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Design Of Water Distribution Network For A Small Town Using EPANET

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Abstract: A well designed and maintained water distribution network system is a cornerstone of modern society, underpinning public health, economic stability and quality of life. Its primary goal is to deliver a reliable supply of water with appropriate quality, quantity and pressure to satisfy the basically needs, etc. The study presents an in-depth analysis of pipe network modeling using EPANET for the District Metered Area (DMA) Gumadam, focusing on the optimization of hydraulic parameters and network performance evaluation. The primary objective was to assess the adequacy of the existing water supply infrastructure in terms of pressure distribution, flow velocities, and head losses at various junctions and pipe segments within the DMA. Comprehensive simulations were performed to evaluate the network, involving junction elevations, required demand, and pressure heads to ensure consistent delivery across all parts of the zone. Key findings indicated considerable variations in pressure and flow rates that were attributed to pipe diameters, material types (primarily HDPE of varying diameters), lengths, and elevations at junction nodes. Further, the study identified critical junctions and pipes prone to head losses, serving as focal points for future interventions to enhance hydraulic efficiency and operational sustainability. The research underscores the vital importance of DMA-based modeling for urban water distribution planning, facilitating targeted infrastructure improvements and energy savings. Through detailed tabulation and systematic analysis, the work provides practical recommendations for system upgrades and efficient resource allocation. Overall, the investigation demonstrates that EPANET-based modeling is a robust tool for optimizing water supply systems, ensuring reliable service and supporting long-term planning initiatives.

Keywords: EPANET, District Metered Area (DMA), hydraulic parameters, network performance evaluation, pressure distribution, flow velocities, head losses, resource allocation, pressure heads, HDPE, operational sustainability.

1. Introduction

The Imperative for Sustainable Water Management in an Urbanizing World Water is the elemental fluid of life, the fundamental resource upon which civilizations are built and sustained [1]. The management, distribution, and conservation of freshwater resources represent one of the most critical challenges of the 21st century. This challenge is magnified by the inexorable trends of global population growth, rapid urbanization, and the escalating impacts of climate change. As urban centers expand, the demand for reliable and safe potable water intensifies, placing unprecedented strain on existing water infrastructure. Many of these systems, often legacies of a bygone era, are grappling with issues of aging, deterioration, and inefficiency, leading to significant water losses and compromised service quality. The imperative, therefore, is not merely to supply more water but to manage the available resources with far greater intelligence, efficiency, and sustainability [2].

The concept of Non-Revenue Water (NRW) sits at the heart of this challenge. NRW is the volume of water put into a distribution system that is "lost" before it reaches the customer, either through physical leaks, metering inaccuracies, or unauthorized consumption. Globally, the scale of NRW is staggering, with estimates suggesting that billions of cubic meters of treated water are lost annually—a colossal waste of a precious resource and the energy expended to treat and transport it. This loss represents a significant economic drain on water utilities, undermines their financial viability, and curtails their ability to invest in necessary infrastructure upgrades. Environmentally, it signifies the needless extraction of water from ecosystems and contributes to the carbon footprint of the water supply chain. Addressing NRW is, therefore, a cornerstone of sustainable urban water management. In response to these multifaceted challenges, the water industry has shifted towards a paradigm of proactive and data-driven management [3].

This approach moves away from reactive "break-fix" cycles towards a model of optimization, control, and strategic planning. Two of the most powerful tools in this modern arsenal are the implementation of District Metered Areas (DMAs) and the application of sophisticated hydraulic modeling [4]. The establishment of DMAs involves the sectionalization of large, monolithic water distribution systems into smaller, discrete, and hydraulically isolated zones. This "divide and conquer" strategy enables utilities to monitor water flow into each district with precision, facilitating rapid leak detection, targeted pressure management, and more efficient operational control. Complementing this physical division is the virtual representation of the network through hydraulic modeling software, such as the industry-standard EPANET. These models serve as digital twins of the physical system, allowing engineers and operators to simulate the complex behavior of water flow and pressure under various operational scenarios.

They are indispensable for designing new networks, optimizing existing ones, planning for future demand, and diagnosing operational problems. The document presented here delves into the results of such a hydraulic analysis for a specific water distribution network located in Gumadam. It showcases the outputs from an EPANET-based simulation of a designated DMA. The provided data, encompassing a detailed network map and comprehensive tables of junction and pipe parameters—including pressure, flow, velocity, and elevation—offers a granular snapshot of the hydraulic performance of the Gumadam network. This introduction aims to provide a comprehensive context for understanding these results by exploring the foundational principles of water distribution systems, the critical challenges they face, and the strategic importance of methodologies like DMA implementation and hydraulic modeling in engineering resilient and efficient urban water futures [5].

1.1 Fundamentals of Water Distribution Systems (WDS)

A Water Distribution System (WDS) is a complex and critical piece of civil infrastructure designed to deliver safe, reliable, and sufficient quantities of potable water to residential, commercial, industrial, and institutional users [6]. It is the final, crucial link in the chain of public water supply, bridging the gap between water treatment facilities and the end consumer [7]. The hydraulic performance of a WDS is paramount, as it must maintain adequate pressure throughout the network to ensure water reaches the highest floors of buildings, meets firefighting requirements, and prevents the intrusion of external contaminants [8]. The primary components of a WDS work in concert to achieve this goal:

1. **Pipes:** These form the arterial network that transports water. They vary significantly in material (e.g., ductile iron, PVC, HDPE), age, and diameter. The results for the Gumadam network indicate the use of High-Density Polyethylene (HDPE) pipes across a range of diameters, from 90 mm to 200 mm. The configuration of these pipes—whether branching, looped, or a combination—determines the system's hydraulic characteristics and redundancy.
2. **Pumps:** Pumps provide the necessary energy to lift water to higher elevations and overcome the frictional losses that occur as water flows through pipes. Their operation is a major contributor to a utility's energy consumption.
3. **Valves:** Valves are used to control the flow and pressure within the network. They serve various functions, including isolation (for repairs), pressure reduction, air release, and preventing backflow. The creation of DMAs relies heavily on the strategic placement and operation of boundary valves to hydraulically isolate a district.
4. **Tanks and Reservoirs:** Storage facilities, such as the tank (T1) identified in the Gumadam system, play a vital role. They serve to balance fluctuating daily demands, provide an emergency supply for events like firefighting or power outages, and help stabilize pressure across the system. The elevation

and water level within these tanks are critical parameters that influence the hydraulic head throughout the network.

5. **Junctions or Nodes:** These are points in the network where pipes intersect or where water is withdrawn by consumers. The results provide extensive data for over one hundred junctions (from J1 to J118 and beyond) within the Gumadam DMA, detailing their specific elevation, demand, resulting hydraulic head, and pressure. The behaviour of water within this intricate system is governed by fundamental physical laws, primarily the principles of conservation of mass and conservation of energy.
6. **Conservation of Mass:** At any junction in the network, the total flow of water into the junction must equal the total flow out of it. This principle ensures continuity of flow throughout the system.
7. **Conservation of Energy:** Between any two points in the network, the change in energy is equal to the energy added by pumps minus the energy lost due to friction in the pipes. This is often expressed through formulations like the Bernoulli equation, adapted to account for head loss. The head loss itself is typically calculated using empirical formulas such as the Hazen-Williams, Darcy-Weisbach, or Manning equations, which relate flow rate, pipe diameter, length, and roughness.

The interplay of these principles within a complex, looped network of hundreds or thousands of pipes results in a hydraulic state defined by the flow in each pipe and the pressure at each junction. The challenge for engineers is to design and operate the system such that pressures and velocities remain within acceptable operational limits under all demand conditions.

1.2 The Strategy of District Metered Areas (DMAs)

The management of vast and interconnected water distribution systems presents a formidable operational challenge [9]. A leak or pressure issue in one part of a large, un-zoned network can have far-reaching and often unpredictable effects. Identifying the source of water loss in such a system is akin to finding a needle in a haystack. The DMA strategy was developed as a direct response to this challenge, offering a structured and systematic approach to water loss management and operational control [10]. A DMA is a discrete section of a WDS that is hydraulically isolated from the rest of the network. This isolation is achieved by closing the boundary valves that connect the district to adjacent areas, creating a well-defined zone with a limited number of controlled inlets and outlets [11]. Each of these entry points is equipped with a bulk flow meter, allowing for the continuous monitoring of the total volume of water entering the DMA [12]. The core benefits of this approach are manifold:

1. **Efficient Leak Detection and Quantification:** The primary advantage of a DMA is its utility in managing real water losses. By continuously measuring the flow into the district and comparing it to the legitimate, metered consumption of all customers within it, the utility can perform a water balance for that specific zone. This allows for the accurate quantification of water loss within a manageable area. Furthermore, by analysing the flow during periods of minimum consumption (typically late at night, known as the Minimum Night Flow or MNF), utilities can quickly identify the emergence of new leaks. A sudden increase in the MNF is a clear indicator of a leak or pipe burst within that specific DMA, allowing for the rapid deployment of leak detection teams to a targeted area, drastically reducing the time and resources required for localization and repair.
2. **Improved Pressure Management:** Excessive pressure is a leading cause of pipe stress and a major driver of leakage rates. Water loss from existing leaks is directly proportional to the system pressure. DMAs provide an ideal framework for targeted pressure management. By installing pressure-reducing valves (PRVs) at the inlets to a DMA, utilities can lower the pressure within the entire district to a level that is sufficient for adequate service but not excessively high. This not only reduces the volume of water lost from existing leaks but also lowers the frequency of new pipe bursts, extending the operational life of the infrastructure.
3. **Enhanced Operational Control and Water Quality Monitoring:** DMAs provide a much clearer understanding of system hydraulics. Operators can better manage flow distribution and respond to incidents like pipe breaks with greater precision. By isolating the affected DMA, repairs can be carried out with minimal disruption to the wider network. This sectionalization also aids in water quality management. If a contamination event is detected, it can be contained within a single DMA, preventing its spread and allowing for targeted flushing and remediation efforts.

The design of a DMA is a complex engineering task that involves a careful analysis of the network topology, customer demand patterns, elevation variations, and operational requirements. It often requires hydraulic modeling to test the impact of closing boundary valves and to ensure that the creation of the DMA does not lead to unintended consequences, such as unacceptably low pressures or poor circulation in parts of the zone.

The provided EPANET results for the Gumadam DMA represent the outcome of such a design and analysis process, verifying that the hydraulic performance (pressures, flows, etc.) of the proposed district is acceptable under the modeled demand conditions.

1.3 The Role of Hydraulic Modeling and EPANET

While DMAs provide the physical framework for improved network management, hydraulic modeling provides the essential virtual tool for analysis, design, and decision-making. A hydraulic model is a computer-based mathematical representation of a WDS. It allows engineers to simulate the behavior of the system without the cost, risk, or impracticality of conducting physical experiments on the live network. The process of creating a hydraulic model involves several key steps:

1. **Network Data Collection:** This is the most labour-intensive phase and requires gathering detailed information about the system's components. This includes the network layout (connectivity of pipes and nodes), the physical characteristics of each pipe (length, diameter, material/roughness coefficient), the location and properties of pumps and valves, and the elevation of each junction.
2. **Demand Estimation:** The model requires an estimation of the water demand at each junction or node. This is typically based on billing records, population data, and land use information. Demands can be modelled as a constant average value or, for more sophisticated analyses, as a time-varying pattern that reflects daily, weekly, or seasonal fluctuations.
3. **Model Construction and Calibration:** Using specialized software, this data is assembled into a coherent model. The model must then be calibrated by comparing its predictions (e.g., of pressure and flow) against real-world field measurements taken from the actual system. This process involves adjusting model parameters, such as pipe roughness, until the model's output closely matches the observed reality.

EPANET, the software used for the Gumadam analysis, is a powerful and widely used tool for this purpose. Developed by the U.S. Environmental Protection Agency, it is a public-domain software that performs extended-period simulation of hydraulic and water-quality behavior within pressurized pipe networks. EPANET is capable of modeling complex systems and can simulate various scenarios, including:

1. **Static Analysis:** Calculating the hydraulic state of the network at a particular point in time, as presented in the Gumadam results tables. This is useful for design verification and for understanding system performance under specific demand conditions (e.g., average day, peak hour, or fire flow).
2. **Extended-Period Simulation (EPS):** Simulating the network's behaviour over time (e.g., 24 or 48 hours), accounting for changing demands and the filling and draining of storage tanks. This is crucial for analysing tank performance, pump scheduling, and energy consumption.
3. **Water Quality Modelling:** EPANET can also track the movement of a substance (like a disinfectant or a contaminant) through the network over time, allowing for the analysis of water age and disinfectant residual levels.

2. Literature Review

In this section provides the methodology background adopted which is relevant literature for the objective of concern study and source of decision making on analyzing the required data to ensure the adequate water supply through distribution over the DMA network.

(Dorothy Zhang. 2024) [13] employed a structured engineering approach to design the water distribution network, using EPANET software as the primary tool. Calculated the expected water consumption for the resort's various facilities, including twenty houses and eighty apartments, as well as a restaurant, a club, and a swimming pool. The model factored in the different consumption needs of various user types and aimed to meet demand during peak periods. A water distribution network was designed based on the consumption calculations and simulated in EPANET using the Darcy-Weisbach equation. The model successfully identified these periods to prevent pressure drops. the performance of a water distribution network is highly dependent on the characteristics of its components. The simulation demonstrated that the network could consistently meet the diverse water demands of the resort while preventing issues from either insufficient or excessive pressure. (Thakur et al. 2020) [16] encroaches the traditional approach method of gathering the topographical, population, demand & existing infrastructure data which is used to create a digital model of the water network using EPANET software & perform a hydraulic analysis. The study reveals pressure deficiencies in certain areas of the campus, particularly during peak demand. It might also identify pipes that are undersized or sections where flow velocity is too low. The efficient and reliable water supply for the NIT Srinagar campus, ensuring all areas have a consistent and safe water flow.

(B. Bartkowska. 2014) [17] A study on the dynamics of water consumption in a tourist resort would typically focus on understanding how, when, and why water is used, with the goal of improving the efficiency and reliability of the water supply system. The required data was collected and performed statistical analysis for daily & seasonal demands and made correlation analysis. the identification of specific times of day with the highest water demand, such as early morning and late evening when guests are showering. The study reveals areas where water conservation measures could be most effective. (Vardhan et al. 2024) [19] the findings would be centered on the results of the EPANET simulation and the final design recommendations. the proposed network design can meet the demand of the study area while maintaining adequate pressure. The optimized specifications for the network's components, such as the appropriate pipe diameters and pump sizes, to ensure efficiency and cost-effectiveness. water pressure at all points is within the acceptable range and that flow velocities are not too high.

(Majed O. Alsaydalani. 2024) The research used hydraulic modeling to analyze and manage water leakage in a water distribution network in Jeddah, Saudi Arabia. The simulation showed that reducing water pressure from 5 bar to 2 bar resulted in a 10% reduction in leakage volume during periods of maximum pressure. the optimal pressure for the pressure-reduction valve, demonstrating that significant water conservation can be achieved without compromising the minimum required pressure at each demand node. The study validated that hydraulic modeling, particularly with software like EPANET, is a practical and effective approach for tackling non-revenue water and enhancing the overall efficiency and sustainability of water supply networks. (Gangwani, L. et al. 2024) [18] The study focused on a specific "two-source benchmark network" that had been used by many researchers over the past 15 years to test various optimization algorithms. optimization algorithm was able to achieve solutions that were either the same as or up to 10.26% less costly than those found by other competitive algorithms. The study validated the effectiveness of the harmony search algorithm for water distribution network optimization, proving its ability to find superior solutions under similar or less favorable conditions.

3. Methodology

The methodology for EPANET involves collecting physical and operational data, analyzing the pipeline network, running a hydraulic model, and then performing a simulation to finalize the design.

3.1 Data Collection:

In EPANET, the data has been collected and input two main categories of data, i.e., physical network data and operational data. These data points describe the components of the water distribution system and how the system operates over time. The point data as nodes are used as analysis categorizing for each respective parameters of elevation and demand. Water demand is assumed for single static amplifier or multiplier over a time pattern. The nodal elevation data has been entered individually at each node from the google earth pro precisely to key and scale. The diameters are chosen as per pressure along distribution of pipe length. Pipe length was kept auto length, since the coordinates along the length was extracted from the google earth survey data. Pipe roughness as constant along all the pipe distribution as 140 (for HDPE). The whole distribution of pipe network among the two DMA was taken under the consideration of Hazen-Willams formula in the EPANET software. In hydraulic analysis the fundamental function of EPANET allows engineers and planners to understand how water flows and how pressure is distributed throughout a network. The flow rate value is adjusted in EPANET (in Liter per Minute) in each pipe, showing the direction and magnitude of water movement. The pressure at every junction (node) in the network is critical for ensuring that all users receive water at an adequate pressure, which is necessary for daily use and other demands.

3.2 Formulas and Calculations:

The Darcy-Weisbach formula is applied over all flow regimes and to all liquids. Each formula uses the following equation to compute head loss between the start and end node of the pipe:

$$h_L = AqB \tag{1}$$

where; h_L = head loss (Length), q = flow rate (Volume/Time), A = resistance coefficient, B = flow exponent. Head loss formula used in EPANET modelling (Hazen-Williams): Resistance Coefficient (A)

$$= 4.727\ C\ (-1.852)\ d\ (-4.871)\ L \tag{2}$$

Where; C = Hazen-Williams's roughness coefficient, d= pipe diameter (ft), L = pipe length (ft)

Roughness coefficient for a pipe chosen as (140-150) HDPE.
The consideration of maximum water levels for cities as per IS Code 1172: 1993 as follows:
For cities/ towns with a population less than 10 lakhs (0.1 million), the recommended maximum water supply levels are, 135 (LPCD).

Table 1: Assumed Average daily consumption of water per person by IS Code 1172: 1993

Purpose	**Quantity (LPCD)**
Drinking	5
Cooking	5
Bathing	55
Toilet flushing	30
Washing utensils	10
Washing house	10
Washing cloths	20
Total	135

With all the data and options set, running the simulation and analysis results with all the data and options set, you can run the model. EPANET's solver will perform the calculations to determine the pressure at each node and the flow rate in each pipe at every time step. The data provides:
Junction Details: Junction ID, Elevation (m), Demand (Lpm), Head (m), and Pressure (m).
Pipe Details: Pipe ID, Pipe Flow (Lpm), Pipe Length (m), Pipe Velocity (m/s), and Pipe Diameter (mm).
The pressure (P) at a junction is calculated by subtracting the junction's Elevation (E) from its Head (H):

$$P = H - E \tag{3}$$

Where, P is in meters of water column (m), and H and E are also in meters (m).
The cross-sectional area (A) of a circular pipe is calculated using its diameter (D):

$$A = \frac{\pi}{4} * D^2 \tag{4}$$

Where, D is in meters (m), and A is in square meters (m^2).
The speed at which a fluid moves is measured as the distance of a fluid particle travels per unit time.

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

Where, V is the velocity flow rate, Q is flow in liter per minute, and A cross-sectional area in mm^2.

The table presents the key values and the results of the two primary calculations:
Calculated Pressure (to verify junction hydraulics) and Calculated Velocity (to check consistency with reported flow and diameter). Due to the length of the original data (118 junctions and 143 pipes), only a representative sample is shown.

Table2: Tabular summary of calculations and values.

ID junction	Elevation (m)	Head (m)	Demand (Lpm)	Pressure (m)	Pressure (m)	Flow (Lpm)	Diameter (mm)	Velocity (m/s)	Velocity (m/s)
J1	159.756	172.46	12.96	12.7	12.704	P1:52.64	90	0.04	0.138
J2	156.098	172.46	26.13	16.36	16.362	p2:106.2	160	0.14	0.088
J3	154.878	172.47	16.2	17.59	17.592	p3:65.81	200	0.93	0.035
J24	148.78	172.11	4.92	23.33	23.330	P34:20.23	110	0.03	0.035
J28	157.927	172.43	32.04	14.51	14.503	p38:130.2	200	0.52	0.069
J31	156.402	172.4	41.82	16.0	15.998	P70:140	180	0.14	0.111
J57	149.695	172.06	4.95	22.36	22.365	p82:20.17	90	0.03	0.053
J92	155.793	173.66	46.92	17.87	17.867	p118:190.7	200	0.94	0.101
J116	148.78	172.01	40.35	23.23	23.230	P139:164.01	90	0.06	0.430

3.3 Theoretical Framework

The flow chart illustrates the key stages in the design and analysis of a pipeline network system, particularly within the context of a hydraulic modeling software like EPANET. The process begins with data collection, which involves gathering both physical network data and operational data. Physical data includes details on nodes (junctions, tanks, reservoirs) and links (pipes, pumps, valves) within the system, such as their elevation, demand, diameter, and roughness. Operational data, on the other hand, consists of time patterns for things like water demand and energy prices, as well as control rules that manage system components.
After data collection, the methodology proceeds to the analysis of the pipeline network. This step involves understanding how water flows and pressure is distributed throughout the network, with EPANET performing fundamental hydraulic analysis. The core of this analysis is the hydraulic model, which determines the pressure at each node and the flow rate in each pipe at every time step of a simulation.
Finally, the process concludes with **simulation and finalization**, which is a crucial step for performing analyses and confirming that the design meets the desired criteria. The flow chart also mentions **DMA pipeline design** as an outcome, highlighting that the entire process is geared toward creating efficient and well-managed water distribution zones. This video provides a practical explanation of a hydraulic modeling methodology, which is similar to the process outlined in the flow chart.

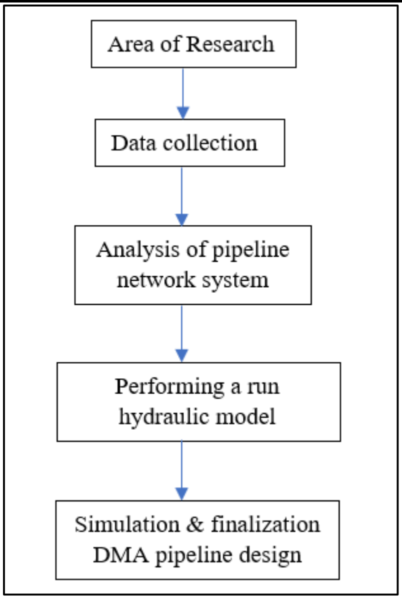

Figure 1: Flow chart for design & analysis.

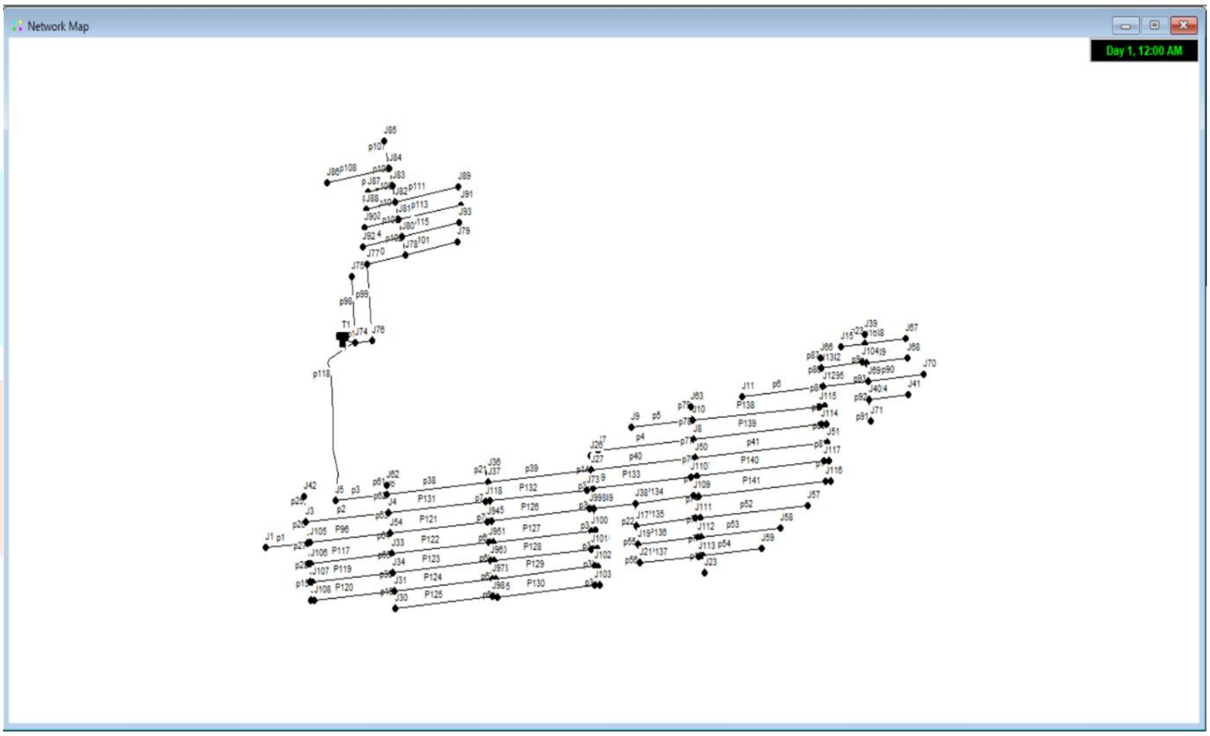

Figure 2: Water distribution network for DMA Gumadam village.

Table 3: Complete distribution of pipe network details from EPANET for DMA Gumadam village.

Gumadam village											
Junction Details					Pipe Details						
Junction	Elevation	Demand	Head	Pressure (m)	Pipe ID	Length (m)	Diameter	Flow (Lpm)	velocity m/s	Diameter (mm) /PIPE	
Junc J1	159.756	12.96	172.46	12.7	Pipe p1	52.64	81.1	12.96	0.04	90	HDPE
Junc J2	156.098	26.13	172.46	16.36	Pipe p2	106.2	144.4	137.67	0.14	160	HDPE
Junc J3	154.878	16.2	172.47	17.59	Pipe p3	65.81	180.6	1427.7	0.93	200	HDPE
Junc J4	155.356	30.27	172.49	17.13	Pipe p4	123.1	81.1	7.59	0.02	90	HDPE
Junc J5	155.793	19.23	172.82	17.03	Pipe p5	78.12	81.1	5.31	0.02	90	HDPE
Junc J6	155.356	25.62	172.52	17.16	Pipe p6	104.2	81.1	4.83	0.02	90	HDPE
Junc J7	153.659	7.59	172.11	18.45	Pipe p8	30.83	81.1	2.49	0.01	90	HDPE
Junc J8	158.537	4.68	172.11	13.57	Pipe p12	18.98	81.1	4.77	0.02	90	HDPE
Junc J9	153.963	5.31	172.09	18.13	Pipe p13	21.58	81.1	4.92	0.02	90	HDPE
Junc J10	154.299	3.81	172.09	17.8	Pipe p14	15.54	81.1	5.37	0.02	90	HDPE
Junc J11	153.354	4.83	172.1	18.74	Pipe p15	19.64	81.1	32.04	0.1	90	HDPE
Junc J12	154.268	4.8	172.1	17.83	Pipe p16	19.5	81.1	63.54	0.21	90	HDPE
Junc J13	153.049	2.37	172.09	19.04	Pipe p21	9.643	81.1	4.83	0.02	90	HDPE
Junc J14	156.98	5.7	172.09	15.11	Pipe p22	23.14	81.1	72.9	0.24	90	HDPE
Junc J15	154.573	2.49	172.09	17.51	Pipe p23	10.08	81.1	4.77	0.02	90	HDPE
Junc J16	155.793	12.12	172.09	16.29	Pipe p24	49.28	81.1	5.52	0.02	90	HDPE
Junc J17	153.963	6.9	172.07	18.11	Pipe p25	28.07	81.1	4.92	0.02	90	HDPE
Junc J18	155.183	5.43	172.06	16.88	Pipe p26	22.08	126.3	116.55	0.16	140	HDPE

Junc J19	154.024	5.46	172.06	18.04	Pipe p27	22.18	99.3	77.46	0.17	110	HDPE
Junc J20	154.878	4.92	172.06	17.18	Pipe p28	19.97	81.1	64.5	0.21	90	HDPE
Junc J21	154.266	4.8	172.06	17.79	Pipe p30	19.57	99.3	161.4	0.35	110	HDPE
Junc J22	155.488	4.86	172.06	16.57	Pipe p32	19.81	81.1	4.8	0.02	90	HDPE
Junc J23	156.402	4.77	172.06	15.65	Pipe p33	19.39	81.1	9.72	0.03	90	HDPE
Junc J24	148.78	4.92	172.11	23.33	Pipe p34	20.03	99.3	15.3	0.03	110	HDPE
Junc J25	148.811	5.64	172.11	23.3	Pipe p35	22.87	126.3	20.7	0.03	140	HDPE
Junc J26	153.354	5.37	172.2	18.84	Pipe p36	21.8	144.4	131.61	0.13	160	HDPE
Junc J27	153.963	4.86	172.2	18.23	Pipe p37	19.75	162.5	167.58	0.13	180	HDPE
Junc J28	157.927	32.04	172.43	14.51	Pipe p38	130.2	180.6	797.76	0.52	200	HDPE
Junc J29	157.622	32.46	172.44	14.82	Pipe p39	132	180.6	577.8	0.38	200	HDPE

Junc J30	156.707	32.82	172.39	15.68	Pipe p40	133.4	180.6	399.99	0.26	200	HDPE
Junc J31	156.402	41.82	172.4	16	Pipe p41	170	162.5	177.84	0.14	180	HDPE
Junc J32	157.012	12.96	172.45	15.44	Pipe p49	52.72	81.1	106.11	0.34	90	HDPE
Junc J33	154.878	33.9	172.45	17.57	Pipe p52	137.8	81.1	4.95	0.02	90	HDPE
Junc J34	155.488	24.93	172.43	16.94	Pipe p53	101.3	81.1	4.83	0.02	90	HDPE
Junc J35	157.012	18.66	172.24	15.23	Pipe p54	75.9	81.1	4.86	0.02	90	HDPE
Junc J36	155.488	4.83	172.31	16.82	Pipe p55	19.59	81.1	47.49	0.15	90	HDPE
Junc J37	155.793	4.86	172.31	16.52	Pipe p56	19.78	81.1	23.58	0.08	90	HDPE
Junc J38	154.268	2.52	172.09	17.82	Pipe p61	10.25	81.1	2.61	0.01	90	HDPE
Junc J39	155.488	4.77	172.09	16.6	Pipe p62	19.4	162.5	601.71	0.48	180	HDPE
Junc J40	154.878	5.4	172.09	17.21	Pipe p63	22	162.5	393.6	0.32	180	HDPE
Junc J41	154.268	5.52	172.09	17.82	Pipe p64	22.38	144.4	333.12	0.34	160	HDPE
Junc J42	154.573	4.92	172.47	17.89	Pipe p65	19.99	126.3	242.61	0.32	140	HDPE
Junc J43	156.098	4.83	172.25	16.15	Pipe p66	19.65	81.1	49.68	0.16	90	HDPE
Junc J44	154.878	4.8	172.19	17.31	Pipe p67	19.48	81.1	84.99	0.27	90	HDPE
Junc J45	155.183	4.92	172.19	17.01	Pipe p68	20.01	99.3	120.84	0.26	110	HDPE
Junc J46	155.823	5.58	172.19	16.37	Pipe p69	22.63	126.3	156.54	0.21	140	HDPE
Junc J47	155.793	5.4	172.19	16.4	Pipe p70	21.9	144.4	192.33	0.2	160	HDPE

Junc J48	155.183	4.8	172.19	17.01	Pipe p71	19.57	162.5	210.27	0.17	180	HDPE
Junc J49	154.573	4.83	172.19	17.62	Pipe p72	19.65	81.1	14.49	0.05	90	HDPE
Junc J50	158.537	4.92	172.14	13.6	Pipe p73	19.99	81.1	24.24	0.08	90	HDPE
Junc J51	151.524	5.7	172.11	20.59	Pipe p74	23.12	81.1	34.62	0.11	90	HDPE
Junc J52	158.547	5.34	172.09	13.54	Pipe p75	21.7	81.1	78.57	0.25	90	HDPE
Junc J53	155.488	4.92	172.31	16.82	Pipe p76	19.94	81.1	124.11	0.4	90	HDPE
Junc J54	154.888	4.8	172.47	17.58	Pipe p77	19.53	81.1	93.12	0.3	90	HDPE
Junc J55	155.823	5.1	172.3	16.48	Pipe p78	20.7	81.1	62.22	0.2	90	HDPE
Junc J56	157.012	3.6	172.06	15.05	Pipe p79	14.62	81.1	12.78	0.04	90	HDPE
Junc J57	149.695	4.95	172.06	22.36	Pipe p82	20.17	81.1	10.56	0.03	90	HDPE
Junc J58	153.659	4.83	172.06	18.4	Pipe p83	19.64	144.4	161.58	0.16	160	HDPE
Junc J59	155.183	4.86	172.06	16.87	Pipe p84	19.79	144.4	143.94	0.15	160	HDPE
Junc J60	154.573	4.95	172.27	17.7	Pipe p85	20.16	144.4	131.07	0.13	160	HDPE
Junc J61	154.878	4.83	172.29	17.41	Pipe p86	19.69	81.1	39.09	0.13	90	HDPE
Junc J62	155.488	2.61	172.52	17.03	Pipe p87	10.6	81.1	5.79	0.02	90	HDPE
Junc J63	153.049	12.78	172.09	19.04	Pipe p88	51.95	81.1	4.89	0.02	90	HDPE

Junc J64	155.488	12.87	172.1	16.61	Pipe p89	52.27	81.1	4.89	0.02	90	HDPE
Junc J65	154.268	17.64	172.1	17.84	Pipe p90	71.67	81.1	14.25	0.05	90	HDPE
Junc J66	152.134	5.79	172.09	19.96	Pipe p91	23.52	81.1	17.43	0.06	90	HDPE
Junc J67	153.659	4.89	172.09	18.43	Pipe p92	19.87	81.1	28.35	0.09	90	HDPE
Junc J68	154.268	4.89	172.09	17.82	Pipe p93	19.93	126.3	34.86	0.05	140	HDPE
Junc J69	155.793	4.89	172.09	16.3	Pipe p94	19.93	99.3	24.27	0.05	110	HDPE
Junc J70	153.659	14.25	172.09	18.43	Pipe p95	57.91	126.3	82.35	0.11	140	HDPE
Junc J71	153.354	17.43	172.08	18.73	Pipe p98	70.84	81.1	12.3	0.04	90	HDPE
Junc J74	158.537	20.01	173.73	15.19	Pipe p99	81.38	162.5	205.98	0.17	180	HDPE
Junc J75	156.253	12.3	173.73	17.48	Pipe p100	50.03	144.4	201.21	0.2	160	HDPE
Junc J76	157.927	16.83	173.73	15.8	Pipe p101	68.37	81.1	4.65	0.02	90	HDPE
Junc J77	156.128	4.77	173.71	17.58	Pipe p102	19.43	144.4	191.91	0.2	160	HDPE
Junc J78	153.354	4.65	173.69	20.34	Pipe p103	18.91	144.4	136.2	0.14	160	HDPE
Junc J79	154.878	4.65	173.69	18.81	Pipe p104	18.95	126.3	107.94	0.14	140	HDPE
Junc J80	153.049	4.59	173.68	20.63	Pipe p105	18.65	99.3	68.34	0.15	110	HDPE
Junc J81	153.079	4.62	173.68	20.6	Pipe p106	18.78	81.1	37.44	0.12	90	HDPE
Junc J82	153.354	7.32	173.68	20.32	Pipe p107	29.79	81.1	9.45	0.03	90	HDPE
Junc J83	153.963	19.95	173.67	19.71	Pipe p108	81.07	81.1	20.01	0.06	90	HDPE

Junc J84	153.659	7.98	173.66	20.01	Pipe p109	32.48	81.1	10.95	0.04	90	HDPE
Junc J85	153.049	9.45	173.66	20.62	Pipe p110	38.37	81.1	19.83	0.06	90	HDPE
Junc J86	156.402	20.01	173.66	17.26	Pipe p111	81.34	81.1	12.45	0.04	90	HDPE
Junc J87	153.99	10.95	173.67	19.68	Pipe p112	44.53	81.1	18.36	0.06	90	HDPE
Junc J88	154.573	19.83	173.67	19.1	Pipe p113	80.65	81.1	5.28	0.02	90	HDPE
Junc J89	155.183	12.45	173.67	18.49	Pipe p114	50.61	81.1	46.92	0.15	90	HDPE
Junc J90	155.183	18.36	173.68	18.49	Pipe p115	74.69	81.1	4.2	0.01	90	HDPE
Junc J91	154.268	5.28	173.68	19.41	Pipe p116	21.44	162.5	222.81	0.18	180	HDPE
Junc J92	155.793	46.92	173.66	17.87	Pipe p118	190.7	180.6	1446.93	0.94	200	HDPE
Junc J93	153.963	4.2	173.68	19.72	Pipe 1	17.1	180.6	1702.05	1.11	200	HDPE
Junc J94	155.823	25.17	172.45	16.63	Pipe P96	102.37	81.1	30.51	0.1	90	HDPE
Junc J95	154.878	25.44	172.43	17.56	Pipe P117	103.42	81.1	31.17	0.1	90	HDPE
Junc J96	154.573	25.41	172.41	17.84	Pipe P119	103.31	81.1	30.87	0.1	90	HDPE
Junc J97	156.098	25.32	172.38	16.29	Pipe P120	102.93	81.1	30.72	0.1	90	HDPE
Junc J98	156.098	30.72	172.36	16.26	Pipe P121	124.85	81.1	25.17	0.08	90	HDPE
Junc J99	155.183	30.69	172.28	17.09	Pipe P122	124.77	81.1	25.44	0.08	90	HDPE

Junc J100	155.793	30.87	172.27	16.47	Pipe P123	125.47	81.1	25.41	0.08	90	HDPE
Junc J101	155.823	30.9	172.25	16.42	Pipe P124	125.6	81.1	25.32	0.08	90	HDPE
Junc J102	155.183	30.48	172.22	17.04	Pipe P125	123.93	81.1	30.72	0.1	90	HDPE
Junc J103	154.878	31.02	172.21	17.34	Pipe P126	126.09	81.1	30.69	0.1	90	HDPE
Junc J104	156.98	30.93	172.08	15.1	Pipe P127	125.78	81.1	30.87	0.1	90	HDPE
Junc J105	156.098	30.51	172.45	16.35	Pipe P128	124.01	81.1	30.9	0.1	90	HDPE
Junc J106	157.012	31.17	172.43	15.42	Pipe P129	126.73	81.1	30.48	0.1	90	HDPE
Junc J107	157.622	30.87	172.41	14.79	Pipe P130	125.46	81.1	31.02	0.1	90	HDPE
Junc J108	157.927	30.72	172.38	14.45	Pipe P131	124.89	81.1	40.17	0.13	90	HDPE
Junc J109	157.012	30.69	172.08	15.07	Pipe P132	124.79	81.1	13.02	0.04	90	HDPE
Junc J110	158.547	31.14	172.17	13.62	Pipe P133	126.6	81.1	31.14	0.1	90	HDPE
Junc J111	155.183	18.51	172.06	16.88	Pipe P134	75.23	81.1	30.69	0.1	90	HDPE
Junc J112	154.878	18.45	172.06	17.18	Pipe P135	75	81.1	18.51	0.06	90	HDPE
Junc J113	155.488	18.78	172.05	16.57	Pipe P136	76.3	81.1	18.45	0.06	90	HDPE
Junc J114	154.268	18.63	172.1	17.83	Pipe P137	75.79	81.1	18.78	0.06	90	HDPE
Junc J115	155.488	40.32	172.04	16.56	Pipe P138	163.9	81.1	40.32	0.13	90	HDPE
Junc J116	148.78	40.35	172.01	23.23	Pipe P139	164.01	81.1	18.63	0.06	90	HDPE
Junc J117	148.811	40.2	172.04	23.23	Pipe P140	163.43	81.1	40.2	0.13	90	HDPE

Junc J118	155.488	40.17	172.45	16.96	Pipe P141	163.31	81.1	40.35	0.13	90	HDPE
Junc J73	154.573	13.02	172.3	17.73	Pipe P142	52.97	81.1	30.93	0.1	90	HDPE
Tank T1	158.841	-1702.05	173.84	15							

4. Study Area

Gumadam is a village located in the Vizianagaram district of Andhra Pradesh, India, within the sub-district of Bondapalle. It is also associated with a village panchayat that includes other hamlets such as J. gumadam and Veduruwada. It has coordinates of 18°32'31"N and 83°13'41"E.

5. Results and Discussion

The calculations performed confirm the integrity of the hydraulic simulation data. The Calculated Pressure values are nearly identical to the Provided Pressure values from the EPANET output, with minor differences attributable to rounding in the source data.

5.1 Pressure Analysis:

The pressure across the Gumadam District Metering Area (DMA) is maintained within a stable and acceptable range. The lowest pressure recorded is 12.7 m at Junction J1. The highest pressure recorded is 23.33 m at Junction J24. The entire network operates with pressures between 12.7 m and 23.33 m. This is a favorable result, as it indicates that there are no areas with excessively low pressure (which could lead to service failure) or dangerously high pressure (which could cause pipe bursts and leaks). The pressures are sufficient for supplying water to consumers, including those in multi-story buildings.

5.2 Velocity Analysis:

The flow velocities in the pipes vary significantly, which is typical for a network with main lines and smaller distribution pipes. The highest velocity is 1.11 m/s in Pipe 1, followed by 0.94 m/s in Pipe p118 and 0.93 m/s in Pipe p3. These pipes are likely major transmission mains carrying large volumes of water from the source. These velocities are well below the typical upper limit of 3 m/s, minimizing the risk of pipe erosion or water hammer. A significant number of pipes exhibit very low velocities, with many being as low as 0.01 m/s to 0.02 m/s. These low velocities are often found in the smaller, peripheral pipes of the network. While not immediately critical, velocities below 0.6 m/s can sometimes lead to the settling of sediments and potential water quality issues over time. However, in a well-managed system with regular flushing, this is often not a major concern.

6. Conclusions

The analysis of the EPANET hydraulic simulation results for the Gumadam DMA leads to the following conclusions:

Model Verification: The provided simulation data is internally consistent and hydraulically sound. The relationship between piezometric head, elevation, and pressure is validated across all junctions in the network.

Adequate Pressure: The network operates under safe and adequate pressure conditions, ranging from 12.7 m to 23.33 m. This ensures reliable water supply to all consumers without stressing the infrastructure.

Acceptable Velocities: The velocities in the main pipes are within optimal design limits, ensuring efficient water transmission. While velocities in some smaller pipes are low, they do not pose an immediate risk to the network's operation.

Overall Performance: The Gumadam water distribution network, as represented by the simulation, appears to be well-designed and operating effectively under the specified demand conditions. The system successfully distributes water to all demand nodes while maintaining appropriate hydraulic parameters.

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