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QUANTIFYING THE WATER LOSS: A CASE STUDY USING EPANET SIMULATION

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Abstract— **This paper centers on the crucial task of water distribution following the treatment process, with a focus on utilizing EPANET software to address challenges in distribution networks. Water distribution systems are vital for delivering water efficiently and reliably to communities. However, leaks within these systems pose significant challenges, resulting in economic losses and environmental concerns. The paper presents a comprehensive literature review on leak assessment methodologies using EPANET, a widely used hydraulic and water quality modeling software. The review includes studies on leak detection, localization, and assessment within the EPANET framework. The introduction emphasizes the importance of managing leaks in water distribution systems, highlighting their economic and environmental impacts. It is followed by a detailed discussion of EPANET's capabilities in modeling pipe networks, flow rates, and pressure—critical parameters for effective leak assessment. Additionally, various leak detection techniques, including pressure-based methods, acoustic methods, and water quality monitoring, are explored within the context of EPANET.**

Keywords— **EPANET, Simulation, Water Loss**

I. INTRODUCTION

Water distribution networks are essential for supplying water to communities, handling high demand through a system of pipelines, tanks, reservoirs, pumps, and valves. These networks must maintain positive pressure to ensure water reaches all areas effectively. Pumps, often sourcing water from rivers like the Krishna and Godavari, pressurize the water as it enters storage tanks located at the highest points in the network. Planning and designing these networks involve civil engineers and city planners, who consider factors such as reservoir location, elevation, current and future water demand, leakage, pressure head, pipe size, pressure loss, and fire fighting flows. Tools like EPANET software are used for pipe network analysis to ensure adequate pressure and flow. Maintaining water quality is crucial as it moves through the system. Corrosion in metal pipes can cause metals to leach into the water, posing health risks. Disinfectants like sodium hypochlorite or monochloramines are added to ensure safe drinking water, with booster stations positioned throughout the network to maintain proper disinfection levels. Effective water distribution is vital for public health and urban planning.

OBJECTIVES OF THE PRESENT STUDY:

The present study is planned for EPANET software with the following objectives in the view of future demand of the people present in Bandakunta,

1. To design the water distribution network using EPANET software of study area.
2. To simulate possibility of leakages in water distribution system by emitter coefficients.

II. REVIEW OF LITERATURE

According to Silvia Meniconi, Bruno Brunone, Kobus van Zyl, Elisa Mazzetti, and colleagues (2017), equilibrium competition is a simple technique for understanding water distribution and supply. The Aqualibrium network, which aims to evenly divide a given volume among three reservoirs located at three nodes on a grid of sixteen nodes, was simulated using EPANET. However, the simulation results showed discrepancies compared to laboratory tests, particularly under specific flow conditions. The simulation is conducted in two phases: the first phase involves guiding and assessing the flow distribution network without considering local head losses, while the second phase incorporates local head losses into the analysis.

In EPANET, the Darcy-Weisbach formula is used to compute friction losses, accounting for energy dissipation through local head losses and friction. It is important to investigate the differences between numerical simulations using EPANET and laboratory results. Two significant factors that could contribute to these discrepancies are: (i) the assessment of local head losses and (ii) the impact of errors in the extended period simulation approach.

As stated by Diogo Moreira da Costa (2008) in "Simulation of Contaminant Concentrations in Drinking-Water Distribution Systems," the primary goal of this work is to develop software tools for evaluating contaminant concentrations in drinking-water distribution systems. To achieve this, a software application was created by integrating Visual Basic for Applications (VBA) code with EPANET software. This combined tool is designed to perform the necessary calculations for assessing contaminant levels throughout the distribution network.

S. Halagalimath, H. Vijaykumar, Nagaraj, and J. S. Patil presented a study on Bagalkot's distribution network, known as the Shivalingaswami network. This network includes 186 links, 120 nodes, and 1 tank, with a skeletonized representation of flow direction. The study focused on calculating the flow and head losses in each pipeline and determining the resulting balance pressure at each location, essential aspects of any water distribution network analysis.

In their 2014 project paper, Harsh Srivastava and Anupam Singhal explored optimizing a supply distribution network using EPANET software. Their main goals were to minimize head loss and reduce pipe costs. As the campus population grew, there was increased demand on the network, necessitating modifications to ensure its continued functionality. A significant challenge was the high head loss caused by pipes buried beneath roads, which resulted in excessive pump usage in residential areas and colonies. By optimizing the network, they aimed to enhance efficiency, ensure reliable water distribution, and manage costs effectively.

III. METHODOLOGY

DESIGNING WATER DISTRIBUTION NETWORK OF BANDAKUNTA:

Certainly! Here's the rearranged version: The design of the drinking water supply network for Bandakunta, located near Medchal, covers an area of 92,631 m² (997,077 ft²). The network features a distribution source reservoir with a capacity of 50 MGD. It includes pipes of varying diameters (100 mm, 150 mm, and 200 mm) and is laid out in a combination of grid and dead-end (or tree) configurations. The total length of the pipeline network is 3.22 km. For EPANET calculations, the reservoir's Low Water Level (LWL) is set at 601 m, while the Maximum Water Level (MWL) is considered to be 605.3 m above Mean Sea Level (MSL).

Analyzing a network Model:

In this analysis of the distribution network, as illustrated in Fig. 1 below It is made up of a source reservoir that is pumped into a network of two-loop pipes to distribute water. A pipe that goes to a storage tank that floats on the system is also present. In Fig. 1, the ID labels for the different components are displayed. Furthermore, the tank (Node 7) has a diameter of 60 feet, a water level of 3.5 feet, and a maximum level of 20 feet. The pump (Link 9) can also supply 150 feet of head at a flow rate of 600 gpm.

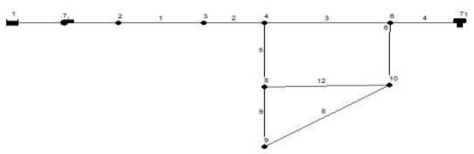


Fig. 1. Layout of pipe network

The network's nodes have the attributes listed in Table 1. Table 1 contains a list of pipe properties.

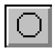
Project set up:

First, open EPANET, create a new project, and make sure all of the default settings are chosen. From the menu bar, choose file New to start a new project. Select the Project indicated in the circle in Fig. 1. By default, the dialog form depicted in Fig. 1 is opened. By using this dialog, you can set EPANET to automatically assign new objects, as they are added to the network, a sequential number starting at 1. Clear all of the ID Prefix fields and set the ID Increment to 1 on the ID Labels page of the dialog. Next, navigate to the Hydraulics page in the dialog box, select "Hazen-Williams" as the head loss formula, and set the Flow Units selection to lps. Before accepting it by clicking OK, you can check the Save box at the bottom of the form if you wanted to save these selections for any future new projects. To access the map options dialog form, select view and then the options displayed in Fig. 1 above. On the form, select the notation page and review the settings. After selecting the symbol page and checking every box, click "OK."

Drawing the Network:

Now, utilize the buttons on the Map Toolbar, which is displayed beneath Fig. 2, to draw the network.

Fig. 2. Map tool bar

- To add a reservoir, click the reservoir button on the map at the necessary location.
- Next add junction node by clicking junction button  on map at required locations.
- Finally add tank by clicking tank button  and click on map where it is located.
- At this point the network diagram looks like the below Fig 1.

We'll add the pipes after that. Pipe 1 should be used first to connect Nodes 2 and 3. Initially, select the Pipe icon from the Toolbar. Next, point the mouse at node 2 and node 3 on the map. As you move the mouse from node 2 to node 3, take note of how an outline of the pipe is drawn. Proceed in the same manner with pipes 2 through 7.

Lastly, add a pump at the beginning of the pipe line by clicking the pump button, node 1 and then node 2. To write something, select the text button on the map tool bar, type your text, and hit Enter. The map will then remain in object selection mode by clicking the selection button on the Toolbar. The network map resembles the previously mentioned Fig. 2.

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MODEL NETWORK:
The model network provides information about the various physical objective parameters in EPANET. It provides an overview of the computational techniques used by EPANET to simulate the behavior of hydraulic systems and water quality.
Pipes :
The closed conduits called pipes are used in the network to move water from one location to another. All pipes are assumed by EPANET to be completely filled with water at all times. From higher hydraulic head to lower hydraulic head is the direction of flow.
The diameter, start, end, roughness coefficient, and length are the input parameters. Flow rate, velocity, head loss, Darcy-Weisbach friction factor, average reaction rate, and average water quality are among the computed outputs. The three different formulas below can be used to calculate the hydraulic head loss that is observed in a pipe as a result of friction with the pipe walls.

- Hazen-Williams formula
- Darcy-Weisbach formula
- Chezy-Manning formula

Table -1 Pipe head loss formulae for full flow

Formula	**Resistance Coefficient (A)**	**Flow Exponent (B)**
Hazen-Williams	$4.727\ C^{-1.852}\ d^{-4.871}\ L$	1.852
Darcy-Weisbach	$0.0252\ f(\varepsilon,d,q)d^{-5}L$	2
Chezy-Manning	$4.66\ n^{2}\ d^{-5.33}\ L$	2

Where C = Hazen-Williams roughness coefficient shown in below Table 1.
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)

The Hazen-Williams formula is the head loss formula that is most frequently used in the US. However, it was designed for turbulent flow and is limited to use with water. For all liquids, the most theoretically used formula is the Darcy-Weisbach formula. It is applicable to all liquids and all flow regimes. For open channel flow, the Chezy-Manning formula is typically utilized.
The head loss formula in between start and end point of the pipe line network is

$$h_l=Aq^B$$

Where A = Resistance Coefficient
B= Flow Exponent are shown in the above Table 1

Table -2 Roughness coefficient for new pipe.

Material	Hazen-Williams C (unit less)	Darcy-Weisbach e (feet x 10^{-3})	Manning's n (unit less)
Cast Iron	130 – 14	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

Viewing The Results:
Graph result:
Graphs can be used to view analysis results as well as other factors. Graphs can be printed after being copied to the Windows clipboard, saved as a data file, or saved as a Windows metafile. The graphs can be accessed by selecting the button found in the standard toolbar or by selecting "open report and select graph." To create a graph, click OK.
Table result:
The results for the chosen project are obtained in tabular format. All of the attributes and outcomes for every node or link at a given point in time are included in a network table and time series table. Tables can be saved to a file and printed, or they can be copied to the Windows clipboard. To generate a table, either click the button located in the Standard Toolbar or select "View and select Table".

Print:
In order to print the current project that is displayed in the "go to file" window, first check the print setup and enter the appropriate margins. Next, choose Print Preview, and lastly click Print. You can also print by selecting the button located in the menu toolbar.

Step by step data execution process in loading of Google map to EPANET software

Open Google earth

↓

Open tools then select navigation bar

↓

Remove the side status bar

↓

Add place mark

↓

Note down the North-East coordinates

↓

Go to tools and make sure that all dimensions are in meters

↓

Length and width values are obtained in meters

↓

Write the calculated coordinates in respective places in ---tool as
Upper right: East + length/2
North + width/2
Lower left: East + length/2
North + width/2

↓

Finally Save image in JPEG format

Open JPEG saved file and convert in to BMP picture file & save it by opening in paint

↓

Open EPANET

↓

Go to view, backdrop

↓

Go to Load and open BMP file

↓

Set dimensions in meters and draw the network

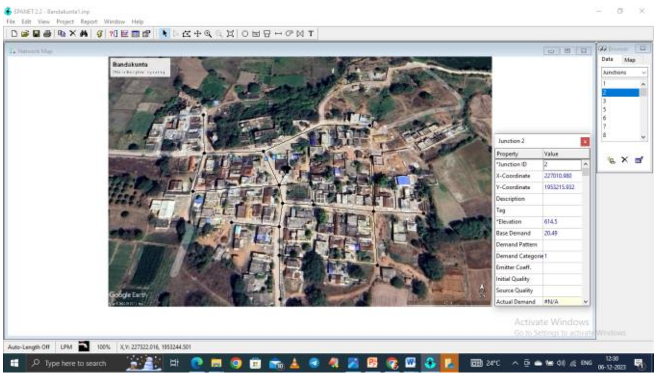

Fig. 3. Google map to EPANET software

As seen in Fig. 3, the network is drawn in EPANET using a Google map.

Flow chart of EPANET software

Open EPANET software

↓

Create the new project by clicking new option which is present at menu bar

↓

Open the default setting, assign the proper properties and labels, and create the network layout on the EPANET network map.

↓

Add reservoir and nodes with the respective elevation at required places

↓

Connect the nodes with link and add check valves

↓

Give base demand value at each and every node

↓

Give the required values and run the project

↓

Run the network

↓

Save the project

↓

If the project run was successful then get the legends of parameters of discharge, velocity and head loss

↓

Get the report as table and graph of required hydraulic parameters.

Collection Of The Data:
In order to carry out the simulation and analysis of Bandakunta locality, the following records were obtained from various sources.

Population data:
Currently, 4150 people live in the Bandakunta area. Hyderabad is a city that is expanding quickly, so the geometric method is used to predict the future population. Accordingly, there will be 13,750 people living in 2024, and that number will rise to 33,880 by 2048. Rate of population growth: 2.92%. The HMWS division office and the census department provided the population data. The population's fluctuations between 1981 and 2011

Quantity of water:
The average amount of water delivered from Bandakunta to Medchal is detailed in the data above. To meet the domestic needs of the 4,750-person Bandakunta area, the geometric population forecast method estimates a requirement of 1.9125

MLD (million liters per day), based on an average daily demand of 150 liters per capita.

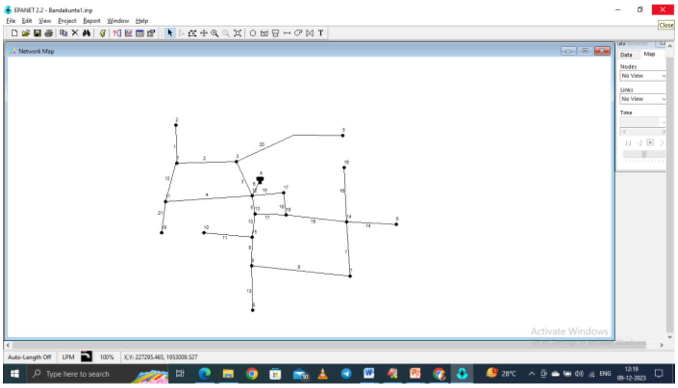

Fig. 4. Layout of Bandakunta

IV.RESULTS AND DISCUSSION

The EPANET results obtained from the software by giving the all required parameters in the form of tables.
Link – Node:
The input values are of link id, pipe length, elevation head, and demand and pipe diameter shown in table
Link - Node Table:

Link ID	Start Node	End Node	Length m	Diameter mm
1	1	2	60	100
2	3	1	75	100
3	12	3	55	200
4	12	11	105	100
5	12	13	35	200
7	7	14	65	100
8	9	7	120	100
9	15	9	35	100
10	13	15	65	200
11	15	10	45	100
12	11	1	65	100
14	14	6	65	100
15	12	17	35	100
16	14	16	105	100
17	13	18	35	100
18	17	18	25	100
19	18	14	75	100
20	3	5	150	100
21	11	19	50	100
6	12	4	37	300
13	9	8	55	100

Node Results
Node Results:

Node ID	Demand LPM	Head m	Pressure m	Quality	
1	14.98	636.49	21.49	0.00	
2	20.49	636.49	21.99	0.00	
3	17.30	636.50	22.00	0.00	
5	17.31	636.49	21.99	0.00	
6	17.39	636.48	21.98	0.00	
7	17.39	636.48	21.98	0.00	
8	10.74	636.49	22.89	0.00	
9	10.86	636.49	22.89	0.00	
10	10.90	636.50	22.90	0.00	
11	10.62	636.49	22.89	0.00	
12	10.86	636.50	22.90	0.00	
13	10.90	636.50	22.90	0.00	
14	10.86	636.48	24.48	0.00	
15	10.90	636.50	22.90	0.00	
16	10.86	636.48	22.88	0.00	
17	10.90	636.50	24.50	0.00	
18	10.62	636.49	22.89	0.00	
19	10.86	636.49	24.49	0.00	
4	-234.74	636.50	11.50	0.00	Tank

Link Results:

Link ID	Flow LPM	Velocity m/s	Unit Headloss m/km	Status
1	20.49	0.04	0.06	Open
2	30.52	0.06	0.12	Open
3	65.13	0.03	0.02	Open
4	26.43	0.06	0.10	Open
5	103.18	0.05	0.04	Open
7	3.22	0.01	0.00	Open
8	20.61	0.04	0.06	Open
9	42.21	0.09	0.23	Open
10	64.01	0.03	0.02	Open
11	10.90	0.02	0.02	Open
12	4.95	0.01	0.00	Open
14	17.39	0.04	0.04	Open
15	29.14	0.06	0.11	Open
16	10.86	0.02	0.02	Open
17	28.26	0.06	0.11	Open
18	18.24	0.04	0.05	Open
19	35.89	0.08	0.17	Open
20	17.31	0.04	0.04	Open
21	10.86	0.02	0.02	Open
6	-234.74	0.06	0.03	Open
13	10.74	0.02	0.02	Open

Leak assessment in EPANET software:
Emitter Coefficient:
Emitter Coefficient can be used to simulate leaks in pipes that are connected to junctions shown in Fig.6.

Devices called emitters, which are connected to junctions, simulate the flow through an aperture or nozzle that releases gas into the atmosphere.

$$Q = C\,p^{\gamma}$$

Where p = pressure,
C = discharge coefficient,
γ = pressure exponent, and
q = flow rate,

Describes how the flow rate through the emitter changes depending on the pressure at the node. γ equals 0.5 for sprinkler heads and nozzles, and the manufacturer typically gives the discharge coefficient value in gpm/psi 0.5

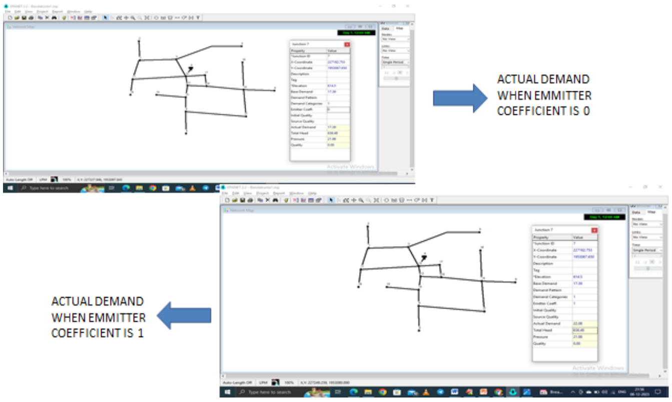

Fig. 5. Emitter Coefficient

Table -3 Actual Demand for Emitter Coefficient

JUNCTION ID	ACTUAL DEMAND FOR EMITTER COEFFICIENT (0)	ACTUAL DEMAND FOR EMITTER COEFFICIENT (1)
7	17.39	22.08
14	10.86	15.81
18	10.61	15.4
13	10.9	15.69
15	10.9	15.69
9	10.86	15.64
8	10.74	15.52

CALCULATION:

To find velocity in the pipe network use Hazen William's formula

$$V = 0.85 \quad (4)$$

Where, C = Roughness coefficient

R= Hydraulic radius (A/P) for full flowing pipe and for half flowing pipe (R=d/4)

A= cross sectional area of pipe

P= Perimeter of the pipe

S= water surface slope (h_f/L)

L= length of given pipe

h_f= elevation difference between respected nodes.

$V_1=0.85*120*(0.1/4)^{0.63}*(0.02/80)^{0.54}$

V_1= 0.1 m/s (at link 7)

Similarly V_2=0.022 m/s (at link 14)

V_3=0.06m/s (at link 15)

V_4=0.015 m/s (at link 27)

Q=A*V(5)

Q_1=0.78lps for the pipe of diameter 200mm.

Similarly Q_2=1.7lps

Q_3=0.47lps

Q_4=3lps

The major head loss due to friction present in the pipe. The frictional head loss in the network can be calculated by using following formula (6)

Where f= friction factor
l= length of the conveyance pipe
g= acceleration due to gravity
d= diameter of the pipe
v= velocity in pipe.

$$h = flv^2/(2gd)$$

h_1= (o.o3*100*.1^2)/ (2*9.81* .1)

h_1=0.015 m/km

Head $loss_1$ = 0.06 m/km (at link 7)

Head $loss_2$ = 0.95 m/km (at link 14)

Head $loss_3$ = 1.15 m/km (at node 15)

Head $loss_4$ = 0.185 m/km (at node 27).

V. CONCLUSION AND RECOMMENDATIONS

CONCLUSION:

1. The salient features of the entire study presented in the paper, the results of EPANET software it is concluded that pressure head & demand at the node and also velocity, discharge and head loss at the link results are within the acceptable range as per HMWS & SB standards and CPHEEO standards.
2. The difference in demand values with emitter coefficients 0 and 1 are obtained at different nodes 7,8, 9, 14, 18, 13 and 15 are 4.69, 4.95, 4.79, 4.77, 4.77, 4.78 and 4.78m^3/s respectively

RECOMMENDATION

1. By simulating the EPANET software we can modify the existed pipe diameter with the appropriate pipe diameter in order to get the results.
2. Leak detection is also identified by simulating the network with emitter coefficient and exponent.

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