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Assessing the Remeneng River's Potential as a Sustainable Raw Water Source Using Water Balance and Pollution Index Approaches

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A B S T R A C T

This study aims to analyze the availability and quality of the Remeneng River, evaluate its potential in supporting PDAM drinking water services in Labuapi District, and formulate management directions for long-term sustainability. Water availability was assessed using the F.J. Mock rainfall-runoff model calibrated against AWLR Keru discharge data (2010-2018), with dependable discharge (Q90) determined through Weibull probability analysis. Water demand was projected using the arithmetic population growth method for 2025-2035, while water quality was evaluated using the Pollution Index method based on Government Regulation No. 22 of 2021. The F.J. Mock model showed a very strong correlation with measured discharge (r = 0.809). The Q90 ranged from 0.009 m³/s in August to 1.144 m³/s in February, with critical deficits occurring from July to October (<12 L/s). Population is projected to increase from 84,959 (2025) to 106,768 (2035), driving raw water demand from 143.30 L/s to 180.08 L/s, while the existing intake capacity of 104 L/s is insufficient to meet future demand. Water quality remained generally good (PI: 0.534-1.513), although iron and color exceeded standards during the wet season due to runoff and erosion. The integrated quadrant matrix revealed that only three months (April-June) represent ideal conditions, while four months (July-October) face critical deficits despite good water quality

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INTRODUCTION

Sustainable drinking water services depend on the ability of raw water sources to provide sufficient water quantity and maintain acceptable water quality over time. As a fundamental human need, clean water plays a crucial role in supporting public health, social welfare, and economic activities. Therefore, ensuring the sustainability of water supply systems has become a major concern in water resource management, particularly in areas experiencing rapid population growth and increasing water demand (Muta'ali, 2012).

The increasing pressure on water resources is closely associated with population growth, land-use change, seasonal variability, and climate-related hydrological fluctuations. These factors influence the availability of surface water and may reduce the reliability of rivers as raw water sources for drinking water services. Although Indonesia possesses substantial water resource potential, effective utilization remains constrained by spatial and temporal variability, highlighting the importance of assessing water resource carrying capacity to ensure sustainable use (Badan Pusat Statistik, 2017; Radhika et al., 2018).

One of the strategic raw water sources supporting drinking water services in West Lombok Regency is the Remeneng River, which is utilized by PDAM Giri Menang to supply clean water to communities in Labuapi District. The river originates from the Sesaot area and flows through several villages before reaching the intake structure that serves the Sembung Water Treatment Plant. With an estimated discharge of approximately 104 L s^{-1}, the Remeneng River represents one of the most important raw water sources within the service system (Apriansyah et al., 2025; Putri, 2024). Consequently, the sustainability of drinking water services in Labuapi is highly dependent on the river's capacity to continuously provide adequate and suitable raw water.

However, growing anthropogenic pressures have raised concerns regarding the long-term sustainability of the Remeneng River as a raw water source. Population growth within the surrounding area has increased the demand for clean water, while rapid urban development in Labuapi District has accelerated land-use conversion and settlement expansion. The number of PDAM service connections supplied by the Remeneng River increased from 15,380 connections in 2023 to 16,437 connections in 2025, indicating a continuous rise in water demand. At the same time, settlement areas expanded substantially between 2015 and 2023, reflecting increasing development pressures on the watershed environment (Al Hidayat, 2025; Badan Pusat Statistik Kabupaten Lombok Barat, 2024). In addition to quantity-related challenges, the river is also exposed to environmental pressures that may affect water quality and intake operations, including sediment accumulation and solid waste transported during high-flow conditions (Firmansyah, 2024).

Previous studies have widely applied water balance approaches to evaluate water resource potential by comparing water availability and water demand. These studies have successfully identified surplus and deficit conditions in various watersheds and water supply systems (Aalimah et al., 2022; Kurniasari et al., 2021; Widiyaningsih et al., 2021; Wintyaswan et al., 2022). Other studies have focused on dependable discharge analysis and projected water demand to assess the sustainability of water supply systems (Aprianto et al., 2026; Kurniawan et al., 2024; Nofitasari et al., 2024). Nevertheless, most existing studies emphasize quantitative aspects of water resources and rarely incorporate water quality conditions into potential assessments. Furthermore, limited studies have integrated water availability, water quality status, and drinking water demand within a single analytical framework for evaluating the potential of raw water sources in supporting public water supply services (Siwabessy et al., 2024; Wardana et al., 2024).

This study addresses that gap by focusing on the Remeneng River as a specific raw water source directly supporting PDAM services in a rapidly developing peri-urban area. The study contributes to knowledge enrichment by integrating dependable discharge analysis, water demand projection, water balance assessment, and water quality evaluation using the Pollution Index method within a unified potential assessment framework. Through this integrated approach, the study provides a more comprehensive assessment of raw water source potential than evaluations based solely on water quantity or water quality. Accordingly, this research aims to analyze the availability and quality of the Remeneng River, evaluate its potential in supporting PDAM drinking water services in Labuapi District, and formulate management directions that support the long-term sustainability of drinking water services.

LITERATURE REVIEW

Balance for Raw Water Availability Assessment

Water balance analysis is a fundamental approach for evaluating raw water availability by comparing water supply and water demand within a particular area. A surplus condition indicates that available water exceeds demand, whereas a deficit condition suggests that water resources are insufficient to meet existing needs (Admadhani et al., 2013; Tufaila et al., 2016). Water balance assessment has been widely used as an important tool for water resource planning and management, particularly in regions experiencing rapid population growth and increasing development pressures. Previous studies have demonstrated that water balance analysis can effectively identify the sustainability status of water resources and support decision-making for future water allocation (Maulina et al., 2022; Ningsih et al., 2020). Therefore, evaluating the balance between water availability and water demand is essential for determining the potential of raw water sources used for drinking water services.

Dependable Discharge as an Indicator of Water Availability

The availability of river water resources is generally assessed using dependable discharge, which represents the minimum river flow that can be expected to occur at a specified probability level. Unlike average discharge, dependable discharge emphasizes supply reliability and is therefore more suitable for evaluating raw water sources intended for continuous water supply services (Soemarto, 1987).

For drinking water systems, dependable discharge with a 90% exceedance probability (Q90) is commonly adopted because it represents flow conditions that can be maintained during most periods, including dry seasons. The use of Q90 reduces the risk of supply failure and provides a more reliable estimate of water availability for public water supply planning (Sarminingsih, 2023; Yekti et al., 2020). Several studies have successfully applied dependable discharge analysis to evaluate the sustainability of river-based water supply systems and to identify periods of potential water shortages (Sari et al., 2019; Yanidar et al., 2020).

Water Demand for Drinking Water Services

Water demand represents the quantity of water required to satisfy domestic and non-domestic activities. Domestic demand includes household water consumption for drinking, cooking, bathing, washing, and other daily activities, while non-domestic demand includes water use by public facilities, commercial establishments, educational institutions, healthcare facilities, and other socio-economic sectors (Salim, 2019).

Future water demand is commonly estimated using population projections combined with per capita water consumption standards. Population growth and urban development significantly influence the magnitude of water demand, particularly in rapidly developing areas. Consequently, water demand projections are essential components of sustainable water resource planning because they provide estimates of future pressure on available water resources and drinking water infrastructure (PUPR, 2020; Salim, 2019).

Water Quality Assessment and Pollution Index

In addition to water quantity, water quality is a critical determinant of the suitability of a river as a raw water source. Water quality is generally evaluated by comparing measured physical and chemical parameters with the applicable water quality standards established under Government Regulation No. 22 of 2021 Annex VI concerning Class I water quality standards for drinking water raw sources. Compliance with these standards indicates whether river water can be utilized for specific purposes, including drinking water supply.

The Pollution Index (PI) method, introduced through Ministerial Decree No. 115 of 2003, is one of the most widely applied approaches for assessing water quality status. The method evaluates the extent to which observed water quality parameters deviate from established standards and integrates these deviations into a single index value. As a result, the Pollution Index provides a practical and comprehensive measure of overall water quality conditions and facilitates the classification of water bodies into categories ranging from unpolluted to heavily polluted.

Previous studies have shown that pollution assessment is essential for identifying environmental pressures originating from domestic activities, urban development, agricultural runoff, and other anthropogenic sources that may compromise the suitability of water resources for drinking water purposes (Haque et al., 2024; Hossain et al., 2025). Therefore, evaluating water quality alongside water availability is necessary for achieving a comprehensive assessment of raw water sustainability.

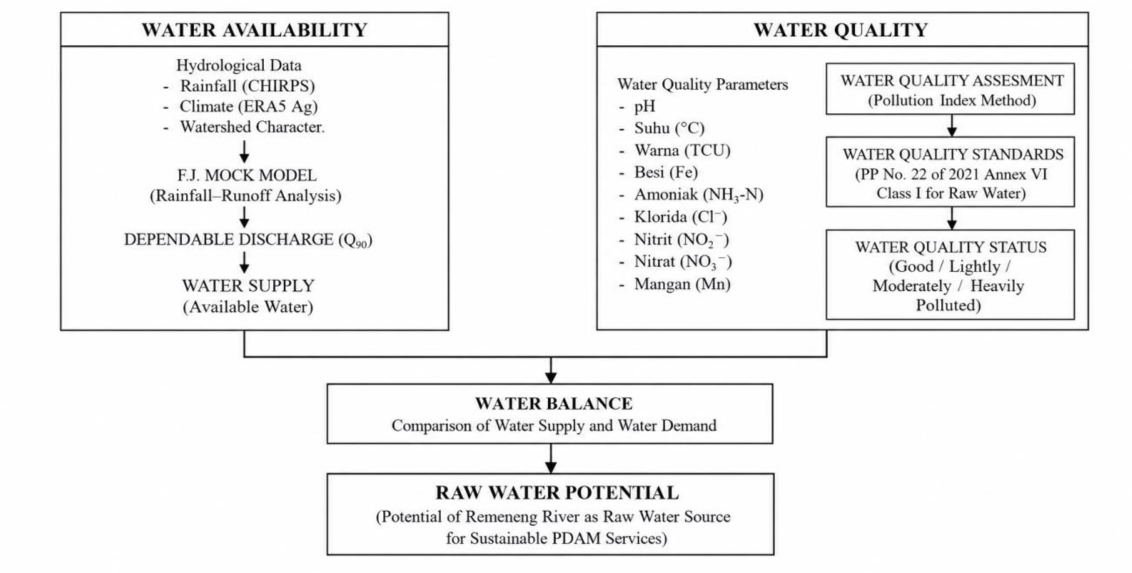

Figure 1. Conceptual Framework

METHODOLOGY

Research Data

The comprehensive datasets utilized in this study encompass water quality records, hydrometeorological parameters, watershed characteristics, and socioeconomic indicators.

Table 1. outlines the specific variables, their types, and data sources

Data Type	Variables	Source
Water quality data	pH, temperature, color, Fe, Mn, NH_3, Cl^-, NO_2^-, NO_3^-	PDAM Giri Menang historical records (2020-2025)
Rainfall data	Daily rainfall (mm/day)	CHIRPS (Climate Hazards Group InfraRed Precipitation with Station data) via Climate Engine
Climate data	Potential evapotranspiration (mm/day)	ERA5 Ag (ECMWF) via Climate Engine
Watershed characteristics	Catchment area, land use, soil type, slope	DEMNAS (BIG), Ministry of Agriculture, Ministry of Environment and Forestry
Population data	Number of inhabitants	Central Bureau of Statistics (BPS), Lombok Barat Regency
PDAM operational data	Number of connections, water consumption, intake discharge	PDAM Giri Menang (Perseroda)

Water Availability Analysis

Water availability was estimated using the F.J. Mock rainfall-runoff model. The model was calibrated against observed discharge data from the AWLR Keru station (period 2010-2018) using the Pearson correlation coefficient (r) to ensure simulation reliability. Daily rainfall (CHIRPS) and potential evapotranspiration (ERA5 Ag) data were processed to simulate monthly river discharge for the period 2010-2025.

The dependable discharge with 90% exceedance probability (Q90) was determined using the Weibull probability method through flow duration curve (FDC) analysis. The Weibull plotting position is expressed as follows:

$$P = \frac{m}{n + 1} \times 100\%$$

where:
P = probability of exceedance (%)
m = discharge rank (descending order)
n = total number of discharge observations

Water Demand Analysis

Future water demand was projected using the arithmetic population growth method, selected as the most representative method based on the lowest Mean Absolute Deviation (MAD) value. Domestic water demand was estimated based on the Water Supply System Planning Criteria issued by the Directorate General of Human Settlements (Direktorat Jenderal Cipta Karya, 1996), with a service coverage of 80%, per capita consumption of 110 L/person/day, non-domestic demand of 20%, and distribution losses of 20%. Total raw water demand was converted into liters per second (L/s) and compared with the dependable discharge (Q90) to evaluate the water balance for the period 2025-2035.

Water Quality Analysis

Water quality status was evaluated using the Pollution Index (PI) method based on the Decree of the Minister of Environment No. 115 of 2003. The Pollution Index was calculated using the following mathematical expression:

$$PI_j = \sqrt{\frac{\left(\frac{C_i}{L_{ij}}\right)^2_M + \left(\frac{C_i}{L_{ij}}\right)^2_R}{2}}$$

where:
PI_j = Pollution Index for water use j
C_i = measured concentration of parameter i
L_{ij} = water quality standard of parameter i for water use j
M = maximum value of C_i/L_{ij}
R = average value of C_i/L_{ij}

The measured parameters were compared with the Class I water quality standards specified in Government Regulation No. 22 of 2021 (Annex VI) for drinking water raw sources.

Table 2. Pollution Index Classification

PI Value	Water Quality Status
PI ≤ 1.0	Good (meets water quality standards)
1.0 < PI ≤ 5.0	Lightly polluted
5.0 < PI ≤ 10.0	Moderately polluted
PI > 10.0	Heavily polluted

Source: Decree of the Minister of Environment No. 115 of 2003

Integrated Water Availability and Water Quality Assessment

Tabel 3. Integrated Water Availability and Water Quality Matrix

Quadrant	Classification
I	Water Deficit - Good Water Quality
II	Water Deficit - Poor Water Quality (Critical)
III	Water Surplus - Poor Water Quality
IV	Water Surplus - Good Water Quality (Ideal)

The classification is adapted from the *One Out, All Out* concept (UNEP, 2020), which integrates water availability and water quality into a single assessment. A water resource is considered ideal only when both quantity and quality meet the required criteria, whereas failure in either component indicates a less favorable condition requiring management attention.

RESEARCH RESULT

Water Availability Assessment

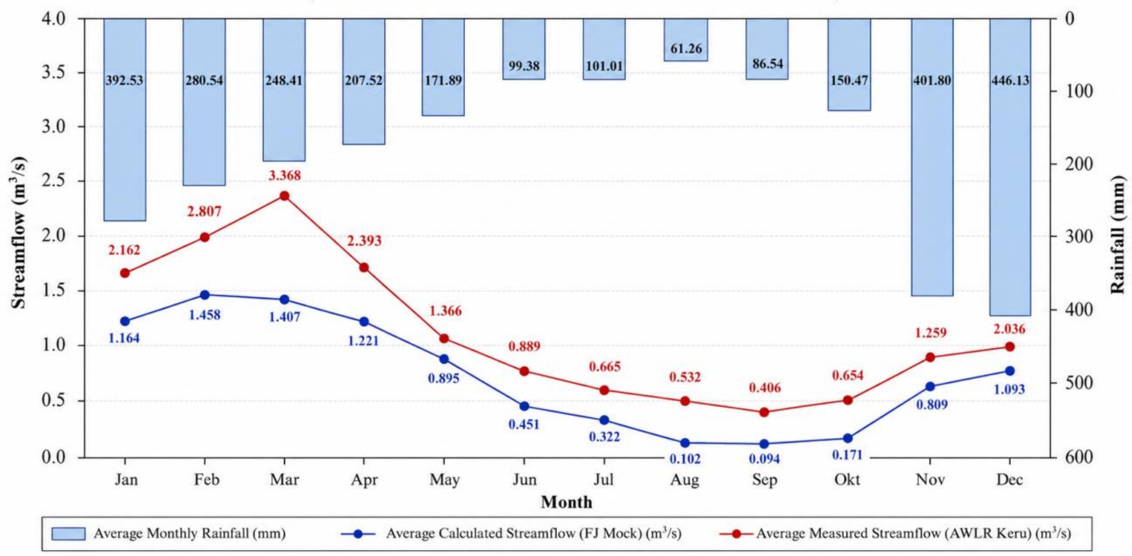

Figure 2. Monthly hydrograph of average rainfall, calculated streamflow (F.J. Mock), and measured streamflow (AWLR Keru)

The F.J. Mock model simulation results showed a very strong correlation with the measured discharge, with a Pearson correlation coefficient of 0.809 (80.9%).

Table 3. F.J. Mock Model Streamflow Probability (m^3/s)

P(%)	Jan	Feb	Mar	Apr	Mei	Jun	Jul	Agu	Sep	Okt	Nov	Des
5.88	1.690	2.058	1.752	1.687	1.638	1.394	1.492	0.510	0.646	1.065	1.459	1.726
11.76	1.617	1.706	1.665	1.580	1.430	0.607	0.627	0.420	0.368	0.574	1.139	1.568
17.65	1.483	1.675	1.598	1.541	1.369	0.551	0.602	0.273	0.299	0.554	1.091	1.513
23.53	1.366	1.643	1.557	1.493	1.293	0.508	0.509	0.112	0.030	0.270	1.073	1.278
29.41	1.266	1.573	1.492	1.460	1.213	0.501	0.304	0.108	0.019	0.120	1.065	1.083

35.29	1.252	1.486	1.456	1.285	1.007	0.474	0.298	0.071	0.019	0.018	0.965	1.069
41.18	1.231	1.484	1.446	1.210	0.948	0.472	0.264	0.018	0.019	0.018	0.904	1.043
47.06	1.227	1.465	1.421	1.149	0.792	0.463	0.246	0.018	0.017	0.018	0.732	0.995
52.94	1.204	1.451	1.389	1.145	0.739	0.424	0.223	0.016	0.017	0.016	0.683	0.977
58.82	1.202	1.375	1.344	1.105	0.675	0.330	0.195	0.016	0.015	0.014	0.679	0.974
64.71	1.001	1.368	1.330	1.100	0.600	0.327	0.143	0.014	0.013	0.014	0.667	0.918
70.59	0.966	1.344	1.307	1.076	0.599	0.297	0.132	0.013	0.013	0.013	0.642	0.914
76.47	0.894	1.263	1.303	1.071	0.574	0.277	0.074	0.013	0.013	0.013	0.558	0.898
82.35	0.850	1.214	1.296	1.058	0.550	0.277	0.014	0.011	0.013	0.013	0.489	0.882
88.24	0.766	1.203	1.081	0.946	0.449	0.260	0.013	0.009	0.011	0.011	0.486	0.843
94.12	0.595	1.006	1.066	0.631	0.445	0.064	0.009	0.009	0.009	0.011	0.321	0.796
90	**0.715**	**1.144**	**1.076**	**0.852**	**0.448**	**0.202**	**0.012**	**0.009**	**0.011**	**0.011**	**0.436**	**0.829**

The Q90 dependable discharge of the Remeneng River ranged from 0.009 m³/s to 1.144 m³/s. The highest discharge occurred in February, while the lowest discharge occurred in August.

Population Projection

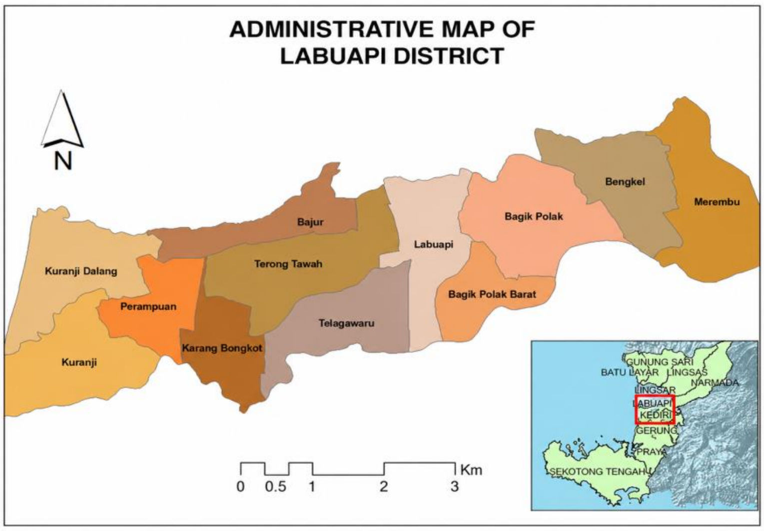

Figure 3. Administrative Map of Labuapi District

Table 4. Population Projection 2025-2035

Years	Actual Population	Arithmetic	Eksponential	Geometric
2016	65.331	65.331	65.331	65.331
2017	65.978	67.512	67.266	67.266
2018	66.598	69.693	69.258	69.258
2019	67.195	71.874	71.310	71.310
2020	78.960	74.055	73.422	73.422
2021	79.932	76.235	75.597	75.597
2022	81.214	78.416	77.836	77.836
2023	84.345	80.597	80.141	80.141
2024	83.728	82.778	82.515	82.515
2025	84.959	84.959	84.959	84.959
2026	-	87.140	87.475	87.475
2027	-	89.321	90.066	90.066
2028	-	91.502	92.734	92.734
2029	-	93.683	95.481	95.481
2030	-	95.863	98.309	98.309
2031	-	98.044	101.221	101.221
2032	-	100.225	104.219	104.219
2033	-	102.406	107.306	107.306
2034	-	104.587	110.484	110.484
2035	-	106.768	113.756	113.756
Korelasi (r)	-	0,9408	0,9402	0,9402
Standar Error	-	2.982,22	3.214,64	3.214,63

The arithmetic method produced the lowest standard error and was selected for population projection. The population of Labuapi District is projected to increase from 84,959 people in 2025 to 106,768 people in 2035.

Raw Water Demand Projection

Table 5. Raw Water Demand Projection 2025-2035

Tahun	Population	%Services	Qdomestic (L/day)	NRW (L/day)	Qnon-dom (L/day)	Average (L/day)	Maks Day (L/day)	Qd (L/s)
2025	84,959	67,967	7,476,392	1,794,334	1,495,278	10,766,004	12,380,905	143.30
2027	89,321	71,457	7,860,248	1,886,460	1,572,050	11,318,757	13,016,571	150.65
2030	95,863	76,690	8,435,944	2,024,627	1,687,189	12,147,759	13,969,923	161.69
2032	100,225	80,180	8,819,800	2,116,752	1,763,960	12,700,512	14,605,589	169.05
2035	106,768	85,414	9,395,584	2,254,940	1,879,117	13,529,641	15,559,087	180.08

The projected raw water demand increased from 143.30 L/s in 2025 to 180.08 L/s in 2035. The increase follows the projected population growth during the planning period.

Table 6. Water Availability and Demand Ratio

Bulan	Q_{90} (m^3/s)	Qd_{2025}	Ratio	Qd_{2027}	Ratio	D_{2030}	Qd	D_{2032}	Ratio	Qd_{2035}	Ratio
Jan	0,715	0,143	+	0,151	+	0,162	+	0,169	+	0,180	+
Feb	1,144	0,143	+	0,151	+	0,162	+	0,169	+	0,180	+
Mar	1,076	0,143	+	0,151	+	0,162	+	0,169	+	0,180	+
Apr	0,852	0,143	+	0,151	+	0,162	+	0,169	+	0,180	+
Mei	0,448	0,143	+	0,151	+	0,162	+	0,169	+	0,180	+
Jun	0,202	0,143	+	0,151	+	0,162	+	0,169	+	0,180	+
Jul	0,012	0,143	-	0,151	-	0,162	-	0,169	-	0,180	-
Agu	0,009	0,143	-	0,151	-	0,162	-	0,169	-	0,180	-
Sep	0,011	0,143	-	0,151	-	0,162	-	0,169	-	0,180	-
Okt	0,011	0,143	-	0,151	-	0,162	-	0,169	-	0,180	-
Nov	0,436	0,143	+	0,151	+	0,162	+	0,169	+	0,180	+
Des	0,829	0,143	+	0,151	+	0,162	+	0,169	+	0,180	+

+ = Surplus; - = Deficit

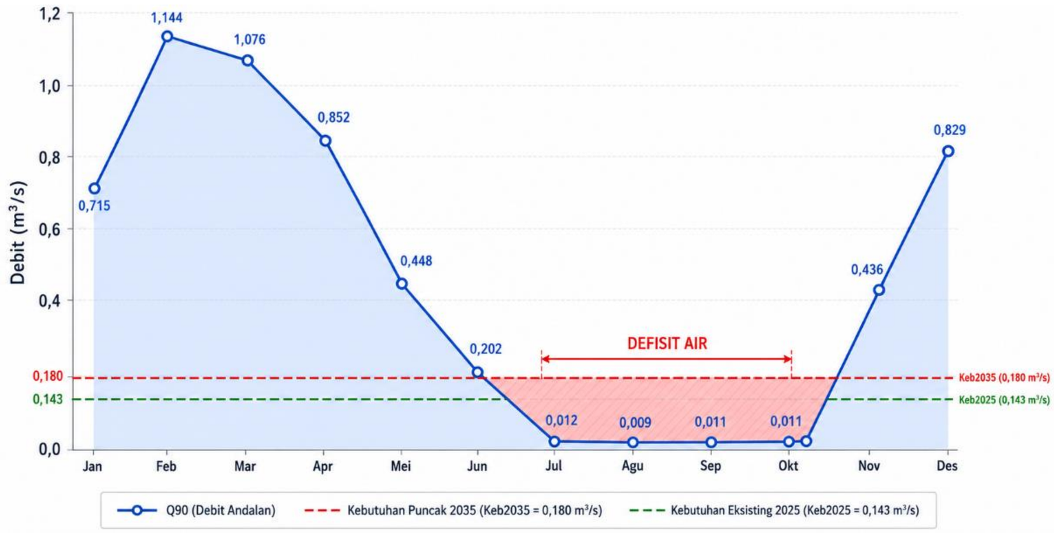

Figure 4. Comparison between Q90 and Water Demand

Most months from November to June exhibit a considerable water surplus, as the Q90 discharge exceeds both the existing intake discharge and future water demand projections. However, during the dry season (July-October), the available discharge falls significantly below the projected demand, indicating a potential water deficit and highlighting the need for water resource management strategies during low-flow periods.

Water Quality Assessment

Water quality assessment was conducted using nine parameters, namely pH, temperature, color, iron, ammonia, chloride, nitrite, nitrate, and manganese. The measured values were compared with Government Regulation No. 22 of 2021.

Table 7. Seasonal Water Quality Monitoring Results (2020-2025)

Tanggal	Season	pH	Suhu	Warna	Fe	NH_3	Cl^-	NO_2^-	NO_3^-	Mn
28/03/2020	Wet	7,1	29	15	0,42	0,09	7,1	0,038	2,1	0,13
15/08/2020	Dry	7,3	28	8	0,21	0,06	5,8	0,028	1,6	0,09
10/02/2021	Wet	6,9	29	10	0,38	0,07	6,9	0,033	1,9	0,12
02/07/2021	Dry	7,2	28	10	0,187	0,05	6,2	0,029	1,7	0,117
20/01/2022	Wet	7,0	30	18	0,51	0,11	8,3	0,044	2,4	0,16
18/09/2022	Dry	7,4	27	7	0,18	0,05	5,5	0,024	1,5	0,08
05/02/2023	Wet	6,8	30	20	0,55	0,13	8,7	0,047	2,6	0,18
10/08/2023	Dry	7,3	28	9	0,22	0,06	6,0	0,027	1,8	0,10
15/03/2024	Wet	7,0	29	16	0,47	0,10	7,8	0,041	2,2	0,15
22/09/2024	Dry	7,5	27	6	0,16	0,04	5,3	0,022	1,4	0,07
18/02/2025	Wet	6,9	30	22	0,58	0,14	9,1	0,050	2,8	0,19
05/09/2025	Dry	7,4	28	8	0,20	0,05	5,7	0,026	1,6	0,09
Quality Standard		6-9	Dev 3	15	0,3	0,1	300	0,06	10	0,1

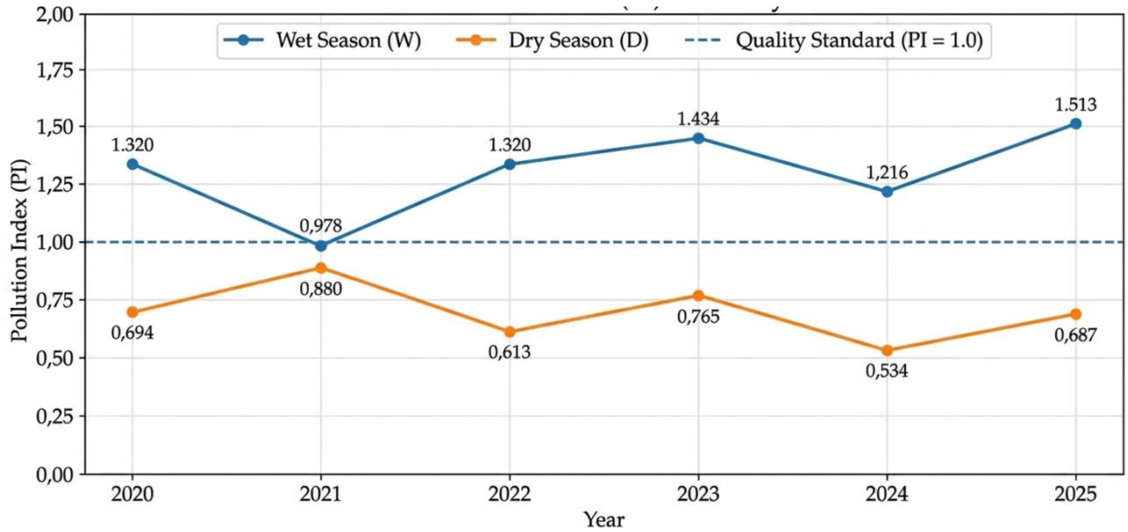

Figure 5. Pollution Index in Wet and Dry Seasons

Integrated Water Availability and Water Quality Assessment

Table 8. Summary of Quadrant Classification by Year

Quadrant	2025	2030	2035
Quadrant I (Deficit-Good Quality)	4 (Jul, Aug, Sep, Oct)	4 (Jul, Aug, Sep, Oct)	4 (Jul, Aug, Sep, Oct)
Quadrant II (Deficit-Poor Quality / Critical)	-	-	-
Quadrant III (Surplus-Poor Quality)	5 (Jan, Feb, Mar, Nov, Dec)	5 (Jan, Feb, Mar, Nov, Dec)	5 (Jan, Feb, Mar, Nov, Dec)
Quadrant IV (Surplus-Good Quality / Ideal)	3 (Apr, May, Jun)	3 (Apr, May, Jun)	3 (Apr, May, Jun)

The quadrant classification remained unchanged across the 2025, 2030, and 2035 scenarios because the assessment was based on the same seasonal pattern of water quality and historical Q90 water availability, while only the projected water demand varied between scenarios.

DISCUSSION

Water Availability and Quality of the Remeneng River

The F.J. Mock model was successfully calibrated using discharge data from AWLR Keru (2010-2018), yielding a Pearson correlation coefficient of 0.809 (80.9%) (Figure 2), indicating a very strong relationship between simulated and observed discharge. Based on Table 4, the Q90 dependable discharge ranged from 0.009 m^3/s in August to 1.144 m^3/s in February, demonstrating pronounced seasonal variability. The highest discharges occurred during the wet season (November-March), while the lowest values were recorded between June and October (0.009-0.202 m^3/s), indicating that river flow is strongly governed by rainfall distribution within the watershed. This pattern is characteristic of tropical monsoonal river systems (Mathew et al., 2021; Wang et al., 2024).

The extremely low dry-season Q90 values are primarily attributed to the physical characteristics of the catchment, which is dominated by Regosol and Litosol soils (Figure 4.1). These soils have high permeability and rapid drainage but low water-holding capacity, causing rainwater to infiltrate quickly without prolonged storage to sustain baseflow during dry periods (Baskoro & Tarigan, 2007; Syukur, 2012). As a result, groundwater storage that contributes to baseflow becomes limited, and river discharge declines drastically after the rainy season ends (Mulyono et al., 2023; Sayama et al., 2021). The rapid response of this small catchment (10.05 km^2) to rainfall events means that once the rainy season ceases, the limited soil moisture storage is quickly depleted.

The extremely low dry-season discharge observed in the Remeneng River is consistent with hydrological patterns documented in other catchments across West Nusa Tenggara Province. Yasa et al. (2023) found that catchments in Bima Regency experience dry periods lasting 8-9 months with maximum deficits reaching 1.09 m^3/s. Similarly, Indrawati et al. (2021) documented that small semi-arid catchments in Sumbawa respond rapidly to rainfall, with streamflow declining sharply once precipitation ceases, while Putranto et al. (2023) confirmed that prolonged low inflows are a persistent feature of the region's hydrological regime. The Q90 value of the Remeneng River (<12 L/s during the critical dry months) is therefore consistent with the behavior of other small, seasonal catchments in NTB's semi-arid climate, reflecting the combined effects of seasonal rainfall patterns, limited groundwater storage capacity, and the physical characteristics of small catchments in this region.

In terms of water quality, Table 8 shows that most measured parameters remained within the Class I standards of Government Regulation No. 22 of 2021. The Pollution Index (Figure 5) ranged from 0.534 during the dry season to 1.513 during the wet season, indicating "good" status ($PI \leq 1.0$) during most dry-season observations and "lightly polluted" status ($1.0 < PI \leq 5.0$) during wet-season events. However, color (up to 22 TCU) and iron (Fe) concentrations (up to 0.58 mg/L) consistently exceeded the standards during the wet season. These exceedances are primarily attributed to surface runoff, soil erosion, and mobilization of naturally occurring iron-rich minerals from the catchment during high-rainfall events (Han et al., 2021; Kritzberg & Ekström, 2011). The dominance of Fe and color contributions to the PI values (C_i/L_{ij} ratios of 1.400-1.933 for Fe and 1.000-1.467 for color) confirms that wet-season water quality degradation is driven by erosion and sediment transport processes rather than continuous point-source pollution (Marselina & Nurhayati, 2025; Yustika et al., 2019). Conversely, during the dry season, all parameters remained within acceptable limits, with PI values consistently below 1.0, indicating stable and good water quality.

Potential of the Remeneng River in Supporting PDAM Drinking Water Services

Population projection using the arithmetic method (Table 5), selected based on the lowest standard error (2,982.22) and highest correlation (0.9408), estimates that the population of Labuapi District will increase from 84,959 inhabitants in 2025 to 106,768 inhabitants in 2035. This demographic growth drives an increase in raw water demand (Table 6) from 143.30 L/s in 2025 to 180.08 L/s in 2035, reflecting domestic consumption (110 L/person/day), non-domestic demand (20%), and distribution losses (20%). The existing intake capacity of 104 L/s is already below the projected demand for all planning years, indicating that current abstraction infrastructure is insufficient to meet future water requirements.

The water balance analysis (Table 7 and Figure 4) reveals a distinct seasonal pattern. Surplus conditions occur from November to June (eight months), while deficit conditions prevail from July to October (four months). In 2025, the surplus ranges from 0.059 m^3/s (June) to 1.001 m^3/s (February), while the deficit ranges from -0.131 m^3/s (August) to -0.134 m^3/s (July). By 2035, the surplus margins diminish, particularly in June (reduced to 0.022 m^3/s), while deficits worsen to -0.171 m^3/s in August. Critically, even in 2025, the Q90 during July-October (0.009-0.012 m^3/s) falls dramatically below the existing intake capacity of 104 L/s (0.104 m^3/s), indicating that the river cannot reliably supply even the current abstraction rate during the dry season.

The persistent deficit pattern across all planning years (2025-2035) indicates that the water shortage is not a temporary phenomenon but a structural imbalance between seasonal hydrological availability and year-round demand. This pattern is consistent with findings from other Indonesian catchments. In the Mayang Watershed, East Java, Sihombing et al. (2021) found that unmet demand occurred continuously from May to December, peaking in October at 0.67 million m^3. Similarly, Basri et al. (2023) documented that the Krueng Jrue sub-watershed in Aceh experienced recurring deficits during June-September, with 4-5 consecutive months of water availability below 3 m^3/s during dry years. Both studies confirm that monsoon-driven catchments in Indonesia commonly experience water deficits during the dry season when rainfall decreases but water demand, driven by domestic consumption, irrigation, and other sectors, remains high.

The deficit pattern in the Remeneng River is closest to the Krueng Jrue case in terms of seasonal timing (June-September), while the Mayang case shows a longer deficit window (May-December). Nationally, Illahi et al. (2025) confirmed that seasonal water stress is concentrated during the dry season in Java, Bali, NTB, and NTT, where low precipitation coincides with peak demand. The pressure is further intensified by population growth, which increases per capita consumption and total water demand (Afifah, 2019; Illahi et al., 2025). In

Bengawan Solo, Trinugroho et al. (2024) showed that dry years are characterized by consistently low monthly water balance and rapidly declining discharge after the early wet-season peak. The Remeneng River therefore exemplifies the seasonal mismatch typical of tropical monsoon regions: water availability declines sharply during the late dry season, while domestic and irrigation demands do not decline proportionally, resulting in recurring annual deficits.

Management Directions for Long-Term Sustainability

The integrated quadrant matrix (Table 3 and Table 9), adapted from the "One Out, All Out" principle (UNEP, 2020), provides a comprehensive evaluation by combining water quantity (surplus/deficit) and water quality (good/polluted). The classification reveals that only three months (April-June) fall into Quadrant IV (Ideal), where water quantity exceeds demand and quality meets standards. Five months (January-March, November-December) fall into Quadrant III (Surplus + Poor Quality), where water is abundant but requires intensive treatment due to elevated Fe and color. Four months (July-October) fall into Quadrant I (Deficit + Good Quality), representing the critical period requiring alternative supply. No months fall into Quadrant II (Critical), indicating no simultaneous failure of both quantity and quality. This demonstrates that the Remeneng River's potential as a raw water source is seasonally constrained, with the critical dry-season deficit posing the greatest threat to supply continuity.

Based on this classification, three strategic management directions are recommended to ensure the long-term sustainability of drinking water services. First, the critical dry-season deficit during July-October (Quadrant I) requires the development of dry-season storage. Since water quality during this period is good (PI < 1.0), the primary challenge is quantity. Studies in Indonesia have demonstrated the effectiveness of small-farm reservoirs (embung) in capturing wet-season rainfall for use during dry periods. In Gondangrejo, Central Java, five small reservoirs successfully harvested 10.4%-30.6% of total rainfall, with sufficient water to support dry-season cultivation of rice and shallots even during four short drought events (Ariyanto & Yoshiyama, 2016). For the Remeneng River, the substantial wet-season surplus (e.g., 1.001 m^3/s surplus in February 2025) could potentially be stored to bridge the four-month dry-season deficit. The identification of suitable sites for rainwater harvesting ponds in Indonesia's semi-arid regions using GIS-based methods (Patrisius et al., 2023) provides a practical approach for implementing such storage solutions in NTB.

Second, wet-season water quality degradation during January-March and November-December (Quadrant III) requires watershed conservation and treatment optimization. The elevated Fe and color concentrations during wet seasons are primarily driven by surface runoff and erosion processes. Integrated watershed management combining land-use planning, reforestation, agroforestry, and water retention infrastructure has been shown to reduce dry-season deficits significantly. In the Upper Cisadane sub-watershed, West Java, a combination of spatial planning, reforestation of converted forest areas, agroforestry, and a 30 MCM reservoir reduced the duration of dry-season deficits from 5 to 4 months and reduced deficit intensity by 72% (Hidayat et al., 2024). For the Remeneng catchment, upstream reforestation, erosion control, and riparian zone restoration could reduce sediment and iron loads entering the river, thereby improving wet-season water quality and reducing treatment costs. Additionally, conservation practices in the Garang Hulu watershed, Semarang, demonstrated that participatory conservation with pond construction reduced runoff potential to only 26.5% of pre-intervention conditions (Basuki et al., 2022). These findings confirm that watershed conservation is an effective strategy for managing both water quality and quantity.

Third, demand-side management and infrastructure development are essential to address the growing water demand. The existing intake capacity of 104 L/s is below the projected demand of 143.30 L/s in 2025, necessitating capacity expansion. However, capacity expansion alone is insufficient without complementary measures. Reduction of non-revenue water (NRW), currently at 20%, could provide additional water equivalent to 28.66 L/s in 2025 and 36.02 L/s in 2035. Although direct evidence of NRW reduction success is limited in the available literature (Nugroho et al., 2022), water conservation campaigns, progressive tariff structures, and diversified water supply portfolios are widely recommended strategies for reducing pressure on single-source surface water systems (Masduqi, 2020; Tan, 2026). For eastern Indonesian semi-arid regions, rainwater harvesting is broadly recommended as a dry-season strategy (Masduqi, 2020; Tan, 2026), reinforcing the relevance of embung development for the Remeneng catchment.

In summary, maintaining the long-term sustainability of drinking water services in Labuapi District requires an integrated approach combining: (1) dry-season storage development (embung or small reservoirs) to capture wet-season surplus; (2) watershed conservation through reforestation, erosion control, and land-use management to reduce wet-season sediment and iron loads; and (3) demand-side management including NRW reduction, water conservation, and capacity expansion. This integrated strategy aligns with the broader framework of sustainable water resource management in Indonesia, which emphasizes balancing supply enhancement, demand management, and watershed conservation to improve long-term resilience under increasing environmental and demographic pressures (Basuki et al., 2022; Nugroho et al., 2022).

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

The Remeneng River demonstrates adequate water quality for raw water purposes, with most parameters meeting Class I standards and Pollution Index values ranging from 0.534 to 1.513, although seasonal exceedances of iron and color during the wet season require treatment optimization. However, its carrying capacity to support PDAM drinking water services is severely constrained by a structural imbalance between seasonal hydrological availability and growing water demand, as the dependable discharge (Q90) ranges from 0.009 m^3/s during the dry season to 1.144 m^3/s during the wet season, while projected water demand increases from 143.30 L/s in 2025 to 180.08 L/s in 2035. The water balance assessment reveals that surplus conditions occur from

November to June, but critical deficits persist from July to October, with the river unable to supply even the existing intake capacity of 104 L/s during the dry season, a pattern consistent with other monsoon-driven catchments in Indonesia. Maintaining sustainable drinking water services therefore requires integrated management strategies that address the critical dry-season deficit, manage wet-season water quality degradation, and moderate growing demand through a combination of storage development, watershed conservation, demand management, and infrastructure expansion.

Recommendations

To ensure long-term water security, PDAM Giri Menang should implement an integrated strategy that prioritizes the development of dry-season storage infrastructure, such as small reservoirs or embung, to capture wet-season surplus for use during the critical July-October deficit period, complemented by upstream watershed conservation measures including reforestation, erosion control, and riparian restoration to reduce wet-season sediment and iron loads and maintain baseflow. Demand-side management through non-revenue water reduction (currently 20%), water conservation campaigns, and progressive tariff structures should be pursued alongside intake capacity expansion and diversification of water sources to reduce dependence on a single surface water system, while continuous monitoring and climate-adaptive planning are essential to anticipate future changes in hydrological conditions and ensure the long-term resilience of drinking water services in Labuapi District.

ADVANCED RESEARCH

Future research should incorporate climate change projections to assess their impacts on river discharge reliability and water availability. Additional studies on groundwater-surface water interactions are needed to better understand dry-season baseflow contributions and potential alternative water sources. Spatial water quality assessments are also recommended to identify pollutant sources within the watershed and support more effective management strategies. Furthermore, the feasibility of rainwater harvesting systems should be evaluated as a supplementary water supply option to reduce pressure on the existing PDAM infrastructure.

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REFERENCES

Aalimah, R. A., Suryadi, E., & Perwitasari, S. D. N. (2022). Analisis status daya dukung air di Sub-DAS Cikeruh berdasarkan neraca air meteorologis Thornthwaite-Mather. Jurnal Agritechno, 15(1), 25-34. https://doi.org/10.20956/at.v15i1.505

Admadhani, D. N., Hajil, A. H. S., & Susanawati, L. D. (2013). Analysis of Water Supply and Water Demand for Carrying Capacity Assessment (Case Study of Malang). Jurnal Sumberdaya Alam Dan Lingkungan, 13-20.

Afifah, E. (2019). THE RELIABILITY STUDY OF RAW WATER SOURCES IN THE DEVELOPMENT OF POTABLE WATER SUPPLY SYSTEMS IN INDONESIA. International Journal of GEOMATE. https://doi.org/10.21660/2019.54.75034

Al Hidayat, M. G. I. (2025). Analisis alih fungsi lahan menjadi permukiman dan dampaknya terhadap stok karbon di Kecamatan Labuapi Kabupaten Lombok Barat. Universitas Islam Indonesia.

Apriansyah, R., Oktavia, L., & Yansyah, E. J. (2025). Analisis Kualitas Sumber Mata Air Berdasarkan Parameter Fisika dan Parameter Kimia. Jurnal 'Aisyiyah Medika, 10(1), 86-100.

Aprianto, K. A., Yastika, P. E., Sudipa, I. N., & Partama, I. G. Y. (2026). Analisis daya dukung air untuk pemenuhan kebutuhan air bersih pada sistem penyediaan air minum regional Buleleng-Jembrana (SPAM Burana). REGION: Jurnal Pembangunan Wilayah Dan Perencanaan Partisipatif, 21(1), 260-281. https://doi.org/10.20961/region.v21i1.92997

Ariyanto, D. P. D., & Yoshiyama, K. (2016). Small-Farm Reservoir Contribution to Annual Crop Cultivation in Rainfed Paddy Field under Tropical Monsoon Climate. *Journal of Rainwater Catchment Systems*, *21*(2), 1-6. https://doi.org/10.7132/jrcsa.21_2_1

Badan Pusat Statistik Kabupaten Lombok Barat. (2024). Kecamatan Narmada dalam angka 2024 [Narmada District in Figures 2024]. https://lombokbaratkab.bps.go.id/id/publication/2024/09/26/748126d83bf8bfc107a142f8/kecamatan-narmada-dalam-angka-2024.html

Badan Pusat Statistik. (2017). Statistik Lingkungan Hidup Indonesia 2017. https://www.bps.go.id/id/publication/2017/12/21/4acfbaac0328ddfcf8250475/statistik-lingkungan-hidup-indonesia-2017.html

Basri, H., Sufardi, S., Helmi, H., Syakur, S., Sugianto, S., Azmeri, A., & Helmi, H. (2023). Drought and water availability analysis for irrigation and household water needs in the Krueng Jrue sub-watershed. PeerJ,

11. https://doi.org/10.7717/peerj.14830

Basuki, T. M., Nugroho, H. Y., Indrajaya, Y., Pramono, I. B., Nugroho, N., Supangat, A., Indrawati, D. R., Savitri, E., Wahyuningrum, N., P., Cahyono, S., Putra, P. B., Adi, R. N., Nugroho, A., Auliyani, D., Wuryanta, A., Riyanto, H., Harjadi, B., Yudilastyantoro, C., ... Simarmata, D. (2022). Improvement of Integrated Watershed Management in Indonesia for Mitigation and Adaptation to Climate Change: A Review. *Sustainability*, *14*(16), 9997. https://doi.org/10.3390/su14169997

Bhagat, H., Ghosh, P., & Kumar, D. (2021). Estimation of seasonal base flow contribution to a tropical river using stable isotope analysis. Journal of Hydrology, 601, 126661. https://doi.org/10.1016/j.jhydrol.2021.126661

Cao, X., Cyuzuzo, C. M., Saiken, A., & Song, B. (2021). A linear additivity water resources assessment indicator by combining water quantity and water quality. Ecological Indicators, 121, 106990. https://doi.org/10.1016/j.ecolind.2020.106990

Devineni, N., Perveen, S., & Lall, U. (2013). Assessing chronic and climate-induced water risk through spatially distributed cumulative deficit measures: A new picture of water sustainability in India. Water Resources Research, 49(4), 2135-2145. https://doi.org/10.1002/wrcr.20184

Gule, T. T., Lemma, B., & Hailu, B. (2024). Factors impacting water quality and quantity in rapidly expanding urban areas based on the DPSIR model: Experiences and challenges from Addis Ababa City, Ethiopia. Environmental Science and Pollution Research, 31, 22131-22144. https://doi.org/10.1007/s11356-024-32550-4

Han, G., Yang, K., Zeng, J., & Zhao, Y. (2021). Dissolved iron and isotopic geochemical characteristics in a typical tropical river across the floodplain: The potential environmental implication. Environmental Research, 197, 111452. https://doi.org/10.1016/j.envres.2021.111452

Haque, A., Holsen, T. M., & Baki, A. B. M. (2024). Distribution and risk assessment of microplastic pollution in a rural river system near a wastewater treatment plant, hydro-dam, and river confluence. Scientific Reports, 14, 6006. https://doi.org/10.1038/s41598-024-56730-x

Heidari, H., Arabi, M., & Warziniack, T. (2021). Vulnerability to water shortage under current and future water supply-demand conditions across U.S. river basins. Earth's Future, 9(9), e2021EF002278. https://doi.org/10.1029/2021EF002278

Hidayat, Y., Rachman, L., Wahjunie, E. D., Baskoro, D. P. T., Purwakusuma, W., Yusuf, S. M., & Araswati, F. D. (2024). Water Balance Prediction by Simulating Land Use Planning and Water Retention Infrastructure in Upper Cisadane Sub-Watershed, West Java, Indonesia. *Jurnal Pengelolaan Sumberdaya Alam dan Lingkungan (Journal of Natural Resources and Environmental Management)*, *14*(2), 415. https://doi.org/10.29244/jpsl.14.2.415

Hossain, M. M., Jahan, I., Dar, M. A., Dhanavade, M. J., Mamtaz, A. F. B., Maxwell, S. J., & Zhu, D. (2025). A review of potentially toxic elements in sediment, water, and aquatic species from river ecosystems. Toxics, 13(1), 26. https://doi.org/10.3390/toxics13010026

Illahi, Y. R., Magome, J., Souma, K., & Ishidaira, H. (2025). MONTHLY WATER BUDGET AND STRESS INDEX FOR WATER SECURITY ASSESSMENT DUE TO SEASONAL RAINFALL VARIABILITY IN INDONESIA. Journal of JSCE. https://doi.org/10.2208/journalofjsce.25-27034

Indrawati, D., Ganguly, A., Taruc, K., & Yakti, B. (2021). Streamflow Estimation Using Regionalized Hydrometeorological Assessment on Associated Ungauged Small Watershed: A Case Study at West Nusa Tenggara Province. *Proceedings of the 2nd International Seminar of Science and Applied Technology (ISSAT 2021)*. https://doi.org/10.2991/aer.k.211106.018

Kritzberg, E. S., & Ekström, S. M. (2011). Increasing iron concentrations in surface waters - A factor behind brownification? Biogeosciences, 9(4), 1465-1478. https://doi.org/10.5194/bg-9-1465-2012

Kurniasari, Y. D., Arifin, H. S., & Purwanto, M. Y. (2021). Analisis neraca air dan prasaran tampungan air di DAS Ciujung. Jurnal Ilmu Lingkungan, 19(2), 227-235. https://doi.org/10.14710/jil.19.2.227-235

Kurniawan, T. A., Bandala, E. R., Othman, M. H. D., Goh, H. H., Anouzla, A., Chew, K. W., Aziz, F., Al-Hazmi, H. E., & Nisa'ul Khoir, A. (2024). Implications of climate change on water quality and sanitation in climate hotspot locations: A case study in Indonesia. Water Supply, 24(2), 517-542. https://doi.org/10.2166/ws.2024.008

Li, W., Jiang, S., Zhao, Y., Li, H., Zhu, Y., Ling, M., Qi, T., He, G., Yao, Y., & Wang, H. (2023). Comprehensive evaluation and scenario simulation of water resources carrying capacity: A case study in Xiong'an New Area, China. Ecological Indicators, 155, 110253. https://doi.org/10.1016/j.ecolind.2023.110253

Masduqi, A. (2020). Solution to Water Scarcity in the Eastern Indonesia: A Case Study of the Lembata Regency. *International Journal of GEOMATE*, *19*(71). https://doi.org/10.21660/2020.71.30531

Mathew, M., K, S., Mathew, M., Arulbalaji, P., & Padmalal, D. (2021). Spatiotemporal variability of rainfall and its effect on hydrological regime in a tropical monsoon-dominated domain of Western Ghats, India. Journal of Hydrology: Regional Studies, 37, 100861. https://doi.org/10.1016/j.ejrh.2021.100861

Maulina, S. M., Christiana, R., & Widodo, M. L. (2022). Analisis curah hujan untuk pendugaan debit banjir dan debit andalan dengan metode FJ Mock (Studi kasus: Sungai Kapuas Kecamatan Tayan Hilir Kabupaten Sanggau). Akselerasi: Jurnal Ilmiah Teknik Sipil, 3(2).

McDonald, R. I., Douglas, I., Revenga, C., Hale, R., Grimm, N., Grönwall, J., & Fekete, B. (2011). Global urban growth and the geography of water availability, quality, and delivery. AMBIO, 40(5), 437-446. https://doi.org/10.1007/s13280-011-0152-6

Muta'ali, L. (2012). Daya dukung lingkungan untuk perencanaan pengembangan wilayah. Badan Penerbit Fakultas Geografi Universitas Gadjah Mada.

Ningsih, S. R., Ekaputra, E. G., & Goembira, F. (2020). Analisis ketersediaan, kebutuhan dan kualitas air pada DAS Batang Merao. Jurnal Ilmu Lingkungan, 18(3), 545-555. https://doi.org/10.14710/jil.18.3.545-555

Nofitasari, I., Sunaryo, S., Suyanto, B., Koesmantoro, H., & Wiyono, W. (2024). Neraca air di PDAM Lawu Tirta Kabupaten Magetan. Nusantara Hasana Journal, 3(12), 92-101. https://doi.org/10.59003/nhj.v3i12.1130

PUPR. (2020). Rencana strategis Direktorat Jenderal Cipta Karya tahun 2020-2024. Kementerian PUPR.

Putranto, Y. D., Harisuseno, D., & Prayogo, T. B. (2023). Study of Tiu Kulit Dam Reservoir Operational Pattern Simulation in Sumbawa Island. *Civil and Environmental Science*, *6*(2). https://doi.org/10.21776/civense.v6i2.402

Putri, A. (2024). Analisis kebutuhan air bersih domestik untuk 20 tahun mendatang: Studi kasus PT Air Minum Giri Menang Kota Mataram [Universitas Muhammadiyah Mataram]. https://repository.ummat.ac.id/9850/

Radhika, R., Firmansyah, R., & Hatmoko, W. (2018). Perhitungan ketersediaan air permukaan di Indonesia berdasarkan data satelit. JURNAL SUMBER DAYA AIR, 13(2), 115-130. https://doi.org/10.32679/jsda.v13i2.206

Salim, M. A. (2019). Analisis Kebutuhan Air dan Ketersediaan Air Bersih (Studi Kasus Kecamatan Bekasi Utara).

Sari, M. A. A., Isman, A. B., Musa, R., Wellang, M., & Umar, M. H. (2019). Analisis water balance Sungai Balantieng ketersaan air baku di Kecamatan Sinjai Selatan. Jurnal Teknik Sipil, 1(3).

Sarminingsih, A. (2023). Water resources assessment for raw water purposes in Serang Watershed, Kulon Progo. Jurnal Presipitasi: Media Komunikasi Dan Pengembangan Teknik Lingkungan, 20(2), 238-246. https://doi.org/10.14710/presipitasi.v20i2.238-246

Sihombing, A. M. C., Indarto, I., & Wahyuningsih, S. (2021). Assessment of Water Balance at Mayang Watershed, East Java. Geosfera Indonesia, 6, 55. https://doi.org/10.19184/geosi.v6i1.23111

Siwabessy, E. L., Nanlohy, W. D., & Putuhena, J. D. (2024). Analisis daya dukung sumber daya air bersih di Kecamatan Nusaniwe Kota Ambon. Equilibrium: Journal of Economics and Development Studies, 2(1), 125-135. https://doi.org/10.30598/equilibrium.2.1.125-135

Soemarto, C. D. (1987). Hidrologi Teknik. Usaha Nasional.

Trinugroho, M. W., Arif, S. S., Susanto, S., & Nugroho, B. D. (2024). Assessing irrigation water demand and pumping operations for rice farming in the Bengawan Solo River, Indonesia. SAINS TANAH - Journal of Soil Science and Agroclimatology. https://doi.org/10.20961/stjssa.v21i1.79343

Tufaila, M., Musa, A. N., & Alam, S. (2016). Analisis Neraca Air Lahan pada Jenis Tanah yang Berkembang pada Bahan Induk Karst di Kecamatan Parigi Kabupaten Muna. Jurnal Tanah Dan Sumberdaya Lahan, 3(1), 295-303.

Twisa, S., & Buchroithner, M. F. (2019). Seasonal and annual rainfall variability and their impact on rural water supply services in the Wami River Basin, Tanzania. Water, 11(10), 2055. https://doi.org/10.3390/w11102055

Wang, G., Xiao, C., Qi, Z., Meng, F., & Liang, X. (2021). Development tendency analysis for the water resource carrying capacity based on system dynamics model and the improved fuzzy comprehensive evaluation method in Changchun City, China. Ecological Indicators, 122, 107232. https://doi.org/10.1016/j.ecolind.2020.107232

Wang, H., Liu, J., Klaar, M., Chen, A., Gudmundsson, L., & Holden, J. (2024). Anthropogenic climate change has influenced global river flow seasonality. Science, 383(6686), 1009-1014. https://doi.org/10.1126/science.adi9501

Wardana, I. G. N. K. M. A., Andayani, K. W., & Winaya, I. N. A. P. (2024). Pemanfaatan mata air Dukuh Blahkiuh untuk sistem pelayanan air terintegrasi. Jurnal Sumber Daya Air, 20(1), 1-16. https://doi.org/10.32679/jsda.v20i1.860

Warner, S., & Saile, P. (2020). *SDG Indicator 6.3.2 Technical Guidance Document No. 4: Level 2 Reporting*. UN Environment Programme, Global Environment Monitoring System for Freshwater (GEMS/Water). https://communities.unep.org/display/sdg632

Wickramaarachchi, T. N. (2023). Water availability assessment in cultivation and non-cultivation seasons to identify water security in a tropical catchment: Gin catchment, Sri Lanka. Paddy and Water Environment, 22(1), 85-97. https://doi.org/10.1007/s10333-023-00954-6

Widiyaningsih, M., Muryani, C., & Utomowati, R. (2021). Analisis perubahan daya dukung sumberdaya air berdasarkan ketersediaan dan kebutuhan air di DAS Gembong tahun 2010-2020. Jurnal Sumberdaya Alam Dan Lingkungan, 8(2). https://doi.org/10.21776/ub.jsal.2021.008.02.1

Wintyaswan, G. R., Sumiadi, S., & Soetopo, W. (2022). Analisis Neraca Air (Water Balance) Pada Daerah Aliran Sungai (DAS) Rejoso Kabupaten Pasuruan. Jurnal Teknologi Dan Rekayasa Sumber Daya Air, 3(1), 324-335. https://doi.org/10.21776/ub.jtresda.2023.003.01.28

Yanidar, R., Hartono, D. M., & Moersidik, S. S. (2020). Water availability for a self-sufficient water supply: A case study of the Pesanggrahan River, DKI Jakarta, Indonesia. Advances in Science, Technology and Engineering Systems, 5(5), 348-355. https://doi.org/10.25046/AJ050543

Yasa, I. W., Setiawan, A., Negara, I. D., Saidah, H., & Dirgantara, A. H. (2023). Sebaran Kekeringan Hidrologi Berdasarkan Debit Aliran di Kabupaten Bima. *Ganec Swara*, 17(1). https://doi.org/10.35327/gara.v17i1.371

Yekti, M. I., Wijakesuma, T. G. R., & Harmayani, K. D. (2020). Evaluasi pola operasi Waduk Tamblang di Kabupaten Buleleng, Provinsi Bali. Jurnal Teknik Pengairan: Journal of Water Resources Engineering, 11(2), 116-127. https://doi.org/10.21776/ub.pengairan.2020.011.02.05