡里特木水区出现缺水，仅有两个月的水盈余期。

关键词：分水岭，水平衡，水区、卡利拉蒙。

1. Introduction

Water resources are basic and essential for all life forms that have provided benefits for humans and their socioeconomic status during the centuries [1]. In the last few decades, the scarcity of water resources has become a factor that seriously affects socio-economic development [2]. Some areas in the world face moderate to heavy water crises due to population growth, industrialization, food production practices, increasing life standards, and strategies for managing bad water according to the United Nations Environment Program of 2011. More than 25% of the world population lives in arid or semi-arid areas where water deficit is a critic and chronic problem that needs a solution [3].

In Indonesia, the water resources condition is quantitatively enough, but they are not evenly distributed, so it causes the water deficit in some specific places, especially Java Island [4]. Water resources are necessary for life, but they are also the strategic resource that determines the national plan and development [5]. In the last few years, there has been a large contradiction between the demand and supply of water resources that causes the water deficits. Besides that, with rapid economic and population growth, water deficits become more and more serious, mainly in dry and semi-dry areas [6]-[8]. In addition, the waste of water resources has exacerbated the crisis of water deficit. For example, approximately 90% of fresh water resources have been used for agricultural irrigation in the northwest of China, which is marked by low rainfall and high evapotranspiration, however, the coefficient of irrigation water usage is approximately on average 0.5 [9].

The Kali Lamong Watershed is an area that is administratively located in Gresik, Lamongan, Mojokerto Regencies, and Surabaya City. The area of the Kali Lamong watershed is about 720 km², with a river length is $\pm$ 103 km, and the average width downstream is 40 m. The watershed has an estuary in the Madura Strait. Kali

Lamong is a water resource for the region to fulfill the ecosystem needs of the region. Nowadays, the Kali Lamong is used for raw water, industry, and agriculture, so it has a critical value for the community in this region. The average yearly rainfall in Kali Lamong is 1,700 mm, however, the hydrology conditions in the Kali Lamong. Like the rivers in Java Island in general, the hydrology condition of the Kali Lamong Watershed is in a critical condition. It is seen from the discharge condition in the rainy season that reaches 700 m³/s, which is far beyond the river capacity of about 250 m³/s. However, in the dry season, drought occurs when the base flow is zero. Due to the hydrological conditions, most of the Kali Lamong Watershed located in Gresik Regency and Surabaya City experience flooding every year as the reason for Kali Lamong overflow. However, in the dry season, this region experiences a fresh water deficit for domestic (household), urban and industrial needs. However, upstream in the Lamongan Regency there is always a water deficit too in the dry season. In the scheme to know the solution of the problem that is happened in Kali Lamong Watershed, there is needed good understanding that is related with the condition of Kali Lamong about water availability that is used for the ecosystem demand in this watershed. Therefore, in this study is to be carried out the water balance analysis in the Kali Lamong Watershed will be carried out based on the water district.

2. Material and Method

The study location is in the Kali Lamong Watershed, and the management is under the Big Institution of Sungai Bengawan Solo Region. The Kali Lamong Watershed includes the administrative areas of Lamongan Regency, Mojokerto Regency, Gresik Regency, and Surabaya City. However, the study location is presented in Figure 1.

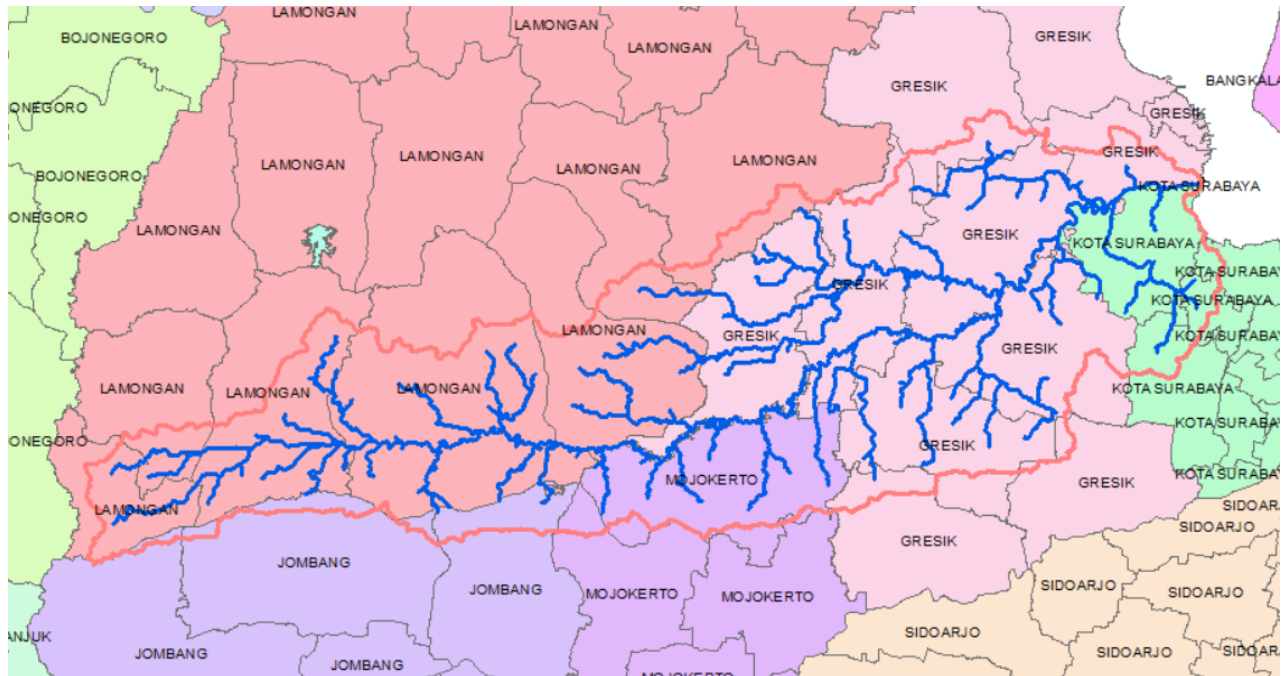


Fig. 1 Kali Lamong watershed location (Own study)

2.1. Data

Data that are used in this study are discharge data obtained from water recorded stations in Kali Lamong - Boboh from 1976 until 2005 due to the half-monthly period. Besides that, the daily rainfall used is from 1980 until 2011 for 6 rainfall stations that are Bluduk, Ngimbang, Bolangpanjang, Bejeng, and Cerme. Besides the rainfall data, the climatology pos in Surabaya was also used from 2006 until 2017.

2.2. Method

The method used for analyzing water balance based on the water district in the Kali Lamong Watershed is by analyzing the secondary data obtained from the related institution. These data are analyzed using the standard method following the flow chart presented in Figure 2.

2.3. The Analysis of Water Availability

The analysis of water availability is principally referred to as the dependable discharge, which is the minimum surface or river discharge due to the certain value that may be reached, so it can be used for few interests [10]-[11]. For the raw water needs, the dependable discharge is determined to be 90%; however, irrigation is 80% [12]. In this research, dependable discharge will be carried out using the two approaches described above. The final dependable discharge used is the average of the two obtained results.

2.3.1. Dependable Discharge Based on Discharge Data

Dependable discharge analysis is determined by data availability. To determine the water availability in an observed point, long enough discharge data is needed, for example, half monthly throughout the year. Then, the data are arranged from the maximum discharge to the minimum discharge, and the arrangement can be expressed in the mass curve form or in the table form.

2.4. RKI Water Need

Water need is water that is needed or used by humans for supporting their life and consists of domestic and non-domestic water needs, irrigation, fishery, husbandry, drainage, and river maintenance.

2.4.1. Domestic Water Need

The projection of the population number in a region for a certain year can be carried out if there is known the level of population growth. In addition, population growth is also dependent on the Spatial Regulation Plan and regency or city area that occurs in the area. In the city or village area that has been serviced by PDAM installation, the connecting speed becomes an important parameter for analyzing the projection of water needs in the future. It is related to the society's view of the water value and the service system of clean water availability.

Table 1 presents the standard domestic water use.

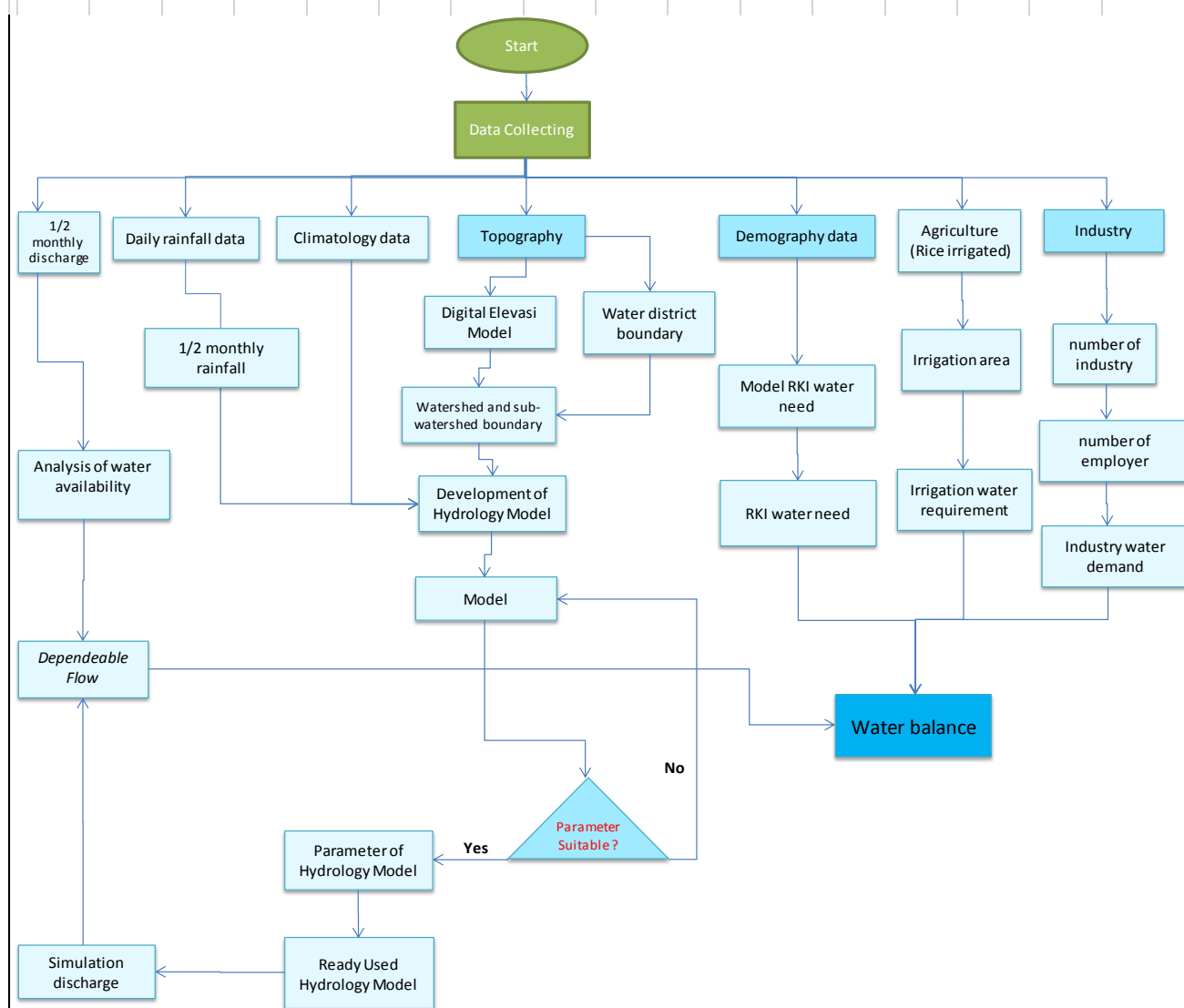


Fig. 2 Scheme of the research stages (Own study)

Table 1 Standard of domestic water use (Ditjen Cipta Karya, DPU, 2006, "Unit Pelayanan", Materi Pelatihan Penyegaran SDM Sektor Air Minum (Peningkatan Kemampuan Staf Profesional Penyelenggara SPAM))

No.	The category of the city	Population size (persons)	Clean water demand (l/person/day)
1	Semi-Urban (capital of district/ village)	3,000–20,000	60–90
2	Small city	20,000–100,000	90–110
3	Medium city	100,000–500,000	100–125
4	Big city	500,000–1,000.000	120–150
5	Metropolitan	> 1,000,000	150–200

2.4.2. Non-Domestic Water Need

Non-domestic water needs include industry water needs and commercial and institutional. Nowadays, the water need for industry can be determined based on production data and industry type. However, the need in the future is difficult enough to be determined. To simplify the analysis, the water need for industry is carried out based on the number of employers according to the equation as follows:

$$KAI = AP \times RL,$$

where:

KAI - industry water need, L/O/H;

AP - industry water needs per employer;

RL - number of employers.

2.5. Irrigated Rice Water Requirement

Irrigation water requirement is the volume of water that is needed for fulfilling the needs for evapotranspiration, water losses, and water needed for crops by attending the water volume that is given by nature through rainfall. The water requirement in the rice-irrigated area is determined by the following factors:

Consumptive use for crop (Etc.); water need for area preparation (IR); water need for water layer change (RW); percolation (P); effective rainfall (ER); efficiency of irrigation (IE); irrigation area (A); and applied cropping pattern

The analysis of irrigation water requirement is based on the Irrigation Design Criteria (KP-01). The beginning of cropping for irrigation water requirement is determined based on the data of the cropping pattern determined or in the beginning of the rainy season. The irrigation water requirement for agriculture is analyzed by multiplying the irrigated area and irrigation water requirement. The irrigation water requirement is analyzed using the equation as follows:

$$KAI = \frac{(Etc + IR + RW + P - ER)}{IE} \times A \quad (1)$$

The irrigation water requirement is analyzed in every water district, and the parameters of irrigation water requirement are analyzed alone for each water district.

3. Results and Discussion

3.1. Water District

To optimize the water resources, the Kali Lamong Watershed is divided into some water districts. In the report on the Management Plan of Water Resources in Sungai Bengawan Solo Region Stage-2, the Kali Lamong Watershed is divided into 6 water districts, as presented in Figure 3. The region in each water district can be seen in Table 2.

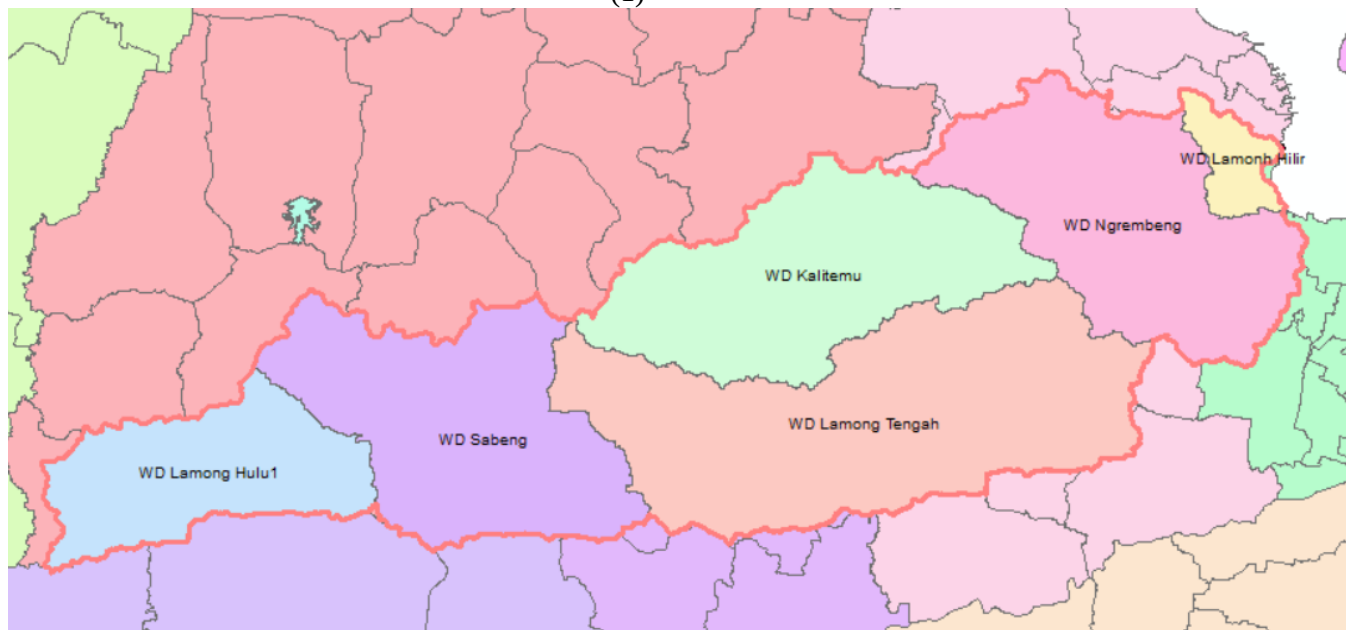


Fig. 3 Water district map of the Kali Lamong watershed (Own study)

Table 2 Water district in the Kali Lamong watershed (Own study)

No.	Service Area	District	Regency/City	District area in WD	District area	% District area
1	WD Lamong Hulu	Bluluk	Lamongan	11,614,533.2	59,983,181.2	19.36
		Ngimbang	Lamongan	43,219,383.7	94,276,687.9	45.84
		Sukorame	Lamongan	23,911,244.6	38,274,238.6	62.47
		Sambeng	Lamongan	6,433,545.9	152,986,723.4	4.21
2	WD Sabeng	Ngimbang	Lamongan	13586310.42	59,983,181.2	22.65
		Kemlagi	Mojokerto	4655783.713	58,844,327.7	7.91
		Mantup	Lamongan	4847725.378	91,743,756.3	5.28
		Sambeng	Lamongan	106553989.3	152,986,723.4	69.65
		Dawarblandong	Mojokerto	6190966.435	81,172,931.5	7.63
3	WD Lamong Tengah	Cerme	Gresik	5549368.244	71,652,903.7	7.74
		Menganti	Gresik	32985072.49	70,938,089.8	46.50
		Benjeng	Gresik	16464332.76	62,758,175.6	26.23
		Driyorejo	Gresik	2383725.819	54,552,185.5	4.37
		Kedamean	Gresik	57820813.89	67,069,775.8	86.21
		Kemlagi	Mojokerto	31056.88128	58,844,327.7	0.05
		Mantup	Lamongan	29970932.72	91,743,756.3	32.67
		Sambeng	Lamongan	334589.5916	152,986,723.4	0.22
		Balongpangpang	Gresik	13520717.12	64,849,176.3	20.85
		Jetis	Mojokerto	319709.6218	56,829,172.3	0.56

		Continuation of Table 2				
4	WD Kalitemu	Dawarblandong	Mojokerto	66054479.52	81,172,931.5	81.38
		Wringinanom	Gresik	8881456.745	62,261,270.3	14.26
		Cerme	Gresik	19110963.09	71,652,903.7	26.67
		Benjeng	Gresik	36886351.11	62,758,175.6	58.78
		Kedamean	Gresik	2484.946012	67,069,775.8	0.00
		Kembangbahu	Lamongan	13148349.17	68,450,164.6	19.21
		Mantup	Lamongan	22099028.21	91,743,756.3	24.09
		Tikung	Lamongan	11804660.75	104,365,663.7	11.31
5	WD Ngrembeng	Balongpangpang	Gresik	51328459.16	64,849,176.3	79.15
		Asemrowo	Kota Surabaya	2379952.116	16,097,061.6	14.79
		Cerme	Gresik	46703563.49	71,652,903.7	65.18
		Kebomas	Gresik	8634936.583	33,744,690.7	25.59
		Lakarsantri	Kota Surabaya	9460647.622	34,776,422.0	27.20
		Menganti	Gresik	27616503.86	70,938,089.8	38.93
		Tandes	Kota Surabaya	5622001.866	11,675,811.3	48.15
		Benowo	Kota Surabaya	32,648,875.97	43,631,088.8	74.83
		Benjeng	Gresik	5514221.167	62,758,175.6	8.79
		Duduksampeyan	Gresik	13274308.33	81,528,991.6	16.28
6	WD Lamong Hilir	Kebomas	Gresik	8640788.654	33,744,690.7	25.61
		Benowo	Kota Surabaya	10,296,171.15	43,631,088.8	23.60

3.2. The Analysis of Water Availability

Water availability in the understanding of water resources comes from rainfall, surface water, and groundwater. In this research, an analysis of water availability was carried out based on the surface water recorded in the Kali Lamong River. However, the analysis of water availability is carried out based on two approaches: 1) based on the record of discharge data and 2) based on the approach of the rainfall-run-off model. The final value of water availability used for further analysis was the average result of the two approaches.

In the first approach, the analysis of water availability is carried out based on the time series discharge data. The

available discharge data are in Kali Lamong-Boboh with an area of about 634 km². However, the available data are from 1976 to 2005. This discharge data is also generated until 2011 through the model approach after and before the model is calibrated, because the available rainfall data is until 2011, as presented in Table 3 and Figure 4. Then, the time series discharge data that is available at Boboh Station is used for analyzing the dependable discharge ($Q_{average}$, $Q_{50\%}$, $Q_{80\%}$, and $Q_{90\%}$) in each outlet of the water district based on the correction factor of the watershed area comparison for each water district, as presented in Table 4.

Table 3 Time series discharge data in the Kali Lamong-Boboh (Own study)

Year	half monthly average discharge (m ³ /s)																							
	Jan-1	Jan-2	Feb-1	Feb-2	Mar-1	Mar-2	Apr-1	Apr-2	May-1	May-2	Jun-1	Jun-2	Jul-1	Jul-2	Aug-1	Aug-2	Sep-1	Sep-2	Oct-1	Oct-2	Nov-1	Nov-2	Dec-1	Dec-2
1976	11.245	16.247	11.422	9.847	18.994	16.921	21.923	11.456	7.346	5.109	3.715	2.716	2.123	1.730	1.460	1.298	1.174	1.071	1.119	2.859	3.611	12.418	12.372	8.277
1977	9.459	12.281	24.638	14.922	13.188	61.079	25.380	16.983	10.133	7.089	5.306	4.344	2.811	2.207	1.779	1.512	1.318	1.190	1.091	1.001	2.187	2.691	13.976	18.661
1978	34.829	109.240	51.499	23.223	22.536	32.334	13.019	8.238	6.284	5.986	4.221	3.988	4.122	2.313	2.699	1.667	3.806	4.326	3.658	1.660	4.662	4.681	18.824	38.005
1979	82.321	120.832	52.131	24.404	24.486	36.913	13.351	8.396	6.391	6.104	4.322	4.080	4.176	2.351	2.727	1.687	3.821	4.396	3.564	1.732	1.126	3.335	2.613	3.727
1980	35.811	63.408	36.089	28.213	29.090	20.765	13.943	17.365	15.684	15.942	9.324	7.749	5.419	3.546	2.794	2.284	1.896	3.150	1.577	1.189	2.842	2.426	5.445	
1981	14.082	13.004	8.348	6.275	4.961	2.781	2.205	2.601	3.768	1.279	1.105	0.973	1.872	2.211	0.703	1.049	0.584	5.172	4.020	1.955	4.026	6.457	11.521	34.565
1982	38.871	30.184	55.287	45.051	50.998	32.810	26.489	20.540	10.484	6.426	4.260	2.949	2.140	1.652	1.437	1.306	1.197	1.107	1.026	0.950	0.879	0.815	0.970	6.358
1983	24.334	11.722	7.413	6.615	6.535	6.079	8.420	6.406	9.184	12.411	7.733	4.956	3.818	2.963	2.326	1.838	1.517	1.308	1.148	1.017	1.185	12.813	18.876	8.718
1984	47.554	37.573	34.803	29.599	17.402	12.676	8.532	5.903	5.816	3.099	2.133	1.638	3.810	2.313	1.184	1.060	1.219	1.962	2.586	2.085	0.888	1.358	3.862	2.270
1985	5.010	63.270	22.334	125.179	112.950	45.521	15.613	13.848	7.175	6.992	8.909	3.597	3.788	3.154	2.158	1.630	1.696	3.227	1.424	12.965	7.785	8.544	7.396	10.254
1986	20.190	26.858	32.231	27.713	22.454	48.181	39.738	27.252	13.901	8.857	7.196	7.064	3.120	3.345	2.747	1.640	1.393	2.274	1.130	2.024	4.977	22.356	12.345	9.320
1987	13.945	53.019	38.012	42.808	30.334	15.216	8.866	7.820	5.235	3.657	3.107	1.766	1.470	1.310	1.203	1.521	1.029	0.954	0.885	0.819	1.063	2.461	13.099	8.245
1988	30.867	38.025	24.327	17.786	16.053	27.781	32.727	3.020	8.173	8.112	2.147	3.987	1.400	0.981	1.252	1.281	1.321	1.371	1.131	2.115	1.388	5.547	14.827	12.800
1989	34.767	17.256	42.987	52.762	33.780	39.771	26.807	26.367	19.460	9.206	16.273	22.673	7.587	6.669	1.400	1.150	0.773	0.280	0.113	1.081	2.933	10.027	8.272	23.170
1990	37.850	32.911	43.952	23.253	26.327	40.581	14.773	22.373	7.247	19.113	13.720	15.567	17.933	4.631	3.200	3.475	3.227	3.067	2.927	2.800	3.200	5.300	28.520	70.444
1991	76.620	44.681	68.067	26.369	56.340	23.263	42.720	76.887	20.160	6.656	5.913	6.093	4.667	3.875	4.087	5.775	5.600	2.561	1.204	1.113	3.574	22.253	46.487	30.025
1992	40.900	52.438	91.247	51.979	71.453	50.925	38.547	23.280	8.980	21.619	12.140	7.380	7.280	6.813	7.600	8.344	17.433	5.440	6.140	6.750	1.420	4.344	27.804	26.411
1993	33.405	74.020	32.123	19.618	15.975	9.832	11.629	11.387	13.569	7.931	8.772	9.764	5.113	1.726	1.322	2.938	0.972	0.892	0.695	1.100	0.695	1.100	11.413	4.163
1994	21.413	48.219	28.327	55.015	71.327	47.769	21.473	9.540	2.280	1.050	1.013	2.203	2.153	1.710	1.438	1.317	1.210	1.119	1.038	0.960	1.107	3.018	12.696	4.000
1995	8.252	8.513	49.340	44.215	32.780	49.275	53.427	6.820	6.227	3.013	3.387	16.780	2.720	1.144	0.767	1.163	1.593	1.307	1.768	1.969	3.793	48.067	19.613	15.350
1996	7.220	16.338	68.187	35.707	53.927	16.650	10.347	9.447	1.153	1.713	0.860	1.127	1.900	2.863	2.487	2.294	1.887	0.933	0.733	1.944	15.467	28.693	62.040	17.419
1997	48.173	23.206	39.373	17.308	16.260	12.219	21.967	6.927	2.653	2.256	2.007	1.900	1.793	1.650	1.500	1.588	1.617	1.415	1.254	1.119	1.007	0.916	1.482	24.163
1998	9.347	12.544	35.460	52.292	48.420	40.731	20.500	24.640	16.773	19.006	5.047	4.853	11.420	7.169	4.120	4.468	3.482	10.984	10.297	27.619	42.647	39.807	21.596	64.036
1999	69.467	67.231	25.800	48.523	33.240	47.375	54.587	39.693	16.320	9.131	6.997	6.450	4.206	3.178	2.569	2.128	1.799	1.557	2.581	2.475	27.420	40.253	17.759	41.844
2000	41.473	60.575	52.747	15.114	28.327	44.944	60.293	16.307	21.620	20.598	16.802	17.573	16.879	6.722	5.036	3.882	3.064	2.475	2.487	24.291	27.046	33.613	14.271	13.778
2001	14.902	47.006	71.190	24.206	79.587	48.913	62.180	45.435	24.889	9.351	26.142	6.888	3.966	3.135	2.538	2.105	1.782	1.544	2.535	16.855	4.191	29.794	27.561	83.240
2002	85.117	93.115	95.236	90.917	117.244	41.626	51.811	28.252	11.994	7.810	5.801	4.463	3.513	2.811	2.303	1.930	1.650	1.441	1.276	1.137	1.111	1.703	4.286	2.008
2003	13.404	20.880	33.652	46.319	35.755	23.091	13.129	8.977	7.662	5.507	3.867	3.268	2.511	2.081	1.761	1.519	1.330	1.184	1.065	0.962	1.801	6.739	10.189	17.339
2004	16.883	18.444	21.525	27.108	99.978	45.725	5.407	2.173	1.567	4.250	2.080	1.490	3.762	2.511	1.902	1.629	1.419	1.258	1.127	1.015	1.837	3.636	2.680	9.744
2005	12.416	12.857	12.357	12.503	33.295	29.682	32.011	23.860	15.369	8.972	8.771	7.643	7.422	5.240	3.774	2.773	2.830	1.945	2.274	5.092	2.948	9.366	24.746	29.886
2006	27.233	4.672	42.840	35.208	7.012	27.011	28.819	16.320	24.801	16.259	6.013	4.930	4.043	3.315	2.719	2.229	1.828	1.499	1.008	0.826	0.678	0.362	55.858	
2007	4.865	35.660	42.120	60.478	20.630	16.496	19.715	14.358	6.453	5.291	4.339	3.558	2.977	2.392	1.962	1.609	1.319	1.082	0.887	0.727	1.755	0.573	11.021	23.806
2008	3.198	20.275	3.088	5.836	35.685	10.244	3.969	3.254	2.668	2.188	1.794	1.741	1.206	0.989	0.811	0.665	0.545	0.447	0.367	0.301	9.493	9.389	60.056	55.025
2009	27.142	35.186	31.165	86.177	64.769	22.970	12.253	33.262	12.446	17.890	7.515	6.162	5.053	4.143	3.397	2.786	2.284	1.873	1.536	1.260	1.033	25.201	2.459	5.758
2010	31.590	48.023	31.710	33.284	50.938	51.302	36.692	27.997	22.291	33.960	32.925	9.312	7.636	7.775	5.244	11.569	10.238	3.771	3.093	2.536	2.079	1.705	1.398	1.147
2011	24.474	38.760	37.599	28.114	50.932	72.550	48.118	15.674	38.704	10.509	8.617	7.066	5.794	4.751	3.896	3.195	2.620	2.148	1.761	1.444	13.217	5.908	14.175	9.799

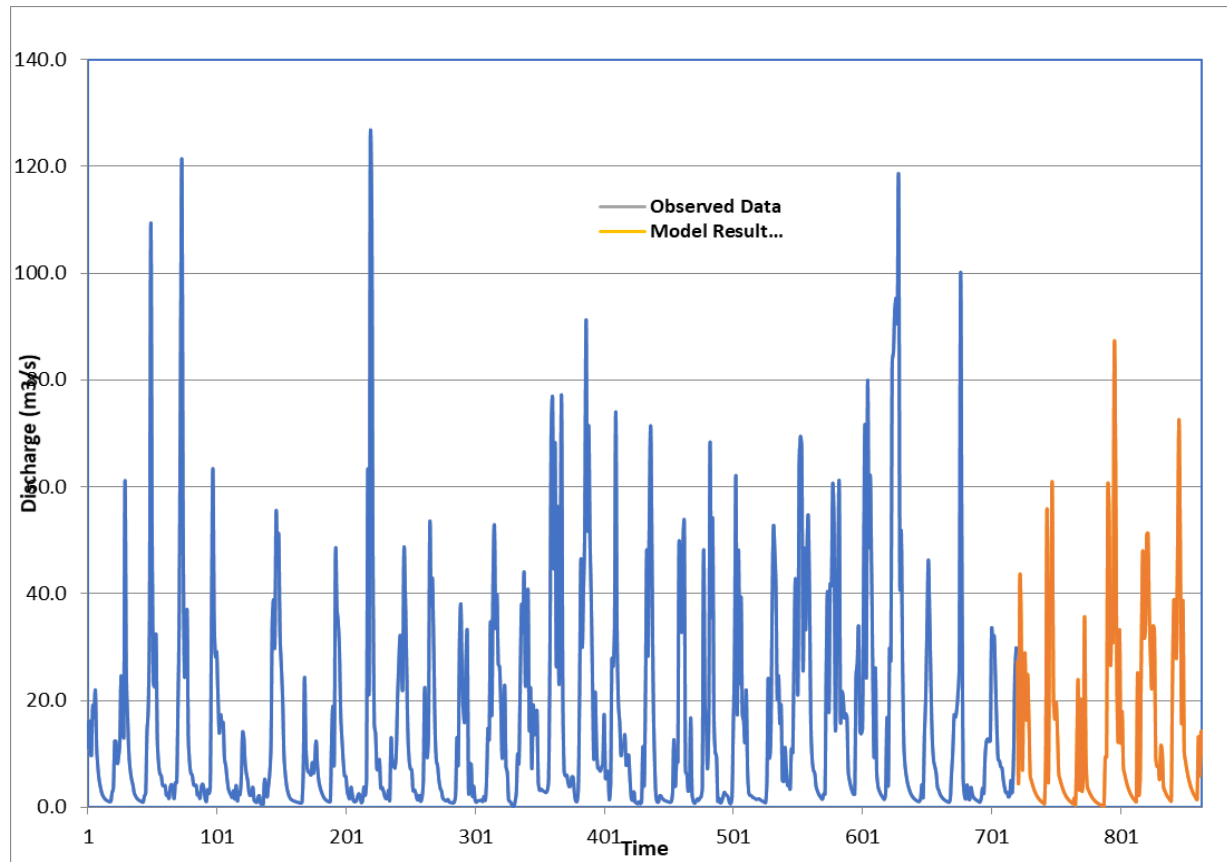


Fig. 4 Time series discharge curve in the Kali Lamong-Boboh (Own study)

Table 4 Correction factors for dependable discharge analysis in each service area (Own study)

No.	The name of the watershed	Area (km ²)	The correction factor (-)
1	WD Lamong Hulu	94.06	0.148
2	WD Sabeng	245.96	0.387
3	WD Lamong Tengah	480.28	0.756
4	WD Kalitemu	154.37	0.243
5	WD Ngrembeng	788.53	1.241
6	WD Lamong Hilir	805.53	1.268
7	Kali Lamong - Boboh	635.18	1.000

The second approach is applied on the basis of the discharge data that is produced from the rainfall-run-off model. The rainfall-run-off model used is the NRECA model. This model is carried out for calibration before being used. Calibration is carried out in the Boboh water recorded with the watershed area of about 635 km². However, the model calibration is used to obtain the model parameter, which is then used for the model usage in the other outlet locations in the Kali Lamong Watershed. The model calibration that receives attention is the value difference in the time series discharge that is produced and the flow duration curve, as presented in Figure 5.

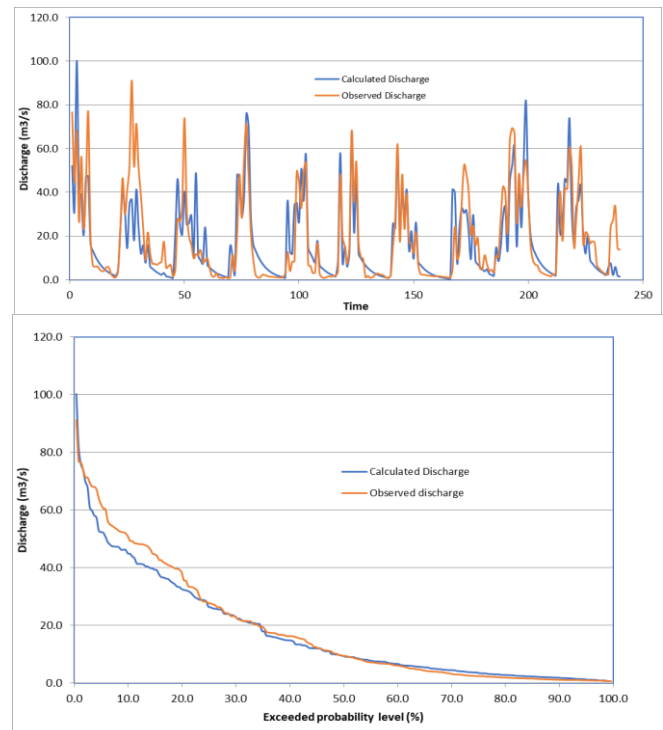


Fig. 5 Curve of flow discharge and flow duration curve (Own study)

After the model is calibrated, it is used to generate the discharge data from rainfall data in each water district. The rainfall data used for each water district are based on

the affected weight of rainfall stations in each water district, as presented in Table 5.

Table 5 Rainfall stations used in each service area outlet (Own study)

No.	The name of the watershed	The weight of the Rainfall Station					
		Cerme	Bluluk	Bejeng	Balongpangang	Ngimbang	Mantup
1	WD Lamong Hulu		0.749			0.251	
2	WD Sabeng		0.286			0.396	0.318
3	WD Lamong Tengah	0.074	0.147	0.054	0.254	0.203	0.269
4	WD Kalitemu	0.018		0.334	0.415		0.233
5	WD Ngrembeng	0.227	0.089	0.115	0.236	0.123	0.209
6	WD Lamong Hilir	0.243	0.087	0.113	0.231	0.121	0.205

For example, discharge as the generated result from 1980 until 2011 in one of the water districts (WD Lamong Hulu) can be seen in Figure 6. Based on the discharge data that is produced, then there is analyzed for obtaining the dependable discharge in WD Lamong Hulu. The result of dependable discharge in a water district area in WD Lamong Hulu is shown in Figure 7. From the figure, it can be seen that the water

available in WD Lamong Hulu is negligible from June until November or about 5 months. The immense discharge happened from February to March. By being obtained the information of dependable discharge in each water district, it can be used for managing the water usage in this area so there is not happened the water deficit.

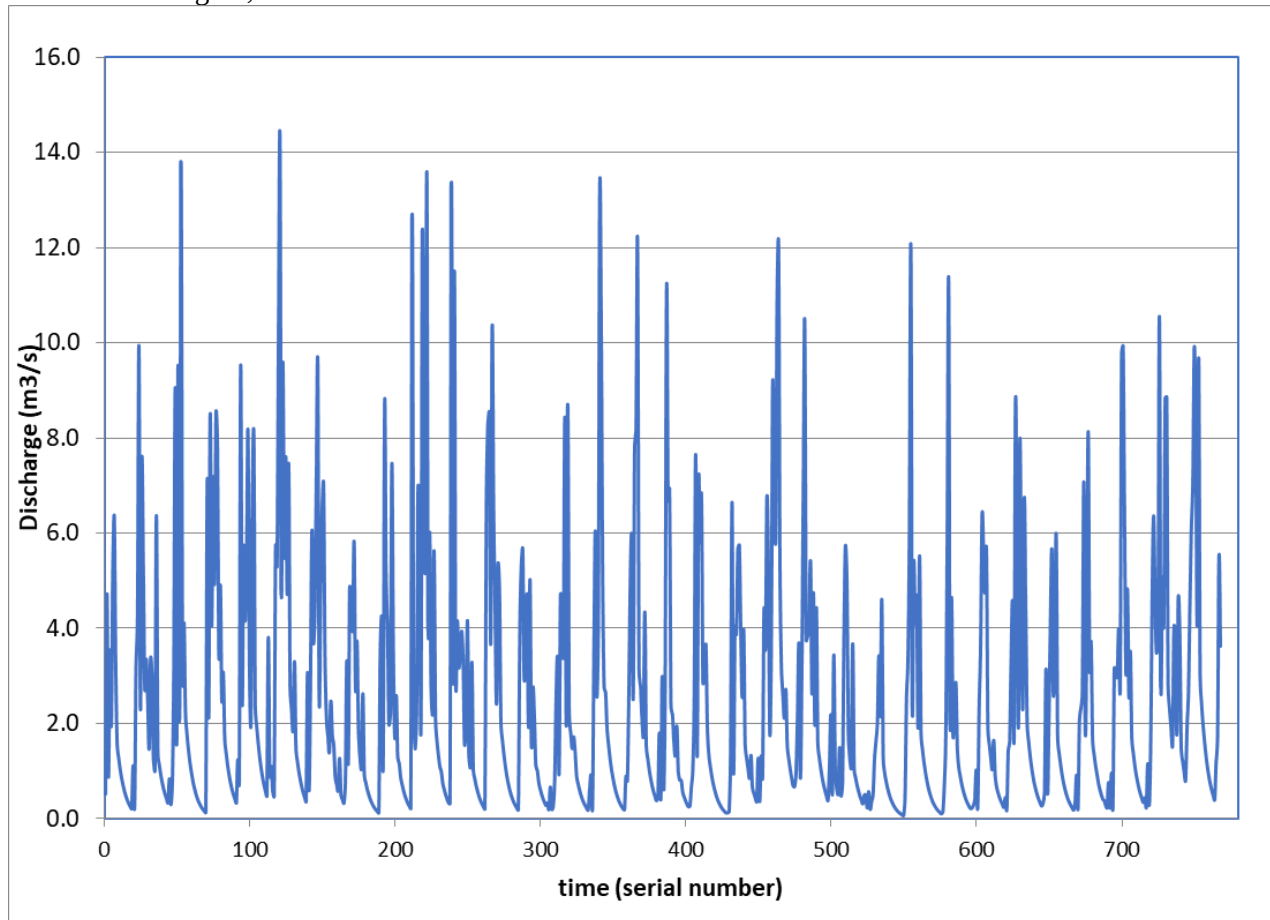


Fig. 6 Flow discharge curve as the model result in the WD Lamong Hulu (Own study)

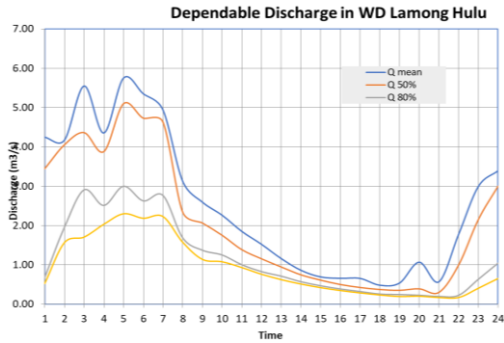


Fig. 7 Dependable discharge in the WD Lamong Hulu (Own study)

The two analysis approaches of water availability that are used above produced the information of dependable discharge in each water district in which the result is not significantly different. To determine the final value of dependable discharge in each water district, it is determined on the basis of the average of the two approaches results. However, the final value of dependable discharge in each water district is shown in Table 6.

Table 6 Final value of dependable discharge in each service area (Own study)

WD Lamong Hulu																								
Year	Half monthly average discharge (m ³ /s)																							
	Jan-1	Jan-2	Feb-1	Feb-2	Mar-1	Mar-2	Apr-1	Apr-2	May-1	May-2	Jun-1	Jun-2	Jul-1	Jul-2	Aug-1	Aug-2	Sep-1	Sep-2	Oct-1	Oct-2	Nov-1	Nov-2	Dec-1	Dec-2
Q mean	4.302	5.025	5.652	4.840	5.871	5.088	4.367	2.888	2.151	1.823	1.472	1.213	0.935	0.675	0.535	0.517	0.520	0.412	0.422	0.826	0.710	1.752	2.685	3.335
Q 50%	3.634	4.650	4.832	4.027	4.995	4.779	3.924	2.285	1.707	1.430	1.107	0.924	0.757	0.586	0.479	0.377	0.336	0.302	0.272	0.323	0.310	0.925	2.006	2.581
Q 80%	1.172	2.181	3.258	2.540	2.797	2.537	2.246	1.359	1.118	0.898	0.666	0.578	0.516	0.414	0.338	0.291	0.251	0.211	0.200	0.189	0.181	0.240	0.636	0.949
Q 90%	0.834	1.702	1.735	1.845	2.232	1.926	1.744	1.128	0.767	0.705	0.609	0.495	0.448	0.365	0.298	0.258	0.216	0.186	0.157	0.171	0.154	0.159	0.390	0.612
WD Sabang																								
Year	Half monthly average discharge (m ³ /s)																							
	Jan-1	Jan-2	Feb-1	Feb-2	Mar-1	Mar-2	Apr-1	Apr-2	May-1	May-2	Jun-1	Jun-2	Jul-1	Jul-2	Aug-1	Aug-2	Sep-1	Sep-2	Oct-1	Oct-2	Nov-1	Nov-2	Dec-1	Dec-2
Q mean	10.213	12.143	13.860	11.974	14.415	11.794	10.560	6.914	4.939	4.216	3.374	2.620	2.084	1.531	1.214	1.148	1.150	0.892	0.794	1.392	1.760	3.717	5.793	7.876
Q 50%	8.608	11.458	12.330	10.420	12.836	10.574	9.272	5.342	3.925	3.560	2.682	2.285	1.872	1.479	1.210	0.950	0.836	0.730	0.617	0.652	0.799	1.752	3.656	5.518
Q 80%	2.916	5.642	7.170	6.489	6.241	5.920	4.573	2.904	2.409	1.821	1.356	1.188	1.051	0.846	0.691	0.597	0.517	0.452	0.414	0.372	0.419	0.511	1.217	2.026
Q 90%	1.900	3.824	3.903	4.736	5.414	4.119	3.321	2.261	1.631	1.286	1.125	0.933	0.907	0.712	0.580	0.510	0.428	0.388	0.343	0.340	0.311	0.331	0.679	1.158
WD Lamong Tengah																								
Year	Half monthly average discharge (m ³ /s)																							
	Jan-1	Jan-2	Feb-1	Feb-2	Mar-1	Mar-2	Apr-1	Apr-2	May-1	May-2	Jun-1	Jun-2	Jul-1	Jul-2	Aug-1	Aug-2	Sep-1	Sep-2	Oct-1	Oct-2	Nov-1	Nov-2	Dec-1	Dec-2
Q mean	18.688	23.923	25.826	22.299	27.367	21.617	19.754	12.887	8.947	7.591	6.149	4.930	3.812	2.836	2.228	2.073	2.014	1.674	1.491	2.321	3.410	7.314	10.961	14.350
Q 50%	15.952	22.517	23.153	17.957	22.669	20.165	16.061	10.474	7.539	6.227	4.445	4.300	3.234	2.542	2.080	1.622	1.517	1.361	1.125	1.188	1.412	3.275	7.086	9.719
Q 80%	4.950	9.660	14.116	12.170	12.435	10.795	8.351	5.573	4.457	3.235	2.353	2.164	1.900	1.627	1.263	1.096	0.951	0.859	0.754	0.704	0.732	1.002	2.181	3.302
Q 90%	3.498	6.424	6.356	8.562	9.883	7.111	6.387	4.282	2.967	2.448	2.051	1.669	1.579	1.335	1.084	0.956	0.804	0.707	0.594	0.630	0.579	0.617	1.305	2.262
WD Kalitemu																								
Year	Half monthly average discharge (m ³ /s)																							
	Jan-1	Jan-2	Feb-1	Feb-2	Mar-1	Mar-2	Apr-1	Apr-2	May-1	May-2	Jun-1	Jun-2	Jul-1	Jul-2	Aug-1	Aug-2	Sep-1	Sep-2	Oct-1	Oct-2	Nov-1	Nov-2	Dec-1	Dec-2
Q mean	5.703	7.923	8.128	7.046	8.894	6.816	6.342	4.098	2.852	2.399	1.983	1.673	1.234	0.964	0.726	0.655	0.619	0.569	0.537	0.735	1.192	2.523	3.661	4.440
Q 50%	4.439	7.152	6.900	5.681	7.786	6.341	4.978	3.447	2.447	1.981	1.579	1.456	1.141	0.938	0.737	0.577	0.525	0.456	0.376	0.398	0.443	1.115	2.615	2.537
Q 80%	1.824	2.624	4.056	3.301	4.204	3.124	2.429	1.863	1.479	1.102	0.753	0.665	0.586	0.477	0.389	0.338	0.294	0.255	0.225	0.204	0.210	0.331	0.655	0.888
Q 90%	1.137	1.860	1.783	2.206	3.304	2.054	1.786	1.168	1.019	0.726	0.573	0.466	0.450	0.366	0.298	0.266	0.224	0.199	0.167	0.173	0.163	0.175	0.410	0.582
D Ngrembeng																								
Year	Half monthly average discharge (m ³ /s)																							
	Jan-1	Jan-2	Feb-1	Feb-2	Mar-1	Mar-2	Apr-1	Apr-2	May-1	May-2	Jun-1	Jun-2	Jul-1	Jul-2	Aug-1	Aug-2	Sep-1	Sep-2	Oct-1	Oct-2	Nov-1	Nov-2	Dec-1	Dec-2
Q mean	29.986	39.690	41.791	36.230	44.636	34.801	31.625	20.478	14.040	12.077	9.682	8.022	6.068	4.586	3.559	3.271	3.110	2.770	2.393	3.664	5.364	11.782	17.154	22.656
Q 50%	24.189	37.491	37.527	28.591	38.320	32.728	26.657	16.441	12.177	9.731	7.143	6.514	5.193	4.196	3.337	2.599	2.395	2.121	1.800	1.978	2.243	5.395	10.674	14.853
Q 80%	8.718	15.992	24.031	19.957	21.564	16.506	13.429	8.911	7.472	5.437	3.967	3.521	3.094	2.527	2.062	1.789	1.553	1.345	1.207	1.102	1.122	1.660	3.481	5.169
Q 90%	5.816	10.250	9.843	12.575	18.459	11.396	9.660	7.003	5.208	4.177	3.497	2.990	2.798	2.280	1.857	1.633	1.372	1.201	1.007	1.018	0.966	0.946	2.190	3.460
WD Lamong Hilir																								
Year	Half monthly average discharge (m ³ /s)																							
	Jan-1	Jan-2	Feb-1	Feb-2	Mar-1	Mar-2	Apr-1	Apr-2	May-1	May-2	Jun-1	Jun-2	Jul-1	Jul-2	Aug-1	Aug-2	Sep-1	Sep-2	Oct-1	Oct-2	Nov-1	Nov-2	Dec-1	Dec-2
Q mean	30.610	40.561	42.653	36.994	45.560	35.505	32.241	20.871	14.302	12.313	9.856	8.186	6.186	4.676	3.628	3.333	3.165	2.829	2.435	3.740	5.448	11.998	17.425	23.093
Q 50%	24.506	38.172	38.227	29.396	39.258	33.481	27.311	16.754	12.341	9.904	7.309	6.601	5.267	4.251	3.383	2.634	2.439	2.166	1.833	2.021	2.282	5.519	10.894	15.267
Q 80%	8.916	16.300	24.623	20.258	21.855	16.859	13.729	9.161	7.648	5.566	4.062	3.631	3.188	2.597	2.119	1.838	1.595	1.381	1.231	1.122	1.156	1.694	3.559	5.324
Q 90%	5.941	10.505	10.047	12.556	18.637	11.605	9.590	7.145	5.311	4.266	3.571	3.051	2.855	2.327	1.895	1.667	1.400	1.226	1.028	1.044	0.985	0.965	2.235	3.505

3.3. RKI Water Need

3.3.1. Domestic Water Need

For the study location, Gresik Regency and Surabaya City are classified in the moderate city category (115 l/person/day), Lamongan Regency is categorized as a semi-urban city (75 l/person/day), and Mojokerto Regency is categorized as a small city (100 l/person/day).

The classification of this category is based on the distance of it to Surabaya City. The closer to Surabaya City, the more it is categorized as a big city. In this study, domestic water needs are analyzed in each water district, the population data is obtained from the Statistic Center Institution in 2023, i.e., the population census data in 2022. Thus, the water needs data for the population for each water district can be seen in Table 7.

Table 7 Domestic water needs for each service area (Own study)

No.	Service Area	Year	Population size	Drinking water need (l/day)	Drinking water need (l/s)
1	WD Lamong Hulu	2023	42,446	3,183,450	36.845
2	WD Sabeng	2023	58,532	4,389,900	50.81

Continuation of Table 7					
3	WD Lamong Tengah	2023	220,499	22,049,900	255.21
4	WD Kalitemu	2023	130,659	13,065,900	151.23
5	WD Ngerembeng	2023	266,061	30,597,015	354.13
6	WD Lamong Hilir	2023	45,322	5,665,250	65.57

3.3.2. Industry Water Need

In this research, water needs for industry are analyzed on the basis of the number of employers in each district administrative region. The water needs for an industrial

employer are determined to be about 10 l per employer a day. The clean water need for industry is analyzed on the basis of the number of employers. The water needs for the industry sector can be seen in Table 8.

Table 8 Water need for industry (Own study)

No.	Service area	The estimation of the employer	The water need (l/day)	The water need (l/s)	The water need (m ³ /year)
1	WD Lamong Hulu	1,799	17,990	0.2082	6,566.35
2	WD Sabeng	5,052	50,520	0.5847	18,439.80
3	WD Lamong Tengah	7,123	71,230	0.8244	25,998.95
4	WD Kalitemu	2,172	21,720	0.2514	7,927.80
5	WD Ngerembeng	16,096	160,960	1.8630	58,750.40
6	WD Lamong Hilir	6,891	68,910	0.7976	25,152.15

3.4. Rice Irrigated Water Requirement

3.4.1. Irrigation Area

The rice irrigated area elaborated for each district in each water district can be seen in Table 9.

Table 9 Irrigated rice area in the Lamong watershed (Own study)

No.	Service Area	Irrigated rice area (ha)
1	WD Lamong Hulu	6,445
2	WD Sabeng	5,760
3	WD Lamong Tengah	9,297
4	WD Kalitemu	11,236
5	WD Ngerembeng	4,417
6	WD Lamong Hilir	112

Based on the data above, it can be seen that the rice irrigated area is the most available irrigated area in Kalitemu water district (WD) and less in the Lamong Hilir water district. By obtaining the irrigation area in each water district, it is used for analyzing the water requirement for irrigation in each water district.

3.4.2. Cropping Pattern

The cropping pattern used in this analysis is generally

the same for all of the water districts starting at the beginning of January with the crop intensity being three times. The selection at the beginning of January can be seen from the dependable discharge and effective rainfall. The determination of the same cropping pattern for all water districts is only for the analysis of irrigation water requirement that is big enough, but if there is needed the optimal water management so the flow discharge in each water district can be maximal utilized, can be carried out with some variations of cropping pattern in each water district.

3.4.3. Evapotranspiration

Evapotranspiration is analyzed using climate data such as temperature, humidity, wind velocity, and the period of sun shining. The analysis of evapotranspiration is carried out by a Hargraves method. This method is selected based on the available climate data. Analysis of evapotranspiration was carried out in the climate station available in Surabaya from 2006 until 2017. The analysis results of evapotranspiration are shown in Table 10.

Table 10 Potential evapotranspiration in the Lamong watershed (Own study)

Year	Jan I	Jan II	Feb I	Feb II	Mar I	Mar II	Apr I	Apr II	May I	May II	Jun I	Jun II	Jul I	Jul II	Aug I	Aug II	Sept I	Sept II	Oct I	Oct II	Nov I	Nov II	Dec I	Dec II
2006	6.0	6.0	5.4	5.4	5.6	5.6	5.3	5.3	4.4	4.4	4.4	4.4	4.9	4.9	4.9	4.9	6.0	6.0	5.9	5.9	6.1	6.1	5.5	5.5
2007	5.8	5.8	5.4	5.4	5.6	5.6	5.0	5.0	4.5	4.5	4.4	4.4	4.4	4.4	5.0	5.0	5.8	5.8	6.0	6.0	6.0	6.0	5.7	5.7
2008	5.8	5.8	5.5	5.5	5.2	5.2	4.7	4.7	5.0	5.0	4.4	4.4	4.6	4.6	5.3	5.3	5.6	5.6	6.4	6.4	5.5	5.5	5.6	5.6
2009	5.6	5.6	5.8	5.8	5.6	5.6	5.1	5.1	4.6	4.6	4.0	4.0	4.7	4.7	4.9	4.9	5.6	5.6	5.8	5.8	6.0	6.0	5.8	5.8
2010	5.9	5.9	6.7	6.7	5.7	5.7	5.0	5.0	4.7	4.7	4.2	4.2	4.6	4.6	4.6	4.6	5.2	5.2	5.7	5.7	5.7	5.7	5.5	5.5
2011	5.3	5.3	5.5	5.5	5.4	5.4	4.7	4.7	4.2	4.2	4.4	4.4	4.3	4.3	4.9	4.9	5.3	5.3	5.8	5.8	5.7	5.7	5.6	5.6
2012	5.7	5.7	5.5	5.5	5.1	5.1	4.7	4.7	4.3	4.3	4.1	4.1	4.4	4.4	5.0	5.0	5.5	5.5	5.8	5.8	5.7	5.7	5.7	5.7
2013	5.4	5.4	5.5	5.5	5.4	5.4	4.6	4.6	4.3	4.3	4.1	4.1	4.4	4.4	5.0	5.0	5.4	5.4	6.2	6.2	6.1	6.1	5.4	5.4
2014	5.5	5.5	5.7	5.7	5.3	5.3	5.3	5.3	4.3	4.3	4.3	4.3	4.3	4.2	4.6	4.6	5.6	5.6	5.9	5.9	5.1	5.1	5.8	5.8
2015	5.6	5.6	5.5	5.5	5.4	5.4	4.8	4.8	4.3	4.3	4.3	4.3	4.3	4.3	4.8	4.8	5.5	5.5	5.8	5.8	5.8	5.8	5.8	5.8
2016	5.9	5.9	5.2	5.2	6.2	6.2	5.0	5.0	4.5	4.5	4.1	4.1	3.9	3.9	4.6	4.6	5.3	5.3	5.3	5.3	5.8	5.8	5.8	5.8
2017	5.4	5.4	5.3	5.3	5.4	5.4	4.7	4.7	4.7	4.7	4.2	4.2	4.4	4.4	4.9	4.9	5.8	5.8	5.9	5.9	4.7	4.7	5.6	5.6
Mean	5.7	5.7	5.6	5.6	5.5	5.5	4.9	4.9	4.5	4.5	4.2	4.2	4.4	4.4	4.9	4.9	5.6	5.6	5.9	5.9	5.7	5.7	5.6	5.6

3.5. The Analysis of Effective Rainfall

Effective rainfall for each water district is analyzed in the amount of 70% from 80% dependable discharge. The

80% dependable rainfall is analyzed based on the rainfall availability in each water district. Effective rainfall for each water district per half monthly can be seen in Table

11. The effective rainfall data reveal that the condition of high rainfall in each water district occurs from December until March.

Table 11 Effective rainfall for each service area (Own study)

No	Water District	Jan I	Jan II	Feb I	Feb II	Mar I	Mar II	Apr I	Apr II	May I	May II	Jun I	Jun II	Jul I	Jul II	Aug I	Aug II	Sept I	Sept II	Oct I	Oct II	Nov I	Nov II	Dec I	Dec II
1	WD LAMONG HULU	3.32	4.50	5.42	3.64	4.34	3.79	3.20	1.08	0.82	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.54	1.81	3.84	3.49
2	WD SABENG	4.88	4.11	3.50	3.49	4.03	2.67	2.36	0.47	0.32	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.44	1.39	2.71	3.06
3	WD LAMONG TENGAH	2.93	3.63	3.19	3.43	3.41	2.46	1.73	0.53	0.63	0.01	0.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.33	0.77	2.55	2.75
4	WD KALITEMU	3.14	3.64	3.54	3.70	3.86	2.70	1.84	0.64	0.60	0.00	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.42	0.94	2.47	3.11
5	WD NGEREMBENG	4.01	4.56	3.41	3.46	2.67	2.03	1.75	0.93	0.21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.26	1.40	2.86	2.34
6	WD LAMONG HILIR	3.61	4.39	3.13	3.22	2.71	1.49	1.63	0.79	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	1.02	2.71	2.52	

3.6. Need Field Requirement (NFR)

The Need Field Requirement (NFR) in rice-irrigated areas for each water district is shown in Table 12. By obtaining the NFR in rice irrigated area and based on the information of rice irrigated area in each water district, it can be analyzed the whole NFR for each water district as

presented in Table 13. The analysis result of water needs demonstrates that the big NFR is in the agricultural sector (rice irrigated area). To make efficient the water need, the significant action involves the efforts to optimize the irrigation water requirement.

Table 12 Water need per irrigation area unit (l/s/ha) for each service area (Own study)

No	Water District	Irrigated rice area (ha)	Dec I	Dec II	Jan I	Jan II	Feb I	Feb II	Mar I	Mar II	Apr I	Apr II	May I	May II	Jun I	Jun II	Jul I	Jul II	Aug I	Aug II	Sept I	Sept II	Oct I	Oct II	Nov I	Nov II
1	WD LAMONG HULU	6,445	0.90	0.94	0.96	1.25	0.49	0.47	0.23	0.07	0.91	1.15	1.15	1.24	0.95	0.73	0.64	0.46	1.28	1.28	1.33	1.33	1.15	0.91	0.69	0.31
2	WD SABENG	5,760	1.03	0.99	0.78	1.30	0.71	0.48	0.27	0.20	1.01	1.22	1.20	1.24	0.95	0.73	0.64	0.46	1.28	1.28	1.33	1.33	1.15	0.91	0.70	0.36
3	WD LAMONG TENGAH	9,297	1.05	1.02	1.00	1.35	0.75	0.49	0.34	0.23	1.08	1.22	1.17	1.24	0.94	0.73	0.64	0.46	1.28	1.28	1.33	1.33	1.15	0.92	0.72	0.43
4	WD KALITEMU	11,236	1.06	0.98	0.98	1.35	0.71	0.46	0.29	0.20	1.06	1.20	1.17	1.24	0.74	0.73	0.64	0.46	1.28	1.28	1.33	1.33	0.96	0.92	0.71	0.41
5	WD NGEREMBENG	4,417	1.01	1.07	0.88	1.24	0.72	0.49	0.43	0.28	1.08	1.17	1.22	1.24	0.95	0.73	0.64	0.46	1.28	1.28	1.33	1.33	1.15	0.92	0.72	0.36
6	WD LAMONG HILIR	112	1.03	1.05	0.93	1.26	0.76	0.52	0.42	0.34	1.09	1.19	1.24	1.24	0.95	0.73	0.64	0.46	1.28	1.28	1.33	1.33	1.15	0.92	0.74	0.40

Table 13 Irrigation water requirement (m³/s) for each service area (Own study)

No	Water District	Irrigated rice area (ha)	Dec I	Dec II	Jan I	Jan II	Feb I	Feb II	Mar I	Mar II	Apr I	Apr II	May I	May II	Jun I	Jun II	Jul I	Jul II	Aug I	Aug II	Sept I	Sept II	Oct I	Oct II	Nov I	Nov II
1	WD LAMONG HULU	6,445	5.783	6.043	6.185	8.067	3.160	3.006	1.503	0.481	5.846	7.431	7.387	7.998	6.141	4.715	4.110	2.955	8.218	8.218	8.602	8.602	7.432	5.867	4.452	2.024
2	WD SABENG	5,760	5.920	5.687	4.489	7.468	4.100	2.790	1.551	1.175	5.790	7.050	6.932	7.147	5.488	4.213	3.673	2.641	7.343	7.343	7.687	7.687	6.642	5.253	4.051	2.089
3	WD LAMONG TENGAH	9,297	9.734	9.518	9.341	12.575	6.949	4.562	3.170	2.127	10.020	11.306	10.855	11.528	8.730	6.801	5.929	4.263	11.854	11.854	12.408	12.408	10.721	8.552	6.650	4.037
4	WD KALITEMU	11,236	11.862	11.031	11.018	15.182	7.950	5.169	3.238	2.260	11.962	13.520	13.169	13.942	8.352	8.219	7.166	5.152	14.326	14.326	14.996	14.996	10.746	10.333	7.927	4.663
5	WD NGEREMBENG	4,417	4.466	4.729	3.885	5.497	3.190	2.152	1.882	1.231	4.748	5.167	5.373	5.481	4.209	3.231	2.817	2.025	5.631	5.631	5.895	5.895	5.093	4.074	3.196	1.596
6	WD LAMONG HILIR	112	0.115	0.117	0.103	0.141	0.084	0.058	0.047	0.038	0.122	0.132	0.139	0.139	0.106	0.082	0.071	0.051	0.142	0.142	0.149	0.149	0.129	0.103	0.083	0.045

3.7. Analysis of Water Balance Based on the Water District in the Lamong Watershed

The analysis result of water balance in each water district in the Lamong Watershed can be seen in Table 14. Based on the analysis result of water balance in Kali Lamong Watershed based on each water district, it is seen that the condition of water balance now in each water district is surplus for certain months and deficit for the other as presented in Figure 8.

Based on the analysis result, it can be concluded that for the Lamong Hulu water district, where the location is in the downstream of the Kali Lamong Watershed, pressure or critical condition to the water resources. It is

seen that there are only two months of water balance condition showing surplus, the remaining experience deficit. The same condition also occurred in the Kalitemu water district, which, from the water balance analysis, shows that the water resources condition experiences crisis. For the other water districts, it can be expressed that the condition of water resources still shows a surplus condition in the rainy season and experiences a deficit in the dry season. The period of water surplus is also long and the same as in the rainy season period. However, the Lamong Hulu and Kalitemu water districts have a shorter surplus period. Figure 8 presents the curve of water surplus and deficit periods in each water district.

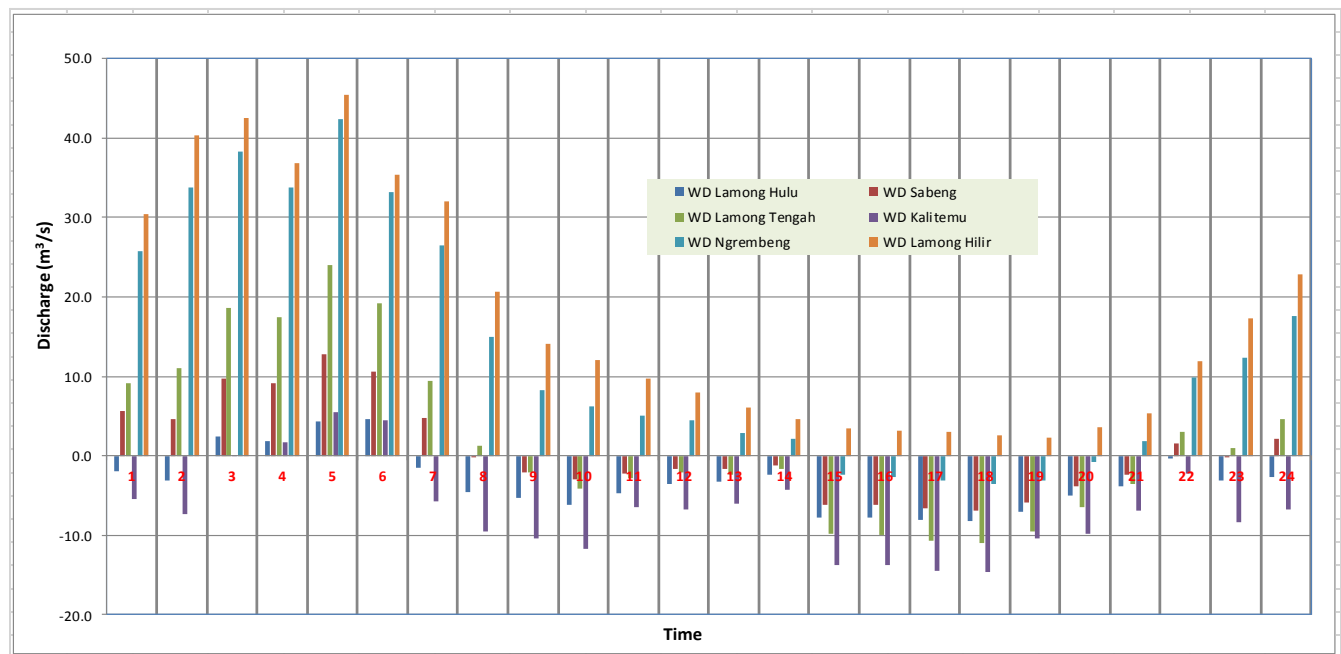


Fig. 8 Curve of water surplus and deficit period in each service area (Own study)

4. Conclusion

Water availability was analyzed on the basis of two approaches: 1) based on the record of discharge data and 2) based on the approach of rainfall-run-off model. The final value of water availability used for further analysis was the average result of the two approaches. In the first approach, the analysis of water availability is carried out based on the time series discharge data. The second approach is carried out on the basis of the discharge data that is produced from the rainfall-run-off model. The rainfall-run-off model used was the NRECA model. This model was carried out for calibration before being used.

Based on the analysis results of water balance for each water district in the Lamong Watershed the following conclusions can be drawn:

1. Water availability in each water district was produced using two approaches based on the estimation of time series discharge data that were recorded in one of the discharge recorders and based on the rainfall-run-off model.

2. Water availability in Kali Lamong Watershed that is reviewed in each water district for $Q_{80\%}$, the highest in Lamong Hulu water district is at the beginning of February, which is about $3.258 \text{ m}^3/\text{s}$, and the lowest is at the beginning of November, which is about $0.181 \text{ m}^3/\text{s}$; in Sabeng water district: the highest is at the beginning of February, which is about $0.171 \text{ m}^3/\text{s}$, and the lowest is at the end of October, which is about $0.372 \text{ m}^3/\text{s}$; in WD Lamong: the highest is at the beginning of February, which is about $14.116 \text{ m}^3/\text{s}$, and the lowest is at the end of October, which is about $0.704 \text{ m}^3/\text{s}$; in WD

Kalitemu: the highest is at the beginning of March, which is about $4.2046 \text{ m}^3/\text{s}$, and the lowest is at the end of October, which is about $0.203 \text{ m}^3/\text{s}$; in WD Ngrembeng: the highest is at the beginning of February, which is about $24.031 \text{ m}^3/\text{s}$, and the lowest is at the end of October, which is about $1.102 \text{ m}^3/\text{s}$; and in WD Lamong Hilir: the highest is at the beginning of February, which is about $24.623 \text{ m}^3/\text{s}$, and the lowest is at the end of October that is about $1.122 \text{ m}^3/\text{s}$

3. The highest water need in each water district is contributed by the agriculture sector. For Lamong Hulu, the highest water need occurred at the beginning of September, at about $8.6 \text{ m}^3/\text{s}$, and the lowest occurred at the end of March, at about $0.48 \text{ m}^3/\text{s}$; in the Sabeng WD: the highest water need occurred at the beginning of September, at about $7.69 \text{ m}^3/\text{s}$, and the lowest occurred at the end of March, at about $1.18 \text{ m}^3/\text{s}$; in the Lamong Tengah WD: the highest water need occurred at the beginning of January, at about $12.57 \text{ m}^3/\text{s}$, and the lowest occurred at the end of March, at about $2.13 \text{ m}^3/\text{s}$; in the Kalitemu WD: the highest water need occurred at the beginning of January, at about $15.18 \text{ m}^3/\text{s}$, and the lowest occurred at the end of March, at about $2.26 \text{ m}^3/\text{s}$; in the Ngrembeng WD: the highest water need occurred at the beginning of September, at about $5.89 \text{ m}^3/\text{s}$, and the lowest occurred at the end of March, at about $1.23 \text{ m}^3/\text{s}$; and in the Lamong Hilir WD: the highest water need occurred at the beginning of September, at about $0.15 \text{ m}^3/\text{s}$, and the lowest occurred at the end of March, at about $0.04 \text{ m}^3/\text{s}$

4. The condition of water balance in each water district has experienced water deficit for a certain period,

and the significant experienced deficit is happened in the Lamong Hulu WD and Kalitemu WD which only 2 months the two WDs experience water surplus based on the dependable discharge ($Q_{average}$).

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