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Master Plan of Water Distribution System for Srinagar and Hanumanth Nagar Wards - using EPANET

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***Abstract*— Every metropolitan city requires a master plan which provides a conceptual layout to guide future growth and development of the city. One of the reasons for water crisis in developing countries is due to inefficient and wasteful water management systems. In this research paper EPANET is used to build the water network model, optimize it, compute head-loss, velocity of flow in each node and flow in each pipe in the water distribution. It can be used to consider and understand the growth of the demand of city with the design period of 30 years. The above knowledge is used to identify the risks related to the growth and to suggest measures to overcome these risks. The design of new model will make the respective authorities aware of the new challenges arising from changing demands.**

Keywords-component; EPANET; Hardy-Cross Method; Master plan; Modelling; Water distribution network; Water Supply System;

I. INTRODUCTION

Water is essential for all living organisms, water is used for various activities by humans from drinking to maintaining hygiene, and for various other domestic purposes, water is also used in agriculture for irrigation and in industrial activities. Therefore, the effective water supply is of paramount importance in modelling a new water distribution system and should be designed in such a way that it should be reliable throughout its design period as adequate water supply can increase the standard of living. The new water distribution network should be designed in such a way that it meets the new increasing demand due to increasing population and provide sufficient pressure even at the last point of the network with minimum loss.

Master planning is the method of developing or improving a design through variety of plans which are long range in scope done at the very beginning of a project. Master plan helps to determine the needs or goals of the project. Masterplan has a great impact on projects involving piece of land or a community through predicting the future concerns and problems related to them. Master plan on water distribution system is the best practice of management for supplying water from the source to sink. It encompasses the factors including service life, demand, reliability, cost for construction, operation and maintenance etc. Simulation and analysis of the designed distribution network for its operating capabilities and physical conditions. Computing the flow, pressure, head loss and other parameters inside a complex network can be challenging and time consuming for design, analysis, construction and maintenance of public water distribution system, they

sometimes create complex problem if the network contains number of nodes and range of pipes.

A. *Background*

The parameters of the source and sink are known and can easily be computed. The flow inside the network is unknown and cannot be easily computed. The earlier theories like Hardy-Cross method which is an adapted from the moment distribution method proposed by Hardy Cross to determine the moments in indeterminate structures. With the introduction of computer solving algorithm which would remove the need for solving non-linear equations manually. The water flow and pressure can be determined in the water distribution system by iterative methods which include the popular Hardy-Cross method which uses the input and output parameters of source and sink to find the pipe network flow, velocity and head loss.

B. *Study area*

Hanumanth Nagar ward is located in Bengaluru south and belongs to Basavangudi constituency. Hanumanth Nagar has an area of 0.848 sq km [1]. Hanumanth Nagar, is a locality inthe Banashankari suburb of south Bangalore and currently has 9483 households [1]. It was built during the time of KengalHanumanthaiah, the then chief minister of Karnataka. The ward number of Hanumanth Nagar is 155.

Srinagar ward is located beside the Hanumanth Nagar ward and is located in Bengaluru south and belongs to Basavangudi constituency. Srinagar has an area of 0.80 sq km [2]. Srinagar has currently 10574 households [2]. The ward number of Srinagar is 156.

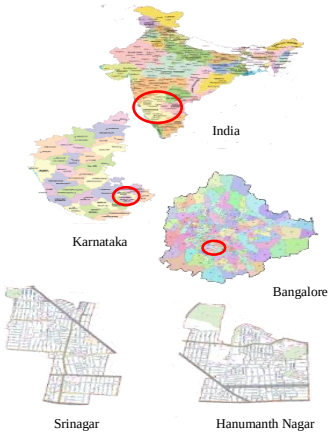

Figure 1:Study Area

II.METHODOLOGY

In order to design the water distribution system, the following methodology is adapted.

A. *Population forecast*

Design of distribution system is based on the demand of water which is obtained from the population of the area. During population forecasting suitable methods have to be adopted as per guidelines in order to avoid over estimation of population as it can be uneconomical or under estimation of population which will not be sufficient to meet the demands in the future. Variation in population of a particular city or area is due to following

- Increase in population due to births, annexation.
- Increase/ decrease due to migration
- Decrease due to deaths.

Population data is important to calculate the demands for each year and also to forecast to the future. The population data is collected from the BBMP (Bruhat Bengaluru MahanagaraPalike) website for the respective wards for the years 1981, 1991, 2011 and the population was forecasted for the next three decades. Population forecasting can be done in following methods

- Arithmetical Increase method
- Geometrical Increase method
- Incremental Increase method
- Graphical Method
- Comparative graphical method
- Master plan method
- Logistic curve method

The population of Hanumanth Nagar ward was forecasted by graphical method and Srinagar ward by geometrical increase method as depicted in Table 1

Table 1:Population Data and Projected Population for the Study Area

Population data		
Year	***Hanumanth Nagar***	***Srinagar***
1991	15334	31653
2001	35065	36045
2011	36982	41379
Projected population		
2021	47309	39016
2031	54088	41162

2041	61839	43426
2051	70700	45814

B. Demand calculation

The design period of the system is taken as thirty years that is till the year 2051. After the population forecast the maximum daily demand was calculated, and various demands are considered as shown in Table 2 according to CPHEEO manual.

Table 2 Demand considerations

Sl no	Characteristics	Range	Assumed value
1	Domestic Demand	135 - 150 lpcd	150 lpcd
2	Public Service	15 lpcd	15 lpcd
3	Fire Demand	10^5* Sqrt (p/1000)	10^5 * Sqrt (p/1000)
4	Industrial Demand	45000 l/ha/day	45000 l/ha/day
5	Institutional and Commercial demand	20 lpcd	20 lpcd
6	Unaccounted for Water	15% of total demand	15%of total demand

$$ADD = PX\ 150\ lpcd \quad (1)$$

Where

ADD is Average daily demand

P is Population

150 lpcd is the recommended per capita water supply level in Metropolitan cities with piped water supply as per the CPHEEO Manual.

C. Design consideration

The road layout maps for the study area are taken to draw the distribution network as the pipes are laid under the existing roads. Therefore, for the design the length of the pipe is taken same as road length. The total road length of Hanumanth Nagar ward is 31.65 kms [1] and Srinagar is 29.72 kms [2].

D. Distribution system

A good distribution will have required quantity of water supplied to each and every consumer with required rate of flow, in order to maintain this, the pressure in the system must be sufficient to force the water to reach every point in the network.

1.Methods of Distribution

Depending upon the methods used to maintain pressure, the systems are classified as:

- Gravity system
- Pumping system
- Dual system

2. Layouts of Distribution

There are four methods of layout of water distribution system:

- Dead end system
- Grid iron system
- Circular or ring system
- Radial system

3. System of Supply

The water supply pattern can vary depending upon duration and pattern of supply. The water may be supplied either continuously for 24 hours daily or only during the peak hours during morning and evening, known as intermittent supply. In order to minimize the wastage of water during non-peak hours, intermittent supply is commonly adopted in India.

In the simulation using EPANET, continuous water supply for 24 hours daily is considered.

E. Steps in designing of water distribution network

The steps as shown in Figure 2 are taken to model a water distribution system

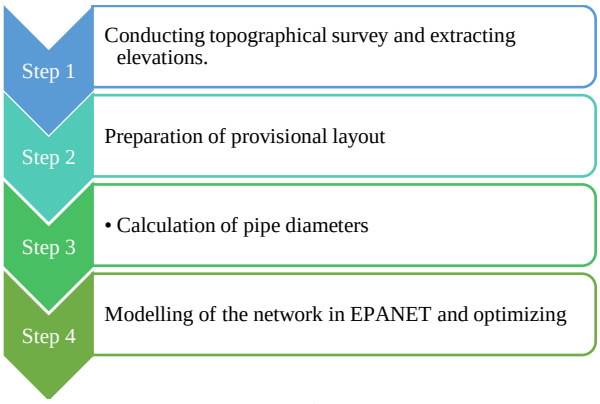

Figure 2: Steps in Designing of Water Distribution Network

1. Conducting topographical survey and extracting elevations.

Elevation was added to the nodes by using QGIS by interpolation. A plugin called Point Sampling Tool was used to extract the elevation for the coordinates of the nodes in Excel format.

2. Preparation of provisional layout

A provisional layout is prepared of the study area and the distribution lines are marked along the road network, the reservoir, hydrants, valves and other features are marked on the map.

The whole wards were divided into smaller sectors depending upon the density of population to allot the main, sub mains and branch lines.

3. Calculation of pipe diameters

The velocity of water inside the pipe is assumed between 0.6 m/s to 1.8 m/s [3] and the quantity of water to be supplied to the sub sectors is taken equal to the sum of all the nodal demands present in that sector and diameter is calculated by the equation

$$Q = Av \quad (2)$$

Where

A is the cross-sectional area of flow

Q is the flow in LPS

v is its average velocity.

$$A = Q/v \quad (3)$$

Where

v is assumed 1.2m/s

Area of circle is $\pi d^2/4$

d is the diameter of the pipe

4. Modelling of the network in EPANET and optimizing

After preparation of provisional layout and assigning initial diameters, the model was created in EPANET software to analyse the rate of flow, pressure of water, head loss etc.

F. Modelling in EPANET

EPANET is an open-source software used to model water distribution network. It was developed by United States Environmental Protection Agency (EPA). EPANET is used to track the flow of water in pipes, determine pressure at each node, quality of water at each node, concentration of chemicals in the network and to find height of water in each tank. Once the flow rate analysis is complete, the water quality computations are then performed.

EPANET is also used to assess alternative management system for improving the overall system quality and efficiency.

Input data file: The EPANET input data file created by using the Keyhole Markup Language (KML) file of the wards present in Open city website [1], [2].

The KML file is converted into a Drawing Exchange Format (DXF) file using Quantum Geographic Information System (QGIS) and is scaled to the correct dimensions using AutoCAD.

The DXF file is converted into input (INP) file using Environmental Protection Agency Computer Aided Design (EPACAD) which converts lines into pipes and junctions into nodes. This network format can be imported into EPANET.

The INP file can also be accessed on Excel and for the particular node at a coordinate, elevation is added.

Nodal demand is calculated assuming that the half of a link is contributing to supplying water to the nodes it is connected to. The sum of half of the links multiplied by the per meter demand gives the nodal demand for each node which is fed into the INP file using Excel.

A reservoir is added to the network which is assumed to supply water infinitely. The location of the reservoir is chosen such that it is at an elevation higher than the highest elevation of the nodes.

Initial pipe diameters are fed into the network using Excel.

An initial run was performed and errors were rectified.

The network was optimized for unit head-loss less than 2 m/km, Velocity ranging 0.6 m/s to 1.8 m/s and Pressure with a minimum value of 7 m [3].

III.RESULTS AND DISCUSSION

The dead-end type of distribution system of Hanumanth Nagar and Srinagar has been assigned with all the necessary input for nodes and links (pipes), the final simulation has been run using EPANET which provides pressure, flow rate, velocity and head loss at different nodes and pipes.

A. Variation of pressure for different nodes at present situation

After simulation, EPANET provided the pressure at the nodes of the water distribution system.

As illustrated from Figures 3 and 4 all the nodes have a minimum pressure of 7m and also satisfies the minimum pressure range. So, this distribution system designed with all the nodes having sufficient pressure is reliable for fulfilling the present water demand.

Figure 3: Contour Plot of Pressure of Water Distribution System for Srinagar Ward

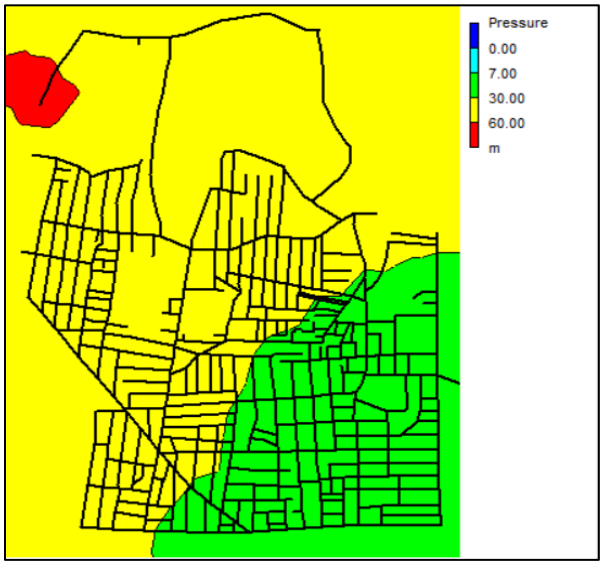

Figure 4: Contour Plot of Pressure of Water Distribution System for Hanumanth Nagar Ward

B. Variation of demand for different nodes for 2021 and 2051 models

Figures 5 and 6 illustrates the variation of base demand at nodes for 2021 and 2051 models. The demand at nodes increases in 2051 model as compared with that of 2051 model due to population increase. When nodes have to carry large water demand, the flow in the pipes also increases. Also, it is found that all the pipes of the designed water distribution system for Hanumanth Nagar and Srinagar wards have appropriate flow in them to fulfil the demand by the supply of water.

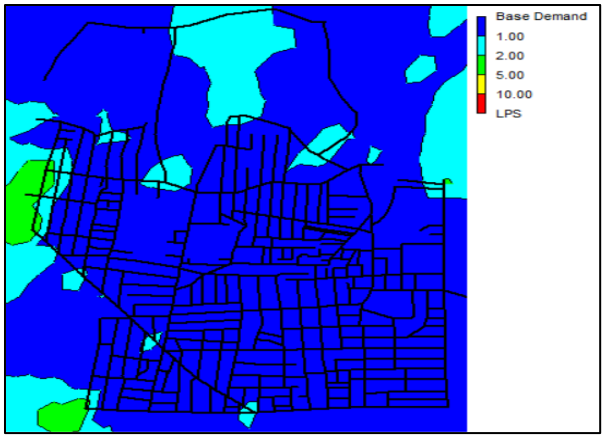

Figure 5: Contour Plot of Base Demand of Water Distribution System for Hanumanth Nagar for the Year 2021.

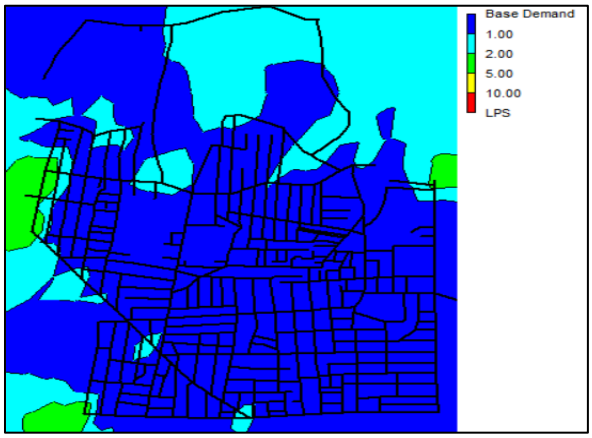

Figure 6: Contour Plot of Base Demand of Water Distribution System for Hanumanth Nagar Ward for the Year 2051.

C. Variation of velocity and head loss at nodes

The water distribution network is designed in such a way that the head loss at pipes is maintained below 2 m/km and velocity above 0.6 m/s, less than 1.8 m/s for the design period of 30 years i.e., from 2021 to 2051 models. From the Figures 7 and 8, it can be seen that all the links are well below the limits and the designed water distribution system for Hanumanth Nagar and Srinagar wards is reliable.

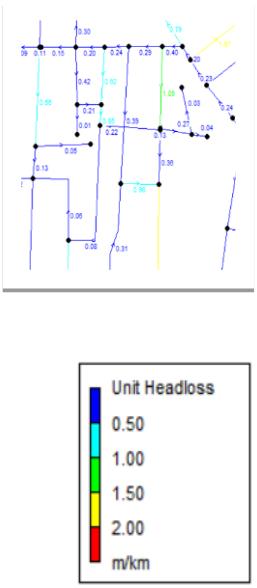

Figure 7: Variation of Head Loss of Water Distribution System for Srinagar Ward

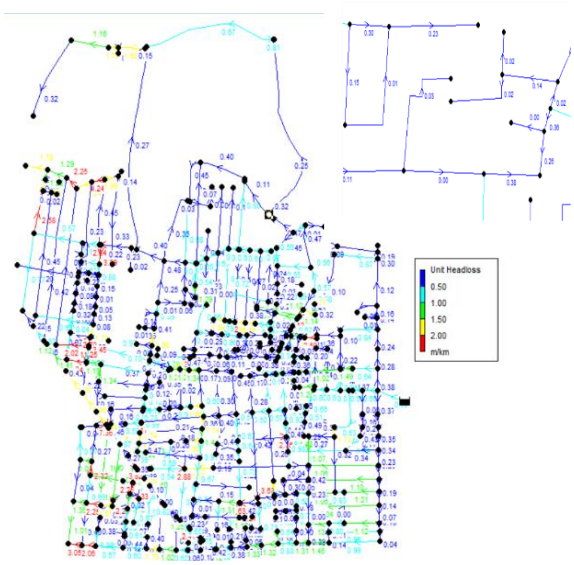

Figure 8: Variation of Head Loss of Water Distribution System for Hanumanth Nagar Ward

D. Validation of the model by Hardy-Cross Method

Hardy Cross Method is one of the methods of analysing water distribution network which follows iterative approach. It is also known as head balance or closed loop method which is applied to pipes forming closed loops. Hardy Cross Method is based on

- Continuity equation which states that sum of inflow is equal to sum of outflow and the assumption made here is that clockwise and anticlockwise direction is considered as positive and negative.
- Energy equation which states that sum of head loss in a closed loop is zero.

The Hazen – Williams(H-W) equation (4) is one of the equations for the calculation of head loss which is incorporated in the software for the calculation of the head loss due to friction, hence, H-W head loss formula was used to validate manually.

$$H_f = \frac{10.67 * L * (Q^{1.852})}{C^{1.85} * D^{4.87}} \quad (4)$$

Where

H_f is Head loss
C is Hazen – William's coefficient
L is length of the pipe
Q is flow rate in pipe
D is pipe diameter

Assuming the flow such that it satisfies continuity equation at nodes and computing head loss coefficient in each pipe following which head loss is computed and the correction Δ is calculated using the equation (5)

$$\Delta = \frac{-\varepsilon Hf}{1.85 * \varepsilon(\frac{Hf}{Q})} \quad (5)$$

Where

Δ is correction
H_f is Head loss
Q is flow rate in pipe

Δ was then added to assumed flow to get actual flow. This iteration is repeated till the sum of head loss reaches zero and assumed flows are correct. Base models and 2051 optimized models of Hanumanth Nagar and Srinagar were validated using Hardy-Cross Method to check the accuracy. Table 5 shows the percentage difference in values between EPANET values as shown in Table 4 and manually calculated values by using Hardy Cross Method as shown in Table 3for Srinagar 2051 model consisting 2 loop network which shows that the results from EPANET is very close to results that were obtained from this method.

Table 3:Manually Calculated Values (Hardy Cross Method)

Pipes	Head loss	Flow	Velocity
AB	0.01196	-11.2938	0.262298
BF	0.790218	1.244612	0.407188
FG	0.025668	-1.45378	0.219757
GA	0.752589	-1.21378	0.3971
BC	0.007489	-8.80839	0.204575
CD	0.321321	1.651612	0.540343
DE	0.501871	1.131612	0.370219
EF	0.025475	-1.45839	0.220454
FB	0.790218	-1.24461	0.407188

Table 4: Simulated Values

Head loss(m)	Flow	Velocity
0.011745	-11.31	0.26
0.772344	1.24	0.41
0.025798	1.47	0.22
0.757918	1.23	0.4
0.00723	-8.82	0.2
0.312553	1.64	0.54
0.477906	1.12	0.36
0.025057	1.47	0.22
0.772344	1.24	0.41

Table 5: Percentage Difference in Values

Head loss	Flow	Velocity
1.82	0.14	0.88
2.31	0.37	0.68
0.50	1.10	0.11
0.70	1.31	0.72
3.58	0.13	2.28
2.80	0.70	0.06
5.01	1.03	2.83
1.66	0.78	0.20
2.31	0.37	0.685

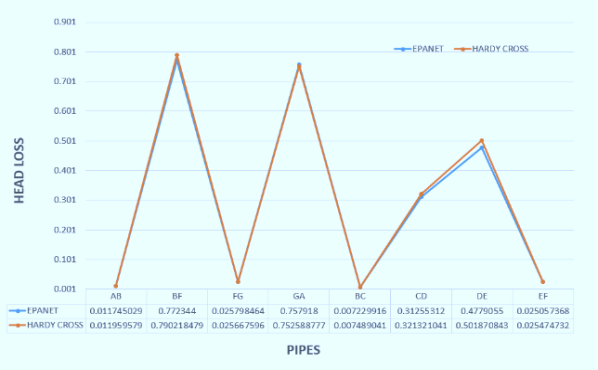

Figure 9: Comparison of EPANET and Hardy Cross Values with respect to Head Loss

The Figure 9 illustrates the comparison of valves obtained from EPANET software and Hardy-Cross with respect to head loss. The values obtained from EPANET coincides with the values obtained from Hardy-Cross at the 20th iteration for the analysis of two loop network in 2051 model of Srinagar ward.

The same check can be done for 2021-2051 models of study area.

E. Identifying the risks associated with the growth

Growth studies was done to analyse the risk associated with the growth. Considering that there was an increase in the demand at aparticular node, total demand was calculated and model was run to identify problems and its effects at that node due to growth.

By comparing the effect of before and after growth in Srinagar and Hanumanth Nagar ward for 2021 Base model,

- Pressure change is negligible.
- Flow increases with increase in head-loss.

Head-loss increases after the growth affecting the pipe flow which is mainly due to lesser surface area for the liquid to flow and internal pipe roughness.Headloss decreases suddenly in one of the pipes which indicates that there is no flow of water in that pipe.

IV.CONCLUSION

Our paper aims in providing a master plan for the wards of Bengaluru city in order to understand the growth trend of demand and population and also to identify risks that occurs due to the trend. With the help of this master plan, we can estimate the cost and materials required to lay down the pipe network.

The water distribution model was designed using EPANET, by entering the parameters like nodal demand, elevation, diameters of pipes.

At the end of analysis, the outputs at different nodes gives us values of pressure, head loss at each junction of the network and the outputs at different links gives velocity and flow rate of water in different pipes.The manual method of water distribution analysis using Hardy-Cross method is easy but time consuming due to number of iterations therefore, cannot be used of analysis of large networks.

The analysis of model using EPANET software saves time as it can be used to analyse complex network containing large number of nodes and links.

Some of the ways to reduce impact of head-loss on flow due to growth are;

- Reducing the interior roughness of the pipe.
- Increasing the pipe diameter is the most preferred solution as flow is also increasing, larger diameter is required to maintain both flow and head-loss values in range.
- Reducing the possible valves and fittings.

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REFERENCES

[1] *Open City Data Meet and Oorvani Foundation. (2017) BBMP Street ID Map - Ward 155 - Hanumanth Nagar. [Online] [Accessed on 21st March 2022]* **https://data.opencity.in/dataset/bengaluru-ward-wise-street-map/resource/bbmp-street-id-map---ward-156----sri-nagar-**

[2] *Open City DataMeet and OorvaniFoundation . (2017) BBMP Street ID Map - Ward 156 - Srinagar. [Online] [Accessed on 21st March 2022]* **https://data.opencity.in/dataset/bengaluru-ward-wise-street-map/resource/bbmp-street-id-map---ward-155---hanumanth-nagar-**

[3] *CPHEEO (1999) "Manual on Water Supply and Treatment" provided by Central Public Health and Environmental Engineering Organisation affiliated to Ministry of Urban Development, New Delhi, India.*

[4] *AjitaGayakwad, Amin Kamani, ChaudhariVaibhavii, KalpanaTumbada and Shivam Chauhan(2020). "Network Analysis of Water Distribution System in Surat Using EPANET", International Journal of Innovative Research in Technology, vol. 6, issue 12,* **https://ijirt.org/master/publishedpaper/IJIRT149443_PAPER.pdf.**

[5] *Anjali.K, Athulya.T, Ullas(2020). "Design of Water Distribution System Using EPANET Software", International Research Journal of Engineering and Technology (IRJET), vol. 7, issue 3,* **https://www.irjet.net/archives/V7/i9/IRJETV7I9413.pdf.**

[6] *Ayşe YeterGünal, Diana Hussein Neamat(2021). "Design of a Gravity Water Distribution System for a Village Using EPANET Software", Journal of Global Scientific Research, Volume 06, Issue 07, ISSN: 2523-9376.*

[7] *KuiliSuganya, M. B. Rajani(2019). "Underground water supply system in the late nineteenth and early twentieth century Bangalore", Water History, vol. 10, pp. 291-311,* **doi:10.1007/s12685-018-0223-8.**

[8] *Arjun Kumar, Bharanidharan B, EshitaDey, Kankesh Kumar, Mahan Singh, Neeraj Malhotra, Neha Matial, Sarit Sharma and Vivek Thakur (2015). "Design of water distribution system using EPANET", International Journal of Advanced Research, vol. 3, issue 9, pp. 789-912,* **http://www.journalijar.com/ .**

[9] *Ashwini. B, Grace Lalremdiki Silo and Tejaswini. MV(2020). "Design of Water Supply Distribution Network Using EPANET Software- A Case study of Kuvempunagar, Mandya", International Research Journal of Engineering and Technology (IRJET), vol. 7, issue 8,* **https://www.irjet.net/archives/V7/i8/IRJETV7I8555.pdf.**

[10] *Hans-Jorgen Albrechtsen, Martin Rygaard, Philip J. Binning (2011). "Increasing urban water self-sufficiency: New era, new challenges", Journal of Environmental Management, Volume 92, Issue 01, pp. 185-194.*

[11] *Hirich, A. Nghira, L. Bouchaou, R. Choukr-Allah(2016). "Water Resources Master Plan for Sustainable Development of the Souss-Massa River Basin", The Handbook of Environmental Chemistry, vol. 53, pp. 1-26* **doi:10.1007/698_2016_67.**

[12] *A. Kumar, G. Anisha, J. Ashok Kumar, P. Suvarna Raju(2016). "Analysis and Design of Water Distribution Network Using EPANET for Chirala Municipality in Prakasam District of Andhra Pradesh", International Journal of Engineering and Applied Sciences, vol. 03, issue 4,* **doi:10.13140/RG.2.1.3131.4320.**

[13] *M.H. Masum, N. Ahmed and S.K. Pal(2020). "Water Distribution System Modelling Using EPANET 2.0, A Case Study of CUET", International Conference on Civil Engineering for Sustainable Development,* **https://www.researchgate.net/publication/339212680_WATER_DISTRIBUTION_SYSTEM_MODELING_BY_USING_EPANET_20_A_CASE_STUDY_OF_CUET.**