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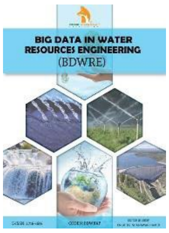

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RESEARCH ARTICLE

ASSESSING THE ADEQUACY OF THE WATER DISTRIBUTION SYSTEM IN THE MUNICIPALITY OF ALIAGA USING DEMAND FORECASTING AND EPANET-JS SIMULATION

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ABSTRACT

The recorded households in the Municipality of Aliaga, Nueva Ecija last 2024 were 19,853, with population steadily growing from 63,543 in 2015 to 70,363 in 2020. Water demand in this area also increases as the population grows over time and this raises concerns about the distribution system's capacity. This study evaluates Aliaga's water distribution system using demand forecasting and hydraulic simulation with EPANET-JS. In projecting water demand for 2030, 2035 and 2040, historical population and consumption data were used. The water distribution system was modelled using EPANET-JS comprising of 82.83 kilometers of pipes, 881 nodes, and five pumping stations and simulated under current and future demand scenarios. Performance was measured by the nodal pressure, velocity of the flow and headloss against hydraulic criteria. Results show that for the present water connections, 0.23% of nodes fall below minimum pressure and when considering the full household coverage, 39.61% of nodes are below minimum pressure, and by the year 2030 and 2040, this number rises to 53.35% and 62.43% respectively. This is due to the fact that water demand increases from 29.30 lps (2025) to 135.65 lps (2040). By this time, future demand exceeds the 128.40 lps maximum production of water sources in Aliaga. Flow velocities are tolerable at maximum of 3.4 m/s from 1.74 m/s. In contrast, headloss in pipes outside the parameters increases from 5.33% to 20.54%. Areas served by newer infrastructure maintain adequate performance, but older sections experience deficiencies due to small pipes and insufficient pumping capacity.The study identifies critical improvements: interlooping the distribution system between Brgy. San Carlos and Brgy. Bibiclat with 150mm PVC pipelines, upgrading Pumping Stations 2 and 4, and upsizing transmission lines from 100mm to 150mm in Brgy. San Juan to Brgy. San Felipe and from Brgy. San Pablo to Sto. Tomas. The current infrastructure system is sufficient for the existing connections, but upgrades are needed to maintain reliability in the service area considering the future demands.

KEYWORDS

Water distribution system, EPANET simulation, demand forecasting, hydraulic modeling, gap analysis

1. THE PROBLEM AND ITS BACKGROUND

1.1 Background of the Study

Water is crucial for life as it directly affects health and economic development. In the Philippines, the entity that manages the majority of the distribution of water falls into the hands of Water Districts (De Leon et al., 2025). Water utilities often experience struggles in delivering water efficiently in developing countries, resulting in low-quality supply at high cost (Briscoe, 1996). These challenges are worsened by different factors like climate change and incorrect policy enforcement, especially in areas where water infrastructure lags behind population growth and urban expansion (Bulti and Yutura, 2023).

Low water pressure and intermittent supply are strong indications of service problems which directly impact customer satisfaction. The evaluation of the adequacy of a water distribution system is measured by its ability to meet the demand through pressure and flow (Ghorbanian, 2016; Friedman et al., 2004). Low pressure conditions and complaints are attributed to factors like sudden changes in pipe diameter, and hydraulic inefficiencies related to aging infrastructure (Pope et al., 2015). Systems that are unable to adapt in growing demand might cause a service gap.

The municipality of Aliaga exhibits these issues and further faces them as the annual population growth rate of 2.17% translates from its baseline population of 63,543 (2015) to 70,363 (2020) along with the increase in the number of households that reaches 16,853 in 2024 (PSA, 2025). These trends highlight the need to assess whether the existing water distribution system can meet current and future needs as this growth leads to increased water consumption.

Hydraulic modelling is a systematic way of evaluating a system's capacity and guiding planning. EPANET is one software used for simulation to understand the hydraulic behavior of water as it checks pressure, velocity, and volume (U.S. EPA, 2020). Calibrated models evaluate operations as they identify areas that are lacking and insufficient (National Research Council, 2006). Predicting future performance supports maintenance and ensures long-term reliability (Dadebo et al., 2023).

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This study combines demand forecasting and hydraulic simulation using EPANET-JS. It is a web-based version of EPANET that operates without installation on a desktop (Butler, 2023). It evaluates the current capacity of the system and examines its performance under projected future demand. Based on the results, the study identifies necessary improvements, including pipe resizing, network interconnection, and additional water source development.

1.2 Statement of the Problem

Water distribution systems in developing countries have challenges that affect their ability to deliver water services. For instance, rapid population growth increases the need for good water systems, however, the deterioration of the existing water distribution systems compromises the quality of water below safe levels and pose health risks (Lee and Schwab, 2005). Rising consumption is due to various factors such as population growth, industrial development, socioeconomic changes, and the expansion of sanitation services. At the same time, water loss, climate change, and poor management prevent systems from meeting demand (Magwilang et al., 2021).

In municipalities like Aliaga, many distribution systems were designed with outdated demand assumptions and cannot adapt to current conditions. Available data indicate that there is a considerable growth in population within Aliaga, thereby increasing uncertainty regarding the system's capacity to meet current and future demands. For a system that does not have a hydraulic model and a long-term forecast of demands, operational issues such as low pressure and flow are not addressed.

Based on a review of the literature and existing records from the local government, it is established that there is no existing hydraulic assessment of the water distribution system in Aliaga using simulation and demand forecasting techniques. The lack of a validated model creates critical issues. First, the system's current hydraulic performance, including pressure distribution, pipe flow velocities, and storage operations, is not fully understood. Second is the inability to forecast if the infrastructure can meet future demands without using demand forecasting and simulation techniques together. Third is the reactive approach in infrastructure planning and development.

This study will help address the gaps and provide evidence-based planning by answering the following questions:

- What is the current hydraulic performance of Aliaga's water distribution system in terms of layout, pressure levels, flow rates, and storage operations?
- What are the projected water demands in Aliaga for 2030, 2035, and 2040, based on population growth and per capita consumption?
- How will the current water distribution system perform under projected future demand, and what deficiencies may limit its ability to meet that demand?
- What infrastructure upgrades are needed to ensure long-term adequacy and sustainability of the system?

1.3 Objective of the Study

General Objective: Evaluate the adequacy of the water distribution system in the Municipality of Aliaga, Nueva Ecija, through demand forecasting and EPANET-JS simulation to support the planning and development of the water distribution system.

Specific Objectives:

- To describe the water distribution system of Aliaga, including system configuration, pipe types and sizes, location and capacity of water tanks, sources of water supply, and current operation.
- To develop water demand forecasts for the years 2030, 2035, and 2040.
- To develop and simulate a hydraulic model of Aliaga's water distribution system using EPANET-JS to assess its adequacy.
- To identify deficiencies and propose improvements to ensure the long-term reliability and sustainability of the system.

1.4 Significance of the Study

For the Aliaga Local Government: This research offers a technical assessment of the current water distribution infrastructure and its ability to meet future water demands. This information can then be used to make informed decisions on investments to improve the water infrastructure based on hydraulic requirements rather than reacting to water service problems. The demand forecasts can also be used to develop a long-term water supply master plan that meets the needs of the community.

For Water Resources Planners and Engineers: This study demonstrates how EPANET-JS simulation and demand forecasting can be used to evaluate water distribution infrastructure in a water utility in the Philippines. It can then serve as a reference or basis for conducting similar studies in other water utilities or local government units facing the same challenges. It also offers practical experience on how to validate hydraulic models using field data in developing countries.

For the Community: This study contributes to the community, particularly the people and establishments within Aliaga, as it offers the technical base for the provision of adequate and sustainable supply of water.

1.5 Scope and Limitation

Scope: The study area for the water distribution system of this study is within the area of operation of Aliaga Water District, Municipality of Aliaga, Province of Nueva Ecija. The time period considered includes the period from 2025 to 2040, including specific demand and adequacy assessments for the years 2030, 2035, and 2040.

The hydraulic assessment will focus only on the analysis of pressure, flow velocity, and storage adequacy using EPANET-JS simulation software. The study relies on existing infrastructure data from the water district, demographic information from the Philippine Statistics Authority, and field measurements collected during the research period.

The evaluation focuses on hydraulic performance and system capacity assessment to support infrastructure planning. The scope shall not include water quality modeling, detailed structural analysis of network components, and comprehensive financial feasibility studies.

Limitations: Estimated hydraulic model accuracy relies on the availability and quality of existing system records. Certain sections of the older network can have insufficient documentation of pipe materials, sizes, or routing configurations.

Detailed cost-benefit assessment and financial feasibility of suggested improvements are beyond the scope of this study. Economic considerations are addressed qualitatively in the recommendations.

The study assesses existing water sources only on their adequacy. Investigation of alternative source development options such as new groundwater extraction points or surface water diversions is limited to conceptual discussion.

Although seasonal demand variation is factored in, it does not provide a thorough analysis of long-term climate change impacts on source yield and consumption patterns.

2. Methodology

2.1 Research Design

This study employed a quantitative approach with a descriptive-analytical design to evaluate the adequacy of the water distribution system within Aliaga, Nueva Ecija. It employed the application of demand forecasting together with hydraulic simulation using existing data: infrastructure data, parameters in operation and consumption records to give a complete assessment of system capacity for current and future conditions.

The descriptive part of the study provides information on the water distribution network, including its current physical configuration, and current operational performance levels. The analytical part of the study employed a hydraulic simulation model using the EPANET-JS tool to simulate the water distribution system performance levels under various demand scenarios. Performance is evaluated using hydraulic criteria for pressure, velocity, and headloss. This approach enabled the quantitative assessment of the water distribution system performance levels and the identification of the deficiencies within the system.

2.2 Research Framework

This study follows a sequential analytical process with six main phases: data collection, demand forecasting, hydraulic model development, scenario simulation, performance evaluation, and recommendation formulation. The framework, shown in Figure 1, starts with gathering infrastructure, operational, consumption, and demographic data. This information is then used for forecasting demand. Using the forecasted demands, the existing infrastructure is simulated using the EPANET-JS model. Hydraulic simulations are then performed for the existing demands, as well as the forecasted demands. Performance is then evaluated based on existing hydraulic standards.

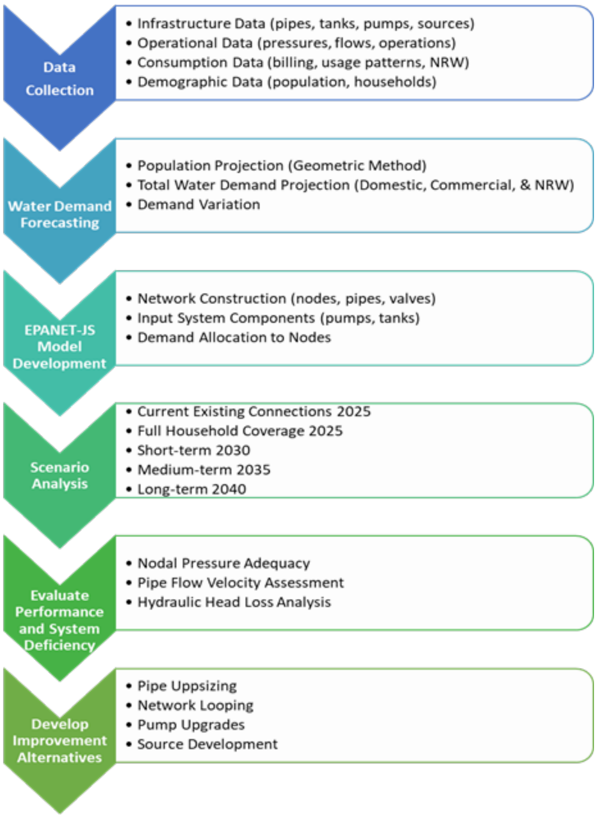

Figure 1: A schematic representation of the research framework

2.3 Data Collection

Data for this study were obtained from secondary and primary sources. Secondary data came from Pamana Water Corporation-Aliaga which includes pipe diameters, lengths, materials, storage tank dimensions and operating levels, pump characteristics, and source capacities. Consumption data including billing records, customer connections, and estimates of non-revenue water were also obtained from the corporation. Census data for the year 2015 to 2024 were collected in Philippine Statistics Authority's website.

Primary data collection involved surveys and actual site measurements to cross-reference existing records and provide more information. This comprised site inspections, in conjunction with GPS verification of pipe routings and node elevations. And if in some cases of conflicting information between records and actual site measurements, actual site measurements were preferred as inputs to the model. Site data collection took place from September to November 2025.

2.4 Water Demand Forecasting

2.4.1 Population Projection

Population projections for 2030, 2035, and 2040 were estimated using the geometric growth method, which assumes a constant percentage rate of population increase. This method is suitable for communities with steady growth patterns. It is expressed mathematically as:

$$P_t = P_o(1+r)^t$$

where P_t is the projected population at year t, P_o is the base year population, r is the annual growth rate, and t is the projection period in years. The growth rate was derived from PSA census data for the years 2015 and 2020.

2.4.2 Water Demand Estimation

Water demand was estimated separately for domestic and commercial sectors using standard engineering parameters from the National Economic and Development Authority (NEDA) and World Bank guidelines. Domestic consumers in small towns typically use 80 to 100 liters per capita per day (lpcd), while urban centers consume 120 to 150 lpcd (World Bank, 2012). Since Aliaga is classified as a rural municipality, a per capita consumption of 80 lpcd was used for domestic demand calculations.

Domestic water demand was estimated using:

$$D_d = P_t \times q_d$$

where D_d is the domestic demand, P_t is the projected population in year t, and q_d is the per capita water demand. Commercial demand was estimated as:

$$D_c = P_t \times f_c \times q_c$$

where D_c is the commercial demand, f_c is the commercial connection ratio (0.003 for rural areas and 0.012 for urban areas), and q_c is the unit commercial consumption.

Total water consumption was computed as the sum of domestic and commercial demands:

$$D_{cons} = D_d + D_c$$

To account for system losses, non-revenue water (NRW) allowances were applied using data from Pamana Water Corporation, which reported a current NRW rate of 24%. This rate falls within the 15–25% range recommended by the World Bank (2012) for developing country water systems. The total water demand representing the system's Average Day Demand (ADD) was calculated as:

$$D_{total} = \frac{D_{cons}}{1 - NRW}$$

Real water demand varies throughout the day and across seasons. To account for these fluctuations, four demand scenarios were defined as multiples of the Average Day Demand (ADD), following standard engineering practice. Table 1 summarizes these demand factors and their application in system analysis.

Table 1: Demand Parameters and Corresponding Demand Factors

Demand Parameter	Demand Factor	Application in System Analysis
Minimum Day Demand	0.3 × ADD	Evaluates the system under minimum demand to check for excessive static pressures; no point in the network should exceed 70 m.
Average Day Demand	1.0 × ADD	Serves as the basis for annual production, revenue, non-revenue water, power costs, and other O&M projections.
Maximum Day Demand	1.3 × ADD	Ensures that the total capacity of existing and future sources can supply the projected maximum day demand; used for treatment plant, pump, and pipeline design considerations.
Peak Hour Demand	2.5 × ADD (>1,000 connections) 3.0 × ADD (<1,000 connections)	Confirms that pressures throughout the network remain above 3 m during peak hours; pumping stations must be adequately sized if no reservoir is available.

2.5 Hydraulic Model Development Using EPANET-JS

The water distribution system was modeled using EPANET-JS, representing the network as interconnected nodes and links. Nodes included junctions (demand points), storage tanks, and water sources. Links consisted of pipes, pumps, and valves. The model geometry was based on infrastructure records and verified GPS coordinates. Node elevations were obtained from digital elevation models and field measurements.

Demand at each node was allocated according to the number of service connections and estimated per-connection consumption. Diurnal demand patterns reflecting typical residential and commercial usage were included, with peak demand occurring from 6:00 to 9:00 AM and 5:00 to 7:00 PM. Pumping stations were modeled using characteristic curves that represent head-discharge relationships based on manufacturer data and field measurements.

2.6 Simulation Scenarios

Hydraulic simulations were conducted under five scenarios representing current conditions and future demand growth:

- Current Existing Connections (2025 Actual Service Level)
- Full Household Coverage (2025 Saturation Scenario)
- Short-term Projection (2030)
- Medium-term Projection (2035)
- Long-term Projection (2040)

Each scenario was simulated over a 72-hour extended period to capture diurnal demand variations.

2.7 Performance Evaluation Criteria

System adequacy was evaluated using hydraulic performance indicators for pressure, velocity, and headloss. These criteria, shown in Tables 2–4, are based on Philippine water supply design standards and international best practices (Solomon, 2023; World Bank, 2012; NEDA, 2021).

Table 2: Pressure Criteria

Parameter	**Recommended Value (m head)**
Minimum Pressure: Customer (Service)	10
Minimum Pressure: Transmission Backbone	12 – 15
Critical / Emergency Pressure	3
Maximum Working Pressure: Distribution	40 – 70
Maximum Working Pressure: Transmission	70 – 100

Table 3: Velocity Criteria

Parameter	**Recommended Value (m/s)**
Maximum Velocity: Transmission	<= 3.0
Maximum Velocity: Distribution	<= 1.0 - 1.5
Minimum Velocity	>= 0.3

Table 4: Headloss Criteria

Parameter	**Recommended Value (m/km)**
Typical Headloss	1–5
Minimum Headloss	0.2
Maximum Headloss	<= 10

Network components that did not meet the established criteria were identified as deficient and prioritized for improvement. Pressure adequacy was evaluated at all junction nodes. Pipe velocities were checked for all links, and headloss was calculated per kilometer to identify segments exceeding acceptable friction losses.

3. Results and Discussion

3.1 Characterization of the Existing Water Distribution System

3.1.1 Network Configuration and Layout

The water distribution system of Aliaga, as simulated in the EPANET-JS model, consists of 881 nodes and 82.83 kilometers of pipelines. Most of the network follows a dead-end configuration, also known as a "tree water distribution" system. In this setup there is a pipe that goes through the center and smaller pipes branch off from it. It is considered to be easily installable and is usually observed in areas such as towns that were not well planned (Francescangeli, 2025). However, in the Poblacion area the pipes are set up in a grid pattern.

Figure 2 is a representation of the layout of the system, which includes the service area and the location of major infrastructure components such as pumping stations, transmission mains, and distribution branches.

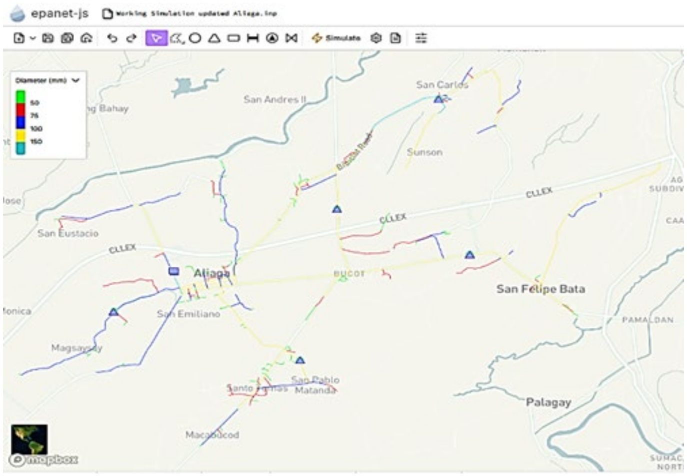

Figure 2: Spatial layout of the distribution network

The network mainly covers residential consumers, with scattered commercial connections. The service area covers 25 out of 26 barangays which is equivalent to 98.15 percent saturation of the barangays in Aliaga. The system has a ground storage tank serving two barangays, namely, La Purisima and San Eustacio, and the rest are served directly with the use of direct pumping to sustain pressure.

3.1.2 Pipe Network Characteristics

The pipe system is mostly PVC (Polyvinyl Chloride) and HDPE (High-Density Polyethylene) for being economically feasible and easy to install. The diameters of the pipes vary from 25 mm, which are used for short-service laterals to 150 mm for main transmission lines. Table 5 summarizes the pipe inventory by diameter.

Table 5: Pipe Network Inventory by Diameter

Pipe Diameter (mm)	**Total Length (km)**	**Percentage of Network**
25	9.44	11%
50	14.31	17%
75	22.99	28%
100	34.85	42%
150	1.24	2%
Total	**82.83**	

The predominance of 75 mm and 100 mm pipes, making up 69.7% of the total length of the network, is in line with the main function of the distribution network. The scarcity of 150mm transmission mains, making up only 1.5% of the total length of the network, may prove to be a future bottleneck for demand increases, particularly for long-distance transmission of water from pumping stations to distant areas of supply.

Small-diameter pipes (25-50mm) making up 28.7% of the total length of the network indicate widespread use of service laterals to supply individual customers. Although this minimizes initial construction costs, it leads to hydraulic inefficiencies and limits capacity for future demand increases. Pipe ages vary from newly installed (0-3 years) in newly developed areas to older (10-15 years) in established neighborhoods.

3.1.3 Water Sources and Pumping Stations

The water supply of Aliaga is entirely from groundwater through its five pumping stations, each with its own deep wells. The dependency on groundwater is typical for Nueva Ecija mainly because of the region's aquifer characteristics. Table 6 below indicates the capacity characteristics of each of Aliaga's pumping stations.

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Table 6: Pumping Station Capacity Summary

Pipe Diameter (mm)	Total Length (km)	Percentage of Network
25	9.44	11%
50	14.31	17%
75	22.99	28%
100	34.85	42%
150	1.24	2%
Total	82.83	

The total design capacity of Aliaga's water system is 128.4 liters per second. It is therefore higher compared to its current operational capacity of 73.05 liters per second. It has an overall utilization rate of 56.9 percent. Each pumping station has a varying utilization rate. For instance, Pumping Station 1 is already operating at 91.1 percent, therefore operating near at its full capacity. On the other hand, Pumping Station 5 is only operating at 13.0 percent.

Stations 2, 3, and 4 are operating at 57%, 62%, and 65%, respectively. This gives buffer when the demand increases. However, capacity does not automatically mean effective service when it is a lack of interconnection between service zones experiencing pressure deficiency. Specifically Station 5 with its low utilization, cannot convey its excess capacity to other locations.

3.2 Water Demand Forecasting Results

3.2.1 Population Projections

By using the geometric growth method and an annual growth rate of 2.17%, which is based on the 2015-2020 census, population projections were computed. The results are shown in Table 7.

Table 7: Projected Population for Planning Horizons

Population (2020)	Population (2015)	Annual Population Growth Rate	Population (2025)	Population (2030)	Population (2035)	Population (2040)
70,363	63,543	2.17%	78,336	87,212	97,095	108,097

The projections show that there is expected population growth in the future, and the population in the municipality is projected to increase by 37,734 persons (53.6%) between 2020 and 2040. There are various factors that may contribute to differences between actual population growth and projected population growth. For instance, economic decline, natural calamities, and agricultural output may contribute to differences between actual and projected population growth.

3.2.2 Water Demand Projections

Using the demand estimation methodology described in Section 2.4.2, with 80 lpcd for domestic consumption, 0.003 commercial connection ratio, 0.8 m^3/day commercial connection, and 24% NRW allowance, water demand projections were calculated and the results are shown in Table 8.

Table 8: Projected Water Demand for Planning Horizons

Year	Population	Domestic Demand (L/s)	Commercial Demand (L/s)	Total Consumption (L/s)	Total Water Demand (L/s)
2025	78,336	72.57	2.18	74.75	98.3
2030	87,212	80.75	2.43	83.18	109.44
2035	97,095	89.9	2.71	92.61	121.84
2040	108,097	100.09	3.01	103.1	135.65

This Average Day Demand (ADD), which is projected to increase from 98.30 L/s in 2025 to 135.65 L/s in 2040, represents an increase of 38% over this 15-year planning period.

To understand this change in demand, it is compared to the current source capacity. Currently, the well capacity is 128.4 L/s. This is more than the ADD until 2035, which is only 121.84 L/s. This gives flexibility within the current system to be able to response during peak demands. By 2040, the projected ADD is 135.65 L/s. This is 7.25 L/s more than the current well capacity. This means it will not be possible to meet this average demand even if all sources are operating at full capacity.

3.3 Hydraulic Performance Under Current and Future Scenarios

This section discusses the hydraulic performance of the existing water distribution system under existing conditions and future demand scenarios using peak demand occurring between 6:00 AM and 9:00 AM and 5:00 PM and 7:00 PM. For this purpose, nodal pressure, velocity in the pipes, and head loss were evaluated using simulation tool EPANET-JS. Five demand scenarios were used for performance evaluation: current operations, full household coverage, and short-term, medium-term, and long-term demand scenarios. Performance evaluation is presented in Table 9.

Table 9: Summary of Hydraulic Performance Indicators Across Demand Scenarios

Scenario	Avg Pressure (m)	Min Pressure (m)	Nodes < Min Pressure (%)	Max Velocity (m/s)	Max Headloss (m/km)	Pipes > Max Headloss (%)
2025 Current	18.98	2.09	0.23%	1.74	52.59	5.33%
2025 Saturated	9.03	-15.27	39.61%	2.35	91.17	11.24%
2030 Short-term	3.89	-26.14	53.35%	2.66	111.15	13.39%
2035 Medium-term	-1.95	-37.63	57.89%	3.01	135.64	15.89%
2040 Long-term	-9.16	-51.58	62.43%	3.4	165.47	20.54%

Note: Minimum pressure criterion = 10 m for customer connections, 3 m emergency minimum; Maximum velocity criterion = 1.5 m/s for distribution, 3.0 m/s for transmission; Maximum headloss criterion = 10 m/km.

Under the current operating conditions, the system is found to satisfy the minimum hydraulic requirements. The average nodal pressure is approximately 19.0 m, and the minimum pressure is 2.09 m. Only 0.23% of the nodes are below the minimum pressure threshold. The velocities and head loss are also within acceptable ranges; the maximum velocity is 1.74 m/s, and only a few exceed the allowable head loss.

3.3.1 Current System Performance (2025 Baseline)

From the current operating conditions, the system demonstrates satisfactory hydraulic performance. The average nodal pressure is 18.98 m, which is well above the minimum service requirement of 10 m. The only 2 nodes (0.23%) are below the minimum service pressure. The maximum velocity is 1.74 m/s, which is within acceptable limits. However, 5.33% of the system is above the maximum allowable head loss of 10 m/km.

As shown in Figure 3 below, the performance varies in different areas. The Poblacion area has consistently high pressures at 20-30 m due to proximity to P.S. 1 and a grid-iron network configuration. The areas served by P.S. 5 also have good performance with varying pressures from 18-25 m along newly constructed pipelines. On the other hand, the peripheral areas served by long transmission lines from P.S. 2 and 4 have relatively low pressures at 8-12 m, just near the minimum requirements during peak demands. Areas with insufficient pressure include parts of Brgy. San Eustacio, Brgy. San Felipe, and remote areas in Brgy. Umangan and Pantoc served by PS 2 and PS 4.

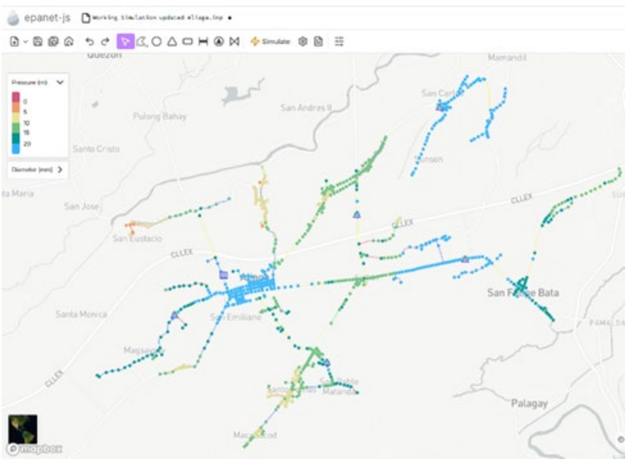

Figure 3: Nodal Pressure Distribution – 2025 Existing Conditions

3.3.2 Scenario 2: Full Household Coverage (2025 Saturation)

3.3.2 System Performance Under Future Demand (2030, 2035, 2040 Projection)

Analysis of future demand

scenarios captures that hydraulic performance deteriorates rapidly when future demands are increased. The 2025 saturation scenario, where all households are assumed to be connected, also shows that the system's latent capacity is limited. Under this condition, 39.61% of nodes are found to be deficient in comparison of the minimum requirement, with some nodes experiencing negative pressures of up to -15.27 m. This implies that the system was designed for partial coverage of the population, not full coverage. The hydraulic loss is also seen to increase significantly, with the maximum head loss increasing to 91.17 m/km, indicating an 11.24% increase in undersized pipes, making them system bottlenecks.

By the year 2030, the deficiencies are no longer local but system-wide. The average nodal pressure is down to 3.89 m, which is below the minimum service level and close to the emergency level. The percentage of nodes below required pressure criteria is 53.35%. At this point, the system changes from generally adequate to generally inadequate. The maximum pipe velocity increases to 2.66 m/s. The percentage of headloss violations increases to 13.39%. The system is generally overloaded. The percentage of pumping utilization increases to 85% of total capacity. However, due to uneven distribution of the stations, some pumps are overloaded beyond the effective capacity, while others are underutilized due to the lack of interconnection in the network.

The 2035 and 2040 scenarios indicate a total hydraulic failure in the water system. In 2035, the average pressure is reduced to a negative value of -1.95 m, while 57.89% of the nodes are not meeting the requirements. In 2040, the average pressure is reduced further to -9.16 m, while 62.43% of the nodes are not meeting the requirements. The maximum velocity in the water pipes exceeds the transmission limits, reaching 3.01 m/s in 2035 and 3.40 m/s in 2040. The headloss violations are increased further in 2040, reaching 15.89% or 20.54% of the total pipes in the water system. The maximum headloss violations are 135.64–165.47 m/km. In 2040, deficit in source capacity is experienced, where the total demand is 135.65 L/s compared to a total capacity of 128.4 L/s by 7.25 L/s.

The results also reveal that the water distribution capacity is a limitation, together with the capacity of the water source. Even if water is available at the source, the distribution system cannot deliver water at a suitable pressure.

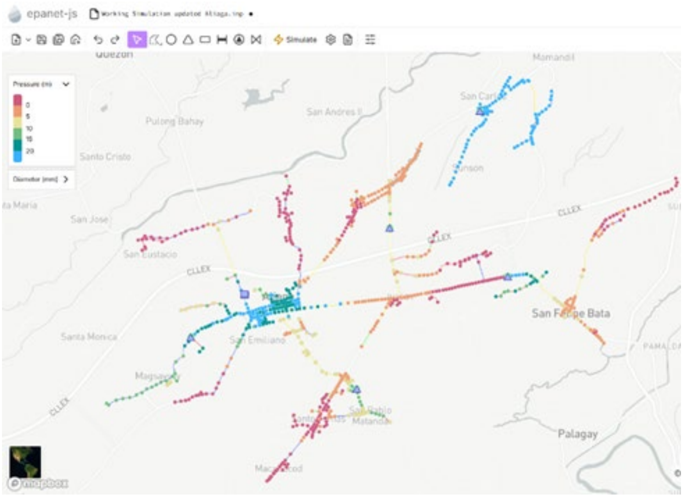

Figure 4: Nodal Pressure Distribution – 2025 Saturated Scenario

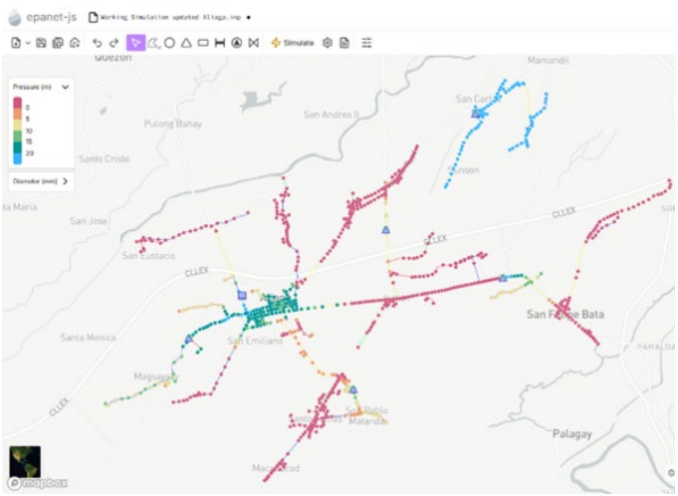

Figure 5: Nodal Pressure Distribution – 2030 Short-term Projection

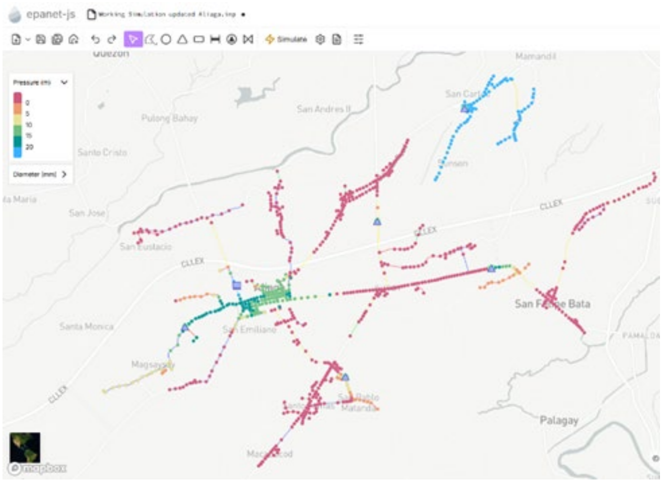

Figure 6: Nodal Pressure Distribution – 2035 Medium-term Projection

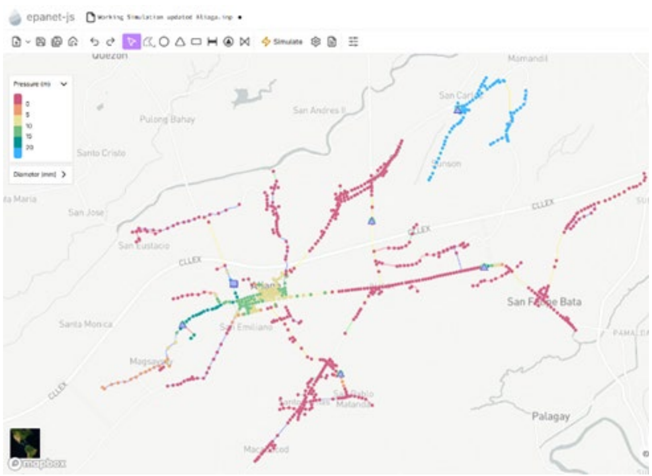

Figure 7: Nodal Pressure Distribution – 2040 Long-term Projection

4. Conclusions and Recommendations

4.1 Conclusions

The hydraulic assessment has further confirmed that the existing water distribution system in the Municipality of Aliaga is able to satisfy the existing demand level but is not structurally able to support the growth in demand that is anticipated. The areas that are served by the new pumping stations and the improved pipelines, particularly in the Poblacion area, are found to have adequate pressure and flow conditions due to the shorter transmission distance.

On the other hand, older and peripheral areas of the network have progressive hydraulic deterioration as the demand increases. From the simulation results, significant pressure drop and excessive headloss are observed along long transmission lines, especially those located in the more remote barangays, were the network is a tree water distribution system. The pipe diameters gradually decrease towards the terminal ends of the network. The existing pipe diameters are not adequate to meet the increasing demand. Although the velocities are found to be within acceptable limits, the headloss exceeds the design criteria in the critical areas of the pipeline network. This confirms the distribution pipe capacity rather than the source capacity as the major hydraulic constraint to the network.

The performance of the system steadily worsens from 2025 to 2040. The localized deficiencies observed in the current conditions have become widespread hydraulic failures in the future scenarios. Negative pressures and widespread head loss failures in the 2035 and 2040 scenarios indicate that the system is unable to effectively convey available supply to meet the demands. The lack of network looping and storage further contributes to the pressure instability issues in the system, especially during peak demand periods.

The high Non-Revenue Water at 24 percent greatly limits the effective system capacity and causes service deficiencies to appear even before overall source capacity is exceeded. While overall pumping capacity is available for the majority of the planning period, the lack of hydraulic connectivity between pumping stations prevents unused sources from serving deficient areas.

The system appears to perform adequately in newly developed areas but demonstrates clear and measurable deficiencies in the older areas of the network. The existing infrastructure is clearly not sustainable and will be unable to meet future service demands in Aliaga unless distribution system upgrades are provided.

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4.2 Recommendations

To enhance pressure balance, interconnection of service areas of pumping stations should be given priority. In particular, interconnection of service areas of Brgy. San Carlos and Brgy. Bibiclat through 150 mm PVC pipelines shall enhance pressure balance.

The capacities of Pumping Stations 2 and 4 located in Brgy. San Pablo and Brgy. San Juan, respectively, should be enhanced to cater to future demands of their respective service areas. These enhancement works should be done in conjunction with improvements in the pipes that these pumping stations serve in order to ensure that future supply is effectively transported through these pipelines.

The critical transmission pipelines that are currently acting as hydraulic bottlenecks should be upgraded in diameter. The pipelines that serve Brgy. San Juan to Brgy. San Felipe and Brgy. San Pablo to Sto. Tomas should be upgraded to 150 mm from the existing 100 mm diameter. This shall alleviate problems of head loss, pressure instability, etc., during peak demands.

Future studies should also include a financial and economic analysis of the proposed infrastructures to be upgraded. This is important in order that the proposed solution is not only technically sound but also financially viable for both the utility and consumers in general.

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