EPANET Modeling for Water Distribution System Assessment in a Growing University Campus

Caryl T. Rafols
Department of Civil Engineering, College of Engineering and Geosciences, Caraga State University

Rea Andrea M. Villamor
Department of Civil Engineering, College of Engineering and Geosciences, Caraga State University

Stephanie Mae Salcedo-Albores
Department of Civil Engineering, College of Engineering and Geosciences, Caraga State University

Christian Dwight C. Dolotina
Department of Civil Engineering, College of Engineering and Geosciences, Caraga State University

https://doi.org/10.5109/7395682

出版情報：Proceedings of International Exchange and Innovation Conference on Engineering & Sciences (IEICES). 11, pp.1322-1329, 2025-10-30. International Exchange and Innovation Conference on Engineering & Sciences
バージョン：

EPANET Modeling for Water Distribution System Assessment in a Growing University Campus

Caryl T. Rafols[1], Rea Andrea M. Villamor[1], Stephanie Mae Salcedo-Albores[1,2], Christian Dwight C. Dolotina[1]
[1]Department of Civil Engineering, College of Engineering and Geosciences, Caraga State University, Philippines
[2]Caraga Center for Geo-Informatics (CCGeo), Caraga State University, Philippines
Corresponding author email: ssalbores@carsu.edu.ph

Abstract: *Water distribution systems are critical infrastructures responsible in delivering water to sustain various functions within a growing educational institution. At Caraga State University – Main Campus, the increasing demand may potentially impose additional stress on the existing system, yet its performance remains uncertain without a comprehensive hydraulic analysis. This study aims to evaluate the campus water distribution network using the Environmental Protection Agency Network Evaluation Tool (EPANET). The hydraulic simulation revealed that the system performed unsatisfactorily with respect to the pressure, velocity, and headloss requirements under both current and future demand scenarios. Hence, modifications of pipe diameters were implemented to improve system performance and achieve the desired hydraulic results. Under the current scenario, nodes within the acceptable pressure range increased to 76.71%, compliant pipe velocities improved by 5.48%, and headloss values by 57.58%. For the future scenario, pressure compliance reached 72.72%, velocity improved by 10.39%, and headloss by 54.55%.*

Keywords: EPANET; Water Distribution System; Pressure; Velocity; Headloss

1. INTRODUCTION

As is widely recognized, water is one of the basic requirements of human beings for survival. Throughout history, the critical role of water has driven the development of water distribution systems, as discussed in [1]. Through an extensive network of pipes, these systems facilitate the complete process of water delivery from source extraction to treatment and final distribution [2], thereby contributing significantly to community well-being [3]. Reliable access to water in higher education institutions is crucial for sustaining academic, administrative, and residential functions, highlighting the need to assess and optimize the university's water distribution system [4]. At Caraga State University – Main Campus (CSU Main), the water distribution system has not been thoroughly assessed, and no comprehensive hydraulic analysis exists that reflects the current state of the system, accounting for modifications in pipes, pipelines, and changes in connections. As the university continues to expand, with ongoing construction of the School of Medicine, the New Gents' Dormitory, and the Ladies' Dormitory, the water demand is expected to rise. The performance of a distribution system can be judged based on the pressures available in the system for a specific rate of flow [5] that may potentially lead to water loss [6], with frictional head loss being a primary factor influencing flow dynamics during system design, and the velocity of water flow in pipes, as these are crucial parameters in assessing the efficiency of water distribution and transmission lines. To assess and analyze the state of the water distribution system at CSU Main, utilizing the most appropriate tools and methods tailored to the study's requirements is crucial, as careful selection will yield effective results [7]. Hence, this research will utilize EPANET, a hydraulic simulation software that offers a versatile platform for modeling, simulating, and visualizing water distribution systems through various formats such as maps and graphs [8].

2. METHODOLOGY

Three activities were integrated into one methodological framework which presents the overall methods' step-by-step process that guided the researchers to achieve the desired outcome. Specifically, these are the data acquisition, model development, and EPANET simulation.

2.1 Data Acquisition

2.1.1 Primary Data

Primary data were gathered through direct observations, on-site inspections, and consultations with university offices. These data include physical verification of the existing pipe network, estimation of peak hour water demand, and hydraulic computations for pipe sizing.

2.1.1.1 Field Verification

The researchers conducted on-site field verification across CSU Main to validate the accuracy of the base map and pipe network layout. Prior to the survey, consultations with the General Services Office and the university plumber confirmed the existing connections and recent system modifications. The researchers, accompanied by the plumbing authority, inspected all network components to verify pipeline routes, service connections, pipe diameters, and materials. Furthermore, geotagging was used to map new or altered nodes, and the updated data were reconstructed in Autodesk Civil 3D to revise the distribution network.

2.1.1.2 Estimating Peak Hour Demand

To estimate water demand, the researchers acquired building plans from the Engineering and Construction Office (ECO) and calculated floor areas of campus facilities. Estimated building occupancy was then derived using Table 1, which follows the floor area basis for population estimation defined in RA 9514, or the Fire Code of the Philippines [9], and the 2024 International Building Code [10].

Table 1. Floor Area Basis for Population Estimation by Occupancy Type

Occupancy Type	RA 9514	IBC 2024
Assembly (concentrated, no fixed seating)	0.65 m²/person	0.65 m²/person
Assembly (less concentrated)	1.40 m²/person	1.40 m²/person
Bench-type seating	1 person/455mm	1 person/455mm
Fixed Seating	No. of fixed seats	No. of fixed seats
Standing space (e.g., waiting)	0.4 m²/person	0.46 m²/person
Kitchens	18.60 m²/person	9.30 m²/person
Library – Stacks	9.30 m²/person	9.30 m²/person
Library –Reading	4.60 m²/person	4.60 m²/person
Stages/ Platform	1.40 m²/person	1.40 m²/person
Classrooms	1.90 m²/person	1.90 m²/person
Inpatient treatment (health)	22.30 m²/person	22.30 m²/person
Sleeping rooms (health)	11.10 m²/person	11.10 m²/person
Ambulatory health care	9.30 m²/person	9.30 m²/person
Detention/ correctional	11.10 m²/person	11.10 m²/person
Residential	18.60 m²/person	18.60 m²/person
Hotels/ Dormitories	-	18.60 m²/person
Apartments, board and care	18.60 m²/person	18.60 m²/person
Business	9.30 m²/person	9.30 m²/person
Storage - mercantile	-	27.90 m²/person
Storage – other	-	46.50 m²/person
Offices	9.30 m²/person	9.30 m²/person
Agricultural buildings	27.87 m²/person	-
Storage/ mechanical rooms	27.87 m²/person	-

Using the estimated population per facility, the Average Daily Demand (ADD) was computed using the formula:

$$ADD = Population \times Water\ Consumption \qquad (1)$$

Water consumption rates depended on the location and building type as per LWUA [11]. General rates for rural, suburban, and urban areas are presented in Table 2.

Table 2. Average Human Water Consumption by Area and Connection Type

Use	Consumption (liters/capita/day)
Rural	
1. Public Faucet	60
2. Individual Household Connection	100
3. Combined Public Faucets & some Household Connection	80
Suburban Area	120
Urban Area	150

Source: LWUA Operations and Manual (n.d)

To support activity-specific estimation, Table 3 shows how daily water use is typically distributed across household tasks.

Table 3. Per Capita Daily Water Usage by Activity

Use	%	120 iters Consumption	150 Liters Consumption
Kitchen	15%	18 liters	22.50 liters
Drinking	5%	6 liters	7.5 liters
Shower	10%	12 liters	liters
Laundry	20%	24 liters	30 liters
Toilet Flush	40%	48 liters	60 liters
Others: Carwash, Water gardens	10%	12 liters	15 liters
TOTAL	100%	120 liters	150 liters

Source: LWUA (n.d)

To refine the demand estimate per building, standard consumption values by building type were used, as shown in Table 4. These rates provide a basis for more accurate water usage projections, tailored to the function and occupancy level of each facility.

Table 4. Water Consumption Rates by Building Type

Building Type	Consumption (liters/capita/ day)
Airports (per passenger)	11 - 19
Apartments (per resident)	151
Boarding Houses (per boarder)	150 - 189
Factories (per person/shift)	57 - 132
Hotels with T & B (twin sharing)	227
Hotels w/o T & B (per person)	189
Hospitals (per bed)	946 -1514
Institutional Building (per person)	284 - 473
Large Residential Houses (per resident)	189 - 284
Restaurants (with toilets, per patron)	26 - 38
Restaurants (without toilets, per patron)	9 - 11
Restaurants (with bar/cocktail, additional)	8
Schools (with gym, canteen, shower)	95
Schools (with canteen only)	76
Schools (w/o gym, canteen, shower)	57
Auditorium (per seat)	19
Stores (per toilet room)	151

Office (per person/shift)	57

Source: LWUA (n.d)

After calculating the Average Daily Demand (ADD), the researchers determined the Peak Hour Demand (PHD) using a demand factor of 3.0, as recommended for networks with fewer than 1,000 connections in the Rural Water Supply Design Manual [12], incorporating a 20% allowance for Non-Revenue Water. The modified standard equation is as follows:

$$PHD = (ADD \times 3.0) + (ADD \times 0.20) \quad (2)$$

2.1.1.3 Pipe Diameter Calculation

Pipe diameters were calculated to optimize both current and future water demands of the campus. Using the total demand per facility (in L/s), the minimum internal pipe diameter was computed using the derived Hazen-Williams equation.

$$d = 303\left(\frac{Q}{C}\right)^{0.38} \quad (3)$$

From the equation above, d represents the diameter in mm, Q is the discharge, while c is the Hazen-Williams roughness coefficient. A roughness coefficient of 140 was applied for all pipes, based on PVC and HDPE standards listed in Table 5.

Table 5. Roughness Coefficients

Pipe	Hazen-Williams c (unitless)
Cast Iron	130 – 140
Concrete or Concrete Lined	120 – 140
Galvanized Iron	120
Plastic	140 – 150
Steel	140 – 150
Vitrified Clay	110

Source: Rossman et al. (2020)

After computing theoretical diameters, the values were compared with available commercial pipe sizes, and the nearest higher size was selected based on standard specifications shown in Table 6.

Table 6. Nominal Pipe Sizes and Dimensions

Nominal Pipe Size (in)	Nominal Pipe Size (mm)	Inner Diameter (in)	Inner Diameter (mm)
1/8	6	0.405	10.3
1/4	8	0.54	13.7
3/8	10	0.675	17.1
1/2	15	0.84	21.3
3/4	20	1.05	26.7
1	25	1.315	33.4
1 - 1/4	32	1.66	42.2
1 - 1/2	40	1.9	48.3
2	50	2.375	60.3
2 - 1/2	65	2.875	73
3	80	3.5	88.9
3 - 1/2	90	4	101.6
4	100	4.5	114.3
5	125	5.563	141.3
6	150	6.625	168.3
8	200	8.625	219.1
10	250	10.75	273
12	300	12.75	323.8
14	350	14	355.6
16	400	16	406.4
18	450	18	457
20	500	20	508
24	600	24	610
30	750	30	762
36	900	36	914
42	1050	42	1067
48	1200	48	1219

2.1.2 Secondary Data

The secondary data used in this study included the existing water distribution layout, pipe specifications and facility plumbing layouts from ECO, along with pipe lengths measured from a scaled DWG file. Future campus expansion plans and tank details were also obtained from the same office and the General Services Office. Elevation data for network nodes came from a 2014 Digital Terrain Model provided by CCGeo. Design standards for pressure, velocity, and pressure were based on guidelines from the LWUA Manual and Operations [11], the Rural Water Supply Design Manual [12], and the Revised National Plumbing Code of the Philippines [13], as summarized in Table 7.

Table 7. Design Constraints Based on National Standards

Design Parameter	Maximum Allowable	Minimum Allowable	Reference
Pressure	70 m	14 m	LWUA Manual and Operations
Velocity	3.0 m/s	0.4 m/s	Rural Water Supply Design Manual, NPCP
Headloss	10 m/km	0.5 m/km	Rural Water Supply Design Manual

2.2 EPANET Model Development

The development of the water distribution network model in EPANET involved three main steps: project setup, layout preparation, and parameter assignment. In the project setup, EPANET settings were configured using SI metric units, the Pressure Driven Analysis (PDA) demand model, and Hazen-Williams headloss formula. The layout was then constructed using a simplified (skeletonized) schematic of the CSU Main water system. Two models were created, one representing the current network and another for the future scenario, including proposed buildings. Nodes and links were placed according to the updated network map, with new pipelines integrated for future infrastructure. Finally, essential node and link parameters such as elevation, base demand, pipe length, diameter, and roughness coefficient were inputted to reflect real-world conditions. This completed the setup for hydraulic simulation, which was carried out separately for both current and projected demand conditions.

2.3 Hydraulic Simulation

This simulation was conducted in two stages: first, under current scenario, and subsequently, under the future scenario. The demand model employed for this analysis was the Pressure Driven Analysis (PDA) approach, conducted as a single-period hydraulic simulation. At this point, the software computed the rate of head loss (m/km) in each pipe, the flow velocities (m/s), and the pressure in each node (m). Moreover, links that do not meet the specified design criteria for pressure, velocity, and headloss, as discussed previously, will be adjusted accordingly with their pipe size diameters. If necessary, the diameters of the pipes were modified to determine the optimal size that achieves pressures, velocity, and headloss within acceptable ranges.

2.4 Validation of Model

The model was validated by manually calculating pressure, velocity, and headloss, and comparing the results with those obtained from the EPANET simulation. The following formula in Equation 4 was used to compute pressure:

$$P = Total\ Head - Elevation \tag{4}$$

For velocity, the equation employed is presented in Equation 5, where v is the velocity, Q is the flow rate and A is the Area of the pipe.

$$v = \frac{Q}{A} \tag{5}$$

Finally, for headloss, the Hazen-Williams Headloss formula in Equation 6 is utilized:

$$H = \frac{10.583LQ^{1.85}}{C^{1.85}d^{4.87}} \tag{6}$$

where L is the length of pipe, Q is the flow rate, C is the Hazen-Williams roughness coefficient and d is the internal diameter of pipe.

3. RESULTS AND DISCUSSION

3.1 Population Per Building

As part of this study, the researchers gathered the population of each building, outlined in Tables 8 and 9.

Table 8. Calculated Population Per Existing Building

Establishment	Population
CAA Building	549
CAS Canteen	50
Molecular Biology and Agricultural Microbiology Building	66
Tissue Culture Laboratory	87
Garden	4
TESDA	87
CEd Building	373
CEd Canteen	58
Old CEIT Building	116
TTLO Office	35
Common Classroom	49
LSG Office	8
Canteen	77
Dancing Hall	43
ORGMS/Book Store	47
Annex 3 Building	237
Old Hostel	199
President's House	6
Lab Facility	15
Farm Mechanization	153
HERO Learning Commons	1806
Batok Hall	2982
New Administration Building	343
Old Administration Building	128
Old CAS Canteen	122
Administration Office	10
Old CAS Building	277
Kinaadman Hall	979
Hiraya Hall	1456
Hinang Hall	1310
Annex 2 Building	274
Masawa Hall	844
Old Gents' Dormitory	110
Gymnasium	3242
Wood Working Factory	3
Agriculture Classroom	55
Piggery	8
Black Native Chicken Project	8
Garden	7
CoFES Buildings	320
Carabao and Goat Centers	6

Table 9. Calculated Population Per Proposed Building

Establishment	Population
School of Medicine	1834
New Gents' Dormitory	558
Ladies' Dormitory	837

As presented in the tables, the Gymnasium accommodates the highest number of occupants among existing buildings, with a population of 3242 individuals. Batok Hall and the HERO Learning Commons followed, with 2,982 and 1,806 occupants, respectively. For proposed buildings, the School of Medicine is projected to have the highest occupancy at 1,834.

3.2 Peak Hour Demand Per Building

The resulting peak hour water demands, expressed in liters per second (L/s), are shown in Tables 10 and 11.

Table 10. Peak Hour Demand of Existing Buildings

Establishment	Peak Hour Demand (liters/second)
CAA Building	1.304
CAS Canteen	0.047
Molecular Biology and Agricultural Microbiology Building	0.157
Tissue Culture Laboratory	0.207
CAA Garden	0.002
TESDA	0.207
CEd Building	0.886
CEd Canteen	0.054
Old CEIT Building	0.276
TTLO Office	0.083
Common Classroom	0.124
LSG Office	0.019
Canteen	0.072

Dancing Hall	0.034
ORGMS/Book Store	0.112
Annex 3 Building	0.675
Old Hostel	0.701
President's House	0.038
Lab Facility	0.036
Farm Mechanization	0.291
HERO Learning Commons	3.367
Batok Hall	2.257
New Administration Building	0.807
Old Administration Building	0.304
Old CAS Canteen	0.138
Old CAS Building	0.064
Kinaadman Hall	2.610
Hiraya Hall	2.508
Hinang Hall	2.743
Annex 2 Building	0.651
Masawa Hall	2.005
Old Gents' Dormitory	0.688
Gymnasium	2.835
Wood Working Factory	0.002
Agriculture Classroom	0.131
Piggery	0.005
Black Native Chicken Project	0.005
Garden	0.004
CoFES Buildings	0.760
Carabao and Goat Centers	0.004

Table 11. Water Demand of Proposed Buildings

Establishment	Water Demand (liters/second)
School of Medicine	4.356
New Gents' Dormitory	3.488
Ladies' Dormitory	5.231

Based on Table 10, the HERO Learning Commons exhibited the highest water consumption among existing structures, with a demand of 3.367 liters per second. In contrast, the Wood Working Factory and the CAA Garden recorded the lowest water demand, each at 0.002 liters per second. Among the proposed campus facilities, the Ladies' Dormitory registered the highest projected water demand as shown in Table 11, at 5.231 liters per second.

3.3 EPANET Model

The EPANET model for Caraga State University – Main Campus shown in Figure 1 features a branched water distribution system operating under gravity, with no pumps included, as existing pumps only transfer groundwater to the elevated tank. The present scenario model consists of 73 junctions, 73 pipes, and 1 tank, while the future scenario includes 77 junctions and pipes, reflecting the addition of the School of Medicine, New Gent's Dormitory, and Ladies' Dormitory. Transmission pipeline diameters range from 20 mm to 100 mm, and all necessary nodal and link parameters were applied in both models.

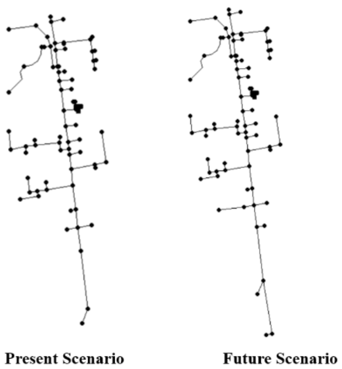

Fig. 1 EPANET Models for Present and Future Scenario

3.4 EPANET Hydraulic Simulation Results

3.4.1 Simulation Under Present Scenario

3.4.1.1 Pressure

Based on Figure 2, the simulation showed that 95.89% of junctions recorded pressure values below the minimum threshold of 14 meters, with only 4.11% meeting the acceptable range.

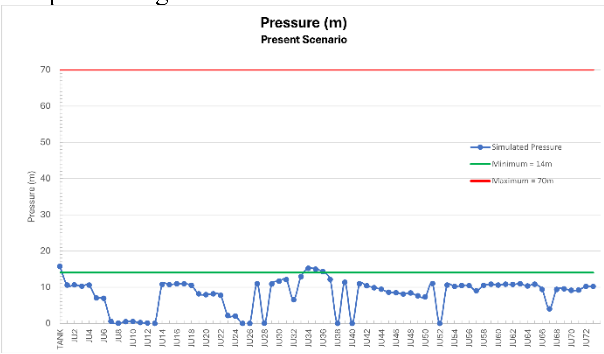

Fig. 2. Simulated Pressure for Present Scenario

3.4.1.2 Velocity

As shown in Figure 3, of the 73 pipes analyzed, 56.16% had velocities within the recommended range, 1.37% exceeded the maximum limit, and 42.47% were below the minimum.

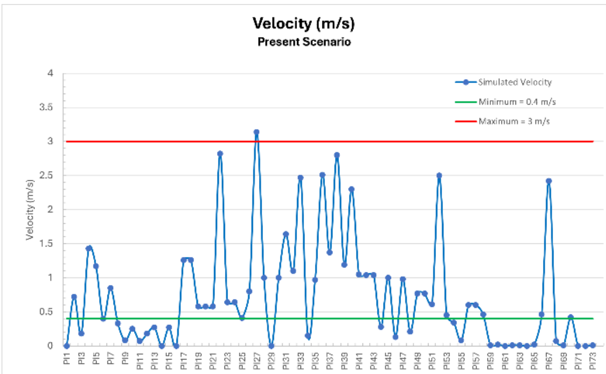

Fig. 3. Simulated Velocity for Present Scenario

3.4.1.3 Headloss

Figure 4 shows that 43.84% of pipes exceeded the upper limit of 10 m/km, 27.40% were below the minimum, and only 20.5% fell within the recommended range, indicating limited overall system efficiency.

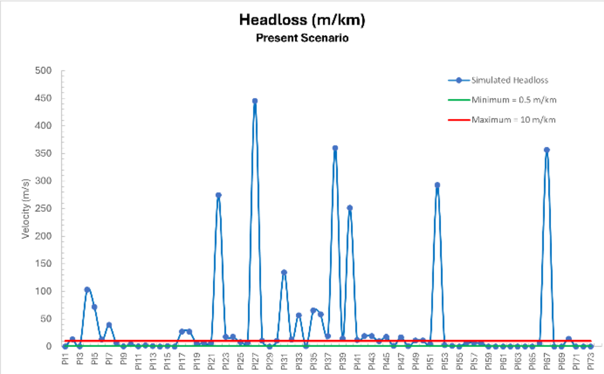

Fig. 4. Simulated Headloss for Present Scenario

3.4.2 Simulation Under Future Scenario

3.4.2.1 Pressure

The graph result in Figure 5 showed that 74 out of 77 junctions, or 96.10%, did not meet the minimum pressure requirement of 14 meters, indicating an increase of 0.21% compared to the present scenario. Only three nodes (3.90%) met the acceptable pressure range, all located near the elevated storage tank.

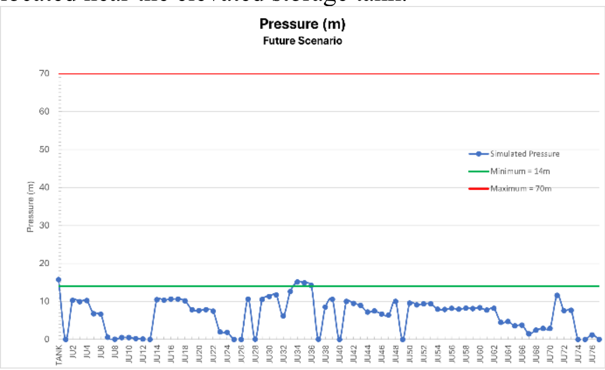

Fig. 5. Simulated Pressure for Future Scenario

3.4.2.2 Velocity

Regarding velocity results in Figure 6, 45 out of 73 pipes (58.44%) fell within the optimal range. Similar to the present scenario, only one pipe (1.30%) exceeded the upper velocity limit, a slight decrease of 2.21% from the previous model. Meanwhile, 31 pipes (40.26%) were below the minimum velocity threshold.

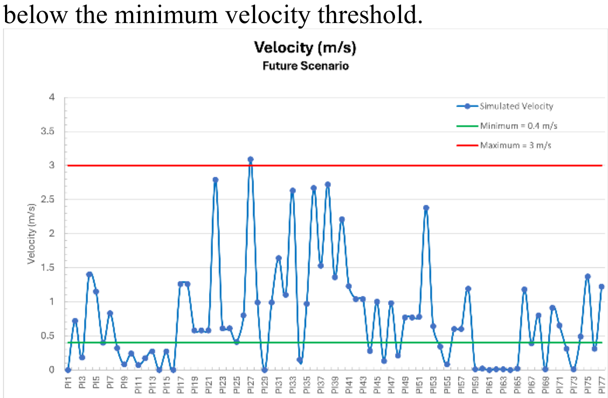

Fig. 6. Simulated Velocity for Future Scenario

3.4.2.3 Headloss

The graph in Figure 7 indicated hydraulic imbalance, with 38 pipes (52.05%) exceeding the maximum allowable headloss, implying 8.21% increase largely in areas with newly added buildings. 17 pipes (23.29%) fell below the minimum headloss threshold, reflecting a 4.11% decrease from the present scenario.

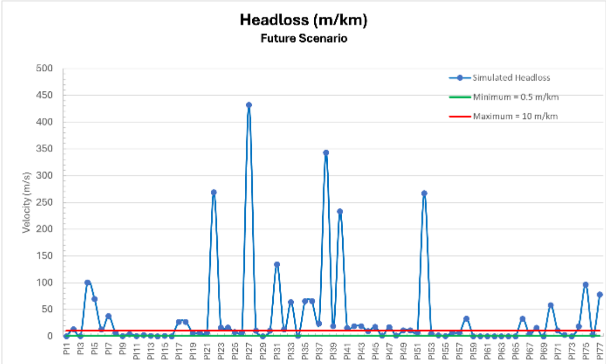

Fig. 7. Simulated Headloss for Future Scenario

3.5 Optimization Under Present Scenario

To ensure that the water distribution network model adhered to the prescribed minimum and maximum thresholds for pressure, velocity, and headloss, the researchers implemented strategic modifications to the pipe diameters throughout the network as presented in Table 12.

Table 12. Optimized Diameters Under Present Scenario

Pipe ID	Assigned Diameter (mm)	Optimized Diameter (mm)
PI2	50	65
PI3	100	65
PI4	25	50
PI5	25	50
PI6	20	25
PI7	25	50
PI8	25	32
PI9	25	15
PI10	25	32
PI11	25	15
PI12	25	32
PI13	100	80
PI15	100	80
PI17	65	125
PI18	65	125
PI22	32	80
PI23	32	65
PI24	32	65
PI25	32	40
PI26	100	150
PI27	25	65
PI28	100	175
PI30	100	175
PI31	25	50
PI32	100	175
PI33	100	175
PI35	20	50
PI36	100	175
PI37	100	175
PI38	25	80
PI39	100	175
PI40	25	80
PI41	100	175
PI42	65	80
PI43	65	80
PI45	65	80
PI47	65	80
PI48	65	50
PI49	65	80
PI50	65	80

PI51	100	125
PI52	25	80
PI54	100	80
PI55	100	40
PI67	20	50
PI70	20	25

A total of 46 pipes (63%) were modified in the optimized EPANET model, primarily through upsizing to enhance pressure distribution and minimize headloss. However, select pipes were downsized to improve velocity and headloss performance. Post-optimization, 59 nodes (80.82%) met pressure requirements, resulting in an improvement of 76.71%. Velocity compliance increased to 61.64% (45 pipes), a 5.48% rise from the original 56.16%. Additionally, 57 pipes (78.08%) satisfied headloss criteria, indicating notable hydraulic performance enhancement.

3.6 Optimization Under Future Scenario

In the future network model, 54 pipes were modified as shown in Table 13. Compared to the unoptimized future scenario, the optimized model showed significant hydraulic improvement.

Table 13. Optimized Diameters Under Future Scenario

Pipe ID	Assigned Diameter (mm)	Optimized Diameter (mm)
PI2	50	65
PI3	100	65
PI4	25	50
PI5	25	50
PI6	20	25
PI7	25	50
PI8	25	32
PI9	25	15
PI10	25	32
PI11	25	15
PI12	25	32
PI13	100	80
PI15	100	80
PI17	65	125
PI18	65	125
PI22	32	80
PI23	32	65
PI24	32	65
PI25	32	40
PI26	100	150
PI27	25	65
PI31	25	50
PI32	100	175
PI33	100	200
PI34	50	32
PI35	20	32
PI36	100	200
PI37	100	200
PI38	25	80
PI39	100	200
PI40	25	80
PI41	100	175
PI42	65	80
PI43	65	80
PI45	65	80
PI47	65	80
PI48	65	50
PI49	65	80
PI50	65	80
PI51	100	175
PI52	25	80
PI53	100	175
PI54	100	80
PI55	100	40
PI58	50	175
PI66	50	175
PI68	50	175
PI70	20	100
PI71	50	150
PI72	50	100
PI74	20	100
PI75	25	90
PI76	50	100
PI77	25	100

A total of 59 nodes (76%) met the pressure criteria, up from only 3.90 percent, reflecting a 72.72% increase. For velocity, 53 pipes (68.83%) met the acceptable range, an improvement of 10.39%. Additionally, 64 pipes (83.12%) satisfied headloss limits, indicating a 54.55% improvement. These results demonstrate that the optimization effectively reduced energy losses and enhanced hydraulic performance.

4. CONCLUSION AND RECOMMENDATIONS

4.1 Conclusion

This study successfully modeled and assessed the hydraulic performance of the Caraga State University Main Campus water distribution system using EPANET under both current and projected future demand conditions. The present network exhibited considerable deficiencies, with only 4.11% of junctions meeting the minimum pressure requirement of 14 meters, and just 56.16% of pipes operating within the recommended velocity range of 0.4 to 3.0 m/s. Additionally, 43.84% exceeded the acceptable headloss threshold of 10 m/km, and only 28.77% were within the acceptable range. Pressure-compliant nodes increased to 80.82%, marking a 76.71% improvement from the existing setup. Velocity-compliant pipes rose to 61.64%, a 5.48% increase, while pipes meeting headloss criteria reached 78.08%, reflecting a 49.31% improvement. These results reflect enhanced pressure distribution and reduced frictional losses through strategic upsizing and downsizing of selected pipes. For the future scenario, which incorporated additional campus infrastructure and demand, the baseline network performance further deteriorated with only 3.90% of nodes maintaining acceptable pressure, 58.44% of pipes operating within velocity limits, and only 28.57% of pipes meeting the allowable headloss requirement. Following optimization, pressure-compliant nodes rose to 76.62%, indicating a 72.72% improvement. Velocity compliance reached 68.83%, reflecting a 10.39% increase. Additionally, 83.12% of pipes met the headloss requirement, showing a 54.55% improvement. Overall, the study concluded that the existing system is not only satisfactory in its current functionality but also lacks the capacity to accommodate future demand without substantial improvements and infrastructure upgrades. The results highlight the need for immediate actions, such as increasing pipe sizes, conducting regular system evaluations, and using resilient design strategies.

4.2 Recommendations

To improve the water distribution performance at Caraga State University – Main Campus, it is recommended to install smart meters throughout the campus facilities, conduct regular surveys to update fixture inventories and occupancy data, and account for seasonal and hourly variations in water consumption. Additionally, the EPANET hydraulic model should be regularly updated to reflect current topographic data, facility changes, and network modifications. Most importantly, other means of optimization strategies beyond pipe diameter adjustments must be implemented out, especially in low-pressure and terminal zones. Moreover, future research should incorporate extended-period simulations using real or estimated hourly water usage data to capture dynamic demand variations, alongside statistical error and sensitivity analyses. It is also recommended to adopt multi-objective optimization approaches that consider cost, energy consumption, and system reliability, as well as to simulate leakage scenarios. While current simulation results offer valuable insight, validating key parameters such as network pressure would strengthen model accuracy; however, this remains constrained in the absence of installed pressure gauges and is considered a necessary step in the succeeding phase of the research project. Finally, integrating Geographic Information System (GIS) technology is encouraged to improve spatial accuracy and enhance system monitoring.

5. REFERENCES

[1] H. Mala-Jetmarova, A. Barton, A. Bagirov, A History of Water Distribution Systems and their Optimisation, Water Science & Technology Water Supply. 15(2) (2014), 224-235.

[2] R.L. Valdez, A.W. Oreta, Integrated Framework for Analyzing Seismic Hazard, Exposure, and Vulnerability in Damage and Loss Assessment of Water Network System, Proceeding of International Exchange and Innovation Conference on Engineering & Sciences (IEICES). 10 (2014), 545-551.

[3] H. Gisha, Water Distribution Network Analysis of Bodditi Town by EPANET. Journal of Information Engineering and Applications. 6 (2016).

[4] B. Hossain, N.C. Roy, P.C. Biswas, N. Azad, E. Yusuf, Analysis and Design of water distribution network using EPANET: A case study of HSTU Campus of Dinajpur, Bangladesh, Hydrology. 9 (2021), 36-47.

[5] M.H. Masum, N. Ahmed, S.K. Pal, Water Distribution System Modeling by Using EPANET 2.0, A Case Study of CUET, International Conference on Civil Engineering for Sustainable Development (ICCESD 2020). (2020).

[6] H. Awad, A. Kawamura, K. Jinno, Application of Artificial Neural Networks for Optimal Pressure Regulation in Supervisory Water Distribution Networks, Proceeding of International Exchange and Innovation Conference on Engineering & Sciences (IEICES). 65 (2005), 29-51.

[7] A. Voinov, K. Jenni, S. Gray, N. Kolagani, P.D. Glynn, P. Bommel, C. Prell, M. Zellner, M. Paolisso, R. Jordan, E.Sterling, L.S. Olabisi, P. Giabbanelli, Z. Sun, C.L. Page, S. Elsawah, T.K. BenDor, K. Hubacek, B.K. Laursen, A. Smajgl, Tools and methods in participatory modeling: Selecting the right tool for the job. Environmental Modelling & Software. 109 (2018), 232-255.

[8] D. Mehta, K. Lakhani, D. Patel, G. Patel, Study of water distribution network using EPANET. International Conference on: Engineering: Issues, Opportunities and Challenges for Development. (2016).

[9] Bureau of Fire Protection, Revised Fire Code of the Philippines, 2019.

[10] International Code Council, International Building Code, 2014.

[11] LWUA, Local Water Utilities Manual and Operation, n.d.

[12] The World Bank Office Manila, Rural Water Supply Volume 1: Design Manual, 2012.

[13] National Masters Plumbers Association of the Philippines, Revised National Plumbing Code of the Philippines, 1999.