© JUN 2026 | IRE Journals | Volume 9 Issue 12 | ISSN: 2456-8880
DOI: https://doi.org/10.64388/IREV9I12-1718554

Sustainable Reduction of Non-Revenue Water Through Maintenance Practices in Cabanatuan City: A Quantitative Descriptive Study

JANNUS NEIL L. CRUZ[1], NOEL T. FLORENCONDIA[2]
[1, 2]Nueva Ecija University of Science and Technology

***Abstract-* Non-Revenue Water (NRW) remains a major inefficiency in urban water distribution systems, representing water losses from leaks, illegal connections, and metering inaccuracies. This study employed a quantitative descriptive research design to evaluate the effectiveness of maintenance practices in reducing NRW in PrimeWater Cabanatuan City operations. The study analyzed NRW performance data, maintenance records, and environmental indicators derived from operational inputs. Results showed that NRW decreased from approximately 40% to 28% following the implementation of maintenance interventions such as leak detection technology, pipeline rehabilitation, and digital asset monitoring systems. Descriptive analysis indicated an average NRW reduction of 12%, with some areas achieving reductions of up to 25%. Environmental indicator analysis based on operational data revealed improved resource efficiency, particularly in reduced water losses per maintenance cycle. The study concludes that structured maintenance practices significantly contribute to NRW reduction and improved system efficiency. Strengthening infrastructure rehabilitation and digital monitoring systems is essential to achieving sustainable water management targets.**

***Keywords:* Non-Revenue Water, Quantitative Descriptive Research, Water Utilities, Maintenance Practices, Cabanatuan City**

I. INTRODUCTION

Water is a critical resource essential for human survival, economic development, and environmental sustainability. However, despite its abundance, freshwater availability is increasingly constrained by population growth, aging infrastructure, and inefficiencies in water distribution systems (Gleick, 2014). Urban water utilities are particularly affected due to high demand and deteriorating pipeline networks.

A major operational inefficiency in water systems is Non-Revenue Water (NRW), defined as water that is produced but not billed due to physical losses, commercial losses, and metering inaccuracies (Liemberger & Wyatt, 2019). NRW represents both financial loss and resource wastage, making it a key performance indicator in water utility management.

Globally, NRW accounts for approximately 126 billion cubic meters of lost water annually, resulting in significant economic and environmental costs (World Bank, 2016). In developing countries, NRW levels frequently exceed 40% due to inadequate maintenance systems and infrastructure aging (Kingdom, Liemberger, & Marin, 2006).

In the Philippines, NRW ranges from 25% to 40%, depending on the water utility. The National Water Resources Board (2020) emphasizes that reducing NRW is a more cost-effective strategy than developing new water sources, particularly in urbanizing areas.

To address these challenges, water utilities such as PrimeWater Infrastructure Corporation have implemented maintenance and system rehabilitation programs through joint venture arrangements with local water districts. However, the effectiveness of these interventions in reducing NRW remains under continuous evaluation, particularly in provincial cities such as Cabanatuan.

Objectives of the Study

This study aimed to determine the effectiveness of maintenance practices in reducing Non-Revenue Water (NRW) in PrimeWater Cabanatuan City using a quantitative descriptive approach.

Specifically, it sought to:

1. Describe the maintenance practices implemented for NRW reduction.
2. Determine the level of NRW before and after maintenance interventions.
3. Compute the percentage reduction in NRW resulting from maintenance practices.
4. Describe the environmental efficiency indicators based on operational water recovery data.

II. METHODOLOGY

Research Design

This study employed a quantitative descriptive research design to assess the effectiveness of maintenance practices in reducing Non-Revenue Water (NRW) within PrimeWater Infrastructure Corporation's operations in Cabanatuan City. Quantitative descriptive research is appropriate for studies that aim to systematically describe existing conditions, operational trends, and measurable outcomes through numerical data analysis without manipulating variables or establishing causal relationships.

The design was selected because the study primarily focused on quantifying NRW levels before and after the implementation of maintenance interventions and describing the operational performance of the water utility based on recorded maintenance and recovery data. Specifically, the study analyzed numerical indicators such as NRW percentages, water recovery volumes, frequency of maintenance activities, and operational efficiency metrics. Through this approach, the researchers were able to present a factual and data-driven description of PrimeWater's maintenance practices and their corresponding effects on NRW reduction.

The study did not involve experimental manipulation or treatment application. Instead, it relied on the analysis of existing operational records and documented utility reports. The quantitative descriptive design enabled the researchers to objectively evaluate observable trends and patterns in water loss reduction and maintenance efficiency within the utility system.

Research Locale

The study was conducted in Cabanatuan City, Nueva Ecija, Philippines, focusing on the operational service area of PrimeWater Infrastructure Corporation. Cabanatuan City is one of the rapidly urbanizing cities in Central Luzon, characterized by increasing water demand due to population growth, commercial expansion, and infrastructure development. These conditions make efficient water distribution management a critical concern for local water utilities.

PrimeWater's water distribution system in Cabanatuan City served as the primary setting of the study because of its ongoing implementation of maintenance interventions aimed at reducing Non-Revenue Water. These interventions include leak detection activities, pipeline rehabilitation programs, digital asset management systems, and operational monitoring strategies. The locale was considered suitable for the study due to the availability of operational records, maintenance reports, and NRW performance data necessary for quantitative analysis.

Data Sources and Respondents

The study primarily utilized secondary quantitative data obtained from official operational records and reports provided by PrimeWater Infrastructure Corporation. These data sources were selected because they contain measurable and documented information directly related to NRW reduction efforts and maintenance operations.

The following records served as the primary sources of data:

1. NRW performance reports containing pre-intervention and post-intervention NRW percentages;
2. Maintenance and repair logs documenting leak repairs, pipe replacements, and rehabilitation activities;
3. Leak detection and pipeline monitoring records indicating the frequency and location of maintenance interventions; and
4. Operational water recovery data reflecting estimated volumes of recovered water resulting from maintenance activities.

© JUN 2026 | IRE Journals | Volume 9 Issue 12 | ISSN: 2456-8880
DOI: https://doi.org/10.64388/IREV9I12-1718554

In addition to documentary sources, selected engineers, maintenance supervisors, and technical personnel from PrimeWater were included as key informants solely for the purpose of validating operational records and clarifying technical details related to the data. These individuals were chosen based on their direct involvement in maintenance operations and NRW monitoring activities. However, their responses were not treated as qualitative data for thematic interpretation, since the study remained quantitatively descriptive in nature.

Research Instruments

To ensure systematic and organized data collection, the study utilized researcher-developed instruments specifically designed for extracting and recording quantitative operational data from official utility records.

The NRW Data Recording Sheet was used to document pre-intervention and post-intervention NRW percentages across identified operational periods. This instrument enabled the researchers to compare changes in NRW levels following the implementation of maintenance interventions.

The Maintenance Activity Log Checklist was utilized to classify and record various maintenance practices implemented by PrimeWater. These activities included leak detection operations, pipeline replacement, pipe rehabilitation, meter monitoring, and preventive maintenance procedures. The checklist facilitated the categorization and frequency analysis of maintenance interventions.

The Operational Efficiency Data Template was used to record measurable operational indicators such as estimated water recovery volumes, frequency of repairs, maintenance response rates, and reduction in water losses. This instrument supported the computation of operational efficiency indicators associated with NRW reduction.

Lastly, the Document Analysis Form was employed to systematically review and extract relevant information from official reports, maintenance summaries, and NRW monitoring documents. The instrument ensured consistency in data extraction and minimized recording errors during document review.

Prior to data gathering, the instruments were reviewed and validated by experts in water utility operations and research methodology to ensure clarity, relevance, and alignment with the objectives of the study.

Data Gathering Procedure

The researcher first secured approval from the appropriate academic authorities and obtained permission from PrimeWater Infrastructure Corporation prior to data collection. After approval was granted, official operational records and maintenance reports relevant to NRW reduction were requested from the utility office.

The collected documents were systematically reviewed using the prepared research instruments. NRW percentages, maintenance activities, and operational efficiency indicators were extracted and recorded accordingly. Validation of technical information was conducted through consultation with selected technical personnel and engineers to ensure the accuracy and consistency of the recorded data.

After all relevant data were gathered, the researchers organized and tabulated the information for statistical analysis and interpretation.

Data Analysis Techniques

The gathered data were analyzed using descriptive statistical techniques appropriate for quantitative descriptive research.

To address the first objective regarding maintenance practices, frequency counts and classification analysis were utilized to describe the types of maintenance interventions implemented by PrimeWater.

To determine the level of NRW before and after maintenance interventions, percentage analysis and mean computations were employed. Comparative analysis was conducted to identify changes in NRW levels across operational periods.

Trend analysis was also performed to examine patterns of NRW reduction across selected service areas and maintenance activities. This allowed the researchers to determine whether maintenance interventions were associated with observable improvements in operational performance.

Furthermore, operational efficiency indicators were computed using simple efficiency ratio analysis to estimate the relationship between maintenance interventions and water recovery outcomes.

The primary statistical formula used in computing NRW reduction was:

$$NRW\ Reduction\ (\%) = \frac{Pre - NRW - Post\ NRW}{Pre - NRW}\ x\ 100$$

This formula was used to determine the percentage decrease in NRW following maintenance interventions. The resulting values served as indicators of maintenance effectiveness and operational improvement.

Ethical Considerations

Ethical standards were strictly observed throughout the conduct of the study. Permission to access operational records and reports was obtained from PrimeWater Infrastructure Corporation. All collected data were used solely for academic and research purposes.

Confidentiality of utility records and operational information was maintained at all times. The researchers ensured that sensitive company data were handled responsibly and that no unauthorized disclosure occurred during the conduct of the study.

III. RESULTS AND DISCUSSION

3.1 Maintenance Practices Implemented

The findings of the study indicate that PrimeWater implemented a range of structured maintenance interventions aimed at reducing Non-Revenue Water (NRW) in Cabanatuan City. These interventions included digital leak detection through mobile tagging systems, pipeline replacement and rehabilitation programs, digital asset management systems, and community-based leak reporting mechanisms. Collectively, these strategies reflect a shift toward more systematic and technology-supported water loss management.

The adoption of digital leak detection tools aligns with the growing global trend of integrating smart technologies into water distribution systems. As emphasized by Farah and Shahrour (2024), smart technologies significantly improve the efficiency of leak identification by enabling real-time monitoring and rapid response to distribution system failures. Such systems reduce dependency on manual inspection and enhance operational responsiveness, which is critical in minimizing water losses.

Similarly, Marmarokopos et al. (2018) highlighted that traditional leak detection methods often face limitations due to the complexity and scale of urban water networks. Their study emphasized that modern leak detection methodologies, particularly those incorporating sensor-based and data-driven systems, provide more accurate and timely identification of leaks. This supports the observed implementation of mobile-based tagging systems in the present study.

Pipeline replacement and rehabilitation activities also formed a major component of PrimeWater’s maintenance strategy. These interventions are essential because aging infrastructure is a primary source of physical water losses in distribution systems. According to Liemberger and Wyatt (2019), physical losses due to deteriorated pipelines constitute a significant portion of global NRW, particularly in developing water systems where infrastructure maintenance is often delayed.

In addition, the implementation of digital asset management systems contributed to more organized tracking of infrastructure conditions and maintenance schedules. Sadeghioon et al. (2018) emphasized that smart monitoring and asset management systems play a crucial role in extending infrastructure lifespan and improving maintenance efficiency through predictive maintenance approaches.

Community-based leak reporting systems further enhanced operational monitoring by involving consumers in identifying visible leaks and system irregularities. This approach aligns with the broader principle that NRW reduction is not solely a technical issue but also requires stakeholder participation and system-wide coordination (World Bank, 2016).

3.2 NRW Levels Before and After Interventions

The analysis of operational data revealed a clear reduction in Non-Revenue Water following the implementation of maintenance interventions. The average NRW level decreased from 40% prior to intervention to 28% after intervention, resulting in a 12% absolute reduction.

This reduction reflects improved efficiency in the water distribution system and indicates that a larger proportion of produced water successfully reached consumers after the implementation of maintenance strategies. NRW reduction is a critical indicator of water utility performance, as high NRW levels represent significant losses in both economic and resource terms.

Globally, NRW remains a persistent challenge in water utilities, particularly in developing countries where system inefficiencies are more pronounced. The World Bank (2016) emphasizes that reducing NRW is one of the most cost-effective strategies for improving water supply efficiency, as it allows utilities to recover lost water without increasing production capacity.

Also, Liemberger and Wyatt (2019) noted that effective NRW reduction programs can significantly improve utility performance by addressing both physical and commercial losses through targeted interventions such as leak detection, pressure management, and infrastructure rehabilitation.

The observed reduction in NRW in this study is consistent with the global understanding that structured maintenance and monitoring systems contribute significantly to improved water system performance (Farah & Shahrour, 2024).

3.3 Percentage Reduction Across Service Areas

The study further revealed variability in NRW reduction across different service areas. Locations that implemented comprehensive pipeline replacement programs recorded the highest reduction, reaching up to 25%. Areas that primarily utilized leak detection technologies achieved moderate reductions ranging from 10% to 15%, while areas with limited interventions recorded reductions below 10%.

These findings suggest that infrastructure rehabilitation plays a critical role in achieving substantial and sustained reductions in NRW. While leak detection technologies are effective in identifying and locating losses, they are less effective in achieving long-term reduction when underlying infrastructure deterioration is not addressed.

Marmarokopos et al. (2018) emphasized that leak detection systems must be complemented by physical infrastructure improvements to achieve meaningful reductions in water losses. Without rehabilitation, detected leaks may recur due to persistent structural weaknesses in pipelines.

In addition, Sadeghioon et al. (2018) highlighted that condition monitoring systems are most effective when integrated into a broader asset management framework that includes preventive maintenance and infrastructure renewal. This supports the observation that areas with combined interventions performed significantly better than those relying solely on leak detection.

Farah and Shahrour (2024) further explain that smart water technologies are most effective when embedded within a holistic water management strategy that includes both monitoring and infrastructure renewal. This integrated approach ensures that detected issues are resolved permanently rather than temporarily.

The results demonstrate that comprehensive maintenance strategies combining digital monitoring and physical rehabilitation yield the highest NRW reduction outcomes.

3.4 Environmental Efficiency Indicators

The analysis of operational efficiency indicators revealed that maintenance interventions not only reduced water losses but also improved resource efficiency within the water distribution system. The reduction in physical losses led to lower water production demand, reduced energy consumption for pumping, and improved efficiency in water delivery per unit of supplied water.

These improvements are significant because water production systems require substantial energy for extraction, treatment, and distribution. Therefore, reducing NRW directly contributes to energy savings and environmental sustainability.

Gleick (2014) emphasized that water efficiency improvements are essential for sustainable water resource management, particularly in urban areas where demand is increasing and supply systems are under stress. Reducing water losses ensures that limited freshwater resources are used more efficiently and sustainably.

The World Bank (2016) highlights that NRW reduction contributes to both economic and environmental benefits by reducing unnecessary production costs and improving system efficiency. Lower water losses reduce the need for additional water extraction, thereby conserving natural water sources.

Liemberger and Wyatt (2019) also emphasize that NRW reduction improves overall system sustainability by reducing wasted treated water and optimizing utility performance. This leads to more efficient use of energy and operational resources.

Furthermore, Farah and Shahrour (2024) explain that smart monitoring systems enhance environmental efficiency by reducing the frequency of emergency repairs and optimizing maintenance schedules, thereby lowering the environmental footprint of water utility operations.

The findings confirm that maintenance interventions contribute not only to operational improvements but also to enhanced environmental efficiency and sustainable resource utilization.

IV. CONCLUSION

The study concludes that maintenance practices significantly reduced NRW in PrimeWater Cabanatuan City, decreasing from 40% to 28%. Integrated maintenance strategies combining leak detection, pipeline rehabilitation, and digital systems were more effective than isolated interventions. Pipeline rehabilitation and leak detection were the most influential factors in reducing NRW. Overall, systematic maintenance practices improve both operational efficiency and environmental sustainability.

V. RECOMMENDATIONS

The study recommends prioritizing pipeline rehabilitation in high-loss areas to address major sources of physical water losses and improve system reliability. It also recommends expanding leak detection systems across all service zones to enhance real-time monitoring and reduce response time for leak repairs. To ensure consistency in implementation, maintenance strategies should be standardized across all areas. In addition, digital monitoring and reporting systems should be strengthened to improve data accuracy and support timely decision-making. Finally, efficiency indicators such as NRW reduction rates and recovery performance should be integrated into operational planning to support evidence-based and sustainable water management.

REFERENCES

[1] Alegre, H., Baptista, J. M., Cabrera, E., Cubillo, F., Duarte, P., Hirner, W., … Parena, R. (2016). Performance indicators for water supply services (3rd ed.). IWA Publishing. https://doi.org/10.2166/9781780406329

[2] Asian Development Bank. (2021). Philippines: Water supply and sanitation sector assessment, strategy, and roadmap. https://www.adb.org/documents/philippines-water-supply-sanitation-sector-assessment

[3] Corominas, L., Foley, J., Guest, J. S., Hospido, A., Larsen, H. F., Morera, S., & Shaw, A. (2013). Life cycle assessment in the water industry: A review. Water Research, 47(15), 5480–5492. https://doi.org/10.1016/j.watres.2013.06.032

[4] Farah, E., & Shahrour, I. (2024). Smart technologies for leakage reduction in water distribution systems: A review. Water, 16(20), 2975. https://doi.org/10.3390/w16202975

[5] Gleick, P. H. (2014). The world's water: The biennial report on freshwater resources (Vol. 8). Island Press.

[6] International Organization for Standardization. (2006). ISO 14040: Environmental management—Life cycle assessment—Principles and framework. https://www.iso.org/standard/37456.html

[7] Kingdom, B., Liemberger, R., & Marin, P. (2006). The challenge of reducing non-revenue water in developing countries. World Bank. https://openknowledge.worldbank.org/handle/10986/17261

[8] Liemberger, R., & Wyatt, A. (2019). Quantifying the global non-revenue water problem. Water Science and Technology: Water Supply, 19(3), 831–837. https://doi.org/10.2166/ws.2018.129

[9] Marmarokopos, K., Doumenopoulou, E., & Karagiannis, T. (2018). Leak detection methodologies in urban water pipe networks: Challenges and opportunities. Measurement and Control, 51(1–2), 1–12. https://doi.org/10.1177/0020294018758526

[10] National Water Resources Board. (2020). Philippine Water Supply Sector Roadmap 2020–2040. https://neda.gov.ph/philippine-water-supply-and-sanitation-master-plan

[11] Sadeghioon, A. M., Metje, N., & Chapman, D. (2018). Smart pipe condition monitoring technologies for water infrastructure systems: A review. Urban Water Journal, 15(5), 475–487. https://doi.org/10.1080/1573062X.2018.1424213

[12] United Nations. (2015). Transforming our world: The 2030 Agenda for Sustainable Development. https://sdgs.un.org/2030agenda

[13] World Bank. (2016). Reducing non-revenue water in developing countries. https://www.worldbank.org/en/news/feature/2016/07/13/reducing-non-revenue-water-in-developing-countries