Rural Development & Panchayat Raj Department
Rural Drinking Water and Sanitation Department

Har Ghar Jal
Jal Jeevan Mission

Rural Drinking Water
Sustainability

Leveraging Decision Support Systems for Operational, Financial and Water Resource Resilience

In association with Uptime Global and the University of Oxford

UNIVERSITY OF OXFORD
SMITH SCHOOL OF ENTERPRISE & ENVIRONMENT
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India's historic investment in household tap connections now faces a pivotal challenge:

Ensuring that these systems work every single day for years to come. State Governments are responding to this challenge by developing policies, data systems and financing commitments to sustain gains made under the Jal Jeevan Mission (JJM). Multi-Village Schemes (MVS) are a key part of infrastructure investments in most States with the design to deliver 55 litres per capita per day (lpcd) to large populations. MVS operator compliance with contractual performance requirements is critical. Effective water resource management is similarly essential. Without effective monitoring, schemes risk failure, wasted public funds and overuse of water resources.

The **Government of Karnataka is responding to these challenges** with a Decision Support System (DSS) to effectively monitor and promptly action challenges to comply with the delivery of drinking water, water resources and public finance objectives. The DSS uses a few daily indicators to guide decisions on lpcd delivery, operator performance and water resource use. Unlike a Management Information System (MIS), which seeks to capture all metrics, the DSS focuses on just a few critical indicators to facilitate timely, targeted action. The DSS focus on key actionable insights is expected to enable robust sustainability of JJM infrastructure for years to come.

This paper illustrates how the Decision Support System is being applied by the Government of Karnataka and its wider potential for application by other State Governments.

Background

Karnataka Context

The unprecedented JJM investment in Karnataka to deliver a functional household tap connection to every dwelling reflects similar ambition across India. Water infrastructure access in Karnataka has soared to c. 8 million household tap connections in only a few years (Figure 1).

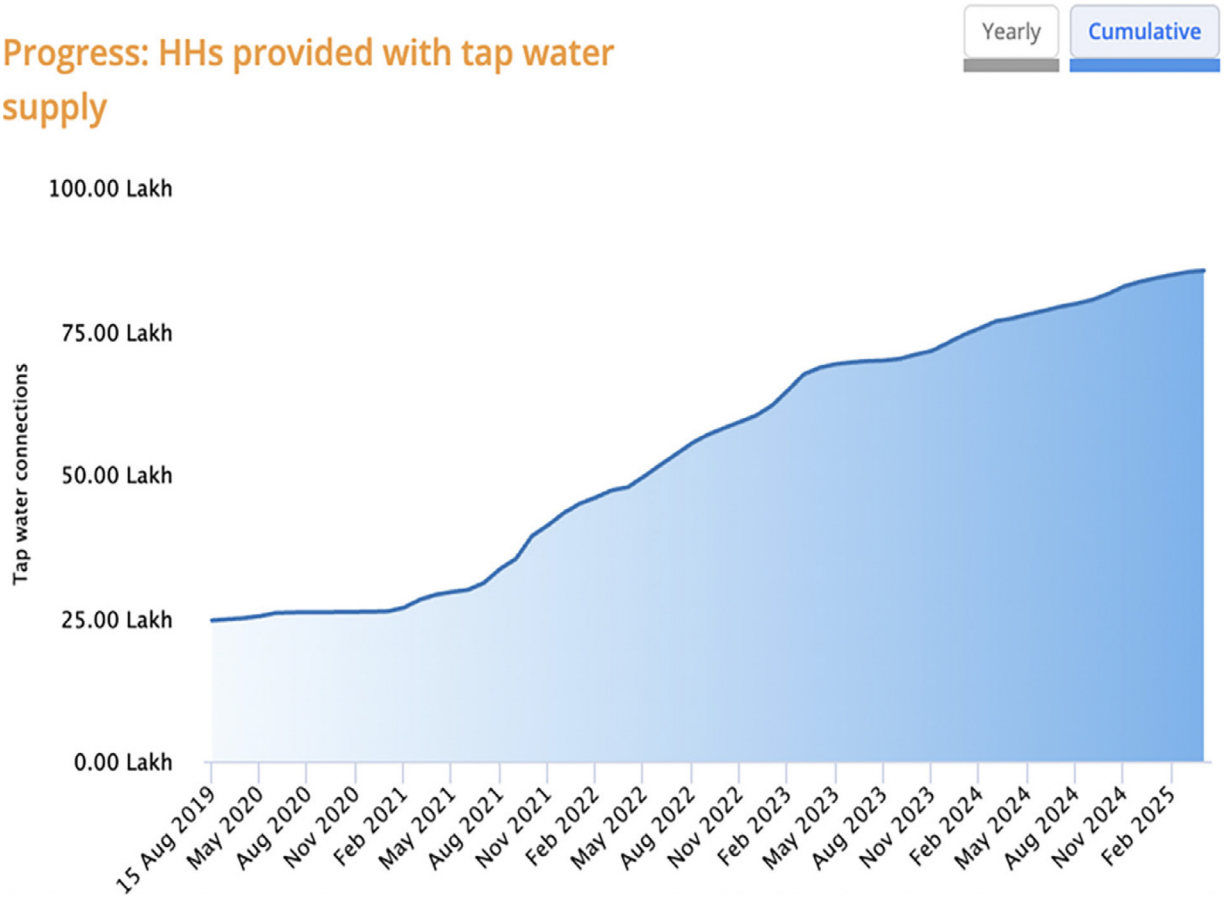

Figure 1. Jal Jeevan Mission dashboard (Karnataka) on number of household tap connections.

Two types of piped water schemes underpin this growth: Single Village Schemes (SVS) and Multi-Village Schemes (MVS). Single Village Schemes serve individual settlements with locally available water sources and are managed by Gram Panchayats. Multi-Village Schemes are much larger and cover many habitations, usually due to insufficient locally available water resources.

Under the operation of a professional operator contracted by the State Government, MVS draw and treat bulk water at a larger source before distributing to Overhead Storage Tanks (OHTs) as bulk reservoirs for each habitation. Over 400 MVS in Karnataka serve c. 12 million people with c. 250 million m^3 of drinking water annually.

Like other States, Karnataka is now transitioning from the challenge of construction to one of sustainability. With capacity for bulk water volume delivery established, the emerging challenge becomes tracking and sustaining the 'daily' part of 55 'lpcd'. Averages are insufficient to track what is actually delivered to households each day. Consistent monitoring and action is critical.

A recently developed O&M policy provides a framework to respond to these operational challenges. Particularly for MVS, the policy includes provision for variable-pay-out contracts to scheme operators based on performance (Table 1). The policy enables operator contracts to include a fixed monthly payment and variable payments linked to water quality and quantity delivery of 55 lpcd daily to OHTs. This framework provides the opportunity to directly incentivise and only pay for effective service delivery, but only if performance can be consistently tracked.

A key information requirement is the daily tracking of water volume quantity delivered to OHTs. Existing monitoring systems in Karnataka capture these records at MVS water treatment plants, at OHT inflows and at functional household tap connections. The majority of MVS have analog meters that are routinely read and recorded and some large MVS have digital SCADA systems that support data tracking. Consistent daily volume records throughout these schemes provide the basis to determine what lpcd is delivered and where, each day, to enable better scheme sustainability, performance-based payments to operators and efficient water resource management. These conditions laid the foundation for an agile and outcome- oriented monitoring approach: the Decision Support System.

Table 1. Contract payment from Karnataka Rural Drinking Water and Sanitation O&M policy

O&M Contract Payment (100%)					
	Key Performance Indicators "Variable-Pay-Out"				
Fixed-Pay-Out	Quantity	Quality		TAT for GRM	Power Consumption
		WTP	OHT		
50%	20%	5%	20%	5%	Excess energy amount is deducted from the monthly bill

Decision Support System Requirements

Three factors support the conditions for an effective Decision Support System, specifically:

1. **Delivery** – completed infrastructure is ready to deliver according to design (i.e. 55 lpcd)
2. **Decisions** – clear scope to act upon specific analysis of scheme and operator performance (e.g. defined policy, variable-pay-out contracts)
3. **Data** – existing monitoring systems and technology to collate records for analysis (e.g. daily volume meter readings at Water Treatment Plants and OHTs)

These conditions created a clear entry point in Karnataka to begin development of a Decision Support System for Multi-Village Schemes focused on water volumes. This is distinct from a Management Information System (MIS) that is typically intended to comprehensively capture all indicators. A DSS is instead focused on a small number of indicators to quickly generate specific actionable insights. Once the basic system is established, the DSS can be expanded in scale and scope as required. Further work could include Single Village Schemes and wider metrics including water quality, tariff collection efficiency and others, depending on State Government needs.

Development of a Decision Support System for Multi-Village Schemes

Development of the Decision Support System focused on three key sustainability outcomes in Multi-Village Schemes:

OPERATIONAL SUSTAINABILITY
ensuring 55 lpcd delivery

FINANCIAL SUSTAINABILITY
applying variable-pay- out calculations to operators in proportion to results achieved

WATER RESOURCE SUSTAINABILITY
identifying and minimising unaccounted-for water

From 2023-2024, the Government iterated on possible designs of the Decision Support System to identify (a) what data sources can be reliably captured in a monthly reporting system; (b) what analytical summaries are most actionable for Government management; and (c) how can data be consistently fed into the system through existing reporting structures? These considerations helped build an efficient system using existing tools and processes.

A key realisation through this process was the importance of daily volumetric meter readings from both Water Treatment Plant bulk supply and volumes reaching Overhead Storage Tanks at each habitation distribution point.

Monthly or quarterly averages were not sufficient to understand fluctuations in daily delivery. These records are kept but were not consistently reported and aggregated centrally. Initial consultant-supported data collection confirmed records could be captured in a standardised format.

The iterative design process has now confirmed the source and format of data required, the stakeholder roles in data submission, and the types of analysis performed in the DSS dashboards. The confirmed Decision Support System design is now considered ready for statewide scale up and institutionalisation across Karnataka.

How the DSS Works

The Decision Support System is intentionally designed around answering three key questions on a monthly basis:

1. **Operational sustainability** – where are schemes over- or under-supplying 55 lpcd?
2. **Financial sustainability** – how much should scheme operators be paid according to their performance?
3. **Water resource sustainability** – how much bulk water production is unaccounted for downstream?

Importantly, only two primary data sources are needed to underpin this system: ***(1) daily Water Treatment Plant (WTP) water volume*** and ***(2) daily bulk water volume flowing into Overhead Storage Tanks (OHTs)***. Additional data on energy costs and payments to operators are also captured for possible further analysis. The OHTs are the end of the main scheme distribution line and mark the transition from multi-village scheme operation to the In Village Distribution Systems (IVDS) managed by Gram Panchayats. These data sources directly support the DSS's core insights:

1. **Operational sustainability**: identify OHTs with insufficient volume delivered
2. Financial sustainability: determine which OHTs meet sufficient volume delivered to qualify for monthly payment to the operator
3. Water resource sustainability: calculate unaccounted-for water as the difference between WTP outflow volume and the sum of OHT inflow volumes.

Opportunities for Expanded DSS Scope

The DSS starts with a few key indicators and can expand once functional. Augmentation with contextual data such as geolocation, OHT population served and so forth supports expanded analysis that can be presented in visual dashboards. Where available, additional information on water quality results, electricity payments and scheme operator payments are also captured with the potential for future incorporation into the system. Similarly, tariff payment records could be included as available.

Daily WTP and OHT volumetric data are captured at their respective sources and expected to be submitted monthly into the centralised Decision Support System. These can be manual or digital records captured by operation, waterperson or government staff depending on context. Previously, records were captured locally but not consistently submitted centrally. During DSS prototyping, a consultant was engaged to collate records to illustrate how the system can work. With the system design and process now confirmed (Figure 2), the process of institutionalising the system is ongoing whereby scheme operators, with support from State Government staff, will be required to submit monthly data as part of their contractual obligations. Updates to the DSS will be generated as performance snapshots at each month end.

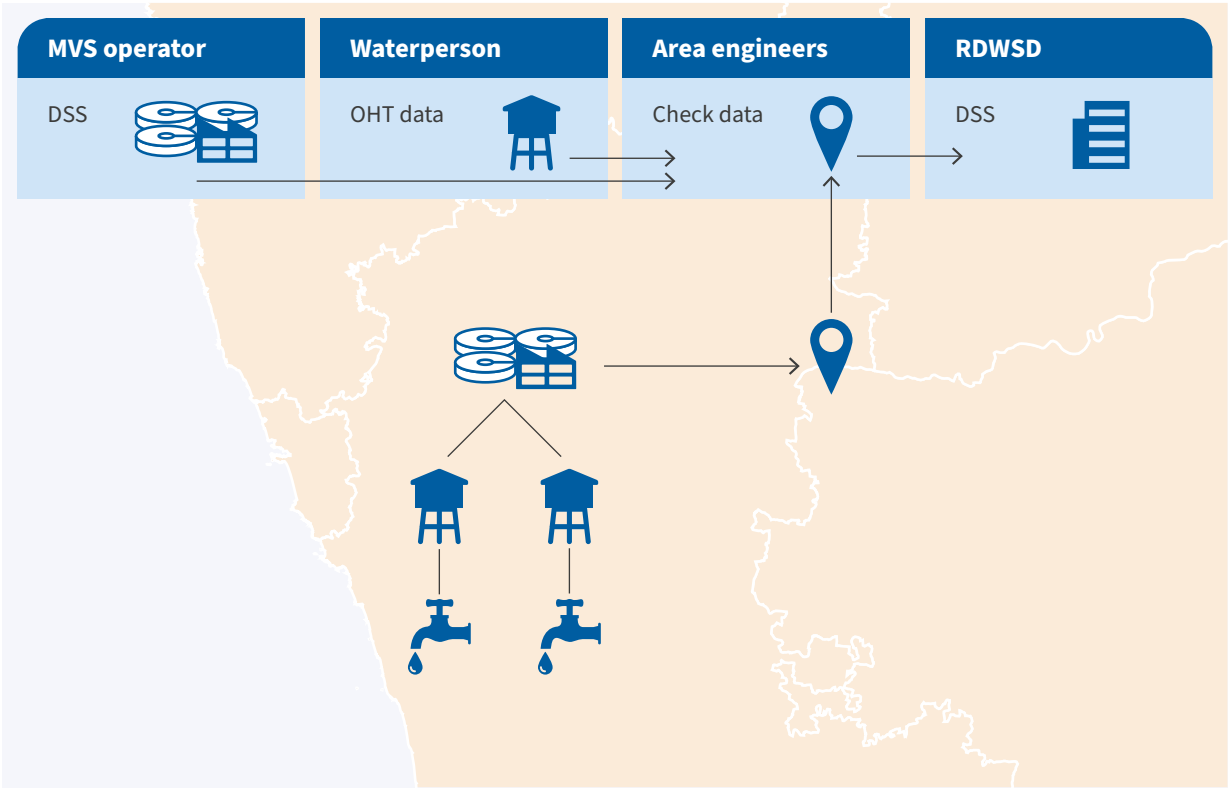

Figure 2: DSS data reporting process overview.

Data Integrity

Ensuring data accuracy is critical in an effective DSS, especially where performance incentives could motivate data manipulation. Two strategies can help to mitigate potential risks: validation and verification[1].

Validation: As the DSS dataset grows, historical records can be used for comparison against new records to identify anomalies for investigation. The process of identifying outliers can be automated. Statistical comparison of data records can help to efficiently process large amounts of data to focus management follow up around the most important areas of inquiry.

Verification: Spot checks through site visits and review of original records can also help to confirm the accuracy of data records. It may not be feasible to subject every datapoint to this level of scrutiny, but support from the validation process and opportunities with AI to process manual and photographic evidence can help this process to be more efficient. Verification can identify areas with systematic discrepancies and recommend corrective actions.

1 For more information, see the Uptime Global publication: The Data Dividend Applying a data integrity methodology to deliver better value for results-based funding for safe drinking water services

DSS Dashboards

Data are captured in a standardised format and ingested into an analytical platform that generates four summary dashboards to inform management actions:

- **Statewide performance summary**
- **Scheme lpcd summary**
- **Scheme operator payment calculator**
- **Scheme water resource sustainability**

Karnataka has approximately 400 Multi-Village Schemes in total of varying sizes. Initial DSS prototyping collated records from 9 of the largest schemes' records from 2023 to 2024. As of April 2025, five of these schemes are beginning to routinely report monthly updates into the DSS. Figure geolocation data in this section are accurate but performance data have been adjusted for data protection purposes. Actual performance data may be available upon request from the Government of Karnataka.

Statewide Performance Summary

The Statewide summary (Figure 3) provides a State-level overview of scheme performance, operator performance and unaccounted-for water. This is designed for senior officials to track overall results across the State and take prompt action. The map shows scheme locations and average monthly lpcd. Pie charts show the total population with sufficient lpcd, number of OHTs receiving sufficient lpcd, and the volume of unaccounted-for water. The aggregate summary provides a quick snapshot of how MVS are performing across the State each month.

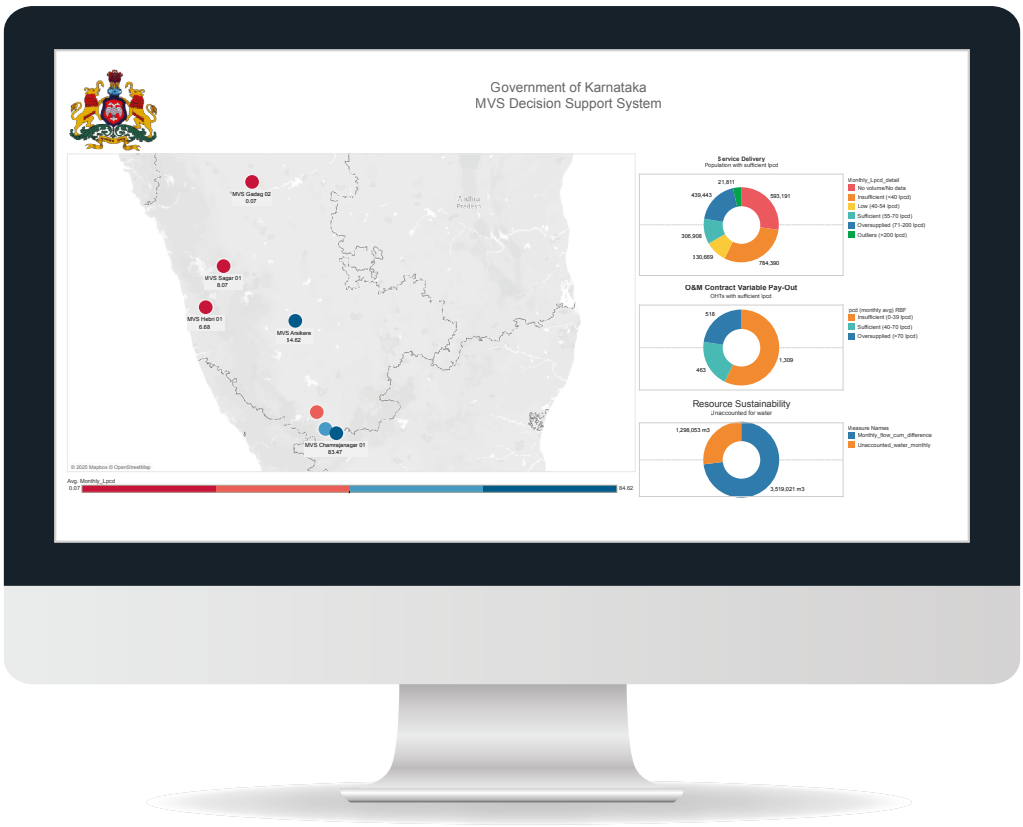

Figure 3: DSS Statewide performance summary dashboard.

Scheme lpcd Summary

This dashboard (Figure 4) presents the monthly volume delivered to each OHT within a scheme to identify areas of under or over supply. Relatedly, reported issues with non-functional bulk water meters suggest whether areas of apparent low volume might be simply due to missing data. Analysis provides scheme managers with specific areas for follow up to address undersupply or maintenance requirements. Bar charts summarise the population receiving sufficient lpcd volumes and the gap between WTP supply and OHT delivery (unaccounted-for water).

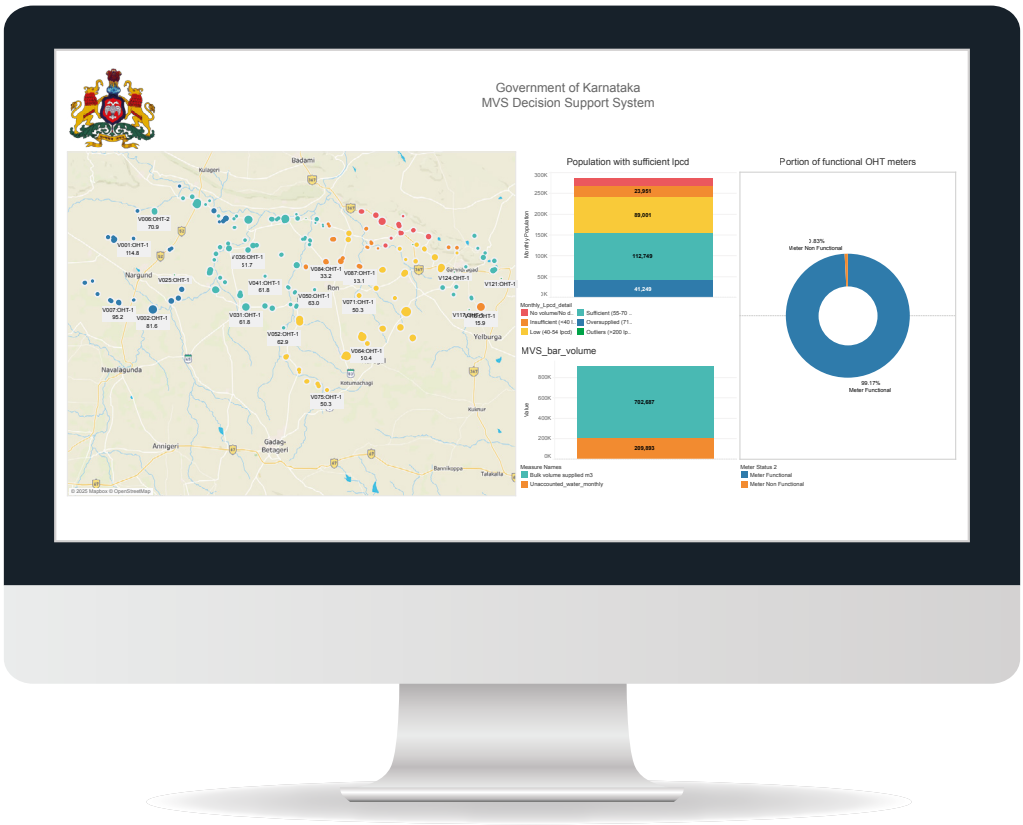

Figure 4: DSS scheme lpcd summary.

Operator Payment Calculator

Similar to the Scheme LPCD Summary, this dashboard (Figure 5) determines which OHTs have met minimum volume requirements to qualify the scheme operator for payment. The proportion of total eligible payment based on OHT volumetric requirements is summarised. Managers can use this dashboard to calculate what each scheme operator is owed according to their contract terms.

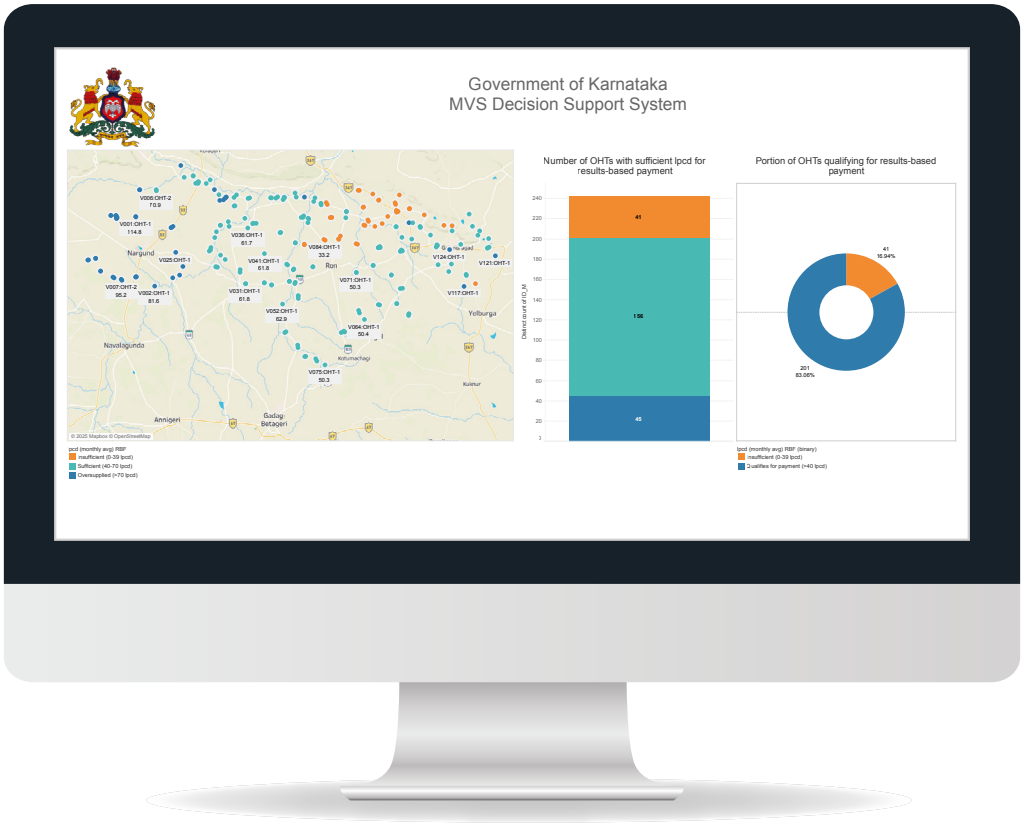

Figure 5: DSS operator payment calculator.

Water Resource Sustainability

The final dashboard (Figure 6) calculates the difference between what is supplied by the WTP and what is cumulatively delivered to the OHTs. Some of this volume will be losses; some will be due to data gaps caused by non-functional meters. As data gaps are addressed, the volume of unaccounted-for water should decrease and analysis will become a truer representation of actual water losses. Managers can use this analysis to track whether interventions to address data gaps and system leaks does indeed reduce the volume of unaccounted-for water over time.

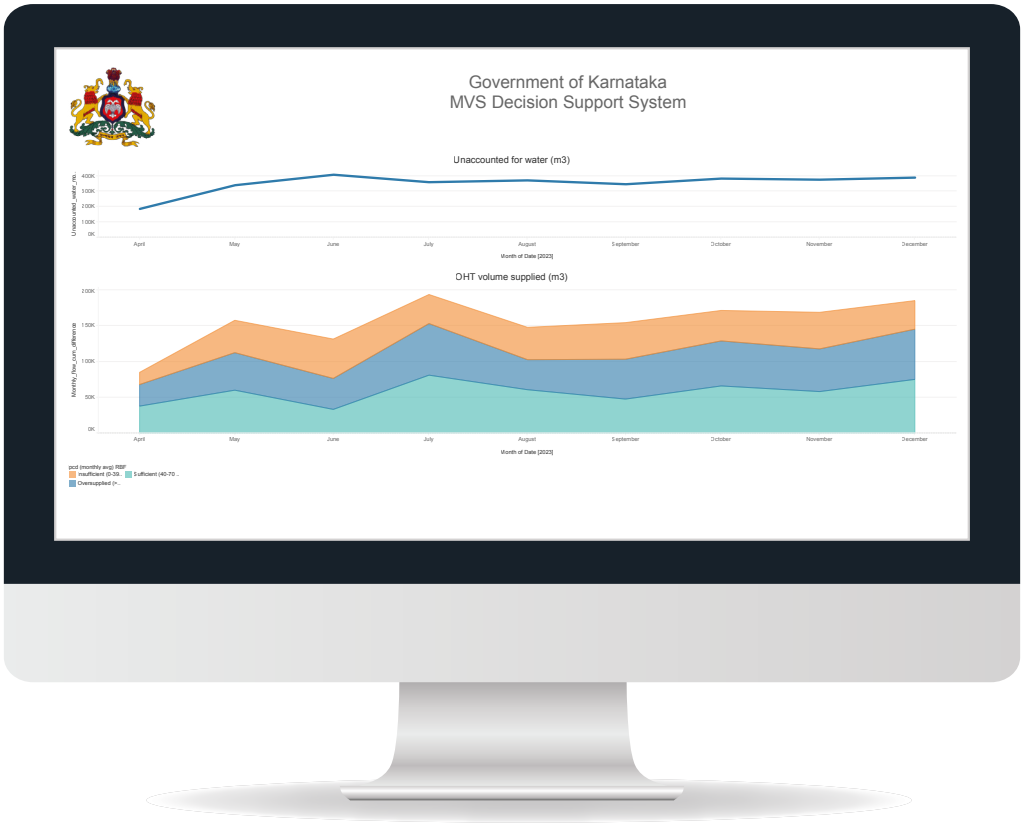

Figure 6: DSS water resource sustainability.

Improving Sustainability of JJM Investments in Karnataka

Application of the Decision Support System for stronger JJM infrastructure sustainability requires regular data updates and analysis to inform action. A typical monthly workflow begins with routine reporting of MVS data to produce standardised analysis for State Government review (Figure 7).

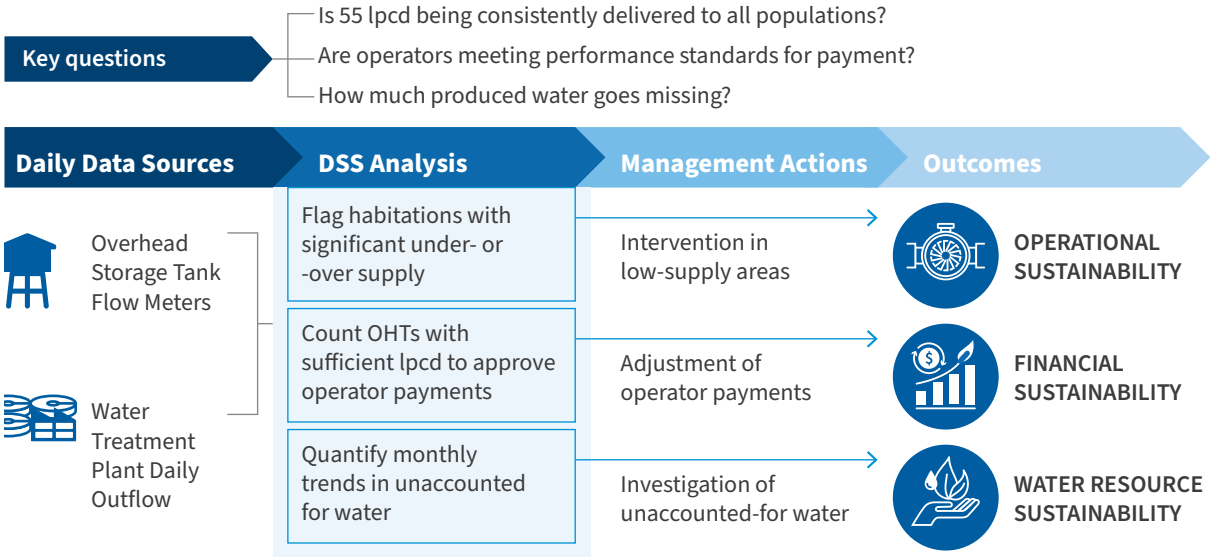

Figure 7: Summary of the DSS process from data to action to outcomes.

Monthly DSS updates guide key Government sustainability actions. Firstly, it will alert officials to areas of under- and over-supply, both on a monthly basis and as a recurring trend. This highlights specific sites for intervention to improve service delivery or to rectify monitoring errors. Over time, repeated application of this process should lead to an optimised 55 lpcd being delivered consistently across all schemes.

Linked to the 55 lpcd requirement are incentives for multi-village scheme operator performance. Under the Karnataka O&M policy, these contracts include a provision for variable-pay- out to punish operators for insufficient treatment plant production or volumetric delivery to overhead storage tanks. Monthly DSS performance reports enable payment only for results delivered. This is expected to motivate improved operator performance, leading to better service delivery and more efficient Government expenditure.

Finally, tracking unaccounted-for water can guide interventions and track results. Initial gains will likely come from identifying and repairing non-functional water meters that create data gaps. Once resolved, unaccounted-for water analysis will more accurately reflect scheme losses. These, too, can be identified by reduced flow to certain scheme areas and addressed over time, ultimately leading to better water resource management.

Addressing Non-Functional OHT Meters

Data from pilot Multi-Village Schemes identified significant areas of undersupply. Widespread challenges with non-functional water meters on OHTs were also identified, raising the possibility that apparent undersupply might in fact be due to data gaps. The Government of Karnataka is able to highlight this issue to scheme operators with the requirement that meters be fixed in order for verifiable water volumes to justify disbursements under the variable-pay-out contracts. Clear and consistent data from the DSS supports the Government to identify and address these issues in an ongoing improvement process.

Beyond direct Government action, the DSS provides wider opportunity to effectively communicate results and challenges, particularly around water resource sustainability. Efficient management of scarce water resources with supporting data could be used to engage a wider range of stakeholders to support the sustainability agenda. The DSS itself is currently an internal State Government tool, but considered disclosure of specific metrics and results might be used to facilitate wider stakeholder coordination around sustainability outcomes.

Prospects for Statewide Scale Up

The Karnataka DSS initially focused on data capture from a small number of the largest State Multi-Village Schemes. Once data requirements and system design were confirmed, the Government of Karnataka moved to institutionalise monthly reporting with these same schemes. As this process becomes routine it can be expanded to eventually cover all Karnataka MVS while progressively improving data quality, service reliability, results-based payments and reduced unaccounted-for water. Later, expanded scope can include other metrics, such as water quality and tariffs, or scale out to similar monitoring of single village schemes. Continued ownership and operation of the DSS has the potential to eventually support the sustainability of all JJM investments Statewide by guiding analysis of key indicators for insight and action.

Conclusions and Recommendations

The Government of Karnataka has piloted different approaches to Jal Jeevan Mission sustainability with a commitment to scale up the Decision Support System to all Multi-Village Schemes by the end of 2026. The DSS would monitor over 400 MVS for approximately 12 million people with an annual drinking water consumption of approximately 250 million m^3. Based on preliminary results, the Government of Karnataka estimates this could more effectively deliver 55 lpcd, significantly reduce water resource consumption from rivers, and progressively improve contracts to protect public finances over decades.

Three conditions underpin the design and execution of a DSS.

1. **Delivery**
   – completed infrastructure is ready to deliver according to design (i.e. 55 lpcd)
2. **Decisions**
   – clear Government mandate and capacity to act upon specific analysis of scheme and operator performance (e.g. defined policy, variable-pay-out contracts)
3. **Data**
   – existing monitoring systems and technology to collate records for analysis (e.g. reliable daily volume meter readings at multiple scheme distribution points)

The Rural Drinking Water and Sanitation Department welcomes critical feedback. The Department also recognises that sustainable water management is a collaborative endeavour. Major stakeholders from the development community and private sector wishing to invest in collective action to manage water efficiently and equitably may see co-investment opportunities. In all cases, the DSS provides a platform to identify and collaborate around key sustainability issues that can secure a water resilient future for years to come.

Glossary of Acronyms and Definitions

JJM: Jal Jeevan Mission

A Government of India initiative aiming to provide functional household tap connections to every rural household.

MVS: Multi-Village Scheme

A large-scale piped water supply scheme that sources and treats water centrally and distributes it to multiple villages. Typically operated by professionals under contract with the State Government.

SVS: Single Village Scheme

A smaller piped water supply scheme serving a single village, often managed by the local Gram Panchayat and using locally available water sources.

DSS: Decision Support System

A data-driven system designed to generate actionable insights by monitoring a few key indicators (e.g. daily volume delivery) for guiding operational, financial, and resource management decisions.

MIS: Management Information System

A system that comprehensively captures a wide range of indicators for administrative and reporting purposes. Distinguished from a DSS by its broader scope.

WTP: Water Treatment Plant

A facility that treats raw water to meet drinking water standards before distribution in an MVS.

OHT: Overhead Storage Tank

A bulk reservoir situated in a habitation where treated water is stored before being distributed to households.

IVDS: In-Village Distribution System

The portion of the water distribution network within a village, typically downstream from the OHT and managed by the Gram Panchayat.

lpcd: Litres Per Capita Per Day

A unit of measurement indicating the average volume of water supplied per person per day. The JJM standard target is 55 lpcd.

O&M: Operation and Maintenance

Refers to the policies and activities related to the regular functioning and upkeep of water supply infrastructure.

Rural Drinking Water and Sanitation Department

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