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Regional Case Study

Water Resources Assessment for Raw Water Purposes in Serang Watershed, Kulonprogro

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Abstract

One source of raw water for drinking water is river water. The raw water source for drinking water must meet the requirements for quantity, continuity, and quality. Raw water for drinking water must meet class I water quality requirements. This study aims to assess of the potential for water availability and water quality in the Serang River. Analysis of water availability used statistical methods and simulated rainfall-runoff with the HEC-HMS model. Calibration of the hydrological model was carried out in sub-watersheds where there were observational discharge data. Water availability is reviewed in the second-order river. Water quality status was analyzed using the Pollutant Index and Storet methods. The results of the analysis of water availability for reliable discharge with a probability of 80%, 90%, and 95% in several sections of the Serang River to order 2 rivers can be presented in the form of a flow duration curve. The results of the analysis of the status of water quality in several sections of the upstream Serang river based on the Storet method and the Polluter Index method show that in general, it is in a slightly polluted condition.

Keywords: Raw water; rain-runoff; reliable discharge; flow duration curve; water quality

1. Introduction

Hydrological information is data that forms the basis for planning activities for the management of water resources in river basins such as planning for intake structures for raw water for irrigation, drinking water, hydropower, flood control structures, and others. In addition to water quantity data, water quality data is also needed to get an overview of the water quality class in a river as the basis for determining its designation.

The standard requirement for drinking water quality is first-class water based on Government Regulation Number 22 of 2021 concerning the Implementation of Environmental Protection and Management. Class one water is water whose designation can be used for raw drinking water, and/or other uses that require the same water quality as that use.

The Serang River Basin has a catchment area of ± 187 km^2 with the length of the main river being ± 28 km. In the Kulonprogo region, the Sermo Reservoir is also operating, which dams the Ngrancah River (a tributary of the Serang River). The main function of the Sermo reservoir is for irrigation and drinking water purposes. The location of the Sermo Reservoir is in the upstream part of the Serang watershed. In the Serang watershed, there are also many tributaries whose discharge potential is unknown. For this reason, this research is intended to analyze the potential availability of water in the sub-watersheds to the downstream Serang watershed. In addition, it also determines the status of water quality compared to water quality for drinking water purposes, namely class 1 water quality.

2. Methods

a. Water Availability

Analysis of water availability in the Serang watershed (DAS) was carried out in the sub-watersheds up to order 2 rivers, with the hope that the discharge potential that could be utilized and its location could be identified. Hydrological data available in the Serang watershed are discharge data from observations of the water level at AWLR and rain data from several rain stations.

Considering that not all sub-watersheds have observation discharge data, the analysis of water availability is carried out by modeling rain into runoff.

In the transformation process to determine the change of rainwater into streams, a rule (statute) is needed that reflects the character of the watershed in processing rain-flow diversion. In this case, the rules (statutes) can be interpreted as a model.

Models in hydrology contain various meanings, Sri Harto (2000), states that models are simplifications of a complex system, whether physical, analog, or mathematical. Whereas Dodge (1983), added that hydrological models apart from being real or abstract structures, tools, schemes, or procedures, hydrological models are a relationship between inputs or stimuli, energy or information, outputs, and influences or responses within a certain time reference. Then, Ponce (1989), stated that the hydrological model is a set of mathematical statements that state the relationship between the phases of the hydrological cycle to simulate the transformation of rain into runoff.

Sarminingsih (2018) stated that one of the models for converting rain into streams, especially for low flow, is the HEC-HMS model. In the HEC-HMS model, the conversion of rain into streams consists of several models and each selected model has a different input. The model contained in the HEC-HMS can be used to calculate runoff volume, direct runoff, baseflow, and channel flow. The calculation and completion of each model have components in the form of fixed variables, parameters, boundary conditions, and initial conditions.

b. Reliable Discharge

Reliable discharge is discharge that can be relied upon for a certain level of reliability or reliability. For irrigation purposes, reliable discharge is usually used with 80% reliability as stipulated in the Irrigation Planning Criteria (Directorate General of Irrigation, 2013). This means that with the possibility that 80% of the discharge that occurs is greater than or equal to the discharge, or in other words, the irrigation system may fail once in five years. For drinking and industrial water needs, higher reliability is required, which is around 90% to 95%. If river water is used for hydroelectric power generation, a very high reliability is required, between 95% and 99% (Goodman, 1984). In its use, the mainstay debit can be a monthly mainstay debit or also a mainstay debit with a certain probability as needed.

There are two ways to calculate the mainstay discharge, namely the plotting position method and the statistical method. The method of plotting position is done by sorting the data from largest to smallest, in the order number 1 to N. Then each sequence is given a probability *of exceedance value*. The recommended plotting position is the Weibull method which gives the r-th order probability r/(N+1), and finally, interpolation is done to get probabilities of 80%, 90%, and 95%. Another way of plotting position is to use the Ms-Excel PERCENTILE function, which is based on the probability P = r/N, which if the amount of data is larger, the result will be close to the Weibull method. Calculation of reliable discharge using the plotting position method produces a flow duration curve or long flow curve, the abscissa of which is the probability of being exceeded, and the amount of flow as the ordinate. With the old flow curve, large numbers of flow discharges can be obtained for various levels of reliability.

c. Water quality

Water quality data obtained from observation points were analyzed for the level of pollution compared to class I river water quality standards based on PP 22/2021 concerning the Implementation of Environmental Protection and Management. The method used is the Storet Method and the Pollutant Index (IP) Method.

i. Store method

According to the Decree of the State Minister for the Environment Number 115 of 2003, the Storet method is a method for determining the status of water quality that is commonly used. With the Storet method, it is possible to identify parameters that have met or exceeded water quality standards. In principle, the Storet method is to compare water quality data with water quality standards adjusted for their designation to determine water quality status.

How to determine the status of water quality by using the value system of the "US-EPA (United States Environmental Protection Agency)" by classifying water quality into four classes as follows:

1. Class A: very good, score = 0 meets the quality standard
2. Class B: good, score = -1 to 10 mildly polluted
3. Class C: moderate, score = -11 to -30 moderately polluted
4. Class D: bad, score = > -31 severely polluted

ii. Pollutant Index (IP) Method

Sumitomo and Nemerow (1970) in KepMen LH No. 115 of 2003 proposed an index related to significant pollutant compounds for a provision. This index is expressed as the Pollution Index which is used to determine the level of pollution relative to the permissible water quality parameters. Management of water quality based on the Pollutant Index (IP) can provide input to decision-makers to be able to assess the quality of water bodies for a designation and take action to improve quality if there is a decrease in quality due to the presence of pollutant compounds. IP includes various independent and meaningful groups of quality parameters.

Meanwhile, to determine the status of river water quality, the Pollution Index (IP) method is used which refers to KepMenLH 115/2003 concerning Guidelines for Determining Water Quality Status. The Pollution Index (IP) calculation formula is as follows:

$$IPj = \sqrt{\frac{(\mathbf{Ci}\ /\mathbf{Lij})^2\ \mathbf{M} + (\mathbf{Ci}\ /\mathbf{Lij})^2\ \mathbf{R}}{\mathbf{2}}}$$

Where:

Lij : Concentration of water quality parameters listed in the quality standard for water use (J)
Ci : Concentration of water quality parameters in the field
Pij : Pollution index for designation (J)
(Ci/Lij)M : Maximum Ci/Lij value
(Ci/Lij)R : Average Ci/Lij value

The relationship between IP value and water quality status is as follows:

- $0 \le PIj \le 1.0$ → Good condition
- $1.0 < PIj \le 5.0$ → Lightly Polluted
- $5.0 < PIj \le 10$ → Moderately Polluted

$PIj > 10$ → Heavy Polluted

3. Result and Discussion

a. Hydrological Data

i. Watershed data

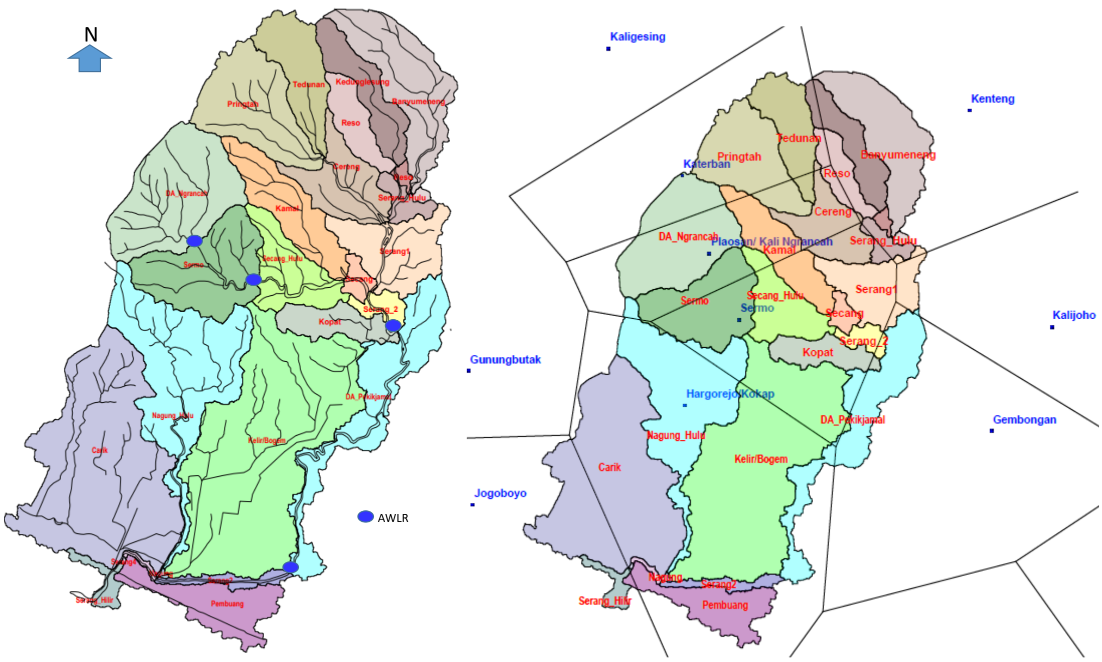
The data used in the analysis are watershed and river data from Digital Elevation Model (DEM) data sourced from DEMNAS with a resolution of 0.27 arcseconds. DEM data is used to define Sub-DAS. The Serang Watershed is divided into several sub-watersheds to know the amount of discharge of each tributary in the Serang River. The Serang watershed and sub-watershed are shown in Figure 1 (a). While the river order data along with the area of the sub-watershed are shown in Table 1b.

Table 1. Data on the area of the Serang sub-watershed

No	Sub-watershed			Area (km2)
	Order 2	Order 3	Order 4	
1	Upstream Attack			20,475
		resort		8.6345
			Hulu Resort	3,317
			Kedunglesung	4,912
		Banyuwangi		10087
2	Pork			21,991
		shading		6.12
		Order		9,913
3	Secang (DA Compassionate)			36,571
		DA Dam		22.95
			DA Ngrancah	13.137
		Kamal		6,765
4	Kopat			3,663
5	DA Pekikjamal			102.09
6	Color			32,245
7	Nagung			16,849
8	Waster			6,074
9	search			27,266

ii. Hydrology Data

Hydrological data contained in the Serang watershed includes rainfall data and discharge data from water level estimation posts. There are 8 (eight) rain posts that influence regional rain analysis in the basin, as well as 4 (four) automatic water level recorder stations. The availability of rain data varies, but in general, the rain data is quite complete for the period 2010 to 2017. Areal rainfall was analyzed using the Thiesen polygon, with the influence factor for each Sub-DAS, the results of which are shown in Figure 1. b.



(a) **(b)**

Figure 1. (a) Serang sub-watershed, (b) Thiesen polygon

b. Hydrological Parameter Modeling and Calibration

Referring to the sub-watershed sub-watershed data, a schematization of the hydrological model was carried out using the HEC HMS, as shown in Figure 2. Not all tributaries have data for recording water level or discharge data, even if there is, in general, the recording period is not long enough. While in general, the recording of rain data is longer than discharge data. Therefore, the discharge calculation can be done by modeling rain into runoff. However, in the rain runoff model, it is necessary to calibrate the model between simulated discharge and observation discharge, to determine the hydrological parameters of the watershed. Furthermore, these watershed hydrological parameters can be used to analyze rainfall in other periods, even for other sub-watersheds which are close together and have almost the same characteristics.

Figure 2. Serang watershed hydrology model using HMS HEC

The available discharge data is in the form of daily data so it is very difficult to calibrate according to the timing of floods and rains with long periods. For this reason, the hydrological parameters are calibrated based on a single flood event, which coincides with a rain event. The magnitude of this flood discharge is calibrated using flood discharge data at the location of the discharge data from the estimated water level data. The existence of discharge data is around 8 years, so the calibration is carried out based on the discharge value that occurred in that period with a return period discharge of 2 years or 5 years. In the analysis, the water estimators of Pengasih and Pekikjamal watersheds were used, which have long and relatively good observation data for optimizing hydrological parameters.

The hydrological parameters that were optimized were Curve Number (CN), *initial abstraction,* and lag time. Using hydrological parameters that have been optimized and then verified using daily rainfall and daily discharge data for 7 (seven) years, the results of calibration of the amount of discharge are quite good, with an RMSE value of 0.95 and a Percent bias of 42.92%. Furthermore, hydrological parameters in the form of *Curve Number (CN), initial abstraction*, as well as *the lag time* in each sub-watershed are used to simulate rain into runoff/discharge in each of these sub-watersheds for as long as available rainfall data. This data is then used as the basis for analysis of the mainstay discharge or water availability.

The results of discharge calibration at the two locations of the water estimating post are shown in Figure 3 and Figure 4. The results of the analysis show that there is a significant difference in high discharge or discharge with a low probability of occurrence, while for small discharge or discharge with a high probability of occurrence. relatively small difference. At small debits, the calculation results are smaller than the observations, this is because the calculation does not include base flow. For selecting a small debit, it is better to use the calculated debit to get more conservative results.

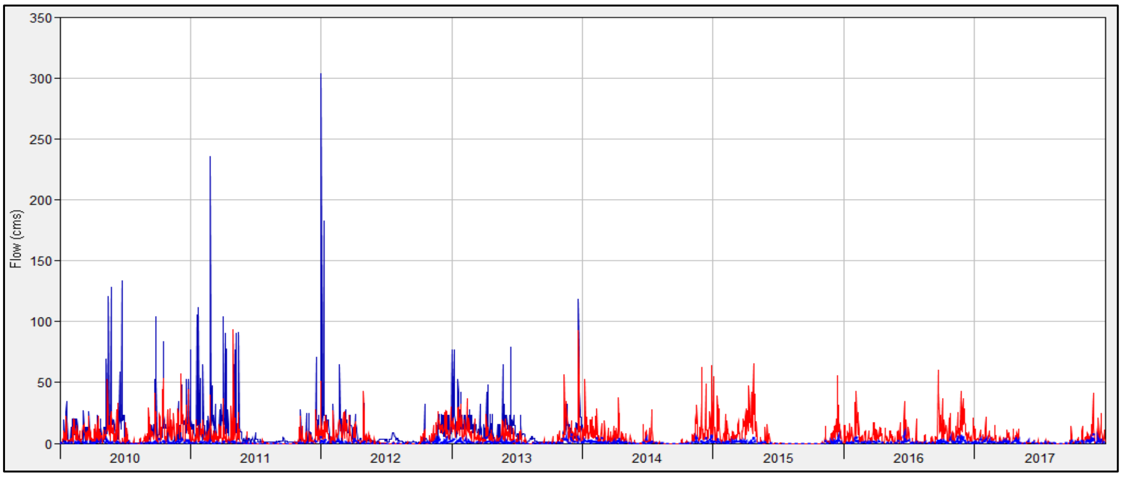


Figure 3. Results of the calibration of the rain-runoff model on the compassionate PDA

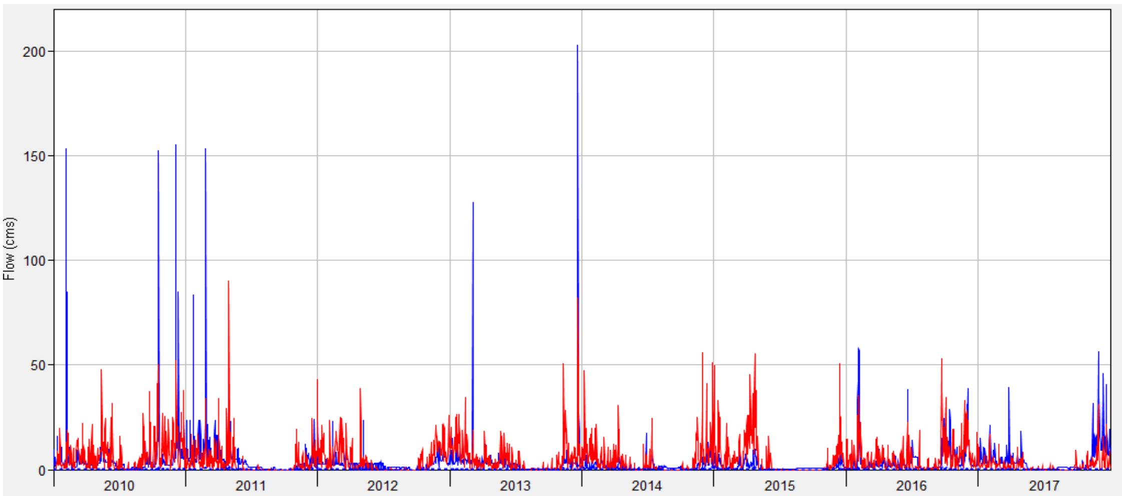
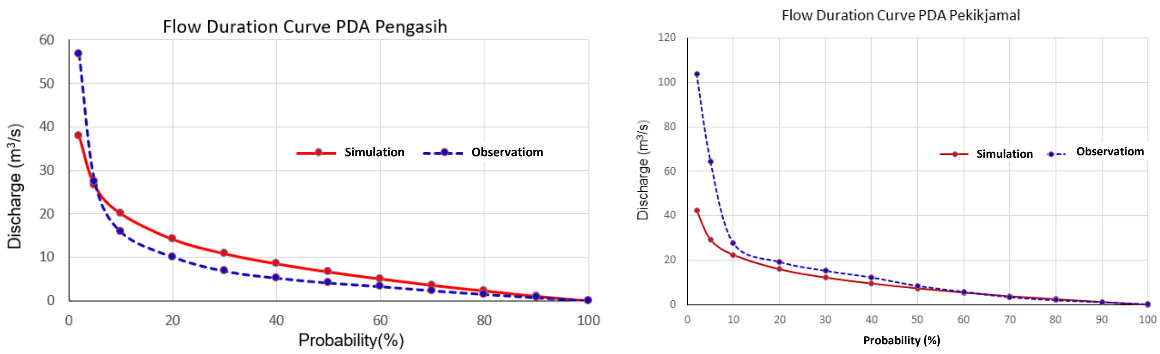


Figure 4. Results of the calibration of the rain-runoff model in Pekikjamal PDA

Based on the daily discharge from the simulation-calibration results, the flow duration curve can then be described using the Weibull method. From the flow duration curve, it is possible to plot the magnitude of the dependable discharge for various probabilities. Flow duration curves for the two observation locations are shown in Figure 5.

The results of the analysis show that there is a significant difference in high discharge or discharge with a low probability of occurrence, while for small discharge or discharge with a high probability of occurrence, there is a relatively small difference. At small debits, the calculation results are smaller than the observations, this is because the calculation does not include base flow.



(a) (b)

Figure 5. Flow duration curve in (a) AWLR Pengasih, (b) AWLR Pekikjamal

c. Dependable Discharge

Based on the hydrological model parameters that have been used for calibration at the two water estimators representing the two sub-watersheds, it is then possible to simulate daily rainfall into daily discharge using the HEC-HMS model for the other sub-watersheds. The magnitude of the reliable discharge presented for probabilities ranging from 50% to 100% for other sub-watersheds in order 2 rivers and meeting points (such as the circle sign in Figure 2) is shown in Figure 6. Meanwhile, discharge values for other probabilities are shown in Table 2.

Table 2. Dependable Discharge of Serang Sub Catchments

Sub Catchment/ Junction	8C Resolution	152B DA Ngrancah	12C Bluebird	22C Cup	24C DA of Compassion	38C DA Jamal screams	5C Attack
Area (km2)	**8.63**	**13.14**	**21.99**	**36.57**	**87.35**	**102.09**	**187.52**
probability(%)				**Discharge (m3/s)**			
2	4.96	9.17	11.68	24.98	38.82	42.48	80.9
5	3.97	7.77	8.95	16.48	26.67	29.34	54.88
10	2.95	5.69	6.45	12.79	20.22	10:55 p.m	42.55
20	2.28	4.1	4.85	8.97	14.29	16.17	28.54
30	1.88	3.28	3.92	6.7	10.95	12.39	20.5
40	1.58	2.72	3.17	5.31	8.62	9.66	16.12
50	1.3	2.19	2.56	4.22	6.75	7.45	12.12
60	1.03	1.68	2.01	3.2	5.11	5.54	9.18
70	0.78	1.26	1.48	2.35	3.67	3.91	6.18
80	0.52	0.84	0.99	1.55	2.36	2.53	3.8
90	0.27	0.43	0.5	0.78	1.13	1.24	1.65
95	0.14	0.22	0.255	0.395	0.57	0.625	0.83
100	0.01	0.01	0.01	0.01	0.01	0.01	0.01

d. Water Quality Status

Sampling locations for water quality in the Serang Watershed are in 7 (seven) locations, namely Ngrancah River (inlet 1 Sermo Reservoir), Gelo River (inlet 2 Sermo Reservoir), Bengkok River, Lurug 1 River, Lurug 2 River, Central Reservoir and Sermo Outlet. Water quality data was taken from 2010 to 2017, with sampling one to three times a year. Parameters taken were in the form of physical and chemical parameters, and no microbiological and radioactive parameters. Water quality parameters taken include temperature, dissolved substance/TDS, suspended matter/TSS, DHL, turbidity, pH, field dissolved oxygen (DO), COD, BOD, dissolved iron (Fe), and ammonium (NH_4).

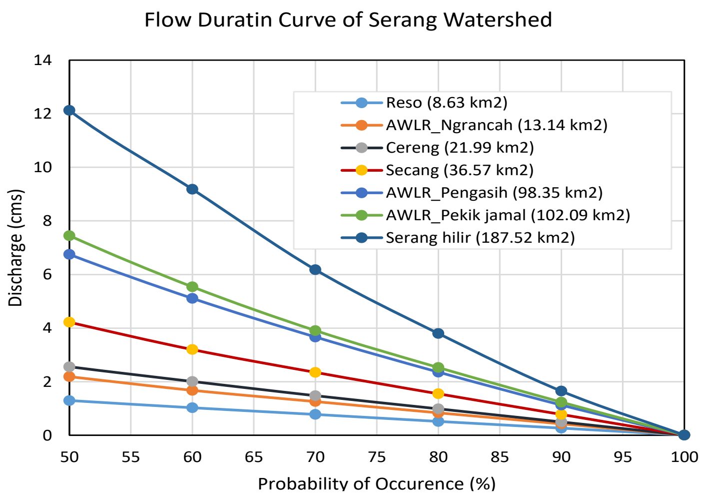
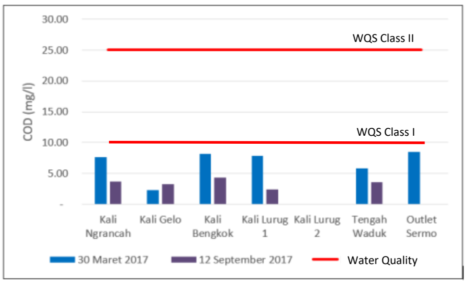
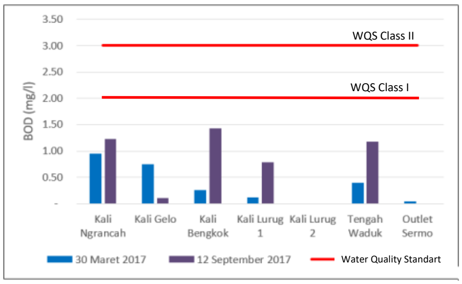


Figure 6. Flow duration curve in some junction in Serang River

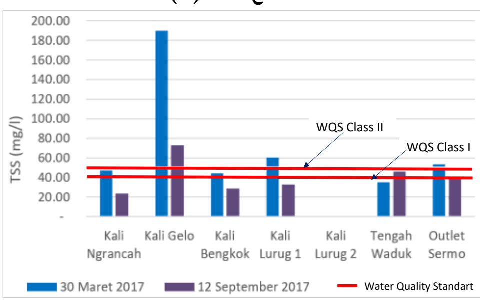
Based on these water quality data, if we review the latest observational data (2021) for five general parameters, namely TSS, TDS, DO, COD, and BOD when compared to the quality standards, it can be concluded that in general they meet the quality standards except for the parameters TSS and DO. While the results of the analysis of water pollution status using the Storet method and the Pollutant Index method show that the water quality status is classified as slightly polluted. The summary of the results of the analysis of water pollution status is shown in Table 3.



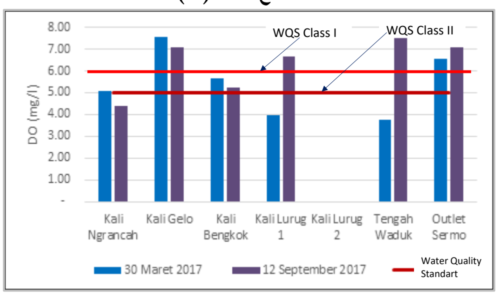
(a) WQ of COD



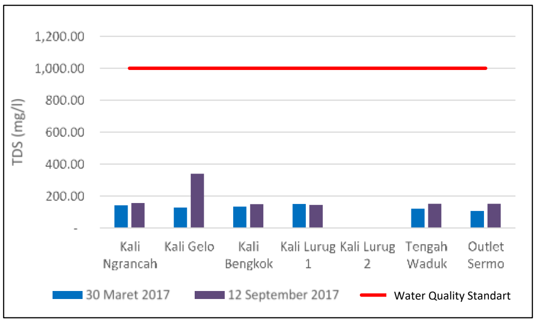
(b) WQ of BOD



(c) WQ of TSS



(d) WQ of DO



(e) WQ of TDS

Figure 6. Water quality of COD, BOD, TSS, DO, and TDS upstream of Serang Catchment

Table 3 . Resume of water quality status of attack capture

No	Sub Catchment Inflow to reservoir	Sampling locations	last data	water quality status	
				Storet	**IP**
1	Ngrancah times	Sermo Reservoir 1	2017	light pollution	light pollution
2	Kali Gelo	Semo Reservoir 2	2017	light pollution	light pollution
3	Crooked Times	Semo Reservoir 3	2017	light pollution	light pollution
4	Lurug River 1	Semo Reservoir 4	2017	light pollution	light pollution
5	Lurug River 2	Semo Reservoir 5	2017	light pollution	light pollution
6	Middle of the Reservoir	Sermo Reservoir 6	2017	light pollution	light pollution
7	Service Outlet	Sermo Reservoir 7	2017	light pollution	light pollution

4. Conclusions

Analysis of water availability in the Serang watershed was carried out in the sub-watershed using the HEC-HMS hydrological model. Calibration was carried out on two water measurement centers. The results of the analysis of the availability of water for drinking water use a probability of 95% with a reliable discharge from the upstream part of the watershed of 0.14 m3/s to 0.83 m3/s in the downstream Serang. The results of the analysis of the status of water quality using the Storet method and the Pollution Index show that the water quality status of class 1 river water is classified as lightly polluted.

References

Anonymous, 2017, Module 5 Hydrology, Water Supply and Demand. Minister For Public Works and Human Settlements. Human Resources Development Agency. Water Resources Education and Training Center and Construction.

Anonymous, 2013, Irrigation Planning Criteria. Ministry of Public Works. Directorate of Water Resources. Directorate of Irrigation and Swamp.

ED Dodge, 1983. Hydrogéologie des aquifères karstiques du Causse Comtal (Aveyron, France) Thèse Sci Univ, Bruxelles.

Goodman, Alvin S., 1984. Principles of Water Resources Planning, Prentice-Hall, Englewood Cliffs.

Indonesia, K. 2003. Decree of the State Minister for the Environment Number 115 of 2003 concerning Guidelines for Determining Water Quality Status. State Secretariat. Jakarta.

Indonesia, P. 2021. Government Regulation Number 22 of 2021 concerning Guidelines for Environmental Protection and Management. State Secretariat of the Republic of Indonesia, *1* (078487A), 483.

Ponce, VM. 1989. Engineering Hydrology, Principles and Practices. Prentice-Hall, Upper Saddle River, NJ.

Sri Harto Bro. 2000. Hydrology: Theory, Problems, Solutions. Offset Trumpet. Yogyakarta

Sarminingsih, A. 2018. Selection of the Flood Discharge Analysis Method for the Coyo Reservoir Design, Grobogan Regency Precipitation Journal: Communication Media and Environmental Engineering Development, Vol. 15 No.1 March 2018.

Weibull, Waloddi. 1951. A Statistical Distribution Function of Wide Applicability. Journal of Applied fechanicu.