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Analysis of Clean Water Needs and Reservoir Storage Capacity in Jepara District (A Case Study of the Kalimati Reservoir, Jepara Regency)

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Abstract

Clean-water availability is essential for community activities, while population growth and socioeconomic development increase pressure on water-supply infrastructure. The Kalimati Reservoir in Jepara District has potential as a raw-water source, but its utilization remains constrained by inadequate storage planning and seasonal fluctuations in water availability. This study aims to determine projected clean-water demand and the reservoir storage capacity required to support reliable supply over a ten-year planning period. An empirical quantitative approach was applied using population data from 2020–2024, domestic and non-domestic water-consumption data, and Kaliwiso River discharge data. Population growth was projected using the geometric method, while water demand was calculated based on domestic, public-tap, non-domestic, and distribution-loss components, followed by maximum daily, peak-hour, and Q80% dependable-flow analyses. The projected population in 2034 reaches 109,714 inhabitants, generating a clean-water requirement of 125.60 L/s, maximum daily demand of 150.72 L/s, and peak-hour demand of 200.96 L/s. A reservoir capacity of 2,604.40 m³ with a planned depth of 3 m requires a footprint of 868.13 m². The available 15,893.22 m² site area is adequate for the reservoir and supporting facilities, with an estimated construction cost of IDR 2,492,850,400. The results indicate that the proposed storage capacity can provide a preliminary buffer against seasonal reductions in raw-water availability and support continuity of the planned supply system. These findings provide an engineering basis for integrated and sustainable clean-water development using the Kalimati Reservoir.

Keywords: *Clean-Water Demand, Population Projection, Reservoir, Small Dam, Storage Capacity.*

INTRODUCTION

Clean water is a fundamental resource that underpins human well-being, domestic activities, public services, and regional economic development, while increasing population, urban expansion, and intensifying socioeconomic activities continue to place greater pressure on water availability and reliability. Global water-resource management has increasingly shifted from a supply-oriented paradigm toward integrated approaches that consider demand dynamics, reservoir storage performance, hydrological variability, ecosystem requirements, and climate-related uncertainty within a single planning framework. Recent research demonstrates that reservoir allocation can no longer be assessed solely from physical storage capacity because competing water demands and environmental services may produce substantial trade-offs under different hydrological and operational scenarios (Bianshiyu et al., 2024). The reliability of water supply is also strongly influenced by rainfall variability, watershed characteristics, land-use change, and the capacity of catchments to retain and regulate water throughout seasonal fluctuations (Asdak, 2018). In this context, soil and water conservation represents an important component of maintaining hydrological balance because declining infiltration capacity and increasing surface runoff can alter the temporal availability of water resources (Arsyad, 2010). The challenge is particularly relevant for developing regions where population growth and expanding settlements may increase water demand faster than the development of dependable raw-water infrastructure.

At the local level, Kecamatan Jepara represents an area in which population dynamics and socioeconomic activities create continuing pressure on the provision of clean water, making the relationship between projected demand and available water storage increasingly important for infrastructure planning. Population statistics for Kecamatan Jepara indicate continuing demographic dynamics that must be incorporated into water-demand projections rather than relying on current consumption conditions as the basis for long-term infrastructure decisions (Badan Pusat Statistik Kabupaten Jepara, 2020–2024). Conventional water-supply planning generally determines domestic and non-domestic requirements using population projections, unit water-consumption standards, service coverage, and peak-demand factors, which provide a technical basis for estimating future design discharge (Badan Standardisasi Nasional, 1995). Hydrological assessment further requires consideration of rainfall characteristics because spatial and temporal rainfall variability determines the amount of runoff potentially available for storage and subsequent utilization (Nurhijriah et al., 2022). For Jepara, the availability of surface water remains closely associated with seasonal rainfall conditions and the capacity of existing water infrastructure to retain water during periods of surplus for utilization during the dry season. The development of Embung Kalimati in Kelurahan Bapangan therefore represents a strategic opportunity to strengthen local raw-water availability by converting seasonal runoff into a regulated source that can potentially support clean-water services. Previous planning documentation for Kalimati indicates that the infrastructure was conceived within the broader effort to develop water resources in the Bapangan area (PDAM Jepara/Dinas PU Jepara, 2017). This local context places reservoir storage planning at the intersection of demographic demand, hydrological availability, infrastructure readiness, and long-term water-service reliability.

Previous studies have established that the adequacy of a reservoir cannot be evaluated exclusively from its nominal geometric volume because effective water-supply performance depends on the interaction between inflow, demand, operating conditions, and storage characteristics. Bachtiar et al. (2023) demonstrated that integrated reservoir optimization can improve raw-water supply performance by coordinating storage utilization with water-demand requirements, highlighting the importance of linking reservoir capacity assessment with operational objectives. A comparable perspective was presented by Haditama et al. (2024), who showed that water-use optimization in a reservoir requires an assessment of available storage against competing utilization patterns rather than treating storage capacity as an isolated design parameter. Research on the Meninting multipurpose reservoir similarly indicates that optimizing reservoir utilization requires an explicit evaluation of water availability and demand over time so that storage can provide a more reliable supply under changing hydrological conditions (Rediasti et al., 2023). These findings indicate that reservoir planning is fundamentally a dynamic water-balance problem in which the timing and magnitude of inflow are as important as the physical storage volume. At the engineering level, performance assessment of reservoir storage also requires determining whether available capacity can accommodate the required water volume while maintaining an appropriate balance between operational reliability and infrastructure constraints (Trimartinni & Limantara, 2024). The analytical implication is that a clean-water reservoir should be dimensioned from projected demand and water availability rather than from an arbitrary storage value.

Evidence from Jepara provides an important empirical foundation for extending this approach, although existing studies have generally addressed either feasibility, structural planning, or broader infrastructure development rather than integrating future clean-water demand with reservoir storage requirements at the Kalimati site. Hidayawan (2017) examined the economic feasibility of developing an embung in Bapangan, Jepara, demonstrating the relevance of Kalimati-related infrastructure for meeting raw-water requirements while emphasizing the feasibility dimension of water-resource development. Prasetya et al. (2021) investigated the planning of a clean-water reservoir structure in Pecangaan Kulon, Jepara Regency, and showed that reservoir infrastructure planning can provide a technical response to localized clean-water requirements. Government documentation has also identified the development of Embung Kalimati as part of Jepara's water-resource development agenda, indicating that the infrastructure has practical significance beyond a purely theoretical hydrological assessment (Pemerintah Kabupaten Jepara, 2019). More recent local reporting indicates that the completion and utilization of the Kalimati project remain matters of public and institutional concern, reinforcing the practical relevance of determining the infrastructure required for effective water utilization (Lingkar Jateng, 2025). Despite these developments, a clear quantitative linkage between the projected clean-water requirement within the Kalimati service area and the reservoir storage capacity required to satisfy that demand over a defined planning horizon remains insufficiently established. This limitation creates a methodological gap because infrastructure availability alone cannot demonstrate whether future water demand can be reliably accommodated under seasonal water-supply fluctuations.

The literature also reveals an important conceptual gap concerning the translation of water-demand projections into an appropriate reservoir-storage requirement under local operating conditions, particularly for relatively small water-supply systems whose performance may be highly sensitive to seasonal deficits. A recent study in Prangat Baru Village applied an integrated analysis of clean-water demand and reservoir storage capacity, demonstrating the relevance of combining demand estimation with storage sizing for localized water-supply planning (Kelawing Kinam et al., 2026). However, the transferability of such an approach to Kalimati cannot be assumed because reservoir performance is dependent on local population characteristics, rainfall patterns, service-area conditions, inflow behavior, and infrastructure configuration. Climate variability further strengthens the need to evaluate reservoir operating rules and storage reliability because changing hydrological conditions may alter the balance between water availability and drinking-water demand over the planning period (Neri & Toth, 2026). Established hydrological engineering principles emphasize that dependable reservoir planning requires systematic analysis of inflow, storage, demand, and temporal water balance rather than reliance on average conditions alone (Linsley, 1995). The scientific problem therefore extends beyond determining how much water consumers require; it concerns how projected demand can be translated into a technically defensible storage volume capable of supporting service continuity during periods of limited inflow. Addressing this problem is particularly urgent for Kalimati because the absence of adequate reservoir and water-treatment facilities limits the conversion of the existing embung into a functional clean-water supply system.

This study positions itself within the emerging field of integrated water-resource and reservoir-capacity planning by connecting demographic demand projection, clean-water service requirements, hydrological considerations, reservoir storage sizing, and infrastructure cost estimation within a single analytical framework for the Kalimati Reservoir service area. The research specifically aims to determine the clean-water requirement of the Kalimati service area over the next ten years, establish the reservoir storage capacity required to accommodate the projected demand, and formulate a preliminary reservoir development plan together with its estimated construction cost. The analysis is intended to provide a quantitative basis for evaluating the balance between future clean-water demand and available storage rather than assessing reservoir development solely from a structural or economic perspective. Methodologically, the study contributes a site-specific framework that translates projected water demand into an engineering storage requirement while retaining the practical constraints associated with local infrastructure development. The study also contributes empirical evidence for Jepara by extending previous Kalimati-related feasibility and development studies toward a more explicit assessment of future demand and reservoir capacity. Its practical contribution lies in supporting local decision-makers in determining the scale of reservoir infrastructure required before the Kalimati water resource can be developed as a reliable component of the regional clean-water supply system. The resulting framework is expected to strengthen the basis for sustainable reservoir planning by integrating future demand, storage adequacy, and infrastructure investment into a coherent engineering decision-making process.

RESEARCH METHODS

The study employed an empirical quantitative approach to assess clean-water demand and the reservoir storage capacity required to support the Kalimati Reservoir service area in Jepara Regency, Indonesia. The research was conducted at Kalimati Reservoir, located in Bapangan Village, Jepara District, which has an average inundation area of 22,216 m^2, an average water depth of 4.5 m, and an estimated storage volume of 99,972 m^3, while the stored water currently remains raw water and has not been fully utilized as a clean-water source for the surrounding community. The research architecture consisted of four sequential stages, namely field observation and literature review, collection and verification of primary and secondary data, quantitative projection and clean-water demand analysis, and determination of reservoir storage capacity followed by preliminary infrastructure planning. Primary data consisted of the location map and service-area map of Kalimati Reservoir, whereas secondary data included population statistics for 2015–2024, domestic and non-domestic water-consumption data from PDAM Tirta Jungporo in 2025, and water-discharge data from the Kaliwiso River. The population and water-consumption datasets were organized as annual time-series data to establish baseline conditions and project clean-water requirements over a ten-year planning period. Field observations were conducted to verify the physical conditions of the reservoir and the correspondence between the mapped service area and the actual area potentially supplied by the planned water-supply system. The overall research design followed established principles for clean-water supply planning, which require population growth, service coverage, water-consumption standards, and water-resource availability to be considered jointly when determining water-supply infrastructure requirements (Departemen Pekerjaan Umum, 1990).

Figure 1. Location of Kalimati Reservoir, Jepara District

The analytical procedure began with data screening and consistency verification by comparing demographic, water-consumption, hydrological, spatial, and field-observation data before their application in subsequent calculations. Population growth was projected using the geometric method, in which the projected population was calculated from the initial population and the average annual growth rate (Departemen Pekerjaan Umum, 1990).

$$P_n = P_0(1 + r)^n$$

Where P_n is the projected population in year n, P_0 is the population in the base year, r is the average annual population growth rate, and is the projection period in years. The same projection principle was applied to estimate changes in water consumption for each customer category. Clean-water demand was calculated by separating domestic and non-domestic requirements, including household consumption, public-tap demand, non-domestic consumption, and distribution losses, with domestic consumption set at 100 L/person/day, public-tap consumption at 30 L/person/day, non-domestic demand at 15% of the domestic requirement, and water losses at 20% of the total calculated requirement (Cipta Karya, 1998). The resulting total requirement was converted into maximum daily demand using a factor of 1.2 and peak-hour demand using a factor of 1.6 to evaluate the water-supply requirement under critical service conditions (Kementerian Pekerjaan Umum, 2002). Water availability was assessed using the dependable flow at the Q80% reliability level of the Kaliwiso River and was compared with projected demand to identify potential supply deficits during periods of limited availability. The required reservoir capacity was determined as 10–20% of the maximum daily water requirement, while the required reservoir land area was estimated by relating the calculated storage volume to the proposed reservoir depth, followed by the preparation of a preliminary reservoir development plan and construction cost estimate. System performance was evaluated using projected population, average daily demand, maximum daily demand, peak-hour demand, Q80% dependable discharge, required reservoir storage volume, storage-to-demand adequacy, required land area, and estimated construction cost, providing quantitative indicators for determining whether the proposed reservoir capacity could support the projected ten-year clean-water requirement under the available water-resource conditions (Linsley, 1995).

RESULTS AND DISCUSSION

Population Projection of the Kalimati Reservoir Service Area

The population of the Kalimati Reservoir service area increased consistently during the 2020–2024 observation period, although the annual growth rate varied considerably between years. The population increased from 91,438 inhabitants in 2020 to 96,315 inhabitants in 2024, representing an absolute increase of 4,877 inhabitants over five years. The annual increase was highest in 2022, when the population rose by 2,455 inhabitants or 2.659%, whereas the lowest increase occurred in 2023 at 540 inhabitants or 0.570%. The variation indicates that population growth in the service area was not uniform, yet the overall trajectory remained positive and provides a reasonable demographic basis for long-term water-demand projection. Population dynamics are a fundamental parameter in water-supply planning because changes in the number of served inhabitants directly influence the magnitude and temporal development of domestic water requirements (Badan Pusat Statistik Kabupaten Jepara, 2020–2024). The demographic pattern observed in the Kalimati service area therefore indicates that future water infrastructure should be dimensioned according to projected rather than current population conditions.

Table 1. Population of the Kalimati Reservoir Service Area, 2020–2024

No.	Year	Population (inhabitants)	Increase (inhabitants)	Percentage (%)
1	2020	91,438	–	–
2	2021	92,320	882	0.965
3	2022	94,775	2,455	2.659
4	2023	95,315	540	0.570
5	2024	96,315	1,000	1.049
	Total		**4,877**	**5.243**
	Average r			**1.311**

As presented in Table 1, the cumulative population increase of 5.243% produces an average annual growth rate of 1.311%, which was subsequently used as the demographic growth parameter in the ten-year projection. The use of an average growth rate is appropriate for translating short-term demographic fluctuations into a planning parameter, particularly when the objective is to estimate future infrastructure requirements rather than predict annual population changes with socioeconomic precision. The geometric projection method was selected because it represents population growth as a proportional process in which each projected period is based on the population of the preceding period, making it suitable for infrastructure planning under sustained positive growth conditions (Departemen Pekerjaan Umum, 1990). This approach also avoids treating the annual absolute increase as constant, which would produce a linear trajectory that may not adequately represent proportional demographic development. The resulting growth parameter provides a consistent basis for subsequent calculations of domestic and non-domestic water requirements. Its application is particularly important for the Kalimati system because an underestimated population would propagate directly into an underestimated water-supply requirement and potentially insufficient reservoir capacity.

Using the 2024 population of 96,315 inhabitants as the base population and an average annual growth rate of 1.311%, the population was projected over a ten-year planning horizon to 2034. The calculation produced a projected population of 109,714 inhabitants, corresponding to an additional 13,399 inhabitants compared with the 2024 baseline. This increase represents approximately 13.91% growth over the planning horizon, indicating that the service area is expected to experience continued demographic pressure on water-supply infrastructure. The resulting projection can be expressed through the following geometric formulation:

$$P_{2034} = 96{,}315(1 + 0.01311)^{10} = 10.714 \text{ inhabitants}$$

The projected value of 109,714 inhabitants was subsequently adopted as the principal demographic input for determining the clean-water requirement in 2034. The magnitude of the projected increase is important because even moderate annual population growth can generate a substantial cumulative requirement when translated into standardized per-capita water consumption over a ten-year period. In water-resource engineering, population projection is therefore not merely a demographic exercise but a controlling parameter that determines the scale of subsequent supply, storage, and distribution infrastructure (Linsley, 1995).

The projected population also provides an important basis for evaluating the future service burden of the Kalimati Reservoir because the reservoir is expected to function as part of a water-supply system rather than merely as a seasonal storage structure. A population increase from 96,315 to 109,714 inhabitants means that the system must accommodate approximately 13,399 additional potential users without compromising the reliability of existing services. This condition becomes more critical when demographic growth coincides with seasonal fluctuations in raw-water availability, since a larger service population increases demand precisely when available inflow may be constrained. Integrated reservoir planning recognizes that storage should be assessed in relation to future demand and supply conditions rather than solely from its physical volume (Bachtiar et al., 2023). The demographic projection consequently establishes the demand-side boundary within which the subsequent analysis of water consumption, dependable discharge, and reservoir storage capacity must operate. The result also provides a quantitative link between local population development and the engineering dimensions of the proposed clean-water infrastructure.

From a broader water-resource perspective, the projected demographic trajectory supports the need for demand-oriented planning in which infrastructure capacity is adjusted to expected future requirements. Reservoir systems are increasingly evaluated according to their ability to balance available water, changing demand, and operational reliability across different conditions rather than simply their nominal storage volume (Bianshiyu et al., 2024). The 1.311% annual population growth identified for the Kalimati service area indicates that demand pressure will continue to accumulate throughout the planning period, even though the observed annual growth rates fluctuate. This finding reinforces the importance of maintaining consistency between population projection and the subsequent calculation of water consumption, maximum daily demand, and storage requirements. A demographic projection that is appropriately linked to engineering demand calculations can reduce the risk of designing infrastructure that becomes inadequate before the end of its intended planning period. The projected population of 109,714 inhabitants therefore becomes the reference condition for the analysis of existing water consumption and its projected development in the following section.

The demographic analysis establishes that the Kalimati Reservoir service area requires a forward-looking water-supply strategy because the projected population in 2034 exceeds the 2024 population by more than thirteen thousand inhabitants. The geometric projection provides a transparent and reproducible method for translating the observed demographic trend into a planning population, while the calculated 1.311% annual growth rate offers a consistent parameter for subsequent water-demand estimation. The projected population of 109,714 inhabitants should not be interpreted as an isolated forecast but as the design population against which the adequacy of water resources and reservoir infrastructure can be tested. This distinction is important because reservoir performance depends on the interaction between storage availability and the magnitude of future demand, particularly under conditions of seasonal hydrological variability (Trimartinni & Limantara, 2024). The population projection consequently forms the first quantitative link in the analytical chain connecting demographic development with clean-water demand and ultimately with the required reservoir storage capacity. The next analysis therefore examines existing domestic and non-domestic water consumption to determine whether the demographic projection is accompanied by a corresponding increase in the volume of water that must be supplied.

Existing Water Consumption and Its Projection

The analysis of existing water consumption provides an important basis for translating demographic growth into the actual water-supply requirement of the Kalimati Reservoir service area. The 2025 consumption data show that total domestic water use reached 44.902 L/s, while non-domestic consumption reached 16.361 L/s, indicating that domestic users represented the dominant component of existing demand. The magnitude of domestic consumption is consistent with the role of household water use as the principal component of clean-water demand in populated service areas, particularly where residential customers constitute the largest proportion of users (Badan Standardisasi Nasional, 1995). The distribution of consumption across customer categories also indicates that water demand is not generated exclusively by households, since commercial, institutional, educational, health, religious, industrial, and social facilities contribute additional requirements to the system. This composition is relevant for reservoir planning because non-domestic consumption may exhibit different temporal patterns from household consumption and can increase the operational variability of the distribution system. The existing consumption profile therefore provides a more representative demand baseline than population data alone and becomes an important reference for evaluating future water-supply requirements.

Table 2. Existing Domestic and Non-Domestic Water Consumption in the Kalimati Reservoir Service Area in 2025

Category	m³/year	L/s	Projection 2034 (L/s)
Domestic			
Household 1	11,139	0.353	0.402
Household 2	981,758	31.131	35.461
Household 3	292,220	9.266	10.550
Large Commercial	27,645	0.877	0.999
Small Commercial	103,276	3.275	3.730
Total Domestic	**1,416,038**	**44.902**	**51.142**
Non-Domestic			
Small Industry	2,976	0.094	0.128
Large Industry	484	0.015	0.020
Places of Worship	179,300	5.686	7.723
Government Institutions	81,502	2.584	3.510
Hospitals	16,409	0.520	0.710
Schools	196,961	6.246	8.848
Special Social Facilities	38,331	1.215	1.650
Total Non-Domestic	**515,963**	**16.361**	**22.589**

As shown in Table 2, the domestic component is concentrated primarily in Household 2, which accounts for 31.131 L/s or approximately 69.33% of the total domestic consumption of 44.902 L/s. Household 3 contributes 9.266 L/s, while Household 1 contributes only 0.353 L/s, producing a substantial difference in consumption intensity among the residential categories. Commercial customers also contribute to the domestic classification used in the dataset, with large and small commercial consumption reaching 0.877 and 3.275 L/s, respectively. This distribution suggests that the existing system is strongly influenced by residential demand, although commercial activity provides an additional consumption component that should not be excluded from infrastructure planning. Water-supply planning based only on aggregate population may fail to capture these differences in customer structure, particularly when the service area contains facilities with substantially different consumption characteristics. The observed customer composition therefore supports the use of category-specific consumption data as a complementary input to population-based demand projection.

The non-domestic component reaches 16.361 L/s in 2025 and is characterized by a wider distribution among institutional and public-service users than the domestic component. Places of worship contribute 5.686 L/s, followed by schools at 6.246 L/s, government institutions at 2.584 L/s, special social facilities at 1.215 L/s, hospitals at 0.520 L/s, small industries at 0.094 L/s, and large industries at 0.015 L/s. The relatively high contribution from schools and places of worship indicates that institutional water use represents a meaningful component of total demand and should be retained in the design basis rather than being treated as a marginal requirement. This condition is consistent with the principle that water-supply systems should incorporate non-domestic demand according to the characteristics and service functions of the area served (Cipta Karya, 1998). The difference among customer categories also indicates that demand management and storage operation may need to consider periods of intensified institutional activity. Such differentiation becomes increasingly relevant when the system is designed to maintain supply reliability during periods when raw-water availability decreases.

Applying the average annual population growth rate of 1.311% to the existing consumption categories produces a clear increase in projected water use by 2034. Domestic consumption is projected to rise from 44.902 L/s in 2025 to 51.142 L/s in 2034, representing an increase of 6.240 L/s or approximately 13.89%. Non-domestic consumption increases from 16.361 L/s to 22.589 L/s, corresponding to an additional 6.228 L/s or approximately 38.07%. The higher proportional increase in the projected non-domestic component indicates that the future demand structure may become more diverse and increasingly influenced by institutional and service-related activities. The combined projected consumption reaches 73.731 L/s in 2034, compared with 61.263 L/s in 2025, producing an increase of approximately 12.468 L/s. This increasing demand illustrates why reservoir planning must account for future consumption rather than using current utilization as the sole design reference, particularly when infrastructure is expected to serve the area for an extended planning horizon (Haditama et al., 2024).

The projected increase in water consumption also demonstrates the relationship between demographic expansion and the functional requirements of the water-supply system. Although the projected domestic increase is closely associated with population growth, the non-domestic increase reflects the application of the same growth parameter to a customer structure that includes schools, government institutions, health facilities, commercial activities, and other public services. This approach provides a consistent projection framework, but it also introduces an assumption that the relative consumption characteristics of each category remain stable throughout the planning period. Such an assumption is acceptable for preliminary infrastructure sizing when detailed socioeconomic forecasts are unavailable, although it should be recognized as a source of uncertainty in long-term demand estimation. Reservoir operation studies emphasize that changes in demand characteristics can influence the balance between storage reliability and water allocation, particularly where multiple demand sectors compete for a common source (Rediasti et al., 2023). For Kalimati, the projected increase in both domestic and non-domestic consumption strengthens the need for a storage system capable of buffering variations between raw-water availability and actual service requirements.

The results demonstrate that the existing water-consumption profile provides a quantitative bridge between the projected population and the clean-water demand that must subsequently be accommodated by the Kalimati water-supply system. The projected domestic consumption of 51.142 L/s and non-domestic consumption of 22.589 L/s indicate that the service area will require a larger and more diversified water supply by 2034 than under the 2025 baseline condition. The projected combined consumption of 73.731 L/s should, however, be distinguished from the final clean-water requirement because the latter also incorporates standardized service coverage, public-tap demand, non-domestic allocation, and distribution losses. This distinction is essential because infrastructure capacity based only on recorded customer consumption could underestimate the actual design requirement of a planned public water-supply system. Reservoir planning research similarly demonstrates that storage requirements should be derived from the relationship between water demand, available supply, and operational conditions rather than from existing consumption alone (Bachtiar et al., 2023). The consumption projection therefore serves as an intermediate analytical input that must be integrated with standardized demand components and dependable water availability. The resulting demand calculation is presented in the following section to determine the 2034 clean-water requirement and establish the design basis for reservoir storage.

Clean-Water Demand and Water Availability Analysis

The projected population of 109,714 inhabitants in 2034 provides the demographic basis for determining the clean-water requirement of the Kalimati Reservoir service area. The calculation incorporates domestic consumption, public-tap requirements, non-domestic demand, and distribution losses so that the resulting design demand represents the water volume required to support the planned service system rather than merely the recorded consumption of existing customers. Based on the adopted service standards, domestic demand (SI) reaches 81.270 L/s, while public-tap demand (Sb) contributes 6.100 L/s. Non-domestic demand (Kn), calculated as 15% of the combined domestic components, reaches 13.106 L/s, indicating that institutional and public-service requirements form a meaningful supplementary component of total demand. The use of differentiated demand components is consistent with established clean-water planning criteria, which distinguish household requirements from public and non-domestic consumption when determining system capacity (Cipta Karya, 1998).

These components were subsequently combined and adjusted for a 20% water-loss allowance to obtain the total clean-water requirement used as the principal design demand.

The calculated clean-water requirement is 125.600 L/s after accounting for the specified demand components and distribution losses. The calculation can be expressed as follows:

$$\text{Pr} = \frac{SI + Sb + Kn}{0.8}$$

$$\text{Pr} = \frac{81.270 + 6.100 + 13.106}{0.8} = 125.600\ L/s$$

Where Pr represents the total clean-water requirement, SI represents domestic demand, Sb represents public-tap demand, and Kn represents non-domestic demand. The resulting value is substantially higher than the projected recorded consumption of 73.731 L/s obtained from the 2034 customer-based projection in the preceding analysis. This difference indicates that infrastructure planning based solely on historical PDAM consumption would not adequately represent the standardized service requirement of the projected population. The inclusion of service-standard components and water losses provides a more conservative design basis and reduces the possibility that infrastructure capacity will be underestimated. Such an approach is important because clean-water system design must account for both actual consumption patterns and the level of service intended for the future service population (Badan Standardisasi Nasional, 1995).

The total requirement of 125.600 L/s represents the average design demand, while the system must also accommodate temporal fluctuations in consumption. Applying the maximum daily demand factor of 1.2 produces a maximum daily requirement of 150.720 L/s, whereas the peak-hour factor of 1.6 produces a peak demand of 200.960 L/s. These values indicate that the water-supply system would experience substantially higher instantaneous requirements than the average demand, making storage an important component for maintaining continuity of service. The maximum daily and peak-hour factors provide a design mechanism for representing short-term demand variability that cannot be captured by average daily consumption alone (Kementerian Pekerjaan Umum, 2002). The difference between average demand and peak demand also indicates why a reservoir should function as a hydraulic buffer rather than being dimensioned only according to the average flow rate. For the Kalimati system, this operational function becomes particularly relevant because raw-water availability from the Kaliwiso River varies across the year.

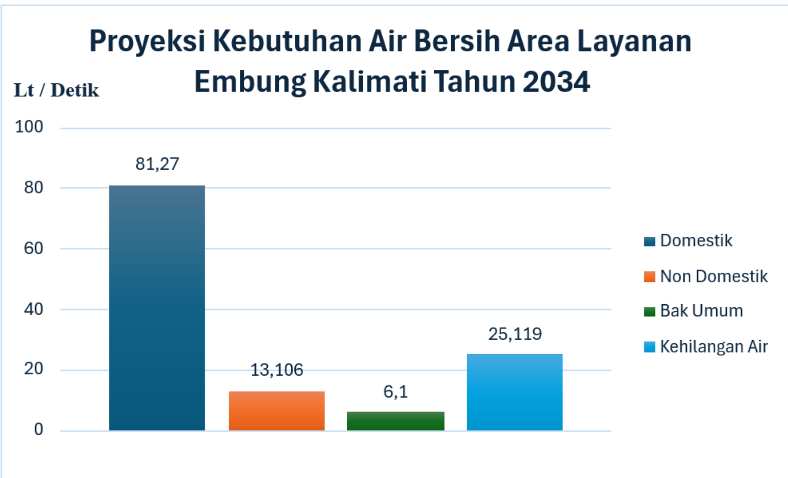

Figure 2. Projection of Clean-Water Demand in the Kalimati Reservoir Service Area in 2034

Figure 2 illustrates the composition of the projected 2034 clean-water requirement and shows that domestic demand constitutes the largest component of the system requirement. The domestic component of 81.270 L/s represents approximately 64.71% of the total calculated requirement, while public-tap and non-domestic requirements contribute approximately 4.86% and 10.43%, respectively, before the effect of water losses is considered. The remaining proportion is associated with the 20% loss allowance incorporated into the calculation, demonstrating that distribution efficiency has a direct effect on the amount of raw water that must be supplied to satisfy the intended service level. This relationship is important because reducing physical losses can decrease the required production and storage volume without reducing the level of service provided to consumers. From a water-resource management perspective, demand efficiency and storage development should therefore be considered complementary rather than independent interventions (Kodoatie & Sjarief, 2010). The demand composition in Figure 2 establishes the volume that must subsequently be compared with the available river discharge to evaluate whether the proposed raw-water source can sustain the planned system throughout the year.

Water availability was assessed using the dependable flow of the Kaliwiso River at the Q80% reliability level and was compared with the planned IPA capacity of 50 L/s. The analysis indicates that the dependable flow from January to August and in December remains above the 50 L/s intake-treatment capacity, suggesting that the planned IPA can receive sufficient raw water directly from the river during these periods. The situation changes during September to November, when dependable discharge decreases substantially and reaches a range of approximately 35–60.89 L/s. This seasonal reduction creates a period in which the river may approach or fall below the planned treatment capacity, making direct abstraction increasingly vulnerable to hydrological conditions. Seasonal variation in rainfall and river discharge is a fundamental factor in determining the reliability of water-resource systems because water availability is not distributed uniformly throughout the annual hydrological cycle (Asdak, 2018). The Q80% analysis therefore identifies September–November as the critical period in which reservoir storage must compensate for the reduction in dependable river flow.

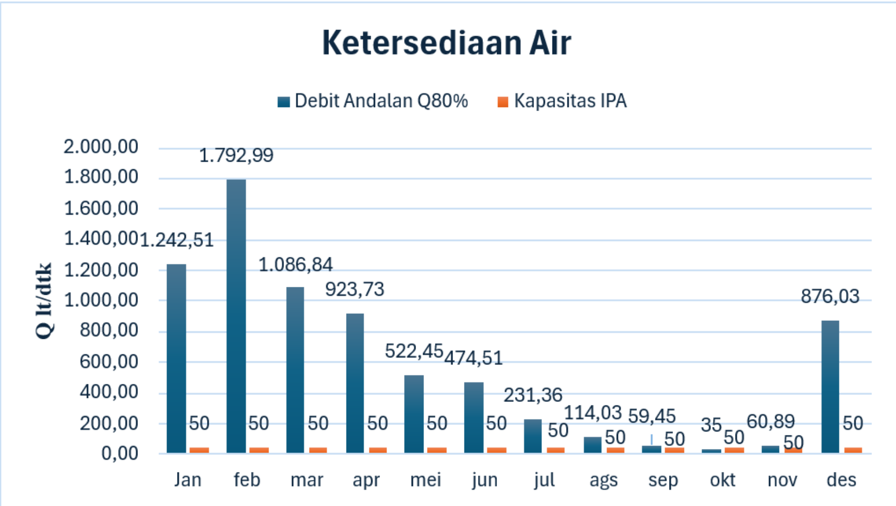

Figure 3. Dependable Flow Availability (Q80%) and IPA Capacity

Figure 3 demonstrates that the principal water-supply challenge is not simply the magnitude of annual water availability but the temporal mismatch between river discharge and continuous clean-water demand. During periods when Q80% discharge exceeds 50 L/s, the planned IPA can theoretically be supplied directly from the Kaliwiso River, whereas lower dependable flows require supplementation from stored water in Embung Kalimati. This operating configuration allows the reservoir to function as a seasonal regulating structure that captures and retains available water during periods of relatively favorable supply for subsequent use during hydrologically constrained months. Reservoir optimization studies have similarly emphasized the importance of coordinating storage with changing water demand and source availability to improve the reliability of raw-water supply (Bachtiar et al., 2023). The Kalimati system therefore requires storage not merely as an additional water source but as a mechanism for reducing the operational consequences of seasonal variability in the Kaliwiso River. The combination of Q80% dependable flow and projected demand provides the technical basis for determining the storage volume required to maintain the planned water-supply service during critical periods.

The relationship between demand and availability also indicates that reservoir planning must consider both the magnitude of demand and the timing of supply deficits. A system may possess sufficient annual water resources while still experiencing service interruptions if the available discharge is insufficient during specific dry-season periods. This condition is particularly relevant to Kalimati because the Q80% analysis identifies a recurring period of reduced river discharge during September–November, while the projected clean-water requirement remains continuous throughout the year. The role of storage is therefore to bridge the temporal gap between source availability and demand, rather than simply to increase the nominal amount of water available to the system. Previous reservoir studies have shown that effective water utilization depends on matching storage operation with demand patterns and hydrological conditions rather than relying solely on the physical storage volume (Rediasti et al., 2023). The results establish a clear engineering requirement for a reservoir capacity capable of supporting the IPA during periods when direct river abstraction becomes insufficient. The storage requirement derived from this demand–availability relationship is subsequently used to determine the physical reservoir capacity, land requirement, and associated construction cost.

Reservoir Storage Capacity, Infrastructure Layout, and Cost Estimation

The reservoir capacity requirement was established by relating the projected maximum daily clean-water demand to the selected storage proportion for the Kalimati water-supply system. The maximum daily demand of 150.720 L/s is equivalent to approximately 13,022.21 m^3/day, which was adopted as the principal demand parameter for preliminary reservoir sizing. A storage proportion of 20% was selected from the applicable range of 10–20%, providing a conservative storage allowance to accommodate short-term differences between raw-water availability and treated-water demand. This selection is particularly relevant to the Kalimati system because the Q80% analysis identified September–November as the period in which dependable discharge from the Kaliwiso River decreases and may approach the planned IPA capacity. Reservoir capacity assessment should consider the relationship between storage volume, water demand, and variations in available supply rather than relying solely on the geometric volume of the reservoir (Trimartinni & Limantara, 2024). The calculated storage requirement therefore represents an operational buffer intended to strengthen supply continuity during periods of reduced source availability.

The required reservoir volume was calculated using the maximum daily water requirement as follows:

$$V = 0.20 \text{ X } Q_{max}$$

$$V = 0.20 \text{ X } 13{,}022.21 = 2{,}604.40 \text{ m}^3$$

The resulting storage capacity of 2,604.40 m^3 represents approximately one-fifth of the maximum daily requirement and provides the preliminary hydraulic design basis for the reservoir. The capacity is not intended to substitute for the Kaliwiso River as the principal raw-water source, but to regulate the temporal mismatch between river discharge and the continuous requirement for treated water. Such storage-based regulation is consistent with integrated reservoir planning approaches in which storage is used to improve raw-water supply reliability under variable hydrological conditions (Bachtiar et al., 2023). The capacity also provides a quantitative benchmark for evaluating the physical dimensions and land requirements of the proposed infrastructure. Further detailed design would require continuous reservoir routing and operational simulation to refine the storage requirement under different inflow and demand scenarios.

Using a planned reservoir depth of 3 m, the required reservoir footprint was calculated by dividing the storage volume by the effective storage depth. The resulting calculation is presented as follows:

$$A = \frac{V}{T}$$

$$A = \frac{2{,}604.40}{3} = 868.13 \text{ m}^2$$

The calculated reservoir footprint is therefore 868.13 m², which represents the estimated area required to accommodate the design storage volume at the selected depth. The available planning area at the Kalimati site reaches 15,893.22 m², indicating that the proposed reservoir can be accommodated without imposing substantial spatial constraints on supporting facilities. After allocating the reservoir footprint, approximately 15,025.09 m² remains available for the IPA, pump house, operational office, laboratory, circulation areas, and green or infiltration zones. The integration of these components is important because a reservoir cannot operate effectively as an isolated storage structure without adequate treatment, pumping, operational, and maintenance facilities. Previous reservoir planning research has demonstrated that clean-water reservoir structures should be integrated with the broader water-supply system to ensure functional and operational compatibility (Prasetya et al., 2021).

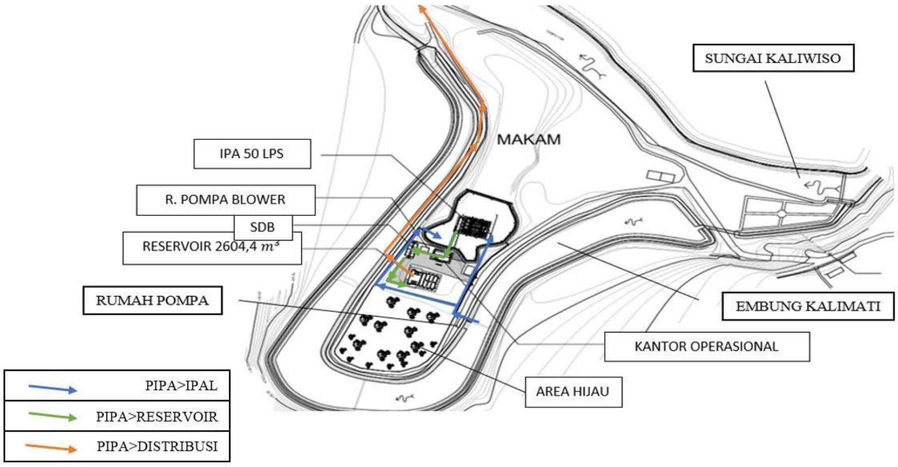

Figure 4. Layout Plan for the Development of the Kalimati Reservoir and Supporting Facilities

Figure 4 illustrates the proposed spatial arrangement of the reservoir and its supporting facilities within the available planning area. The layout incorporates the 2,604.40 m³ reservoir, a planned 50 L/s IPA, pump house, operational office, laboratory, circulation space, and green or infiltration areas within a single infrastructure configuration. The substantial difference between the available land area and the required reservoir footprint provides flexibility for arranging these facilities while maintaining operational access and functional separation. Spatial planning of water infrastructure should consider not only the hydraulic capacity of the storage structure but also accessibility, maintenance requirements, drainage, and compatibility between individual facility functions. The provision of green and infiltration areas is also relevant because maintaining infiltration functions can support local water conservation and reduce the adverse hydrological effects associated with intensive land development (Arsyad, 2010). The proposed layout consequently translates the hydraulic calculation into a preliminary infrastructure configuration that can be developed further during detailed engineering design.

The preliminary construction cost was estimated from six principal work components, consisting of preparation, earthworks, structural works, mechanical and piping works, electrical works, and architectural and finishing works. The cost distribution provides an indication of which physical components contribute most strongly to the investment requirement and therefore provides an initial economic dimension to the technical planning.

Table 3. Recapitulation of the Estimated Construction Cost for the Reservoir

No.	Work Component	Total Cost (IDR)
I	Preparation Works	162,050,400
II	Earthworks	537,740,000
III	Structural Works	1,501,420,000
IV	Mechanical and Piping Works	21,400,000
V	Electrical Works	70,000,000
VI	Architectural and Finishing Works	200,240,000
	Total Reservoir Cost	**2,492,850,400**

As shown in Table 3, the estimated total construction cost reaches IDR 2,492,850,400, with structural works accounting for the largest component at IDR 1,501,420,000. The dominance of structural expenditure is technically reasonable because the reservoir requires structural elements capable of resisting hydrostatic pressure, supporting the stored water volume, and maintaining long-term structural stability. Earthworks constitute the second-largest expenditure at IDR 537,740,000, reflecting the substantial role of excavation, preparation, and formation of the reservoir site. The combined structural and earthwork components account for approximately 81.87% of the total estimated cost, indicating that civil construction represents the primary investment requirement rather than mechanical or electrical equipment. This cost structure is consistent with the engineering characteristics of storage infrastructure, where the physical containment and preparation of the site generally determine a major proportion of construction expenditure (Departemen Pekerjaan Umum, 2010). The estimated cost therefore provides an initial financial benchmark for assessing the feasibility of proceeding from preliminary planning toward detailed design and implementation.

The relationship between the calculated storage volume, available land, infrastructure configuration, and construction cost indicates that the proposed Kalimati reservoir can be technically accommodated within the identified site under the adopted design assumptions. The 2,604.40 m^3 storage requirement provides a preliminary buffer against seasonal reductions in raw-water availability, while the 868.13 m^2 reservoir footprint occupies only a small proportion of the available 15,893.22 m^2 planning area. The remaining land creates sufficient spatial opportunity for integrating treatment, pumping, operational, laboratory, and environmental functions into the proposed water-supply facility. The estimated investment of IDR 2,492,850,400 establishes an initial cost benchmark that can support subsequent feasibility assessment and detailed budgeting. Reservoir performance, however, should be evaluated through more detailed operational analysis because storage adequacy depends on inflow variability, demand fluctuations, and reservoir operating rules in addition to nominal storage volume (Neri & Toth, 2026). The findings provide a preliminary engineering basis for developing the Kalimati Reservoir as an integrated clean-water supply system, while detailed hydrological routing, structural design, and economic evaluation remain necessary before construction implementation.

CONCLUSION

The analysis of clean-water requirements and reservoir storage capacity for the Kalimati Reservoir service area indicates that the projected population in 2034 will reach 109,714 inhabitants, based on an average annual population growth rate of 1.311%. The corresponding clean-water requirement is estimated at 125.60 L/s, while the maximum daily demand and peak-hour demand reach 150.72 L/s and 200.96 L/s, respectively, indicating the need to account for temporal fluctuations in water consumption when designing the supply system. The availability analysis based on the Q80% dependable flow of the Kaliwiso River shows that water availability is generally sufficient to support the planned 50 L/s IPA during most months, while reduced discharge during September–November requires supplementary storage from Embung Kalimati. A reservoir capacity of 2,604.40 m^3 is therefore proposed based on 20% of the maximum daily water requirement, with a planned effective depth of 3 m resulting in a required reservoir footprint of 868.13 m^2. The available planning area of 15,893.22 m^2 provides adequate space for integrating the reservoir with the proposed IPA, pump house, operational office, laboratory, circulation facilities, and green or infiltration areas. The estimated construction cost of IDR 2,492,850,400 provides an initial financial benchmark for developing the proposed reservoir and its supporting infrastructure. Collectively, these findings demonstrate that the Kalimati Reservoir has potential to support a more reliable clean-water supply system, although detailed hydrological, structural, water-quality, operational, and economic assessments are required before implementation.

Future implementation should prioritize the integrated development of the reservoir and its supporting facilities so that raw water from Embung Kalimati can be processed, stored, and distributed efficiently to the designated service area. Reservoir operation should receive particular attention during the dry season through systematic monitoring and regulation of storage levels to maintain supply reliability when Kaliwiso River discharge declines. Reduction of distribution losses should also be incorporated into system management through network rehabilitation, leakage control, and improvement of water-metering accuracy because lower losses can reduce the volume of raw water that must be produced and stored. Continuous monitoring of river discharge and reservoir storage is recommended to identify changes in water availability and support adaptive operational decisions under increasing hydrological uncertainty. Further research should examine the physical and chemical quality of raw water in Embung Kalimati to determine the appropriate treatment processes and ensure compliance with applicable clean-water standards. Detailed engineering studies should also address reservoir structural design, treatment facilities, transmission and distribution networks, hydraulic modelling, operational rules, and economic feasibility before construction is undertaken. The results of this study can serve as a preliminary technical basis for local authorities and water-resource managers in developing a sustainable clean-water supply system for the Kalimati Reservoir service area.

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