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Quality Control in Water Supply System

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Abstract - This study emphasizes the crucial role of Quality Control (QC) in Rural Water Supply Systems (RWSS) to ensure clean, safe, and reliable drinking water for rural communities. It outlines key components of RWSS—including sources, pumping machinery, rising mains, treatment units (WTPs/RO), reservoirs (ESRs/GSRs), distribution networks, and FHTCs—while identifying common challenges like contamination, weak infrastructure, and inadequate monitoring.

To address these, the study advocates for smart technologies such as SCADA, IoT-based monitoring, and Water GEMS for real-time hydraulic and water quality analysis. It also promotes decentralized solutions like Package-Type WTPs and RO Plants, along with regular source monitoring, storage inspections, and consumer-end sampling.

The document stresses community empowerment through training and involvement in operations and QC processes. A notable outcome is a proposed QC framework spanning from source to tap, complemented by case studies, gap analysis, and sensor-based monitoring. This comprehensive approach supports the goals of the Jal Jeevan Mission (JJM), aiming for sustainable, inclusive, and resilient water infrastructure development in rural India.

***Key Words*:** Quality Control (QC), Rural Water Supply System (RWSS), Rural Infrastructure, Hydraulic Modelling, Sustainable Water Infrastructure, Water GEMS.

1.INTRODUCTION

The rural water supply sector is vital for ensuring public health, economic growth, and sustainable development in rural communities. Unlike urban areas with centralized infrastructure, rural regions often rely on decentralized systems using local water sources such as groundwater, rivers, lakes, and rainwaters harvesting. These systems face challenges including scattered populations, inadequate infrastructure, contamination, and limited financial and technical resources.

A well-functioning rural water supply system includes components like - Source of Water, Water Transmission System, Pumping System, Water Treatment Units, Storage Structures, Distribution Network, Functional Household Tap Connections (FHTCs). Common issues include waterborne diseases due to untreated sources, poor maintenance, and over-dependence on women and children for water collection, impacting education and productivity.

Innovative solutions such as solar-powered pumps, decentralized treatment, and smart technologies (e.g., IoT, SCADA, Water GEMS) are improving water access and quality. Sustainability is reinforced through community participation, awareness programs, and water conservation practices like rainwater harvesting and wastewater reuse. Government schemes and NGO initiatives are essential in expanding infrastructure and promoting local ownership. Strengthening quality control, adopting climate-resilient practices, and investing in efficient water systems are crucial for securing long-term, reliable water access in rural areas. This study aims to develop a hydraulic model of the Ghota Village Rural Water Supply Scheme, located in Taluka Barshitakli, District Akola, using Water GEMS software.

Parameter	Details
Village / City / State	Ghota, Akola, Maharashtra
Latitude / Longitude	20°33'30"N / 77°19'08"E
Area	930.12 hectares
Average Annual Rainfall	666.30 mm
Average Altitude	308 - 359 m above sea level
Population (2011)	1605
Existing Water Source	Supply Well
Existing Storage	ESR: 40 KL

Table -1: Details of Ghota Village Water Supply

2.WORK FLOW FOR DESIGNING

- ➢ Preliminary Survey: Gather data on existing water sources, ESRs, pipelines, and village layout.
- ➢ Detailed Survey: Use DGPS/Total Station for topography, elevation, and proposed alignments.
- ➢ Base Map Preparation: Plot survey data in CAD to draw layout showing source, ESRs, pump houses, and pipelines.
- ➢ Water Demand Estimation: Calculate demand using population, LPCD norms, and future projections; assign to junctions.
- ➢ Network Creation in Water GEMS: Import layout or draw manually; place junctions, pipes, tanks, pumps, reservoirs.
- ➢ Elevation Assignment: Use survey data or DEM to assign accurate elevations to elements.
- ➢ Demand Allocation: Apply realistic demand patterns to simulate usage over time.
- ➢ Input Design Data: Enter pipe lengths, diameters, materials, Hazen-Williams values, and pump curves.

- Tank Details: Define base elevation, diameter, and water levels (min/max/initial) for tanks/ESRs.
- Scenario Modeling: Create alternatives for peak demand, normal day, and emergency conditions.
- Hydraulic Analysis: Run simulation to check pressures, velocities, and tank behaviors.
- Result Interpretation: Analyze maps, graphs, and profiles to evaluate performance.
- Design Optimization: Modify pipe sizes, pump specs, or tank dimensions for better efficiency.
- Report Generation: Prepare final output with hydraulic results, pipe sizes, pressure zones, and efficiency for DPR.

3.METHODOLOGY

3.1.Survey & Maping

- Topographical data collected using survey equipment.
- Survey points plotted in CAD software.
- Base map prepared showing source, ESR, pump house, and pipeline alignments.

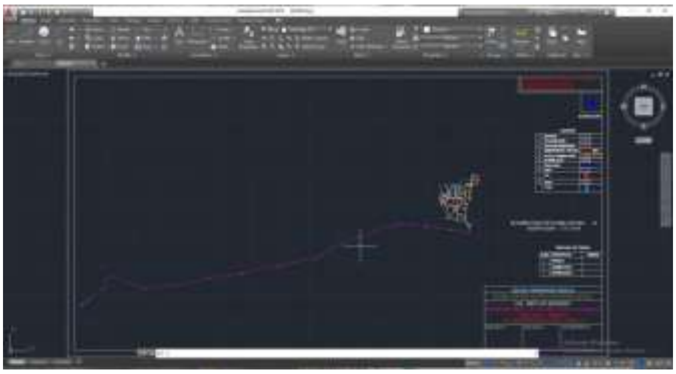

Fig -1: Base Map in AutoCAD

3.2.Design Calculations

Further are the calculations for population forecasting, daily water demand, rising main design, and pumping machinery. The methods and standards used for these calculations are outlined below:

- Population forecasting is based on Census data (e.g., 2011) as per IS 1172:1993 for estimating per capita water demand.
- Daily water demand is calculated using JJM guidelines in accordance with IS 1172:1993.
- Rising main diameter is designed following JJM guidelines and IS 13755:1993, with cost estimations based on Central and State Schedule of Rates.
- Pumping machinery is designed as per JJM guidelines, IS 15382:2003, and IS 6530:1980 to ensure efficiency and durability.

Year	1971	1981	1991	2001	2011
Population	1089	1179	1356	1564	1605

Table -2: Population Projection as per Census

Sr. No.	Year	Arith. Method	Geo. Method	Inc. Method	Average
1	2023	1760	1806	1738	1768
2	2038	1953	2092	18772	1972
3	2053	2147	2424	1968	2180

Table -3: Population Forecasting

Stage	2023	2038	2053
A) Domestic Demand			
Population (souls)	1768	1972	2180
Supply Rate (LPCD)	55	55	55
Demand (L/day)	97,240	108,460	119,900
Demand (MLD)	0.0972	0.1085	0.1199
B) Institutional			
Inst. Demand (L/day)	850	850	850
Inst. Demand (MLD)	0.00085	0.00085	0.00085
C) Cattle Demand			
Cattle (L/day)	19,931	20,601	24,841
Cattle (MLD)	0.0199	0.0206	0.0248
D) Total Net Demand			
Net Demand (L/day)	118,021	129,911	369,160
Net Demand (MLD)	0.1180	0.1299	0.3692
With 15% Losses			
Demand @ ESR (L/day)	138,848	152,837	434,306
Demand @ ESR (MLD)	0.1388	0.1528	0.4343
E) Gross Demand (MLD)	0.1388	0.1528	0.4343
F) Design Discharge			
12 hr Pumping (LPH)	11,571	12,736	36,192
12 hr Pumping (MLD)	0.278	0.306	0.869

Table -4: Demand Calculations

Based on the above methodology and data inputs, the following outcomes and insights have been derived.

Sr. No.	Item	Details
1	ESR Capacity	25 KL, 12 M Staging Height
2	Rising Main (Economical Diameter)	160 mm HDPE, PN 8 - 3940 M
3	Pumping Machinery	10.00 BHP (Submersible Pump, Head - 82M)

Table -5: Details of RWSS Parameters

3.3.Network Modeling

- Network layout is developed in Water GEMS using topographic survey or GIS data for accurate spatial representation.
- Key components like source, ESRs, pumping stations, valves, and pipelines are placed based on hydraulic, technical, and topographic considerations.
- ESRs are placed on higher elevations for gravity head; pumps are located near the source for efficient lifting.
- Each component is assigned design parameters such as elevation, capacity, discharge, head, and storage volume.
- Junctions (nodes) are added to represent consumer points, tagged with actual ground elevations for realistic pressure and flow modeling.
- Pipes are defined by diameter, length, and material - HDPE for Rising Main and PVC for Distribution System.
- Element symbology (colors/line styles) is used in Water GEMS to distinguish between pipe sizes and materials, aiding in model interpretation.

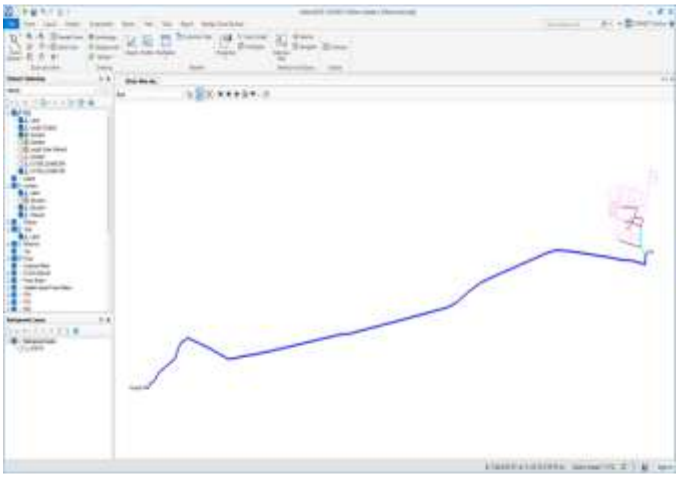

Fig -2: Water Gems Software Window

3.4.Demand Allocation

- Unit Area Method is used to estimate water demand, based on total service area and population density, especially when detailed consumption data is unavailable.
- LoadBuilder tool in Water GEMS is used for demand allocation; the Area Load → Unit Line method is selected for assigning demand per unit area or length.
- A default K-Factor (demand factor) is applied to standardize per-unit demand across the network.
- A Selection Set is created to define the specific network components (junctions/nodes) that will receive the allocated demand.
- The LoadBuilder wizard is completed to distribute the demand, and the process is finalized by clicking Finish.
- The model is then validated using the Validation Tool to check for issues (e.g., missing data or disconnected elements) before running the hydraulic simulation.

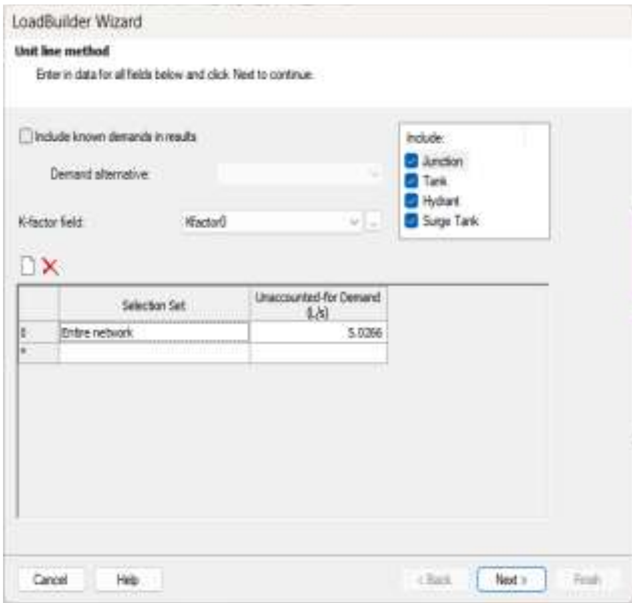

Fig - 3: Demand allocation

3. RESULTS

After performing the hydraulic computation, the model generated the following results, providing critical insights into the network's performance. These results reflect system behavior under given conditions, enabling assessment of flow, pressure, and demand satisfaction across the entire distribution network.

Sr. No.	Description	Details
1.	Distribution Pipes:	
	110 mm, PVC, 4 Kg/Sqcm.	152 M
	90 mm, PVC, 4 Kg/Sqcm.	382 M
	75 mm, PVC, 4 Kg/Sqcm.	2660 M
2.	Rising Main:	
	160 mm, HDPE, 8 Kg/Sqcm.	3940M
3.	Pumping Machinery & Head:	
	10.00 BHP -Submersible Pump, Head - 82M	

4.	ESR & Staging Height:
	25 KL, 12 M Staging Height

Table -6: Model Stimulation Result

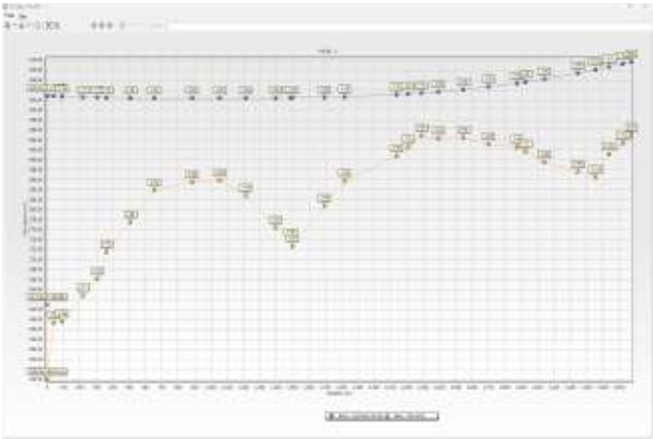

Fig -4: Rising Main Elevation Profile

Hydraulic checks are carried out to assess system performance, ensuring flow, pressure, velocity, and headloss meet design standards: Pump Flow & Head - Ensure pumps operate within design range.

- Pipe Velocity - Maintain 0.3-2.0 m/s to avoid friction loss/sedimentation.
- Junction Pressure - Keep within 7-50 m H_2O.
- ESR Performance - Monitor inflow, outflow, and storage levels.
- Demand Satisfaction - Confirm junctions meet demand.

4.CONCLUSION

Water GEMS plays a critical role in enhancing quality control (QC) in water supply systems by providing detailed hydraulic analysis. One of the key advantages is ensuring adequate pressure at junctions, which guarantees that consumers receive the required water pressure for proper flow. This helps in maintaining uniform distribution and prevents issues such as water shortages or supply interruptions, which can arise from insufficient pressure. By simulating real-world conditions, Water GEMS ensures the network operates optimally and meets the specified performance standards for pressure.

Another significant aspect of Water GEMS is its ability to optimize flow in pipes, which is essential for maintaining the correct quantity and quality of water throughout the system. Accurate flow modeling helps identify potential areas of high friction loss or low flow, both of which can impact water quality and system efficiency. Proper flow ensures that water reaches every user without contamination or stagnation, which is critical in maintaining safe and potable water. This precise flow distribution also reduces the risk of pipeline issues that can lead to water quality degradation, such as sedimentation or pipe deterioration.

Furthermore, Water GEMS helps optimize component sizing across the network, ensuring that pipes, pumps, and reservoirs are neither oversized nor undersized. This optimization is essential for improving operational efficiency and reducing costs. The software allows for easy identification of design flaws and helps with proactive adjustments, ensuring that the system meets both quantity and quality requirements while maintaining long-term sustainability. By leveraging data-driven decision-making and modeling different scenarios, Water GEMS strengthens quality control and helps ensure that the water supply system is reliable, efficient, and capable of delivering high-quality water to end users.

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