Performance Evaluation of Drinking Water Supply System Management in Palu City

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Abstract: The Drinking Water Supply System (SPAM) is a vital infrastructure that supports public health and community welfare. The implementation of the Drinking Water Supply System (DWSS) in Palu City continues to face various challenges, including limited-service coverage, suboptimal water supply continuity, high levels of Non-Revenue Water (NRW), as well as financial and institutional constraints, as reflected in clean water service issues in the Petobo Permanent Housing (Huntap Petobo) area and several other parts of Palu City. This study aims to evaluate the existing performance of DWSS management in Palu City based on the BPPSPAM performance indicators, identify the factors influencing its management performance, and determine the priority factors requiring improvement to ensure sustainable management. The study employed a descriptive-evaluative quantitative approach by integrating secondary data, consisting of the 2025 Regional Water Utility (BUMD Air Minum) performance report, analyzed descriptively, and primary data obtained through questionnaires administered to customers of Perumdam AVO. The sample size was determined using the Slovin formula and proportionate stratified sampling. The primary data were analyzed using reliability testing, Pearson correlation analysis, and Exploratory Factor Analysis (Principal Component Analysis with Varimax rotation), complemented by hydraulic network analysis using EPANET for the four DWSS units. The results indicate that the overall performance of the Palu City DWSS falls into the "Less Healthy" category, with a total score of 2.57 out of a maximum score of 5.00. The service (0.35) aspects were identified as the weakest dimensions and human resources (0.40), while the financial (0.81) and operational (1.01) aspects performed relatively better. Hydraulic analysis revealed that the Duyu DWSS exhibited the most stable pressure distribution, the Watutela and Kawatuna DWSS experienced pressure imbalances at several network nodes, and the Poboya DWSS presented the highest hydraulic risk. Factor analysis identified six principal components explaining a cumulative variance of 83.18%, which were subsequently synthesized into three hierarchical development priorities: improving service quality and tariff collection, strengthening institutional capacity, and enhancing technical and operational performance maintenance.

Keywords: *SPAM, Management Performance, Factor Analysis, EPANET, Palu City*.

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I. INTRODUCTION

Drinking water is a fundamental human need that plays a critical role in supporting quality of life, public health, and sustainable development. The Drinking Water Supply System (SPAM) is an integrated network of facilities and infrastructure encompassing raw water abstraction, treatment, transmission, distribution, and customer service. In Indonesia, SPAM management is generally carried out by Regional Water Utility Companies (PDAM) or municipally-owned enterprises engaged in water supply services. The success of SPAM implementation is heavily influenced by the effectiveness and efficiency of its management across technical/operational, financial, institutional, and public service dimensions.

As the capital of Central Sulawesi Province, Palu City has experienced continuous population growth. According to data from the Statistics Indonesia (BPS) spanning 2024–2026, the average annual population growth rate reached 1.31%. This demographic increase directly intensifies the demand for drinking water, thereby necessitating a supply system capable of delivering optimal, sustainable, and equitable services.

However, SPAM implementation in Palu City still faces various constraints. These challenges include limited service coverage, suboptimal distribution continuity, poor distributed water quality, high levels of Non-Revenue Water (NRW), as well as various financial and institutional constraints. Consequently, these conditions have led to a decline in SPAM management effectiveness and the quality of service received by the community.

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These issues are clearly observable in the clean water services within the Petobo Permanent Housing (Huntap) area. According to a report by Media Alkhairat on April 22, 2025, residents of Huntap Petobo have faced ongoing limitations in clean water supply since the beginning of 2024. Even after the completion of the core infrastructure, drinking water services remain suboptimal. Constraints in production and distribution capacity have necessitated the implementation of a service zoning system, in which the Petobo Huntap area is divided into four zones that receive water supply on a rotational basis. Water distribution issues are also experienced by SPAM customers across various regions of Palu City. In reality, water that is supposed to flow daily is only available once every two to three days. These multifaceted issues demonstrate that the challenges of SPAM management in Palu City extend beyond infrastructure provision to encompass technical/operates, service, financial, and institutional aspects. If not addressed comprehensively, these conditions risk diminishing the quality of drinking water services, increasing customer dissatisfaction, and adversely impacting public health and quality of life.

II. LITERATURE REVIEW

- *The Drinking Water Supply System (SPAM)*

According to Government Regulation Number 122 of 2015 concerning the Drinking Water Supply System, SPAM is defined as an integrated network of facilities and infrastructure dedicated to the provision of drinking water. The implementation of SPAM encompasses activities related to the availability of SPAM facilities and infrastructure aimed at fulfilling the quantity, quality, and continuity of drinking water, which includes new construction, upgrades, and expansions. The primary objective of SPAM implementation is to guarantee the fulfillment of the public's right to adequate drinking water.

The benchmark for success in SPAM implementation lies in the infrastructure development that comprehensively covers operations, maintenance, repairs, human resources enhancement, and institutional strengthening. To execute these responsibilities, water resources management licenses are required for operational activities, as regulated by statutory provisions concerning water resources. The institutions tasked with these responsibilities include the Central Government through the SPAM Technical Implementation Unit (UPT) and Regional Governments through the SPAM Regional Technical Implementation Unit (UPTD). Both units are specifically established to carry out technical and operational duties, endowed with specialized authority from both their parent organizations and regional jurisdictions. These two units collaborate closely with State-Owned Enterprises (BUMN), Municipally-Owned Enterprises (BUMD), and Community Groups to meet the drinking water demands of individuals or collectives.

These activities are anchored in the Provincial Policy and Strategy for SPAM Implementation, hereinafter referred to as the SPAM Policy and Strategy (Jakstra SPAM) and the SPAM Master Plan (RiSPAM). The foundations of SPAM implementation consist of:

- *Policy and Strategy for SPAM Implementation (Jakstra SPAM)*

Jakstra SPAM serves as a strategic planning document specifically for the drinking water sector, providing directional policy for SPAM over a 5-year period. Jakstra SPAM is structured into three administrative tiers: National, Provincial, and Regency/City levels. This policy and strategy document is formulated and enacted every five years by the respective Minister, Governor, Regent, or Mayor, in accordance with their respective levels of regional autonomy.

- *SPAM Master Plan (RiSPAM)*

RiSPAM encompasses the planning of piped drinking water networks and non-piped drinking water systems based on drinking water demand projections within a single period, which is divided into several phases and outlines the primary components of the system along with their dimensions. The formulation of RiSPAM takes into account water resources management plans, regional spatial planning, SPAM implementation policies and strategies, the socioeconomic and cultural environment of the local community, as well as urban conditions and development plans. RiSPAM consists of:

- ✓ Cross-Provincial SPAM Master Plan (Formulated and enacted by the Minister),
- ✓ Cross-Regency/City SPAM Master Plan (Formulated and enacted by the Governor),
- ✓ Regency/City SPAM Master Plan (Formulated and enacted by the Regent/Mayor).

The enactment period for RiSPAM spans 15–20 years and is subject to review every five years. Furthermore, the formulation of RiSPAM strictly mandates public consultation.

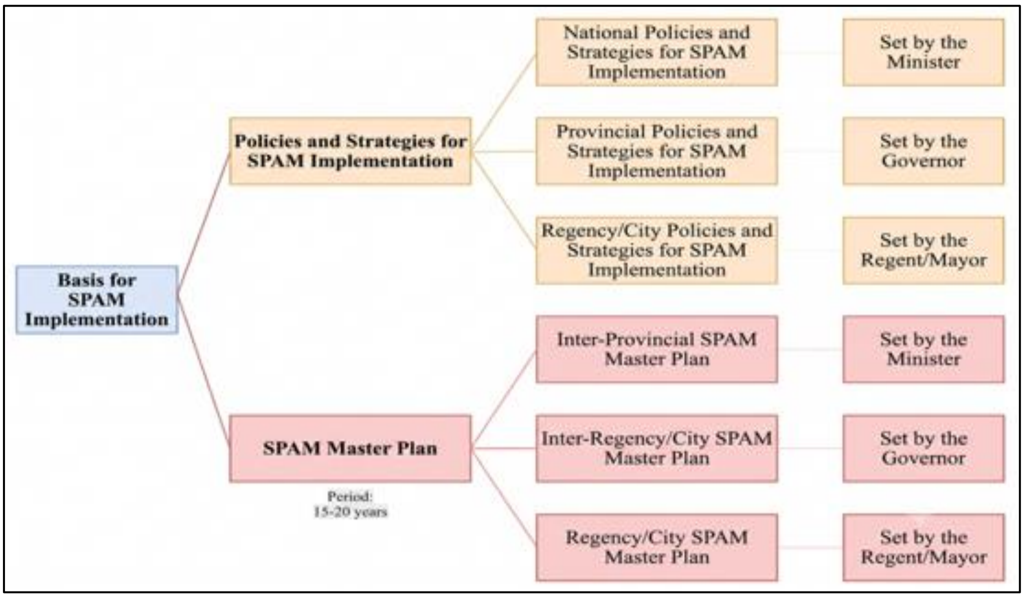

Fig 1 The Foundations of SPAM Implementation

According to the Regulation of the Minister of Public Works and Public Housing Number 27/PRT/M/2016, SPAM consists of several primary components, namely:

- ✓ Raw water sources (surface water, groundwater, or rainwater).
- ✓ Raw water abstraction facilities (intakes).
- ✓ Water treatment plants (WTP/IPA).
- ✓ Transmission and distribution networks.
- ✓ Reservoirs or storage tanks.
- ✓ House connections and customer meters.

➢ *SPAM Management System*

According to Government Regulation Number 122 of 2015 concerning the Drinking Water Supply System, SPAM management is defined as activities carried out in relation to utilizing the functions of constructed SPAM facilities and infrastructure, which encompass operations and maintenance, repairs, human resources enhancement, and institutional strengthening.

SPAM management covers the entire spectrum of planning, construction, operation, maintenance, and monitoring activities for drinking water supply facilities and infrastructure.

According to the Directorate General of Human Settlements (Ministry of Public Works and Public Housing, 2019), SPAM management can be categorized into several primary dimensions, namely:

- *Technical Dimension*

Concerns the physical performance of the system, such as production capacity, water quality, distribution efficiency, and water loss rates.

- *Institutional Dimension*

Encompasses organizational structure, governance, human resource competencies, and coordination between units.

- *Financial Dimension*

Relates to operational financing, cost efficiency, tariffs, revenue, and financial sustainability.

- *Service Dimension*

Includes service coverage, water continuity, customer satisfaction, and responsiveness to complaints.

These four dimensions are closely interconnected in determining the ultimate success of SPAM management.

The implementation of SPAM in Indonesia adheres to the '4K' principles, which comprise:

✓ *Quality (Kualitas)*

The quality of drinking water must meet health quality standards in accordance with statutory regulations.

✓ *Quantity (Kuantitas)*

The quantity of water must be sufficient to meet the basic needs of the community.

✓ *Continuity (Kontinuitas)*

Continuity relates to the sustainable availability of water for 24 hours a day.

✓ *Affordability (Keterjangkauan)*

Affordability refers to the community's ability to pay for drinking water tariffs without compromising other basic needs.

These four principles serve as the primary benchmarks for assessing the success of SPAM implementation. A failure to meet any single principle can lead to a decline in service quality and customer satisfaction levels.

➢ *SPAM Management Performance*

SPAM management performance reflects the success rate of an institution in achieving drinking water supply objectives effectively and efficiently.

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According to the Agency for Supporting the Development of Drinking Water Supply Systems (BPPSPAM), the performance evaluation of SPAM management is conducted using indicators spanning the following four primary dimensions:

- *Technical Dimension*

Evaluates the extent to which SPAM facilities and infrastructure function properly. The indicators include:

- ✓ Drinking water quality in accordance with the Regulation of the Minister of Health Number 2 of 2023.
- ✓ Distribution continuity (hours of water service per day).
- ✓ Non-Revenue Water (NRW) levels less than or equal to 20%.
- ✓ Production capacity relative to customer demand.

- *Financial Dimension*

Assesses the institution's capability to manage finances efficiently and sustainably. Indicators:

- ✓ Operating cost efficiency ratio.
- ✓ Revenue-to-cost ratio.
- ✓ Customer payment collection rate.
- ✓ Water tariff structure.

- *Institutional Dimension*

Evaluates the effectiveness of the organizational system and governance in SPAM management. Indicators:

- ✓ Organizational structure and clarity of functions.
- ✓ Human resource competency and performance.
- ✓ Support from regional policies and regulations.
- ✓ Coordination capability between working units.

- *Service Dimension*

Measures the extent to which the SPAM operator provides adequate drinking water services to the community. Indicators:

- ✓ Service coverage (number of served customers).
- ✓ Customer satisfaction.
- ✓ Responsiveness to complaints.
- ✓ Accessibility and service transparency.

According to the BPPSPAM guidelines (2020), the performance evaluation indicators for PDAM consist of four dimensions: financial, service, operational, and human resources. Each dimension is further detailed into several parameters, and the subsequent evaluation results are classified into three categories: Healthy, Less Healthy, and Unhealthy.

- *The respective dimensions within the BPPSPAM performance indicators comprise:*

- ✓ Financial Dimension, with a weight of 25%
- ✓ Service Dimension, with a weight of 25%
- ✓ Operational Dimension, with a weight of 35%
- ✓ Human Resources Dimension, with a weight of 15%

The PDAM performance evaluation across these four dimensions yields a performance score that classifies PDAM into three categories:

- ✓ Healthy, with a score greater than 2.8
- ✓ Less Healthy, with a score between 2.2 and 2.8
- ✓ Unhealthy, with a score less than 2.2

➢ *Analysis Factor*

In studying SPAM management performance, factor analysis is utilized as a multivariate statistical tool to:

- Identify the primary factors influencing SPAM management performance.
- Simplify numerous performance indicators into a few latent factors.
- Test the construct validity of SPAM performance indicators.

Factor analysis is positioned after the questionnaire data collection phase and prior to further analysis or conclusion drawing.

- *Validity Test*

The validity test reflects the degree of reliability and accuracy of the measuring instrument utilized. A questionnaire item is declared valid if it can effectively reveal the specific variable that the questionnaire is designed to measure. Validity testing is performed using the SPSS (Statistical Package for the Social Sciences) software via the Pearson Product Moment correlation method. The Pearson Product Moment test is a correlation method used to determine the degree of relationship between two variables measured on an interval or ratio scale. The analysis is conducted by correlating each item score with the total score, where the total score represents the summation of all item scores. To evaluate the appropriateness of an item, a significance test of the correlation coefficient is conducted at a significance level of 0.05. A questionnaire item is considered valid if the p-value is less than 0.05. Conversely, if an item fails to meet this requirement, it is excluded from further investigation, and only the compliant items proceed to the next stage of analysis.

- *Reliability Test*

The reliability test is a method used to measure the extent to which a questionnaire is dependable or consistent in producing uniform results over time. A questionnaire item is declared reliable if the Cronbach's Alpha value is above 0.6. A larger α value indicates greater reliability (α is greater than 0.6), and high reliability is demonstrated by an r-value approaching 1.

- *Factor Analysis*

Factor analysis is a multivariate statistical method that attempts to explain the relationships among a number of mutually independent variables so that they can be condensed into one or more sets of factors that are fewer in number than the initial variables. The types of factor analysis are as follows:

- ✓ Exploratory Factor Analysis
- ✓ Confirmatory Factor Analysis

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- *The Procedure for Factor Analysis is Outlined Below:*

✓ *Variable Selection*

Variable selection is conducted by performing validity and reliability tests to select the appropriate variables. If several variables are found to be irrelevant or unsuitable, they must be discarded beforehand, as they can distort the results of the factor analysis.

✓ *Kaiser-Meyer-Olkin (KMO) and Measure of Sampling Adequacy (MSA) Testing*

Following variable selection, the operational variables are filtered based on their inter-correlations. Variables with strong correlations are included in the factor analysis, whereas those with weak correlations are excluded. To distinguish between strong and weak correlations, the Kaiser-Meyer-Olkin (KMO) and Measure of Sampling Adequacy (MSA) tests are conducted. These tests aim to verify whether the research variables are valid for further analysis.

The KMO test is considered valid if the KMO value meets the requirement of being greater than 0.5 up to 1. Meanwhile, the significance level of Bartlett's Test must be less than 0.05. Factor analysis can proceed to further stages only if both KMO and Bartlett's Test values satisfy these prerequisites. Once a KMO value between 0.5 and 1 is achieved, it can be concluded that the factor analysis technique is appropriate for use. Subsequently, if the KMO and Bartlett's Test criteria are met, the analysis proceeds to MSA testing.

An MSA test is deemed valid if the MSA value is greater than 0.5. The MSA value is observed through the anti-image correlation matrix. However, if a variable fails to meet the MSA threshold (less than 0.5), the analysis must be repeated using the same procedure after removing the non-compliant variables one by one. The variables must be excluded sequentially, starting from the one with the smallest MSA value. KMO and MSA testing are conducted iteratively until all research variables meet the threshold value of 0.5. Once all KMO and MSA values are compliant, the data can proceed to the next stage.

✓ *Factor Extraction*

Factor extraction is the process of separating variables that meet the correlation requirements derived from the MSA values. The factor extraction method relates to determining the number of factors that accurately represent the data structure. Factor analysis consistently aims to generate a smaller number of factors compared to the initial number of variables. To perform factor extraction, the Principal Components Analysis (PCA) method is employed. The number of formed factors is determined based on the total initial eigenvalues. Factors with a total initial eigenvalue greater than 1 will be retained, whereas those with a total initial eigenvalue less than 1 will be excluded from the model because a variable with a value less than 1 is no better than the original variable. Total initial eigenvalues greater than 1 serve as the core factors that determine the number of newly formed factors, with the expectation that these factors can contribute a Cumulative Variance Explained greater than 60%, allowing the extraction process to be terminated.

✓ *Factor Rotation*

Factor rotation is performed to achieve factor simplicity and to facilitate interpretation when determining which variables are associated with a specific factor, as some variables may exhibit high correlations with more than one factor. Two continuously developed rotation methods in factor analysis are:

- Orthogonal Rotation Method: A rotation performed by maintaining the axes perpendicular to one another.
- Oblique Rotation Method: Used to obtain a number of factors that are theoretically meaningful.

✓ *Factor Naming*

Factor naming is carried out on factors that have been fully formed based on factor loading values deemed representative of the constituent variables. Once the factors—each consisting of specific variables or sub-factors—are established, the assigned names should underlie and adequately represent the characteristics of their constituent variables. There are no strict rules for factor naming; however, it should ideally be based on characteristics that align with the member variables.

III. RESEARCH METHOD

➢ *Type of Research*

This study utilizes a quantitative approach with a descriptive-evaluative design, aiming to delineate the existing conditions of the Drinking Water Supply System (SPAM) management in Palu City based on the performance indicators of the Agency for Supporting the Development of Drinking Water Supply Systems (BPPSPAM), while simultaneously analyzing the factors that influence management performance through statistical analysis of respondents' perception data.

➢ *Research Location*

This study was conducted in Palu City, specifically focusing on the Palu City Regional Public Water Utility Company (Perumdam Avo). According to the Palu City SPAM Institutional Profile Book of 2025, Perumdam Avo manages four active SPAM units. The water supply systems managed by Perumdam Avo are detailed as follows:

- *Watutela SPAM (Surface Water)*

The Watutela SPAM is one of the drinking water supply systems operating within the Palu City region. This system utilizes raw water sourced from the Watutela River, with an abstraction capacity of 10 L/s utilized by the Palu City PDAM. The intake is situated at an elevation of +430 meters above sea level (masl), and water is conveyed through a 6-inch diameter transmission pipeline to a reservoir with a storage capacity of 300 m³. The Watutela SPAM commenced operations in 2018 and employs a gravity-based distribution system. As of 2026, this system serves a total of 2,685 house connections.

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- *Poboya SPAM (Surface Water)*

The Poboya SPAM is another drinking water supply system operating in the Palu City region. This system leverages raw water sourced from the Poboya River with a total discharge of 400 L/s, of which 100 L/s is utilized by the Palu City PDAM. The intake is located at an elevation of +555 meters above sea level (masl), and water is transmitted through an 8-inch diameter transmission pipeline to a reservoir with a capacity of 400 m³. The Poboya SPAM began operations in 2005 and 2013, applying a gravity-driven distribution system. As of 2026, it serves 1,282 house connections.

- *Kawatuna SPAM (Surface Water)*

The Kawatuna SPAM is a drinking water supply system operating within the Palu City region. It utilizes raw water sourced from the Kawatuna River with a total discharge of 350 L/s, with 30 L/s utilized by the Palu City PDAM. The intake is positioned at an elevation of +380 meters above sea level (masl), and water is distributed via an 8-inch diameter transmission pipeline to a reservoir with a storage capacity of 300 m³. The Kawatuna SPAM was commissioned in 2007 and utilizes a gravity distribution system. By 2026, this system serves 523 house connections.

- *Duyu SPAM (Surface Water)*

The Duyu SPAM is a drinking water supply system operating in the Palu City area. This system utilizes raw water sourced from the Lawara River with a capacity of 340 L/s. The intake is located at an elevation of +210 meters above sea level (masl), while the water is channeled through an 8-inch diameter transmission pipeline to a reservoir with a storage capacity of 500 m³. The Duyu SPAM began operating in 2007 and implements a gravity-based distribution system. As of 2026, it serves 726 house connections.

The research timeline is projected to span approximately 4 months, encompassing the preparation stage, data collection, data processing, analysis, and the final report compilation.

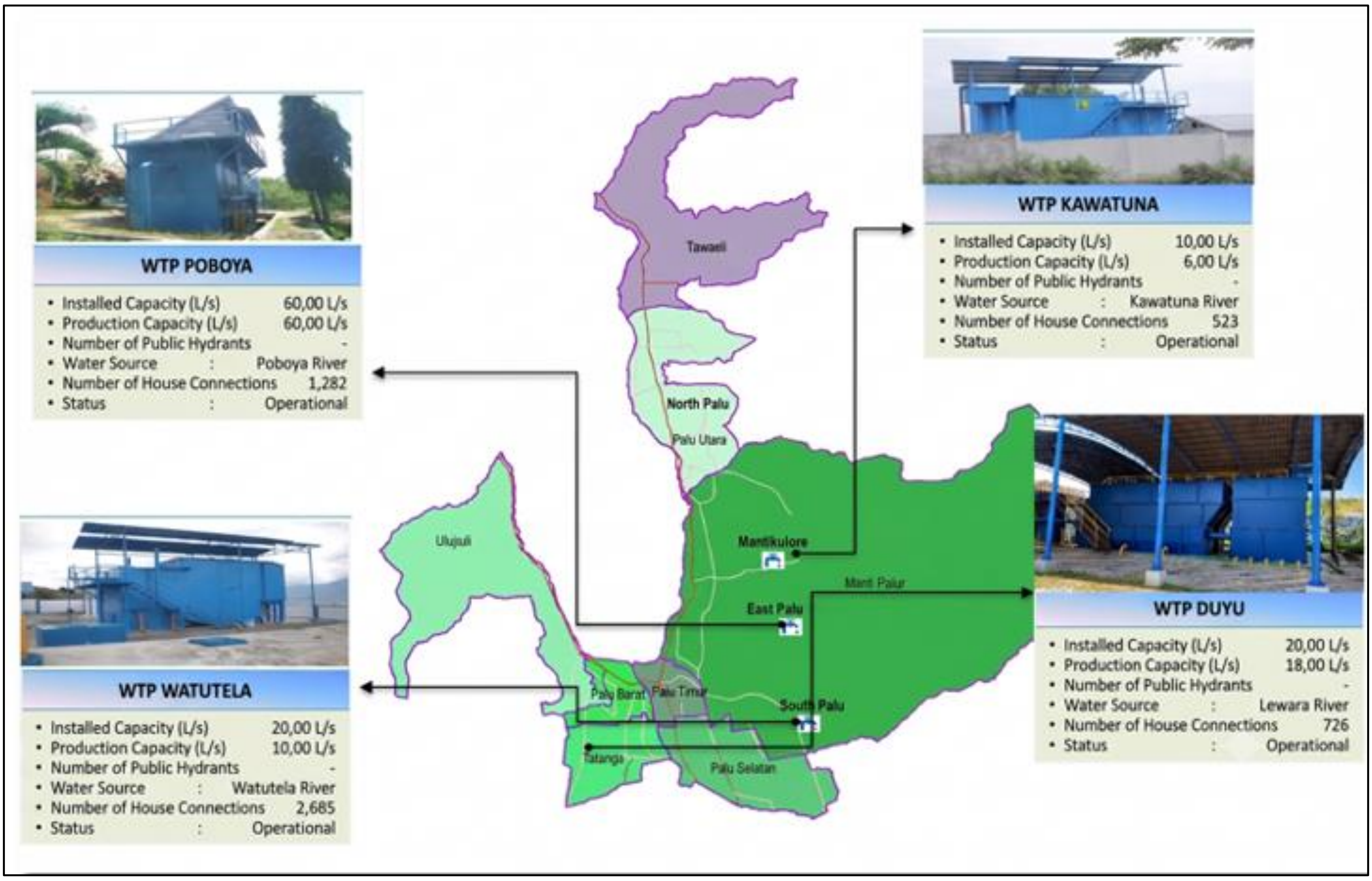

Fig 2 Research Location

> *Data Collection Techniques*

Data collection in this study was conducted using the following techniques:

- Questionnaires: The distribution of a structured list of statements to 99 respondents to obtain perception data regarding the factors influencing SPAM management performance in Palu City.
- Documentary Study: The retrieval and collection of secondary data from official reports, BUMD performance audit results, as well as institutional and technical documents related to SPAM implementation in Palu City.
- Field Observations: Direct observation of the physical conditions of the SPAM infrastructure (water treatment plants, transmission-distribution networks) to complement and verify the gathered secondary data.

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- Interviews: Direct communication with regulators and operators to obtain additional qualitative information that supports the interpretation of quantitative data.

The variables examined in this study encompass the dimensions established by the BPPSPAM. This study utilizes four primary variables, as detailed in Table 1 below:

Table 1 Research Variables and Indicators

Variable	Primary Indicators	Item Code
Technical Dimension	a. SPAM production capacity	X1.1
	b. Distribution network conditions	X1.2
	c. Water distribution pressure	X1.3
	d. Distribution system reliability	X1.4
	e. Network maintenance	X1.5
	f. Water service continuity	X1.6
	g. Received water quality	X1.7
Service Dimension	a. Service coverage	X2.1
	b. Ease of obtaining services	X2.2
	c. Complaint handling speed	X2.3
	d. Service satisfaction	X2.4
	e. Service continuity to customers	X2.5
	f. Water availability relative to demand	X2.6
Financial Dimension	a. Water tariff appropriateness	X3.1
	b. Ease of billing payment	X3.2
	c. Billing collection effectiveness	X3.3
	d. Corporate financial management	X3.4
	e. Revenue utilization for service improvement	X3.5
Institutional Dimension	a. Employee competency	X4.1
	b. Adequacy of staff size	X4.2
	c. Staff responsiveness	X4.3
	d. Organizational coordination and governance	X4.4
	e. SPAM management professionalism	X4.5

- *The Operational Definitions for Each Variable are Outlined Below:*

✓ Technical/Operational Dimension refers to the respondents' perceptions regarding production capacity conditions, the utilization rate of water treatment plants, the reliability of transmission and distribution networks, as well as the continuity and quality of raw water used in SPAM implementation.
✓ Financial Dimension denotes the respondents' perceptions concerning the tariff structure, Full Cost Recovery (FCR) principles, collection effectiveness, Non-Revenue Water (NRW) levels, and the financial management efficiency of the BUMD operating the SPAM.
✓ Service Dimension represents the respondents' perceptions regarding service coverage, the drinking water quality received by customers, and the operator's responsiveness to public needs and complaints.
✓ Institutional/Human Resources Dimension signifies the respondents' perceptions regarding the organizational structure, human resources competency and capacity, availability of planning documents and operational guidelines, and the management information system of the SPAM operator.

➢ *Data Analysis Technique*

Data analysis in this study was conducted sequentially to address the three research questions: the existing condition of SPAM management, the driving factors influencing it, and the development priorities for management sustainability. The analytical stages are outlined below.

- *Descriptive Analysis of Existing Conditions Based on BPPSPAM Indicators*

To address the first research question, secondary data regarding the existing condition of SPAM management in Palu City was analyzed using a descriptive-qualitative approach based on the four dimensions of the BPPSPAM indicators: technical/operational, financial, service, and institutional/human resources. The analysis was performed by comparing actual achievement data (such as production capacity, tariffs, service coverage, and institutional frameworks) with prevailing standards and regulatory thresholds (including guidelines from the Ministry of Public Works and Public Housing, Minister of Home Affairs Regulation Number 2 of 2007, and Minister of Home Affairs Regulation Number 21 of 2020). Consequently, each dimension was qualitatively categorized into three levels: Highly Healthy/Good, Healthy/Sufficient, or Less Healthy/Poor.

- *Research Instrument Testing*

Before the questionnaire data was utilized for advanced analytical stages, the quality of the instrument was rigorously evaluated through the following tests:

✓ Reliability Test: Conducted using the Cronbach's Alpha coefficient to measure the internal consistency of the instrument. The instrument is declared reliable if the

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Cronbach's Alpha value is greater than 0.60, with the following classifications: 0.60–0.70 (acceptable), 0.70–0.90 (good), and greater than 0.90 (excellent).

- ✓ Item Validity Test: Assessed using the Corrected Item-Total Correlation value. A questionnaire item is deemed valid if the item-total correlation coefficient is greater than or equal to 0.30.
- ✓ Inter-dimensional Pearson Correlation Test: Employed to identify the correlation patterns among the total scores of each variable (Total X1, Total X2, Total X3, Total X4). This serves as the baseline interpretation before conducting factor analysis. The correlation is declared significant if the probability value (p) is less than 0.05 or less than 0.01.

Data processing for the instrument testing was carried out using the Statistical Package for the Social Sciences (SPSS) software.

- *Exploratory Factor Analysis (EFA)*

To address the second research question regarding the factors influencing SPAM management performance in Palu City, Exploratory Factor Analysis (EFA) was performed through the following procedural steps:

- ✓ Factor Analysis Feasibility Test: Evaluated using the Kaiser-Meyer-Olkin (KMO) Measure of Sampling Adequacy and Bartlett's Test of Sphericity. The dataset is deemed suitable for further analysis if the KMO value is greater than 0.50 and the significance value of Bartlett's Test is less than 0.05.
- ✓ Factor Extraction: Executed using the Principal Component Analysis (PCA) method based on the Kaiser criterion (eigenvalue greater than 1) to determine the number of components or factors formed from the 23 structured items.
- ✓ Factor Rotation: Applied via the Varimax rotation method with Kaiser Normalization to achieve a more equitable variance distribution across components, thereby facilitating a clearer interpretation of the factor structure.
- ✓ Factor Interpretation: Performed based on dominant factor loading values (greater than 0.50) within the Rotated Component Matrix to identify items clustering within each component. Subsequently, factor labeling was established based on the conceptual uniformity of the items clustered in each respective component.

The factor analysis processing was conducted using the SPSS software.

- *Determination of Development Priorities*

To address the third research question concerning the critical priorities requiring intervention for sustainable SPAM management in Palu City, a synthesis was performed by merging two distinct information sources: (1) the magnitude of variance contribution (statistical weight) of each component derived from the factor analysis; and (2) the severity level of the existing conditions across each BPPSPAM dimension obtained from the descriptive analysis. Integrating these two information streams ensures that the resulting development priorities are not solely statistically driven but also heavily account for the real-world urgency on the ground. Factors or dimensions characterized by the highest variance contribution coupled with the most critical existing baseline condition were designated as top priorities. This hierarchical ranking was applied continuously down to the factors or dimensions with relatively lower development urgency.

IV. RESULTS

- ➢ *Existing Condition of SPAM Management in Palu City*

This section delineates the existing conditions of the Drinking Water Supply System (SPAM) management in Palu City, evaluated against the BPPSPAM performance indicators.

The SPAM performance evaluation based on the indicators established by the Agency for Supporting the Development of Drinking Water Supply Systems (BPPSPAM) serves as the analytical benchmark for assessing the current state of SPAM management in Palu City. This assessment comprehensively encompasses four primary dimensions: operational, financial, service, and human resources. The evaluation utilizes 2025 secondary data as a representative baseline of the most recent performance conditions of the SPAM implementation at the time of this study, given that the official performance report for the current fiscal year of 2026 has not yet been formally compiled by the operator.

Table 2 SPAM Performance Evaluation Result (2025)

Category	**Standard for "Healthy" PDAM**	**Existing Condition**			
		2025			
		Calculated Score	**Scale**	**Point**	**Final Score**
FINANCIAL DIMENSION					**0.81**
Return on equity (ROE)	≥ 10%	-49.68%	1	0.055	0.06
Operational ratio	≤ 0.5	1.28	1	0.055	0.06
Cash ratio	≥ 100%	275.44%	5	0.055	0.28
Billing collection effectiveness	≥ 90%	92.45%	5	0.055	0.28
Solvency	≥ 200%	1041.38%	5	0.03	0.15
SERVICE DIMENSION					0.35
Technical service coverage	≥ 80%	9.08%	1	0.05	0.05
Customer growth rate	≥ 10%	-1.72%	1	0.05	0.05
Complaint resolution rate	≥ 80%	89.34%	5	0.025	0.13

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Customer water quality compliance	≥ 80%	0.00%	1	0.075	0.08
Domestic water consumption	≥ 30 m^3/bln	6.57	1	0.05	0.05
OPERATIONAL DIMENSION					1.01
Production efficiency ratio	≥ 90%	37.49%	1	0.07	0.07
Water loss (Non-Revenue Water)	≤ 25%	32.55%	3	0.07	0.21
Hours of service supply	21-24 Jam	22	5	0.08	0.40
Water pressure at house connections	≥ 80%	72.13%	4	0.065	0.26
Customer meter replacement/calibration	≥ 20%	0.83%	1	0.065	0.07
HUMAN RESOURCES DIMENSION					0.40
Staff-to-customer ratio	≤ 6 (Kota)	6.29	4	0.07	0.28
Employee training ratio	≥ 80%	35.71%	2	0.04	0.08
Training budget ratio	≥ 10%	0.37%	1	0.04	0.04
Total Cumulative Score		2.57			
Performance Status (Ministry of PUPR)		Less Healthy			

Based on the results in Table 2, a cumulative score of 2.57 out of a maximum scale of 5.00 was obtained, placing the management performance in the 'Less Healthy' category (general classification thresholds: Healthy ≥ 2.8; Less Healthy 2.2–2.8; Unhealthy < 2.2). This evaluation score indicates that upgrading the overall performance status of the PDAM can be achieved most effectively not by improving each dimension in isolation, but by strategically allocating the existing financial surplus to fund the expansion of service coverage and operational optimizations—specifically targeting production efficiency and water loss reduction. Executing these measures will simultaneously drive up the Service and Operational dimension scores, which will ultimately enhance long-term Financial performance through customer growth and increased revenue generation.

- *Financial Dimension*

The financial dimension achieved a score of 0.81, placing it within the 'Good' category. This performance was realized because three out of the five evaluated indicators successfully reached a scale score of 5. Nevertheless, the financial condition continues to face several challenges, particularly concerning the Return on Equity (ROE) indicator, which exhibited a significant negative value, and the operational ratio, which remained below the established standard. This condition indicates that the PDAM is still experiencing structural losses, presumably driven by water tariffs that have not yet achieved full cost recovery or ongoing inefficiencies in both production and distribution costs. Conversely, the exceptionally high cash and solvency ratios (exceeding 1,000%) do not necessarily reflect a healthy financial state. Instead, these values may signify underutilized cash reserves or underproductive assets, indicating that the available funds have not been optimally reallocated for investments in infrastructure upgrades and rehabilitation.

- *Service Dimension*

The service dimension obtained a score of 0.35, categorizing it as the most critical dimension. This low performance is attributed to the fact that four out of the five assessment indicators were at the lowest scale score of 1. One of the primary causes is the technical service coverage, which reached only 9.08%, demonstrating that the vast majority of the population within the service area still lacks access to the piped network. Furthermore, a customer growth rate of -1.72% indicates a decline in the total number of active customers, which is presumed to be influenced by disconnections resulting from payment arrears or customer dissatisfaction with service quality.

Another critical issue requiring attention is the customer water quality compliance, which scored 0%, indicating that the customer water samples failed to meet the required quality standards. This condition poses potential risks to public health while simultaneously impacting regulatory compliance regarding drinking water supply operations. Additionally, domestic water consumption reached only 6.57 m^3 per month, falling far below the standard of 30 m^3 per month. This low water consumption indicates that the water supply is either not continuously available or that customers are limiting their water usage due to tariff considerations or the perceived low quality of the service received.

- *Operational Dimension*

Within the technical-operational dimension, several indicators demonstrated relatively good performance; namely, the hours of service supply reached 22 hours per day, nearly fulfilling the established standard, and the water pressure stood at 72.13%, which remains in a reasonably good category. Nonetheless, the production efficiency ratio reached only 37.49% of the installed capacity, indicating that the production facilities are significantly underutilized. This condition aligns with the low service coverage, showing that the available plant capacity has not been able to maximize its service delivery to the community.

Furthermore, the customer water meter replacement or calibration rate was only 0.83%, implying that the majority of water meters have been in use for an extended period and are highly susceptible to reduced accuracy. This situation can lead to revenue losses due to non-technical (non-physical) water losses and adversely affects the accuracy of total water loss data. Meanwhile, the Non-Revenue Water (NRW) level was recorded at 32.55%, remaining above the recommended standard of less than 25%. However, this value is not yet categorized as critically high, meaning it can still be progressively reduced through leakage control programs, network rehabilitation, and enhanced distribution system management.

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- *Human Resources Dimension*

The human resources dimension achieved a score of 0.40, placing it in the 'Weak' category. Within this dimension, the staff-to-customer ratio reached 11.92, which is higher than the established standard of less than 6. This condition indicates that the organizational structure is relatively inefficient compared to the volume of customers served. This does not necessarily denote an absolute surplus of personnel, but rather reflects that human resource utilization is not yet optimal, particularly given the low service coverage. Consequently, this condition is closely intertwined with the poor performance in the service dimension.

In addition, the ratio of employees participating in education and training programs stood at 35.71%, while the training budget ratio reached only 0.37%, falling far below the standard of greater than 10%. These figures demonstrate that the organization's investment in human resources competency development remains highly limited. The low budget allocation for training and education potentially hampers capacity building, professionalism, and the overall quality of services provided by the enterprise.

➢ *Existing Piping Network Evaluation via EPANET Simulation*

To obtain a comprehensive overview of the existing field conditions of the piping network, hydraulic simulations were performed using the EPANET software across the four active SPAM units. This simulation aims to identify and evaluate the actual pressure conditions occurring within the drinking water distribution network.

- *Watutela SPAM*

Based on the hydraulic simulation results, the pressure within the distribution network ranges from 19.21 m to 84.03 m, with an average pressure of 46.52 m. In general, these pressure values remain within an adequate range to support water distribution services. However, three specific nodes exhibit pressures exceeding 80 m, indicating the presence of high-pressure zones. This condition is presumed to occur in areas adjacent to the reservoir or located at lower elevations. If left unmanaged, this excessive pressure potentially heightens the risk of leakages and structural damage within the piping network. Consequently, pressure control interventions, such as the installation of Pressure Reducing Valves (PRVs), are required to maintain network pressure within safe operational limits.

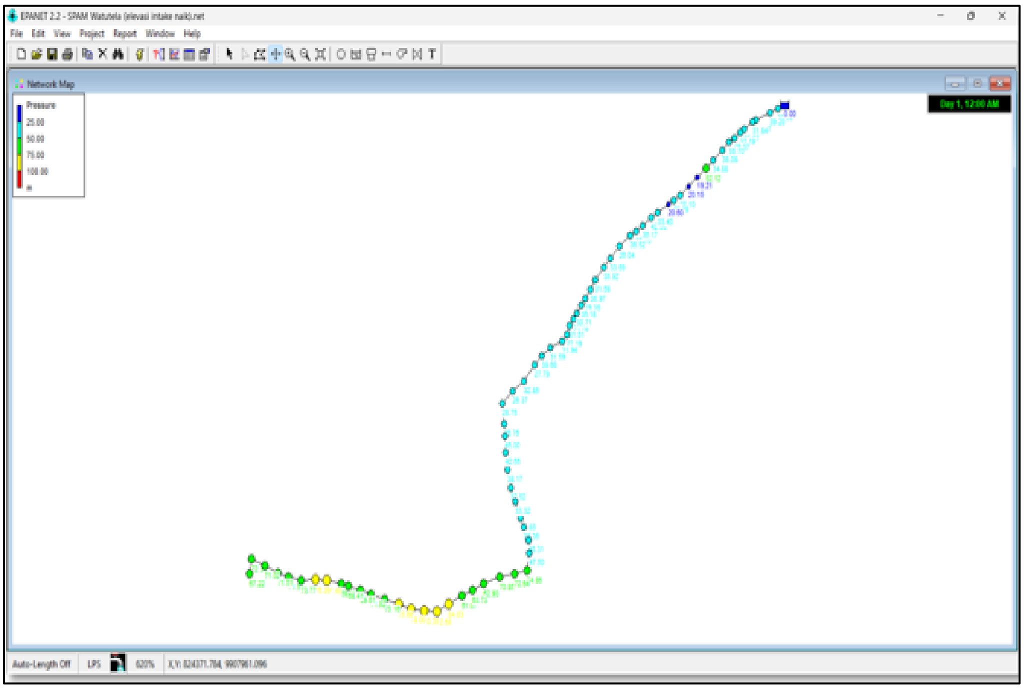

Fig 3 Existing Hydraulic Simulation of the Watutela SPAM

- *Poboya SPAM*

The simulation results show that the pressure within the distribution network ranges from 11.17 m at Junction 30 to 99.96 m at Junction 108, with an average pressure of 64.62 m. Additionally, 28 nodes exhibit pressures between 10 and 20 m, placing them near the minimum service pressure limit and making them susceptible to supply reductions, particularly during peak demand periods. Based on these findings, the Poboya SPAM represents the unit with the highest hydraulic risk level. This condition is driven by a combination of the relatively high reservoir elevation and a steep downward topographic gradient, which induces excessive pressure across most of the distribution network. This excessive pressure potentially increases the frequency of pipe bursts and is presumed to contribute to the high Non-Revenue Water (NRW) levels indicated in the previous performance evaluation. Therefore, pressure management interventions are required through the implementation of District Metered Areas (DMAs) or distribution network zoning, along with the installation of Pressure Reducing Valves (PRVs) at strategic locations to maintain network pressure within safe operational limits.

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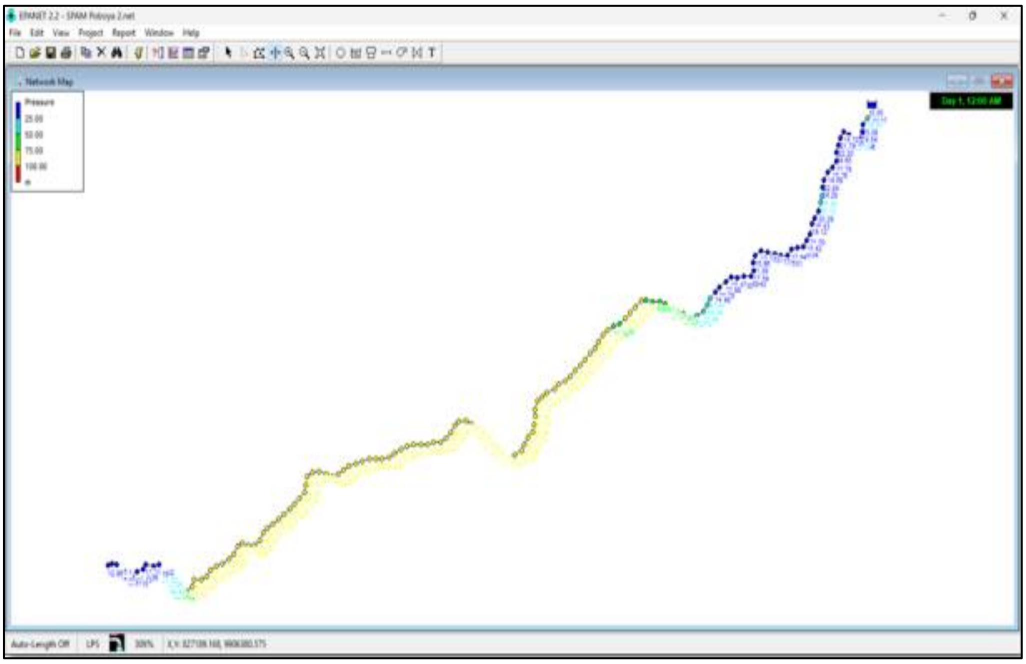

Fig 4 Existing Hydraulic Simulation of the Poboya SPAM

- *Kawatuna SPAM*

Based on the hydraulic simulation results, the pressure within the distribution network ranges from 11.99 m at Junction 74 to 99.61 m at Junction 4, with an average pressure of 56.87 m. These findings indicate a significant imbalance in pressure distribution across the network. Specifically, excessively high pressure occurs in areas near the reservoir, approaching 100 m at Junction 4, whereas at the periphery of the network, the pressure drops near the minimum threshold to approximately 12 m at Junction 74. This substantial pressure variance confirms that the network's pressure distribution is not uniform. Therefore, optimal valve configuration and operation are required to achieve a more balanced pressure distribution, thereby maintaining drinking water service quality and minimizing the risk of network damage caused by excessive pressure.

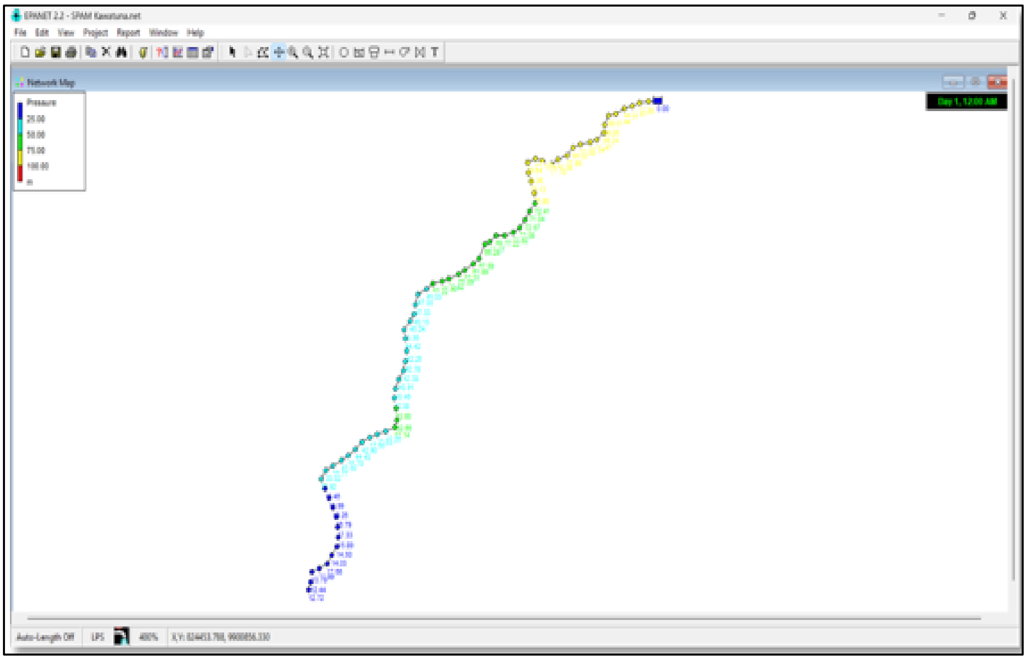

Fig 5 Existing Hydraulic Simulation of the Kawatuna SPAM

- *Duyu SPAM*

Based on the hydraulic simulation results, the pressure within the Duyu SPAM distribution network ranges from 16.41 m at Junction 2 to 39.49 m at Junction 59, with an average pressure of 32.50 m. These findings demonstrate that no nodes exhibit pressures exceeding 80 m, indicating the absence of excessive pressure within the network. Furthermore, only four nodes fall within the 10–20 m pressure range, which remains within service limits despite approaching the minimum threshold.

Overall, the Duyu SPAM exhibits the most uniform and controlled pressure distribution compared to the other three SPAM units. No extreme pressure variances—either excessively high or critically low—were detected, suggesting that the hydraulic conditions of this system are the most ideal for supporting the operational reliability of the drinking water distribution network.

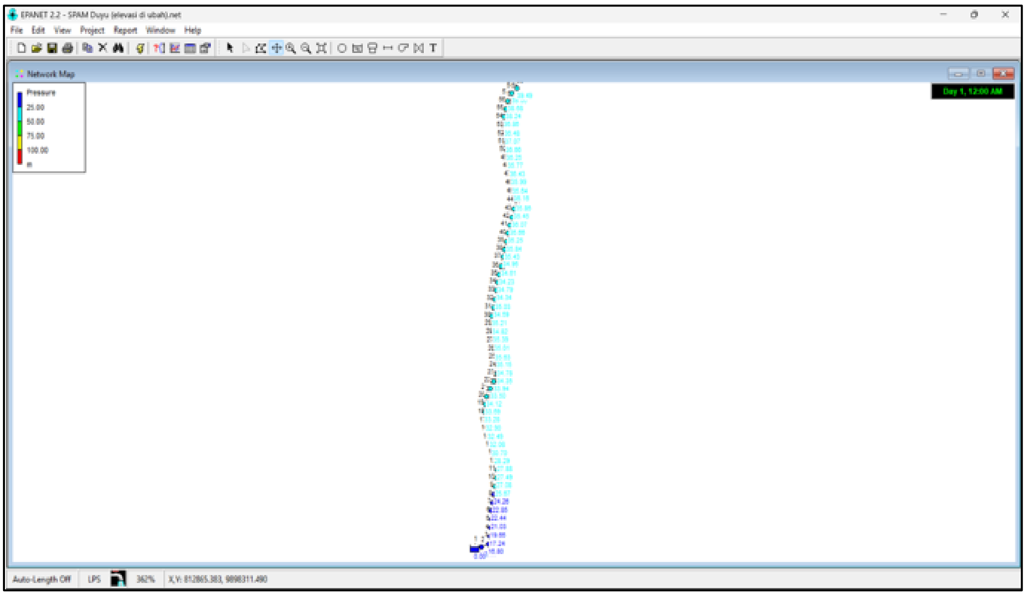

Fig 6 Existing Hydraulic Simulation of the Duyu SPAM

➢ *Analysis of Factors Influencing SPAM Management Performance in Palu City*

To address the second research question regarding the factors influencing the management performance of the Drinking Water Supply System (SPAM) in Palu City from the users' perspective, an Exploratory Factor Analysis (EFA) was performed. The analysis utilized the Principal Component Analysis (PCA) extraction method and Varimax rotation applied to 23 structured items across four dimensions (X1–X4). Factor analysis aims to condense (reduce) correlated variables into a smaller set of factors (components) capable of explaining most of the data variance, thereby identifying the dominant clusters of factors that influence SPAM management performance.

- *Validity Test*

The validity test was conducted to determine the validity of each item within the research instrument. Utilizing a critical value distribution (r-table) at a 5% significance level with N=99 (the total number of respondents), the decision rule dictates that if the calculated r-value (r-statistic) is greater than the r-table value, the item is declared valid; conversely, if the r-statistic is less than the r-table value, the item is deemed invalid.

Table 3 Pearson Correlation Analysis

Correlations			
Variable	**r hitung**	**r tabel**	**Status**
X1.1	0.846	0.196	Valid
X1.2	0.735	0.196	Valid
X1.3	0.542	0.196	Valid
X1.4	0.773	0.196	Valid
X1.5	0.568	0.196	Valid
X1.6	0.557	0.196	Valid
X1.7	0.859	0.196	Valid
X2.1	0.841	0.196	Valid
X2.2	0.728	0.196	Valid
X2.3	0.711	0.196	Valid
X2.4	0.710	0.196	Valid
X2.5	0.848	0.196	Valid
X2.6	0.745	0.196	Valid
X3.1	0.832	0.196	Valid
X3.2	0.739	0.196	Valid
X3.3	0.843	0.196	Valid
X3.4	0.840	0.196	Valid
X3.5	0.869	0.196	Valid

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X4.1	0.859	0.196	Valid
X4.2	0.817	0.196	Valid
X4.3	0.877	0.196	Valid
X4.4	0.839	0.196	Valid
X4.5	0.830	0.196	Valid

- *Reability Test*

The reliability test aims to evaluate the internal consistency of the research instrument in measuring the same underlying construct. The evaluation of the 23 structured items across 99 valid cases (with no missing data) yielded a Cronbach's Alpha coefficient of 0.901, as presented in Table 4. The validity test was conducted to determine the validity of each item within the research instrument. Utilizing a critical value distribution (r-table) at a 5% significance level with N=99 (the total number of respondents), the decision rule dictates that if the calculated r-value (r-statistic) is greater than the r-table value, the item is declared valid; conversely, if the r-statistic is less than the r-table value, the item is deemed invalid.

Table 4 Pearson Correlation Analysis

N of Items	***Cronbach's Alpha***	**Status**
23	0,901	Reliabel

The Cronbach's Alpha value of 0.901 stands significantly above the standard acceptable threshold of 0.60 commonly required in social science research. Therefore, the measurement instrument is declared highly reliable (excellent) for evaluating respondents' perceptions regarding the factors influencing SPAM management performance in Palu City.

The Corrected Item-Total Correlation results indicate that the majority of the items (20 out of 23 items) achieved an item-total correlation coefficient above 0.30, thus validating their contribution to the overall construct of the instrument. Three specific items—X1.3, X1.4, and X1.6, all originating from the Technical Dimension (X1)—demonstrated low item-total correlation values, approaching zero in the case of item X1.3 (r=-0.0005). However, this low correlation does not necessarily indicate that the items are substantively invalid. Rather, it is primarily driven by the relatively independent (freestanding) nature of the Technical Dimension compared to the other three dimensions.

- *Inter-Dimensional Correlation Analysis Test*

To obtain a preliminary overview of the relationships among dimensions prior to executing the factor analysis, a Pearson correlation test was conducted on the total scores of each dimension (Total X_1, Total X_2, Total X_3, Total X_4).

Table 5 Correlation Matrix Among SPAM Management Dimensions

Dimension	**Total X1 (Technical)**	**Total X2 (Service)**	**Total X3 (Financial)**	**Total X4 (Institutional)**
Total X1 (Technical)	1.000	0,09305556	0.091	0,08263889
Total X2 (Service)	0,09305556	1.000	0.629**	0.824**
Total X3 (Financial)	0.091	0.629**	1.000	0.577**
Total X4 (Institutional)	0,08263889	0.824**	0.577**	1.000

The correlation results demonstrate a consistent and critical pattern: (1) The Technical Dimension (Total X1) exhibits no significant correlation with the other three dimensions (r ranges from 0.091 to 0.134; p is greater than 0.05), indicating that technical/operational issues within Palu City's SPAM operate relatively independently and are not directly related to financial, service, or institutional conditions; (2) The Service (Total X2), Financial (Total X3), and Institutional (Total X4) dimensions are positively and significantly inter-correlated (p is less than 0.01), with the strongest correlation observed between the Service and Institutional dimensions (r=0.824). These findings indicate that these three dimensions constitute an integrated system where weak institutional capacity (organizational structure, HR, and governance) contributes to suboptimal financial performance (non-FCR tariffs and low billing collection rates), which in turn constrains the expansion of public service coverage.

- *Feasibility Test for Factor Analysis (KMO and Bartlett's Test)*

Prior to factor extraction, dataset adequacy and feasibility were evaluated utilizing the Kaiser-Meyer-Olkin (KMO) Measure of Sampling Adequacy and Bartlett's Test of Sphericity, as presented in Table 5.

Table 6 Results of KMO and Bartlett’s Test

Test Parameter	**Value**
Kaiser-Meyer-Olkin (KMO) Measure of Sampling Adequacy	0,724
Bartlett's Test of Sphericity - Approx. Chi-Square	2.514,250
Bartlett's Test of Sphericity - df	253
Bartlett's Test of Sphericity - Sig.	0,000

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The KMO value of 0.724 (greater than 0.50) indicates that both the sample size and the inter-correlations among variables are adequate for factor analysis. Furthermore, Bartlett's Test of Sphericity yielded a significance value of 0.000 (less than 0.05), confirming the presence of sufficiently robust correlations within the matrix. Therefore, the dataset is highly feasible for further exploratory factor analysis.

- *Communalities*

Communalities indicate the proportion of variance in each structured item that can be explained by the extracted factors. The extraction results show that all 23 items achieved communality values above 0.70 (ranging from 0.712 to 0.919). This demonstrates that more than 70% of the variance in each item is accounted for by the six extracted components, indicating excellent factor representation. The highest communality values were identified in items X3.1 (0.919), X4.5 (0.916), and X2.3 (0.910), whereas the lowest value was observed in item X2.1 (0.712).

- *Factor Extraction and Total Variance Explained*

Based on the Kaiser criterion (eigenvalue greater than 1), the factor analysis successfully extracted six components from the 23 analyzed items, explaining a cumulative total variance of 83.18%. The details of the extraction results are presented in Table 6.

Table 7 Total Variance Explained

Component	Initial Eigenvalue	% of Variance (Pre-Rotation)	Cumulative % (Pre-Rotation)	% of Variance (Post-Rotation)	Cumulative % (Post-Rotation)
1	8,709	37,87	37,87	20,84	20,84
2	4,116	17,90	55,76	19,18	40,03
3	2,486	10,81	66,57	16,67	56,69
4	1,564	6,80	73,37	11,69	68,38
5	1,202	5,23	78,60	7,54	75,93
6	1,055	4,58	83,18	7,26	83,18

The cumulative total variance of 83.18% indicates that the six extracted components are highly representative in explaining the dataset variance regarding the factors influencing SPAM management performance in Palu City, as this exceeds the 60% threshold commonly required in social science research. Following the Varimax rotation, the variance distribution among components became more uniform (shifting from 37.87% to 20.84% for the first component), thereby facilitating a clearer interpretation of the factor structure.

- *Rotated Component Matrix and Factor Interpretation*

The interpretation of the six components was conducted based on items exhibiting dominant factor loadings (greater than 0.50) on each component resulting from the Varimax rotation. A summary of the item clustering for each component is presented in Table 7.

Table 8 Item Clustering Based on the Rotated Component Matrix

Component	% of Variance	Dominant Items (Factor Loading)	Original Dimension	Factor Name (Interpretation)
1	20.84%	X3.5 (0.886), X3.4 (0.875), X2.6 (0.791), X3.3 (0.783), X3.1 (0.728), X3.2 (0.582), X2.1 (0.553)	Financial (X3) & Service (X2)	Revenue/Retribution and Service Integration Factor
2	19.18%	X4.5 (0.824), X1.5 (0.795), X4.3 (0.758), X2.2 (0.733), X4.4 (0.620), X2.5 (0.536)	Institutional (X4), Technical (X1), Service (X2)	Institutional Capacity and Management Support Factor
3	16.67%	X1.4 (0.885), X1.1 (0.882), X1.7 (0.825), X1.2 (0.758)	Technical (X1) - pure	Core Technical-Operational Factor
4	11.69%	X2.3 (0.887), X4.1 (0.642), X2.4 (0.640)	Service (X2), Institutional (X4)	Service and Governance Factor
5	7.54%	X4.2 (0.742)	Institutional (X4)	Specific HR Capacity Factor
6	7.26%	X1.6 (0.826), X1.3 (0.781)	Technical (X1)	Supporting Technical Factor (Continuity/Quality)

✓ *The Extracted Factor Structure Aligns Closely with the Inter-Dimensional Correlations:*

Components 3 and 6 consist exclusively of Technical (X1) items, confirming their structural independence. Component 3 (16.67% variance) represents core capacity and distribution reliability, while Component 6 (7.26% variance) reflects supporting technical aspects (water continuity and quality).

Component 1 (20.84% variance, the largest) blends Financial (X3) and select Service items (X2.6, X2.1). This indicates that customer perceptions inextricably link service quality and coverage to billing and revenue capabilities—

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reflecting baseline challenges where billing effectiveness (93.14%) and service coverage (8.14%–18.64%) are concurrently problematic.

Components 2, 4, and 5 are dominated by Institutional (X4) items intermixed with Service (X2) and Technical (X1.5) variables. This confirms that governance acts as a cross-cutting dimension influencing both service delivery and operational reliability.

➢ *Existing SPAM Conditions and Customer Perception Factors*

This discussion aims to interconnect the results of the technical-administrative performance evaluation based on the 2025 BPPSPAM indicators with the structure of customer perception factors derived from the 2026 factor analysis. It is crucial to emphasize that these two datasets were obtained across different periods. The BPPSPAM indicators represent the performance status in 2025 as the latest available official baseline data, whereas the customer perceptions were gathered in 2026 as a follow-up confirmation of those conditions. Given that SPAM infrastructure characteristics typically do not undergo significant transformations within a span of less than a year unless major expansion works are executed, both datasets are assumed to remain highly relevant for joint analysis to provide a comprehensive depiction of performance.

➢ *Priorities of Factors in SPAM Management in Palu City*

The determination of factor priorities requiring development was conducted by merging two distinct information sources: (1) the magnitude of variance contribution (statistical weight) of each component derived from the factor analysis in Subsection 4.2; and (2) the severity level of the existing conditions across each BPPSPAM dimension as delineated in Subsection 4.1. This integrated approach ensures that the resulting priorities are not solely statistically driven but also heavily account for the real-world operational urgency on the ground.

- *Convergence of Service and Revenue Factors as the Top Priority*

This finding exhibits a robust causal coherence: the low Service score in the BPPSPAM evaluation (technical service coverage of 9.08%, customer growth of -1.72%) is directly linked to suboptimal retribution revenues, which is reflected by the clustering of items X2.6 and X2.1 (Service) into Component 1 of the EFA. In other words, customer perception does not isolate service quality from the perceived fairness of the tariffs or retributions they pay; both are perceived as a single packaged experience. This condition explains why customer growth is negative despite the PDAM's exceptionally high cash and solvency ratios (exceeding 1,000%): liquid funds are available but have not been effectively converted into network expansions or service quality improvements that are directly perceived by customers.

- *Institutional and Governance Dimensions as Mediating Factors (Second Priority)*

The distribution of the Institutional items (X4) across three distinct components (2, 4, and 5)—rather than clustering within a single cohesive component like the Service or Technical dimensions—provides robust empirical evidence that the institutional framework is cross-cutting rather than functioning as an isolated problem domain. This pattern is consistent with the inter-dimensional correlation test results, where Total X4 correlates significantly with Total X2 ($r=0.824$) and Total X3 ($r=0.577$). Consequently, improving institutional aspects (staff competency, organizational structure, management information systems) will not exert an immediate, isolated impact on a single indicator. Instead, it operates as a lever that simultaneously enhances billing collection capacity (Financial) and service reliability (Service). This condition aligns with the BPPSPAM finding that the inefficient staff-to-customer ratio (11.92 compared to the standard of less than 6) is directly tied to the low service coverage they are required to operate.

- *Independence of Core Technical-Operational Factors as a Necessary Condition*

The statistical independence of the Technical Dimension (showing no significant correlation with Total X2, X3, or X4; $p>0.05$) demonstrates that technical issues in Palu City—such as the 37.49% production efficiency ratio and the 32.55% Non-Revenue Water (NRW) levels—are purely physical infrastructure problems. Their solutions require capital investment and technical engineering (network rehabilitation, meter calibration) rather than governance or service modifications. Because the BPPSPAM Operational score was relatively the highest (1.01) and this factor stands completely isolated statistically, this dimension does not require urgent intervention as a top priority. However, it remains a necessary condition: improvements in Service and Institutional aspects will not be optimal if production capacity and water loss levels are not maintained or upgraded in parallel, albeit with a lower priority and funding allocation compared to the two preceding factors.

Table 9 Priority Matrix for Sustainable SPAM Management Development Factors in Palu City

Factor	BPPSPAM Urgency (Score & Category)	EFA Dominance (% Variance)	Nature of Interconnection	Priority
Service & Retribution Revenue	Extremely low (0.35 - most critical)	Highest (20.84%)	Strongly convergent, mutually reinforcing	I
Governance & Institutional Capacity (including HR)	Low (0.40 - weak)	Dispersed (19.18% + 11.69% + 7,54% = 38.41%)	Mediating, cross-cutting dimension	II
Core Technical-Operational	Relatively good (1.01 - sufficient)	Independent (16.67% + 7.26% = 23.93%)	Prerequisite, freestanding domain	III

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Based on the triangulation results between the 2025 BPPSPAM existing baseline conditions and the 2026 customer perception factor structures, the factor priorities requiring development for sustainable SPAM management in Palu City are hierarchically structured as follows:

- ✓ Enhancing service coverage and quality integrated with tariff/revenue optimization, as the top priority because it is corroborated by two independent data sources and serves as the highest leverage point for long-term financial sustainability;
- ✓ Strengthening institutional capacity and management governance, as the second priority because it functions as a mediating factor that bridges service improvements with corporate financial performance; and
- ✓ Maintaining and optimizing core technical-operational performance, as a necessary baseline condition that must be sustained despite not being an urgent priority, given its relatively independent nature and its existing baseline condition which is superior to the other evaluated dimensions.

V. CONCLUSION

Based on the research findings regarding the Performance Analysis of the Drinking Water Supply System (SPAM) Management in Palu City, several conclusions can be drawn as follows:

- ➢ The performance of SPAM management in Palu City based on BPPSPAM indicators remains in the 'Less Healthy' category. The evaluation yielded a total score of 2.57 out of a maximum scale of 5.00. The financial dimension achieved the highest score at 0.81, whereas the service dimension (0.35) and the human resources dimension (0.40) represented the lowest-performing aspects. The operational dimension obtained a score of 1.01 but continues to face various constraints, such as low production efficiency, high Non-Revenue Water (NRW) levels, and low customer meter replacement rates. The core issue in Palu City's SPAM management lies in the low service coverage and sub-optimal public service quality. Technical service coverage reached only 9.08%, customer growth experienced a decline of -1.72%, customer water quality failed to meet established standards, and domestic water consumption remained far below the BPPSPAM standards. These conditions indicate that the service capacity is not yet capable of optimally meeting community needs.

- ➢ The results of the hydraulic simulation using EPANET demonstrate that the distribution network conditions across each SPAM unit exhibit distinct characteristics. The Duyu SPAM exhibits the most stable and uniform pressure distribution, whereas the Poboya SPAM presents the highest hydraulic risk due to excessive pressure across most of the network. The Watutela SPAM and Kawatuna SPAM also show pressure imbalances that potentially increase the risk of leakage and network damage if pressure control mechanisms are not implemented.

- ➢ Factor analysis indicates that six primary factors influence the performance of SPAM management in Palu City, accounting for a total explained variance of 83.18%. The most significant factor is Service Integration and Revenue/Retribution (20.84%), followed by Institutional Capacity and Management Support (19.18%), Core Technical Operations (16.67%), Financing and Governance (11.69%), Specific HR Capacity (7.54%), and Supporting Technicalities (Water Continuity and Quality) (7.26%). These results demonstrate that enhancing SPAM performance depends not only on technical aspects but also fundamentally requires institutional strengthening, service improvement, financial capacity, and human resource development.

REFERENCES

[1]. Ghozali, I. (2018). Applications of multivariate analysis with the IBM SPSS 25 program (9th ed.). Badan Penerbit Universitas Diponegoro.

[2]. Guritno, A. (2018). SWOT analysis of sustainable drinking water supply system (Green SPAM) implementation at Keburejo regional SPAM in Central Java. Prosiding Seminar Nasional Aplikasi Sains & Teknologi (SNAST), A-203-A-218.

[3]. Julisman, I., Purba, A., & Despa, D. (2023). Master plan for the development of drinking water supply system. Jurnal Profesi Insinyur Universitas Lampung, 4(1), 19–24. https://doi.org/10.23960/jpi.v4n1.93

[4]. Kamulyan, P., Wiguna, I. P. A., & Slamet, A. (2018). Sustainability assessment of community-based drinking water supply system management in Blitar City. Journal of Civil Engineering, 32(2), 60–68. https://doi.org/10.12962/j20861206.v32i2.4559

[5]. Kementerian Pekerjaan Umum dan Perumahan Rakyat Republik Indonesia. (n.d.). Provisions for minimum service standards and performance of the drinking water supply system (SPAM). Kementerian PUPR.

[6]. Badan Peningkatan Penyelenggaraan Sistem Penyediaan Air Minum (BPPSPAM). (n.d.). PDAM performance evaluation indicators and dimensions (Technical/operational, financial, service, institutional/HR). Ministry of Public Works and Public Housing.

[7]. Mahardika, D. B. (2025). Analysis of challenges and strategies for community-based drinking water supply in East Flores Regency (A case study of PAMSIMAS community-based infrastructure activities for the 2024 Fiscal Year). Technopex 2025, 9(1), 1033–1037.

[8]. Maharestu, R., Andri, S., Sadad, A., Mirad, A., & Astuti, W. (2025). Governance of clean water supply and distribution in Tembilahan District, Indragiri Hilir Regency. Jurnal Niara, 18(3), 936–948. https://doi.org/10.31849/08brne34

[9]. Maherda, F., Winarti, W., & Pramono, J. (2023). Sustainability evaluation of the community-based drinking water supply and sanitation program (PAMSIMAS) in Madiun Regency. JI@P, 12(2), 126–137. https://doi.org/10.33061/jp.v12i2.9000

[10]. Masduqi, A. (2023). Implementation of smart water supply systems to enhance premium drinking water

services [Research report]. Institut Teknologi Sepuluh Nopember.
[11]. Nasution, A., Helard, D., & Indah, S. (2021). Performance assessment of drinking water supply system (SPAM) management in Solok Regency and Solok City based on the performance book of the Agency for Supporting the Development of Drinking Water Supply Systems (BPPSPAM). Jurnal Teknik Lingkungan UNAND, 8(3), 190-201.
[12]. Pabura, F. S., Musa, R., & Mallombasi, A. (2024). Evaluation of drinking water supply system (SPAM) performance services in Tapalang District, Mamuju Regency. Jurnal TESLINK: Teknik Sipil dan Lingkungan, 6(1), 167–175. https://doi.org/10.52005/teslink.v6i1.351
[13]. Regulation of the Minister of Health of the Republic of Indonesia Number 2 of 2023 concerning the Implementing Regulations of Government Regulation Number 66 of 2014 concerning Environmental Health (2023).
[14]. Regulation of the Minister of Public Works and Public Housing Number 27/PRT/M/2016 concerning the Implementation of the Drinking Water Supply System (2016).
[15]. Government Regulation Number 122 of 2015 concerning the Drinking Water Supply System (2015).
[16]. Riduan, R., & Dhiaksa, A. (2020). Performance evaluation of the water treatment plant in the drinking water supply system (SPAM) in East Jejangkit Village, South Kalimantan. Jurnal Teknik Lingkungan, 6(2), 113–128.
[17]. Rifay. (2025, April 22). These are the facts behind the lack of clean water supply to the Petobo permanent housing. Media Alkhairaat. https://media.alkhairaat.id/ini-fakta-penyebab-kurangnya-pasokan-air-bersih-ke-huntap-petobo/
[18]. Safitri, A. M. D., Affandi, M. I., & Abidin, Z. (2025). Analysis of the current condition of the drinking water supply system in Bandar Lampung City. Jurnal Pendidikan Indonesia, 6(5), 2531–2541.
[19]. Sudiarti, S. U., & Utama, S. (2024). Study of dominant factors on the performance assessment of the drinking water supply system (SPAM) in West Nusa Tenggara Province. Jurnal Teknik Sumber Daya Air, 4(2), 127–138.
[20]. Sugiyono. (2017). Quantitative, qualitative, and R&D research methods. Alfabeta.
[21]. Sumiati, S., Hariyani, S., & Surjono. (2024). Strategy for improving clean water distribution services by village-owned enterprises (Bumdes) in Sumbertlaseh Village. Jurnal Teknik Pengairan, 15(1). https://doi.org/10.21776/ub.pengairan.2024.015.01.5
[22]. Tekile, A., & Legesse, Y. S. (2023). Overall performance evaluation of an urban water supply system: A case study of Debre Tabor Town in Ethiopia. Journal of Water, Sanitation and Hygiene for Development, 13(4), 250–264. https://doi.org/10.2166/washdev.2023.157
[23]. Tufa, G., & Abate, B. (2022). Assessment of accessibility and hydraulic performance of the water distribution system of Ejere Town. Journal of Water Supply: Research and Technology – AQUA, 71, 577–592. https://doi.org/10.2166/aqua.2022.012.