



Archives available at journals.mriindia.com

International Journal of Recent Advances in Engineering and Technology

ISSN: 2347 - 2812

Volume 14 Issue 02s, 2025

Hydraulic Modeling and Design of Water Distribution System – A Case Study

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Peer Review Information	Abstract
<p>Submission: 21 Oct 2025</p> <p>Revision: 18 Nov 2025</p> <p>Acceptance: 05 Dec 2025</p> <p>Keywords</p> <p>Water Distribution System, Simulation, Pressure.</p>	<p>Water is an essential resource for human survival, economic development, and environmental sustainability. As urbanization and population growth continue to rise, ensuring an efficient and reliable water distribution system becomes a critical challenge. A well-designed WDS plays a crucial role in delivering adequate and consistent water supply while minimizing losses, optimizing pressure, and ensuring long-term sustainability. This research focuses on the design and optimization of a water distribution network using modelling and simulation techniques to enhance system performance and reliability. Using WaterGEMS software, the research focuses mainly on calibrating the current WDS in this area and analysing different operating conditions.</p>

Introduction

This Water is essential for daily life, agriculture, industry, and sanitation, especially in a populous state like Maharashtra. The design and maintenance of water distribution systems are vital to ensure that communities have reliable access to clean water. With increasing urbanization and population growth, traditional water supply infrastructure is often inadequate to meet rising demand, making it essential to build and upgrade water distribution networks that can sustain future growth.

A water distribution system is a network that includes pipelines, pumps, reservoirs, valves, and treatment plants, all working together to deliver clean water from sources (like rivers, lakes, or groundwater) to consumers. In Maharashtra, a large state with diverse geography and population density, designing efficient water distribution systems can be complex. This complexity requires specialized software to manage the planning, design, and optimization of these systems.

The purpose of the water distribution system is

to convey water to the consumer. A water distribution system is not only the network of pipes, but also involves several hydraulic components such as valves, pumps, storage reservoirs, water meters, and fire hydrants.

WaterGEMS is one such software that allows engineers to simulate and improve water distribution networks by analyzing different factors such as demand, flow, pressure, and leak detection. This approach helps create an efficient and sustainable system that addresses present and future water demands.

The water distribution system is to convey wholesome water to the consumer at adequate residual pressure in sufficient quantity at convenient points. water distribution typically accounts for 40 to 70 percent of the water supply project's capital cost. As a result, the proper design and layout of the system have great importance. Important design parameters include water demand, minimum pressure requirements, the topography of the service area, system reliability, economics, pipe material, pumping

Using specialized software such as WaterGEMS or EPANET enables engineers to design, analyze, and optimize water distribution systems efficiently. WaterGEMS is particularly valuable for its ability to model complex networks, simulate real-world scenarios, and test the effects of different variables. Water is essential for daily life, agriculture, industry, and sanitation, especially in a populous state like Maharashtra. The design and maintenance of water distribution systems are vital to ensure that communities have reliable access to clean water. With increasing urbanization and population growth, traditional water supply infrastructure is often inadequate to meet rising demand, making it essential to build and upgrade water distribution networks that can sustain future growth.

Abbreviations and Acronyms

WDS – Water Distribution System
 WDN – Water Distribution Network
 ESR – Elevated Service Reservoir
 GIS – Geographic Information System
 SHP – Shape file
 DXF- Drawing Exchange Format
 LPCD – Liter Per Capita Per Day

Study Area And Methods

A. Study Area

First, Jaysingpur is a city located in the Shirol taluka of Kolhapur district in the western Indian state of Maharashtra. The landscape surrounding Jaysingpur is flat, typical of the Deccan Plateau. Jaysingpur city is situated near the Krishna River. The city is located approximately 7-8 km from Krishna River, hence supporting and developing agriculture. Jaysingpur geographically lies at an altitude of about 16.7788° N and 74.5571° E. The city's elevation is about 560 meters (1,837 feet) or about above MSL. Jaysingpur city covers an area of almost 8 square kilometers. It is famous for its agricultural activities as well as small-scale industries. According to the Census of 2011, a population figure of nearly 48,528 people resides in Jaysingpur. Since then, the population has grown, with a mix of urban and semi-urban characteristics. The population density is moderate with a mixed multitude of different communities and cultures.

The primary source of water for Jaysingpur water supply system is the Krishna River. Water is drawn from the river and treated before being distributed to the city's residents. The water drawn from the Krishna River undergoes a series of treatments, including coagulation, filtration, and disinfection, to ensure it meets potable water standards before being supplied to the city. In cases of water scarcity or

maintenance, bore wells and additional surface water sources may be used as backups. Jaysingpur has a comprehensive network of pipelines that distribute water throughout the city. The network includes main pipelines, secondary distribution lines, and service connections that ensure water reaches every household, commercial establishment, and public utility. The city is divided into several wards, each receiving water from the centralized network. The distribution system is designed to ensure that each ward gets an equitable share of the water supply. Jaysingpur has 7 Elevated Service Reservoirs (ESRs), located throughout the city. These ESRs are critical components of the water distribution system, storing treated water before it is distributed to various parts of the city.

B. Scope of Study

From the literature review it is observed that design of Water Distribution System and calibration of hydraulic model of future extended area is important. It is found that many studies are carried out modeling using different software packages like EPANET, WaterGEMS etc. The water carrying capacity of the system reduces due to corrosion, leaks, breaks and tuberculation. It increases as the age of the system increases.

Materials And Methodology

A. Modeling of existing WDS

1) *Skeletonization of existing water supply network using Google Earth Pro* : Information related to existing water distribution system was collected from the Jaysingpur Municipal Council authorities. The network was drawn with reference to the information collected from the municipal council. Google Earth Pro software was used for drawing the network. The boundary of the study area was first marked to get an idea about the exact area of the network. The position of existing elevated storage reservoir (ESR) was first marked to get the idea of the starting point. The pipe network was marked on Google Earth Pro software with consideration of the material and diameters.

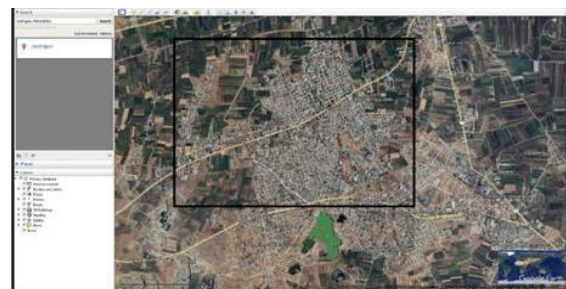


Fig.1. Study Area

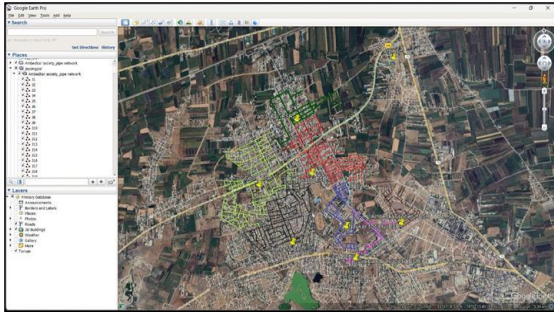


Fig. 2. Skeletonization of existing water supply network using Google Earth Pro

2) Conversion of kmz file into SHP and DXF format using QGIS : The network marked on the Google Earth Pro software is the 'kmz' format. It was converted into DXF format so that it could be extracted into the WaterGEMS software. The KMZ file was first converted into SHP format and then this file was allowed to be converted to DXF format. The conversion of both files was done by using a vector layer.

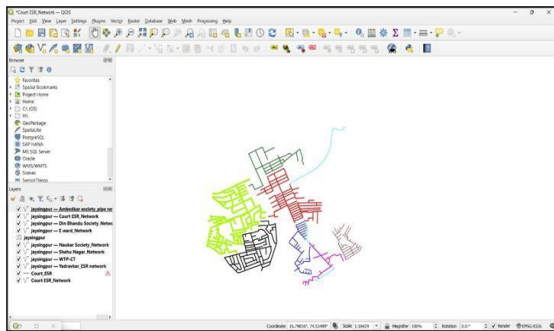


Fig.3. SHP format

3) Assigning elevations using QGIS : The elevations of the study area have been calculated to get an idea about ground levels. The pipes are laid according to the ground slope. The nodes must be assigned with the elevation QGIS software that was used to generate the elevation.

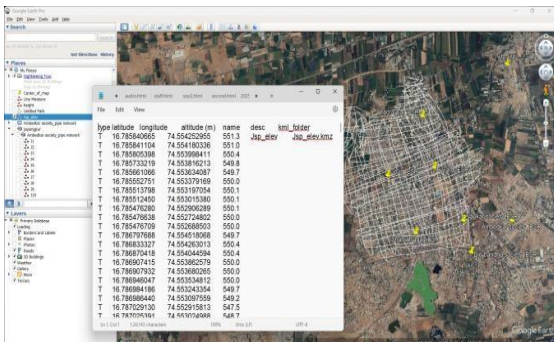


Fig. 4. Assigning elevations

4) Generation of the hydraulic model using WaterGEMS : various stages involved in developing the

model of WDS in WaterGEMS. The steps are:

- i. Preliminary data collection
- ii. Creating hydraulic model in WaterGEMS
- iii. Assigning elevation to each node
- iv. Estimation of base water demand at node
- v. Allocating water demand
- vi. Assigning roughness coefficients
- vii. Setting demand patterns
- viii. Setting pump data and control set
- ix. Developed hydraulic model

5) Creating hydraulic model in WaterGEMS :In this part the steps are described for creating model in WaterGEMS. The dialog box for Model Builder is shown in Figure 3.6. There are different ways to develop the model. The general method is that if the dimensions are available, the user can draw the network. One of the great features of WaterGEMS is the file can be import from EPANET & AutoCAD. The next step is to specify the coordinates of source data. Normally, tolerance should be taken as 1 m. With the help of tolerance option, pipes and nodes can be assembled which are in one meter span. The Model Builder offers two options whether the data should be transported as a present or a new layout. The key fields can be assigned for identification of object mapping in the next window. Once the model is created, then we can edit parts in the network.

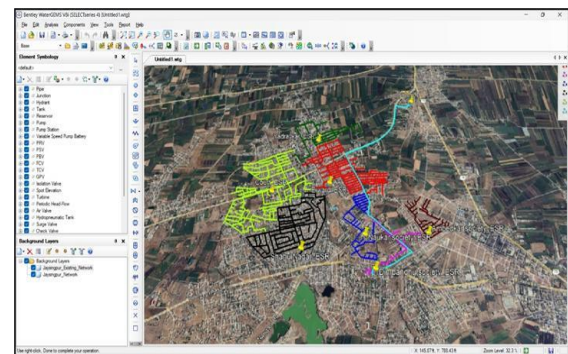


Fig.5. Existing WDN

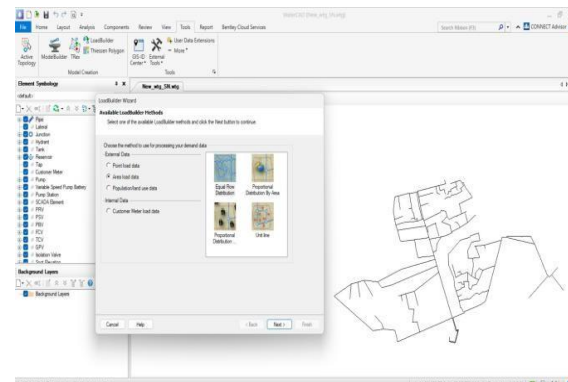


Fig.6. Development of Hydraulic Model

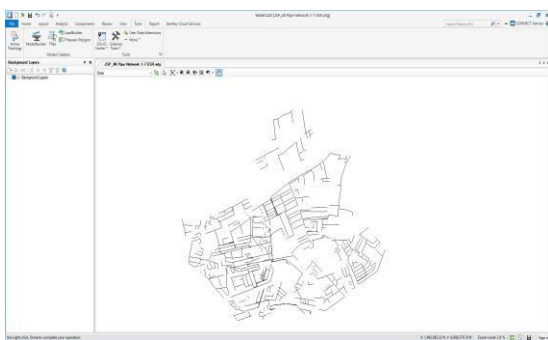


Fig. 7. Existing WDN of study area

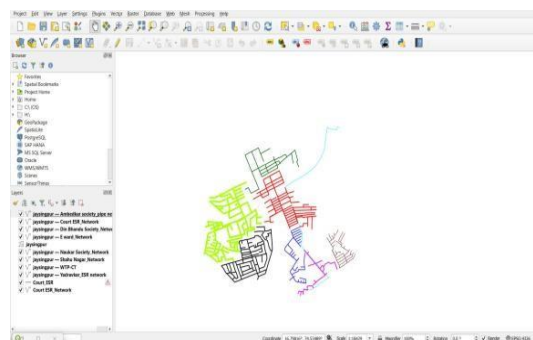


Fig. 8. Water Demand Allocation

B. Population Forecasting Methods: Population forecasting is done by using previous census data and various methods of population forecasting like Arithmetic Mean Method, Geometric Mean Method, Incremental Increase Method etc.

- i. Arithmetic Increase Method
- ii. Geometric Increase Method
- iii. Incremental Increase Method
- iv. Simple Graphical Method
- v. Logistic Curve Method
- vi. Exponential Growth Method
- vii. Decreasing Rate of Growth Method

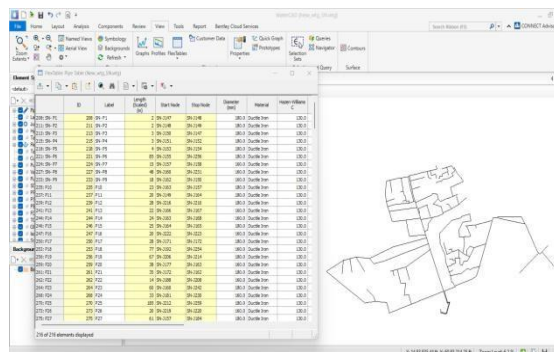


Fig. 9. Flex Table of Pipe Network

Table 1: Water Demand Guidelines

Sr. No.	Classification of towns/cities	Recommended Maximum Water Supply Level (LPCD)
1.	Town provided with pipes water supply but without sewerage system	70
2.	Cities provided with piped water supply where sewerage system is existing/contemplated	135
3.	Metropolitan and Mega cities provided with piped water supply where sewerage system is existing/contemplated	150

(Source: CPHEEO Manual)

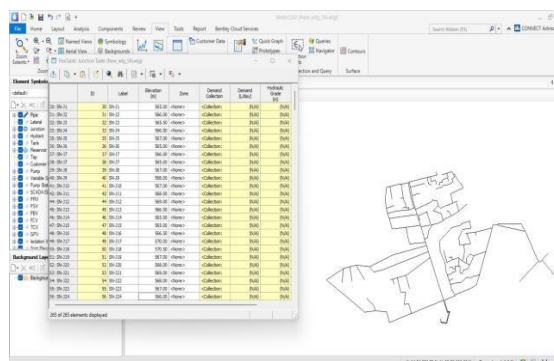


Fig. 10. Flex Table of Junctions

Conclusion

- The existing Water Distribution System is inadequate for an intermittent supply system and provides water with adequate pressure and quality.
- The water supply rate for the present scenario doesn't meet CPHEEO guidelines. There was no separate consideration of water demand for hospital, institutional etc.

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