Improving Intermittent Urban Water Distribution System through a Human Sensor based Smart Grid

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KEYWORDS
Human Powered Smart Grid, Sustainable and Efficient Domestic Water Supply in Urban Areas, Urban Water Information System, Information and Communication Technology for Development

ABSTRACT: (9 pt)
Urban residents in most towns/cities in India receive municipal water intermittently with varying periodicity for few hours. This intermittent water supply does not follow a reliable schedule due to limitations such as scarce water resources for municipal use, unscheduled power outages, old and poor quality pipe infrastructure in many areas leading to frequent breakdowns. There are no systems in place through which any information on water supply schedules, delays and outages can be conveyed to the residents or the utility in a timely manner. While relevant system operation information is collected at the ground level, it is not organized, standardized or relayed back in real time to the utility system operators. A centralized system to collect and organize all relevant water supply data is essential to optimize the operation of an intermittent water distribution network. The system must also be capable of relaying this information to residents and utility engineers through the most user-friendly modes of communication in standardized formats. Such an information system has been piloted successfully in Hubli-Dharwad municipal area in India. The system leverages the use of mobile phones by ground level utility staff to turn them into human sensors transmitting all relevant water supply data to a centralized system. This paper outlines the improvements in the operation of the water distribution system through the use of such a water information system (WIS) in Hubli, Karnataka. This new WIS has helped Hubli Water Board staff monitor the performance of the valvemen, monitor and receive real time updates via SMS.

1. Background

The twin cities, with a population of about one million residents have about 150,000 households out of which about 114,000 households have a direct water connection (Hubli Dharwad Municipal Cooperation, 2013). The normal water service in the twin cities was once in 2 to 3 days, but now it extended to once in 3 to 4 days due to drying of Neersagar dam, which is one of the two main water sources. Presently, complete dependency is on the other source Malaprabha dam (Times of India, 2013). Consequently, the bulk water supply has been reduced from about 185 MLD to 150 MLD (Karnataka Urban Water Sanitation Drainage Board,2013).The WIS operating in Hubli-Dharwad, sources water distribution system data from the ground level utility staff and validates it through a feedback mechanism from the residents in the Hubli Dharwad municipal area in the state of Karnataka. All data is inputted to the WIS using an interactive Voice response System (IVR) and is easily accessible via SMS and web based dashboard.

2. Components of the NextDrop Water Information System

The WIS obtains real time information on water supply timings, pipe damages, electricity outages and reservoir levels from the ground level utility staff that actually turn the water supply valves on and off. The utility staff is provided an easy-to-operate Interactive Voice Response System (IVR) through which they can report all the relevant data to the WIS in real time. This IVR system is identical to the ones extensively used in customer care phone numbers by various businesses such as banking, telecom and utilities. The IVR can be accessed through a mobile or landline telephone and consists of a series of voice prompts that can be answered using the keypad of the phone. All voice prompts are in Kannada making it easy to understand and operate. Figure 1 below depicts the flow diagram of the

information system. The red arrows show feedback from residents to the utility employees.

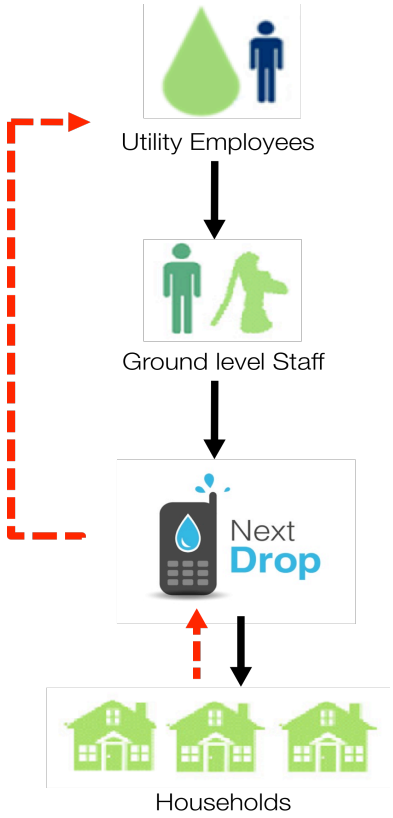

Figure 1: Flow Diagram of NextDrop Information System

Once the system receives the information from the utility employees, the water delivery timings are directly transmitted to customers in the given area. Each residential area supplied by a particular valve is mapped using GPS technology to place residents in right areas. This ensures that each resident is getting the water supply schedule for his/her area. The system also seeks feedback from the customers on whether the reported schedule was the same as the actual schedule of supply to validate the data received from the utility staff. The feedback enables the utility to verify the quality of service to customers and performance of the ground level staff. The system is built to relay all collected information on verified water supply timings, pipe damages, electricity outages and reservoir levels to utility engineers in real time. They can access this information through a medium of their choice such as SMS, email or a web based interface at any time. All the above system information can be viewed on a live map based dashboard that tracks all area level data. System operators can use the live dashboard to make decisions such as rationing, finding alternative supply options and exact locations of pipe damages as shown in Figure 2 below.

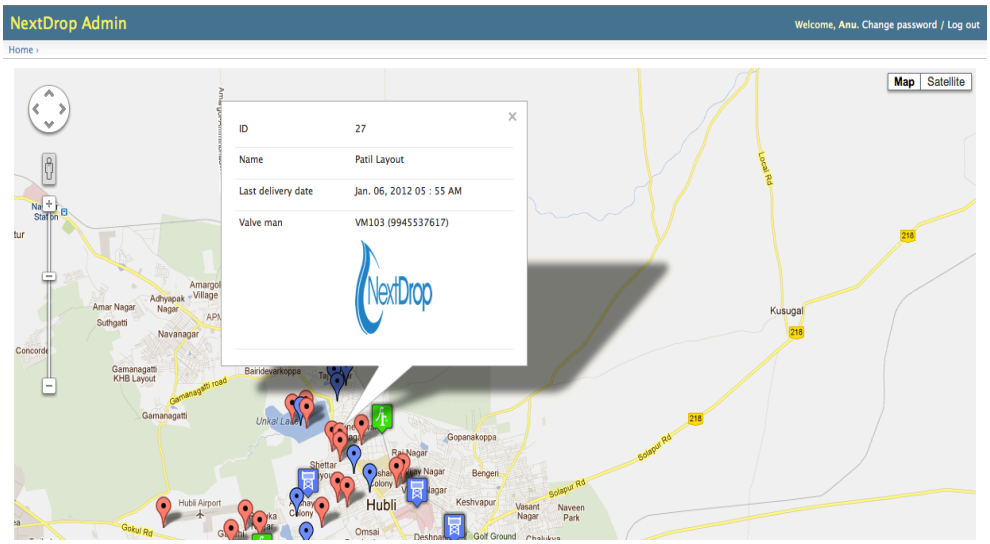

Figure 2: GPS Map based Dashboard

There are many advantages gained from this information system. These improvements have been on two fronts – first for the residents and second to the system operators. First, it has improved access by informing the residents when to expect water thereby reducing the instances when they missed their scheduled supply and it has also helped them plan ahead in the event of a missed supply cycle. The valuable time of consumers wasted in waiting for water has been saved apart from saving in their telephone call charges. Second, the system operators have benefitted from reduced complaints from consumers about deviated water supply schedules. Before this service, the consumers had to call the system operators whenever they needed to know the exact supply timings.

The other improvement has been in coordinating supply schedules in the gravity fed distribution network where they have been able to eliminate problems of low pressure supply to households. The reports having real time access to validated water supply data, can be adopted for optimal utilization of the water distribution network. System operators monitor water levels in the overhead and ground level supply reservoirs through the information system and can use this information to adjust and ration water supply according to water availability in the bulk supply reservoir. They can also use the system to do preventive pipe repairs for reduction of leakages.

Finally, the main aim of this information system is to create more transparency and accountability at all levels of the utility and reduce cases of inequity in water supply by monitoring supply schedules by validating data from customers and ground level supply staff. There are several benefits of such a two way communication channel between the end-user/customer and the water utility. One of the most important features of the WIS is that customer feedback is geo-tagged. In other words, the information system can pin point the exact location from where the feedback on water distribution is being received. This is possible since each customer in the database is mapped to a city valve through his/her mobile phone number. As a result, when the same phone number is used to relay feedback, the WIS instantly identifies the customer location. One of the major limitations of the traditional customer care and complaint system is to be able to ascertain the geographical location of the problem. The WIS overcomes the limitation and in the process builds a much richer database of quantitative and qualitative data on end-user water supply.

3. APPLICATIONS AND FEATURES OF WIS

One of the first applications of this geo-tagged customer feedback system has been to assess valvemen performance and quality of “water supply”. Table 1 shows the data from a random survey of customers. It describes the number of areas that actually received water at the time reported time by the valveman. From the sample dataset, 29 areas out of 34 areas surveyed reported to receive water at the exact time as intimated by the area valveman. In other words, about 85% water supply follows the schedule as determined by the Junior Engineers and Section Officers.

It also presents the areas where there are problems of low pressure and insufficient supply. This

feedback can be used by the Water Board in Hubli to rectify problems and make necessary changes/adjustments to reservoir and valve operations to improve the existing system. How the above could be accomplished is discussed in further detail in Section 3.3.

Table 1. Random Water Distribution Quality Survey

Areas Surveyed	Water Supply at the reported Timings	% accuracy of valvemen reported data	Instances of Feedback on Water Supply
34	29	85%	15

3.1. Supply Schedule Monitoring

The distribution system relies on Overhead and Underground tanks for the supply of water within the city. The valvemen are also organized by tanks and assigned areas to supply according to the valves connected to a given tank. The WIS records each time a valve is opened in a centralized database instantly. Once the valveman has informed the WIS using the IVR system, it is no longer required to maintain the supply register since the information is instantly digitized, stored and organized in the database. The WIS also relays actual supply timings to the concerned Section Officers and Junior Engineers in real time. This allows more efficient monitoring of supply areas by enabling the utility staff to make changes and decisions based on most up-to-date information.

The utility staff uses the WIS to ensure minimal deviation from the scheduled supply time for an area. If the supply timing to an area deviates by more than 3 hours, the staff checks with his tank staff and valvemen for reasons for the change or delay. Figure 3 provides the supply characteristics in a valve area between January 1 and March 9, 2013. As the trend depicts, there is severe variation in supply timings during early and mid January but supply normalizes over the next 6 weeks.

The system also facilitates effective monitoring of the valvemen. The instant information on supply timings helps Officers provide instant feedback to the valveman and reduces the instances of ad-hoc decisions taken by the valveman.

The historical data on supply for any valve can be easily accessed through the WIS database instantly in formats ready for analysis using a web interface.

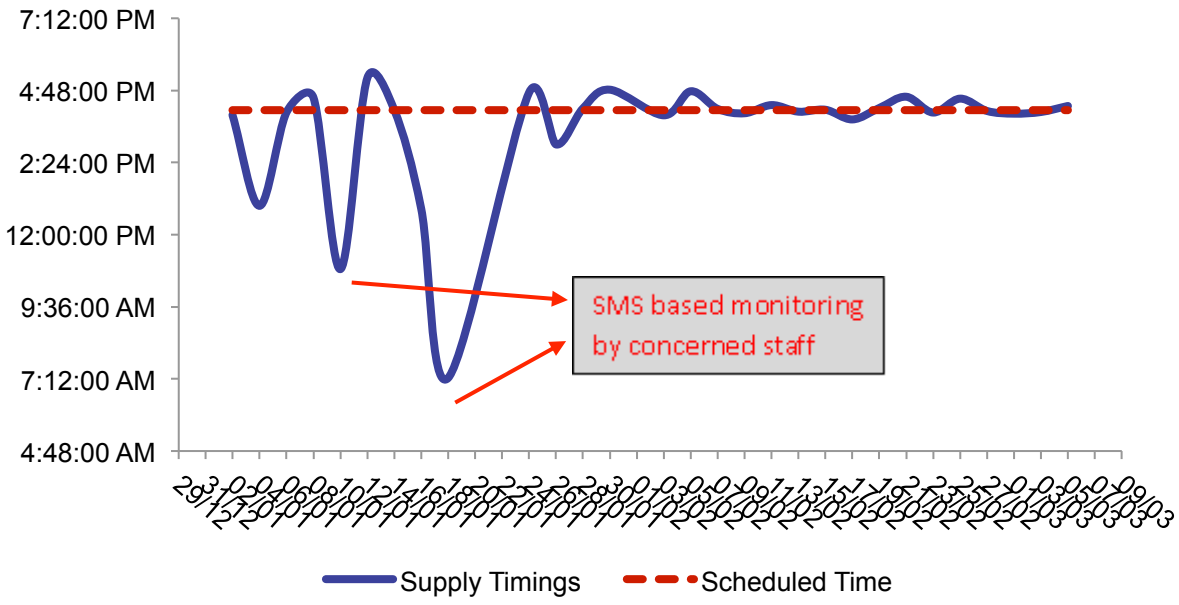

Figure 3: Difference in Scheduled and Actual valve operation timings

3.2. Keeping Track of Pipe Damages and Power-cuts

The WIS also requires the valvemen to report pipe damages, power cuts and any other reasons due to which supply has been delayed or cancelled in each area. The input mechanism for this information is also the IVR system. All pipe damages and power-cuts in the areas where the WIS is operational are provided in Table 2. Each of these pipe damages and power cuts can be traced to a highly localized area. The information can be instantly accessed through the WIS web dashboard.

Table 2. Reported Pipe Damages and Power Cuts between July 1, 0212 – March 17, 2013

Month	Pipe Damage	Power Cuts
July	15	17
August	9	5
September	26	5
October	42	14
November	46	10
December	60	12
January	34	18
February	6	23
March*	10	7

3.3. Monitoring Reservoir Levels

One of the most important functions of the WIS is to monitor bulk supply reservoir and distribution overhead and underground tanks. These levels are reported once every hour, 24 hours a day by designed staff in charge of operating the tanks and the pumps that maintain the tank pressure head during supply hours. There are three main features of reservoir level monitoring functionality of the WIS.

3.3.1. Warning and Alerts when the tank level reaches threshold levels

The water board has designated threshold levels for each tank. When the water level falls below or rises above these threshold marks an instant SMS is sent to the assistant executive engineer and junior engineers to take corrective action. The SMS warnings are useful in preventing water wastage and prevent damage of the infrastructure. It is crucial in the demonstration zone in Hubli where the water board is supplying bulk water to 24X7 water service pilot project. Figure 4 presents how the warning system works in the WIS. The dotted red line demarcates the threshold level assigned by the water board for the reservoir.

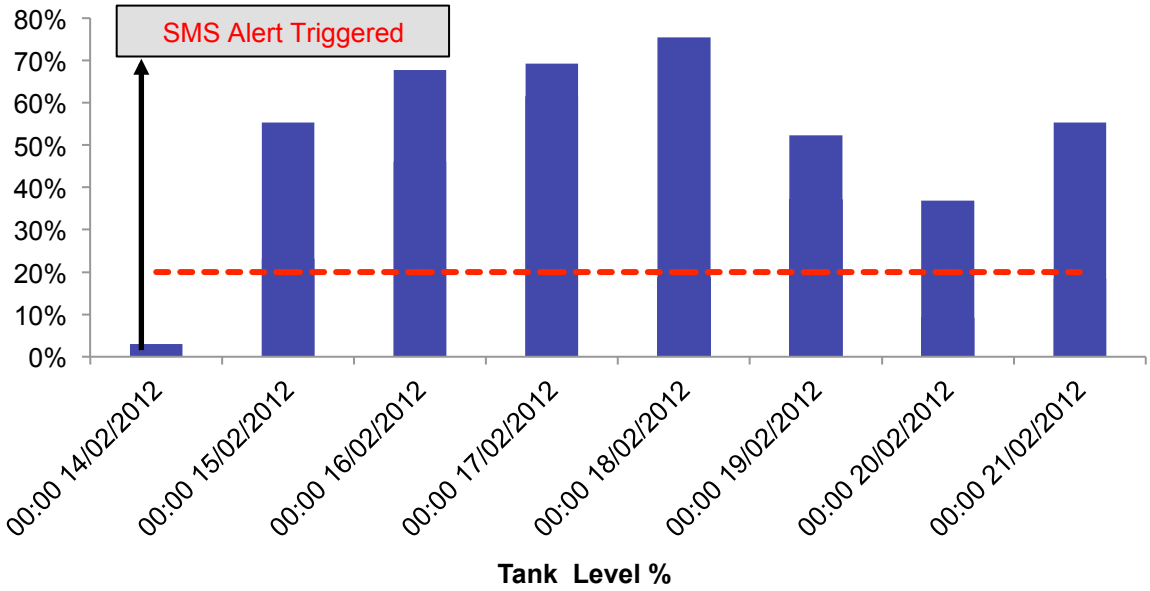

Figure 4: Reservoir Level Warning System

3.3.2. Optimizing the storage capacity of the distribution tanks

For effective utilization of storage capacity, all the distribution tanks in Hubli must be empty so that water pumped from the upstream treatment plant can be stored in the distribution system downstream. Such an arrangement would minimize the wastage of treated water that cannot find a storage tank. Hubli receives about 75 Million Liters per Day (MLD) at a rate of 3.1 ML/Hour from the main upstream pumping station. At that rate, city tanks would fill up about 80% in 2-6 hours during the night provided the tanks are e mpty or below 20% capacity after the day's supply has been completed. In this case, the pump operations at the main pumping station would also be optimized since they would run at full capacity during the night. It would prevent any pump to remain idle or worse operated at a lower than optimal capacity.

Figure 5 provides a snapshot of total available storage level at the distribution level at the end of the day's supply at midnight. It also shows how this capacity is utilized at the commencement of the next day's supply at 6 am. The total available level provides a way for comparing current operations vis-a-vis optimal running of the system. For example, in the case below, out of a total of 17 m of designed storage level, about 16 m or 93% is available at midnight on 15th March 2013. During the next 6 hours, water is pumped from upstream to the tanks such that at 6 am, only about 4.5 m of level is still available representing about 85% capacity utilization at the commencement of supply the next day. In other words, an optimal system would have about 90% more water at the distribution level at 6 am resulting in a higher pressure head without the need of the tank level pumps. All data for the analysis is reported by tank operators via the IVR to the WIS. It is possible to conduct such an analysis everyday to extract additional efficiency from the current system without the expenditure of any capital.

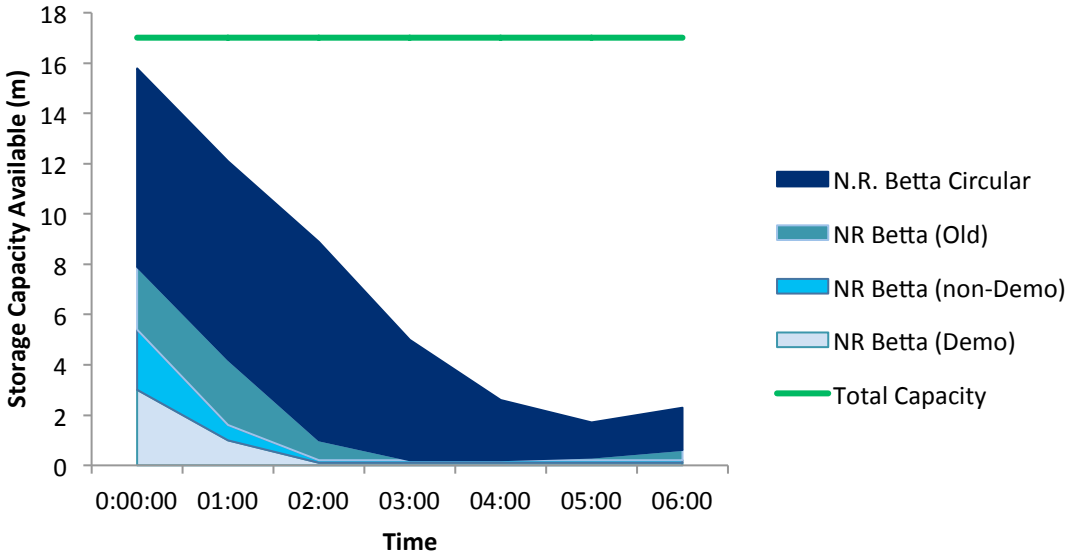

Figure 5: Utilization of Reservoir Storage Capacity during Night

3.3.3. Coordination of Supply Timings according to Tank Levels

The primary factor in ensuring that supply to each household comes with adequate pressure is the maintaining the head of pressure in the supply tank. If the pressure head is insufficient, then the tail-end houses will have complaints of low pressure supply. With consistent monitoring of the water levels in supply tanks, these complaints of low pressure and inadequate supply can be minimized.

Low pressure supply is one of the most frequent complaints of end users in Hubli. Table 3 provides supply timings to 3 areas supplied by the Keshwapur tank and Figure 6 shows the change in tank level at Keshwapur underground tank on the 12th of March 2013. These areas were supplied water for 2 hours in accordance to the standard practice in Hubli. While there were more areas supplied on the same day, the pressure head was not adequately maintained in the case below. Between the 2 and 3 pm, the level is retained at 2.1 meters but during the hour between 3 to 4 pm, the level drops significantly from 2.1 to 0.9 meters. Such a situation can be avoided if Pacific Park, Vivekananda Colony and Bhavani Nagar are supplied water at different times. That would make it easier for tank operators to maintain the pressure head consistently and consequently reduce the problems of low pressure and inadequate supply at the tail-end of these colonies. As expected, end-users in area had complained about low pressure supply on the 12th of March.

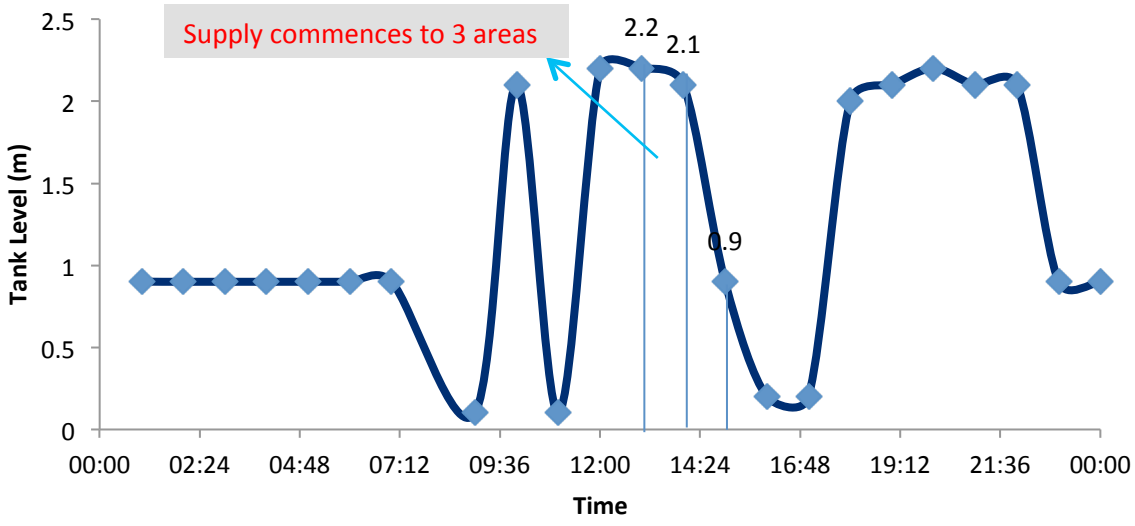

Figure 6: Keshwapur Tank Level Change with respect to Supply Timings

Table 3. Supply Timings between 1-2 pm of Areas in Keshwapur

Date	Time	Employee Name	City Area	Call Type
12-03-2013	1:14:22 PM	Maanjunath	Pacific Park	opened
12-03-2013	1:39:00 PM	Chanagoudra	vivekanda colony	opened
12-03-2013	1:39:38 PM	Chanagoudra	Bhavani Nagar Garden line	opened

The WIS can help the officials in-charge make these decisions in real time and provide clear guidance to valvemen and ground level staff to operate the distribution system. This will enhance the efficiency of service in much challenged intermittent supply system and gains customer satisfaction.

4. CONCLUSION

In conclusion, the WIS fills two crucial gaps in the operation of the intermittent water distribution system. First, it has established a two way communication channel between the end-user and the utility staff. While on the one hand this SMS based communication method has reduced the uncertainty faced by end-users and thus improved access to water for all residents of the city. On the other hand, it allows an easy way for the end users to convey location specific feedback on system operations to system operators. This feedback enhances the geo-tagged information available to the operator to redress complaints faster, plug leaks quicker and enhance the efficiency of the system.

Second, the WIS provides alerts, warnings and system operation data in real time to system operators that directly improve their ability to make data driven decisions. Using simple SMS, additional efficiency can be extracted from the existing water delivery infrastructure. It provides a better means to manage the already installed water distribution system by monitoring and analyzing reservoir levels in real time, integrate it with supply timings to each area and area specific end-user feedback.

Additional functionalities such as real time water balance for a tank, receiving water quality feedback from end users and tracking of Non-Revenue Water are currently being developed for the WIS.

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