Modelling Water Distribution System for a Village

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Key Message(s):

- **Grid distribution system layout is used and the network generally follows the road pattern. Saga-gis used for nodal demand data**
- Of all the factors, the topography of the area and population play the most crucial role in the modeling.
- Optimal pipe parameters are found out by adjusting flow velocities in the required range, keeping water demand for households in consideration.

Abstract

In this project, we have modeled a water distribution network for a village, Bhora Khurd, situated in Gurgaon, Haryana. The primary source of water used is a nearby reservoir. The topography is flat, so the elevation is nearly the same at all junctions, so only gravity could not be relied upon, and pumps had to be used. There is a requirement that velocities in pipes should be in the range of 0.5-1.5 m/s, and a pressure range from 150-500 kPa has to be maintained, so we've tried to achieve that. Also, unit-headloss is preferable to be kept below 10m/km. The modeling has been done using the EPANET software, and Google Earth was used for topographical information. For base-demand at nodes, Saga-gis and Epanet network were used. Hazen-Williams formula has been used for estimating the head losses in pipes.

1 Introduction

Water is one of the basic human needs. So, it is crucial to design a water distribution system if a township is to be established. We need to plan and run the simulations to ensure no problems when the actual execution occurs. It is to be assured that the water demand is met, pressure is within feasible range, and there is workable flow velocity in the pipes to avoid damage and serviceability. The unit-headloss must be kept as low as possible to reduce energy wastage.

There are many computer software available that can be used to model and analyze water networks. One such software EPANET is used for modeling piped water distribution network. It has various elements used in the water supply system; pipes, junctions, pumps, reservoirs, tanks, etc. Based on the topography of the area, elevations of different junctions and reservoirs can be set. We have assigned various parameters such as diameter, power of the pump, the elevation of the tank, etc as hyperparameters. Once we have successfully modeled the network, we can run it and check the flow velocities, pressures, head losses, etc., and then adjust parameters to make the network more efficient. In EPANET, there are three approaches for friction headloss that can be chosen; Darcy-Weisbach, Hazen-Williams, or Chezy- Manning formula. Each one has its advantages and shortcomings and its historical significance. We have used the Hazen-Williams formula, which we will discuss later.

Although we were unable to model the perfect design for the network, **we have provided the best feasible design out of designs we have tried**, and it did familiarize us with the approach and things that needed to be taken into account for this task.

2 Methods and Data

1. The map of the village was obtained using Google Earth [1]

Grid distribution system layout was used and an EPANET network with only links and nodes was created. To obtain the length of the pipes and coordinates, the elevation of junctions, data from Google Earth was used.

2. For the population, 2011 Census data[2] was available. So, we used the decadal population growth rate [3]. Then, using the geometric increase model, the current population and population after 15 years were estimated, since that needs to be taken into consideration while designing the network. The Geometric increase formula is: $\mathbf{P = P_0(1+r)^n}$, where P_0 = 1943 is the current population, r = 19.9% is the decadal population growth rate, and n = 2.5 is the time for projection in decades. Now, taking the average water consumption as 135 liters/person/day for domestic households, loss as 15% of total water supplied, and commercial demand as 20% of total water supplied, we obtained total demand as Total demand = Projected population * per person consumption, which is divided by the total area to get demand per unit area = Total demand/ Total area.

3. Next Nodal base demand was obtained using the EPANET network, the above data, and SAGA-GIS software. The boundary outline of the Epanet network and nodes file were fed separately to SAGA-GIS. Using nodes, Thiessen polygons (which distributes area of influence for each node, using the concept of construction of perpendicular bisectors to the lines joining each station) were created, which was then intersected with the network boundary to get areas corresponding to each node within the boundary. Tabular data of area for each node is extracted, and the area corresponding to each node was multiplied with demand per unit area to get Nodal base demand for each node.
4. The next task was to assign the different hyperparameters like position, power of the pump, positions, elevation/head of tank/reservoirs, and diameter of pipes to the EPANET network.
5. Since the water demand is not constant throughout the day, a demand pattern was required. Actual data was not available, so we opted for a typical demand pattern, with demand peaking in the morning and evening.
6. For pipe diameters and roughness, an online commerce site [4] for pipes in Gurgaon was used. RCC np3 concrete pipes having Hazen Williams roughness coefficient as 130 with different sets of pipe diameter were given.
7. As stated above, for friction head loss, the Hazen-Williams formula has been used. In all three approaches, the expression for the formula used to compute head loss between the start and end node of the pipe is the same: $h_L = Aq^B$. Where h_L is the head loss, and q is the flow rate. A is the resistance coefficient, and B is the flow exponent. *A and B* are what vary in the three approaches.

Hazen-Williams formula: $A = 4.727C^{-1.852}\ d^{-4.871} L$ and $B = 1.852$

where d and L are pipe diameter and pipe length, respectively, and C is the Hazen-Williams roughness coefficient.

This roughness coefficient is known for pipes of different materials (here, concrete).

For diameters, we first assigned them arbitrarily and ran the simulation. Then based on the project report, adjusted the network so that negative pressures are not created anywhere. Then, the major task was to adjust the diameters of pipes, position, elevation/head of tank/reservoir respectively, power of the pump, etc. iteratively, so that the velocities come in the range of 0.5-1.5 m/s, and unit-head loss in all pipes is below 10m/km. This was a mammoth task, and we couldn't perfect it. So, the best we achieved is provided.

3 Results

After adjusting and running the network simulation multiple times, we have the various pipe diameters, which give the following velocities and headloss in the network :

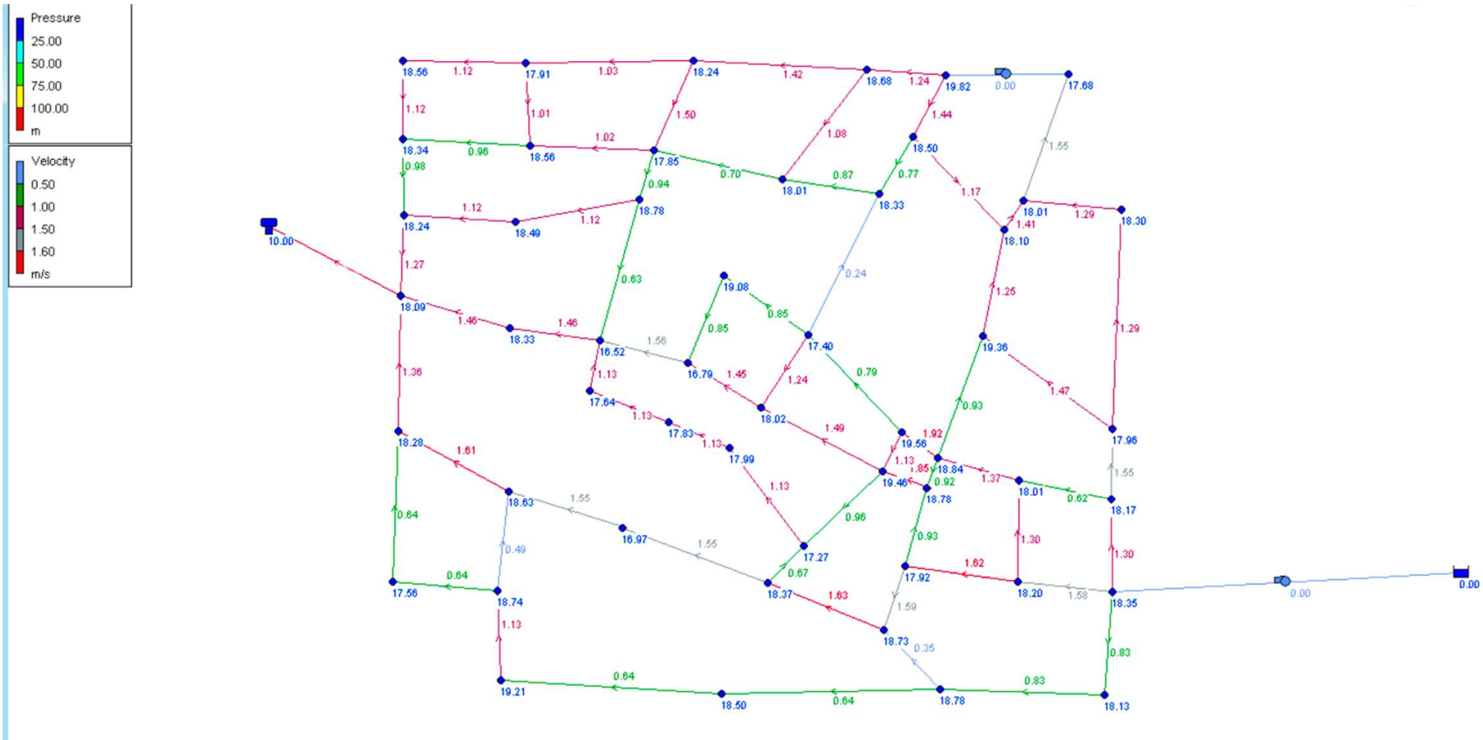

Figure 1. Flow velocity in pipes (m/s), and pressure head at junctions (m) are shown numerically at corresponding pipes and nodes in the network and through legends with specified ranges of velocity and pressure.

The velocity of water should be maintained within a range such that sedimentation or erosion is avoided, and pressure at junctions is within acceptable limits. The supply through the distribution system should be adequate for the households according to the demand data. The pipe parameters are adjusted such that the damage to the pipes is prevented.

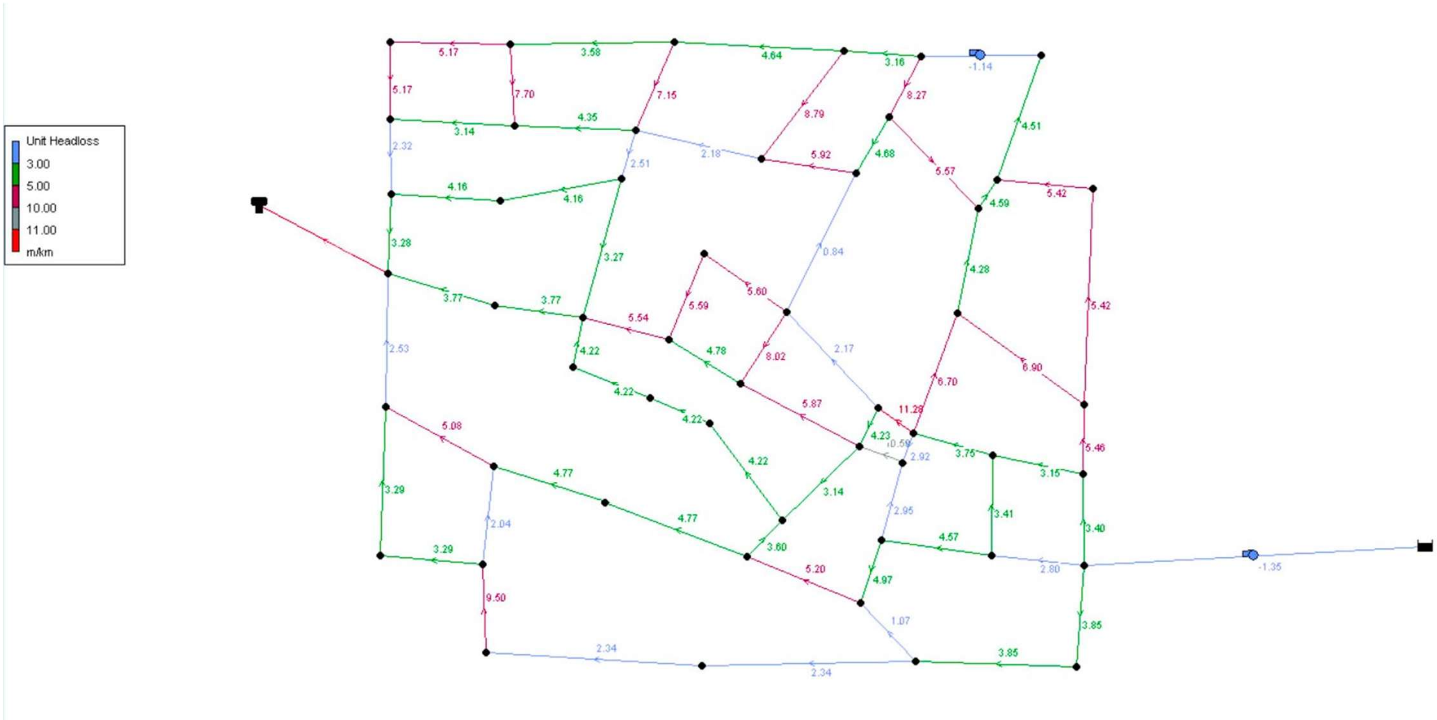

Figure 2. Unit-head loss in the pipes is shown numerically and through legends in the figure.

While adjusting parameters to accommodate flow, attention has also been paid to head losses in pipes to ensure that they don’t exceed the acceptable limit.

All the settlements need an adequate water supply. The implications of network analysis using computer softwares are truly limitless. Simulations can be run and potential problems can be detected and dealt with, without any major economic consequences.

The lack of precise demand data poses a serious limitation to our analysis. To distribute the total demand, the best method available was using the Theissen polygons, but it doesn’t show the actual consumption. So, we cannot only rely on the softwares. The actual place needs to be surveyed to ensure the feasibility of the proposed theoretical model.

4 Conclusions

A proper design for the network of the working model is made for the map. Various network parameters like pipe diameter, slope, roughness have been set using the above-mentioned techniques in such a way that flow velocity requirements are met with the water demand being fulfilled for all the households. Adjustments are made to keep the headloss within limits.

Suppose we had the complete data(i.e.water demand pattern and pressure requirements for every household separately), a pressure-driven approach could have been followed which would have provided both accurate and precise results.

We have gotten a lot of experience and a better understanding of the application of known concepts and methods. The use of various softwares and computer applications has helped in developing our skills. We had a lot of fun working as a team and exploring different methods, and applying multiple concepts to design the network for the water distribution system.

5 References

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[2] https://www.census2011.co.in/data/village/62891-bahora-khurd-haryana.html

[3]https://censusindia.gov.in/2011-prov-results/paper2/data_files/Haryana/8-pop-decadal-15-19.pdf

[4]https://www.brhcconcreteindustries.in/rcc-np3-class-pipes.html