Hydraulic Modelling for Equating the Uneven Pressure of Elevated Service Reservoir

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***Abstract*— A water distribution network is a necessary infrastructure for the supply of water but also to maintaining the pressure in that system is also important. Hydraulic models are efficient decision-support tools for the effective management of water distribution networks. It connects consumers to sources of water using hydraulic components such as pipes, valves, pumps and tanks. In the present study, the water distribution network of the Aurangabad zone-B area on the east side of the city has 18 existing ESRs, which are analyzed and designed with help of Bentleys WATERGEMS software. This analysis reveals the scenario computed about the conduit pressure, flow characteristics as discharge, velocity, pressure head and head-loss and so on. The pressure in network nodes is identified to be higher at some ESRs than the standard requirement. Aurangabad Municipal Corporation at present, have not employed any means to measure pressure head at ESR on a regular or at an interval to check water inflow. As complexity in the distribution system is more and manual valve operation is too to create uneven pressure in a pipe. Due to this will create tremendous pressure on the surface of the pipe that can cause pipe bursting, cracks, leakages, water losses that cause to non-revenue to a municipality, etc. The Project focuses on the study of the identification of locations/spots with uneven supply pressure, reducing the unnecessary diversion of water flow, period of filling ESRs is also matching so that water can be evenly distributed in a specific time. Water distribution networks are designed to minimize the overall cost while meeting the water demand requirements at adequate/equal pressures at ESR by changing the valve opening to the same to reduce unnecessary controlling and make the network more economical, and more sustainable, to achieve these objectives we have planned this project.**

***Index Terms*— Bursting; Cost; Diversion of water; Economical; ESR; Equal Pressure; Hydraulic Modelling; Leakages; Non-revenue; Pressure Head; Time to fill ESR; Uneven pressure; Valve; WaterGEMS; Water loss; Sustainable.**

1. INTRODUCTION

1.1 General Information

Hydraulic models of water distribution networks (WDNs) are efficient decision support tools for the development of various management scenarios to improve the efficiency and reliability of existing networks and to optimize and design new ones. It is composed of a different set of pipes, hydraulic devices and storage reservoirs. The main objective of the water supply system is to provide the system with the cheapest cost but it is for the consumer what about the providing municipality or another provider? However, not every drop of water generated hits consumers and produces income for municipalities but we can reduce it by doing some changes in operations in the system. A good water distribution network should meet the following requirements (I) Water quality should not deteriorate in the system; (ii) Every consumer should get sufficient water at desired pressure; (iii) The design and layout should be economical; (iv) The system should meet fire demand; (v) It must afford easy maintainability, and (vi) Deliver water of correct quality and quantity continuously with minimum service interruptions. But when we see it in practical work it isn't, especially in developing countries like

India, the gap in supply and demand of water is increasing and predominant. As same in Aurangabad city the existing system of water supply system facing abnormal conditions such as pipe breakage, mechanical failure of pipes, valves, and control systems, power outages, low pressure and inaccurate demand projections. In the city, a new WSS is under construction and we choose to optimize it to get each drop of water to be utilized. Aurangabad is considered as developing city so water demand is continuously increasing but improperly as newly emerging areas have low populations and future demand will be difficult to calculate. The design period of the new WSS is as Present 2022, Intermediate 2037 and Ultimate 2052. As per collected data from DPR city needs now 317MLD water in 2022, 450MLD in 2037 and it goes to 610MLD by the year 2052, so to have proper distribution conditions mentioned above must be reduced as much also at present most of the city area gets the water once in a week even after having one of the largest dams as a source.

To tackle problems we decided to study the new Water Supply Scheme of the water distribution network by Bentleys WaterGEMS software hence it will be helpful to know the gap of water to be in distribution. Design and analysis of water distribution network using WaterGems Connect software foundto be user friendly and it has a graphical interface which facilitates analyses more effectively and also, lesser time is required to reanalyze the network.

1.2 Problems in Area

As there is new water supply scheme is continued to be executed, a large number of diameter pipes are used to convey water through it with a different number of diameter pipes at different zones of the city, as the topography of the city is very uneven to be placed it as somewhat straight. As of now, the practice is that if one ESR is filled then the man (valve operator) closes the valve and diverts the water to the next ESR due to this operation,

(1) Unnecessary friction is generated in the pipe and also pressure reduces as a result of this increasing and decreasing pressure in the pipe, bursting of pipe is common and leakages in pipes result in wastage of water.

(2) Variation in pressure will be more in the case of this operation.

(3) The water supply network is maintained at positive pressure to ensure that water reaches all parts of the network but as a result, this uneven operation of the valve to divert flow when ESR is full, cause a negative pressure to that node and chances of damages in pipe and failure in the system will be there.

1.3 Objectives

By analyzing the network we found that there is a tremendous negative pressure generated at the node when the valve closes and an uneven pressure head at ESR that causes the filling time of ESR. So our objectives are,

1) To study these uneven pressure differences at existing ESRs to reduce and equate them to the same by using an operating valve in WaterGEMS software.
2) To minimize the operational cost of human operation and avoid mistakes of it.
3) To give proper water supply to the consumer.
4) Whatever system they make, they didn't tell whatever pressure they getting, and that's why we give them how they can get equitable pressure.
5) By doing this, we make it economical, more sustainable, reduce unnecessary controlling of the valve, cost saving and reduce manpower.

2. SYSTEM DEVELOPMENT

2.1 Study Area

Aurangabad Municipal Council (AMC) is one the oldest Municipal Councils established in 1982. The town is geographically situated in between the geographic coordinates of DMS latitude 19^0 54’ 3.7944” N and DMS longitude 75° 21' 8.9208" E. System maps of the Aurangabad city have been collected from DPR. These maps helped to make an understanding of the water distribution networks of the city. The maps illustrate a wide range of system characteristics of Aurangabad city such as pipeline diameter, length & alignment, elevations of nodes, location of tanks, reservoirs and valves, Population as per design period, demands, etc. The primary network (transmission main from MBR to the various service tanks in different zones) is obtained from the DPR shown in the figure,

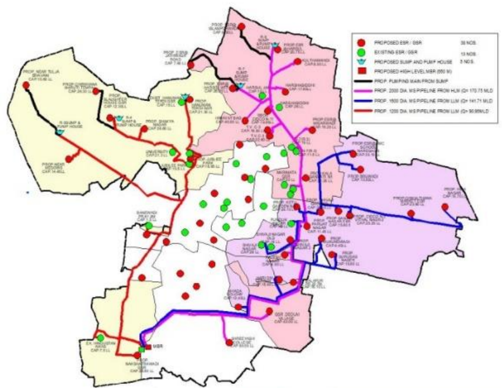

Fig. 1: Elevated Service Reservoirs and Rising Mains

Eventually, ESR located on the eastern side of the city covering CIDCO, Chikalthana and the surrounding area, havinghigher elevations were suffers till the year 2003. Rising mains feeding to this area's service tanks is a 2000mm diameter pipeline that is designed to move larger quantities of pure water by gravity from the MBR. So we decided to choose this as our study area to overcome upcoming problems.

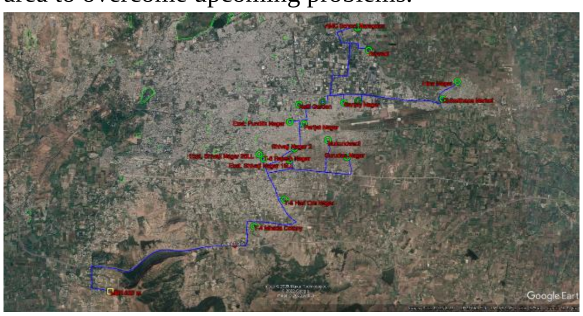

Figure: Study Area

The area we selected are having 18 ESR, and from them, three are existing at full capacity. The population of this area is 7, 57,372 in 2052, 5, 69,354 in 2037 and 3, 94,368 in 2022. It has the biggest diameter of rising main feeding to this Zone-6. It's an Easter part of the city and the water in the rising main are come to a Low-Level MBR that has a capacity of 5ML and with FSL at RL of 632m. Mostly this area has fewer undulations than other areas of the city.

2.2 WORKING OF EXISTING WATER DISTRIBUTION SYSTEM

Godavari River flows through nearly this city and has a Jayakwadi dam over it with an LSL of 446m it is one of the longest earthen dams in Asia feeding water to the city. Aurangabad city is located on the North side of it and the WTP and MBRs at Nakshatrawadi which has been the main sourceof water distribution for the city for decades. The raw water is taken from river Godavari by an intake well located left side of the dam. The existing Pure Water Rising Main with strengthening will be capable of catering 100 MLD demand of the city. For the balance demand of 504.86 MLD two new lines of 1932 mm and 1528 mm are proposed.

Approximately in the existing system, a 967 km network mostly comprises AC, CI, and PVCpipes laid for more than 30 years. In the proposed scheme, a 1911 km network comprising HDPE pipes up to 200 mm diameter oflength 1727.50 km and for 250 mm and above DI pipeline of 183.55 Km.

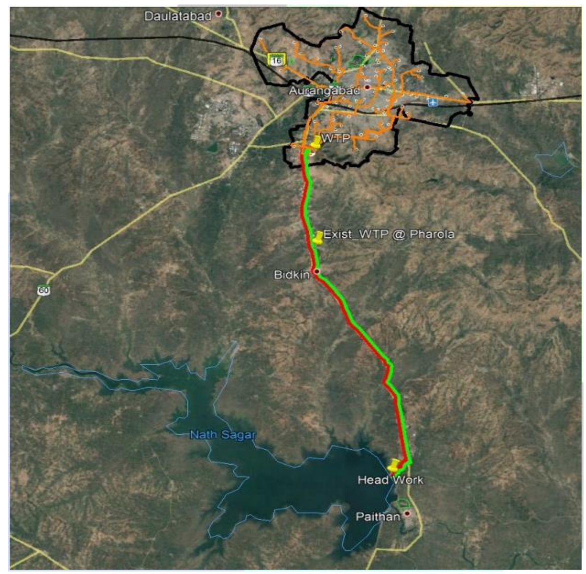

Fig. 2: Flow of water from the intake to the treatment plant

3. METHODOLOGY

Modelling the water supply system is a critical part of designing and operating water networks.It helps the distribution system to serve the community reliably, safely and efficiently in daily operations. Hydraulic models give commanding knowledge of the water infrastructure and help to make informed decisions. To proceed with the work to be carried out, we have carried out the following steps firstly we discussed with various experts related to the field of water supply then for WaterGEMS software work discussed with the software Ex. Deputy Engineer MJP Paithankar sir & we have attended basic hands-on training under them. We were directed by him about the proper way to the better result for the project.

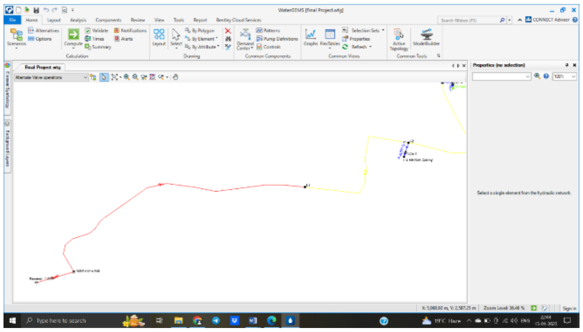

Fig. 3**:** Physical component in a Water distribution system

Getting an AutoCAD file in .dxf format in WaterGEMS. This file contains essentially all of the information needed to run the model like locations of tanks, intermediate nodes, demand nodes and pipeline alignment of the study area. WaterGEMS models a water distribution system as a collection of links connected to nodes. The links represent pipes, pumps, and control valves. The end nodes represent ESR, tanks, and reservoirs. Figure 5 above, illustrates how these objects can be connected to form a network.

Steps to run the model for analyzing the existing water distribution system using WaterGEMS:

1. Tracing of existing network on WaterGEMS by putting AutoCAD file on background;
2. Color coding the network on the bases of the diameter of the pipe;
3. Insert Throttle Control Valve;
4. Inserting elevation at each junction, Valve, Tank and Reservoir;
5. Inserting Length and diameter of the pipe;
6. Making scenarios;
7. Inserting demands according to scenarios i.e.2022, 2037 & 2052;
8. Changing Valve Relative closure until we get the required pressure head at ESR;
9. Validate and simulate the program.

After running the model successfully, the software computes the Head Losses (Mt.), the flow (Liter/sec), and velocities (Mt. /sec) in each pipe and the pressure (m H2O), Pressure Head (Mt.) and Hydraulic Grade (Mt.) in each node. This validation and computation are done for every scenario separately as their properties are different.

The base scenario is separated into various child scenarios by making inactive elements of other zones and making active elements of the zones that are considered separate child scenarios as shown in Figure,

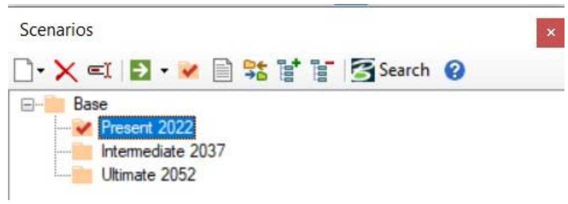

Fig. 4: Scenario

After computing successfully, the flux table of the pipe and junction is studied.

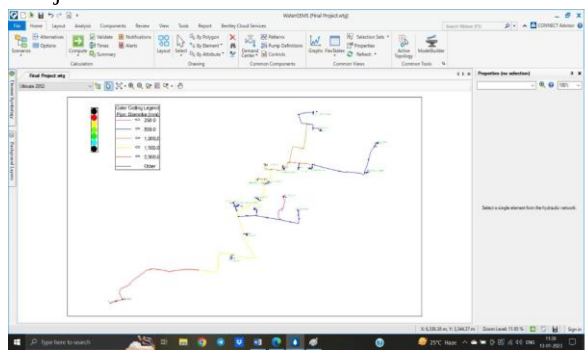

Fig. 5: Final Model

4. RESULT AND DISCUSSION

The network was analyzed using the Water GEMS program based on two scenarios, through which they were compared, and the optimal scenario was found based on the proposals, and conclusions were approved as follows, the primary network is checked for the demand of 2022, 2037 and 2052.

4.1 Study of Pipe

The software takes into considerations of the elevation, contour, demands, pipe material and other parameters. In the given network D.I. pipes and M.S. pipes are used and the different colors of pipe show in different diameters. There are 58 pipes in the system. The material of main pipe is M.S. while distributary pipes are D.I. pipes and the Hazen-Williams C is 140 and 130 respectively. The length of pipes has variations form a minimum of 34Mt. to 4621Mt. having total length of the network as 33,190Mt. The pipe diameter were in a range of 250mm to 2000mm having a circular shape.

The flow in the conduits was ranging from 15 liter/sec. to 1781 Liter/sec. The velocity varies from 0.3 Mt. /sec. to 1.79 Mt. /sec. at the Base scenario when valves are open and the flow in the conduits was ranging from 14 liter/sec. to 1781 Liter/sec. The velocity varies from 0.29 Mt. /sec. to 1.79 Mt. /sec when valves opening are closed according to to achieve head. This shows that unwanted flow is there that can be reduced if we control valve operation and keep it as it is without man operated.

4.2 Junctions Result

The input parameters of the junction are elevation and demand. By computing the network the software generates simulated values of pressure and hydraulic grade. In the system, the coverage area of zone-6 waterworks is very high, so that at starting junctions the pressure picks a high of 17.78 m H_2O, but as the distance from the waterworks increases the pressure lowers down to a low of 2.73 m H_2O. It shows that the quantity of water in delivery by the system has vast variations and the distribution is not equal. The simulated results were verified by the process of validation discussed in an earlier section of the paper. The junctions (ESR) had a variation of elevation ranging from a minimum of 599 Mt. to a high of 621.79 Mt. depending on the natural topography of the network-covered area. The demands in the system at various junctions were in a range of 46 Liter/sec. to 176.330 Liter/sec. based on the service population. The demands were matched through the computation of hydraulic grades that were in a reflective range of 611.27 Mt. to 625.57 Mt with pressure variations as mentioned above.

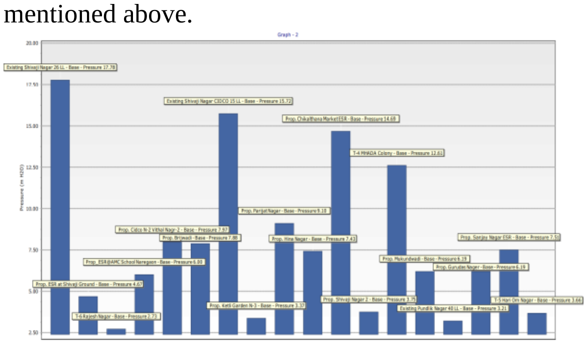

Fig. 6 (a): Pressure Head before Optimization

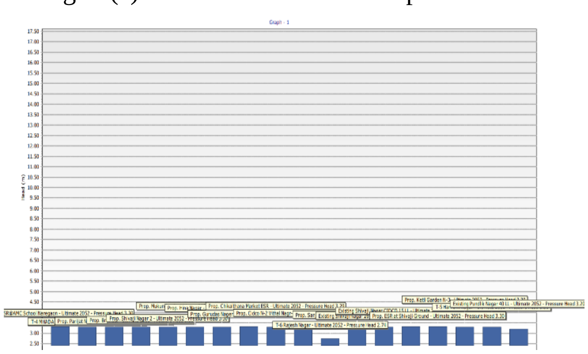

Fig. 6 (b): Pressure Head after Optimization

As seen below results in table 6.2 (a) and (b) & Figure 6.1 (a) and (b) pressure head is gone above 15m is not mostly required head, but we can manage it by reducing it without affecting the demand. Now, we have done valve operation to maintain the same pressure head at each ESR and it ranges from 2.74m to 3.46m, Result in reducing extra burden in the pipe and wastage of water

Study of Problems in operation as above,

1. Each ESR is getting an uneven pressure head, due to which each ESR fill in uneven timing after fulfilling ESR, water has to divert to other ESR, so that 'Q' already designed for a particular pipeline may be double or more than this.
2. They may be laid to the chances of leakages due to these leakages in some period there will be chances of the bursting of a pipe, reduction in life of pipe and distribution

Network and reduction in ‘c’ valve cause the internal surface of the pipe rough and increase to friction and lossin the smooth surface.

4.3 Valve Result

Butterfly valves are used to regulate and stop the flow, especially in large-size conduits. They are sometimes cheaper than sluice valves for larger sizes and occupy less space. Butterfly valves with no sliding parts have the advantages of ease of operation, compact in size, reduced chamber or valve houses and improved closing and retarding characteristics. The valve used here are Butterfly Valve, and their Closure with initial closure is mentioned below,

According to the results shown in Figure 6.2, it is seen that there is a lot of difference between the closure of the valve that will affect the pressure and discharge of the pipe at a junction (ESR).

To avoid this we have to equate the pressure by using existing operation only, which is at minimum cost and whatever the minor specific pressure difference is there, we can control it using SCADA controlling and using PCV.

Alternative: Initial Settings

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Label	Element Type	Field	Unit	Value Base	Value Ultimate 2052
TCV-1	TCV	Relative Closure (Initial)	%	0.00	84.95
TCV-2	TCV	Relative Closure (Initial)	%	0.00	60.00
TCV-3	TCV	Relative Closure (Initial)	%	0.00	89.90
TCV-4	TCV	Relative Closure (Initial)	%	0.00	83.50
TCV-6	TCV	Relative Closure (Initial)	%	0.00	92.68
TCV-7	TCV	Relative Closure (Initial)	%	0.00	78.45
TCV-8	TCV	Relative Closure (Initial)	%	0.00	75.00
TCV-9	TCV	Relative Closure (Initial)	%	0.00	86.70
TCV-12	TCV	Relative Closure (Initial)	%	0.00	62.50
TCV-13	TCV	Relative Closure (Initial)	%	0.00	82.70
TCV-14	TCV	Relative Closure (Initial)	%	0.00	77.80
TCV-15	TCV	Relative Closure (Initial)	%	0.00	83.30
TCV-16	TCV	Relative Closure (Initial)	%	0.00	82.60
TCV-17	TCV	Relative Closure (Initial)	%	0.00	82.80
TCV-18	TCV	Relative Closure (Initial)	%	0.00	70.00

Final Project.wtg
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Fig. 7: Valve Closure Difference in %

By doing this, unnecessary diversion of flow to another pipe may be avoided due to this cost of the establishment will reduce. Not only the cost of establishment but the time is also matched, so that water can be evenly distributed in a specific time. Now they do this manually, if get some error while doing valve operation in closing and opening can cause the bursting of the pipe suddenly.

5. CONCLUSION

For this study area of i.e. zone B of Aurangabad city, the software Bentley WaterGems connect has been used and it helped in analyzing the entire network system and visualizing the effects of constituent components and parameters. It was found that

a. The pressure head at the junction is detected as high, as compared to its economical valve and can be reduced to the required value at the Ultimate stage (2052) without hampering the demand.
b. The effect of valve operation in the network led to an improvement in the current network pressures' performance, where the minimum pressure was (2.73 m), and the maximum pressure was (17.81 m).
c. To improve the field results, it recommended putting a flow control valve with a fixed closure in the nodes to represent the same pressure head simultaneously for different nodes. Also, actuators are to be provided at the valve to control the remaining variation in the head during the design period.
d. Also reduction in friction and maintain the pressure during all times to fulfil the capacity of ESR.
e. Loss of water is also reduced as the pressure at the backside of it will be high if valve operation isdone manually causing high pressure in a pipe.
f. Reduction in required manpower reduces the burden on the department and cost savings.
g. Timely filling of ESRs will result in the same timing of the water conveyed to the consumer.
h. Strategy, which would help Aurangabad Municipal Council (AMC) to design the pipe network of the distribution system of the city to allow AMC to achieve continuous (24X7) water supply.

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