LINGKAR
Journal of Environmental Engineering
E-ISSN: 2986-8807, P-ISSN: 2746-2498
https://journal.ar-raniry.ac.id/index.php/lingkar/index

Published by
Dept. of Environmental Engineering
UIN Ar-raniry Banda Aceh, Indonesia

A SIMULATION-BASED APPROACH FOR IDENTIFYING AND ANALYZING THE WATER DISTRIBUTION NETWORK OF LHOKSEUMAWE CLEAN WATER SUPPLY

Iqbal Adinata Setia Helmy[1], Nanda Savira Ersa [1*], Wesli[1], Nura Usrina[1], T. Mudi Hafli[1]
[1] Civil Engineering Department, Universitas Malikussaleh, Lhokseumawe, Indonesia, 24353

Corresponding Email: nanda.savira@unimal.ac.id
DOI: 10.22373/ljee.v6i1.7575

Abstract

Lhokseumawe City faces significant clean water distribution challenges due to increasing demand from population and economic growth. This study aimed to identify and evaluate the performance of the existing water distribution network using WaterCAD V8i. The methodology involved projecting water demand until 2033 based on 10 years of population data and conducting a hydraulic simulation of the current pipeline system. The simulation results showed that the 2023 clean water demand was 84.5 liters per second, with projections showing a significant increase by 2033. The analysis identified critical operational issues, including backflow in pipe segments P-230 and P-235 and extreme pressure loss gradients in others, with segment P-276 reaching 275 psi during peak hours. It was concluded that the network requires optimization to meet future demand efficiently. Improvement recommendations include replacing critical pipes, resetting valves, and adding pressure regulators to optimize flow.

Keywords: *WaterCAD V8i, clean water distribution, hydraulic analysis, piping network, pressure loss*

How to cite this article: *Adinata et. al. 2025. "A Simulation-Based Approach for Identifying and Analyzing the Water Distribution Network of Lhokseumawe Clean Water Supply." Lingkar: Journal of Environmental Engineering 6 (1): 11–18. https://doi.org/ 10.22373/ljee.v6i1.7575*

1. Introduction

Clean water is vital for human survival, underpinning domestic needs like drinking, cooking, hygiene, and fueling various economic activities. In Indonesia, clean water provision must adhere to the quality standards set forth in Regulation of the Minister of Health No. 492/MENKES/PER/IV/2010, which outlines required physical, chemical, and microbiological parameters for water to be considered safe for consumption

Manuscript received 01 May 2023; revised 23 May 2023; accepted 28 June 2025

(Kementerian Kesehatan Indonesia 2010). These standards play a critical regulatory role in ensuring public health. However, delivering adequate clean water remains a significant challenge, particularly in densely populated areas undergoing rapid urban growth such as Lhokseumawe City.

PDAM Ie Beusaree Rata is a clean water supply company serving Lhokseumawe city. It is experiencing a steep rise in demand for clean water, driven by population growth and economic expansion. The distribution system in this region frequently encounters technical issues, including pressure drops, pipe leaks, and backflow that threaten the continuity and reliability of service (Wesli et al. 2024). If the distribution network's performance is not managed correctly, service quality can deteriorate and lead to customer dissatisfaction (Rishaq et al. 2024).

A comprehensive hydraulic assessment of the existing pipeline infrastructure is therefore essential. WaterCAD V8i enables detailed hydraulic modeling, yielding insights into flow patterns, pressure distribution, and potential head or pressure loss across the network. Its capabilities extend to steady-state and transient-condition simulations, making it possible to analyze normal operating conditions and stress scenarios like hourly peak demand or sudden increases in water usage (Zuhairini et al. 2020).

This study aims to evaluate the performance of the clean water distribution network in the Ie Beusaree Rata PDAM, Lhokseumawe area using WaterCAD V8i. By simulating the hydraulic behavior of the system, the research aims to identify optimal strategies to reduce pressure loss, mitigate backflow risks, and achieve efficient, equitable water distribution (Fidari et al. 2017). Additionally, it seeks to forecast water demand for the next decade, supporting more strategic and forward-looking water resource management planning.

2. Method

This study employed an applied research methodology integrating empirical field with hydraulic simulations using the WaterCAD V8i. The research began with a literature review to understand the fundamental principles of water distribution systems, methods of water demand calculation, and the application of WaterCAD V8i in analyzing pipeline networks. The references reviewed included scientific studies, technical reports, and relevant regulatory guidelines, particularly the *Guideline T-09-2005-C* published by the Research and Development Agency of the Indonesian Ministry of Public Works, which provides technical standards for water distribution systems (Pusat Penelitian dan Pengembangan Permukiman 2005).

The data collection process was conducted through both primary and secondary sources. Primary data were obtained from direct field surveys, which involved observing the existing condition of the distribution pipeline network and measuring water pressure at several key points. Secondary data were supported by PDAM Ie Beusaree Rata, including network layout maps, topographic profiles, customer statistics, water production capacity, and demographic data. These datasets were essential for developing future water demand projections and for accurately representing the system within the simulation environment.

Manuscript received 01 May 2023; revised 23 May 2023; accepted 28 June 2025

Population projections were carried out using both arithmetic and geometric growth methods to estimate the water demand up to 2033. Ten years of historical population data formed the basis of these projections, with adjustments made according to the annual growth rate. This approach is consistent with methods widely applied in water demand forecasting studies in Indonesia (N.k.n 2023).

The hydraulic simulation was conducted by inputting parameters such as pipe length, elevation, diameter, material type, and Hazen–Williams roughness coefficients to the WaterCAD V8i. The simulation assessed critical hydraulic parameters, including flow velocity, pressure distribution at multiple nodes, and pressure loss gradients resulting from friction and flow variations. Steady-state and extended-period simulations were performed to evaluate network performance under normal and extreme conditions, including peak demand scenarios. Studies have demonstrated the effectiveness of WaterCAD V8i in providing detailed evaluations of flow and pressure conditions within urban distribution networks (Zuhairini et al. 2020).

The results were then analyzed to identify network having operational issues such as backflow, excessive pressure losses, or velocities outside acceptable standards. Based on these findings, recommendations were formulated, including potential pipeline replacement, installation of pressure-regulating systems, and optimization of network configuration. It also seeks to forecast water demand for the next decade to support strategic planning. A similar approach has been successfully implemented in other Indonesian case studies, such as the evaluation and development of PDAM Unit Lawang's distribution network (Fidari et al. 2017).

3. Result and Discussion

3.1 Projected Water Demand

Based on a decade of demographic data analyzed using mathematical and geometric forecasting methodologies, the population in PDAM Ie Beusaree Rata service area is expected to reach 34,871 by 2033. This expansion will necessitate an anticipated average water demand of 49,592 L/s, increasing to a maximum daily demand of 59,509 L/s and peak-hour usage of 79,346 L/s. These findings demonstrate the increasing trend of water consumption as a result of population growth and intensified economic activities in the region.

Table 1: Projected Population and Water Demand in Service Area 2023-2033

Year	Total Population	Clean Water Demand (liter/second)	Maximum Daily Demand (liter/second)	Peak Hour Usage (liter/second)
2023	33.362	44,550	53,460	71,281
2028	34.470	47,921	57,505	76,756
2033	34.871	49,592	59,509	79,346

Manuscript received 01 May 2023; revised 23 May 2023; accepted 28 June 2025

3.2 Pipe Network Hydraulic Simulation Results

The hydraulic simulation conducted using WaterCAD V8i provided critical insights into the condition of the existing pipeline network. The analysis of flow velocity showed that most pipe segments were operating within acceptable planning criteria. However, anomalies were identified in several sections, particularly in pipelines P-230 and P-235, which displayed reverse flow characterized by negative velocity values. This indicates a substantial pressure imbalance within the network. The case study of Karbala City, which also utilized WaterCAD, similarly identified areas of significant pressure drop and high velocity as key operational challenges, confirming the validity and widespread applicability of this analytical approach (Hussein, Al Baidhani and Alshammari 2021).

The evaluation of headloss gradients revealed that certain segments experienced significant energy losses, especially during peak-hour conditions. For instance, pipeline P-276 recorded a headloss gradient as high as 75%, reflecting severe flow resistance and highlighting the vulnerability of the system under high-demand scenarios.

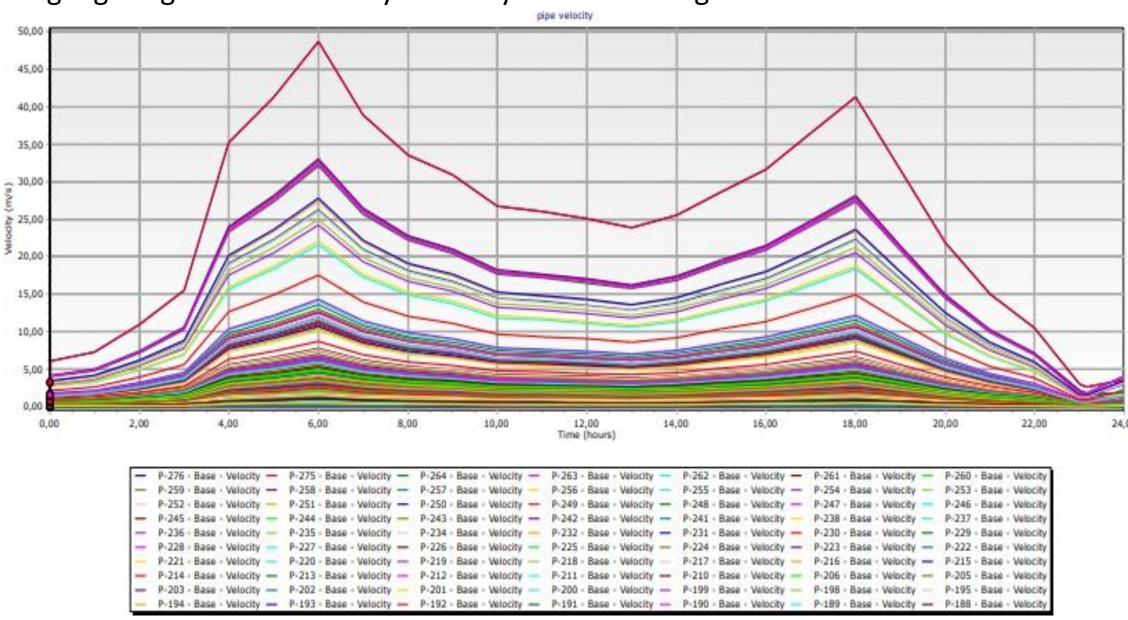

Figure 1: Graph of Flow Velocity in Pipe Segment

3.3 Loss of Pressure

A more detailed evaluation of pressure loss indicated that some pipelines experienced significant pressure deficits, which could impair service reliability. Segment P-276, for instance, showed a pressure loss as high as 275 psi during peak demand periods, a result likely caused by high internal friction and increasing consumption rates. Segments P-230 and P-235 also displayed notable losses of 200 psi and 150 psi, respectively.

Table 2: Pressure Loss in Some Pipe Segments

Pipe Segment	Length (ft)	Diameter (mm)	Velocity (m/s)	Headloss Gradient (%)	Pressure Loss (psi)
P-230	500	300	-0,5	0,429	200
P-235	600	250	-0,3	0,253	150
P-276	700	400	1, 2	0,382	275

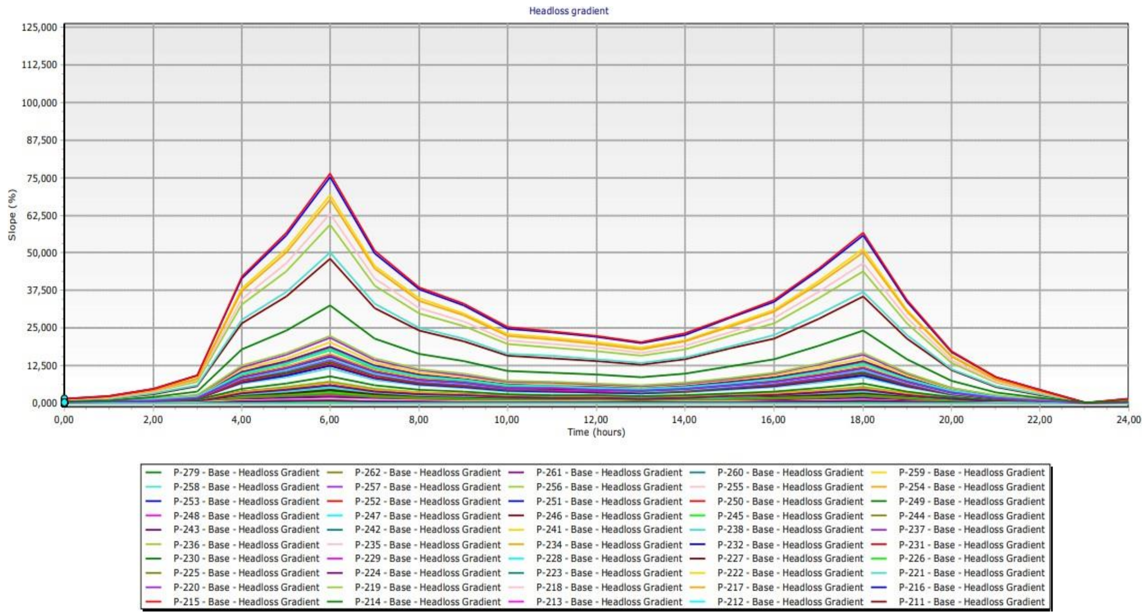

Figure 2: Headloss Gradient

3.4 Clean Water Requirement

The analysis of clean water requirements confirmed that the projected demand for 2033 will place significant pressure on the current infrastructure. The maximum daily requirement is expected to reach 59,509 liters per second, with peak-hour demand reaching 79,346 liters per second. Without improvements in distribution efficiency and capacity expansion, the system is unlikely to meet this demand adequately. This finding reflects a broader trend across Indonesian municipalities, where rapid urban growth has driven increasing demand for water supply systems beyond their original design capacities.

Manuscript received 01 May 2023; revised 23 May 2023; accepted 28 June 2023

Parameters	Requirement (liter/second)
Average Requirement	49,592
Maximum Daily Requirement	59,509
Peak Hour Usage	79,346

The results highlight the urgent need for network optimization strategies, including hydraulic balancing, targeted pipe replacement, and the introduction of pressure-regulating systems. Strategic planning based on accurate demand forecasts and simulation analysis is critical to ensuring that PDAM Ie Beusaree Rata can provide sustainable, efficient, and equitable water distribution in the coming decade.

Piping network analysis shows that most pipelines function according to standards, but some segments are experiencing problems. In specific segments, such as pipes P-276 and P-279, very high flow velocities and large pressure loss gradients were observed, especially during peak hours. It indicates a significant bottleneck that reduces distribution efficiency and increases the potential for damage to the pipeline. In addition, several pipe segments recorded reverse flow values, indicating instability in pressure distribution and the risk of leaks that could result in inefficiencies in the water distribution system. The results show that the water distribution system still requires optimization, especially in segments that experience backflow and high pressure losses.

To optimize the existing piping system, some recommendations are important to improve the efficiency and reliability of the water distribution system in the Ie Beusaree Rata PDAM area. First, to replace or repair pipe segments that exhibit backflow and high pressure losses. These segments need to use pipe materials more resistant to high pressure, such as HDPE material, to reduce the potential for damage and leakage. In addition, adding pressure pumps at strategic points in the distribution network can help maintain pressure stability, especially during peak hours, so that clean water distribution becomes evener and more efficient. A framework for evaluating pipe criticality based on its impact on the network's overall hydraulic performance was developed (Mazumder, et al. 2021). Applying such a model would allow PDAM Ie Beusaree Rata to move beyond simply replacing the pipes with the worst hydraulic performance and instead prioritize assets whose failure would cause the most significant and widespread service disruptions.

Valve resetting at some point in the network is also recommended to ensure balanced pressure distribution. Adjusting the valve settings is expected to control pressure better throughout the network, reducing the potential for backflow. It is also recommended to conduct regular evaluations using WaterCAD V8i. Periodic simulations will enable early detection of potential problems in flow and pressure patterns, so that repairs can be made in a promptly before greater damage occurs. However, the future of pipeline integrity management lies in predictive analytics such as using Machine Learning (ML) models to predict pipe failures, detect leaks, and optimize network

Manuscript received 01 May 2023; revised 23 May 2023; accepted 28 June 2023

operations in real-time (Chen, Wang and Javanmardi 2025). By integrating the hydraulic data from simulations like this one with real-time sensor data, ML algorithms can forecast failures. Overall, implementing these suggestions is expected to improve the reliability and efficiency of clean water distribution in the service area of PDAM Ie Beusaree Rata Lhokseumawe City, to meet the increasing needs of the community with optimal and sustainable distribution.

4. Conclusion

Based on the results of the analysis, it can be concluded that the demand for clean water in the service area of PDAM Ie Beusaree Rata Lhokseumawe City is projected to increase significantly along with population growth. A multifaceted approach is needed to provide a consistent and long-term water supply. This includes replacing defective pipe segments on a targeted basis, adding pressure pumps to ensure stability, and systematically resetting valves to distribute pressure evenly. Additionally, periodic hydraulic simulations should be used for proactive maintenance and early problem diagnosis. Implementing these data-driven methods is critical for improving system reliability and addressing the long-term water requirements of Lhokseumawe City's rising population.

REFERENCES

Chen, Runfei, Quiping Wang, and Ahad Javanmardi. 2025. "A Review of the Application of Machine Learning for Pipeline Integrity Predictive Analysis in Water Distribution Networks." *Archives of Computational Methods in Engineering.*

Fidari, Jadfan Sidqi, Rahmah Dara Lufira, Endang Purwati, Riyanto Haribowo, and Ira Puspita. 2017. “Evaluation and Development of Network Distribution of Clean Water PDAM Unit Lawang.” *The 7th Annual Basic Science International Conference (BaSIC 2017)* 1: 194.

Hussein, Hussein Ali, Jabbar H Al Baidhani, and Musa Habib Alshammari. 2021. "Evaluation the effects of some parameters on the operational efficiency of the main water pipe in Karbala city." *J. Phys.: Conf. Ser.* doi:10.1088/1742-6596/1973/1/012118.

Kementerian Kesehatan indonesia. 2010. *Peraturan Menteri Kesehatan No 492 Tahun 2010 tentang Persyaratan Kualitas Air Minum*. Peraturan Menteri Kesehatan 492. Kementerian Kesehatan indonesia. https://stunting.go.id/kemenkes-permenkes-no-492-tahun-2010-tentang-persyaratan-kualitas-air-minum/.

N.k.n, Milyandari. 2023. “Planning Of The Main Distribution Network Of Gerokgak Distribution Reservoir In The Burana Drinking Water Supply System (SPAM), Buleleng Regency.” *Jurnal Indonesia Sosial Teknologi* 4 (8): 1175–85. https://doi.org/10.59141/jist.v4i8.656.

Mazumder, Ram K, Abdullahi M Salman, Yue Li, and Xiong Yu. 2021. "Asset Management Decision Support Model for Water Distribution Systems: Impact of Water Pipe Failure on Road and Water Networks." *Journal of Water Resources Planning and Management* 147 (5). doi:doi.org/10.1061/(ASCE)WR.1943-5452.000136.

Pusat Penelitian dan Pengembangan Permukiman. 2005. *Pedoman Pd-T-05-1-2005-C: Penyediaan Air Minum Berbasis Masyarakat (PAM BM)*. Pusat Penelitian dan

Manuscript received 01 May 2023; revised 23 May 2023; accepted 28 June 2023

Pengembangan Permukiman. Bandung. //perpustakaan.ciptakarya.pu.go.id%2Fopac%2Findex.php%3Fp%3Dshow_detail%26id%3D11745.

Rishaq, Alief Muhammad, Syarifah Asria Nanda, Fadhliani Fadhliani, et al. 2024. "Analisis Perubahan Hidrograf Aliran Akibat Konversi Tutupan Lahan DAS Keureuto." *Jurnal Teknik Sipil* 14 (1): 122–32. https://doi.org/10.29103/tj.v14i1.1038.

Wesli, Muthmainnah, Nura Usrina, and Burhanuddin. 2024. "Analysis of Drinking Water Needs on the Availability of Krueng Buloh River Discharge in Lhokseumawe City." *Tuijin Jishu/Journal of Propulsion Technology* 45 (03): 1487–500. https://doi.org/10.52783/tjjpt.v45.i03.7435.

Zuhairini, Arni, Lily montarcih, and Moh. Sholichin. 2020. "Evaluation of Clean Water Network and Development System of Clean Water Supply in District of South Morotai in Morotai Island (Case Study: Pandanga Village)." *International Research Journal of Advanced Engineering and Science* 5 (3): 40–44.

Manuscript received 01 May 2023; revised 23 May 2023; accepted 28 June 2023