Government of India
Ministry of Jal Shakti
Department of Drinking Water & Sanitation

Har Ghar Jal
Jal Jeevan Mission

NATION FIRST
POLICY RESEARCH CENTRE

STRENGTHENING THE RURAL WATER SERVICE PARADIGM

A Policy Evaluation of Jal Jeevan Mission and Pathways for Sustainable Delivery

CENTRE FOR ACCELERATING INDIA'S GROWTH

NATION FIRST POLICY RESEARCH CENTRE

(February, 2026)

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February, 2026
CAIG, NFPRC,
New Delhi

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STRENGTHENING THE RURAL WATER SERVICE PARADIGM

A Policy Evaluation of Jal Jeevan Mission and Pathways for Sustainable Delivery

(February, 2026)

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C R Paatil

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29 JAN 2026

Foreword

Access to safe and adequate drinking water is not merely a basic necessity; it is the foundation of public health, human dignity, and socio-economic development. The Jal Jeevan Mission, launched under the leadership of Prime Minister Shri Narendra Modi Ji with the vision of providing Functional Household Tap Connections to every rural household, represents one of India's most ambitious and people-centric initiatives. Its success lies not only in infrastructure creation but in the transformative impact it has had on the lives of millions across the country.

In this context, the Impact Evaluation of Jal Jeevan Mission undertaken by the Centre for accelerating India's Growth at the **Nation First Policy Research Centre** is both timely and valuable. The report offers a comprehensive, evidence-based assessment of the Mission's outcomes on health, livelihoods, gender empowerment, and overall quality of life. By combining field-level insights with rigorous analytical frameworks, the study goes beyond output metrics to capture the real, lived impact of assured water supply at the household level.

I commend the Nation First Policy Research Centre for its meticulous research, balanced analysis, and constructive recommendations. The report reflects a deep understanding of ground realities and highlights best practices, implementation challenges, and pathways for strengthening service delivery and sustainability. Such evaluations are essential for informed policymaking and for ensuring that large-scale national missions remain responsive, inclusive, and outcome-oriented.

I am confident that the findings and insights presented in this report will serve as a valuable resource for policymakers, implementing agencies, researchers, and development practitioners. They will not only aid in further strengthening the Jal Jeevan Mission but also contribute meaningfully to India's broader journey towards water security and sustainable development.

I congratulate the research team for their dedication and contribution, and I wish them continued success in their efforts to support evidence-driven public policy.

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Abbreviations

AGR	Artificial Groundwater Recharge
ATE	Average Treatment Effect
DALYs	Disability-Adjusted Life Years
DBOT	Design-Build-Operate-Transfer
DiD	Difference-in-Differences
DPR	Detailed Project Reports
FHTC	Functional Household Tap Connections
FTK	Field Test Kits
GIS	Geographic Information System
IEC	Information, Education and Communication
IoT	Internet of Things
IVRS	Interactive Voice Response System
JJM	Jal Jeevan Mission
JMP	Joint Monitoring Programme
LPCD	Litres Per Capita Per Day
MGNREGA	Mahatma Gandhi National Rural Employment Guarantee Act
NAQUIM	National Aquifer Mapping and Management Programme
OBC	Other Backward Class
OTP	One Time Password
O&M	Operation and Maintenance
PAMSIMAS	Indonesia's Community-Based Drinking Water Supply and Sanitation Program
PHED	Public Health Engineering Department
PMU	Project Management Units
PPP	Public Private Partnership
SC	Scheduled Caste
SHG	Self- Help Groups
SLA	Service-Level Agreements
SNWDP	China’s South-North Water Transfer Project
ST	Scheduled Tribe
SWSM	State Water and Sanitation Mission
UNICEF	United Nations Children’s Fund
VGF	Viability Gap Funding
VWSC	Village Water and Sanitation Committee
WHO	World Health Organisation

List of Tables

List of Figures


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Table of Contents

Executive Summary

Launched in 2019, the Jal Jeevan Mission has reoriented rural drinking water policy from a predominantly infrastructure focused approach towards a service delivery framework centred on household level functionality, quality assurance, and long term sustainability. Supported by cumulative public investment of approximately ₹3.6 lakh crore between 2019–20 and 2023–24, the Mission has expanded rural tap water coverage from 16.7% in 2019 to over 81% by 2025, reaching close to 15 crore households and covering around 90% of villages. This scale of expansion represents a major advance in basic service provision and establishes a national platform for sustained rural water service delivery.

This policy evaluation draws on a primary household survey and empirical analysis to assess both implementation performance and household level outcomes. Survey evidence indicates substantial welfare gains associated with functional household tap connections. Nearly 74% of households with functional taps report improved quality of life, consistent with reductions in the physical and time burdens of water collection and with perceived improvements in day to day wellbeing. The analysis further indicates that time savings accrue in contexts where water collection responsibilities are concentrated within households, and that improvements are often larger among households facing higher baseline constraints in secure and proximate access. Taken together, these findings suggest that the Mission's contribution extends beyond connection creation to measurable changes in household experience of water access.

Beyond coverage and welfare outcomes, the analysis identifies institutional and behavioural correlates of sustained service performance. Regression results indicate that Mission awareness is strongly associated with connection uptake, underscoring the role of information and outreach in enabling last mile adoption. In addition, routine user contributions and repair responsiveness are associated with higher reported functionality, greater year round availability, and better reported water quality, indicating that local financing arrangements and community level operational practices are material to system performance.

As the Mission enters its consolidation phase, the principal policy challenge is to translate infrastructure scale into consistently reliable services across diverse geographies. Service regularity, sustained functionality, and water quality assurance remain uneven across states and districts, reflecting variation in source conditions, technical design, institutional capacity, and local operations and maintenance arrangements. Public familiarity with the Mission remains limited at around half of respondents in the survey, suggesting further scope to deepen communication strategies and strengthen community level feedback and accountability mechanisms.

The report concludes that the next phase of JJM will be defined less by incremental asset creation and more by consolidation of service delivery systems. Priorities include strengthening source security, standardising commissioning and performance protocols, institutionalising operations and maintenance financing and routines, and enhancing citizen facing accountability and monitoring frameworks. A focused emphasis on awareness, user participation, and performance oriented governance will be central to sustaining gains and ensuring reliable access to safe drinking water for rural households.


138
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Jal Jeevan Mission
2022-23
FHTC

1. Background and Program Context

India's rural landscape has historically contended with a profound multi-dimensional water security crisis, marked by the confluence of severe resource scarcity, systemic quality deficits, and institutional capacity constraints. Prior to 2019, only a marginal 16.7% of rural households possessed a functional tap connection delivering the mandated 55 litres per capita per day (JJM Dashboard, 2025). The roots of this crisis are embedded in intersecting ecological and governance failures:

1.1 Hydrological Stress and Scarcity

Uneven monsoon dynamics, combined with a pronounced dependence on groundwater extraction, have intensified aquifer depletion, with 256 districts classified as water-stressed as early as 2017 (Operational Guidelines JJM, 2019). Forward projections suggest that per capita water availability could decline to approximately 1,140 cubic metres by 2050, approaching the scarcity threshold and signalling that India's water stress was fundamentally structural in character (Niti Aayog, 2019).

1.2 Contamination and Public Health

The crisis is further compounded by widespread contamination: nearly 70% of India's surface water sources are estimated to be polluted, contributing to the country's ranking of 120th out of 122 nations on the global water quality index as of 2024 (Niti Aayog, 2019). This degradation has direct public health implications, with over 163 million citizens lacking access to safe and proximate drinking water (Niti Aayog, 2019).

1.3 Governance Failure and Socio-Economic Burden

Preceding water schemes were predominantly construction-focused, marked by chronic underfunding and weak mechanisms for local accountability. This systemic failure imposed a significant gender and health burden, disproportionately taxing women and girls whose time poverty, caused by water collection, curtailed educational and economic participation.

2. The Jal Jeevan Mission : A Paradigm Shift in Service Delivery

The launch of JJM in August 2019 represents a decisive policy intervention intended to transition rural water sector from coverage targets to a robust service delivery framework. The mission's overarching mandate is the provision of a Functional Household Tap Connection (FHTC) to every rural household, ensuring potable water at 55 LPCD. This undertaking, extended to 2028, signifies a monumental national commitment.

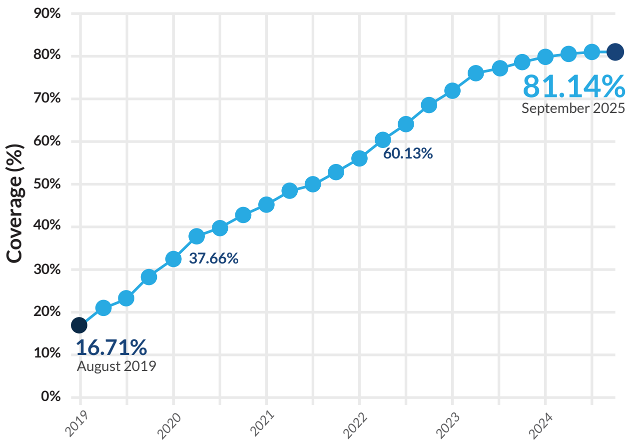


Figure 1: Rural Tap water Coverage (2019-2025) (JJM Dashboard, 2025)

JJM's foundational theory of change rests on three mutually reinforcing pillars:

2.1 Human Capital and Welfare Gains

Reliable household access to tap water is hypothesised to yield significant welfare dividends through reduced health expenditures and the liberation of time, especially for women, facilitating enhanced social and economic engagement (Agénor and Agénor, 2023).

2.2 Subsidiarity and Accountability

Decentralisation of management to local institutions, specifically through Village Water and Sanitation Committees under Gram Panchayats, with a mandatory minimum of 50% women's representation is designed to institutionalise accountability and encourage community ownership over water assets and service delivery (Operational Guidelines JJM, 2019).

2.3 Holistic Sustainability

The Mission mandates simultaneous attention to the sustainability of water sources, infrastructure assets, and the financial models required for long-term operations, thereby moving beyond short-term infrastructure deployment.

The operational strategy is defined by four core strands of action: universal access with prioritisation of disadvantaged areas, a critical shift in focus from coverage to functionality (measured by quantity, regularity, and quality), embedding long-term sustainability measures and robust local capacity building for O&M (Operational Guidelines JJM, 2019).

3. Scope of Evaluation and Policy Relevance

The analysis is organised around four complementary pillars. First, the Institutional pillar examines the governance architecture underpinning JJM by assessing how roles and responsibilities are distributed across the delivery system, including the formation and functioning of Village Water and Sanitation Committees and the coordination roles of Gram Panchayats and state and district authorities. Second, the Infrastructural pillar reviews the physical systems created and strengthened under the Mission, including source development, treatment capacity, storage, transmission, distribution networks, and household connections. Third, the Financial pillar assesses the financing framework that supports service delivery, covering budget allocations, fund flows, cost sharing arrangements, and the adequacy of resources for operations and maintenance. Fourth, the Information and Communication pillar evaluates awareness and engagement efforts, including IEC outreach and the extent to which households understand the Mission, participate in local systems, and use available mechanisms to seek service improvements. Together, these pillars provide a consolidated view of implementation progress and the enabling conditions required for reliable, equitable, and sustainable rural water services.

Together, these pillars provide a clear picture of JJM's on ground progress and the systems supporting it. This establishes the operational context for the survey based analysis in subsequent chapters, where attention shifts from programme growth to service quality, implementation performance, and household level impacts.

4. Methodology

The study uses a two-part analytical framework: (1) Programme Evaluation to assess whether JJM services are delivered equitably, and (2) Impact Evaluation to estimate the causal effects of functional tap connections on household welfare. Together, these methods provide a rigorous assessment of both the equity of JJM implementation and the magnitude of its welfare impacts. The approach also helps identify the institutional and technical conditions that enable the programme to deliver its intended benefits.

4.1 Programme Evaluation

The programme evaluation assesses whether implementation outcomes such as tap functionality, supply regularity and water quality differ across the 3,065 surveyed households located in 12 districts across 6 states. A Bayesian multinomial regression model is applied to examine whether these outcomes vary with technical conditions such as the type of water source, with household socio-economic characteristics, and with programmatic drivers such as household contributions towards repair and maintenance. This approach helps determine whether JJM services are being delivered equitably across villages and household groups.

4.2 Impact Evaluation

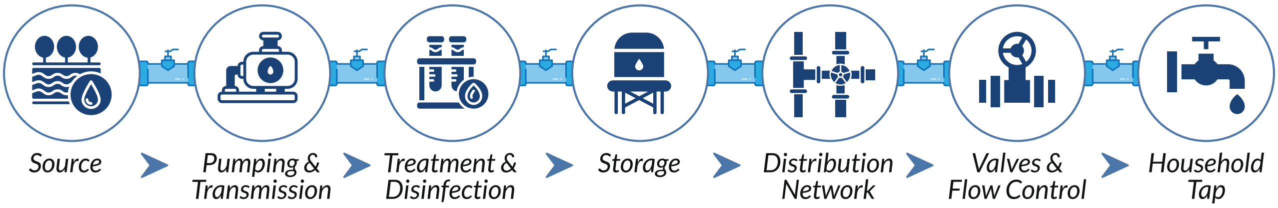
Since JJM is a universal programme, there is no natural untreated comparison group. The study therefore adopts a Pipeline Evaluation Approach. Households that received tap connections in earlier phases form the treatment group, while eligible households still awaiting connection form the pipeline comparison group.

A Difference in Differences (DiD) model compares changes in outcomes such as the time and distance saved between the treated and the pipeline group because of the intervention of the scheme. This method controls for fixed household and village characteristics and for common time shocks, helping to isolate the effect of having a functional tap. The baseline balance checks suggest that pre-intervention outcome reported by treatment and pipeline control households were broadly similar and not statistically distinguishable. While pre-intervention balance checks support comparability, the absence of multiple pre-treatment periods limits direct testing of the parallel trends assumption. Therefore, the credibility of the causal estimates therefore rests on the baseline comparability findings and the assumption that, in the absence of JJM, both treatment and pipeline control groups would have experienced similar trends in water access outcomes.

5. Program Achievements and Progress

5.1 Understanding The Rural Piped Water Supply System

A Rural Piped Water Supply System (RPWSS) is a community oriented service delivery mechanism designed to provide safe and adequate drinking water directly to households through a network of pipes. Unlike traditional rural water sources such as hand pumps, open wells, or distant standposts, an RPWSS ensures that every household can access potable water conveniently through a functional tap connection. An RPWSS functions as an integrated chain of stages must work together for the system to be effective and sustainable. These stages typically include:



Component	Description
Source	Water is drawn from borewells, rivers, lakes, springs, or other safe natural sources.
Pumping and Transmission	When water cannot flow by gravity, pumps lift and transport it to treatment units or storage structures. Reliable pumping ensures consistent flow and reduces system downtime.
Treatment and Disinfection	Water is filtered and disinfected, usually through chlorination, to eliminate pathogens and ensure potability before entering the distribution system.
Storage	Overhead tanks or sumps store treated water, regulate pressure, and provide buffer capacity to stabilise supply during peak demand or short term interruptions.
Distribution Network	A network of main lines, branch lines, and household service connections carries water across the village. Leak free, properly laid pipelines prevent contamination and wastage.
Valves and Flow Control	Control valves regulate flow, maintain pressure, isolate sections for maintenance, and protect the distribution system.
Household Tap	The final delivery point that provides safe, regular drinking water at or near the household, eliminating the need for manual water fetching.

Table 1: Components Required for Effective Functioning of RWPS

5.2 Institutional Mechanisms and Governance Structures

The institutional architecture of JJM is a multi-tier governance system spanning national, state, district and village levels. The National Jal Jeevan Mission (NJJM) serves as the apex body, providing overall direction and strategic guidance. At the state level, the State Water and Sanitation Mission (SWSM) leads coordination, planning and capacity building to strengthen institutional capability. District implementation is overseen by the District Water and Sanitation Mission (DWSM), which acts as the central node for on-ground execution. At the grassroots, service delivery is managed by Gram Panchayats and VWSCs or Paani Samitis, which function as the primary community-facing institutions.

This layered structure reflects the multi-level nature of delivering piped water services in rural India, where effective coordination between technical agencies, implementing bodies, and community institutions is essential for sustained service delivery. The framework is built to balance top down policy direction with bottom up community ownership.

Total Villages	No. of VWSC/ Pani Samiti/ Village Council constituted under JJM	Percentage
5,85,907	5,31,380	90.7%

Table 2: Status of VWSCs (Ministry of Jal Shakti, 2025)

5.3 Infrastructure Development and Capacity Building

JJM is one of India's largest rural infrastructure programmes, combining extensive physical asset creation with significant local capacity building. As of 2025, the Mission has established more than 35,000 water treatment plants (Lok Sabha 2025, Unstarred Question No. 2810), laid over 86 lakh kilometres of pipelines(Lok Sabha 2025, Unstarred Question No. 103) and commissioned nearly 3,000 water quality laboratories (Ministry of Jal Shakti, 2025). To reach remote and water-scarce areas, JJM uses adaptable engineering models such as Single Village Schemes, Multi-Village Schemes and solar-based stand-alone systems. The Mission has also strengthened community institutions by forming more than 5.3 lakh Village Water and Sanitation Committees (Lok Sabha 2025, Unstarred Question No. 2787) and training over 24.8 lakh women to test water quality (PIB, Ministry of Jal Shakti, 2025).

Alongside infrastructure, JJM has generated large-scale employment, with an estimated 2.82 crore person-years of work across construction and operations (Naik, Singh, and Jas 2023). As the Mission advances, the need of the hour is to shift from expanding tap coverage to ensuring reliable and safe water supply. This requires strong operations and maintenance systems, sustainable source management and robust water quality monitoring to translate infrastructure into dependable household service.

5.4 Financial Investment and Resource Mobilisation

JJM constitutes one of the largest public investments in rural water supply undertaken in India. Since its launch, the Mission has been allocated a total of ₹3.6 lakh crore, reflecting a sustained commitment to expanding rural drinking water access and strengthening service delivery systems (Ministry of Jal Shakti, 2024). Annual budgetary allocations indicate both the increasing fiscal prioritisation of rural water security and the intensity of capital expenditure required for piped water infrastructure.

Year	GoI Share	State Share	(Tentative) Total Allocation
2019-20	20,798	15,202	36,000
2020-21	34,753	25,247	60,000
2021-22	58,011	41,989	1,00,000
2022-23	48,708	35,292	84,000
2023-24	46,382	33,618	80,000
Total	**2,08,652**	**1,51,348**	**3,60,000**

Table 3: Budgeted Outlay over Five Years, Amount in ₹ Crores (Ministry of Jal Shakti, 2019)

5.5 Awareness, Behaviour, and Public Engagement

IEC activities are a central pillar of JJM, intended to promote safe water practices and strengthen community participation in managing rural drinking water systems. Despite the scale of infrastructure created and the establishment of VWSCs across villages, survey findings show that public awareness of the Mission remains limited. Only about half of all respondents reported being familiar with JJM, indicating the need to strengthen communication efforts to ensure universal access.

Awareness of the Mission varies across social and income categories, with relatively higher awareness among OBC and General category households, indicating an opportunity to strengthen communication and last mile outreach among aspirational communities, particularly the Scheduled Caste and very low income households that earn less than ₹1 lakh per annum. Education also shows a clear gradient, with awareness increasing from 40% among individuals with no schooling to nearly 67% among those with graduate-level education. While awareness does not increase uniformly across all income groups, it is consistently lowest among very low-income households, who often face the greatest water access challenges. These gaps suggest that current IEC strategies are not fully reaching marginalised and low-literacy populations and need to be adapted to local social contexts and information environments.

5.6 Analytical Evidence On Implementation Outcomes

While national administrative data confirms extensive coverage, the project survey provides ground-level verification, reporting that only 62.1% of sampled households possess a JJM tap connection. This figure partly reflects differences in measurement, as the survey distinguished JJM tap connections from other household taps and water access arrangements recorded locally. To move beyond these mere connection metrics, Bayesian Multinomial Regression Models were utilised to discern the determinants of sustained service functionality and quality. Key insights from the analysis are:

Evaluation Parameters	Results
Availability Of A Tap Connection	Households that were aware of the Mission had 77% higher odds of having a JJM tap connection, highlighting the importance of communication and outreach in improving uptake.
Functionality Of Tap Connection	Households that pay a monthly fee have higher odds (approximately 84% higher odds) of reporting a functioning tap, implying fee-based connections are associated with better service outcomes.
Reliability of Service	Households that pay service providers for repairs are 35% less likely to report summer only supply, indicating more continuous access. Similarly, households that pay a monthly user charge show approximately 71% higher likelihood of reporting year round water availability.
Quality of Water	Households that pay a monthly user charge have 36% lower odds of reporting poor water quality from the tap, indicating an association between user contributions and better perceived water quality.

Table 4: Key Insights From Bayesian Multinomial Regression Analysis

The regression results indicate that the determinants of improved service outcomes extend beyond infrastructure provision. Awareness of the Mission is positively associated with connection uptake, while routine user contributions are consistently associated with higher reported functionality, greater year round availability, and lower reporting of poor water quality. These empirical patterns suggest that sustained service delivery in the next phase will depend on strengthening institutional capacity, reinforcing communication and outreach mechanisms, and formalising predictable operations and maintenance financing arrangements, rather than relying solely on further asset expansion.

6. Impact Assessment and Welfare Outcomes

6.1 Primary Impacts

This section begins by examining the most proximate welfare effects of improved household water service delivery. Distance travelled to obtain water and time spent collecting water are treated as the primary impacts because they are the most direct and immediate channels through which a functional household tap connection generates welfare gains. In rural contexts, access deficits are first experienced as recurrent costs in physical effort and time, with clear opportunity costs for income generation, schooling, and care work. These indicators therefore offer an empirically tractable measure of whether infrastructure provision has translated into usable, reliable service at the household level. They also support rigorous distributional analysis, since baseline collection burdens and the resulting gains are typically heterogeneous, with disproportionate effects for women and socio economically disadvantaged groups.

6.1.1 Impact on Distance Travelled to Fetch Water

6.1.1.1 Descriptive Improvements in Physical Access

The initial survey results highlight a substantial and equitable shift towards within-household water access across various socio-economic segments following the installation of functional taps. This section details the descriptive findings on the improved accessibility and equity dividends generated by the intervention.

- **Improved Access and Reduced Travel Burden**
  The share of households reporting travel distances of more than 250 metres fell by almost half following the intervention. This suggests that functional tap connections substantially reduced the physical burden of water collection for many beneficiary households, indicating that JJM infrastructure translated into meaningful improvements in day to day access.

- **Equity and Distributional Effects**
  Improvements in access following the introduction of functional tap connections were not uniform across households; gains were larger among households, particularly amongst aspirational communities, that faced greater constraints in access prior to the intervention.

  - Among social categories, Scheduled Caste households registered a substantial 23.5 percentage point increase in access to a household-level water source, while Scheduled Tribe households experienced a 19.6 point improvement.

  - A similar gradient is observed across economic strata: low-income households reported a 21.6 point increase in access, and middle-income households experienced an even larger improvement of 23.2 points.

These distributional patterns demonstrate that the rollout of functional tap connections under JJM has effectively reached those who have traditionally faced barriers to secure and proximate water access. This reinforces the interpretation of JJM not simply as an infrastructure provision scheme, but as a redistributive service-delivery programme contributing to reduced socio-economic disparities in basic service access.

- **The Role of Intra-Household Gender Dynamics in Shaping Access Gains**
  Households in which women hold primary responsibility for water-related decision-making experienced some of the most substantial gains, with a 22.6 percentage point increase in access to a household-level water source. This pattern should not be interpreted solely as an effect of women's participation. Instead, it is more appropriately situated within an intra household framework in which gendered divisions of labour shape the perceived returns to improved water services and, consequently, household adoption and utilisation. In contexts where women bear primary responsibility for water collection, reductions in collection burdens generate immediate and salient welfare gains, which may increase the propensity of households to prioritise the uptake and sustained use of the service.

  Complementing this interpretation, the qualitative evidence suggests that these gendered divisions of responsibility also shape post adoption behaviour and local accountability practices. In households where women manage day to day water needs, respondents reported greater attentiveness to service attributes such as reliability, contamination risks, and tap functionality, which was associated with more frequent engagement with local institutions and frontline service providers when disruptions occurred. This engagement strengthens routine monitoring and can support more sustained utilisation of the service over time. Accordingly, the observed reductions in travel distance and the associated physical burden reflect not only infrastructural provision, but also the differentiated incidence of welfare gains arising from women's central role in household water management.

6.1.1.2 Results from Difference-in-Differences Analysis

- **Identification Strategy and Hypothesis Framework**

  The impact evaluation adopts a pipeline comparison design where households that received a JJM tap connection in earlier phases constitute the treatment group, while eligible households that are yet to receive a connection constitute the pipeline comparison group. This structure leverages phased roll out to estimate the Average Treatment Effect of access to a functional tap by comparing changes in outcomes between households already served and those still awaiting service. The estimand is evaluated under the following hypotheses:

  H0: Access to a functional tap has no effect on the distance travelled to fetch water; and
  H1: Access to a functional tap reduces the distance travelled to fetch water.

  Under the identifying assumption that, in the absence of JJM, both groups would have followed similar trends in collection distance, this specification isolates the effect of functional service provision and enables a rigorous assessment of how improved service delivery translates into reduced household physical effort.

- **Causal Effect and Magnitude**

  Table 5 shows that access to a functional tap connection is associated with a marked reduction in the distance households travel to collect water. The estimated interaction term, which captures the Average Treatment Effect, is minus 104.46 metres ($p < 0.001$) implying that treated households experienced an additional post intervention decline of about 104 metres relative to the comparison group. The magnitude of this effect suggests a meaningful reduction in the day to day physical burden of water collection.

Variable	Estimate	Robust standard errors clustered at village level	t-value	p-value
Treatment Status (Functional Tap)	−25.42	15.66	−1.62	0.11
Post-Intervention Period	4.04e−13	0.000001	0.000004	1
Difference-in-Differences Effect (ATE)	−104.46	9.33	−11.2	< 0.001***

Table 5: Difference In Difference Results For Distance Travelled

*** *Significant at 99% confidence interval*

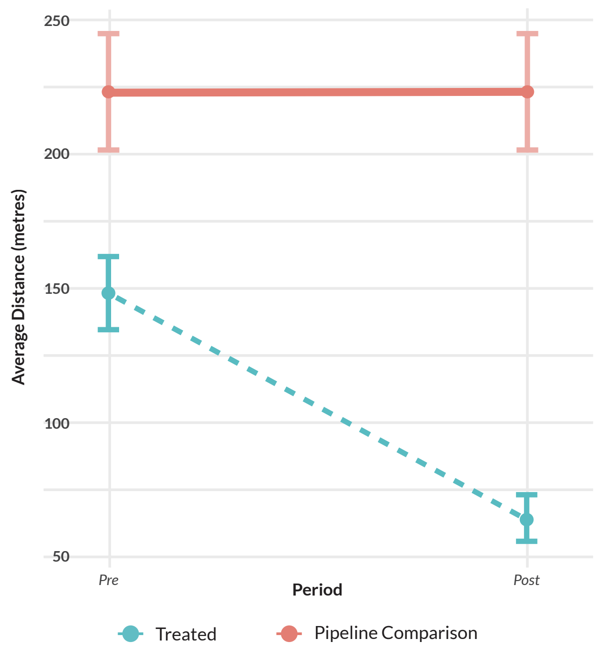


Figure 2: Difference in Difference Estimates of Distance Travelled, by Treatment Status

6.1.2 Impact on Time Spent to Fetch Water

6.1.2.1 Descriptive Improvement in Physical Access

Survey findings indicate a substantial reduction in the time households spend collecting water following access to a functioning tap, with improvements observed across social and income groups. The proportion of households reporting spending more than two hours per day in collecting water declined sharply by 57.5%. Consistent with the corresponding reduction in collection distance, these results point to a marked easing of the time burden associated with routine water collection.

- **Improved Access and Reduced Time in Fetching Water**

  The average time spent in collecting water for treated households fell from about 52 minutes before the tap became functional to about 37 minutes after, which is a reduction of roughly 28%. This indicates that the installation of functional taps has directly alleviated the time savings for the beneficiary households. The shift reflects a clear translation of JJM infrastructure into everyday access gains.

- **Greater Time Savings for Female-Headed Households**

  The reduction in collection time was particularly pronounced among female headed households. After receiving a functioning tap, the share of female-headed households able to obtain water within one hour or less was 11.5 percentage points higher than among other household types. In settings where women bear primary responsibility for water collection, the time saved is typically reallocated to household management and care work, supporting children's schooling, livelihood activities, and rest.

6.1.2.2 Results from Difference-in-Difference Analysis

- **Identification Strategy and Hypothesis Framework**

  The pipeline comparison group comprises eligible households that have not yet received a JJM tap connection and do not have access to a functioning JJM provided service. This design enables estimation of the Average Treatment Effect by comparing changes in water collection time between households with access to operational tap service and those that remain unserved within the programme pipeline. The estimand is evaluated under the following hypotheses:

  Ho: Access to a functioning tap has no effect on time spent collecting water.

  H1: Access to a functioning tap reduces time spent collecting water.

  Within this framework, the specification isolates the effect of functional service provision and assesses whether improvements in service reliability translate into reductions in household time burdens

- **Causal Effect and Magnitude**

  Table 6 reports a statistically significant reduction in water collection time associated with access to a functional tap connection. The estimated interaction term, interpreted as the Average Treatment Effect, is minus 14.74 minutes ($p < 0.001$), indicating that treated households experienced an additional post intervention decline of roughly 15 minutes relative to the comparison group.

  In substantive terms, this represents a meaningful reduction in the daily time burden of water collection and is consistent with the corresponding decline in collection distance.

Variable	Estimate	Robust standard errors clustered at village level	t-value	p-value
Treatment Status (Functional Tap)	−3.815996e-01	1.88	−0.20	0.84
Post-Intervention Period	-1.920000e-13	0.000001	-0.000000192	1
Difference-in-Differences Effect (ATE)	−1.474228e+01	1.21	−12.2	< 0.001 ***

Table 6: Difference in Difference Results for Time Spent in Collecting Water

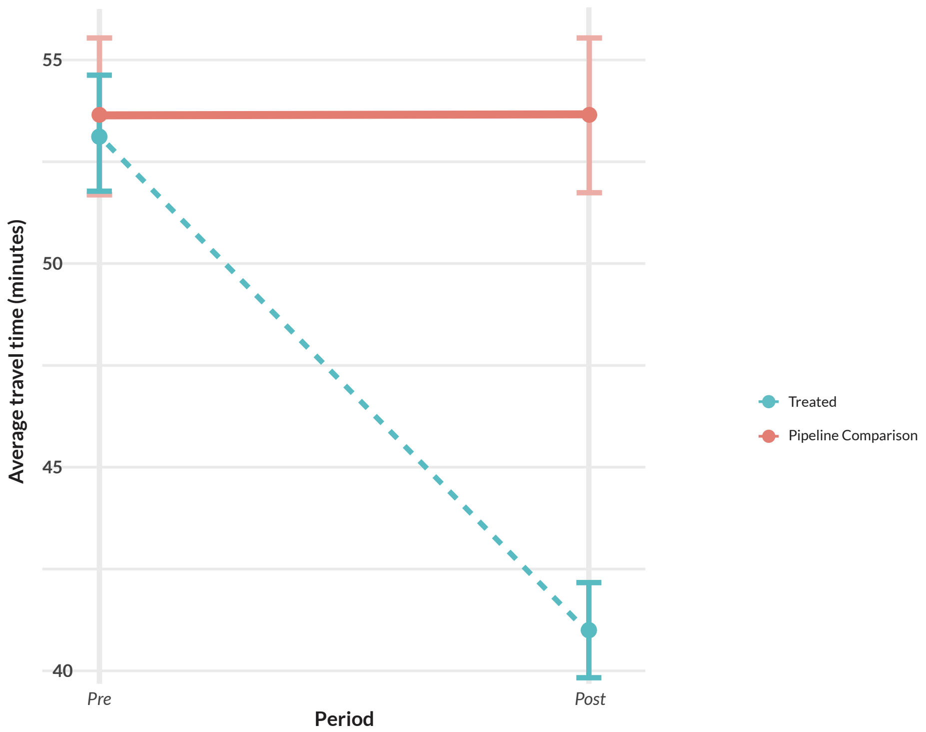


Figure 3: Difference in Difference Estimates of Time Taken, by Treatment Status

6.2 Secondary Impacts

6.2.1 Impact on Water Source Costs

Overall, 35.4% of households reported a change in water related expenditure. Within this group, only 3.58% reported an increase, while 96.42% reported a decrease.

This reduction in water related expenditure was not uniform across households and was more pronounced in certain socio economic segments such as medium income households earning between ₹2 lakh to ₹5 lakh per annum. Among households reporting any change in expenditure, 55.5% reported that water related financial decisions were primarily taken by male household members, indicating that household level decision making structures influence how costs and payments are managed.

*** *Significant at 99% confidence interval*

6.2.2 Health Risk Reduction

The level of service that JJM commits to is in line with the higher level of drinking water services defined by the WHO/UNICEF Joint Monitoring Programme for Water Supply, Sanitation and Hygiene (JMP) (Jal Jeevan Samvad, 2023). JJM has the potential to significantly reduce child mortality by expanding access to safe drinking water across India. Estimates suggest that the Mission could prevent approximately 1,36,000 deaths among children under five each year (Kremer et al., 2023). Projections further indicate that if JJM maintains a steady implementation pace, diarrhoeal deaths and disability-adjusted life years (DALYs) could decline by nearly half (45.4%). Over the programme period, this could translate into nearly 400,000 lives saved and almost 14 million DALYs averted (WHO, 2023).

6.2.3 Educational Participation

Educational outcomes also reveal improvements, particularly for girls who previously bore the responsibility for water collection activities. Availability of clean water, improved toilet facilities and enhanced hygiene and sanitation in school has encourages female students to attend school regularly. Less than 1% of surveyed households reported that children occasionally missed school due to water-related issues. With access to functional taps, children's regular school attendance was generally observed to have improved.

6.2.4 Economic Development through Employment Generation

A study by IIM Bangalore estimated that JJM could generate 2.82 crore person-years of employment during the construction phase (Naik, Singh, and Jas 2023), together with an additional 13.3 lakh person-years annually during the operations phase (PIB, Ministry of Jal Shakti, 2025). A large share of the direct employment created is in skilled and semi-skilled trades such as engineers, managers, plumbers, electricians, motor mechanics and chemists. Annual direct employment during Operations & Maintenance was estimated at 11.84 lakh person-years per year (Naik, Singh, and Jas 2023).

The transition from the asset creation to the service delivery phase should focus on skills development for local workers, inclusive (gender-sensitive) hiring practices, and secure financing for O&M.

6.2.5 Women's Empowerment and Gender Equity Outcomes

Household survey responses indicate high reported satisfaction with JJM among women respondents, with qualitative accounts suggesting that time savings from reduced water collection were reallocated towards routine household responsibilities, increased support for children's education, and rest. Collectively, these responses are consistent with a reduction in women's time burdens and associated opportunity costs, with implications for day to day wellbeing.

Village Water and Sanitation Committees have supported women's participation in community level water governance by creating structured platforms for engagement and local leadership. Evidencing this, 24.64 lakh women have been trained for testing the water samples through Field Test Kits (PIB, Ministry of Jal Shakti, 2025). Moreover, guidelines mandate 50% women representation in Village Water and Sanitation Committees (Operational Guidelines JJM, 2019). Qualitative accounts also indicate that implementation has created livelihood opportunities, including SHG linked roles in collecting JJM water user fees, which some women view as a pathway towards sustained income and greater financial agency. In addition, survey responses suggest that time savings from reduced water collection are associated with greater participation of women in household decision making processes, indicating a potential expansion in perceived decision making autonomy.

6.2.6 Household Welfare and Quality of Life Improvements

JJM has generated substantial improvements in household welfare and day to day quality of life for rural families. As discussed in the primary impacts section, access to a functional household tap has reduced the distance households need to travel to fetch water, easing the physical burden of collection and supporting improved household management. Consistent with these access gains, the primary household survey finds that 73.8% of households with a functional tap connection reported overall satisfaction and a noticeable improvement in quality of life, underscoring the perceived benefits of reliable in-home water access for everyday living conditions.

JJM Impact at a Glance

Impact on Water-Related Expenditure	• 35.4% of households reported a change in their water source expenditure with almost 97% reporting a reduction in expenditure. • Among the households reporting any cost change, 55.5% reported that males were primary decision makers with respect to financial matters.
Health Impact	• Up to 1,36,000 child deaths prevented annually (WHO, 2023)
Education Participation	• Almost all respondents acknowledged that the availability of clean water, improved toilet facilities and enhanced hygiene and sanitation in school further encourages female students to attend school regularly
Economic Impact	• 2.82 crore person-years of employment generated during construction (Naik, Singh, and Jas 2023) • 11.84 lakh annual O&M jobs created (Naik, Singh, and Jas 2023)
Women's Empowerment	• Guidelines mandate 50% women representation in Village Water and Sanitation Committees • Over 24.8 lakh women have been trained in water quality testing (PIB, Ministry of Jal Shakti, 2025)
Household Welfare	• 73.8% of households report improved quality of life • Approximately 105 meters reduction in average distance to fetch water • Approximately 15 minutes saved daily, primarily benefiting women

Table 7: JJM Impact Overview (Insights from Primary Survey and Secondary Data)

Map 1: States Covered in the Primary Survey for the JJM Impact Evaluation

7. Heterogeneity in Implementation: State and Regional Variations

7.1 BIHAR
Rapid Coverage Momentum

Bihar's implementation trajectory reflects rapid scale up in rural tap coverage, building on the state's Har Ghar Nal Ka Jal initiative. Administrative reporting indicates that coverage rose from 1.89% to 95.71% between 2019 and 2025, with expansion supported largely by increased reliance on state financing (JJM Dashboard , 2025). Household survey results from the sampled districts corroborate this substantial penetration, with 82.6% of households reporting a tap connection under the scheme and 83% reporting improvements in perceived water quality. Service frequency is reported as relatively regular among connected households, with 68% receiving supply six to seven days per week, and many households reporting two daily supply windows, consistent with service scheduling to meet normative supply benchmarks.

Household Tap Connection in Bihar

Given this edifice, the upcoming phase in Bihar concerns institutional consolidation rather than network creation. Field observations indicate that where Village Water and Sanitation Committees meet regularly and possess basic technical and bookkeeping capacity, systems are more likely to have an identified operator, clearer supply scheduling, and a functional pathway for repairs and complaint resolution. In this context, priorities for the next phase include scaling VWSC capacity building, ensuring timely remuneration for operators, and improving coordination between Mission processes and state water institutions so that installed assets translate into stable household service.

7.2 HARYANA
High Service Reliability

Haryana represents a mature service delivery context within the study sample. Administrative reporting shows coverage rising from 58.08% in 2019 to near universal levels by 2023 (JJM Dashboard , 2025), and the survey records 96.5% functionality among connections classified as Mission attributed at the time of fieldwork. Reliability indicators are high, with 94.6% reporting supply six to seven days per week and 98.2% reporting year round availability; reported maintenance response times are also recorded to be typically one to two days. These patterns are consistent with a delivery system in which local operations are integrated with stable financing under the 50:50 Centre-State arrangement.

Two analytical refinements emerge for Haryana's next phase. First, survey findings suggest that a portion of observed connections reflect pre existing private assets and legacy scheme networks; reporting that distinguishes Mission

JJM Pump room in Ladana village in Ambala, Haryana funded connections from prior infrastructure and would improve attribution clarity and support more precise planning. Second, where deep borewells are the dominant source in high extraction zones, a longer term service strategy benefits from stronger aquifer management, recharge interventions, and feasible integration of surface water sources to protect continuity.

7.3 ASSAM
Rapid Infrastructure Gains

Assam recorded substantial expansion in household tap coverage, with administrative reporting increasing from 1.54% to 81.63% between 2019 and 2025 (JJM Dashboard , 2025). Implementation occurred in a context characterised by dispersed habitations and seasonal disruption risk, including flood exposure. Fund utilisation strengthened over time, rising from 34% in 2019-20 to 61% by 2023-24, indicating increasing administrative absorption capacity (JJM Dashboard , 2025). Survey evidence indicates welfare relevant changes among connected households, including an increase in the proportion completing water collection within one hour and reported improvements in perceived health outcomes.

Water tank built under JJM in Sonitpur, Assam

To translate the rapid infrastructural scale up into sustained service delivery, an emerging priority for the state is consolidation and standardisation of service operations. District level variation suggests that effective delivery models already exist within the state system. Given this precedence, priority measures include establishing district maintenance hubs with trained personnel and spare part availability, adopting flood resilient engineering design where relevant, provision of Viability Gap Funding by the state for geographically challenging regions, clarifying financial authority for routine O&M expenditure at the village level, and introducing performance linked incentives that reward service continuity alongside physical connections. These reforms aim to align system monitoring with household experienced service.

7.4 KARNATAKA
Operational Innovation

Karnataka's administrative series records coverage growth from 24.2% in 2019 to 85.91% by 2025 (JJM Dashboard , 2025). Of this, survey results in sampled districts report 63.12% of households report connections under the Mission. Among connected households, reported outcomes include improvements in women's collection time, 68% reporting improved water quality, and 61.3% reporting improved quality of life. Fiscal participation under the 50:50 funding framework remains sustained with continued subnational commitment even during later implementation and maintenance stages (JJM Dashboard , 2025).

As one of the mature performing states, the next opportunity for the state can be framed as service quality improvement. Rapid extension of connections through integration with panchayat tanks and legacy networks supported coverage expansion but appears to have produced service regimes that remain uneven across locations. To address this, operational strengthening measures such district specific engineering adaptations in topographically constrained areas, service quality audits linked to district level performance incentives, and structured activation of Village Water and Sanitation Committees with defined technical roles and clear authority for routine O&M decisions can be prioritised. The state's institutional base provides a platform for shifting administrative attention from installation outputs to operating outcomes.

JJM Tap Connection in Bidar, Karnataka

7.5 MADHYA PRADESH
Steady Delivery Trajectory

Madhya Pradesh shows a comparatively stable implementation profile. Administrative reporting indicates coverage increasing from 12.12% to 65.05% (JJM Dashboard , 2025), out of which the survey records 59.32% households with functional connections under JJM, indicating relatively close alignment between administrative progress and household reporting in sampled districts. Perceived water quality improvements are reported by 75.3% of households, and women's collection time declines materially, with the proportion completing collection within one hour rising from 66.5% to 91.2% after implementation. More than 2/3rd of beneficiary households reported reductions in child illness episodes, consistent with anticipated benefits from improved proximity and improved water handling.

Water Tank built under JJM, Dewas

With specific districts exhibiting standard operating models resulting in sustained service delivery, the emerging opportunity is to scale it across the state. For example, the Khatamba Panchayat case illustrates the role of scheduled supply, pre and post monsoon water testing, and risk sensitive pipeline placement. Similarly, the Self Help Group facilitated fee collection model in Dewas provides an implementable approach to routine cost recovery. Scaling such practices through clearer O&M handover protocols, milestone based contractor accountability, and feasible integration of Narmada surface water in groundwater stressed districts can strengthen reliability and enhance service delivery.

7.6 RAJASTHAN
Progress In Water Stressed Contextss

Rajasthan's coverage increased from 10.9% to 56.92% between 2019 and 2025 (JJM Dashboard , 2025), indicating material progress in a water stressed environment. District level experience illustrates differentiated execution trajectories. For example, Alwar increased from 12.02% to 63.42%, which is higher than the aggregate growth of coverage in the state. Where schemes have reached full commissioning, functionality is reported at 90.9%, indicating that completed systems perform effectively once operationalised.

The next phase in Rajasthan centres on improving continuity and strengthening execution systems suited to scarce source conditions. Where fund utilisation has remained below allocations, targeted project management capacity at the district level and streamlined procurement with state provision of Viability Gap Funding can improve delivery timelines. In addition, long source distances and dependence on grid power make a case for coordinated source strengthening, recharge interventions, integration of surface water where feasible, and decentralised backup power for critical pumping assets. Formalising VWSC operating roles, ensuring predictable maintenance budgets, and timely operator salary disbursement can improve local stewardship. A context sensitive service strategy calibrated to local hydrology, with performance linked incentives for reliability, can consolidate gains and protect continuity.

Water Tank built in Dausa, Rajasthan

Map 2: Countries Referenced for International Best Practices in Water Services

8. Global Best Practices

8.1 Overcoming Geographical Barriers and Proximity Challenges: Lessons from China's South-North Water Transfer Project

8.1.1 Overview

China's South-North Water Transfer Project (SNWDP) is a landmark initiative that transfers water from the water-rich southern regions, primarily the Yangtze River basin, to the water-scarce northern regions, including Beijing, Tianjin, and the North China Plain. As one of the world's largest and most ambitious water infrastructure projects, it was launched to tackle severe water scarcity in northern China. The project diverts water through three main routes: Eastern, Central, and Western. The SNWDP offers valuable lessons in managing inter-regional water transfers, particularly in addressing challenges related to proximity, infrastructure, and resource allocation.

8.1.2 Key Takeaways

Project Architecture and Key Components	Technical and Operational Insights	Lessons for India's Jal Jeevan Mission	Strategic Recommendations for Implementation
Eastern Route	The Grand Canal has been upgraded to a length of 1,152 km and includes 23 pumping stations. Tunnels under the Yellow River carry water northward from the Yangtze to Shandong and Tianjin.	Leveraging existing canals and lift infrastructure, along with engineered pumping stations and tunnels, can help expand rural water coverage and overcome topographic constraints.	Upgrade and adapt existing canal networks, such as the Ganga and Yamuna canals. Install modern pumping stations and tunnels to cross rivers, with a focus on connecting distant and water-deficit districts.
Central Route	The Central Route consists of a gravity-fed canal running from the Han River, a tributary of the Yangtze, to Beijing and Tianjin. The canal spans over 1,200 km, and the Danjiangkou Dam was raised to enable downhill flow.	Gravity should be used wherever possible to minimise operational costs. Strategic upgrades to reservoirs support efficient gravity-based water flows.	Identify dam and reservoir sites to increase elevation and enable gravity transfer for long pipelines. Prioritise gravity-fed routes to improve cost efficiency in water distribution.

Table 8: Key Takeaways from China

China's South-North Water Transfer Project demonstrates significant engineering innovations, including long gravity channels, underground tunnels, large-scale pumping stations, aqueducts, and reservoirs. These innovations are combined with upgrades to traditional canal networks, with a focus on system reliability and minimising water loss due to evaporation or pollution. For India's Jal Jeevan Mission, adopting a best-fit combination of engineering solutions including gravity-fed channels, tunnels, canals, and pipelines tailored to local terrain and distance, can effectively mitigate challenges posed by geographic proximity. Employing advanced materials and technologies can enhance efficiency and durability, ensuring sustainable water delivery. Such robust infrastructure not only addresses the issue of distance but also supports the sustainability of water sources and helps prevent the overexploitation of groundwater resources.

8.2 Ensuring Groundwater Sustainability: Lessons from Artificial Groundwater Recharge in Saudi Arabia

8.2.1 Overview

Saudi Arabia faces severe water scarcity compounded by arid climate conditions, high evaporation rates, and heavy groundwater extraction exceeding natural recharge rates. The country's natural water supply is largely reliant on non-renewable fossil aquifers, leading to declining groundwater levels and threats to agricultural productivity, drinking water availability, and ecological sustainability.

To mitigate this, Saudi Arabia has launched an extensive artificial groundwater recharge (AGR) program, aiming to replenish aquifers by capturing and redirecting surface runoff, rainwater, and dam-stored water back into underground aquifers. This method reduces surface water evaporation, stabilises groundwater tables, and improves water quality by diluting salts and contaminants in over-exploited aquifers. The program integrates modern techniques such as injection wells, reservoirs/dams, remote sensing, and hydrogeological assessments to optimise recharge efficiency and sustainability.

8.2.2 Key Takeaways

Project Architecture and Key Components	Technical and Operational Insights	Lessons for India's Jal Jeevan Mission	Strategic Recommendations for Implementation
Recharge Techniques	Use of dams/ reservoirs, injection wells, artificial ponds, runoff harvesting	Combination of surface water storage and underground recharge maximises water retention and reduces evaporation losses	Combine surface storage (small dams/ tanks) with injection wells for rural groundwater recharge in arid regions
Recharge Efficiency	Variable but up to 86–94% recharge rate with injection wells, dam water infiltration 82–94.5%	Injection wells upstream of dams drastically increase infiltration efficiency and reduce evaporation	Incorporate injection wells near recharge structures to boost efficiency and lower water loss
Hydrogeological Assessment	Site selection based on remote sensing, Digital Elevation Model (DEM), geophysical surveys to optimise recharge locations.	Data-driven, context-specific approaches ensure higher recharge rates and aquifer sustainability.	Use GIS and satellite imagery for optimal site selection of recharge points in water-scarce Indian regions

Table 9: Key Takeaways from Saudi Arabia

The artificial groundwater recharge program in Saudi Arabia has achieved significant milestones in restoring groundwater resources. Notably, the water table in recharge areas has risen by up to 11.6 meters, demonstrating effective replenishment of depleted aquifers (Al-Shayea and Al-Ghamdi, 2023). Additionally, the recharge has led to a reduction in groundwater salinity by diluting the aquifers with fresh recharge water, thereby improving the water quality for both agricultural and drinking purposes. These achievements have enabled sustainable groundwater use, reversing the long-term decline of aquifer levels. Importantly, this experience underscores that groundwater is not inherently an unsustainable water source, instead, its sustainability depends on the balance between extraction and natural or artificial replenishment. Artificial recharge programs can restore depleted water tables and mitigate salinisation issues in over-exploited aquifers, offering a replicable model for India's Jal Jeevan Mission to enhance groundwater sustainability and rural water security in water-stressed regions.

8.3 Community-Based Water Management: Lessons from Indonesia's PAMSIMAS Initiative

8.3.1 Overview

Indonesia's Community-Based Drinking Water Supply and Sanitation Program (PAMSIMAS), launched in 2007, stands as one of the world's largest rural water supply initiatives. By 2020, the program had reached 22 million people across 32,000 villages throughout the Indonesian archipelago, addressing the persistent challenge where only 82% of rural households had access to basic water services compared to 95% in urban areas. The program's core philosophy centers on community ownership and management at the village level. PAMSIMAS was designed to overcome the limitations of top-down approaches by empowering local communities to plan, implement, and maintain their water supply systems. This community-driven development approach has proven remarkably effective, with 85.4% of PAMSIMAS systems functioning fully, 9.1% partially functioning, and only 5.5% non-functional as of 2020 (Pamudji, Djono, and Daniel, 2022).

8.3.2 Key Takeaways

Project Architecture and Key Components	Technical and Operational Insights	Lessons for India's Jal Jeevan Mission	Strategic Recommendations for Implementation
The program emphasises community ownership and management through local water boards	Local water boards are supported by district facilitators, resulting in sustained operation and maintenance of water supply schemes. PAMSIMAS integrates capacity building and mentoring for local institutions, ensuring continued technical and financial skills development.	Village water committees must be strengthened through capacity building, mentorship, and active facilitation. Mere existence of committees is insufficient, sustained support ensures they become effective, empowered institutions.	Provide regular training, mentoring, and technical support to existing village water committees. Introduce monitoring, accountability mechanisms, and community engagement strategies to transform them into active and effective management bodies rather than symbolic structures.

Table 10: Key Takeaways from Indonesia

The experience of Indonesia's PAMSIMAS program highlights that the establishment of village water committees, while important, needs to be complemented by sustained capacity building, mentoring, and active facilitation. Without continued institutional support, such committees may face challenges in effectively managing water supply systems. Strengthening their technical, financial, and managerial capabilities is therefore essential to enhance the sustainability and reliability of rural water services under JJM.

8.4 Integrated and Sustainable Water Governance: Lessons from Germany's National Water Strategy

8.4.1 Overview

Germany's National Water Strategy (2023) establishes a long-term vision for securing clean, affordable and climate-resilient water supply through 2050. Developed after an extensive National Water Dialogue involving 200 stakeholders, it integrates water policy across agriculture, urban planning, industry and environmental management. The strategy responds to mounting stress from climate change, droughts, heatwaves and floods, by linking federal, state and local responsibilities under a single "Water in All Policies" framework. (BMUV, 2023; SDG Partnership Platform, 2023).

8.4.2 Key Takeaways

Project Architecture and Key Components	Technical and Operational Insights	Lessons for India's Jal Jeevan Mission	Strategic Recommendations for Implementation
Long-Term (2050) Planning Horizon with explicit targets on quality, affordability and ecosystem resilience.	Enables anticipatory planning for climate-driven scarcity and extreme situations such as flood and drought.	Introduce multi-decadal district-level water budgets and stress indices to guide investment priorities under JJM.	Integrate climate-risk mapping and hydrological modelling into JJM District Action Plans.
Strict Drinking Water Quality Standards aligned with EU Directive.	Strong regulation and monitoring maintain public confidence in tap water.	Enhancing rural water testing labs and real-time public disclosure can raise quality compliance.	Expand NABL-certified labs and publish village-level quality dashboards for transparency.
Participatory Governance via National Water Dialogue engaging citizens, utilities and experts.	Builds broad ownership and public trust in water policy decisions.	JJM can institutionalise community consultations on tariffs, water quality and maintenance.	Establish state-level "Rural Water Dialogues" for input and feedback by VWSCs on implementation.

Table 11: Key Takeaways from Germany

Germany's National Water Strategy demonstrates that long-term, integrated water governance, anchored in participatory decision-making and strict quality standards, is as critical to water security as physical infrastructure. By aligning federal, state, and local responsibilities under a unified "Water in All Policies" framework, Germany has built public trust while ensuring climate-resilient and ecologically sustainable water management. For India's Jal Jeevan Mission, the key lesson is that delivering piped water to rural households is the first step. Sustaining that delivery over the long term requires anticipatory planning that protects water sources from climate-driven stress, maintains quality through strong monitoring systems, and builds community ownership through transparent governance. Embedding these principles into JJM's planning architecture will be essential to ensuring that rural water access remains reliable, safe, and uninterrupted for generations to come.

8.5 Federal Water Governance and Equity: Lessons from Argentina's National Water Plan

8.5.1 Overview

Argentina's National Water Plan (Plan Nacional del Agua), launched in 2016, builds on the country's Guiding Principles of Water Policy (2003) to coordinate actions across a highly decentralised federal system. With more than 75 percent of its land arid or semi-arid and water resources concentrated in the La Plata basin, Argentina links water policy to social equity, territorial development and climate resilience. The plan targets drinking water and sanitation expansion, irrigation modernisation, flood control and ecosystem restoration. (OECD, 2019; Americas Quarterly, 2024).

8.5.2 Key Takeaways

Project Architecture and Key Components	Technical and Operational Insights	Lessons for India's Jal Jeevan Mission	Strategic Recommendations for Implementation
National Water Plan (2016) with four axes: drinking water & sanitation, irrigation, flood control and hydro-energy.	Links infrastructure investment to regional economic and social development goals.	JJM could be embedded within a broader National Water Mission to align drinking water with livelihood and climate programmes.	Integrate JJM planning with rural livelihood and resilience schemes.
Integration of Nature-Based Solutions in urban and peri-urban projects	Combines grey and green infrastructure to reduce flood risk and improve water quality.	JJM designs in flood-prone villages can adopt similar wetland or rain-garden features for water recharge.	Pilot eco-infrastructure elements within JJM projects in water-logged or semi-arid districts.

Table 12: Key Takeaways from Argentina

By linking water infrastructure to social equity, flood management, and ecosystem restoration across a predominantly arid landscape, Argentina has shown that rural water availability cannot be secured in isolation from broader climate and livelihood goals. The integration of nature-based solutions alongside conventional infrastructure further reflects an approach that works with natural systems to enhance long-term water security. For India's Jal Jeevan Mission, the key lesson is that sustaining rural water availability demands a coordinated, multi-axis approach ensuring that rural households have access to reliable water not just today, but in the face of an increasingly variable climate.

9. System-Level Challenges and Opportunities Ahead

Six years into the Jal Jeevan Mission, India has achieved unprecedented expansion in rural water infrastructure. As states move from the construction-intensive phase towards stable, service-oriented delivery, several system-level challenges have emerged that present opportunities for targeted strengthening. Addressing these will help ensure that every household not only receives a tap connection but experiences dependable, safe and regular water supply.

9.1 Infrastructure Architecture and Physical Systems

A central infrastructural challenge concerns the conceptualisation and measurement of coverage and service delivery. The current reporting architecture aggregates tap connections created under JJM with those inherited from earlier schemes, which makes it difficult to identify the Mission's marginal contribution and constrains the precision of planning and resource allocation. A more differentiated approach distinguishing between installed connections, verified functional systems and service-regular supply would provide a clearer basis for assessing progress and directing technical support.

In addition, the rapid expansion of distribution networks has been an important achievement of the programme's asset creation phase; however, this expansion now needs to be underpinned by sustained investments in source strengthening, including groundwater recharge, conjunctive-use planning and surface-water integration, to ensure year-round reliability. Furthermore, field observations suggest that in some districts, strengthening post commissioning stabilisation protocols, including pressure testing, chlorination calibration, and leak detection, could aid in improving system performance. Thus, a more structured commissioning process, together with clearer protocols for transitioning newly completed schemes into routine O&M, would strengthen the long-term performance of infrastructure created in Phase I and support the programme's shift towards service-oriented objectives in Phase II.

9.2 Institutional Architecture and Governance Systems

A second set of opportunities relates to strengthening the institutional architecture that underpins rural water service delivery. State Water and Sanitation Missions and PHEDs currently shoulder expansive administrative and technical responsibilities, yet their engineering and hydrogeology capacity remains uneven. Expanding this technical bandwidth would enhance quality assurance, reduce commissioning delays and support systematic troubleshooting.

At the same time, district-level facilitation structures such as District Water and Sanitation Missions and Technical Units are critical intermediaries in the service-delivery chain but remain variably operational across states. Fully activating these bodies would improve field supervision, enable more responsive problem-solving and create a stronger feedback loop between local conditions and state-level planning.

At the village level, the lack of defined roles for the Gram Panchayat and the dedicated administrative body of VWSC has produced overlapping mandates for repairs, tariff collection and routine operations, resulting in ambiguity over accountability. Clarifying their respective roles will aid in strengthening the day-to-day management of systems and improve local ownership. More broadly, incentive structures continue to emphasise construction progress and fund utilisation, rather than sustained functionality and reliability. As the Mission transitions into a long-term service-delivery phase, recalibrating incentives towards verified performance can help institutionalise norms of continuity, quality and user satisfaction.

9.3 Financial Architecture and Sustainability

A third area for strengthening concerns the financial architecture that supports long-term service delivery. In particular, strengthening Detailed Project Reports (DPRs) with more granular site specific hydrological assessment, demand projections, and lifecycle costing is required to anchor schemes that are both technically robust and financially sustainable. Enhancing the rigour and local grounding of DPRs would not only accelerate approvals but also improve the efficiency of fund absorption and reduce downstream implementation risks.

At the village level, tariff pathways remain highly variable and are frequently shaped by political sensitivities, which can limit sustainable financing of maintenance and constrain the efficiency of routine operations. Developing transparent, community-endorsed tariff approaches that reflect local affordability while safeguarding system sustainability can help stabilise O&M financing. More broadly, Panchayats and VWSCs often operate without predictable recurrent budgets, leaving them reliant on intermittent grants for essential repairs. Establishing stable O&M financing mechanisms, including the potential use of performance-linked disbursements, would strengthen service reliability and support the Mission's shift from infrastructure creation to sustained water provision.

9.4 Behavioural and Social Systems

A final set of challenges relates to behavioural drivers that shape household uptake, community participation and responsiveness within rural water systems. In many locations, public trust in piped water remains uneven, influenced by past experiences of irregular supply or uncertainty about water quality. Strengthening transparency through regular public reporting of water quality results, visible monitoring practices and consistent supply schedules can help rebuild confidence in the system.

Community ownership, a central pillar of sustainable rural water governance, is still evolving. Limited participation in VWSCs, uneven representation of women and marginal groups, and low engagement in collective decision-making reduce the social foundations needed for system upkeep, tariff compliance and conservation practices. Enhancing civic participation through structured training, inclusive committee formation and routine community dialogues can reinforce shared responsibility for water management. In addition, grievance redressal mechanisms remain largely informal despite the introduction of app-based portals by the Government Developing clear, accessible and trackable grievance pathways can strengthen accountability and ensure timely resolution of service disruptions as the Mission moves into a more service-oriented phase.

10. Strategic Policy Recommendations: Guiding the Trajectory for Sustained Water Security

Given the identified challenges and opportunities, this section delineates on the emerging policy priorities for the Mission. The large coverage achieved under JJM suggests that a strategic policy recalibration is now timely. With the pronounced success of the primary phase of asset creation, the recommendations highlight the need for a shift in focus towards institutionalising sustained functional and resilient service delivery.

The box summarises key empirical associations from the Bayesian regression analysis, highlighting how Mission awareness, routine cost sharing, local engagement in repairs, and service quality mechanisms are linked with improved connection uptake, higher reported functionality, and better reported water quality.

Based on the Bayesian regression findings, we can identify the following success factors:

- **Community Awareness**
  Households aware of JJM show 77% higher odds of having a tap connection.
- **Financial Sustainability**
  Households paying a monthly fee show 84% higher odds of reporting a functioning tap.
- **Local Ownership and Responsiveness**
  Households that pay service providers for repairs show 35% lower odds of reporting summer only supply, consistent with more continuous access.
- **Quality Assurance**
  Households paying a monthly fee show 36% lower odds of reporting poor tap water quality.

Building on these successes, the next phase of JJM should focus on five critical, macro-level directions to ensure long-term impact:

10.1 Infrastructural Recommendations

Over the past six years, JJM has scaled up primary asset creation, including tap connections supported by local tank based sources. To transition from asset creation to service delivery, a strengthened focus on system performance prioritising source security, ensuring rigorous commissioning, and institutionalising routine maintenance is required. To operationalise this shift, the following measures are proposed. To achieve this, the following recommendations can be undertaken:

10.1.1 Measurement Architecture and Coverage Redefinition

A first step in this direction includes strengthening the Mission's measurement architecture requires shifting from installation-based reporting to a verified service-delivery framework. States should clearly distinguish JJM-created connections from legacy infrastructure and adopt a three-tier reporting system that tracks coverage, functionality and service compliance. Over time, norms may be progressively revised upward from the current 55 lpcd towards higher service levels to encourage behavioural adoption, as many households with functional taps still rely on alternative sources. Complementary digital reforms are needed to improve data accuracy, including GIS-tagged asset IDs, mobile-based verification tools, selective sensor deployment and a unified digital O&M platform. These upgrades reduce manual reporting errors, provide real-time performance data and create a verifiable, machine-assisted monitoring ecosystem.

10.1.2 Strengthening Source Sustainability and Conjunctive Use

With more than 85% of rural schemes dependent on groundwater, long-term water security hinges on improving source resilience through coordinated aquifer management, catchment protection and source diversification (Ministry of Jal Shakti, 2025). A formal Catchment Convergence Protocol can align JJM with MGNREGS, Watershed Development and other programmes to rejuvenate recharge zones of priority sources. Completion of National Aquifer Mapping and Management Programme (NAQUIM) 2.0 is advised to be followed by micro-level Source–Aquifer Linkage Assessments and Sustainability Scorecards to guide investment decisions. In regions where borewells are unviable, springshed management should be adopted, while greywater reuse should be reframed as a source-substitution strategy. States may also gradually transition a share of groundwater-dependent schemes towards blended or surface-water systems to address quantity and quality risks. Strategic digital tools such as sentinel monitoring, Digital Twin pilots and GIS-based vulnerability mapping can further enhance anticipatory source management.

10.1.3 Ensuring Smooth Transition from Asset Creation to O&M

The next phase of JJM requires a structural shift from construction-driven delivery to professionalised and accountable O&M. Standardised trial-run protocols, two-year stabilisation periods and certified Jal Mitras can ensure systems are hydraulically sound before handover. Moving towards Design, Build, Operate and Transfer (DBOT) contracts with performance-linked payments and cluster-based O&M agencies will create continuity of technical responsibility and reduce dependence on underprepared Panchayats. Service Level Agreements (SLAs) tied to Finance Commission grants provide strong incentives for maintaining service standards, while graded user charges combined with Viability Gap Funding can secure financial viability. Digital protections such as IoT-enabled pump safeguards reduce equipment failures, and institutionalising certified Nal Jal Mitras and consumer-centred billing systems strengthens local accountability and embeds long-term service stewardship within communities.

10.2 Institutional Recommendations

The sustainability of the upcoming phase of JJM depends on transforming the institutional architecture from a construction-focused hierarchy into a coherent service-delivery ecosystem. Clarifying roles, enhancing capacity and establishing transparent accountability systems will improve implementation and sustain long-term service delivery.

10.2.1 Strengthening SWSM and PHED Capacity (State Level)

State-level institutions require deeper technical and managerial capacity to guide the Mission towards reliable service delivery. SWSMs may establish specialised Project Management Units (PMUs) with multidisciplinary expertise, reposition themselves as technical auditors through PPP-based quality assurance frameworks. Digital capacity should be upgraded through an end-to-end project management system and evidence-based remote quality assurance using geo-tagged construction records. Regular state-level Jal Jan Sunwai forums can institutionalise citizen feedback and strengthen transparency.

10.2.2 Reviving District-Level Water Governance

District-level institutions are central to scheme stabilisation and day-to-day performance monitoring but currently lack adequate staffing and accountability structures. States may operationalise functional DWSM secretariats with dedicated coordinators, planners and technical staff, and assign district engineers clear responsibility for verifying hydraulic balancing, pressure stability and chlorination before handover. Structured forums such as bi-monthly District Jal Chaupals can create direct channels between district engineers and village representatives, facilitating problem-solving on delays, contractor disputes, tariff-setting and emerging source risks. Institutionalising these platforms strengthens downward accountability and ensures field realities inform district-level oversight.

10.2.3 Strengthening Local Institutions for Last-Mile Delivery

Effective last-mile delivery depends on empowered VWSCs with financial autonomy, legal mandate and community oversight. States may ring-fence VWSC water funds to ensure uninterrupted O&M financing, and adopt standardised Village Water By-laws that formalise tariff collection, penalties, and operational authority. Participatory governance can be strengthened through mandatory annual Jal Gram Sabha sessions where VWSCs present water budgets, audited expenditures and planned maintenance. Social audits conducted by women-led SHGs add an independent and trusted oversight layer, verifying functionality, reviewing O&M spending and documenting household grievances, thereby deepening local accountability and fostering more sustainable rural water governance.

10.3 Financial Recommendations

Long-term sustainability of JJM depends on predictable O&M financing, transparent resource management and cost-sharing models that protect vulnerable households. Financial reforms can help rural water systems remain functional without imposing unaffordable burdens.

10.3.1 Strengthening DPR Quality and Fund Utilisation

Improving DPR quality and financial governance requires embedding long-term sustainability into the design and appraisal process. States may mandate 15-year lifecycle costing in all DPRs and grant Technical Sanction only when projected O&M costs are matched by credible revenue sources. Standardised design libraries can streamline DPR preparation and raise engineering consistency, while strict implementation of the Single Nodal Account system ensures transparent, just-in-time fund flow linked to verified physical progress. Integrating District Project Management Support (DPMS, GIS-tagged asset registries and dashboard-based financial monitoring creates a unified digital control spine that ties every expenditure to a verifiable asset, improves auditability and strengthens the alignment between money spent, infrastructure created and services delivered.

10.3.2 Reforming Tariff Systems and Ensuring Equitable User Fee Models

A predictable statewide tariff framework is essential for sustainable O&M financing. States may transition to volumetric tariff bands set within central minimum and maximum thresholds, enabling Gram Panchayats to adopt graded pricing structures that promote fairness, discourage wastage and support cost recovery. Ring-fencing water revenues through dedicated water accounts ensure that user fees are used exclusively for operator wages, electricity bills, chlorination, and minor repairs. To strengthen community acceptance, structured "Value of Water" discussions can clarify why user fees matter, how O&M costs are incurred and how small contributions can significantly reduce breakdowns. These norm-setting processes improve tariff compliance and build collective ownership of water system sustainability.

10.3.3 Financing Long-Term O&M and System Reliability

Ensuring long-term service reliability requires targeted financial mechanisms that address structural cost differences across geographies. States may institutionalise Viability Gap Funding (VGF) for remote, tribal and hill clusters, allowing these villages to maintain reliable service without imposing unaffordable tariffs. At the village level, VWSCs should maintain an Emergency Reserve Fund equivalent to at least three months of O&M costs to respond quickly to pump failures, major leakages or electrical disruptions. Together, VGF and emergency reserves provide financial resilience, prevent system collapse due to funding gaps and enable continuous, responsive service delivery across diverse rural contexts.

10.4 Behavioural Recommendations

Behavioural adoption, trust in piped supply and active community participation are essential for the sustainability of JJM assets. Strengthened IEC, transparent communication and inclusive platforms for grievance redressal can support long-term behavioural ownership.

10.4.1 Building Trust in Water Quality and Source Safety

Strengthening trust in rural water systems requires a shift from reactive testing to a preventive, risk-based approach. States may adopt WHO-aligned Water Safety Plans, with VWSCs conducting Sanitary Surveys to identify contamination risks across the catchment–treatment–distribution chain. Mandatory public disclosure of pre- and post-monsoon test results, alongside deployment of Mobile Water Testing Units, ensures timely, transparent quality assurance even in remote areas. Digital reforms such as QR-enabled FTK-to-cloud uploads and IoT-based inlet sensors create verifiable, real-time quality data for households through simple green–red visual flags. Community engagement through student-led "Jal Doots" and structured roles for village groups in source cleaning and monitoring further strengthens local confidence and embeds preventive water-safety culture.

10.4.2 Establishing Responsive Grievance Redressal

A reliable grievance system is critical for maintaining service standards and public trust. States may notify legally binding Service Level Guarantees under the Right to Public Services Act, outlining clear timelines for resolving disruptions and assigning responsibility across operators, VWSCs, block engineers and district authorities. A structured escalation matrix ensures that unresolved complaints automatically move up administrative levels, while OTP-based complaint closure prevents false resolution reporting. In this direction, omnichannel platforms such as WhatsApp and Interactive Voice Response System (IVRS) have already been introduced which makes fault reporting simple and accessible to all households. Community-facing reforms, including quarterly Jal Chaupals that publicly review grievance performance and household-level contact cards with key helpline numbers, reinforce transparency and create a culture of shared vigilance and accountable service delivery.

10.4.3 Community-Based Audits and the Jal Index

To supplement administrative verification, the government can mandate states to introduce community-based audits, supported by accredited private agencies under a PPP model. These audits can generate a district or village level Jal score aggregated as an annual Jal Index at the central level, benchmarking infrastructure reliability and service regularity across habitations. Publishing Jal Index rankings can encourage healthy competition, guide targeted state support and provide an independent check on dashboard reporting, thus embedding citizen oversight within the performance architecture.

11. Conclusion and Way Forward

The Jal Jeevan Mission represents a profound national success, having achieved an unprecedented surge in rural water coverage and significantly reduced the gendered spatial and temporal burdens associated with water collection. The analysis confirms that the Mission has established the foundational infrastructure necessary for national water security and yielded tangible secondary benefits in dignity and quality of life. The evaluation highlights that, going forward, JJM's priorities are evolving, with greater attention required on sustained functionality alongside coverage. While household tap connections are widespread, service reliability and quality are critically mediated by local O&M finance and institutional capacity. Therefore, the strategic way forward involves a dedicated institutional transition. It is advised that policy priorities be immediately recalibrated towards securing source resilience through diversification, empowering local VWSCs as autonomous service managers, and enforcing rigorous standards for supply regularity and water quality. Continued strengthening of institutional and financial frameworks will enhance the Mission's capacity to ensure that its monumental investments translates into perpetual, reliable, and equitable water security for all rural households.

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Appendix

1. Research Design and Analytical Framework

This section outlines the integrated survey and analytical framework adopted to rigorously evaluate the Jal Jeevan Mission. The design embeds causal inference strategies within a stratified sampling framework to generate internally valid and externally generalisable evidence across heterogeneous implementation contexts.

1.1 Survey Design

The survey design is constructed to balance statistical rigor with policy relevance, using a stratified sampling strategy that captures variability in JJM implementation across diverse contexts. The design operates at multiple levels including households, habitations, schools, Anganwadis, and local Government institutions, to ensure that both service outcomes and governance processes are systematically measured.

1.1.1 Sample State Selection

The first stage of sampling involved the classification of states into performance strata, defined by the proportion of rural households with functional tap water connections in 2025. This information was deduced from the official JJM dashboard (Jal Shakti, n.d.), which provides state-level coverage data. Three strata were specified to capture systematic variation in implementation outcomes:

- High-performing states (90–100% coverage), representing contexts of near-universal access.
- Medium-performing states (75–90% coverage), where substantial progress has been made but gaps persist.
- Low-performing states (50–75% coverage), reflecting areas with continued structural and implementation challenges.

Based on this categorisation, two states were purposively selected from each stratum to approximate the median performance of that category. This stratification ensured that the study design embedded both inter-stratum contrasts (e.g., high vs. low coverage states) and within-stratum representativeness of average performance levels.

1.2 District Selection

Within each selected state, districts were identified through a dual-criteria procedure designed to balance comparability with intra-state heterogeneity.

First, candidate districts were restricted to those lying within ±25% of the state median for the proportion of households with tap water connections. This threshold constraint reduced the risk of biasing results towards outliers. Second, to capture heterogeneity in implementation within the state, one district was drawn from the second quartile and another from the third quartile of the state distribution.

This approach ensured that sampled districts represented "typical" contexts while also embedding variability around the state median. The application of this procedure yielded twelve districts across six states.

1.3 Household Sample Selection

Following the selection of districts, household sample sizes were determined using probability proportional to size (PPS), with weights derived from each district's share of total households within its performance stratum. This approach ensured that larger districts contributed proportionately more to the overall sample, while preserving adequate statistical power for stratum-level comparisons.

Within each district, the household pool was further stratified by social category, gender, and primary occupation, using projected 2025 demographic distributions as benchmarks. From within these strata, households were then randomly selected, producing a sample that is both representative of the district's socio-economic composition and free from selection bias. This two-step procedure thus guarantees inclusivity across key social groups while maintaining the integrity of randomisation. Through this method, a minimum of 2,000 sample households across 12 districts was determined.

2. Detailed Sampling Methodology

2.1 Determination Of Least Sample Size Using Cochran's Formula:

To determine the optimal sample size, Cochran's formula was used with a 95% confidence level and a margin of error of 0.05, providing a precise estimate. The conservative estimate of p = 0.5 was used. The least sample size was calculated as follows:

$$n_0 = \frac{1.96^2 . 0.5\,(1-0.5)}{(0.05)^2} \approx \textbf{384 (384.16) households}$$

2.2 Accounting For Finite Population Correction:

Post the calculation of the least viable sample size, a correction for a finite population was applied. Given the large size of the household populations within each stratum, this adjustment had a negligible effect, and the corrected sample size remained at approximately 384 per group.

2.3 Application Of Design Coefficient:

To adjust for the skewness, a design coefficient (DEFF) was employed to increase the reliability of the research findings. Since the survey will be conducted at the village level to assess the availability of tap water connections, it is expected that households within the same village will exhibit similar responses due to shared local conditions. To adjust for this intra village homogeneity, a standard DEFF coefficient of 1.5 was applied. This adjustment inflated the sample size to 576 to compensate for the potential lack of independence among observations within a district (Niti Aayog, 2022).

2.4 Attrition and Dropout Rate:

Finally, a standard 10% dropout rate was incorporated to ensure the study meets its statistical power requirements even in the presence of non-response or data attrition. The sample size was therefore inflated to 634 (633.6) samples per stratum to account for potential losses.

2.5 Determination Of Sample Size And Proportional Stratified District Sampling:

Based on the sample size calculated for each stratum, the total sample size was estimated at 1,902. For practical purposes, this was rounded to the nearest thousand, resulting in a the minimum required sample size of 2,000 respondents. This total sample was proportionally allocated among the 12 districts. To do this, each district's share of the total population within that stratum (across the 4 districts in each stratum) was calculated. This proportion was then multiplied by the total sample size for each stratum (667) to determine the specific number of samples to be collected from that individual district. This ensures that districts with larger populations contribute a proportionally larger number of samples, making the final combined sample a true representation of the 12-district region as a whole.

Proportional Stratified Sampling For Districts					
State	**District**	**Households**	**Proportion Of Stratum (%)**	**Allocated Sample Size**	**Actual Sample Size**
Bihar	Rohtas	432,866	39.52	263	328
	Gopalganj	385,187	35.17	234	329
Haryana	Ambala	119,431	10.9	73	152
	Kaithal	157,897	14.41	96	145
	Total (High)	1,095,381	100	667	955
Assam	Udalguri	210,555	18.21	121	207
	Sonitpur	296,340	25.64	171	306
Karnataka	Bidar	314,887	27.24	182	295
	Dakshin Kannada	334,185	28.91	193	242
	Total (Medium)	1155967	100	667	955
Madhya Pradesh	Dewas	231,639	24.08	160	273
	Jabalpur	222,006	23.07	154	258
Rajasthan	Alwar	251,884	26.17	174	277
	Dausa	256,772	26.68	666	252
	Total (Low)	962,301	100	667	1,060
	Gross Total	3,213,649		2000	3065

Table 2.1: Proportional Stratified Sampling for Districts

3. Technical Model Specifications

3.1 Overview of Analytical Models

This study employs Bayesian Multinomial Regression Models to analyse implementation outcomes and a pipeline Difference in Differences (DiD) model to assess program impacts. All models account for the hierarchical structure of the data (households nested within villages within districts) and incorporate survey weights to ensure representativeness.

3.2 Implementation Analysis: Bayesian Multilevel Regression

To estimate the determinants of implementation outcomes, we employ a Bayesian multilevel multinomial regression model with district-level random effects. For each of our implementation outcomes, the model specification is:

$$P(Y_i = k) = Categorical(\pi_i)$$

where the probability for each category k is modeled as:

$$\pi_{i,k} = exp(\eta_{i,k}) \,/\, \Sigma_j \, exp(\eta_{i,j})$$

and the linear predictor for the outcome category (e.g., "Yes" for tap availability) is:

$$\eta_i = \beta_0 + \Sigma \, \beta_i \, X_{ij} + \Sigma \, \gamma_k \, (X_i \times Z_i)_k + u_d + \varepsilon_i$$

Where:

Y_i = Categorical outcome for household i (e.g., tap availability: Yes/No)
$\pi_{i,k}$ = Probability that household i falls into category k
β_0 = Intercept term representing baseline linear predictor for the reference category
X_{ij} = Key Predictors
$\gamma_k \, (X_i \times Z_i)_k$ = Interaction terms capturing conditional effects between key predictors
u_d = District-level random effects, ud ~ N(0, σ²d), accounting for unobserved spatial and administrative heterogeneity across districts
ε_i = Household-level error term

3.3 Interaction Term Selection and Model Specification

Rather than including all possible interactions, we employ a systematic two-stage approach to identify meaningful interaction terms while avoiding model overfitting and estimation issues:

3.3.1 Stage 1: Sparsity Analysis

We first assess the feasibility of potential interaction terms using contingency table analysis. For each candidate interaction, we construct cross-tabulations with the outcome variable and apply the following exclusion criteria:

i. at least one cell contains fewer than 10 observations
ii. more than 50% of cells fall below this minimum count (sparsity > 50%)
iii. structural zeros appear (empty cells in combinations that are theoretically possible)

Interactions failing these criteria are excluded to ensure stable parameter estimation and avoid separation problems in the categorical regression framework.

3.3.2 Stage 2: Association Testing

For interactions passing the sparsity threshold, we conducted chi-square tests of association with the outcome variable and calculated Cramér's V as a measure of effect size. We prioritised interactions demonstrating a statistical significance of $p < 0.05$ and meaningful effect sizes (Cramér's V ≥ 0.1 for medium effects, ≥ 0.15 for strong effects, and ≥ 0.2 for very strong effects). This dual filter ensures we keep interactions that are both detectable and practically relevant.

3.3.3 Bayesian Estimation Framework

The model is estimated using Hamiltonian Monte Carlo (HMC) via the "brms" package in R with Stan as the backend, employing the following specifications:

I. Prior distributions:

Priors were specified model-by-model rather than imposed globally. For each specification, we enumerated parameter classes with *brms::get_prior()* and assigned weakly informative, family-consistent priors on the link scale:
Category-specific intercepts ~ *N*(0,2) ;
Fixed-effect coefficients on standardised covariates ~ *N*(0,1.5);
and District-level standard deviations ~ *Exponential* (1).
Priors were applied per outcome category via *dpar* and vetted through prior-predictive checks; sensitivity to alternative coeffi cient scales (e.g., ~ *N*(0,3) and ~ *N*(0,1)) produced substantively unchanged posteriors.

II. Sampling parameters:

Models were estimated with four HMC chains, each comprising 4,000 iterations (2,000 warm-up and 2,000 sampling), yielding 8,000 post-warm-up draws. Survey design was accounted for via scaled probability weights.

III. Convergence diagnostics:

Convergence diagnostics were satisfactory: the potential scale reduction factor R was < 1.01 for all parameters, the effective sample size (ESS) ratio exceeded 0.10, and no divergent transitions were observed, indicating stable HMC exploration and adequate mixing.

3.3.4 Model Fit and Validation

Model performance is assessed using:

I. Leave-One-Out Cross-Validation Information Criterion (LOO-IC): Lower values indicate better out-of-sample predictive performance

II. Pareto k diagnostics: Values < 0.7 indicate reliable LOO estimates

III. Posterior predictive checks: Comparing observed data to model-generated predictions

3.3.5 Effect Estimation and Interpretation

Results are reported as odds ratios (OR) with 95% credible intervals (CrI). For the multinomial model, odds ratios represent the multiplicative change in the odds of being in the alternate category versus the reference category for a one-unit change in the predictor. An odds ratio greater than 1 indicates increased odds of the outcome, while an odds ratio lesser than 1 indicates decreased odds.

Credible intervals that exclude 1.0 are considered substantively meaningful, indicating that the predictor has a clear directional association with the outcome after accounting for other factors and district-level clustering. The district-level random effects variance ($\sigma^2 d$) quantifies the extent of unexplained heterogeneity across administrative units, with larger values indicating greater between-district variation in outcomes beyond measured household characteristics

3.4 Impact Analysis: Difference-in-Difference Analysis

The impact outcomes are analysed by comparing households on two different aspects: availability of a tap under JJM and functionality of the tap received under JJM tap using Pipeline Evaluation Approach (Leeuw et al., 2009) combined with DiD estimation. This strategy leverages the phased rollout of JJM, comparing households that received tap connections in early implementation phases (treatment group) to eligible households awaiting connection in later phases (pipeline comparison group that consists of households with no JJM tap connections). Program impact is estimated using a DiD specification that compares changes in outcomes between pre- and post-intervention periods across treatment and pipeline groups. This approach nets out time-invariant household and village-level characteristics as well as common temporal shocks, thereby isolating the causal effect of tap access from confounding factors. To validate the pipeline comparison group as a credible counterfactual, we conducted Baseline Balance Checks confirming statistical similarity between treatment and pipeline groups along key socio-economic and welfare characteristics in the pre-intervention period.

I. Model Structure:

Based on these outcomes, the model is specified as follows:

$$Y_{it} = \alpha + \beta_1 Post_t + \beta_2 Treatment_i + \beta_3 (Post_t \times Treatment_i) + \gamma_d + \epsilon_{it}$$

Where,

Y_{it} = Outcome for household i at time t.

β_1 = Binary indicator for the post-implementation period with 1 for post-JJM period (2025), 0 for baseline (2019)

β_2 = This indicates whether the household has a functional JJM tap with 1 for functional tap.

β_3 = This variable estimates the causal impact β3

γ_d = District level fixed effects to account for unobserved heterogeneity across villages.

ϵ_{it} = Household-level error, clustered at the village level.

Notes

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Ministry of Jal Shakti
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