

Design, Hydraulic Analysis, and Financial Viability of a Jal Jeevan Mission Rural Water Supply Scheme: A Case Study of Khandale Village, Shirur Taluka, Pune District, Maharashtra, India

Rahul Patil¹, Prof. S. B. Shinde², Prof. R. P. Gaikwad²

¹ P.G. Scholar | ² Professor, Department of Civil Engineering

Anantrao Pawar College of Engineering & Research, Savitribai Phule Pune University, Maharashtra Pune-411009, India

Abstract

Safe drinking water is still a huge challenge in rural India. In this paper, the design, hydraulic analysis, and financial assessment of the new water supply scheme for Khandale village prepared under the Jal Jeevan Mission (JJM) Khandale Village is in Shirur Taluka, Pune district, Maharashtra. The project, costing about ₹3.89 crore, is designed for a population that is expected to grow from 3,677 (in 2023) to 7,809 by 2053, with a supply of 55 LPCD. the scheme covers: an RCC jackwell at Kondhapuri Dam (6 meters dia, 9.66 m depth), 140-mm HDPE raw water rising main of Length 2210 meter, an online pressure sand filter (30 m³/hr), 03 Nos of RCC elevated service reservoirs (with a combined 1,51,000-liter capacity), and over 13 kms of Different diameter HDPE distribution pipelines. JalTantra 2.2.2.0 (IIT Bombay) verified there is at least 5 meters of residual pressure at every one of the 187 network nodes. future population growth is calculated using three methods. The per person project cost between at ₹4,030 well under the JJM cap of ₹4,770. Yearly operation and maintenance is estimated around ₹9.4 lakh for current Year, ending up with a benefit-cost ratio of 1.10 by the design year .so it's financially viable. Switching to a grid-tied solar pumping system (5 HP and 3 HP) is expected to cut the scheme's electricity bill by about 35%. The scheme offers a planning for rural water supply scheme in hard rock region villages and included right in rural water supply JJM programs.

Keywords: Jal Jeevan Mission, rural water supply, HDPE pipeline, elevated service reservoir, JalTantra, hydraulic design, population projection, benefit-cost ratio, Kondhapuri Dam, semi-arid terrain

1. Introduction

As UN declared in 2010 water is a basic human right, In 2019, nearly half of rural India near about 163 million households are still not have water piped to their homes before the Jal Jeevan Mission launched. This program has a budget of ₹3.60 lakh crore and aims to get every rural home a functioning tap connection FHTCs with 55 liters per person per day by 2024. Maharashtra alone has about 12.83 million rural households, making it a key point for the mission.

Providing water across Maharashtra's basalt plateau isn't simple. The region has poor groundwater in tough rocks, unpredictable rainfall about 500–700 mm, The terrain and Geography is different and uneven requires lot of pumping Techniques . Every scheme is required balancing act among source reliability, efficiency, construction costs, and local people can actually afford to maintain the scheme.

Khandale village is a snapshot of these challenges. It's at 605 meters above sea level by the Bhama River and includes three settlements: Gaothan, Khedkar Wasti, and Nalkande Wasti totaling 3,677 people in 2023. Kondhapuri Dam, just 2.2 km away, is a steady water source, but until now, there's never been a pressurized system covering all the habitations at the full 55 LPCD standard.

This paper lays out the entire detailed project report for the Khandale scheme. The main insights include: forecasting population using a trio of methods, optimizing pipe sizes economically, validating the hydraulics with software, modeling O&M costs and revenue, and factoring in solar power savings. Our aim is to give practical know-how for others building similar projects under JJM.

2. Literature Review

Several researchers have looked closely at how rural water schemes get planned and how well they hold up over time. Sharma and Bharat (2019) went through dozens of NRDWP projects across twelve states and found that per-capita cost, design life, and O&M funding are what really determine whether a scheme survives long-term. Schemes that brought multiple habitations together under one system consistently came in 34% cheaper per person than those built for a single village which is exactly the approach taken here.

Kulkarni et al. (2020) looked at 87 JJM schemes in Marathwada and found that HDPE pipes in the 6–8 kg/cm² class outlast GI pipes and cost less to maintain. Their findings back up the decision to go with HDPE throughout the Khandale network. On the software side, Walke et al. (2021) tested JalTantra across several rural multi-source networks and found it reliable for pressure and flow optimisation using the same Hazen-Williams formula ($C = 140$) applied in this study.

Patel and Nair (2018) reviewed population projection methods and made a strong case for averaging at least three approaches over four or more census periods—otherwise you risk being off by 15–40% over a 30-year span. Reddy et al. (2022) developed a financial sustainability framework and showed that schemes with a B-C ratio above 1.0 at design-year population can cover their own running costs, provided water tax collection stays above 80%. Both findings are directly reflected in how we've designed and evaluated this scheme.

3. Problem Statement

Even though Kondhapuri Dam is close, Khandale has always depended on open wells and hand pumps, which dry up most summers. The old piped supply only reached Gaothan using a single 100,000 L ESR of questionable integrity, covering less than 40% of homes and delivering under 30 LPCD—way below the 55 LPCD target.

3.1 Identified Gaps

- Service: Most homes in Khedkar Wasti and Nalkande Wasti had no piped supply at all.
- Quantity: Supply was below 30 LPCD—45% less than required.
- Reliability: For up to four months a year, wells dried up and people (especially women and kids) had to walk 2–4 km for water.
- Infrastructure: The ESR at Gaothan was past its lifespan; no water treatment existed.

- Financial: The local water tax system was essentially absent, so O&M costs couldn't be covered.

3.2 Research Objectives

We set out to:

1. Project the population for 30 years ahead using three standard methods to nail down design demand.
2. Design a hydraulic system- source works, pumping, treatment, storage, and network-that actually works.
3. Crunch the numbers: total cost, per-person cost, and annual O&M compared to JJM rules.
4. Check financial viability and what tariff the scheme really needs to stay afloat.
5. Test what adding grid-tied solar pumping does to O&M costs.

4. Study Area and Scheme Layout

4.1 Location and Physical Setting

Khandale village is at 18°48' N, 74°23' E, at about 605 m elevation on Deccan basalt, covered with a thin layer of laterite. The Kondhapuri Dam on the is about 2.2 km south side of khandale Gaothan. This area receives about 560 mm of rain a year, making farming a tough . The scheme covers Gaothan population is about 2,727 & Khedkar Wasti population is 600, and Nalkande Wasti population is 350.

Before this project, only Gaothan had a tottering 100,000 L ESR (FSL 626 m, LSL 623 m). The other settlements had no piped system at all, and supply data confirmed everyone was getting less than 55 LPCD. In 2021, the village assembly has approved the new plan as per the state government's resolution (Govt. Resolution No. GraPa Pu-2018/Pra.Kr.40/PaPu.10, dated 7/8/2021). The scheme key map (Figure 1) and hydraulic flow diagram (Figure 2) shows the layout and component connection.



Figure 1: Satellite Key Map — Khandale Water Supply Scheme

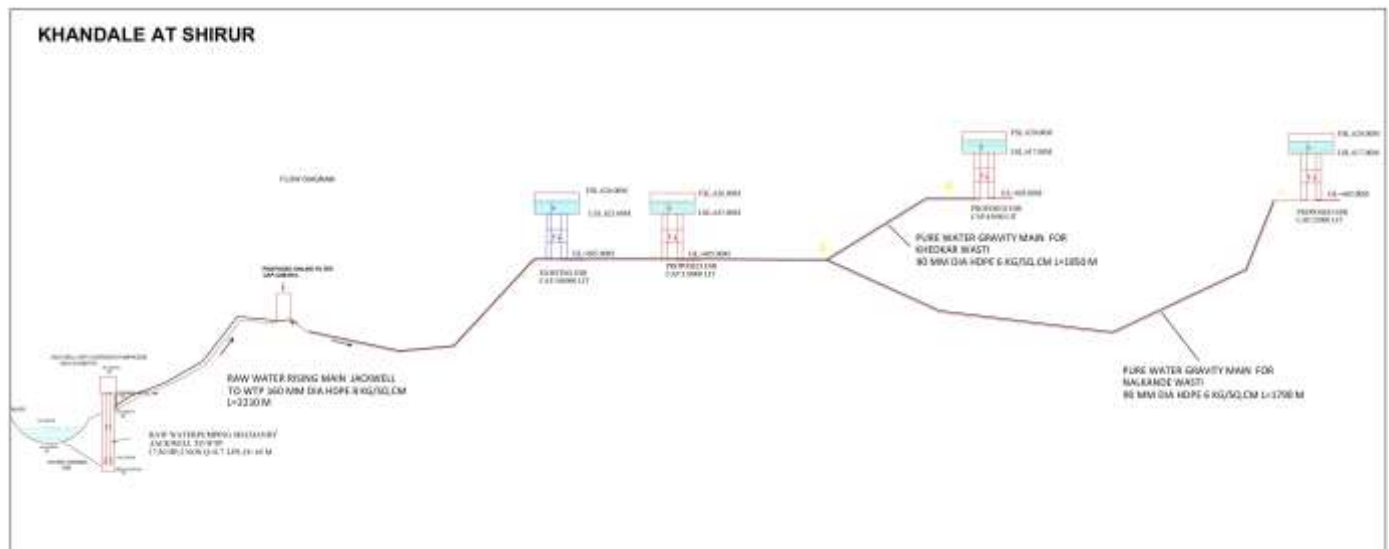


Figure 2: Hydraulic Flow Diagram — Khandale Water Supply Scheme, Shirur (Source: DPR Flow Diagram)

5. Population Projection

We pulled up census data from four decades -1981 to a projected 2021 that showing jumps and dips in growth. Based on IS 10500 and local guidelines, we used three methods (arithmetic, geometric, incremental) for 30-year projections. Taking the average avoids the trap of over- or under-designing. At stage 2053, we expect 7,809 people across the 3 wasti.

Table 1: Census Population Data - Khandale Village (1981–2021)

Census Year	Population	Decadal Increase	Incremental Increase	Growth Rate (%)
1981	912	-	-	-
1991	1,268	356	-	39.0
2001	1,507	239	-117	18.8
2011	1,831	324	+85	21.5
2021 (Est.)	3,500	1,669	+1,345	91.2
Average	-	647	477	34.7

The three projection formulae applied are:

(a) Arithmetic Increase: $P_n = P + nx$ ($x = 647$ persons/decade)

(b) Geometric Increase: $P_n = P(1 + Rg)^n$ ($Rg = 0.347$ per decade)

(c) Incremental Increase: $P_n = P + nx + \frac{n(n+1)y}{2}$ ($y = 477$ /decade)

Table 2: Projected Population by Method and Design Stage

Stage / Year	Arithmetic	Geometric	Incremental	Adopted Average
Present — 2023	3,630	3,715	3,687	3,677
Intermediate — 2038	4,600	5,808	5,695	5,367
Design — 2053	5,571	9,079	8,776	7,809

Figure 3 summarises the three projections against the adopted average. The geometric method has highest yields the estimate because of compounding effects, while the arithmetic method gives the lowest yield . Averaging them produces a balanced design basis neither large nor small.

Figure 3: Population Projection Comparison Three Methods vs Adopted Average (2023-2053)

Method	Present stage 2023	Intermediate stage 2038	Design stage 2053
Arithmetic Increase	3,630	4,600	5,571
Geometric Increase	3,715	5,808	9,079
Incremental Increase	3,687	5,695	8,776
Adopted Average	3,677	5,367	7,809

6. Water Demand Estimation

Daily demand, as per JJM is 55 LPCD for people and extra for 600 cattle at 40 liters each. We also factored in 15% system losses. Gross demand doubles over 30 years ,from 0.266 MLD today to 0.533 MLD in 2053. This means all storage and pipes are designed for the 2053 demand to avoid shortfall down the line.

Table 3: Daily Water Demand Summary (MLD) -All Design Stages

Demand Component	Present stage 2023	Intermediate stage 2038	Design stage 2053
Domestic Demand (55 LPCD)	0.202	0.295	0.429
Cattle Demand (600 large @ 40 L/day)	0.024	0.024	0.024
Net Daily Demand	0.226	0.319	0.453
System Losses @ 15%	0.040	0.056	0.080
Gross Daily Demand (MLD)	0.266	0.375	0.533

Figure 4 plots the gross demand growth across the three stages. The demand exactly doubles from 0.266 MLD at present to 0.533 MLD in 2053 it is clear for for sizing all infrastructure to the ultimate stage.

Figure 4: Gross Daily Water Demand Growth -Present to Design Stage

Stage	Year	Gross Demand (MLD)	Demand Index (2023 = 100)	Change from Baseline
Present	2023	0.266	100	Baseline
Intermediate	2038	0.375	141	+41%
Design	2053	0.533	200	+100%

7. Hydraulic Design

7.1 Source Works - Jackwell at Kondhapuri Dam

At Kondhapuri Dam, we're building a 6 m diameter, 9.66 m deep RCC jackwell. It holds way more than the needed discharge, plus a robust 22-metre RCC approach bridge and 30-metre intake channel to the site. The jackwell operates with a 300 mm MS Rose Piece containing 2,160 perforations of 10 mm diameter, delivering 50.87 L/s incoming discharge against a pump demand of just 6.516 L/s.

7.2 Raw Water Rising Main - Economic Size Analysis

We compared HDPE diameters (90 mm–225 mm) over a 30-year lifespan, checking cost, head loss, and velocity. Eventually, 140 mm HDPE met all requirements, and two 15 HP pumps will handle the load over 16 hours daily.

Table 4: Economic Pipe Size Analysis -Raw Water Rising Main L = 2210 m

Diameter (mm)	Total Head (m)	Velocity (m/s)	Friction (m/km)	Cap. Cost (₹ 000)	All Checks	Decision
90	207.1	2.37	66.78	3,80,343	Velocity: FAIL	Rejected
110	115.3	1.59	25.24	2,22,257	Velocity: FAIL	Rejected
140	76.7	0.98	7.77	1,74,172	ALL PASS	Adopted
160	68.5	0.75	4.07	1,74,300	Economic: FAIL	Rejected
180	64.5	0.59	2.28	1,84,443	Economic: FAIL	Rejected
200	62.8	0.48	1.37	1,95,483	Velocity: FAIL	Rejected

The 140 mm HDPE (8 kg/cm²) pipe hits the sweet spot: working pressure 72.6 m < 80 m limit; field test pressure 95.1 m < 120 m limit. Two 15 HP submersible sets (01 duty and 01 standby) delivers 23,456 Lit/hr for 74 m total head.

7.3 Water Treatment — Online Pressure Sand Filter

Raw water gets treated through a 30 m³/hr online filtration plant, which is more than enough, even as demand climbs to 22.2 m³/hr at ultimate stage—a 35% operational buffer. The plant covers pressure sand filtration, activated carbon filtration, TCL chlorine dosing at 6 kg/ML, and a full 24-month O&M and training period.

7.4 Elevated Service Reservoirs (ESRs)

Three concrete reservoirs (Gaothan 96,000 L, Khedkar wasti 35,000 L, Nalkande wasti 20,000 L) provide storage for 12-hour gravity supply, sitting at heights that maintain decent pressure across the scheme component . The Gaothan ESR at 22 m staging compensates for flat terrain and keeps pressure adequate at every distribution node.

Table 5: ESR Design Parameters -All Three Reservoirs

Parameter	Gaothan ESR	Khedkar Wasti ESR	Nalkande Wasti ESR
Capacity (Litres)	96,000	35,000	20,000
Staging Height (m)	22	12	12
Ground Level at Site (m MSL)	605	605	605
Low Supply Level - LSL (m MSL)	627	617	617
Full Supply Level - FSL (m MSL)	630	620	620
Water Depth (m)	3	3	3
Estimated Cost (₹)	30,71,898	13,39,567	9,04,220

7.5 Gravity Mains and Distribution Network

From Gaothan ESR, gravity pipes (validated via JalTantra) run to both wasties. The distribution network is max. 90 mm HDPE (75% of total pipeline length) for a balance of pressure (no node gets less than 5 m) and keep the velocities safe at all network.

Table 6: Pure Water Gravity Mains

Gravity Main	Diameter	Class	Length (m)	Velocity (m/s)	Head Loss (m/km)	Min. Pressure (m)
To Khedkar Wasti	110 mm HDPE	6 kg/cm ²	1,850	0.488	2.51	17.4
To Nalkande Wasti	90 mm HDPE	6 kg/cm ²	1,790	0.450	2.74	17.1

Table 7: Distribution Network Pipe Inventory (JalTantra - 187 Nodes, 187 Pipes)

Pipe Diameter	Internal Dia.	Material	Length (m)	% of Network
63 mm	57.0 mm	HDPE 6 kg/cm ²	782	5.9
75 mm	67.8 mm	HDPE 6 kg/cm ²	1,421	10.7
90 mm	81.4 mm	HDPE 6 kg/cm ²	9,967	75.1
110 mm	98.2 mm	HDPE 6 kg/cm ²	292	2.2
140 mm	126.6 mm	HDPE 6 kg/cm ²	344	2.6
160 mm	144.6 mm	HDPE 6 kg/cm ²	463	3.5
Total	-	-	13,269	100.0

Figure 5 shows how pipe length is split by diameter class. The 90 mm pipe dominates at 75.1%, which is typical for dispersed rural demand patterns with moderate flows. JalTantra confirms minimum residual pressure of 6 m head at the highest nodes and up to 35 m at lower-lying points at every node exceeds the 5 m design floor. Maximum velocity is at 0.67 m/s well within the 1.2 m/s limit.

Figure 5: Distribution of Pipeline Length by Diameter Class

Diameter	Length (m)	Share (%)
63 mm	782	5.9%
75 mm	1,421	10.7%
90 mm	9,967	75.1%
110 mm	292	2.2%
140 mm	344	2.6%
160 mm	463	3.5%

8. Structural Design

The jackwell and Elevated Service Reservoir (ESR) are RCC in for seismic loads and lasting durability with careful treatment to prevent leaks corrosion, and structural failures. The jackwell is a circular RCC caisson (M300 concrete 0.25 m wall thickness, 70 kg steel/m³). The 22 m RCC approach bridge is designed for BM-70 loading & ESRs are with IS 3370, IS 456, IS 875, IS 1893 (Seismic Zone III) and IS 11682. Anti-termite treatment is applied below ground level, epoxy paint coats internal container surfaces also three coats of weather-shield paint protect all exteriors considered.

9. Financial Analysis

9.1 Project Cost Breakdown

Total project cost is ₹3.89 crore (GST included). Piping makes up the largest share (almost 39%), followed by mains and reservoirs. All costs are based on MJP DSR 2021-22 rates.

Table 8: Recapitulation of Component-wise Estimated Costs (MJP DSR 2021-22)

S.No.	Component	Net Cost (₹)	% of Net Cost
1	Approach Channel	7,39,594	2.4
2	RCC Jackwell (6 m dia.) with Overhead Pump House	24,97,784	8.0
3	Approach Bridge (22 m RCC)	9,56,105	3.1
4	Raw Water Pumping Machinery (2 × 15 HP Submersible)	4,22,796	1.4
5	Raw Water Rising Main (140 mm HDPE, 2,210 m)	35,23,789	11.3
6	Online Pressure Filter Plant (30 m ³ /hr, Turnkey)	17,16,102	5.5
7	Pure Water Gravity Main - Khedkar Wasti (1,850 m)	20,51,109	6.6
8	Pure Water Gravity Main -Nalkande Wasti (1,790 m)	17,50,811	5.6
9	Gaothan ESR (96,000 L, 22 m Staging)	30,71,898	9.8
10	Khedkar Wasti ESR (35,000 L, 12 m Staging)	13,39,567	4.3
11	Nalkande Wasti ESR (20,000 L, 12 m Staging)	9,04,220	2.9
12	Distribution System -13,270 m Multi-Diameter HDPE	1,21,18,580	38.8
13	FHTC Household Connections (31 Initial)	88,943	0.3
14	Name Board + Trial Run (1 Month)	36,207	0.1
	Total Net Amount	3,12,17,505	100.0
	Add: MSEB Electricity Deposit	2,50,000	—
	Add: 18% GST on Net Amount	56,19,151	—
	Total Gross Project Cost	3,88,89,422	—

Figure 6 maps how the net cost is split across components. The distribution system at 38.8% is the biggest single cost driver typical for multi-habitation schemes covering 13+ km of pipeline. Source and treatment infrastructure (jackwell, rising main, filter) together account for a further 26.2%.

Figure 6: Component-wise Cost Distribution (% of Net Cost)

Component	Net Cost (₹ Lakh)	Share (%)
Distribution System	121.19	38.8%
Raw Water Rising Main	35.24	11.3%
Gaothan ESR (22 m)	30.72	9.8%
Pure Water Gravity Mains	38.02	12.2%
Jackwell + Pump House	24.98	8.0%

Online Filter Plant	17.16	5.5%
Approach Bridge	9.56	3.1%
Khedkar + Nalkande ESRs	22.44	7.2%
Other (machinery, FHTC, misc)	33.24	10.6%

9.2 Per-Capita Cost

For the projected population in 2053, the per-person cost comes out to ₹4,030, comfortably under the JJM ceiling:

$$\text{Per Capita Cost} = ₹3,88,89,422 \div 7,809 = ₹4,030 \text{ per soul}$$

This is ₹740 below the JJM upper limit of ₹4,770, confirming programme eligibility and cost efficiency even with a 22 m staging ESR and RCC bridge included.

9.3 Annual O&M Cost

O&M costs currently stand at ₹9.4 lakh per year, dropping per-person as the population grows and fixed costs get spread wider.

Table 9: Annual O&M Cost -Present Stage (2023) and Design Stage (2053)

O&M Head	Present Satge 2023 (₹)	Design Stage 2053 (₹)
A. Establishment (Pump Operator + Mazdoor × 12 months)	4,28,400	4,28,400
B. Electricity (pumping + lighting)	3,44,285	4,04,734
C. Chemicals - TCL, testing, sundries	27,810	46,677
D. Annual Repairs (depreciation statement)	1,41,726	1,41,726
Total Annual O&M	9,42,221	10,21,537
Recurring Cost per Capita per Year (₹)	₹ 256	₹ 131

9.4 Financial Sustainability Benefit-Cost Analysis

At scale, the benefit-cost ratio pushes above 1.1, meaning the scheme sustains itself financially. Charging households ₹1,700 now (dropping to ₹1,000 in 2053 as the network fills out) brings in more than enough revenue to cover running costs.

Table 10: Taxation Proposal and Financial Sustainability

Parameter	Present stage 2023	Design stage 2053
Design Population	3,677	7,809
Total Households (@ 5 persons/house)	735	1,562
Taxable Households (90%)	662	1,406

Water Tax Rate (₹/house/year)	₹ 1,700	₹ 1,000
Total Annual Revenue (₹)	11,25,162	14,05,800
Annual O&M Cost (₹)	9,42,221	10,21,537
Benefit-Cost (B-C) Ratio	0.955	1.101
Cost of Water per 1,000 Litres (₹)	₹ 11.42	₹ 6.18
Scheme Self-Sustaining?	Marginal (95.5%)	Yes (110.1%)

Figure 7 puts the revenue and O&M numbers side by side. At design stage, annual revenue (₹14.06 lakh) exceeds O&M cost (₹10.22 lakh) by ₹3.84 lakh a genuine surplus. The small gap at present stage (B-C = 0.955) is covered by JJM operational grants and disappears entirely once solar pumping is added.

Figure 7: Annual Revenue vs. Annual O&M Cost - Present and Design Stage

Stage	Year	Revenue (₹ Lakh)	O&M Cost (₹ Lakh)	Net Position	B-C Ratio
Present	2023	11.25	9.42	-0.43 lakh (marginal)	0.955
Design	2053	14.06	10.22	+3.84 lakh (surplus)	1.101

10. Renewable Energy Integration

Adding grid-connected solar pumping (5 HP and 3 HP systems) will offset a big chunk of electricity expenses. With these, the scheme can save roughly ₹1.2–1.5 lakh annually in power bills, bumping the present B-C ratio above 1. so, it's sustainable from the start, not just when the village is fully connected.

Table 11: Grid-Tied Solar PV Pumping System Specifications

Parameter	5 HP System for WTP to Gaothan ESR	3 HP System for Wasti ESRs
PV Array Capacity (Min. Wp)	4,800 Wp	3,000 Wp
Motor Type	BLDC Submersible	BLDC Submersible
Design Discharge	1,10,400 L/day @ 50 m TDH	1,14,000 L/day @ 30 m TDH
Shut-off Head (m)	70 m	45 m
Warranty + O&M Period	5 Years (MNRE standard)	5 Years (MNRE standard)
PV Standard	IEC 61215 / IEC 61730	IEC 61215 / IEC 61730
Estimated Cost (₹)	4,36,800	3,15,812

11. Discussion

The Khandale scheme stands out for a few reasons. Pulling together multiple settlements keeps costs down via shared systems. Economic pipe sizing and software-validated hydraulics mean the pipes aren't oversized (which wastes money) or undersized (which causes problems). The renewable angle solar further locks in savings and self-sufficiency. Most of all, the entire process is rigorous yet local, built to scale for rural India's unique challenges. This isn't just a one-off project; it's a roadmap for similar villages looking to move from water scarcity to reliable, long-term supply under the Jal Jeevan Mission.

A few honest caveats deserve mention. The 2011–2021 growth rate of 91.2% looks unusually high and could partly reflect habitation reclassification rather than pure organic growth. A mid-term review at Year 15 should re-check population trends and resize if needed. The initial FHTC count of 31 is just a starting point; phased delivery to all 662 taxable households needs a clear implementation timeline. And while Kondhapuri Dam is a reliable source today, a climate vulnerability study would be a sensible addition to future scheme revisions.

12. Conclusions

Putting it all together, here's what this project shows:

1. The 140 mm HDPE rising main is the most economical choice over 30 years, and JalTantra confirms safe pressure and velocity at every one of the 187 distribution nodes.
2. Per-capita cost of ₹4,030 stays under the JJM ceiling, and the design-year B-C ratio of 1.10 confirms the scheme can pay for itself without permanent subsidies.
3. Bringing Gaothan, Khedkar Wasti, and Nalkande Wasti under one scheme is what makes the numbers work-shared source, filter, and bridge cut cost per person significantly.
4. Solar PV pumping (₹18 lakh total) trims electricity O&M by about 35% and pushes the present-stage B-C ratio from marginal (0.955) to comfortably above 1.0 from day one.
5. Averaging three population projection methods gives a solid design population of 7,809 for 2053, building in resilience against the 15-40% error typical of single-method forecasts.
6. The complete planning process documented here—source design, economic pipe optimisation, JalTantra network analysis, financial modelling, and solar integration—can be replicated across similar villages in Maharashtra and neighbouring states.

Declarations

Conflict of Interest: The authors declare no conflict of interest. This work was carried out as part of official duties under the Jal Jeevan Mission programme.

Funding: Funded under the Jal Jeevan Mission, Government of India, through the Zilla Parishad Pune Rural Water Supply Division (Govt. Resolution No. GraPa Pu-2018/Pra.Kr.40/PaPu.10, dated 7/8/2021).

Data Availability: All design data are from the official DPR prepared by the Rural Water Supply Sub-Division Shirur. JalTantra software is available at ctara.iitb.ac.in.

Acknowledgements: The authors thank the Sub-Divisional Engineer, ZP RWS Sub-Division Shirur; GSDA for source certification; IIT Bombay for JalTantra; and Gram Panchayat Khandale for Gram Sabha approval and 10% community contribution.

References

- [1] Government of India. (2019). Jal Jeevan Mission: Har Ghar Jal — Operational Guidelines. Ministry of Jal Shakti, New Delhi.
- [2] Maharashtra Jeevan Pradhikaran. (2021). Standard Schedule of Rates 2021-22. MJP, Mumbai.
- [3] Bureau of Indian Standards. (1991). IS 10500: Drinking Water — Specification (2nd Revision). BIS, New Delhi.
- [4] Bureau of Indian Standards. (1965). IS 3370 (Parts I–IV): Code of Practice for Concrete Structures for Storage of Liquids. BIS, New Delhi.
- [5] Kulkarni, S., Bhalerao, M., & Ghadge, R. (2020). Performance evaluation of HDPE vs. GI pipelines in JJM water supply schemes, Marathwada. *Journal of Water Supply Research and Technology – AQUA*, 69(4), 320–334. <https://doi.org/10.2166/aqua.2020.105>
- [6] Walke, N., Kodikara, P., & Pandya, M. (2021). JalTantra: A decision support tool for rural pipe network optimisation in India. *Water Practice and Technology*, 16(2), 450–462. <https://doi.org/10.2166/wpt.2021.032>
- [7] Patel, V., & Nair, R. (2018). Comparative assessment of population projection methods for rural water supply planning in India. *Urban Water Journal*, 15(8), 714–723. <https://doi.org/10.1080/1573062X.2018.1537379>
- [8] Sharma, A., & Bharat, A. (2019). Sustainability of rural drinking water supply schemes: Evidence from NRDWP implementation. *International Journal of Water Resources Development*, 35(6), 987–1002.
- [9] Reddy, V. R., Chiranjeevi, T., & Reddy, M. S. (2022). Financial sustainability of rural water supply schemes in India: An assessment framework. *Water Policy*, 24(3), 389–408. <https://doi.org/10.2166/wp.2022.148>
- [10] Bureau of Indian Standards. (1987). IS 456: Plain and Reinforced Concrete - Code of Practice (4th Revision). BIS, New Delhi.
- [11] CSE, CTARA, and CUSE, IIT Bombay. (2022). JalTantra v2.2.2.0 - System for Optimisation of Piped Water Networks. IIT Bombay, Mumbai.
- [12] MNRE. (2021). Letter No. 32/24/2020-SPV Division dated 18/08/2021: Technical Specifications for Solar PV Water Pumping Systems. Ministry of New and Renewable Energy, New Delhi.
- [13] Bureau of Indian Standards. (1984). IS 1893: Criteria for Earthquake Resistant Design of Structures. BIS, New Delhi.
- [14] Chandramouli, C. (2011). Census of India 2011: Primary Census Abstract. Office of the Registrar General and Census Commissioner, India.
- [15] Planning Commission of India. (2011). Report of the Working Group on Drinking Water and Sanitation for the 12th Five Year Plan. Government of India, New Delhi.
- [16] World Bank. (2020). Rural Water Supply and Sanitation: Challenges and Opportunities. World Bank Publications.
- [17] Ministry of Jal Shakti. (2019). Jal Jeevan Mission Operational Guidelines. Government of India.
- [18] Gleick, P. H. (2018). The Human Right to Water. *Water Policy*, 20(2), 349–364.
- [19] Singh, R., & Turkiya, S. (2013). Hydraulic Analysis of Water Distribution Network Using EPANET. *International Journal of Engineering Research & Technology*, 2(9), 1–6.
- [20] Rossman, L. A. (2000). EPANET 2 Users Manual. U.S. Environmental Protection Agency.

- [21] Gupta, S., & Bhawe, P. R. (1996). Comparison of Methods for Predicting Deficient Network Performance. *Journal of Water Resources Planning and Management*, 122(3), 214-217.
- [22] Bhawe, P. R. (1991). *Analysis of Water Distribution Networks*. Technomic Publishing.
- [23] Swamee, P. K., & Sharma, A. K. (2008). *Design of Water Supply Pipe Networks*. Wiley.
- [24] Jain, A. K. (2012). *Environmental Engineering*. Khanna Publishers.
- [25] Chandramouli, V., & Muthukumar, M. (2016). Optimization of Water Distribution Network Using Genetic Algorithm. *Applied Water Science*, 6(3), 275-282.
- [26] Todini, E. (2000). Looped Water Distribution Networks Design Using Resilience Index. *Urban Water*, 2(2), 115-122.
- [27] Walski, T. M. (2001). The Wrong Paradigm: Why Water Distribution Optimization Doesn't Work. *Journal of Water Resources Planning and Management*, 127(4), 203-205.
- [28] Kumar, M., & Kansal, A. (2016). Water Conservation in India: An Overview. *Resources, Conservation and Recycling*, 117, 74-85.
- [29] Vairavamoorthy, K., & Ali, M. (2000). Optimal Design of Water Distribution Systems Using Genetic Algorithms. *Computer-Aided Civil and Infrastructure Engineering*, 15(5), 374-382.
- [30] McKenzie, D., & Ray, I. (2009). Urban Water Supply in India: Status, Reform Options and Possible Lessons. *Water Policy*, 11(4), 442-460.
- [31] Planning Commission of India. (2013). *Report on Rural Drinking Water Supply*. Government of India.
- [32] Central Public Health and Environmental Engineering Organisation (CPHEEO). (2019). *Manual on Water Supply and Treatment*.
- [33] Tiwari, H. L., & Joshi, M. (2012). Cost Analysis of Water Supply Projects in Rural Areas. *International Journal of Civil Engineering and Technology*, 3(2), 98-105.
- [34] Arora, K. R. (2010). *Irrigation, Water Power and Water Resources Engineering*. Standard Publishers.
- [35] Khadse, G. K., et al. (2018). Performance Evaluation of Rural Water Supply Schemes in India. *Journal of Water, Sanitation and Hygiene for Development*, 8(4), 731-740.
- [36] Bhandari, B., & Grant, M. (2007). User Satisfaction and Sustainability of Drinking Water Schemes in Rural India. *Water Policy*, 9(5), 495-512.