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STUDY OF WATER DISTRIBUTION NETWORK USING EPANET

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Abstract: ***Pipe network analysis is the fluid flow through a hydraulics network containing several or many inter connected branches whose aim is to determine the flow rates and pressure drops in the individual sections of the network. Classical approach for automatically solving the problems of network is by using specialized software such as EPANET. The purpose of this study is to assess the performance of Limbayat zone water supply scheme using hydraulic simulation software and to address any improvements required to existing infrastructure and/or the mode of operation, in order to improve quantity and quality of water distributed to the consumers. As, Limbayat zone is facing water scarcity problem. The reason behind this scarcity is the pressure fluctuation. There is large variation in pressure head and the pressure supplied is not sufficient to fulfil the requirement of water demand of Limbayat zone. There may be leakages in the pipes which results in the pressure difference which consequently results into the scarcity of water.***

Keywords: **EPANET, Pipe flow, Pipe Network, Simulation, Water Demand.**

I. INTRODUCTION

Water Distribution Networks (WDNs) serve many purposes in addition to the provision of water for human consumption, which often accounts for less than 2% of the total volume supplied. Piped water is used for washing, sanitation, irrigation and fire fighting. Networks are designed to meet peak demands; in parts of the network this creates low-flow conditions that can contribute to the deterioration of microbial and chemical water quality. The purpose of a system of pipes is to supply water at adequate pressure and flow. However, pressure is lost by the action of friction at the pipe wall. The pressure loss is also dependent on the water demand, pipe length, gradient and diameter. Several established empirical equations describe the pressure–flow relationship (Webber, 1971) and these have been incorporated into network modelling software packages to facilitate their solution and use. There is still not a convenient evaluation for the reliability of water distribution systems. Traditionally, a water distribution network design is based on the proposed street plan and the topography. Using commercial software, the modeller simulates flows and pressures in the network and flows in and out to/from the tank for essential loadings.

Water distribution networks play an important role in modern societies being its proper operation directly related to the population's well-being. However, water supply activities tend to be natural monopolies, so to guarantee good service levels in a sustainable way the water supply systems performance must be evaluated. The incorporation of performance assessment methodologies in the management practices creates competitiveness mechanisms that lead to the culture of efficiency and the pursuit of continuous improvement.

The primary task for water utilities is to deliver water of the required quantity to individual customers under sufficient pressure through a distribution network. The distribution of drinking water in distribution networks is technical challenge both in quantitative and qualitative terms. It is essential that each point of the distribution network be supplied without an invariable flow of water complying with all the qualitative and quantitative parameters. The water supply in most Indian cities is only available for a few hours per day, pressure is irregular, and the water is of questionable quality. Intermittent water supply, insufficient pressure and unpredictable service impose both financial and health costs on Indian households. Leakage hotspots are assumed to exist at the model nodes identified. For this study area Limbayat Zone of Surat City has been identified and the network model for the area under consideration will be prepared and studied for water losses.

II. OBJECTIVE

To analyse the existing water distribution system using EPANET and to suggest some measures if present network does not fulfil the present and future demand.

III. STUDY AREA

Limbayat zone is a part of surat city. Limbayat zone occurs in the south-east zone of surat. Limbayat zone covers the following villages under the water distribution system:-

- Dindoli
- Gamtal-Dindoli
- Parvatgoda
- Godadragamtal
- Parvatgamtal

The population of study area according to 2011 census is 1, 22,560. The study area covers residential area about 882.9 ha.

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Figure 1- Map of Limbayat Zone

(Source: Surat Municipal Corporation)

The water distribution system of Limbayat zone i.e. WDS-1 consists of following 3 network systems:-

1. ESR-SE-1
2. ESR-SE-2
3. ESR-SE-3

IV. EPANET SOFTWARE

EPANET is a computer program that performs extended period simulation of hydraulic and water quality behaviour within pressurized pipe networks. A network consists of pipes, nodes (pipe junctions), pumps, valves and storage tanks or reservoirs. EPANET tracks the flow of water in each pipe, the pressure at each node, the height of water in each tank, and the concentration of a chemical species throughout the network during a simulation period comprised of multiple time steps. In addition to chemical species, water age and source tracing can also be simulated.

EPANET was developed by the water supply and water resources division (formerly the drinking water research division) of the U.S Environmental protection agency's national risk management research laboratory. It is public domain software that may be freely copied and distributed.

EPANET is designed to be a research tool for improving our understanding of the movement and fate of drinking water constituents within distribution systems. It can be used for many different kinds of applications in distribution systems analysis. Sampling program design, hydraulic model calibration, chlorine residual analysis, and consumer exposure assessment are some examples. EPANET can help assess alternative management strategies for improving water quality throughout a system.

Running under windows, EPANET provides an integrated environment for editing network input data, running hydraulic and water quality simulations, and viewing the results in a variety of formats. These include color-coded network maps, data tables, time series graphs, and contour plots.

V. HYDRAULIC MODELLING CAPABILITIES

Full-featured and accurate hydraulic modelling is a prerequisite for doing effective water quality modelling. EPANET contains a state-of-the-art hydraulic analysis engine that includes the following capabilities:

1. places no limit on the size of the network that can be analysed
2. computes friction head loss using the Hazen-William, Darcy-Weisbach or Chezy-Manning formula
3. Includes minor head losses for bends, fittings, etc.
4. models constant or variable speed pumps
5. computes pumping energy and cost
6. models various types of valves including shutoff, check, pressure regulating, and flow control valves
7. allows storage tanks to have any shape (i.e., diameter can vary with height)
8. considers multiple demand categories at nodes, each with its own pattern of time variation
9. models pressure-dependent flow issuing from emitters (sprinkler heads)
10. Can perform system operation on both simple tank level and timer controls and on complex rule-based controls.

EPANET's Windows user interface provides a network editor that simplifies the process of building piping network models and editing their properties. Various data reporting and visualization tools such as graphical views, tabular views, and special reports, and calibration are used to assist in interpreting the results of a network analysis (EPA, 2000).

By employing these features, EPANET can study water quality phenomena as:

- blending water from different sources
- Age of water throughout a system
- Loss of chlorine residuals.
- Growth of disinfection by-products.
- Tracking contaminant propagation events.

- **Model Input Data**

In order to analyze the WDN using EPANET following input data files are needed:

1. Junction Report

Junctions are points in the network where links join together and where water enters or leaves the network.

The basic input data required for junctions are:

1. Elevation above some reference (usually mean sea level)

2. Water demand (rate of withdrawal from the network)
3. Initial water quality.

The output results computed for junctions at all time periods of a simulation are:

1. Hydraulic head (internal energy per unit weight of fluid)
2. Pressure
3. Water quality.

Junctions can also:

- Have their demand vary with time
- Have multiple categories of demands assigned to them
- have negative demands indicating that water is entering the network
- be water quality sources where constituents enter the network
- Contain emitters (or sprinklers) which make the outflow rate depend on the pressure.

2. Pipe Report

Pipes are links that convey water from one point in the network to another. EPANET assumes that all pipes are full at all times. Flow direction is from the end at higher hydraulic head (internal energy per weight of water) to that at lower head.

The principal hydraulic input parameters for pipes are:

1. start and end nodes
2. diameter
3. length
4. roughness coefficient (for determining headloss)
5. Status (open, closed, or contains a check valve).

Computed outputs for pipes include:

1. flow rate
2. velocity
3. headloss
4. Darcy-Weisbach friction factor
5. average reaction rate (over the pipe length)
6. Average water quality (over the pipe length).

The hydraulic head lost by water flowing in a pipe due to friction with the pipe walls can be computed using one of three different formulas:

1. Hazen-Williams formula
2. Darcy-Weisbach formula
3. Chezy-Manning formula

The Hazen-Williams formula is the most commonly used headloss formula in the US. It cannot be used for liquids other than water and was originally developed for turbulent flow only. The Darcy-Weisbach formula is the most theoretically correct. It applies over all flow regimes and to all liquids. The Chezy-Manning formula is more commonly used for open channel flow.

Each formula uses the following equation to compute headloss between the start and end node of the pipe:

$$h_L = Aq^B$$

Where, h_L= headloss (Length), q = flow rate (Volume/Time), A = resistance coefficient, and B = flow exponent. Table 1 lists expressions for the resistance coefficient and values for the flow exponent for each of the formulas. Each formula uses a different pipe roughness coefficient that must be determined empirically.

TABLE 1- PIPE HEADLOSS FORMULA'S FOR FULL FLOW

Formula	*Resistance coefficient (a)*	*Flow exponent (b)*
Hazen-Williams	$4.727c^{-1.852}d^{-4.781}l$	1.852
Darcy-Weisbach	$0.0252f(\varepsilon,d,q)d^{-5}l$	2
Chezy-Manning	$4.66n^{2}d^{-5.33}l$	2

Notes:
c = Hazen-Williams roughness coefficient
ε = Darcy-Weisbach roughness coefficient (ft)
f = friction factor (dependent on ε, d, and q)
n = Manning roughness coefficient
d = pipe diameter (ft)
L = pipe length (ft)
q = flow rate (cfs)

Pipes can be set open or closed at preset times or when specific conditions exist, such as when tank levels fall below or above certain set points, or when nodal pressures fall below or above certain values.

VI. METHODOLOGY

Following are the steps carried out to model water distribution network using EPANET.

Step 1: Draw a network representation of distribution system or import a basic description of the network placed in a text file.

Step 2: Edit the properties of the objects that make up the system. It includes editing the properties and entering required data in various objects like reservoir, pipes, nodes and junctions.

Step 3: Describe how the system is operated.

Step 4: Select a set of analysis option.

Step 5: Run a hydraulic/water quality analysis

Step 6: View the results of the analysis which can be viewed in various form i.e. in form of tables and graphs.

Step 7: Repeat the procedure for two other distribution networks i.e. WDS ESR-SE-1 and WDS ESR-SE-2.

VII. RESULTS AND DISCUSSION

After collecting data of three distribution networks of Limbayat zone pressure, flow and velocity have been computed using EPANET and by following methodology described, results by EPANET are obtained. Analysis of results has been carried out and error between computed results and actual results are compared for junction as well as pipe report of three distribution networks namely:

1. WDS ESR-SE-1
2. WDS ESR-SE-2
3. WDS ESR-SE-3

1. WDS ESR-SE-1

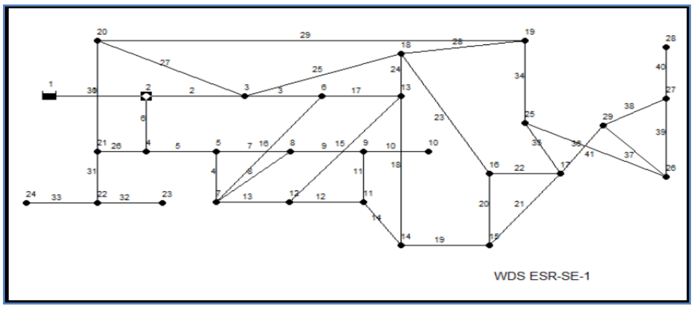

Figure 2- Network Diagram of WDS ESR-SE-1

➢ **Junction Report**

It includes 29 junctions. The result obtained using EPANET software for WDS ESR-SE-1 is calculated. The error between actual pressure and the pressure computed using EPANET software is also compared.

Following are some of the findings of above study:-

- The pressure is computed using Hazen-William approach.
- For WDS-ESR-SE-1 j-2, j-3, j-4, j-5,j-6, j-7, j-8, j-9, j-10, j-11, j-12, j-13, j-14, j-15, j-16, j17,j-18, j-19, j-20, j-23, j-24, j-25, j-26, j-27, j-28, j-29 junction gives negative pressure.
- There is fluctuation in the pressure head.

➢ **Pipe Report**

Pipe report of WDS ESR-SE-1 includes 41 pipes. The result obtained using EPANET software for WDS ESR-SE-1 is presented. The error between actual flow and flow computed using EPANET software is compared. The error between actual headloss & headloss computed EPANET software is also compared.

Following are some of the findings of above study:

- The flow computed using EPANET is nearly equal to the actual flow.
- The velocity computed using EPANET is nearly equal to the actual velocity.
- The headloss computed using EPANET is nearly equal to the actual headloss.

2. WDS ESR-SE-2

➢ **Junction Report**

It includes 29 junctions. The result obtained using EPANET software for WDS ESR-SE-2 is calculated. The error between actual pressure and the pressure computed using EPANET software is also compared.

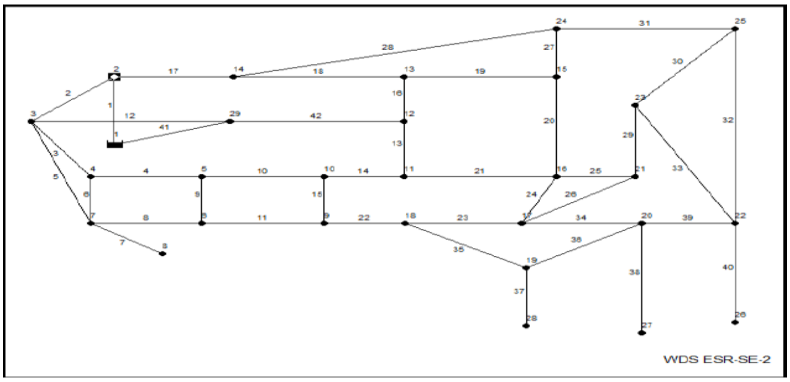

Figure 3- Network Diagram of WDS ESR-SE-2

Following are some of the findings of above study:

- The pressure is computed using Hazen-William approach.

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- For WDS-ESR-SE-1 j-5, j-6, j-7, j-8, j-9, j-10, j-11, j-12, j-13, j-14, j-15, j-16, j-17, j-18, j-19, j-20, j-21, j-22, j-23, j-24, j-25, j-26, j-27, j-28, j-29 junction gives negative pressure.
- There is fluctuation in the pressure Head

➢ **Pipe Report**

Pipe report of WDS ESR-SE-2 includes 42 pipes. The result obtained using EPANET software for WDS ESR-SE-2 is presented. The error between actual flow and flow computed using EPANET software is compared. The error between actual headloss & headloss computed EPANET software is also compared.

Following are some of the findings of above study:

- The flow computed using EPANET shows variation when compared to the actual flow. P-1, P-2, P-8, P-12, P-13, P-14, P-16, P-18, P-19, P-21, P-23, P-24, P- 25, P-27, P-29, P-30, P-33, P-34, P-36, P-39, P-41, P-42 pipes show negative flow.
- The velocity computed using EPANET shows variation when compared to the actual velocity. P-2, P-12, P-13, P-14, P-16, P-18, P-19, P-20, P-21, P-22, P 23, P-24, P-25, P-26, P-27, P-29, P-30, P-32, P-33, P-36, P-41, P-42 pipes have negative decreasing velocity of flow.
- The headloss computed using EPANET shows variation when compared to the actual headloss. P-2, P-4, P-5, P-6, P-8, P-9, P-10, P-11, P-12, P-13, P-14, P- 15, P-16, P-19, P-20, P-21, P-22, P-23, P-24, P-25, P-27, P-29, P-30, P-32, P- 33, P-34, P-36, P-39, P-41, P-42 shows negative and decreasing headloss gradient.

3. WDS ESR-SE-3

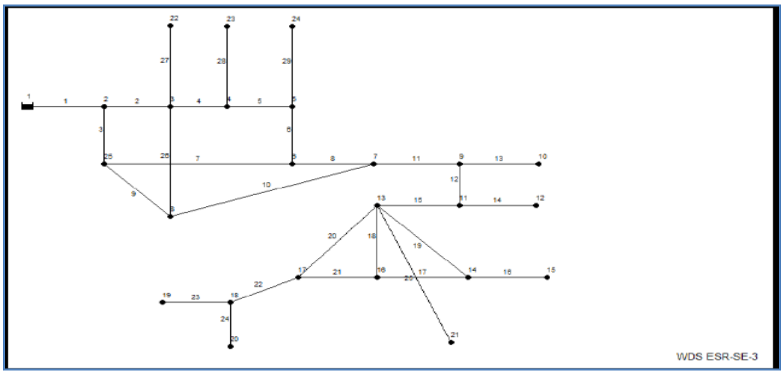

Figure 4- Network Diagram of WDS ESR-SE-3

➢ **Junction Report**

It includes 25 junctions. The result obtained using EPANET software for WDS ESR-SE-3 is calculated. The error between actual pressure and the pressure computed using EPANET software is also compared.

Following are some of the findings of above study:

- The pressure is computed using Hazen-William approach.
- For WDS-ESR-SE-1 J-2, J-3, J-5, J-6, J-8, J-9, J-12, J-13, J-14, J-16, J-17, J-19, J-20, J-21 junction gives negative pressure.
- There is fluctuation in the pressure head

➢ **Pipe Report**

Pipe report of WDS ESR-SE-3 includes 29 pipes. The result obtained using EPANET software for WDS ESR-SE-3 is presented. The error between actual flow and flow computed using EPANET software is compared. The error between actual headloss & headloss computed EPANET software is also compared.

Following are some of the findings of above study:

- The flow computed using EPANET is nearly equal to the actual flow.
- The velocity computed using EPANET is nearly equal to the actual velocity.
- The headloss computed using EPANET is nearly equal to the actual headloss.

VIII. CONCLUSIONS

- In this paper attempt has been made to develop a Water Distribution System using EPANET software a tool to assist the assessment of the hydraulic behaviour of water supply distribution network. After doing analysis of water distribution network of Limbayat zone, we can conclude that the flow & velocity of the water supplied to this zone is appropriate and there is no problem in the flow & supply of water. But still it is facing water scarcity problem. The reason behind this scarcity is the pressure fluctuation. There is large variation in pressure head.
- There may be leakages in the pipes which results in the pressure difference which consequently results into the scarcity of water.
- Comparison of these results indicates that the simulated model seems to be reasonably close to actual network.

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