e-ISSN: 2455-5703

Analysis of Continuous Water Distribution in Surat City using EPANET: A Case Study

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Abstract

The present study of 'Analysis of Continuous Water Distribution System in Surat City using EPANET software: A Case study' was carried out with a specific objective of effective planning, development of water distribution network and analysis using EPANET software. For this analysis the data for existing water distribution network was acquired from Surat Municipal Corporation and Multimedia Consultancy, Ahmedabad. The Google Earth Image of Surat City is downloaded and the elevation of node, length of pipe was recorded for nearly 214 junctions and 293 pipes. These data was used in EPANET software for analysis of pressure, head loss and elevation. This analysis resulted in pressure and elevation at various nodes and head loss at various pipes. Result of data analysis in software are compared with the actual data which will indicate that there is less head loss which is very essential for continuous pressure required for continuous water supply system in Surat City.
Keyword-Elevation, EPANET 2.0, Nodes, Pipe Network, Pressure, Water Supply

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I. INTRODUCTION

Water is the most precious gift of nature. It is most crucial for sustaining life and is required in almost all the activities of mankind i.e., domestic use, industrial use, for irrigation; to meet the growing food and fibre needs, power generation, navigation, recreation etc., and also required for animal consumption. The common source of water mainly comprises of Rain water, Surface water, Ground water and Water obtained from reclamation. The development, conservation and use of water form one of the main elements in country's development planning. It is necessary to adopt a new approach to design urban water supply networks; water shortages are expected in the forthcoming decades and environmental regulations for water utilization and waste-water disposal are increasingly stringent.

Water distribution systems consist of pipeline networks and associated components, most of which is underground and exposed to soil corrosion and mechanical stress from the surrounding soil, surface traffic, and internal water pressure. Pipe failure in water distribution systems disrupts the water supply to consumers and reduces the reliability of the system. It is found that about 10% to 15% of the supplied volume is wasted due to pipe leakages. Therefore, inspection, control and planned maintenance and rehabilitation programs are necessary to properly operate existing water distribution systems. 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. For this study area Punagam Zone of Surat City has been identified and the network model for the area under consideration will be prepared and studied for water losses.

A. Aim of the Study

To assess the performance of existing water distribution network of Punagam area of Surat city using hydraulic simulation i.e EPANET and to suggest some measures if present network does not fulfil the present and future demand.

B. Objective of Study

To study the existing water supply network
To collect pipe report and junction report
To analyse the data by using EPANET software
To check the pressure, elevation and head loss in existing network
To compare the analysed result with actual result

II. STUDY AREA

Surat is located on the western part of India in the state of Gujarat. It is one of the most dynamic cities of India with one of the fastest growth rate due to migration from various parts of Gujarat and other states of India. It has experienced a very rapid growth during the last 20 year with highest decadal growth rate of 47% (Census, 2001) and second highest population density after Ahmadabad due to its important location between Ahmadabad-Mumbai golden corridors. Piped water supply system for the Surat City was started first time in year 1894 and first water works was setup at Varachha. Initially water was supplied through surface water from the River Tapti. Gradually, other sources of water came in to existence as the need aroused with respect to population and industrial growth in the city. Main source of water for Surat is the river Tapi flowing through the city. Surface water is drawn by intake wells from perennial channel of the river throughout the year. Water thus drawn is treated by the water treatment plants and then the same is supplied to the citizens after post chlorination. In the year 2006 area of Surat city was increased from 12.28 km^2 to 326.51 km^2. Punagam area is a part of Surat city.

Punagam area is located in East zone of Surat. The population of study area is 2, 22,252. The study area covers residential area about 600.83 Ha. When the water from the distribution network reaches to the Punagam area there is sudden decrease in the pressure head due to which water related problems arises. Leakages, failure of pipes and other factors are there which affects the water distribution network. Therefore it's required to analyse the existing network of the Punagam area using EPANET and compared computed result with actual result which is obtained from Surat Municipal Corporation. The water distribution system of Punagam area i.e. WDS-E3 consists of following five network systems namely ESR-E7, ESR-E8, ESR-E9, ESR-E9A, ESR-E10.

Fig. 1: Map of Punagam Area, Surat City

III. OVERVIEW OF EPANET SOFTWARE

EPANET was developed by 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 a computer program that performs extended period simulation of hydraulic and water quality behavior 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 is designed to be a research tool for improving our understanding of the movement and fate of drinking water constituents within distribution systems. EPANET can help assess alternative management strategies for improving water quality throughout a system. These can include:

- Altering source utilization within multiple source systems,
- Altering pumping and tank filling/emptying schedules,
- Use of satellite treatment, such as re-chlorination at storage tanks,
- Targeted pipe cleaning and replacement.

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.

IV. HYDRAULIC MODELLING CAPABILITIES

Full-featured and accurate hydraulic modeling is a prerequisite for doing effective water quality modeling. 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 analyzed
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.

A. Model Input Parameters

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 Head-loss)
5) Status (open, closed, or contains a check valve)

Computed outputs for pipes include:

1) flow rate
2) velocity
3) Head-loss
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 head-loss 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 head-loss between the start and end node of the pipe:

$$h_L = Aq^B$$

Where, h_L= head-loss (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.

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	$4.66n^2d^{-5.33}L$	*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)*		

Table 1: Pipe Head-loss formula for full flow

Material	*Hazen Williams C*	*Darcy-Weisbach*	*Manning's*
Cast Iron	*130-140*	*0.85*	*0.012 – 0.015*
Concrete or Lined Concrete	*120-140*	*1.0-1.0*	*0.012 – 0.017*
Galvanized Iron	*120*	*0.5*	*0.015 – 0.017*
Plastic	*140-150*	*0.005*	*0.011 – 0.015*
Steel	*140-150*	*0.15*	*0.015 – 0.017*
Vitrified Clay	*110*		*0.013 – 0.015*

Table 2: Roughness Coefficient for new pipe

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.

V. METHODOLOGY

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

1) Step 1: Draw a network representation of distribution system or import a basic description of the network placed in a text file.
2) 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.
3) Step 3: Describe how the system is operated.
4) Step 4: Select a set of analysis option.
5) Step 5: Run a hydraulic/water quality analysis
6) Step 6: View the results of the analysis which can be viewed in various form i.e. in form of tables and graphs.
7) Step 7: Repeat the procedure for other distribution networks

VI. RESULT AND DISCUSSION

After collecting data of three distribution networks of Punagam 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 distribution network.

A. WDS-ESR-E7

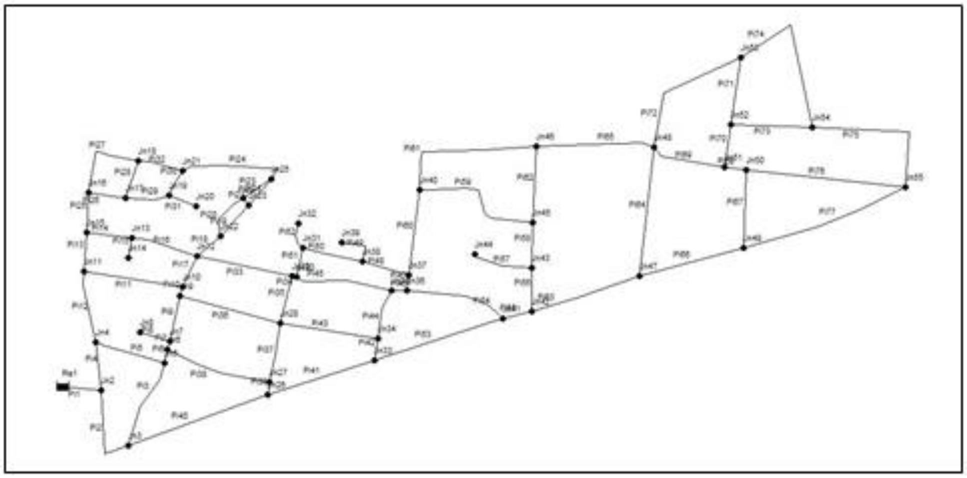

Fig. 2: Network Diagram of WDS ESR E7

1) Junction Report

It includes 55 junctions. The results obtained using EPANET software for WDS ESR E7 is calculated. The error between actual pressure and the pressure computed using software is also compared. Pressure profile for WDS ESR E7 is shown in Fig – 3.

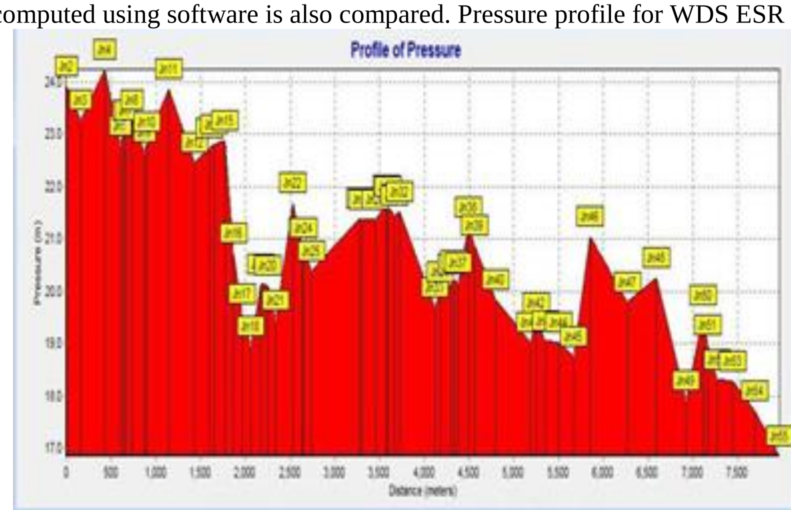

Fig. 3: Pressure profile of WDS ESR E7

Following are some finding of above study:

- The total numbers of junction are 55.
- The pressure is computed using Hazen-William approach.
- For WDS ESR E7 jn-2, jn-5, jn-9, jn-10, jn-11, jn-13, jn-14, jn-15, jn-16, jn-17, jn-18, jn-19, jn-20, jn-21, jn-22, jn-23, jn-24, jn-25, jn-29, jn-30, jn-33, jn-34, jn-39, jn-40, jn-45, jn-47, jn-49, jn-50, jn-51, jn-54, jn-55 junction gives negative pressure.
- There is fluctuation in the pressure head.

2) Pipe Report

Pipe report of WDS ESR E7 includes 77 pipes. The result obtained using EPANET software for WDS ESR E7 is presented. The error between actual flow and flow computed using software is also compared. The error between actual head-loss & head-loss computed EPANET software also compared.

Following are some of the findings of above study:

- Total numbers of pipes are 77.
- 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.

B. WDS-ESR-E8

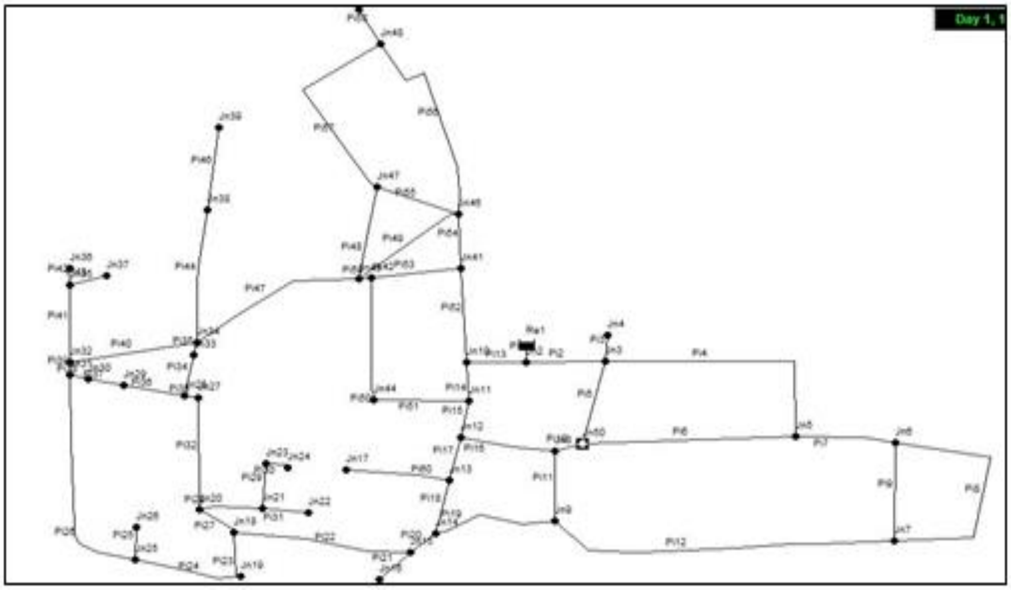

Fig. 4: Network Diagram of WDS ESR E8

1) Junction Report

It includes 50 junctions. The result obtained using EPANET is presented. The results obtained using EPANET software for WDS ESR E7 is calculated. The error between actual pressure and the pressure computed using software is also compared. Pressure profile for WDS ESR E8 is shown in Fig – 5

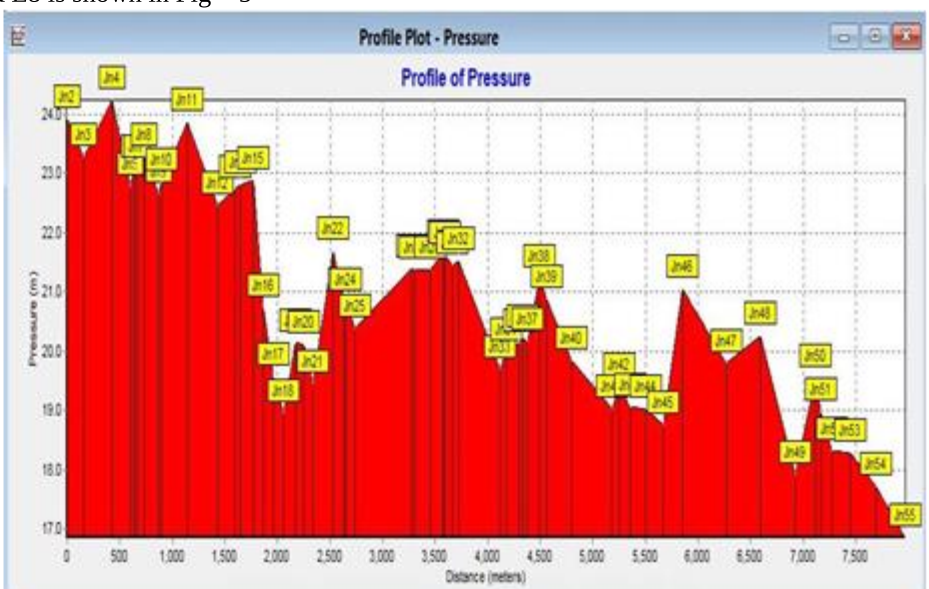

Fig. 5: Pressure profile of WDS ESR E8

Following are some finding of above study:

- The total numbers of junction are 50.
- The pressure is computed using Hazen-William approach.
- For WDS-ESR-E8 jn-2, jn-3, jn-4, jn-9, jn-11, jn-12, jn-13, jn-15, jn-20, jn-25, jn-26, jn-27, jn-28, jn-30, jn-31, jn-32, jn-33, jn-34, jn-39, jn-41, jn-44, jn-46, jn-47, jn-49 junction gives negative pressure.
- There is fluctuation in the pressure head.

2) Pipe Report

Pipe report of WDS ESR E8 includes 60 pipes. The result obtained using EPANET software for WDS ESR E8 is presented. The error between actual flow and flow computed using software is also compared. The error between actual head-loss & head-loss computed EPANET software also compared.

Following are some of the findings of above study:

- Total numbers of pipes are 60.
- 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 head-loss computed using EPANET is nearly equal to the actual head-loss.

VII. CONCLUSION

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 behavior of water supply distribution network. The main focus of this study is to analyze the water distribution network and identify deficiencies (if any) in its suitability, implementation and its usage. At the end of the analysis it was found that the resultant pressures at all the junctions and the flows with their velocities at all pipes are adequate enough to provide water within the study area. It was observed that the pipes connected to the tanks as distribution pipes to the other pipes have smaller diameters. Comparison of these results indicates that the simulated model seems to be reasonably close to actual network. Discharge should be increased to achieve the base demand. This study would help the water supply engineers

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