Strategy for Control of Water Loss by Optimizing District Meter Area: Case Study at Perumda Tirta Manuntung Balikpapan

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Abstract. Loss of water orNon-Revenue Water(NRW) is a major challenge in the implementation of clean water supply systems in Indonesia, including at Perumda Tirta Manuntung Balikpapan (PTMB). The high NRW value recorded at 26% in February 2024 indicates the need for an effective control strategy. This study aims to analyze the main factors causing water loss, evaluate the effectiveness of the implementation of the clean water supply systemDistrict Metered Area(DMA), and identify technical and managerial challenges in optimizing DMA. The impact of DMA zoning on NRW levels is measured quantitatively using multiple linear regression analysis. The investigation shows that DMA installation and optimization may greatly minimize water loss; such as in the Perum WIKA Sub Zone, the leakage rate was successfully reduced from 29.98% to 15.78% after the application of the methodstep test, sounding, and infrastructure improvements. These findings indicate that a zoning-based strategy through DMA can improve the efficiency of water distribution management, detect leaks faster, and reduce physical and non-physical water losses. However, the implementation of DMA still faces various obstacles, including limited human resources, old infrastructure, and the lack of integration of real-time monitoring technology. Therefore, optimization of DMA needs to be supported by data-based water management policies, institutional strengthening, and the use of digital technologies such as the Internet of Things (IoT) for continuous monitoring of water pressure and discharge. This study provides strategic recommendations in controlling NRW through strengthening the DMA system as a sustainable solution in water management in urban areas.

1 Introduction

Clean water is a basic need that is very important for improving the quality of life of the community. The rising population and urbanization have increased the demand for clean water, making it difficult for drinking water service providers to deliver quality, quantitative, and sustainable water. One of the biggest challenges faced by drinking water supply system (SPAM) organizers is the high level of water loss or NRW, namely water

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that is produced but does not contribute to revenue due to physical leaks, theft, measurement errors, or administrative errors.

Perumda Tirta Manuntung Balikpapan (PTMB) as a regional-owned business entity responsible for providing clean water services in Balikpapan City, is facing the problem of a still high NRW level, which is 26% in February 2024. This high figure indicates low efficiency of water distribution and has the potential to cause significant financial losses. In an effort to reduce NRW, PTMB has implemented an approachDistrict Metered Area(DMA), which is the segmentation of water distribution areas into isolated zones equipped with master meters and control valves. This approach allows early detection of leaks, pressure monitoring, and more efficient management of water distribution.

However, the implementation and optimization of the DMA system in PTMB still faces various challenges, such as aging network infrastructure, limited human resources and technology, and weak monitoring and maintenance systems. Therefore, a strategic and comprehensive analysis is needed to evaluate the effectiveness of DMA and identify factors that influence the success of water loss control.

This study focuses on answering the main questions: (1) What are the main factors causing water loss based on NRW conditions in PTMB? (2) How effective is the implementation of the DMA system in reducing water loss? and (3) What are the technical and managerial challenges faced in optimizing DMA?

To preserve focus, this research is confined to Balikpapan City and DMA implementation in six PTMB service sub-districts from March to November 2024. This research tests the influence of DMA zoning on NRW levels using a quantitative approach with multiple linear regression analysis and technical assessments based on water balance data, step test, and infrastructure leakage index.

This research analyzes NRW causes, evaluates the DMA system's leakage control, and develops an appropriate and sustainable DMA management approach. This research is anticipated to provide theoretical and practical contributions to PTMB's drinking water efficiency improvement efforts and national water management policy formulation.

The systematics of writing this research report consists of: (1) Introduction containing the background, problem formulation, objectives, benefits, methods, and scope of the research; (2) Literature review explaining theories related to water loss and the DMA system; (3) Research methodology; (4) Results and discussion; and (5) Conclusions and recommendations.

2 Theoretical Basis

2.1 Non-Revenue Water (NRW)

Non-Revenue Water(NRW) no-revenue Water is the major indication of drinking water system efficiency. NRW is the differential between water entering the distribution system and water sold (International Water Association, 2000). The components of NRW consist of:

1. Physical Water Loss (real losses): leaks from transmission pipes, distribution, house connections, and storage facilities.

2. Non-Physical Water Loss (apparent losses): meter reading errors, water theft, and administrative errors.
3. Unbilled Consumption: water used for fire purposes, pipe cleaning, or legal consumption without payment.

Mathematically, NRW can be calculated as:

$$\text{NRW} = \text{System Input Volume} - \text{Billed Consumption} \quad (1)$$

$$\text{NRW (\%)} = (\text{NRW} / \text{Volume Input Sistem}) \times 100 \quad (2)$$

High NRW values reflect technical and financial inefficiencies and potentially large revenue losses for water operators.

2.2 Water Balance

Water balance is used to map the distribution of water from production to use. The main elements in the water balance according to IWA (2000) are:

- Volume input system
- Official consumption (received and unreceived)
- Non-physical water loss
- Physical water loss

With the equation:

$$\text{System Input Volume} = \text{Official Consumption} + \text{NRW} \quad (3)$$

$$\text{NRW} = \text{Physical Water Loss} + \text{Non-Physical Water Loss} + \text{Unrevenue Consumption} \quad (4)$$

2.3 Infrastructure Leakage Index (ILI)

Infrastructure Leakage Index(ILI) is an indicator to assess the efficiency of physical water leakage management. ILI is obtained by comparingCurrent Annual Physical Losses(CAPL) withMinimum Achievable Annual Physical Losses (MAAPL).

$$\text{ILI} = \text{CAPL} / \text{MAAPL} \quad (5)$$

ILI values close to 1 indicate the piping system is managed efficiently, while high values indicate a need for significant improvement.

2.4 District Metered Area (DMA)

DMA divides a water distribution network into tiny zones with master meters and control valves. DMA helps monitor water flow, pressure, and leaks.
Farley et al. (2008) suggest that the ideal DMA design includes between 1,000–2,500 household connections, taking into account area topography, pressure stability, and installation cost efficiency.

2.5 Step Test and Sounding

Step Testis a zone narrowing method for detecting leaks by closing part of the network and measuring the discharge gradually.

$$\text{Water loss value per connection} = dQ / dSR \quad (6)$$

Criteria:

- < 0.005 L/sec → low leakage
- 0.005–0.01 L/sec → moderate leakage
- > 0.01 L/sec → high leakage

Meanwhile, sounding is a sound-based leak detection method using an acoustic detector. This procedure is used after step test to determine the location of the leak precisely.

2.6 Multiple Linear Regression Analysis

To analyze the relationship between NRW levels and DMA zoning, a multiple linear regression model was used:

$$Y = \beta_0 + b_1X_1 + b_2X_2 + ... + b_nX_n + e \quad (7)$$

With:
Y = NRW level
X_n= DMA variables per region
b_n= Regression coefficient
e = Galat/error

The coefficient of determination (R^2) is used to determine the contribution of independent variables in explaining the variation of the dependent variable. An R^2 value approaching 1 indicates a high predictive power of the model.

3 Research Method

3.1 Research Object Overview

The object of this research is the Regional Public Company Tirta Manuntung Balikpapan (PTMB), which is a Regionally-Owned Enterprise (BUMD) responsible for providing clean water for the people of Balikpapan City. PTMB serves six main sub-districts, namely West, East, Central, North, South, and City Balikpapan, with a total of more than 116,000 SR house connections in 2024.

The main problem faced is the high level of water loss (NRW), which reached 26% based on February 2024 data. The high NRW has a negative impact on operational efficiency, company revenue, and the sustainability of clean water services for the community.

3.2 Problem Analysis

Problems in the PTMB water distribution system can be classified as follows:

- Technical problems: physical leaks in the distribution network due to old pipes, low pipe quality, and fluctuating water pressure.
- Non-technical problems: illegal connections, meter reading errors, water meter damage, and inaccurate administrative records.
- Distribution management: limited ability to detect leaks quickly and accurately due to the suboptimal implementation of the District Metered Area (DMA) system.
- Limited resources: both in terms of infrastructure, human resources, and real-time monitoring technology.

This research is aimed at solving these problems by reviewing and designing NRW control strategies through optimizing the DMA system in the PTMB service area.

3.3 Research Method

The research approach used is quantitative with explanatory design. The analysis technique used is multiple linear regression to see the effect of DMA implementation on NRW levels. The independent variables analyzed are the number and condition of DMA in each sub-district, while the dependent variable is the percentage of NRW.

The stages of systematic research methods include:

1. Preliminary study: secondary data collection from PTMB related to water distribution profiles and NRW reports.
2. Primary data collection: carried out through pressure and discharge measurements in each DMA, physical leak surveys (step test, sounding), and evaluation of customer consumption data (DRD).
3. Data analysis: - Preparation of Water Balance (WB-0 and WB-1) before and after intervention. - Calculation of Infrastructure Leakage Index (ILI). - Multiple linear regression analysis of the influence of DMA variables on NRW.
4. Interpretation and evaluation: evaluate the effectiveness of DMA strategies based on changes in NRW and system efficiency.
5. Formulate recommendations: designing technical and managerial policies to strengthen water loss control.

3.4 Research System Design

(a) General Plan

The research was designed as a quantitative-field study combining technical (flow and pressure measurement) and managerial (assessment of the effectiveness of DMA implementation) approaches. The DMA system was used as the technical intervention unit and the research observation unit.

(b) Specific Plan

- Observation unit: 45 DMA areas in 6 sub-districts
- Technical Parameters: inflow (main flowmeter), customer consumption (DRD), pressure, detected leaks, water meter accuracy

- Performance indicators: NRW percentage, ILI value, and amount of water saved (m3 / month)
- Main equipment: magnetic flowmeter, leak detector, pressure logger
- The statistical analysis includes multiple linear regression, F, t, and R2 tests to evaluate the impact of each variable.

3.5 System Validation and Evaluation

The evaluation was conducted by comparing the NRW and ILI values before and after the intervention through step tests and leak repairs in selected DMA zones. In addition, customer consumption data and total input were compared to compile a water balance. The results became the basis for evaluating the effectiveness of the DMA system in controlling water loss.

4 Conclusions and Suggestions

This study aims to analyze the water loss control strategy through optimization of the District Metered Area (DMA) at Perumda Tirta Manuntung Balikpapan (PTMB). Based on the results of literature studies, system design, and technical evaluations, several main conclusions were obtained as follows:

First, the implementation of the DMA system has proven effective in reducing the level of Non-Revenue Water (NRW). Technical interventions such as step tests, sounding, leak repairs, and network pressure regulation can significantly reduce physical leaks. For example, the Perum WIKA Sub Zone experienced a decrease in NRW from 29.98% to 15.78%.

Second, DMA simplifies the process of identifying and isolating leaks, and improves the accuracy of monitoring water distribution and customer consumption. This system allows for early detection of leaks and faster, more targeted repair responses.

Third, Multiple linear regression analysis shows that the variables of the number of active DMAs and technical response to leakage have a statistically significant effect on the NRW level, with a high coefficient of determination (R^2) value.

Fourth, the Infrastructure Leakage Index (ILI) value as an indicator of leakage management efficiency shows improvement after DMA implementation. The decrease in ILI reflects the success of the system in managing physical water loss.

Fifth, Obstacles in the implementation of DMA are still found, including limited human resources, old infrastructure, and minimal use of digital technology. System optimization needs to be supported by strengthening data management, personnel training, and supportive institutional policies.

Based on the conclusions above, several strategic suggestions that can be put forward for the sustainability of water loss control at PTMB are as follows:

1. Gradual expansion of DMA coverage across distribution zones, accompanied by the installation of digital measuring devices such as magnetic flowmeters and pressure loggers based on the Internet of Things (IoT)

2. Strengthening human resource capacity through regular technical training, especially in leak detection techniques, distribution data processing, and water balance management.
3. Real-time data-based water management information system integration for dynamic monitoring of water pressure, flow and consumption
4. Periodic evaluation of the effectiveness of the DMA system using performance indicators such as NRW, ILI, and volume of water saved, as a basis for strategic decision making.
5. Synergy between technical aspects and institutional policies is essential to ensure the sustainability of water loss control programs as part of efficient and equitable public services.

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