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Design & Monitoring Continuous Water Supply at Bileshvarpura, Kalol Using Geo-Informatics & Epanet Software

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Abstract:

The main focus of this research paper is to analyze and establish the necessary requirements for a water distribution system in bileshwarpura, kalol, using EPANET. The aim is to ensure a equitable supply of water to customers with sufficient pressure head, while also adhering to budget constraints. To enhance the service life and reliability of the distribution network, high-grade cast iron pipes have been considered. The design of the distribution network aims to minimize hydraulic losses and meet the minimum pressure head of 12 m, as well as maintain velocities within the range of 06 to 23 m/s. Various distribution network models have been simulated and analyzed to meet the peak water demand hour and ensure a supply of at least 135 liters per capita per day. Additionally, entropy tests were conducted to determine the optimal sensor placement in the network.

Keywords: Water distribution system, Metering system, Network of distribution, EPANET

1. Introduction

1.1 Importance of Water

Throughout human history, access to clean water has been a critical concern, driving ancient civilizations to settle near water sources. As our population has grown, the challenge of meeting the increasing demand for clean water has become more significant. The ancient Romans ingeniously transported water over long distances using aqueducts (Pitroda, 1993). Today, modern water supply systems rely on crucial infrastructures such as collection centers, storage tanks, and distribution networks. In India, where rainfall patterns are becoming more erratic and perennial water sources are scarce, there is an urgent need to develop a distribution network that minimizes hydraulic losses. While numerous studies have been conducted in this field, many are site-specific. Therefore, it is essential to conduct comprehensive studies during the project design phase to identify and address potential obstacles and to validate the findings of other esteemed researchers in order to effectively meet the rising demand for water supply.

1.2 Water Distribution Network

WDN's main objective is to guarantee that the distribution network efficiently satisfies the pressure and flow rate needs for water delivery at the consumer level. A strong distribution system must meet the following essentials:

1. Preserving the purity of the water in the distribution tubes without any degradation.
2. Making sure there is enough pressure in the water supply at all the places it is supposed to be.
3. Supplying the necessary amount of water when battling fires.
4. Constructing the system so that no client is left without water while repairs are being made.
5. It is preferable to place all distribution pipes above or at least one meter above sewer lines.
6. Making certain that the system is leak-proof to reduce losses.

1.3 EPANET

The U.S. Environmental Protection Agency (EPA) has developed EPANET, an open-source software used for designing and analyzing water supply models globally. EPANET serves several key purposes (EPANET, 2019):

1. Determining pipe diameters for optimal usage.
2. Identifying necessary network improvements and extensions.

3. Locating ideal positions for installing tanks, valves, and pumps.
4. Studying chlorine behavior and the need for establishing secondary chlorination points.
5. Adjusting source utilization within multiple source systems.
6. Utilizing formulas such as Hazen-Williams, Darcy-Weisbach, or Chezy-Manning to calculate friction head loss.
7. Modeling the age of water throughout a network.

1.3.1 Steps Using EPANET

Hydraulic engineers employ the procedures listed below to precisely mode the water supply distribution network in EPANET; these procedures are used worldwide (EPANET, 2019);

1. Importing a basic network description stored in a text file or creating a representation of the distribution system network.
2. Modifying the system objects' properties.
3. An explanation of how the plan works.
4. Choose many options to be evaluated.
5. Choose several options for evaluation of the water quality.
6. Examining the results of the analysis.

1.3.2 Water Distribution Network Problem

The aging of water distribution network components increases the risk of failure, leading to greater hydraulic losses. Each year, hundreds of kilometers of pipes are replaced or upgraded globally to reduce water loss from pipe bursts. Water losses in a distribution network refer to the portion of drinking water that does not reach paying customers or approved users. These losses are broadly categorized as either apparent or real. Apparent losses occur when water is used but not accurately measured, accounted for, or paid for. Real losses include physical water losses within the distribution system, such as pipe breaks and leaks (Christodoulou, 2015). To monitor real-time data, supervisory control and data acquisition systems (SCADA) and

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strategically placed sensors across the network are now commonly used. The primary goal of sensor placement is to maximize efficiency and minimize deployment and operating costs.

1.3.3 Overview of site under Investigation

This village is situated on Kalol-Mehsana highway. The civic service of village is provided by Gandhi-Nagar Municipal Corporation. This is established in 1950 and is governed by provision of Bombay provisional municipal corporation act 1949. This municipal corporation is responsible for the provision of adequate water supply service and it is obligatory duty of them. In this village local authority is gram-pnchayat & all existing process is operated by them. In this village there are available one school, hospital all require facility. In this village they give gas pipeline to each house. The normal timing of water supply in the village is 5:00 to 7:00 in the morning (2 hours).

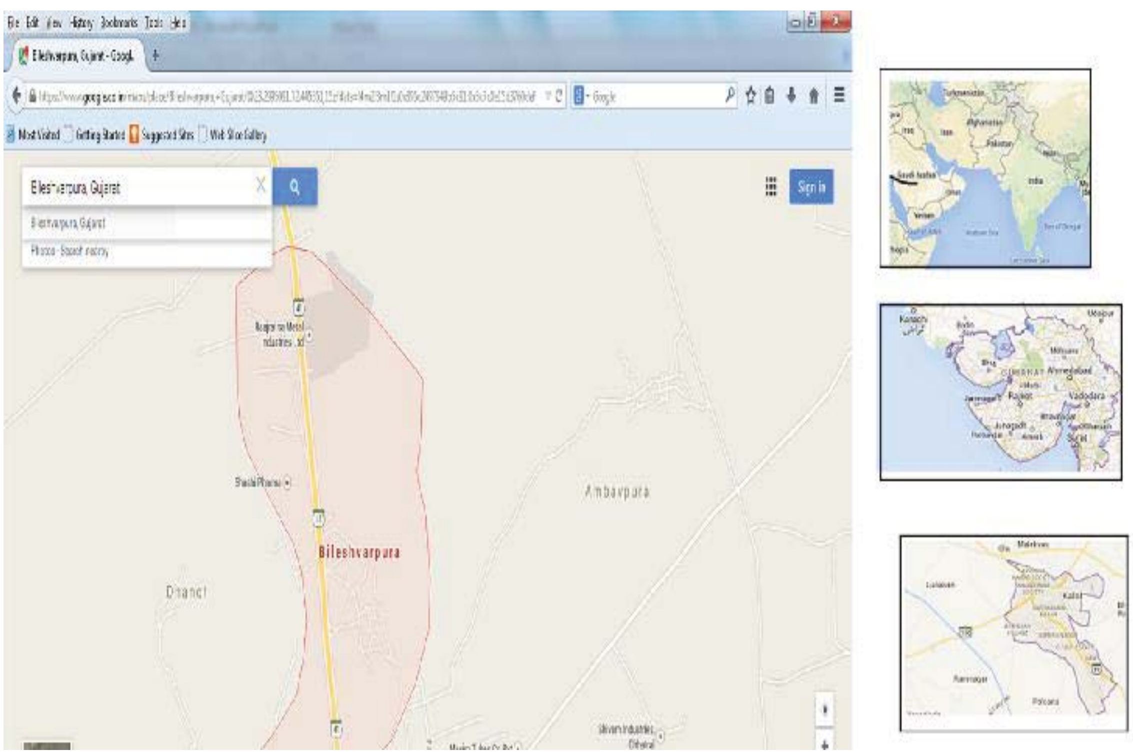

Figure-1: Location of Site on Map

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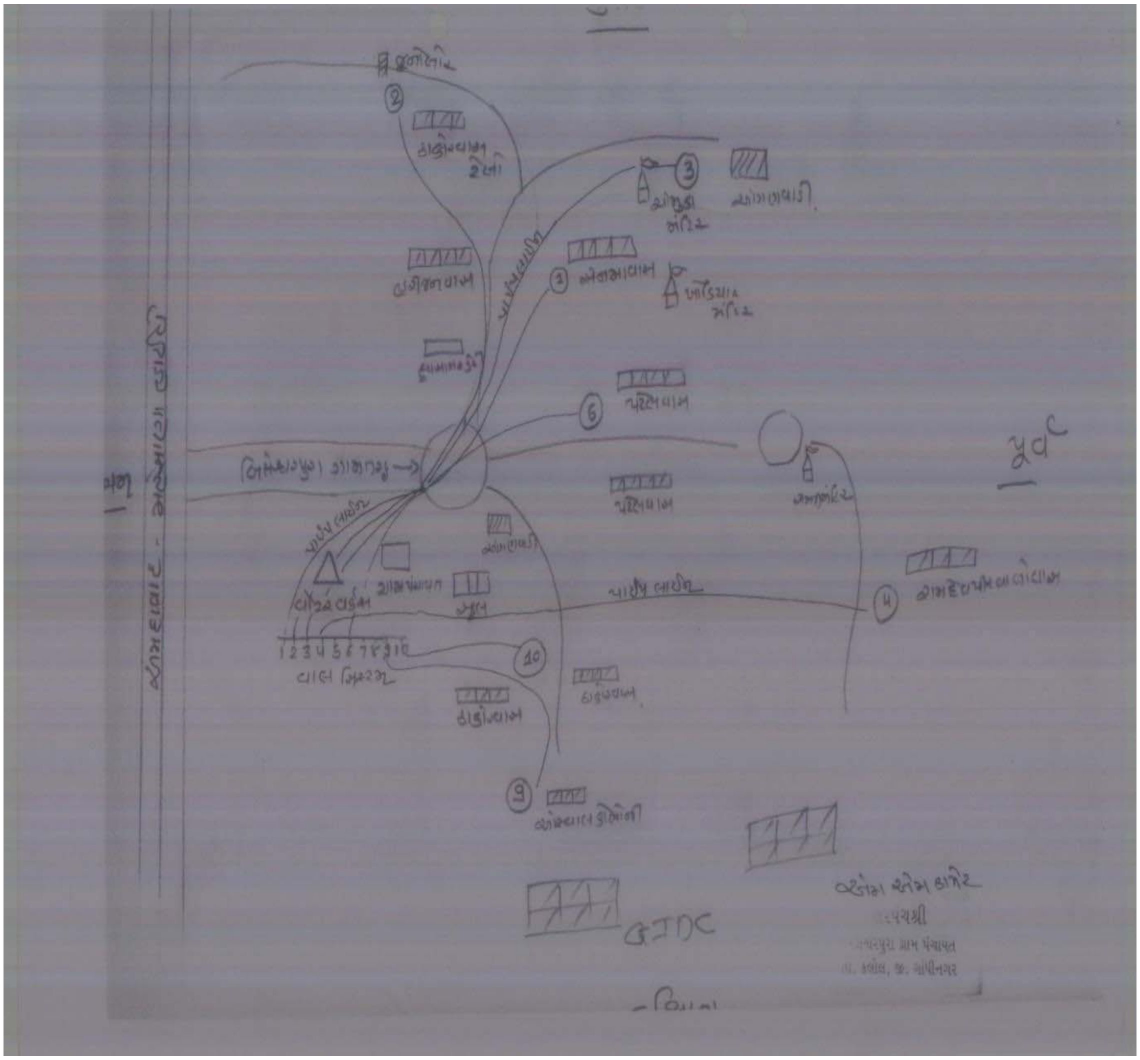

Figure 2: Present Water Supply Map

2. Methodology

The methodology adopted for the project is as shown below.

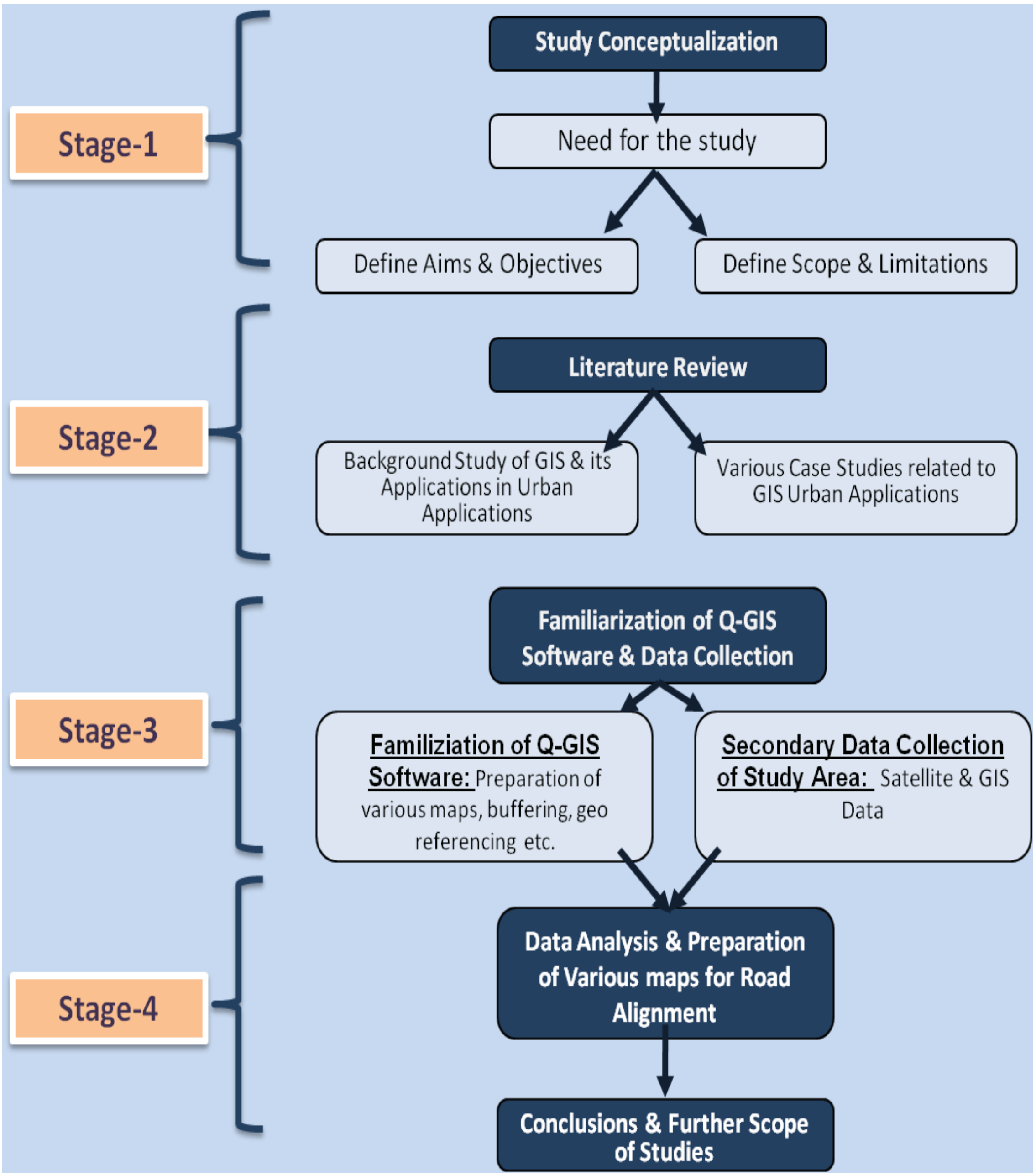

Figure 3: Methodology for designing WDN

When developing the WDN project, it is crucial to address several realistic design constraints:

Economic Constraints: The system design must align with the project budget.

Environmental Constraints: Considering the location near Jaipur, Rajasthan, the system should be efficient, prevent water loss, and include heat-resistant sensors to withstand the hot climate.

Sustainability Constraints: The system design should have minimal environmental impact and aim to reduce water losses.

Health and Safety Constraints: The system's goal is to supply pure and hygienic water to the entire colony, thus improving the overall health status.

3. Data Analysis

3.1 Obtaining Water Demand

The water demand for the building was determined in accordance with IS 1172:1993 (Pitroda, 1993). The water usage per construction in terms of liters per head per day (l / h / d) is as follows:

Houses: 135 l/h/d
Office: 45 l/h/d

The water demand for each building was calculated by multiplying the population of each block with the per capita demand. The formula used for this calculation is: Water Demand = Population × Per Capita Demand. The water demand for each node of the tanks of each building, in terms of cubic meters per hour (m^3/hour), and elevation data for all the nodes in the layout can be found in Annexure-I & II.

3.2 Hydraulic Modeling and Simulation

We have successfully opened the pipeline designs, system boundaries, and facility shape files for the entire campus with QGIS 2.8.7. The *.shp file has been transformed into a bitmap image (.bmp) file so that it can be used as a backdrop in EPANET Software. With the help of this transformation, we can assign prefixes to the pipes and junctions and build a functional representation of the system in EPANET. Before every building, each intersection has been connected to its unique base needs and joined with tubes of varying lengths. Google Earth has been used to determine and incorporate the lengths of the pipelines between the nodes into EPANET. In order to meet the necessary water demand, we have additionally placed pumps in the network scheme with enough pressure head. Our next goal is to allocate water requirement and elevation to the individual nodes and pipe properties like pipe length, pipe diameter, and roughness coefficients to the appropriate tubes after creating a functional model of the WDN scheme in EPANET (Santiago, 2011). Water demand and elevation are assigned to individual nodes once the network scheme's pumps with enough pressure head to satisfy the needed water supply have been installed. Once a functional model of the WDN scheme is generated in EPANET, this involves entering pipe details for the associated tubes, such as length, diameter, and roughness coefficients. Interestingly, the two daily times of greatest water demand from 6 to 9 a.m. and 6 to 9 p.m. occur in university residence halls, where it is especially high (Strategies smart cities mission, 2019). The subsequent procedures for modeling the water distribution network using EPANET are as follows:

1. Create a representation of the distribution system network or import a basic network description.

2. Modify the properties of the system component objects, involving adjustments and inputting essential information in various objects such as reservoirs, pipes, nodes, and intersections.

3. Explain the operation of the scheme.

4. Select from a range of options for evaluation.

5. Conduct hydraulic and water quality analyses.

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3.3 Findig EPANET Analysis

During the simulation, we observed changes in different nodes every hour in the selected parameters, including flow, velocities, head, and water pressure. The water distribution network consists of 111 tubes with 1 pump, 1 source reservoir, and 110 intersections. The diameters of the tubes used were 32 mm, 50 mm, 65 mm, and 80 mm, which were chosen after a heuristic approach to address elevated head values.

3.3.1 Junction Report

Junctions serve as points in the network where connections converge and where water enters or exits the network. The essential input information required for intersections includes being higher than a reference (typically mean sea level) and water demand. The output results calculated for junctions during all time periods of a simulation include hydraulic head, actual demand, and pressure. Figure 4 depicts the proposed water distribution network plotted in EPANET 2.0.

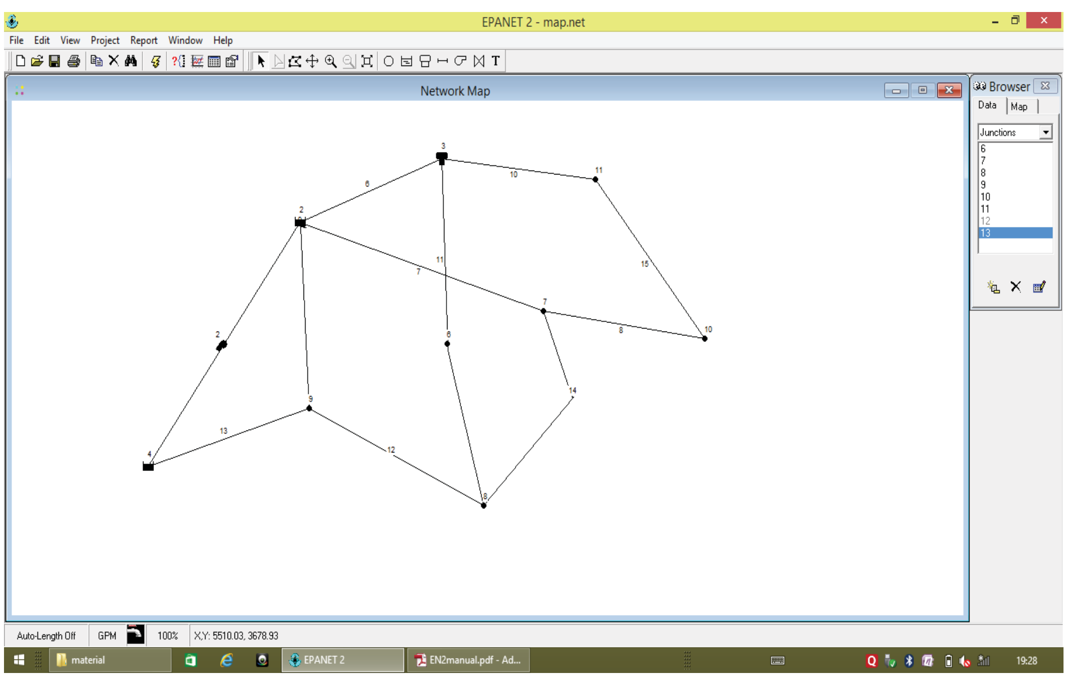

Figure 4: EPANET Design of WDN

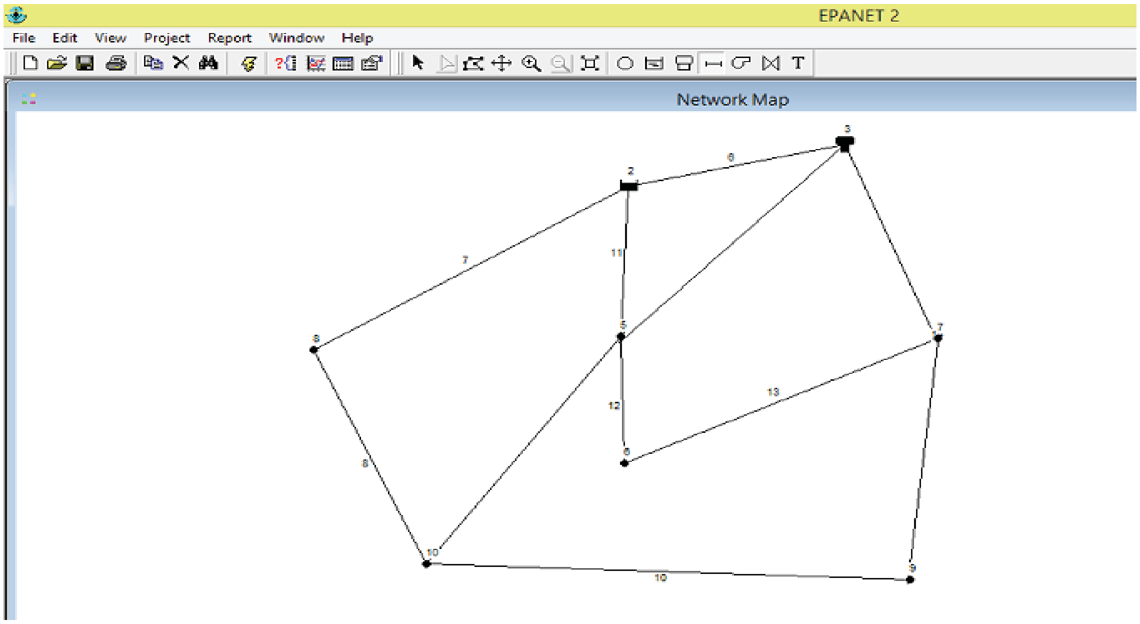

Figure 5: EPANET Alternative Design

The result of the simulation in form of Actual demand, Head & Pressure in Node-ID manner & base demand to actual demand ratio of the end nodes

4. Conclusion

The research study was focused on thoroughly examining the water distribution network to pinpoint any deficiencies in design, execution, and use. The ultimate goal was to transform the existing network into an intelligent water distribution system. After the analysis, it was determined that factors such as water pressure, velocity, and flow rate at all intersections were adequate to ensure equitable water supply in the study area. One significant issue identified was the presence of dead ends in the distribution scheme. It was recommended to connect these dead ends through looping to enhance system reliability and maintain steady water flow in the pipes. System simulations indicated that adding a few extra pumps would be necessary to ensure the water distribution system had sufficient pressure head and velocity. Every attempt was made to reduce the distribution system's hydraulic restrictions. The study also guaranteed that the minimum pressure head and water demand could be met even during peak hours to fulfill the required water quantity. The scheme was optimized for sensor deployment using a mathematical entropy approach with a greedy search algorithm. Sensors were strategically placed in regions with significant entropy and then optimized throughout the network for standardized deployment.

The assessment demonstrated that it is feasible to provide adequate water to the entire study area network at all intersections and speeds in all tubes. Based on the study findings, it was evident that the water supply exceeded the needs of the entire colony, as the Actual Demand to Base Demand ratio exceeded 1 at all end nodes (refer Annexure-IV). Additionally, all nodes maintained a residual pressure of over 12 m, allowing for smooth water flow to the tank located at a 10 m elevation. The assumed pipe diameters showed the capability to withstand the network's pressure, while the pipe network's velocity fell within the recommended range of 0.6 m/s to 2.5 m/s as per BIS (IS 2065:1983). Furthermore, the system has the potential to be converted into a smart water distribution network through sensor deployment. The strategic placement of sensors was determined using a mathematical approach, resulting in the identification of the most efficient locations.

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