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Analysis of the Availability and Utilization of Raw Water for the Drinking Water Supply System of Perumda Tirta Bhagasasi

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ABSTRACT

Babelan District, Bekasi Regency, faces the pressure of 2.2% annual population growth, significantly increasing the need for raw water. This area has a single raw water source, the BUT.6 Secondary Canal, with a usable discharge of 726.27 liters/second after accounting for the tolerance coefficient and irrigation allocation. The installed capacity of the Perumda Tirta Bhagasasi water treatment plant (IPA) of 896.5 liters/second results in a supply deficit of 170.23 liters/second even under normal discharge conditions. This study analyzes raw water availability using field measurement methods ($Q = A \times v$) at four cross-sectional points, projects water demand for the 2025–2035 period, evaluates the monthly and annual water balances, and formulates a data-driven optimization strategy. The water balance analysis indicates a deficit that begins in 2027 and reaches 279–309 liters/second by 2030 under the baseline scenario. A sensitivity analysis of three scenarios a 20% increase in demand, a 10% decrease in discharge, and a combination of the two (worst-case) reinforces the urgency of strategic intervention, with a worst-case deficit reaching 552 liters/second. The novelty of this research lies in the integration of field discharge measurements from four cross-sectional points with monthly water balance analysis and a multi-scenario sensitivity analysis of a single irrigation canal serving as a raw water source for the SPAM. Five priority optimization strategies intake operation optimization, progressive non-revenue water (NRW) reduction, water source diversification, water treatment plant (IPA) roadmap adjustments, and watershed (DAS) conservation are recommended for gradual implementation over three development phases from 2025–2035 to achieve a sustainable balance in raw water supply.

Keywords: raw water, water balance, mainstay discharge, Secondary Canal BUT.6, SPAM, non-revenue water, optimization.

INTRODUCTION

Water is a basic, irreplaceable need. Standards for raw water and drinking water quality that are safe for health are set internationally by the World Health Organization [30] and nationally through the Indonesian Minister of Health's Regulation on Environmental Health [4], which serves as the primary reference for Drinking Water Supply System (SPAM) providers. With the pace of urbanization and population growth, the need for clean water continues to increase, while the availability of water sources is increasingly pressured by seasonal fluctuations and the risk of surface water contamination [2]. Studies on bottled water in Indonesia also show that limited access to reliable piped water drives households to switch to alternative sources whose quality is not guaranteed [19].

The Indonesian government has set targets for increasing drinking water service coverage through the Directorate General of Human Settlements' Strategic Plan 2020–2024 [5] and the National Medium-Term Development Plan 2020–2024 [17]. Technical guidelines for SPAM implementation [6] and national performance evaluations of regionally-owned drinking water companies [7] serve as operational references for SPAM providers in various regions, including Perumda Tirta Bhagasasi in Bekasi Regency.

Bekasi Regency, West Java Province, is one of the regions with the highest water demand pressures in Indonesia. Longitudinal studies in the Bekasi region show that many households still use multiple

water sources simultaneously due to the limited availability of safe and continuous piped water [18]. Population growth of 2–4% per year is driving massive residential expansion, while the provision of raw water from a single source—as is the case with the Secondary Canal BUT.6—increases the risk of supply constraints if not managed with simultaneous attention to both quantity and quality [10], [11].

Babelan District, in the northern part of Bekasi Regency, is experiencing rapid residential growth. The entire raw water supply of the Babelan Branch of Perumda Tirta Bhagasasi relies on a single source, the Secondary Canal BUT.6, which originates from the Tarum River in Kalimalang. This reliance on a single source, combined with high fluctuations in discharge between the rainy and dry seasons, poses a serious risk to the continuity of drinking water services.

Based on field measurements, the maximum discharge of the BUT.6 Secondary Canal at the intake point (Point A) reaches 1,290 liters/second. However, after taking into account the tolerance coefficient and irrigation needs, the discharge that can be used for raw water is only 726.27 liters/second. Meanwhile, the planned installed capacity of the WTP is 896.5 liters/second, resulting in a deficit of 170.23 liters/second even under normal discharge conditions. This situation is exacerbated by the planned gradual expansion of the WTP capacity to 1,080 liters/second by 2028 without a comparable increase in raw water sources.

The reliable discharge (Q90) is the minimum reliable discharge with a 90% reliability level and is a common basis for SPAM planning because it provides an adequate safety margin [25]. Measuring open channel discharge using the cross-sectional area-velocity method ($Q = A \times v$) is a commonly used approach for field conditions, as applied to evaluating the efficiency of secondary irrigation channels [23]. The National Rural Electric Cooperative Association (NRECA) method is also widely used in Indonesia to estimate dependable discharge from rainfall data when direct discharge data is limited, using both conventional approaches [24] and geographic information systems such as ArcGIS [22]. A comparison of the F.J. Mock and NRECA rainfall-to-discharge conversion methods in several watersheds in Indonesia shows that both methods provide relatively consistent results for raw water planning [14], [20].

Population projections using arithmetic and geometric methods are commonly used in urban water supply planning (SPAM), with domestic water demand referring to technical guidelines for SPAM implementation that establish consumption standards based on city classifications [6]. Total gross demand is calculated by accounting for water losses through non-revenue water (NRW) factors; NRW control through pressure management and distribution network operation optimization has been proven effective in reducing water loss levels in several SPAM providers in Indonesia [13], [29].

A water balance compares raw water availability to drinking water production needs, with analysis conducted monthly and annually to identify periods of surplus and deficit [10]. Geographic information system-based modeling of potential infiltration zones can support watershed conservation strategies to maintain long-term discharge reliability [12].

Sulistyarso, Marsudi, and Nurhayati [24] found a reliable discharge of 0.45 m^3/s in the Sambas watershed with a sufficient surplus for up to 20 years using the NRECA method. Wahyudi and Prasetyo [28] on Ternate Island emphasized the importance of monthly water balance analysis because seasonal deficits can occur even when the annual balance remains positive. Kurniawan et al. [9] emphasized the need to synchronize the development of water treatment infrastructure capacity and the availability of raw water sources, in line with findings from SPAM planning in the capital area of Konawe Regency [21] and a study of SPAMs that meet health standards [27]. Evaluation of the efficiency of the Srengseng Hilir Jatiluhur secondary irrigation canal and analysis of water losses in other secondary irrigation canals indicate that water losses in secondary canals can account for a significant proportion of the reliable discharge due to sedimentation and technical leaks [23], [26], in line with the tolerance coefficient applied in this study.

This study aims to: (1) analyze the raw water availability of the BUT.6 Secondary Canal through field measurements and hydrological analysis; (2) project the raw water needs of Babelan District

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for 2025–2035; (3) evaluate the water balance and identify critical deficit periods; and (4) formulate a data-driven optimization strategy that can be implemented.

RESEARCH METHODS

Research Data and Location

The study was conducted in Babelan District, Bekasi Regency. The data used included: (a) primary data in the form of field discharge measurements at four cross-section points (A, B, C, D) of the BUT.6 Secondary Canal; (b) secondary data in the form of monthly rainfall from 2013–2023 from PJT II (Perum Jasa Tirta II), WTP capacity data from the Perumda Tirta Bhagasasi Business Plan 2023–2027, and demographic planning assumptions.

Measurement Method and Data Analysis

Discharge was measured using the cross-sectional area-velocity method with the formula $Q = A \times v$, where the wetted cross-sectional area (A) is calculated from the measured cross-sectional dimensions and the average flow velocity (v) is measured using the float method. A 40% tolerance coefficient was applied to account for sedimentation, evaporation, and technical losses. The discharge usable for raw water was obtained after deducting the allocation for agricultural irrigation. Monthly rainfall data for Bekasi Regency from PJT II for the 2013–2023 period was analyzed using the arithmetic mean to identify seasonal patterns and critical (dry) months to estimate seasonal discharge reductions proportional to rainfall.

Water Demand Projection and Water Balance Analysis

The projected growth in customer connections and the served population used the geometric method with r = 2.2%/year. Each connection serves 4 people. Consumption per customer increased by 0.25 m³/SL/month per year, while NRW was targeted to decrease by 0.5%/year. A maximum daily factor of Fmd = 1.2 and a peak hour factor of Fpeak = 1.5 were applied for design requirements. Annual and monthly water balances were calculated by comparing Q90 (726.27 l/d) against increasing production demand. Three sensitivity scenarios were tested: (1) demand +20%; (2) available discharge -10%; and (3) worst-case, a combination of both.

RESULTS AND DISCUSSION

Rainfall Characteristics

The average annual rainfall in Bekasi Regency from 2013–2017 was 1,602.4 mm/year, with significant variation (Table 1). The rainfall pattern is unimodal: peak rainfall occurs in January–February and the dry season occurs in June–September. The driest month is August (average 41.6 mm) and the wettest is January (299.1 mm). Significant interannual variation (CV ≈ 0.20) reinforces the need for a conservative approach (Q90) in raw water planning.

Table 1. Annual Rainfall in Bekasi Regency, 2013–2017 (Source: PJT II)

Years	Total CH (mm)	Month Max	CH Maks (mm)	Month Min	CH Min (mm)
2013	1.619,4	Jan	351,6	Sep	8,3
2014	1.676,9	Jan	560,2	Sep	4,3
2015	1.176,9	Feb	280,5	Okt	5,3
2016	1.991,1	Okt	251,6	Agu	150,6
2017	1.547,7	Feb	367,2	Agu	8,4
Average	**1.602,4**	—	—	—	—

Secondary Channel Discharge Measurements BUT.6

Discharge measurement results at four cross-section points are presented in Table 2. Point A (main intake) has the largest dimensions and the highest discharge. The flow velocity is uniform at 0.43

m/s across all points. After applying a 40% tolerance coefficient and reducing irrigation allocations, the discharge available for raw water is obtained.

Table 2. Discharge and Available Discharge Measurement Results per Cross-Section Point

Point	A (m²)	Measured Q (l/s)	Tolerance coeff.	Available Q (l/s)	Irrigation (l/s)	Raw water Q (l/s)
A	3,00	1.290	40%	774	47,73	726,27
B	1,00	430	40%	258	0	258,00
C	0,75	322,5	40%	193,5	19,35	174,15
D	0,55	236,5	40%	141,9	28,38	113,52
Total*	—	—	—	**774**	**47,73**	**726,27**

*The total raw water is calculated from Point A as the intake point.

With a usable discharge of 726.27 l/d and an installed WTP capacity of 896.5 l/d (Table 3), there is a raw water supply deficit of 170.23 l/d (19.0% of WTP capacity). In addition to the quantity aspect, monitoring the quality of raw water and produced water at the water treatment plant is also an important indicator of the reliability of SPAM services [1], especially when a single raw water source, such as the Secondary Channel BUT.6, experiences seasonal discharge fluctuations. This quantity deficit already occurs under normal conditions and will worsen as WTP capacity increases.

Table 3. Installed WTP Capacity of Perumda Tirta Bhagasasi, Babelan Branch

IPA	Kap. (l/d)	Ops. Year
IPA PDAM (unit 1)	125	Existing
IPA PDAM (unit 2)	140	Existing
IPA Grenex 1	200	2026
IPA Grenex 3	150	2027
IPA Grenex 2 (2 unit)	200	2028
Total	**815 + (max. 10% design capacity) = 896.5**	**2028 (full)**

Water Capacity and Demand Projections 2025–2035

Based on the 2023–2027 Business Plan, the system capacity will increase gradually: 265 l/d (2025, old WTP) → 730 l/d (2026) → 880 l/d (2027) → 1,080 l/d (full 2028). Projected production needs increase in line with population growth of 2.2%/year and increased consumption. The interplay between WTP capacity and raw water availability results in a balance pattern as shown in Table 4. This pattern of production capacity expansion not matched by raw water availability is a common challenge also identified in the national performance evaluation of regionally-owned drinking water companies [7].

Table 4. Annual Raw Water Balance 2025–2035 (Baseline Scenario)

Years	WTP Capacity (l/d)	Available Q (l/d)	Production Demand (l/d)	Balance (l/d)	Status
2025	265	726,27	~220–250	+476–506	Surplus
2026	730	726,27	~680–700	+26–46	Critical
2027	880	726,27	~800–830	−74 s/d −104	Deficit
2028	1.080	726,27	~960–990	−234 s/d −264	Large Deficit
2030	1.080	726,27	~1.005–1.035	−279 s/d −309	Large Deficit

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Years	WTP Capacity (l/d)	Available Q (l/d)	Production Demand (l/d)	Balance (l/d)	Status
2035	1.080	726,27	~1.115–1.145	−389 s/d −419	Critical Deficit

In 2025, there will still be a surplus because only the old WTP (265 l/d) is operational. The transition to a deficit begins in 2027 with the operation of the Grenex 3 WTP. The deficit widens dramatically in 2028 when the total active WTP capacity reaches 1,080 l/d, almost 49% greater than the available supply.

Monthly Water Balance Analysis

The discharge of the BUT.6 Secondary Channel fluctuates according to rainfall patterns. Based on the correlation between rainfall and discharge, August (average rainfall of 41.6 mm) is estimated to experience a decrease in discharge of up to 40% of normal values (Table 5). Under these conditions, August will be the most vulnerable month in 2025, with available discharge of only ≈ 290 l/d.

Table 5. Estimated Monthly Discharge and Water Balance (Critical Condition 2025)

Month	CH Average (mm)	% Normal Discharge	Q Available (l/d)	Keb. 2025 (l/d)	Balance Sheet (l/d)
Jan	299,1	110	799	~250	+549
Feb	303,5	115	835	~250	+585
Mar	147,4	90	654	~250	+404
Apr	150,9	85	617	~250	+367
Mei	99,1	75	545	~250	+295
Jun	70,6	60	436	~250	+186
Jul	74,5	55	399	~250	+149
Agu	**41,6**	**40**	**291**	**~250**	**+41**
Sep	50,6	45	327	~250	+77
Okt	94,3	70	508	~250	+258
Nov	145,5	90	654	~250	+404
Des	145,2	95	690	~250	+440

*Production needs in 2025 are still low because only the old WTP (~265 l/d) is operational. In 2028, demand will be significantly higher, making August–September a particularly critical period.

Sensitivity Analysis

Three scenarios were tested for 2030 to assess system resilience (Table 6).

Table 6. Summary of Sensitivity Analysis — 2030

Scenario	Available Q (L/day)	Production Req. (L/day)	Balance (L/day)	Status
Baseline	726,27	~1.005	−279 s/d −309	Def. Besar
Requirements +20%	726,27	~1.206	−480	Def. Kritis
Flow −10%	653,64	~1.005	−351	Def. Besar
Worst-Case	**653,64**	**~1.206**	**−552**	**Def. Sangat Kritis**

The results indicate that a 10% decrease in discharge due to climate change and a simultaneous 20% increase in demand (worst-case scenario) could result in a deficit of -552 l/d, or 76% of availability.

This figure equates to a 72% loss of supply—a situation that could potentially lead to mass service failures.

Optimization Strategies

Based on the analysis findings, five optimization strategies are recommended (Table 7), implemented in three sequential phases.

Table 7. Optimization Strategy Matrix and Implementation Roadmap

Priority	Strategy	Target Outcome	Phase	Party Responsible
I	Optimization of intake operations (SCADA + buffer pond)	+15% intake efficiency, buffer ≥ 500 m³	2025–2026	Regional Public Corporation (Perumda) + PJT II
II	Progressive reduction of Non-Revenue Water (NRW) (0.5%/year)	Savings of ≥ 50 L/s over 10 years	2025–2035	Regional Public Corporation (Perumda)
III	Diversification of water sources (negotiations with PJT II + groundwater studies)	Capacity increase of ≥ 200 L/s	2026–2028	Regional Public Corporation (Perumda) + Water Resources Agency (Dinas SDA)
IV	Synchronization of the Water Treatment Plant (WTP) roadmap with water supply	Elimination of the capacity gap between the water treatment plant (WTP) and raw water supply	2026–2028	Regional Public Corporation (Perumda)
V	Watershed conservation (reforestation + control of land-use conversion)	Maintenance of long-term Q90 (90th percentile flow)	2025–2035	Water Resources Agency (Dinas SDA) + River Basin Organization (BBWS)

Strategy I (intake optimization) requires attention to the licensing procedures for water resource use as stipulated in Minister of Public Works and Public Housing Regulation Number 2 of 2024 [8]. Strategy III (water source diversification) can consider designing an independent raw water supply scheme on a limited area scale as a medium-term alternative [3]. Strategy V (watershed conservation) aligns with the mandate of Government Regulation Number 22 of 2021 concerning the Implementation of Environmental Protection and Management [15], which regulates the protection of water catchment areas as part of sustainable environmental management. Strategies I and II can be initiated immediately (2025–2026) because they utilize existing infrastructure, while Strategy IV emphasizes that increasing WTP capacity must be conditioned on the availability of sufficient water sources.

Discussion

The findings of this study are consistent with the view that investment in drinking water treatment infrastructure should not precede the availability of raw water sources, as emphasized by Kurniawan et al. [9] and also reflected in the national performance evaluation of regionally owned drinking water companies (BUMDs), which revealed similar challenges across various SPAM providers [7]. This contrasts with Sulistyarso et al. [24] found a surplus in a natural watershed in Sambas Regency. The BUT.6 Secondary Canal is an artificial irrigation canal with a water withdrawal capacity that is shared among users, so its effective availability is much more limited than the nominal discharge—a pattern consistent with the findings of the Jatiluhur secondary irrigation canal efficiency evaluation and water loss analysis in other secondary irrigation canals [23], [26].

The monthly analysis in this study reinforces the findings of Wahyudi and Prasetyo [28] that an apparent annual water balance surplus can conceal a severe seasonal deficit. August–September in Babelan is a critical period that requires special management, especially after the expansion of the WTP in 2027–2028. A pattern of raw water supply vulnerability dependent on a single source was also identified in household drinking water supply in Bagan Deli Village, Belawan District [16],

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which strengthens the conclusion that coastal areas with limited raw water sources are generally vulnerable to seasonal and structural supply deficits.

Dependence on a single source is a systemic vulnerability reflected in studies of multi-source household water use in the Bekasi area, which show that limited safe piped supply forces people to utilize alternative water sources whose quality is not guaranteed [18], [19]. Efforts to diversify raw water sources—including through independent raw water supply schemes at a limited regional scale [3] need to be prioritized in parallel, not sequentially, with the development of WTP capacity, in line with applicable water resource use permit provisions [8].

CONCLUSION

The usable discharge from the BUT.6 Secondary Channel of 726.27 l/s is less than the installed WTP capacity (896.5 l/s), resulting in a deficit of 170.23 l/s (19.0%) under normal conditions. The deficit will begin to occur in 2027 and worsen to 279–309 l/s by 2030 as WTP capacity expands without additional raw water sources. August is the most critical month, with an estimated discharge of only 40% of normal (≈ 290 l/d), requiring a dedicated storage reserve. A sensitivity analysis indicates a worst-case deficit of -552 l/d in 2030 if discharge decreases by 10% and demand increases by 20% simultaneously. Five recommended optimization strategies—intake optimization, NRW reduction, source diversification, water resource roadmap synchronization, and watershed conservation—need to be implemented in a phased and coordinated manner over three phases from 2025 to 2035 to achieve a sustainable balance in raw water supply.

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