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To assess the prevailing Water Distribution Network using EPANET

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Abstract - ***Water supply system is a system of engineered hydrologic and hydraulic components which provide water supply. Water is one of the basic necessities of every living being in the world. Water demand is increasing day by day whether it is domestic, industrial and agricultural etc., but the source of water is limited. So, authorities around the world are faced with the problem to provide sufficient water from limited water source. Water distribution network are very important for development of an area as they serve many purposes in addition to the provision of water for human consumption and it directly influences the nation's development. Water distribution network play vital role in preserving and providing desirable life quality to the public, of which reliability of supply is the major component. To solve this problem, design of new or up-gradation of existing water distribution network is necessary. Such type of problem can be solved manually as well as by using different computation technologies like LOOP 4.0, MIKENET, STANET and EPANET 2.0 software. This study is based on assessment of existing water distribution network using EPANET 2.0 software, as different areas of Surat city face problems like water scarcity and low pressure. Keeping focus on this problem the selected study area is Punagam area of Surat city. The pipe network and junction network system is simulated to understand its behavior for different inputs using EPANET 2.0. Simulation has been carried out for hydraulic parameters such as head, pressure and flow rate. The results obtained verify that the pressures at all junctions and the flows with their velocities at all pipes are feasible enough to provide adequate water by the network of the study area.***

Key Words: *EPANET, Leakages, Water Distribution Network*

1. INTRODUCTION

Water is the most precious gift of nature. It is the most crucial for sustaining life and is required in almost all the activities of mankind i.e., domestic and industrial use, irrigation to meet the growing food and fiber 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 obtain from reclamation. The development, conservation and use of water form one of the main elements in country's development planning. With the increase in population, demand of water supply on the civic amenities including water supply for domestic purposes, irrigation, industry etc. has increased. Therefore, identification of sources of water supply, their conservation and optimal utilization is of utmost importance.

Water distribution system, hydraulic infrastructure consisting of elements such as pipes, tanks, reservoirs, pumps and valves etc. is crucial to provide water to the consumers. Elements of a distribution system include distribution mains, arterial mains, storage reservoirs and system accessories (valves, hydrants, mainline meters, service connections, and backflow preventers). Distribution mains are the pipelines that make up the distribution system. Their function is to carry water from the water source or treatment works to users.

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 modeler simulates flows and pressures in the network and flows in and out to/from the tank for essential loading.

1.1 Aim of Study

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

1.2 Objective of Study

- To study the existing water supply network of PUNAGAM area of SURAT city.
- To collect pipe report and junction report of existing network.
- To analyze the data by using EPANET software.
- To check the discharge & pressure head in existing network.

2. STUDY AREA

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 capacity of water distribution network. Therefore it is required to analyze the existing network of the Punagam area using EPANET and compare computed result with actual result which is obtained from Surat Municipal Corporation.

The water distribution system of Punagam area, WDS-E3 network systems includes ESR-E7, ESR-E8, ESR-E9, ESR-E9A, ESR-E10. In this present paper analysis of WDS ESR-E7 is done using EPANET.

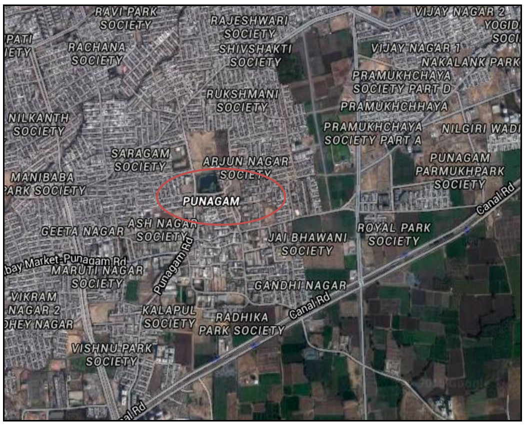

Fig -1: Map of Surat showing Punagam Area

3. METHODOLOGY

This includes process of EPANET software & methodology to analyze the flow of water distribution network.

3.1 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 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.

3.2 Hydraulic Modeling 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:

- Places no limit on the size of the network that can be analyzed
- Computes friction head loss using the Hazen-William, Darcy-Weisbach or Chezy-Manning formula
- Includes minor head losses for bends, fittings, etc.
- Models constant or variable speed pumps
- Computes pumping energy and cost
- Models various types of valves including shutoff, check, pressure regulating, and flow control valves
- Allows storage tanks to have any shape (i.e., diameter can vary with height)
- Considers multiple demand categories at nodes, each with its own pattern of time variation
- Models pressure-dependent flow issuing from emitters (sprinkler heads)

- 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.

3.3 Model Input Data

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

- Junction report
- Pipe report

3.3.1 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:

- Elevation above some reference (usually mean sea level)
- Water demand (rate of withdrawal from the network)
- Initial water quality.

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

- Hydraulic head (internal energy per unit weight of fluid)
- Pressure
- 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.

3.3.2 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:

- Start and end nodes
- Diameter
- Length
- Roughness coefficient (for determining head loss)
- Status (open, closed, or contains a check valve).

Computed outputs for pipes include:

- Flow rate
- Velocity
- Head loss
- Darcy-Weisbach friction factor
- Average reaction rate (over the pipe length)
- 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:

- Hazen-Williams formula
- Darcy-Weisbach formula
- 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:

$$H_l = a\, q^b$$

Where,
HL= head loss (length),
q = flow rate (volume/time),
a = resistance coefficient,
b = flow exponent.

Table 1 lists expressions for the resistance coefficient and values for the flow exponent for each of the formulae. Each formula uses a different pipe roughness coefficient that must be determined empirically.

Table 2 lists general ranges of these coefficients for different types of new pipe materials. Be aware that a pipe's roughness coefficient can change considerably with age.

Table -1: Pipe Head Loss Formula 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	$4.66n^2d^{-5.33}l$	2

Where,
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 -2: Roughness Co-efficient for new pipe

Material	Hazen-williams C	Darcy-Weisbach ε	Manning's n
Cast Iron	130-140	0.85	0.012-0.015
Concrete or concrete lined	120-140	1.0-10	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

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.

3.3.3 Steps to analyze the Water Distribution Network

Following steps has been carried out to model a water distribution network using EPANET:

- Draw a network representation of your distribution system or import a basic description of the network placed in a text file.
- Edit the properties of the objects that make up the system. It includes editing the properties and entering of the required data in various objects like reservoir, pipes, nodes or junctions, etc.
- Describe how the system is operated
- Run a Hydraulic/Water Quality Analysis
- View the results of the analysis which can be viewed in various forms i.e. in form of tables and graphs.

4. Result and Discussion

After collecting the data of distribution network of Punagam area pressure, flow and velocity have been computed using EPANET by the methodology as described earlier. Analysis of results hase been carried out and error between computed result and actual results are shown in table 3 to 4 for junction as well as pipe report of distribution network.

- **WDS ESR E7**

The network diagram of WDS ESR E7 drawn in EPANET is shown in fig. 2.

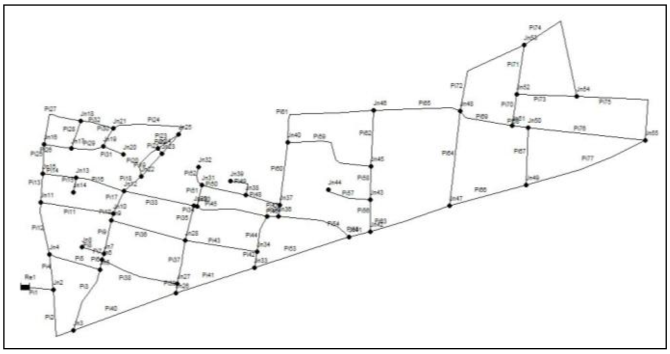

Fig -2: Network Diagram of WDS ESR E7

4.1 Junction Report (WDS ESR E7)

It includes 55 junctions. The error between actual pressure and pressure computed by EPANET is also shown in Table -3. Pressure profile for WDS ESR E7 is shown in Fig – 3.

Table -3: Analysis of Junction report (WDS ESR E7)

Label	Pressure (m)		% Error
	Actual	EPANET	
Jn2	24	23.92	-0.0008
Jn3	23	23.28	0.0028
-	-	-	-
Jn25	21	20.4	-0.006
-	-	-	-
Jn55	17	16.86	-0.0014

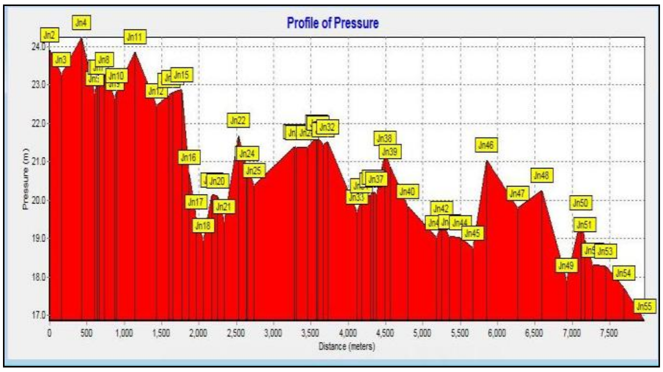

Fig -3: Pressure Profile of WDS ESR E7

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.

4.2 Pipe Report (WDS ESR E7)

Pipe report of WDS ESR-E8 includes 77 pipes. . The error between actual flow and flow computed using EPANET software is shown in Table 4. The error between actual head-loss & head-loss computed EPANET software is also shown in Table 4.

Table -4: Analysis of Pipe report (WDS ESR E7)

Label	Flow (L/s)		Velocity (m/s)		Head-loss Gradient (m/km)	
	Act.	EPA.	Act.	EPA.	Act.	EPA.
Pi1	516.15	516.15	1.83	1.83	4	4
Pi2	207.17	207.37	1.3	1.30	2.99	3
-	-	-	-	-	-	-
-	-	-	-	-	-	-
Pi18	40.66	43.22	1.29	1.38	7.62	8.54
Pi27	9.16	8.06	0.52	0.46	1.95	1.54
-	-	-	-	-	-	-
Pi29	4.69	3.97	0.27	0.22	0.56	0.42
Pi75	7.83	8.06	0.25	0.26	0.36	0.38
Pi76	38.38	-38.24	0.54	0.54	0.95	0.94
Pi77	5.21	5.12	0.3	0.29	0.69	0.67

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 head loss computed using EPANET is nearly equal to the actual head loss.

5. CONCLUSIONS

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 in saving time as this process is fast and less tedious.

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