Hydraulic Modeling and Simulation of Smart Water Distribution Network

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Abstract - *Water utility is the basic requirement to meet the needs of the growing population of a developing city. For this water supply system should work efficiently and effectively so that people of the city receive water with adequate pressure and quality. Pimpri Chinchwad city is developing as a smart city and its population is rapidly increasing day by day. To achieve smart city aspirations, Pimpri Chinchwad Municipal Corporation (PCMC) is looking forward to implementing 24 X 7 water supply in the city. However, this immensely large-scale water supply system is an intricate structure with vigorous randomicity and multiple operation controls. To ensure the reliability of the water distribution network, hydraulic modeling and simulation through various specialized softwares plays a significant role. This paper presents the study of the water supply network from Water Treatment Plant (WTP), Nigdi to Elevated Storage Reservoirs(ESRs) at Swapnanagar, Nehrunagar, Vallabhnagar out of the whole PCMC region and the distribution network of Swapnanagar ESR. WaterGEMS V8i software is used to build the hydraulic model for its analysis. The model provides information about probable locations of nodes with inadequate pressure and necessary improvements are made in network to make it adequate.*

Key Words: WaterGEMS, Hydraulic Model, Water Distribution Network, ESR

1. INTRODUCTION

Water distribution network is a crucial part of city's infrastructure that conveys treated water from Water Treatment Plant to the consumer end. It comprises of pipes, pumps, valves, reservoirs and is the costliest asset of the overall supply system. Water distribution system can be broadly classified into two types as intermittent and continuous system. In intermittent water supply system, water is supplied to the users for less than 24 hours for a specified period. Generally, water is supplied at peak hours i.e. in morning 6 A.M to 9 A.M and evening 5 P.M to 8 P.M. In India, this system is typically followed by many cities and consumer needs to store water during supply hours. In continuous water supply system, water is supplied to the users 24 hours a day and 7 days a week. The water is adequately pressurized to reach consumers end and consumer need not store the water, avoiding wastage of water.

In 24 x 7 water supply scheme, water will not remain stagnant in pipes at any instant. Thus, there is always availability of fresh water which will also help in improving the overall health of city. In order to maintain the quality, pressure and flow parameters at each node in the water distribution system, computation of hydraulic parameters and water quality at each node is essential. Hydraulic modeling simplifies the analysis of water distribution system. With its help, the uncertainties in present and future demands can be predicted. Hence the reliability of water distribution system can be computed and special measures to improve the system can be suggested.

1.1 Significance of work

With the help of hydraulic modelling the pressure variations in the pipe network can be monitored. It helps to check the adequacy of pipe network i.e. their diameters and number of pipes. If the pipe network is not adequate necessary modifications can be made such that water is conveyed to the users with adequate pressure.

1.2 Objectives

1. To study hydraulic parameters of present water distribution system of study area.

2. To design hydraulic model for the study area.

3. To identify the location of critical points in the existing water distribution system.

2. STUDY AREA

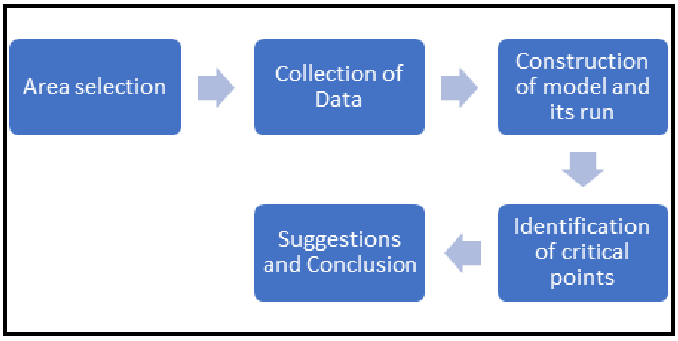
Pimpri Chinchwad is located to the north-west of Pune city in Maharashtra, India. The coordinates of the city are 18°37'07.04''N 73°48'13.43" E. Pawana dam is the main source of water for the city which is 35 km away from the city. The water distribution network from Water Treatment Plant, Nigdi to Swapnanagar, Nehrunagar and Vallabhnagar is identified as the study area out of the whole PCMC region and the further distribution network ahead of the Swapnanagar ESR is also analyzed for the study. The main reason for the selection of the above study area is uneven pressures and tremendous fluctuations observed in the flow rate.

3. INTRODUCTION TO WATERGEMS

Bentley WaterGEMS V8i is a user-friendly software which can be utilized as a decision support tool for water distribution network. This soft computing tool is useful to understand the behaviour of infrastructure as a system and its responses to operational strategies. A water supply system should develop as population and demand increases and this software simulates the same. WaterGEMS V8i is a hydraulic modeling software for water distribution systems with advanced interoperability, geospatial model building, optimization and asset management tools. It provides an easy to use environment for engineers to analyze, design and optimize water distribution network from fire flow, water quality simulation and constituent concentration analysis to criticality, energy consumption and capital cost management.

4. METHODOLOGY

Following steps have been carried out to analyze existing water distribution network using WaterGEMS V8i:



Step 1: Selection of Study Area.

As discussed in the section no.2 study area is selected to fulfill the objectives.

Step 2: Collection of data.

For hydraulic analysis in the software all the required input data was collected from Water Treatment Plant, Nigdi. Pipe data such as pipe diameter (mm), C-value and length (m) are assigned to the network. Input for nodes are elevation (m), water demand (lps) and time pattern. Pump head (m) and flow (lps) are required data for the construction of pump curve. Layout of the water supply system in AutoCAD file is also an essential input.

Table -1: Input Data for the ESRs

Details	Units	Swapna-nagar	Nehru Nagar 1	Nehru Nagar 2	Vallabh-nagar
Capacity	Lacs litre	16.5	17.5	17.5	20
Tank top level	m	605.367	605.555	605.555	588.974
Tank bottom level	m	599.697	599.711	599.711	583.166
Tank plinth level	m	588.498	584.459	584.459	560.531
Existing population		15406	26717	45985	30908
Water demand	MLD	2.619	4.542	7.817	5.254
Water supply timings (hours)	Inlet	7 am - 12 pm & 7pm - 12 am	11 am - 4.30 pm & 11 pm - 2.30 am	11 am - 4.30 pm & 11 pm - 2.30 am	10 am - 4.30 pm & 10 pm - 4.30 am
	Outlet	4 am - 7 am & 4 pm - 7 pm	5 am - 8 am & 5 pm - 8 pm	5 am - 8 am & 5 pm - 8 pm	4.30 am - 7.30 am & 4.30 pm - 7.30 pm

Table -2: Input Data for the pipes

Locations	Diameter mm	length m
WTP - S2	1000	3600
S2 - Junction 13 (SEC-4)	900	1100
Junction 13 - Vallabhnagar ST stand	700	6700
Vallabhnagar ST stand - Vallabhnagar ESR	600	92
Junction 17 - Nehrunagar ESR	600	107
Chainage 600 - Swapnanagar ESR	400	182
Distribution Network main line	200	
Distribution Network submain line	100	

Table -3: Input Data for the pumps

Details	Units	WTP Pump
Discharge	m3/h	1710
Head	m	19
Pumping hours	hours	20-21.5
Power	Hp	150
Frequency	rpm	985
No of pumps	NOs	20 (for study 2+1)

Step 3: Construction of Model.

The model is constructed using WaterGEMS software by giving all the necessary inputs as mentioned in step no.2. Figure 1. shows the constructed model of the water supply network from WTP, Nigdi to the ESRs mentioned in the study area and figure 2. shows the zoomed in image of the constructed model of water distribution system of Swapnanagar ESR.

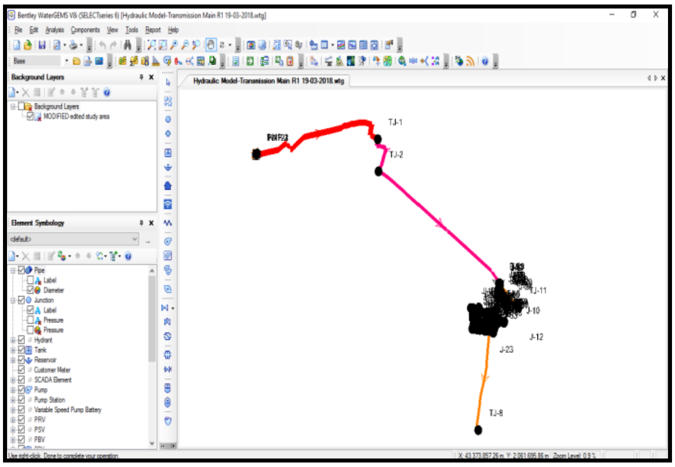


Fig -1: Constructed model of the network

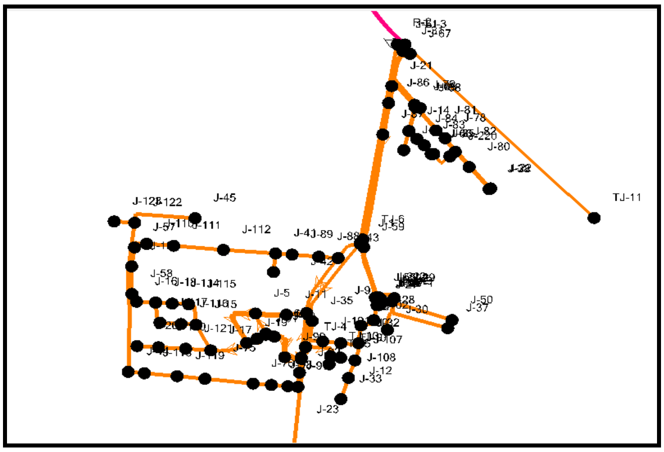


Fig -2: Constructed model of the distribution network

Step 4: Identification of Critical Points.

A color coding is specified for several ranges of pressure heads at the junctions before obtaining the results. The color coding will help to understand the difference in pressure range at various junctions. The figure 3 and figure 4 show the model after hydraulic run in WaterGEMS.

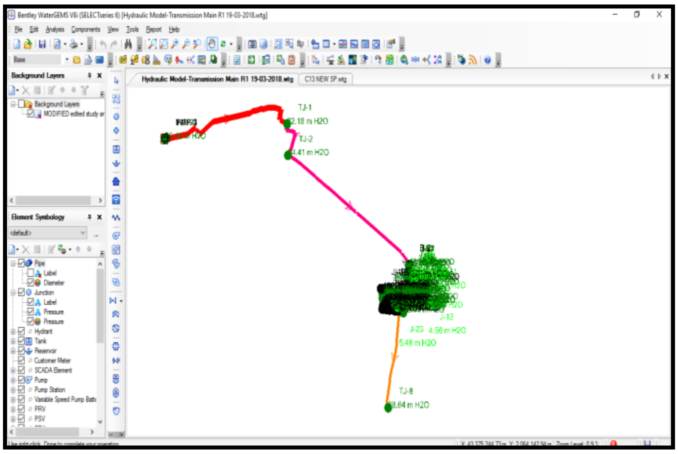


Fig -3: Model after hydraulic run

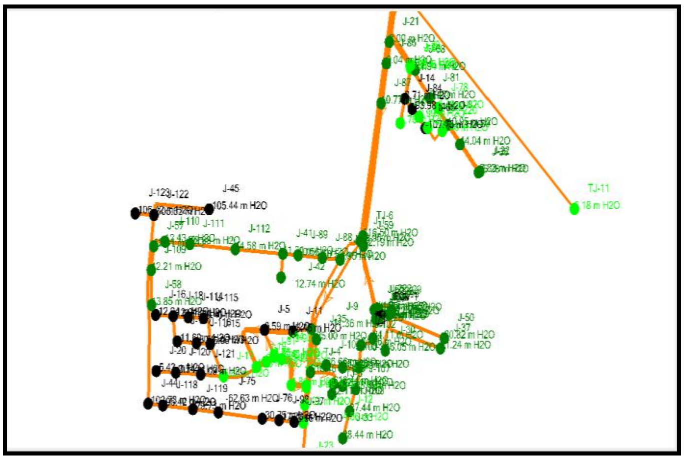


Fig -4: Model of distribution network after hydraulic run

In the figure 4, the black color nodes denote the critical points in the distribution network with pressure below 3m of H_2O while the nodes in the light green and dark green color have pressure heads between 3m-7m of H_2O and above 7m of H_2O respectively.

Step 5: Assessment of Hydraulic Model

There are total 102 nodes in the model, out of which 25 nodes receive water with less than or equal to 3m pressure head of H_2O which is inadequate. It is observed that the pipe capacity is insufficient to convey water with the required pressure. To maintain the pressure head at those nodes parallel pipes are added in the network.

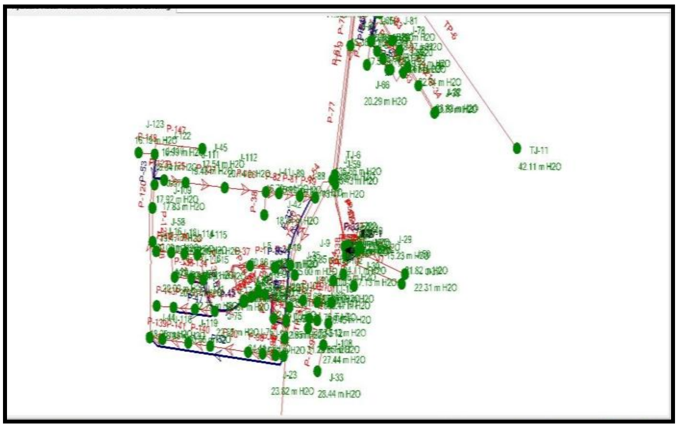


Fig -5: Model of distribution network after addition of parallel pipes

After inserting the parallel pipes in the system, the model showed adequate pressures at all the nodes. Figure 5 shows the network with parallel pipes and dark green color at every node indicates adequate pressure which is above 7m pressure head of H_2O. The parallel pipes of diameters such as 100 and 200 mm are introduced in the network at the necessary sections. The total length of additional pipes is 1846 m.

5. RESULTS

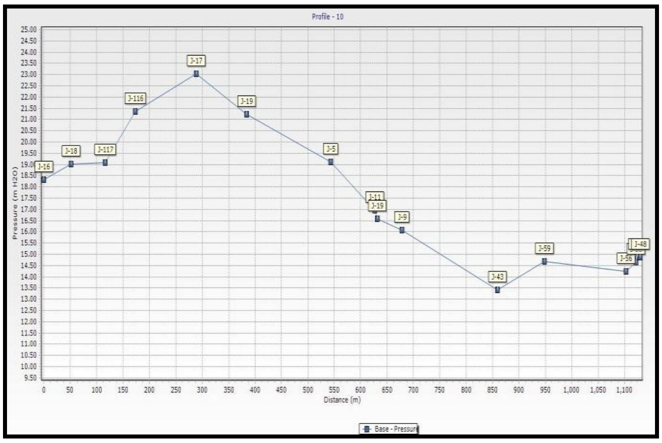


Chart -1: Pressure Profile of water distribution network

The chart 1 shows the pressure profile of the junctions in the distribution system ahead of ESR at Swapnanagar after adding the parallel pipes.

In the above profile there is variation in pressure head, but all are in the adequate range i.e. 7m to 23 m of H_2O. Table 4 shows the pressure head at some of the junctions after modifications in the network. It is evident from the result table that after introducing parallel pipes sufficient pressure can be obtained in the network at every junction.

Table -4: Results of pressure head at the junctions

ID	Label	Elevation (m)	Pressure (m H_2O)
1	J-5	583.56	19.15
2	J-9	586.58	16
3	J-10	582.66	20.76
4	J-11	585.71	17.71
5	J-16	584.33	18.46
6	J-17	579.6	23
7	J-18	583.66	19
8	J-19	581.41	21.19
9	J-43	589.26	15.17
10	J-48	587.8	16.63
11	J-56	588.43	15.99
12	J-59	588	14.83
13	J-116	581.28	21.43
14	J-117	583.58	19.23

6. CONCLUSION

It is observed that insufficient pressures in some of the junctions in the distribution network occur due to inadequacy of pipe. Adequate pressures can be obtained by adding parallel pipes of equivalent diameters or replacing the pipe with higher diameters. Adding parallel pipes can be more feasible as the older pipes can be retained in the network and the network can be improved with new pipes.

Replacing the older pipes can cause difficulties for the users as water supply is cut off and higher costs are likely to incur.

There can be certain limitations to modelling due input data inaccuracy, C value of pipe and unaccounted population due to prevailing slum areas.

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