Comparative study of pressure variations in water distribution network due to change in location of elevated service reservoir

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Abstract. This paper compares the pressure variations in a water distribution system due to a change in the location of an elevated service reservoir with an intermittent type of supply for a continuously increasing demand. For this study Water Gems connect edition software is used for the design of a water distribution network. This study is conducted in the Etturnagaram habitation of Mulugu district. The Water Distribution Network is designed for 30 years with PVC as pipe material and intermittent type of supply. Further, this water distribution system is analyzed for pipe bursts and proposes a framework for the operation and maintenance of the water distribution network.

Keywords: Water distribution system, Water Gems, Pressure variations, Operation and maintenance, Pipe networking.

1. Introduction

Water is a basic need and it is essential not only to health but also to poverty reduction, food security, peace, and human rights, ecosystem, and education [1]. With the increase in population, the demand for the supply of clean adequate safe drinking water with adequate pressure continues to be one of the major challenging tasks[2].

This paper reviews the scenario of Etturnagaram Town. Initially, the water distribution system (WDS) is divided into two zones A and B and designed for 30 years with a per capita demand of 100 LPCD. Population forecasting is done using the Incremental Increase Method for an intermittent type of supply. The parent WDS consists of 34km of pipeline made from PVC with diameters between 75mm to 315mm. It has two storage tanks each of 250KL capacity. Due to the unavailability of land for the construction of Elevated Service Reservoir (ESR) in zone B, the location is changed to zone A. Now the water is entering into WDS from zone A to zone B. Due to the change in location of ESR, there is an additional requirement of pipeline and pressure regulatory valves, which adds to the overall cost of the project.
As per the CPHEEO manual on Operation and Maintenance (O&M)[2], the major constraints in this WDS are Intermittent type of supply (where the external pollution may get sucked into the system through points of a leak during non-supply hours when the system is not under pressure, causing health hazards) and Design velocity (should not be less than 0.6m/s to avoid depositions and due to sudden decrease in velocity of water in pipes may lead to water hammer which may have sufficient magnitude to rupture the pipes or pipe connections). To avoid pipe breakages and water losses and to maintain adequate pressure at the consumer end, there is high importance for O&M. The main aim of the maintenance of WDS is preserving the hygiene quality and adequate flow. The functions of maintenance are assessment, detection, and conservation of water.

Vidhi N. Mehta and Geeta S. Joshi (2019)[3] mentioned Water Gems software as user-friendly and its graphical interface analyses more effectively.

1. Study Area

![Figure 1: Map of Eturnagaram Town](image)

Eturnagaram is a Town and a Mandal in Mulugu district in the state of Telangana in India. The village area is surrounded by forest. The population of the village as per the 2011 census is 8278. The village have no piped water supply, in other words, there is no existing water distribution network. The village uses borewells for meeting their demand. Due to the decrease in groundwater quality in the village as well as in the state[4] the Rural water supply and sanitation department of Telangana initiated Telangana Drinking Water Supply Project (TDWSP) for providing treated water for every household in the state. The map of Eturnagaram town is shown in figure1.

2. Input Data

For the design of a water distribution network, the data required is collected from TDWSP. 
Census population year: 2011
Base year as per TDWSP: 2018
Prospective year as per TDWSP: 2033
Ultimate year as per TDWSP: 2048
The population as per 2011 census: 8278
Population growth rate as per TDWSP: 0.8
Rate of Growth: Incremental Increase

**Population forecast**
a) Base year-2018: 8753
b) Prospective year-2033: 9864
c) Ultimate Year-2048: 11116

**Water demand**
a) Per capita supply- 100 LPCD
b) Base year- 875 KL per day
c) Prospective year- 986 KL per day
d) Ultimate year- 1112 KL per day

The required capacity of ESR @ total demand/2: 493 KL
Demand considered for the design of the distribution network: 1112 KL per day
Hours of supply: 6 hours (3 hours in the morning and 3 hours in the evening)
Discharge: 3088.89 LPM
Peak factor: 4
Pipe material: PVC 6 kg/cm²
Pipe roughness constant in terms of Hazen William’s C: 140

The network maps are prepared in AutoCAD by taking field measurements with the help of a roadometer and the ground elevations of each junction and ESR’s are taken using hand GPS.

### 3. Hydraulic simulation model

The hydraulic network consists of 5667 pipes contributing to 3400km, 35 pressure-reducing valves, 2 storage tanks, and 1800 nodes. Initially, the network is divided into two zones A and B. Each zone consists of one tank and there is no interaction between the zones. Among the demand zones, 1000 nodes belong to zone B while the remaining 800 nodes belong to zone A. Due to a lack of land with soil bearing capacity to sustain the construction loads, the location of the elevated service reservoir in zone B is shifted to Zone A. Now the tanks are connected in parallel to the network which is equivalent to have a single tank of 500KL capacity and both zones A and B are connected with the pipeline and pressure regulating valve making no changes to the water distribution network as shown in figure 4. The existing network is designed for an extended stimulation period of 6 hours (3 hours in the morning and 3 hours in the evening). The water flow rate in the water distribution network depends on the diameter, length, and number of bends or valves in the system. The direction of water flow is illustrated with color coding in the figure3. Water from zone A have to reach the tail end of zone B which may cause low pressure in zone B, may lead to breakage of pipe (due to increase in pipe length) but increases the pressure in zone A (due to an excess rate of supply) which may also lead to breakage of pipe. Water demand varies in the water distribution network and a single pressure reducing valve in the intersection of both zones, may not be able to handle the maximum water demand flow rate, highlighted in the figure2. The point of intersection of zones is also a hotspot for the breakage of pipes and wastage of water.

### 4. Methodology
The procedure adopted for stimulating the hydraulic model involves the following

- Creating the map of the town using drafting software
- Creating the network consists of reservoirs, Junctions, Tanks, Pipes, Valves, Patterns in Water GEMS
Collection of data and assigning object properties such as elevation, demands, materials, length, etc.
Stimulating for steady-state and extended period analysis
Minimization of errors and generation of reports

Figure 2: Identified location of nodes in the network

Figure 3: Identified location of Pressure regulating valves in the network in zones A and B
5. Results and discussion

The simulated model with the existing case has negative pressures in some parts of zone A and entire zone B due to fluctuations in the diameters of pipes. To maintain sufficient pressure in the water distribution network, this study suggests an alternate scenario where there is a change in the diameters of the water distribution network. Comparison is made to find out the cost-effectiveness of the proposed model and the existing models. Diameter wise comparison is made for the existing project and alternate project in figure 5. This comparison is useful in the replacement of pipes with the alternate network in the event of breakage or damage of pipes. In general, the cost of maintenance of a project will be more but this alternate network designed will help in reducing the maintenance cost of the project. The overall cost of the existing network is 85 lakhs excluding pressure regulating valves and the cost of an alternate network can be completed in 50 lakhs by reducing the diameter of the pipes. To distribute water with adequate pressure and in adequate quantity the pressure regulating
valves are placed in the network and the location of these PRVs are shown in figure 3. In order to make the distribution system more sustainable to varying pressures the distribution system should have designed for ductile iron as pipe material but the cost of project will increase drastically.

6. Conclusion
The existing network is stimulated and found that the lower diameters have 0 or null velocities. In order to maintain the pressure in the network as per guidelines, the diameters are reduced so that project cost can also be reduced by 42%. This analysis is found that the initial or existing design is stimulated for extended period analysis or intermittent type of supply but this comparison states the network is not suitable for extended period analysis as more pressure will be on the network causing more damage and breakage to pipes. The existing network and the alternate network are not suitable for intermittent supply so provisions should be made for a continuous supply.

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