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Design of Water Distribution Network for Malliala Village, Telangana using EPANET

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Abstract

Water is one of the most essential natural resources supporting life on Earth, and both its availability and quality play a critical role in shaping human well-being and livelihoods. Although freshwater exists in abundance globally, it is often unevenly distributed in space and time, and its quality may not always be suitable for domestic use. In this context, the present study focuses on developing an efficient water distribution network for Malliala Village using the EPANET platform to reliably meet domestic water requirements. As population growth directly influences future water demand, population projection techniques were applied to estimate the design-period population and corresponding water needs. Spatial information required for network planning was generated using Google Earth Pro and ArcGIS, enabling accurate assessment of village layout, settlement patterns, and service coverage. The design approach incorporated the number of households, projected population, estimated demand, and discharge from the overhead tank. The network consists of concrete and HDPE pipes, assigned roughness coefficients of 140 and 145 respectively, and was formulated for continuous 24-hour operation. Hydraulic analysis was carried out using EPANET 2.0 to determine node-specific parameters such as actual demand, pressure, and hydraulic head, along with pipe characteristics including flow, velocity, and unit head loss. The results confirm that the designed system is capable of delivering adequate water throughout the network under the assumed operating conditions.

Keywords Water distribution system: EPANET: Population forecasting: Water demand: Hydraulic analysis.

Introduction

Providing safe and sufficient drinking water is the primary objective of any water supply system. According to CPHEEO (1999), an effective supply system consists of well-designed hydrologic and hydraulic components that minimize water-related issues and consistently deliver water of acceptable quality to consumers. A water distribution system must therefore be both reliable and adequate. Reliability implies that consumers can access the required quantity of water whenever needed, while adequacy refers to the ability of the system to supply water at the appropriate quality and pressure. To meet these expectations, the distribution network must be capable of functioning efficiently under varying demand conditions and should maintain its performance even during peak usage periods. Many places are in the development stage due to this the growth of population is also increase. So the water distribution system is designed for increased population growth. In our country shifting climatic conditions and high temperatures have resulted in shortage of water and restrictions in usage of water. Demand for water is increasing every day. If appropriate water supply networks are not built, this will be problem for water availability of all regions affected. It is important for designing an optimal water distribution system. As manual research becoming difficult for large areas, nowadays software assisted analysis is used (Sahu and Singh, 2020). Several research works were carried out on the performance modelling and simulation for water distribution networks using EPANET (Amin and Banyai, 2021; Aniket et al., 2021; Wadekar et al., 2021; Hossain et al., 2021; Junaid et al., 2022; Mohseni et al., 2022).

The main aim of this research is to develop 24 hrs water network to whole village with adequate pressure and reliable quantity of water throughout the day using EPANET. Hydraulic analysis of a network was carried out in order to determine the available pressures and flow pattern of the system, and it involved determining the flow rate and head loss in each pipe in the network, as well as the pressures at critical points in the system under different demands.

Materials and Methods

Study Area

Malliala is the small village, in Ellandakunta Mandal, of Karimnagar District, Telangana State, India. Total area of this village is about 1454 hectares. The Geographical coordinates of village Malliala are 18°15'30.51"N and 79°32'7.44"E. Malliala village has an average elevation of 236m from above mean sea level. This village is 53 km towards East from District headquarters Karimnagar. Malliala is in the border of Karimnagar District and Warangal District and is surrounded by Moguallapalle Mandal towards East, Huzurabad Mandal towards West, and Kamalapur Mandal towards South. Malliala Village is divided into 9 wards as shown in Figure 1. The normal cumulative rainfall at this area is about 746.8 mm. People are using wells, hand pumps and bore wells for the purpose of drinking water. There is no piping water supply system in this village. As the water is contaminated with high fluoride, people were facing health issues.

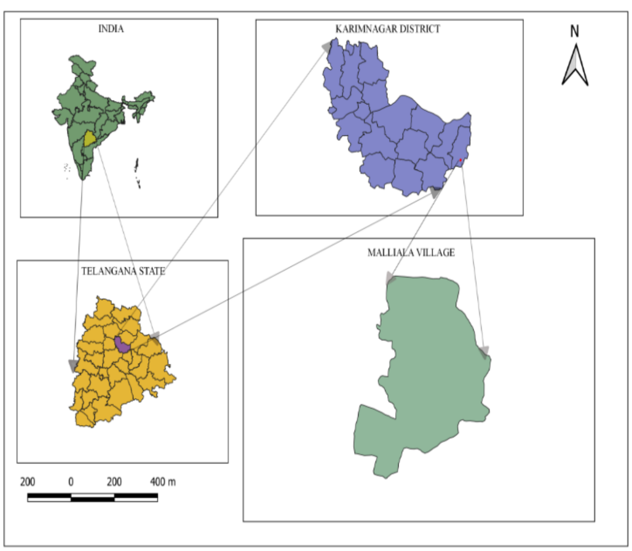

Fig. 1 Study area map of Malliala village

Data Collection

Preliminary survey was conducted for village Malliala and the Gram Panchayat provided the data for past and present population of village, number of houses in village and present water demand of the village. Topographic image of the Malliala village was obtained from Google Earth. Elevation data of the village (for fixing the elevation of the junctions) was obtained from DEM of the village using ArcGIS.

Population Forecasting

In the design of water supply systems, population expected in design period is considered instead of present population. Population forecasting can be accomplished with many mathematical methods by using past and present population records that can be obtained from local census office. While planning or designing any water supply project, the prime importance is given to water demand for present and future. As Malliala is a small village, the demand of water is mostly for domestic purposes. The amount of domestic water consumption per person may vary according to the living conditions of the consumers. As per IS: 1172-1993, basic requirements of water supply, drainage and sanitation, the minimum domestic consumption is about 135 lpcd as shown in Table 1. Losses from a water distribution system consists of over flow from reservoirs and leakages, leakage from main and service pipe connections, leakage and losses on customer premises. Considering upto 10% of minimum losses, the total consumption of water in a day i.e. taken as 150 lpcd.

Table 1 Minimum water requirements for domestic purpose

S.No	Activity	Consumption of water in liters per head per day
1	Drinking	5
2	Cooking	5
3	Bathing	55
4	Washing of clothes	20
5	Washing of utensils	10
6	Cleaning of houses and residences	10
7	Flushing of water closets, etc.	30
	Total	135

Study area is simulated in EPANET as backdrop using the latest imagery of the study area using Google earth pro image as per the known latitudes, longitudes for the study area (Fig. 2). From the known latitudes and longitudes, contours were generated with an interval of 0.25m by using ArcGIS software as shown in Fig. 3. Prominent care should be taken while generating contours because contours play a key and vital role in any network analysis. The data collected from these contours helped in deciding the route of distribution system and can provide sufficient elevation details required for design.

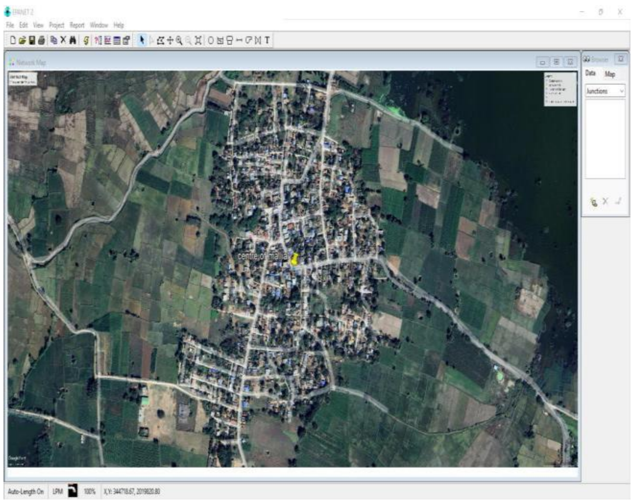

Fig. 2 Backdrop Google earth image of study area in EPANET

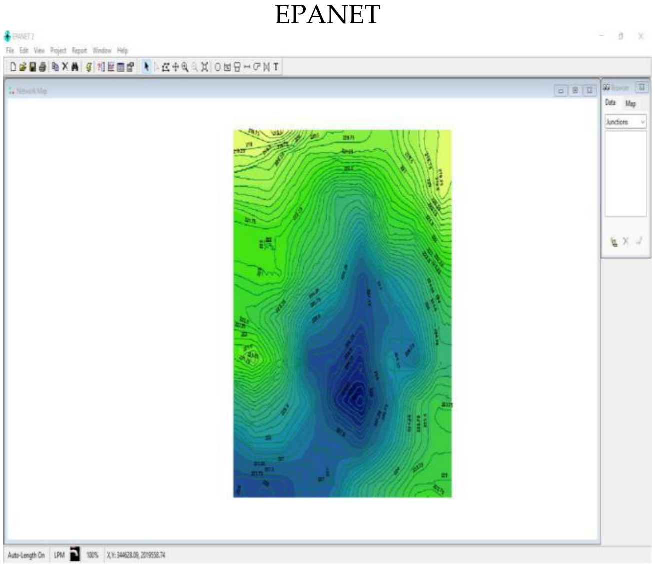

Fig. 3 Backdrop image of contours generated using ArcGIS

From Google earth map, the network pipes and junctions (nodes) along the roads were drawn. Fixing total demand from overhead tank based on hydraulic scheme. Assigning units of flow as LPM, fixing the head loss formula to Hazen Williams (H-W) method. Assigning network parameters length of pipe, diameter of pipe and roughness coefficient of pipe based on pipe material for each pipe and each node with elevation and base demand. Now run a hydraulic analysis of network and the results were thoroughly checked with standards. After successful RUN, the obtained output results were cross checked thoroughly with standard required values. If any of the corresponding values are not within permissible limits, then the network is adjusted accordingly by trial and error method by changing the input parameters until the output parameters like velocity, flow rate, friction factor pressure head is in specified range (Fig. 4).

Hazen Williams formula is the most commonly used head loss formula and was originally developed for turbulent flow only. Table 2 shows the resistance coefficient and values for the flow exponent for each of the formulae. Each formula uses a different pipe roughness coefficient that must be determined empirically. Table 3 shows general ranges of these coefficients for different types of new pipe materials (Roosman, 2000).

Table 2 Pipe head loss formulae for full flow

Formula	Resistance Coefficient (A)	Flow Exponent (B)
Hazen Williams	$4.727\ C^{-1.852}\ d^{-4.871}\ L$	1.852
Darcy Weisbach	$0.0252\ f(\varepsilon, d, q)\ d^{-5}\ L$	2
Chezy-Manning	$4.66\ n^{2}\ d^{-5.33}\ L$	2

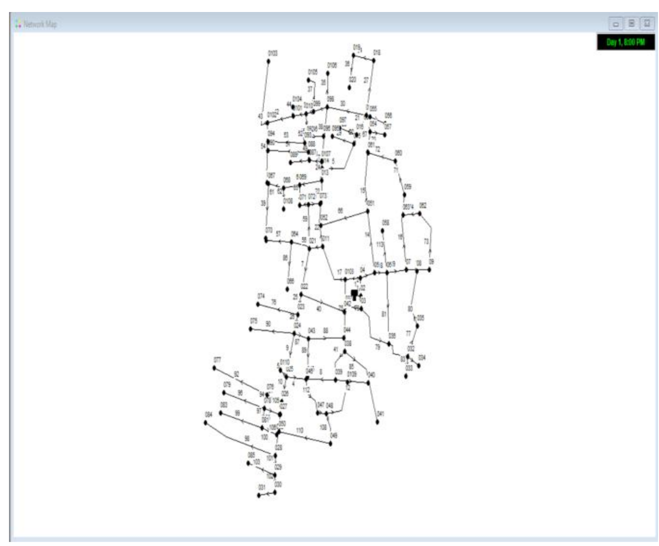

Fig. 4 Water distribution network of Malliala village

Table 3 Roughness coefficients for new pipe

Material	Hazen-Williams (C) (Unitless)	Darcy-Weisbach(Ɛ) (feet x 10^{-3})	Manning's (n) (Unitless)
Cast iron	130- 140	0.85	0.012 - 0.015
Concrete or Concrete Lined	120 - 140	1.0 - 10	0.012 - 0.017
Galvanized Iron	120	0.5	0.015 - 0.017
Plastic	140 - 150	0.005	0.011 - 0.015
Steel	140 - 150	0.15	0.015 - 0.017
Vitrified Clay	110		0.013 - 0.015

Results and Discussion

As per the census of India, Malliala village population in last 3 decades is 2001 is 570, 2011 is 1560, 2021 is 2200. Incremental increase method was applied to forecast the population and it was found as 2665, 2780 and 2820 in the year 2031, 2041 and 2051, respectively. As per Gram panchayat data obtained,

Total number of houses in Malliala village = 568

Number of people in each house = 5

Total number of population in Malliala village = 568 × 5 = 2840

Water demand for each person = 150 lpcd

Total water demand for each house = 150× 5 = 750 liters/day = 0.52083 liters/minutes

Total water demand for entire village = 2840 × 150 = 426000 liters/day = 0.426 MLD

The water distribution model consists of one main overhead tank, 109 junctions, and 110 pipes. Pipe materials used are concrete pipes of outer diameter 1200mm, 710mm and HDPE of outer diameter 560mm, 225mm, 110mm, 75mm and 63mm which were used throughout the network. Roughness coefficient of the concrete pipes and HDPE pipes are 140 and145, respectively. The key feature of the research is the analysis of the water delivery network and the detection of shortcomings in its design, operation and application.

Analysis of Junctions and Pipes

As the network is designed for 24 hrs supply, data obtained at peak hour in morning is observed at 6:00 to 10:00hr and in evening at 17:00 to 20:00hrs. In the morning peak hour at 6:00 hrs, the peak demand was obtained as 231.25 lpm and minimum as 0.83 lpm and at 10:00 hr, the maximum and minimum demand was obtained as 317.97 lpm and 1.15 lpm, respectively. In the evening peak hours at 17:00 hr, peak demand obtained was recorded as 433.59 lpm and minimum as 1.56 lpm, and at 20:00 hr, the maximum and minimum demand was obtained as 433.59 lpm and 1.56 lpm, respectively. Figure 5 and 6 show the variation in demand distribution in whole network in junctions 6:00 to 10:00 hrs and 17:00 to 20hrs respectively.

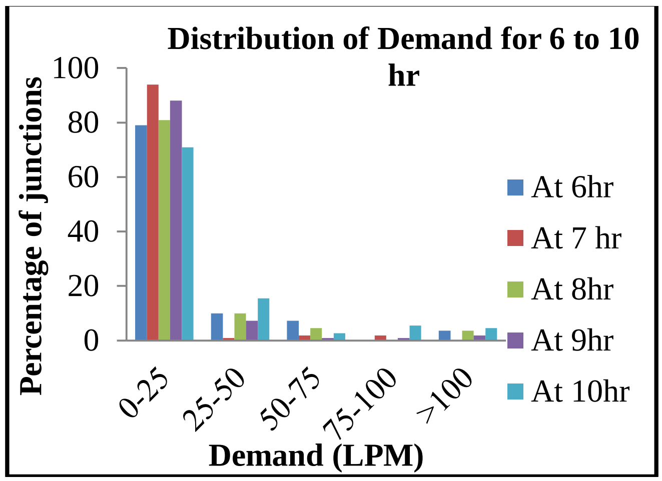

Fig. 5. Distribution of demand in morning peak hours

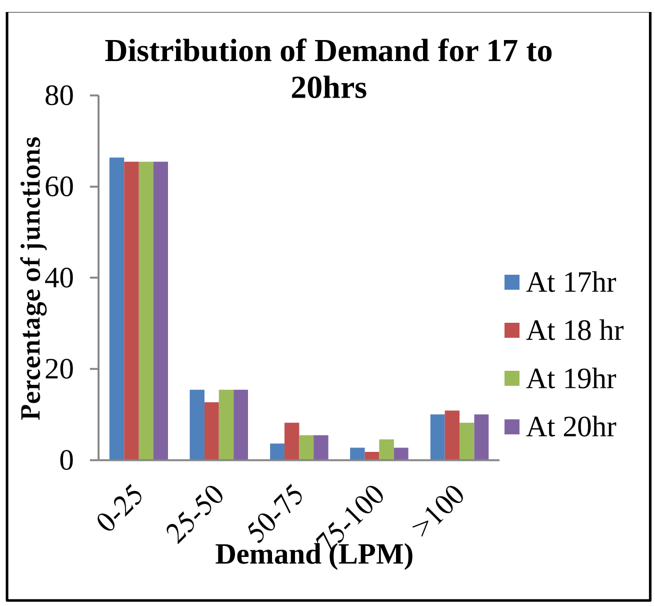

Fig. 6. Distribution of demand in evening peak hours

Contour Maps of Pressure and Demand

Figure 7 and 8 shows the contour plots of pressure of whole network at 6:00 hrs and 17:00 hrs, respectively. At 6:00 hrs the network is hydraulically safe overall but not equitable: central consumers are under-pressurized while some peripheral zones have unnecessarily high pressure, indicating scope for re-balancing and optimization. The pressure contour at **17:00 hrs** shows that the **c**entral part of the network continues to experience low pressure (around 12 m), similar to the morning, indicating persistent head loss and inadequate supply in this zone. The surrounding areas **maintain moderate pressure** (about 14 m), reflecting stable and balanced performance. The outer regions still show higher pressure (around 16 m), suggesting that the periphery receives more head than the core. The northern patch remains over-pressurized (about 18 m), indicating a structural issue that may cause leakage or bursts. Overall, the pattern shows that the system is hydraulically unbalanced, with consistently low pressure in the core and excess pressure at the edges, highlighting the need for network re-balancing and pressure management (Fig. 8).

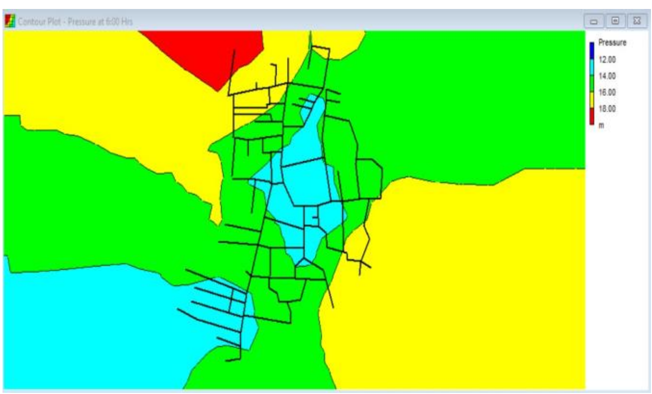

Fig. 7. Pressure contour of network at 6:00 hrs

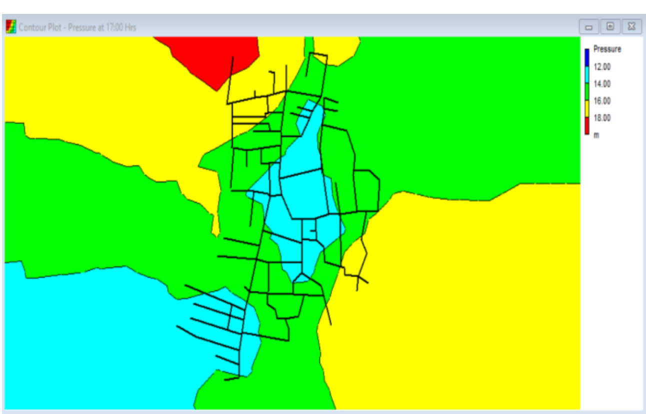

Fig. 8. Pressure contour of network at 17:00 hrs

The demand contour at 06:00 hrs clearly shows the morning peak demand pattern in the network. The central and south-central zones appear in red**,** indicating very high water demand (25–30 LPM) due to intensive domestic use at this hour (Fig. 9). Surrounding this core, the yellow band represents moderate demand, showing areas where usage is high but not at peak level. The outer zones in green and blue show low demand, reflecting residential areas with lower consumption or regions farther from the main activity centre. Overall, the contour shows that morning demand is heavily concentrated in the central and densely populated parts of the network**,** leading to higher withdrawal and increased stress on nearby pipelines. The demand contour **at 20:**00 hrs shows a strong evening peak consumption pattern, with a large portion of the central distribution area appearing in red, indicating very high water demand (around 30 LPM**)**. This widespread red zone suggests that evening usage is higher and more spatially extensive than the morning peak, as more households engage in activities such as cooking, cleaning, and bathing. The yellow areas around the central core indicate moderately high demand, reflecting the spread of consumption into surrounding residential zones (Fig. 10). The outer regions in green and blue continue to show low demand, consistent with lower population density or lesser evening usage. Overall, the 20:00 hrs contour indicates that the network experiences its maximum system load during the evening, with high-demand clusters concentrated throughout the central and south-central parts of the service area.

Fig. 11 shows the distribution of actual water demand in junction and water flow in pipes in the whole design network of the village at 6 hrs. Fig. 12 shows the distribution of pressure in junction and velocity in pipes in the whole design network of the village at 6 hrs.

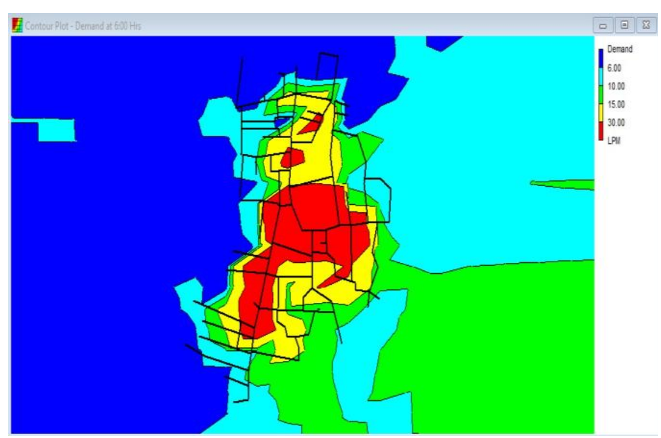

Fig. 9. Demand contour of network at 6:00 hrs

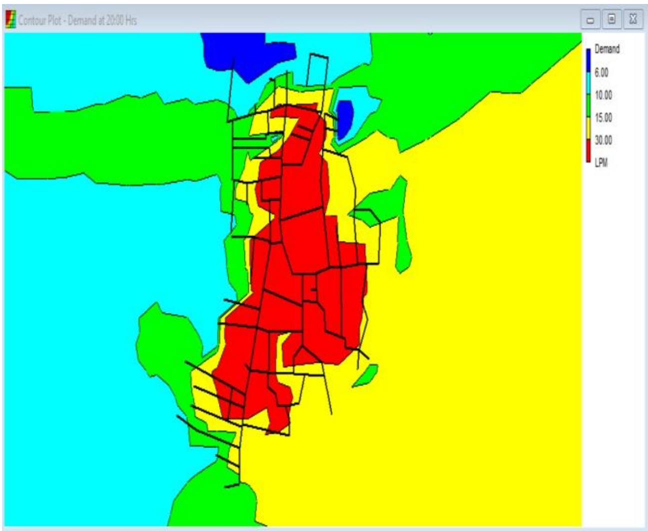

Fig. 10. Demand contour of network at 20:00 hr

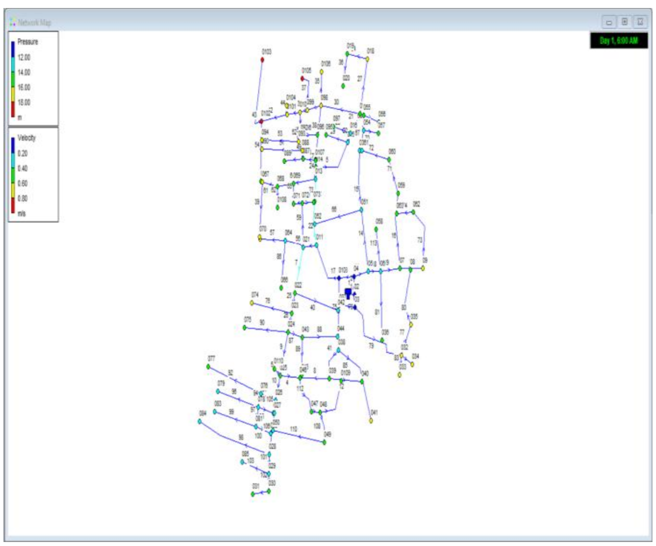

Fig. 11. Demand vs flow distribution

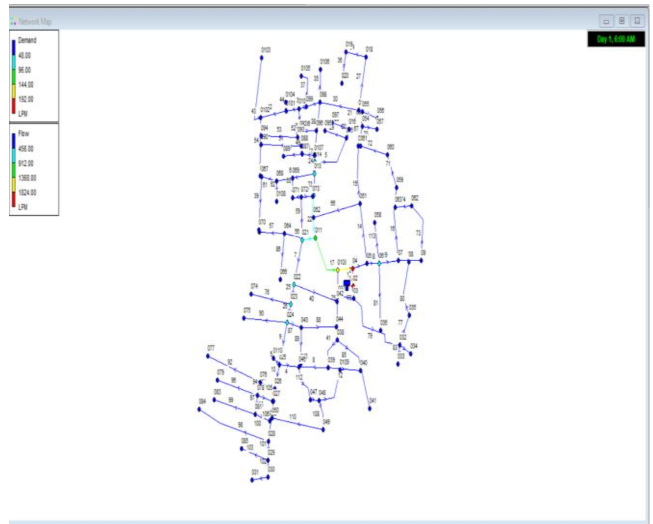

Fig. 12. Pressure vs velocity distribution

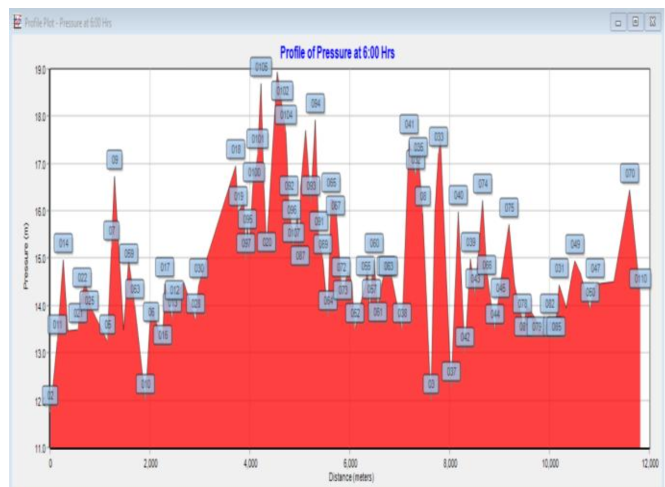

Fig. 13. Pressure profile of junctions based on distance at 6:00 hrs

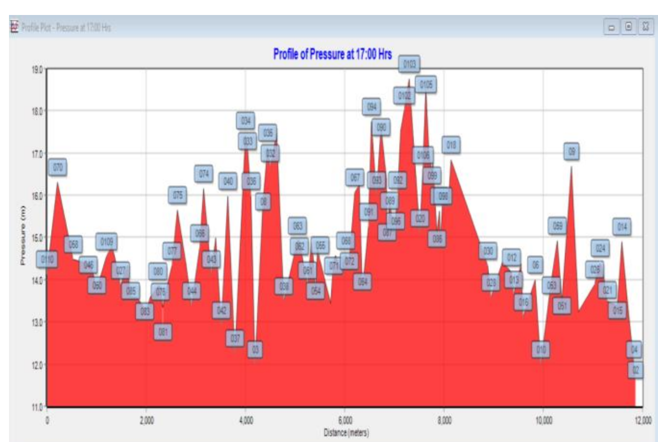

Fig. 14. Pressure profile of junctions based on distance at 17:00 hrs

Figure 13 and 14 shows the pressure profile of whole network junctions based on distance at starting peak hours in morning and evening respectively. The profile indicates that morning peak demand causes significant pressure variability, with several junctions experiencing low residual pressure, signalling the need for better balancing, potential pipe upsizing, or pressure management in the central area (Fig.13). The 17:00 hrs profile indicates that evening demand is moderate, leading to more stable pressures compared to 06:00 hrs. The system shows improved performance, though some fluctuations persist across the central and far-end junctions, highlighting areas that may benefit from pipeline strengthening or network balancing (Fig. 14).

Conclusions

In this study, the water distribution network for Malliala Village, Telangana was developed and analysed using EPANET by incorporating tanks, junctions, and pipes. The system was simulated for a 24-hour supply scenario, with a particular focus on the morning and evening peak-demand periods. Key hydraulic parameters at junctions such as actual demand (LPM), hydraulic head (m), and pressure (m), along with pipe characteristics including flow (LPM), velocity (m/s), head loss (m/km), and Darcy friction factor, were evaluated during these peak hours. The results clearly show that water demand increases significantly during peak periods, which is also reflected in the demand variation graphs generated in EPANET. Base demand was estimated based on the projected population, and the entire hydraulic network was assessed for its ability to meet this demand. The simulated hydraulic head and pressure values were found to be adequate to supply the required demand throughout the 24-hour cycle at all junctions. Occasional negative flows in some pipes indicate flow reversal, while the velocities across the network remained within the acceptable limits, confirming safe and stable operation. The major findings of the study are as follows:

The design-period population of Malliala Village, estimated using the incremental increase method, is 2,840, with a corresponding total water demand of 0.426 MLD. The EPANET model developed for the study consists of 110 pipes and 109 junctions, with end junctions serving between 2 and 30 households depending on their location. The 24-hour demand pattern features two peak periods, occurring from 6:00–10:00 AM and 5:00–8:00 PM. During these peak hours, most junctions are required to supply up to 25 LPM of demand, while the majority of pipes convey flows of up to 100 LPM, indicating the system's operational behaviour under maximum load conditions. Most junctions exhibit pressures between 14 and 16 m during peak demand, and a large number of pipes show velocities ranging from 0 to 0.05 m/s, indicating safe operational conditions. The designed network performs satisfactorily under peak-demand conditions, and the hydraulic parameters remain within acceptable limits, demonstrating that the proposed system can reliably meet the present and future water requirements of Malliala Village.

Data Availability Statement

The datasets generated during the current study are available from the corresponding author on reasonable request.

Conflict of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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