

Economic Design of Pipeline Using Watergems Software and Cpheeo Guidelines in the Rejuvenation of Existing MI/ZP Tanks in Aurad Taluka, Bidar District, India.

AMAREGOUDA¹ AND RAGHAVENDRA PRASAD H D²

¹PG Scholar, Department of Civil Engineering, FET, JAIN (Deemed-to-be University),
Bengaluru-562112, Karnataka, India

*Corresponding author: amaregouda.kar@gmail.com

²Assistant Professor, Department of Civil Engineering, FET, JAIN (Deemed-to-be University),
Bengaluru-562112, Karnataka, India
p.raghavendra@jainuniversity.ac.in

ABSTRACT:

Water scarcity in semi-arid regions demands efficient planning and management of water resources. This study presents the hydraulic and economic design of a pipeline network for the rejuvenation of Minor Irrigation (MI) and Zilla Panchayat (ZP) tanks in Aurad Taluka, Bidar District, Karnataka. The system is modeled using WaterGEMS software to analyze flow characteristics, pressure distribution, and head losses. Pipe diameters are optimized using CPHEEO guidelines, ensuring permissible velocity and head loss limits. A comparative economic analysis between Mild Steel (MS) and High-Density Polyethylene (HDPE) pipes is conducted. Results indicate that the hydraulic performance satisfies all design constraints, while HDPE pipes are found to be more economical in most scenarios. The study demonstrates a sustainable and cost-effective approach for tank rejuvenation and water distribution.

Keywords— WaterGEMS, Pipeline Design, Water Distribution, Economic Diameter, CPHEEO, HDPE, MS Pipes.

1. Introduction

Aurad is the biggest among the five talukas of Bidar district. It is situated in the North West reason of Bidar. The boundaries of Aurad Taluka are as under River Manjra on South Telangana on East, Maharashtra on North and West, Taluka Bhalki is towards west.

There are 149 villages with a population of 278400 and total area of Aurad 1233. 00 Sqkm.

There are 31 tanks project built by MI department and 5 to 6 percolation Tanks for agriculture benefit of the people in the area.

The Taluka situated in the Manjra sub basin of Godavari Basin. Due to shortage of rain fall in the area, the tanks are going dry and not even filled up at least for once during monsoon. Viilagers of the surrounding area are mainly dependent on these tanks for drinking and irrigation are often affected due to shortage of water in tanks.

The source for the project is Manjra River, which is a major tributary of Godavari and originate in beed District of Maharashtra. Many major Dams and Barrages are built across this river.

Aurad taluk, often referred to as Aurad(B), is a significant administrative and agricultural hub located in the northernmost part of the Bidar district in Karnataka, India. As the largest of the five talukas in the district, Aurad plays a critical role in the region's socio-economic landscape, blending a rich cultural heritage with a traditional, agrarian lifestyle.

1.1 Project Location



Figure -1: Project Location

1.2 Water Requirement

It is proposed to lift the water for 75 days. As there is no restriction on utilization of water. It is proposed to fill the tanks and replenish groundwater recharge.

Table 1: Details of Water Requirement

No.	Particulars	Details
1	Total storage capacity of identified of MI/ZP tank.	1266.44 Mcft (1.266TMC).
2	Proposed average filling @ 50% of the live capacity as per the specified request	633.22 Mcft (0.633 TMC)
3	Consider 25% for evaporation and Percolation losses	949.83 Mcft (0.95 TMC).
4	Total water requirement	Say 949.83 Mcft (0.95 TMC).

2. Literature Review

2.1 Literature Analysis of Evaluation of Water Supply Projects

Darshan J. Mehta., et al (2017) Water-GEMS V8i is a powerful software tool that helps engineers optimize the design of water distribution systems. Its advanced interoperability features allow engineers to leverage geospatial data, CAD drawings, databases, and spreadsheets to streamline the model-building process. The software's automated calibration, design, and operations optimization engines, such as Darwin Calibrator and Darwin Designer, enable engineers to quickly find the best solutions that meet pressure, velocity, and cost constraints. Additionally, the SCADA Connect module allows for real-time system simulation and forecasting, helping utilities better manage their operations. The study found that the resulting pressures and flows at all junctions and pipes are adequate to provide water to the study area as per consumer needs. However, leakages in the pipes may result in pressure differences, leading to water scarcity. The simulated model is reasonably close to the actual network, and the software can analyse the network and foresee design errors, allowing for necessary changes. The software has the capability to handle various pipe network problems without changing the model or mathematical formulation, and it is a viable alternative to other methods, particularly in terms of accuracy and simpler algorithms.

Khan, N S., et al (2021) The paper "Design of Haraulipur Group of Villages Water Supply Scheme at Hamirpur District of Uttar Pradesh" addresses the critical issue of drinking water scarcity in rural areas, particularly in the Kurara Block of Hamirpur District. The study aims to develop a water supply system that provides safe drinking water to 39 villages, ensuring individual household tap connections by 2024, in line with the Government of India's Jal Jeevan Mission.

2.2 Literature Analysis of Economic Diameter Analysis

Vance C. Lischer., et al (1948) The paper "Determination of Economical Pipe Diameters in Distribution Systems" aims to help people figure out the best pipe sizes for water distribution systems. It's all about finding the most cost-effective combination of pipe sizes, pumping power, and storage for water. The paper talks about the different costs involved, like how much it costs to set up the pipelines and pumping stations, and other things like maintenance and power. It's trying to show how all these different factors are connected and how they affect the best pipe size to use.

Davis, P., & Marlow, D. (2008) The article "Quantifying Economic Lifetime for Asset Management of Large-Diameter Pipelines" addresses the challenges faced by water authorities in managing large-diameter water pipelines. These pipelines, while generally having low failure rates, can cause significant damage and costs when they do fail. The authors emphasize that many of these pipelines are buried and not easily visible, making it difficult to assess their condition over time. This lack of visibility, combined with limited historical failure data, complicates efforts to predict future performance and plan for maintenance or replacement.

3. Objectives of the Study

- **Hydraulic Modelling with WaterGEMS**

To model the pipeline network using *WaterGEMS*® software.

- **Economic Design Optimization**

To optimize parameters (diameter, material, cost) for the most cost-effective solution.

4. Methods and Methodology

This section details the methodology for achieving the study's objectives: analyzing the water distribution network with WaterGEMS software, and determining the economic diameter of pipes using CPHEEO manual guidelines.



Figure -2: Process flow chart detailing the project's workflow

4.1 WDN Design from Source to Existing MI/ZP Tanks-Lift and Distribution Network using WaterGEMS

WaterGEMS is a versatile tool designed to optimize water distribution networks and tackle issues related to water scarcity. It offers several powerful features, starting with its ability to use genetic algorithms for network optimization. This means it can automatically calibrate models, spot leaks, and manage pipelines and pumps to make the system work more efficiently. The software also integrates with SCADA systems to provide real-time data, which helps in managing the network proactively. Another significant feature is its ability to establish and manage pressure zones, adjusting settings as needed to maintain consistent pressure throughout the system. Overall, these features make

WaterGEMS an invaluable tool for enhancing the efficiency, reliability and sustainability of water distribution systems. (Source: Overview of WaterGEMS ‘Le Huynh Tuyet Trinh’, et al)

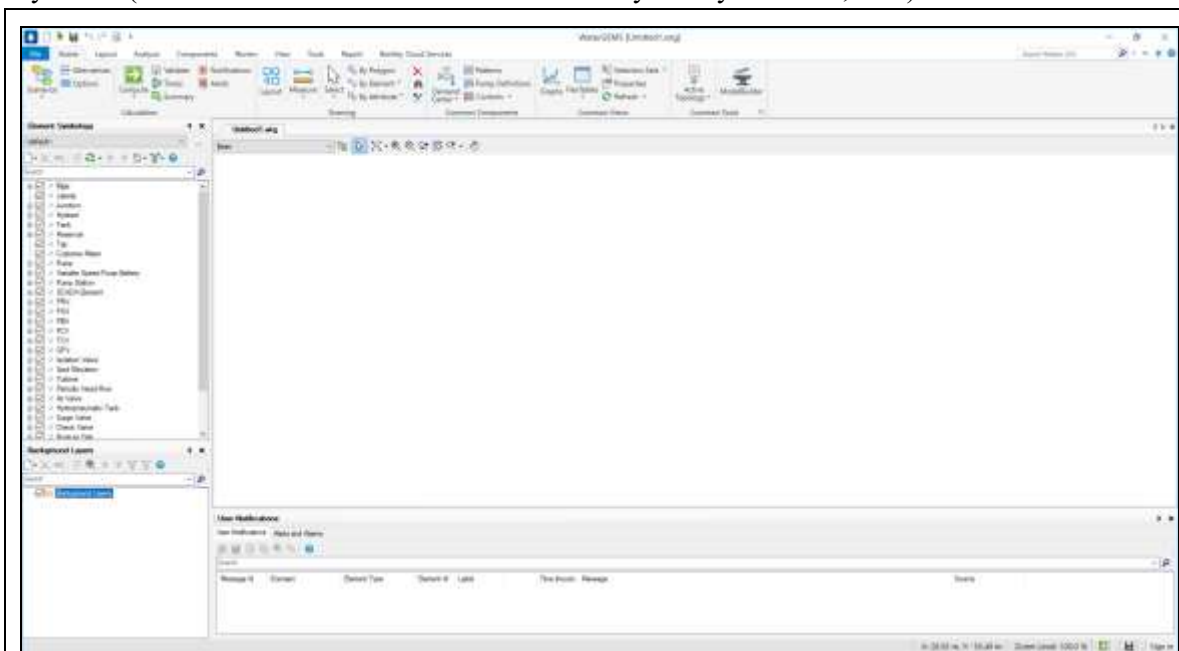


Figure -3: WaterGEMS Software Interface (Source: WaterGEMS)

4.1.1 Input Data to WaterGEMS Software

The input data provided to the WaterGEMS software includes critical elevation parameters that define the hydraulic profile of the water supply system sourced from the Manjra River. The suction level at the jackwell is set at an elevation of 528.50 meters, representing the point from which raw water is drawn. Rising Main is proposed from Jackwell Cum Pump House to Delivery Chambers at an elevation of 630.00 meters. From Delivery Chamber water will be distributed to each MI/ZP tanks. These elevation inputs are essential for simulating the energy requirements, pump sizing, and overall flow dynamics within the WaterGEMS model, ensuring accurate representation of the water transmission system.

Table 2: Input data for Junctions

Label	Elevation (m)
Jackwell (Suction Level)	528.00
Delivery Level	630.00

After providing all the necessary data, such as demand, junction levels, pipe diameters, and lengths, one should perform a sample trial run. Following this run, head loss values will be obtained, which can then be used to calculate the total pump head. After calculating the total pump head, it should be assigned as the total elevation, or a pump should be added, and the pump head value should be adjusted accordingly. Following this adjustment, the system should undergo an actual run after proper validation.

4.2 Economic Diameter Analysis

In optimizing pipeline design, selecting the appropriate diameter of pipe is crucial for achieving both efficient head loss and flow velocity. Hydraulic modeling software, such as WaterGEMS, provides valuable insights by calculating head loss values across different pipe diameters. According to the Central Public Health and Environmental Engineering Organization (CPHEEO) manual, the permissible head loss should not exceed 5 meters per kilometer to ensure system efficiency.

Maintaining flow velocity between 0.4 and 2.0 meters per second is crucial to avoid sediment buildup and excessive pipe wear. To determine the optimal pipe diameter, one must balance minimizing head loss with keeping velocity in

this range. Larger pipes reduce head loss but may lower velocity and vice versa. Analyzing hydraulic modeling results and adhering to these guidelines ensures an optimal pipe diameter that balances head loss and flow velocity for efficient pipeline performance.

The Formulas used for calculating Head loss and Velocity through a pipe are given below,

4.2.1 Hazen Williams equation for Head loss:

The head, pressure, or energy (they are the same) lost by water flowing in a pipe or channel as a result of turbulence caused by the velocity of the flowing water and the roughness of the pipe, channel walls, or fittings. Water flowing in a pipe loses head as a result of friction losses.

In WaterGEMS software, the default formula used to calculate head loss in a system is the Hazen-Williams equation. This equation is a widely used and proven method for calculating head loss due to friction in pipes.

The formula is given by, $h_f = 10.67 * Q^{1.852} * L / C^{1.852} * d^{4.8704}$

Where, h_f – head loss due to friction

Q – flow rate (m^3/s)

C – Hazen Williams co-efficient

D – internal pipe diameter

5. Results and Discussions

This section provides the details of the results obtained at each step WaterGEMS modelling and economic diameter Analysis.

5.1 Water Distribution Modeling using WaterGEMS

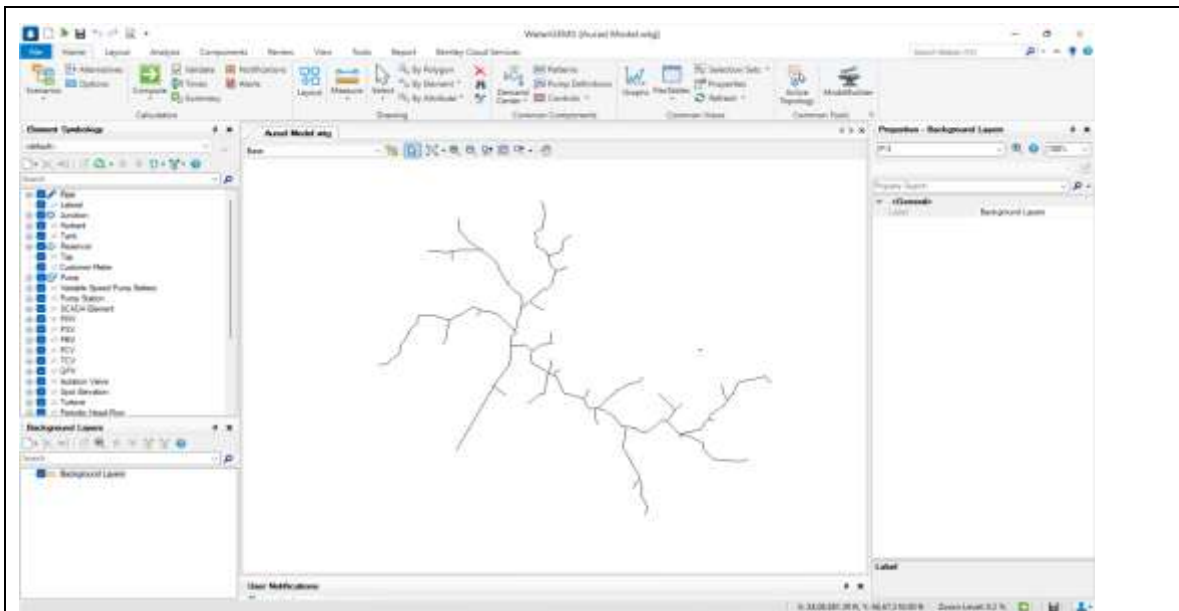


Figure 4: Hydraulic model in WaterGEMS interface (Source: WaterGEMS)

The figure show that network is draw from the source to each MI/ZP tanks using WaterGEMS software.

5.1.1 Rising Main

Table 3: Details of Rising Main

No	Description	Particulars		
		Reach-1 (Ch: 0+000 to Ch: 10+655)	Reach-2 (Ch: 10+655 to Ch: 13+470)	Reach-3 (Ch: 13+470 to Ch: 15+300)
1.	Length of the Rising Main (m)	10655	2815	1830
2.	Design Discharge (Cumecs)	4.5280	4.193	1.841
3.	Number of Rows (No)	1	1	1
4.	Actual Velocity (m/s)	2.00	1.96	1.94
5.	Type of Pipe	MS	MS	MS
6.	Type of Steel	E 250	E 250	E 250
7.	Diameter of Pipe (ID) (mm)	1700	1650	1100
8.	Thickness of Pipe (mm)	9.6	9.3	6.2
9.	Internal Epoxy Lining (mm)	0.406	0.406	0.406
10.	External tape Coating (in mm)	4.0	4.0	4.0

The modeling results were accurate when the total pump head was set as the input for the start node, and validation showed no issues; after running the model, all velocity and head loss values were within limits, and the model ran successfully without errors which has been shown in fig 6 and 7.

5.1.2 Bleeders from Rising Main

Table 4: Details of Bleeders from Rising Main

No .	From	To	Length (m)	Discharge Q (cumecs)	Velocity V= Q/A (m/s)	Diameter (mm)			Type of Pipe
						External Diameter (mm)	Thickness of pipe (mm)	Internal Diameter (mm)	
BLEEDER 01									
1	Junction-1	Mudhole Tank-2 (36)	420	0.1690	1.81	355.6	5.00	344.6	MS Pipe (ERW)
BLEEDER 02									
2	Junction-1	Mudhole (B) MI Tank-23	1510	0.1660	1.79	355.6	5.00	344.6	MS Pipe (ERW)
BLEEDER 03									
3	Junction-2	Break Pressure Tank -1	1440	2.3520	1.92	1267.0	8.00	1250.00	MS Pipe (E-250)

Table 5: Length Abstract

No.	Description	Length (Km)
1	Length of Rising Main	15.30
2	Length of Bleeder from Rising Main	3.37
Total Length of Rising Main & Bleeders =		18.67

Table -6: Length abstract of pipeline

No.	Description	Length (Km)
1	Length of Rising Main	15.30
2	Length of Bleeder from Rising main	3.37

Total Length of Rising Main & Bleeders=		18.67
3	Length of Gravity Distribution Network-1	73.04
4	Length of Gravity Distribution Network-2	91.31
Total Length of Gravity Distribution Network=		164.35
Total length of pipe =		183.02

5.2 Economic Diameter Analysis

A detailed cost analysis has been carried out between **Mild Steel (MS) pipes** and **High-Density Polyethylene (HDPE) pipes** for various diameters and pressure ratings (PN). The comparison includes base pipe cost, coating costs (for MS), and total cost per meter.

1. Cost Components Considered

- **MS Pipes:**
 - Base pipe cost per meter
 - Tape coating cost
 - Including coating cost (total cost)
- **HDPE Pipes:**
 - Cost per meter for different pressure ratings: PN 4, PN 6, PN 8, PN 10, PN 12.5, and PN 16
 - No additional coating cost required

2. Key Observations

- **HDPE pipes are generally more economical** than MS pipes across most diameters and pressure classes.
- For **lower to medium pressure ratings (PN 4 to PN 10)**:
 - HDPE pipes are **significantly cheaper** compared to MS pipes.
- For **higher pressure ratings (PN 12.5 and PN 16)**:
 - HDPE pipes still remain economical in many cases, but the cost difference reduces.
- At **very high diameters and higher PN ratings**, HDPE pipe cost increases substantially and in some cases may approach or exceed MS pipe cost.

3. Diameter-wise Trend

- For **small to medium diameters (160 mm to ~400 mm)**:
 - HDPE pipes are consistently **cheaper for all PN ratings**.
- For **larger diameters (>400 mm)**:
 - HDPE is economical up to certain pressure ratings (typically PN 10 or PN 12.5).
 - Beyond this, **cost advantage reduces**.

4. Coating Cost Impact (MS Pipes)

- MS pipes require **external protection (tape coating)** to prevent corrosion.
- This adds a **significant cost component**, increasing total MS pipe cost.
- HDPE pipes, being corrosion-resistant, **do not require coating**, making them more economical overall.

5. Practical Considerations

- **HDPE Advantages:**
 - Lower cost (in most cases)
 - Corrosion resistance
 - Easier handling and installation
 - Reduced maintenance cost
- **MS Pipe Advantages:**
 - Suitable for **very high pressure applications**
 - Higher structural strength
 - Better for **long-distance high-head pumping systems**

Table 7: Cost comparison of MS and HDPE Pipes

No.	MS Pipe						HDPE Pipe								
	OD mm	t mm	ID mm	Rate of Bare pipe/ meter	Rate of tape Coating	Rate/ meter including tape coating	OD mm	PE - 100 PN 04			PE - 100 PN 06			PE - 100	
								t mm	ID mm	Rate Per meter	t mm	ID mm	Rate Per meter	t mm	ID mm
1	168.3	4.0	159.5	1461.15	397.83	1858.98	160	5.5	149.0	528	8.6	142.8	743	10.6	13
2	168.3	4.0	159.5	1461.15	397.83	1858.98	180	6.2	167.6	647	9.6	160.8	914	11.8	15
3	219.1	4.0	210.3	1968.69	524.55	2493.24	200	6.8	186.4	776	10.7	178.6	1109	13.1	17
4	219.1	4.0	210.3	1968.69	524.55	2493.24	225	7.7	209.6	957	12.0	201.0	1374	14.7	19
5	219.1	4.0	210.3	1968.69	524.55	2493.24	250	8.5	233.0	1139	13.3	223.4	1662	16.3	21
6	273.0	4.0	264.2	2507.20	659.00	3166.20	280	9.5	261.0	1393	14.8	250.4	2044	18.3	24

7	323.9	4.0	315.1	3015.75	785.96	3801.71	315	10.7	293.6	1728	16.6	281.8	2538	20.6	27
8	355.6	4.0	346.8	3332.46	865.04	4197.50	355	12.0	331.0	2211	18.7	317.6	3289	23.1	30
9	406.4	4.0	397.6	3840.00	991.75	4831.76	400	13.5	373.0	2774	21.1	357.8	4136	26.1	34
10	457.0	4.0	448.2	4345.55	1117.97	5463.52	450	15.2	419.6	4070	23.8	402.4	6125	29.3	39
11	508.0	4.0	499.2	4855.08	1245.19	6100.27	500	16.8	466.4	4970	26.4	447.2	7518	32.6	43

Notes:

1 Rates of Common SoR 2023-24 continued for 2025-26 and issue rates are considered for rates and all rates in Rupees.

6. Conclusion

The technical evaluation of the Rejuvenation of Existing MI/ZP tanks in Aurad Taluka demonstrated a sustainable design and hydraulic network efficiency.

Hydraulic modelling using WaterGEMS has validated the performance of the entire water distribution network. The observed pipe velocities, ranging from 0.4 to 2.0 m/s, fall within the recommended limits of the Central Public Health and Environmental Engineering Organization (CPHEEO), confirming the design's adherence to national standards.

The design of the Rising Main from the jack well to the Break Pressure Tank (BPT) spanning 15,300 meters with a 1,700 mm diameter, ensures the smooth delivery of water at a flow rate of 4.528 m³/sec and velocity of 2.0 m/s. The system successfully meets the demand and pressure requirements at the BPT. This confirms adequate water volume under necessary pressure conditions.

Moreover, the application of economic diameter analysis has resulted in the selection of pipe sizes that are not only hydraulically sound but also cost-effective. The cost comparison carried out for each diameter of pipe and cost effective one is considered for reducing cost of the project. This balance between technical and financial efficiency highlights the project's well-optimized planning and design approach.

In summary, the integration of sustainable water sourcing, technically validated hydraulic design, and cost-effective infrastructure planning positions the project as a model for rejuvenation of MI/ZP tanks systems. It ensures reliable

water delivery, energy efficiency, and long-term operational sustainability, ultimately contributing to improved public health and quality of life for the served communities.

From the above analysis, it can be concluded that:

- **HDPE pipes are more cost-effective** than MS pipes for most pipeline applications, especially for **low to medium pressure systems**.
- **MS pipes may be preferred** in cases where:
 - Very high pressure ratings are required
 - Structural strength is critical
- Selection should be based on a **combined evaluation of cost, pressure requirement, durability, and project conditions**.

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