





Report on Water Audit - Case of Vadodara

Karelibaug Overhead Tank and Command Area

CWAS CENTER FOR WATER AND SANITATION | CRDF CEPT RESEARCH AND DEVELOPMENT FOUNDATION | CEPT UNIVERSITY

Water Audit in Vadodara

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Center for Water and Sanitation

CRDF, CEPT University

Acknowledgements

Indian water utilities report 30 to 40 percent NRW. However, in most cases, these estimates are not based on proper measurements. While a full-fledged water audit can be very expensive, this report demonstrates application of a 'low-cost' methodology that enables estimation of water losses in the system and compute NRW.

This report provides findings of the preliminary water audit conducted by Center for Water and Sanitation (CWAS-CRDF-CEPT University) in association with Soham Technologies in Vadodara city during February–April 2022.

At CWAS, the research team included Dhruv Bhavsar, Jaladhi Vavaliya, Saubiya Sareshwala and Apoorva Bhate under the guidance of Dinesh Mehta and Meera Mehta.

We are also grateful to VMC officials of Water Supply Department Mr. Amrut Makwana, Mr. Prashant Yadav, Mr. Yogesh Vasava who co-ordinated well during the process. As other cities in Gujarat and Maharashtra begin to explore similar studies, lessons and experiences from this pilot study will be valuable. We see this as an evolving piece of work that will benefit from this experience.

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Abbreviations

VMC	Vadodara Municipal Corporation
ESR	Elevated Storage Reservoir
GSR	Ground Water Storage Reservoir
NRW	Non-Revenue Water
OHT	Over Head Tank
WTP	Water Treatment Plant
WDS	Water Distribution Station
MoHUA	Ministry of Housing and Urban Affairs
MoUD	Ministry of Urban Development
SCADA	Supervisory Control And Data Acquisition

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1. Background

The global annual water loss quantity is predicted to be 126-billion-meter cube, costing over 3900 crore dollars each year. (Liemberger & Wyatt, 2019) The UN-mandated Sustainable Development Goal (SDG) 6 aims to “ensure availability and sustainable management of water and sanitation for all. At the COP26, water has been discussed at the central place. NITI Aayog (2018), mentions that India is undergoing the worst water crisis in its history and nearly 600 million people are facing high to extreme water stress. (Niti Aayog, 2018) To address issues of water scarcity and management, scientific interventions are important as they become the necessary base to build political will. Understanding the severity, Government of India (GoI) has launched AMRUT 2.0 (Atal Mission for Rejuvenation and Urban Transformation) which focuses on making cities water-secure and self-sufficient through circular economy of water. (MoHUA, 2021) Under AMRUT 2.0, GoI strongly emphasises cities to reduce their Non-Revenue Water (NRW) losses through scientific process of water audits and conserve water.

Water audits are essential for various reasons, particularly in contexts where water resources are scarce or under stress. They are essential tools for promoting efficient and sustainable water management practices, conserving precious water resources, and ensuring the long-term resilience of communities, businesses, and ecosystems.

The city of Vadodara in western India is facing issues of water scarcity and demand management. Vadodara Municipal Corporation (VMC) has an existing water supply network spread across an area of 159 sq. km. Approximately, on a day-to-day basis, total water supplied to by VMC is 550 MLD, out of which 12 MLD is supplied to surrounding villages. Thus, total water supplied to Vadodara is 538 MLD. The daily per capita water consumption is estimated as 166 lpcd, exceeding the benchmark of 135 lpcd proposed by MoHUA (MoUD). (CWAS, 2020) In future, the city plans to expand its water supply network. The city is already making arrangements for improving its existing water supply system by augmenting its source. VMC has been receiving complaints from its consumers of inadequacy of water supply. However, the city claims to meet the required demand. For effective water demand management and understand the volume of water consumption at the consumer end, it becomes essential to assess the Non-Revenue Water (NRW) losses of the city.

Vadodara has an existing SCADA system in place to record the water supply data through its transmission and distribution network. The flow meters at the distribution stations daily record the volume of water in ESRs and GSRs. The calculated NRW loss in the transmission network of the city from source and Water Treatment Plant (WTP) to the Water Distribution Stations (WDS) is estimated to be around 18%. Hence, a detailed water audit is necessary in the distribution network to find out the actual consumption of water at the consumer end. In order to understand water losses in the distribution network and to estimate consumer demand, pilot OHT Karelibaug (Harni) has been selected for a detailed water audit.

Table 1 Total water supply by VMC and city-wide water losses from source to distribution stations

	Source	**Water Supply (in MLD)**
1	Khanpur WTP	75
2	Fajalpur RCW	69
3a	Raika RCW	71
3b	Raika Tube well	10
4a	Dodka RCW	29
4b	Dodka WTP	50
5	Poicha RCW	81
6	Nimeta WTP	153
	Total water from source (in MLD)	538
A	Total water at ESRs / GSRs (in MLD)	441
B	NRW losses in distribution channel from source to WDS	97
C	**NRW losses in distribution channel from source to WDS (in %)**	**18%**

Source: NRW losses in the distribution network from source to Water Distribution Stations is calculated based on SCADA results.

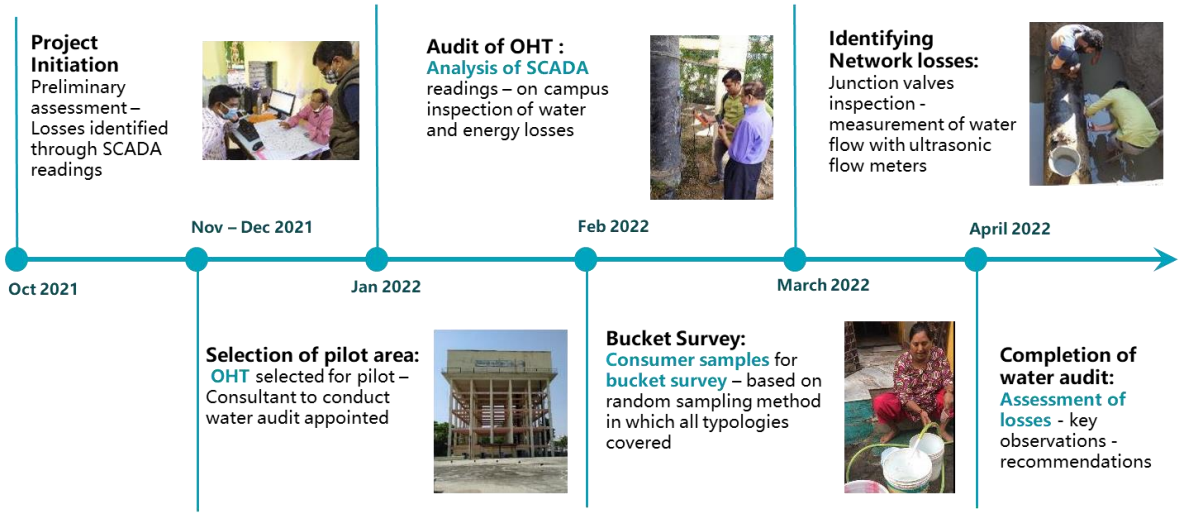
Karelibaug OHT command area is spread across 6.6 sq. km. and 24.2 MLD water is daily supplied through this storage reservoir. The OHT premise has 1 ESR of 1.8 MLD and 3 GSR of 3.5 MLD each. The OHT is 44 years old. There were lot of leakages in the tank till water proofing was done for it. The OHT Command area is further divided into 9 sub-zones according to time duration of water supply. There are total 28,770 water connections registered in the tax base, however, many unauthorised connections have been found out in the command area during water audit site visits. The industries are completely dependent on

ground water and there is no municipal connection. There are 4 slum pockets in the area. Due to proximity of the area near the airport, almost seventy percent of the area has low rise structures.

1.1. Approach and methodology

To execute the water audit process, discussions were carried out with VMC officials - water supply engineer, site engineer, OHT pump operators, SCADA system specialist etc. for understanding each component of the water supply system of the selected pilot area. Detailed water audit was carried out in a period of 45 days at the overhead water tank, leakage detection of valves and pipelines in the network through flow meters and bucket survey at consumer ends (slum and non-slum households). 260 samples were selected for bucket survey at the flag and near end of the OHT based on random sampling method with 90% confidence level. Around 149 samples were taken from non-slum residential areas, 71 from slums and 24 samples were taken from commercial spaces for bucket survey. Regular discussions were carried out with the administrative department including the electrician, housekeeping and canteen in charge were conducted throughout the exercise based on the current situation and the past trends in water consumption, current sources, supply amount, source metering, distribution storage, wastewater generation etc.

Figure 1 Timeline of water audit process in Vadodara



2. Key findings from water audit process

There is inequity in water supplied to various zones within the command area which leads to overconsumption of water in these zones. The duration of water supplied is double in few zones.

Based on the results from the bucket survey of 260 samples, the average water delivered in non-slum residential areas is 609 litres per connection per day, 451 litres per connection per day in slum areas and 851 litres per connection per day in commercial areas. However, it has been observed from the results that there is inequity in amount of water supplied within the command area and duration of water supply varies in different zones. Residential zones like Zone -5 (Refer figure 1) consume more water as water is supplied for 130 mins per connection per day, which is double the time duration as compared to other zones of 60 mins per connection per day. Also, 40% of zone- 5 comprises of commercial connections of 1" diameter. There is a huge gap in the minimum, maximum and average water supplied in various zones. For example, the maximum amount of water supplied in non-slum areas per connection per day is 1440 litres, whereas the minimum is only 150 litres per connection day. There are four slum-pockets in Zone and the average water supplied in slum areas is 421 litres per connection per day which means water supplied is not equitable within slum and non-slum households of the same command area. The minimum water supplied in slum areas is 273 litres per connection per day and the maximum is 857 litres per connection per day.

Figure 2 Bucket Survey at consumer end (20 litres bucket) and samples collected

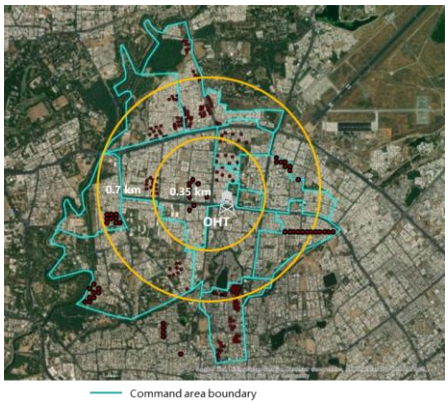
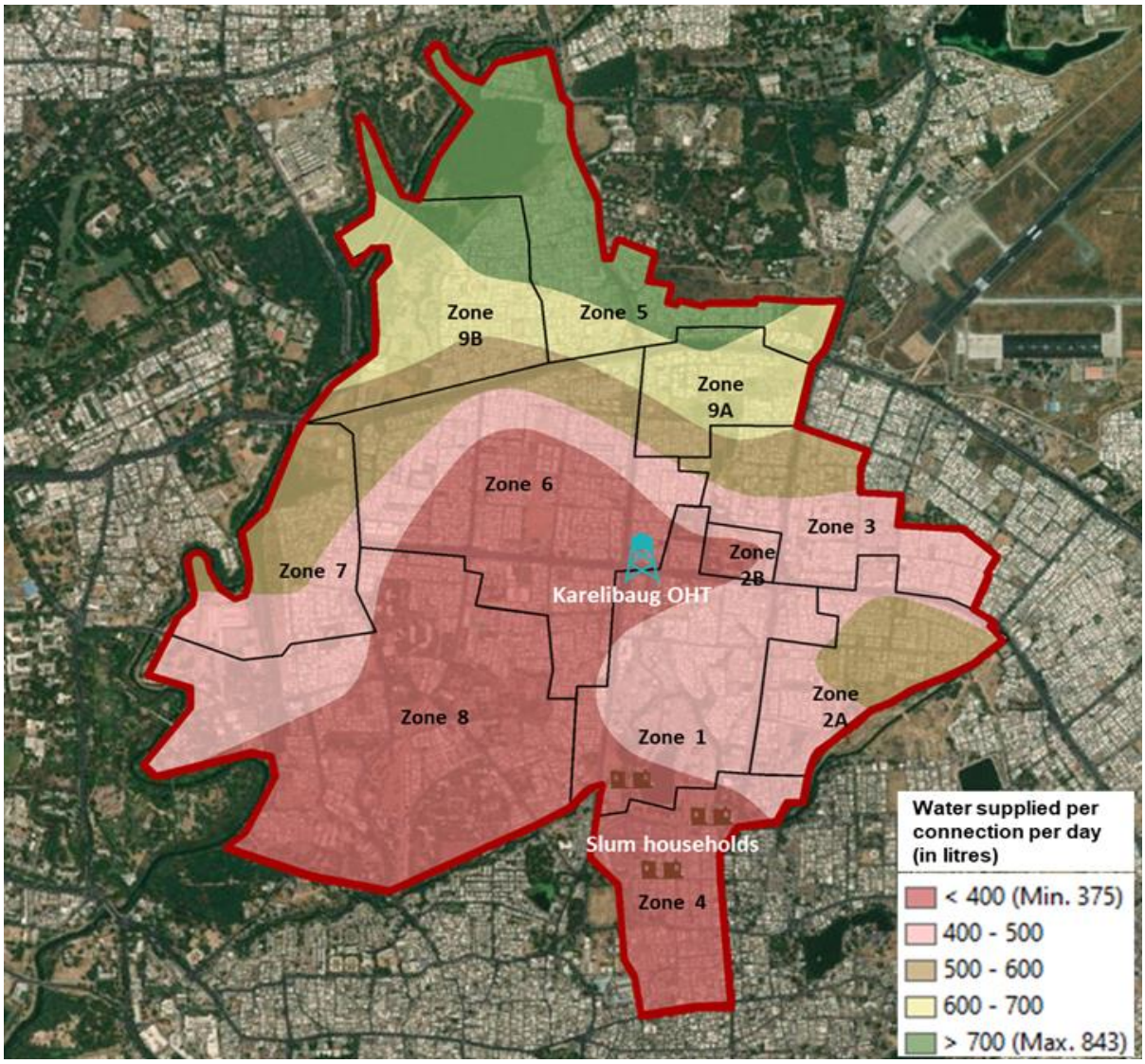


Figure 3 Average water supplied in litres per connection per day at Karelibaug command area



Source: Based on bucket survey results at HH level in Karelibaug command area, February-March 2022

Refer Annex-4 and 5 for time duration of each zone of water supply from Karelibaug OHT

Table 2 Average water supplied in slum, non-slum, and commercial areas per connection per day

Water supplied per connection (in litres)			
	Max	**Min**	**Average**
Non-slum area	1440	150	609
Slum area	857	273	451
Commercial	1300	555	851

Source: Calculated based on bucket survey at HH level for Karelibaug command area, February-March 2022

2.1. Assessment of water losses

The real water losses reported in the OHT, valves, pipes and in the network based on bucket survey and water audit is 28%. The losses due to unauthorised consumption is estimated to be 4%. The total non-revenue water at the Karelibaug OHT and command area is calculated as 31%.

During the water audit, real losses and water demand are calculated at the following locations:

1. Losses at the Overhead Tank and pumping station
2. Losses in the distribution network- valves and pipelines
3. Losses in transmission network

(Refer annexure 1,2 & 3 to understand details of calculations)

The following table represents the total losses identified against 24.2 MLD water delivered to the consumers of 9 sub-zones from Karelibaug OHT. The total real losses at the OHT and within the pipes and valves of the distribution network and transmission losses are calculated as 31%.

Table 3 Real water losses at the OHT, valves, pipelines, and network losses

Sr.No	Water Losses Locations	Water Loss in MLD	Water loss (in %)
1	Loss at OHT premises	2.6	11%
2	Leakage In the valves and pipes	0.2	01%
3	Network losses (Calculated based on bucket survey)	3.8	16%
4	**Total real losses**	**6.6**	**~28%**

Source: Losses are calculated based on water audit, February-March 2022

There is no metering at the consumer level in Karelibaug command area.

System input: The OHT receives water from a pipeline near Mahisagar French wells and from an 18-inch feeder line from Raika and Dodka. 24.2 MLD water is supplied from the Karelibaug OHT.

Authorised consumption: According to the bucket survey results, the average daily water supplied through Karelibaug tank per connection is 588 litres. The total no. of authorised connections is found out to be 28,770.

Unauthorised consumption: As per site survey and discussions with water supply engineer of VMC, the area has many unauthorised connections (approximately 1500 has been considered for analysis). This results in high end water losses of approximately 0.9 MLD (~4%).

Real losses: These losses have been observed at the storage tank, in the valves of distribution network and transmission network.

i. **Losses at the OHT**: The command area has high water losses at the OHT. As per water audit, the losses are calculated as 2.63 MLD (11%). This has been calculated based on hourly flow meter readings taken from OHT for seven days.
ii. **Losses in valves and pipelines**: The overall losses in the distribution network is found to be 0.20 MLD (1%). There are in total 103 valves.
iii. **Losses in network**: The overall losses in the transmission network reported due to bucket survey on consumer end is quite high and is calculated to be 3.8 MLD (16%).

Figure 4 Water losses in the distribution network and water tank

Source: Images clicked during water audit process by CWAS, CEPT and Soham Technologies

Table 4 : IWA Chart for Non-Revenue Water (NRW) in Karelibaug area

<table>
<tr><th colspan="5">Karelibaug OHT</th></tr>
<tr><td rowspan="6">System Input volume
(24.2 MLD)</td><td rowspan="3">Authorised consumption
(16.7 MLD)
69%</td><td rowspan="2">Billed authorised consumption
(16.7 MLD)
69%</td><td>Billed metered consumption
(NA)</td><td rowspan="2">Revenue water

(16.7 MLD)

69%</td></tr>
<tr><td>Billed unmetered consumption
(16.7 MLD)
69%</td></tr>
<tr><td rowspan="2">Unbilled authorised consumption
(0.02 MLD)</td><td>Unbilled metered consumption
(NA)</td></tr>
<tr><td>Unbilled unmetered consumption
(0.02 MLD)
0.05%</td><td rowspan="4">Non-revenue water
(7.5 MLD)
31%</td></tr>
<tr><td rowspan="4">Water losses
(7.5 MLD)
31%</td><td rowspan="2">Apparent losses
(0.9 MLD)
4%</td><td>Unauthorised consumption
(0.9 MLD)
4%</td></tr>
<tr><td>Metering inaccuracies
(NA)</td></tr>
<tr><td rowspan="3">Real losses
(6.6 MLD)
28%</td><td>Leakage in transmission mains
(3.8 MLD)
16%</td></tr>
<tr><td>Leakage and overflows at storage tanks
(2 .63 MLD)
11%</td></tr>
<tr><td>Leakage distribution and on service connections up to the measurement point
(0.20 MLD)
(1%)</td></tr>
</table>

Note: IWA chart for Karelibaug OHT is prepared based on water audit done at Karelibaug OHT and command area, February-March 2022.

Non-revenue water comes at a cost!

Water losses from source to OHT are reported as 18% which is equivalent to **4.3 MLD** for the Karelibaug OHT. Water losses from OHT to households are calculated as **7.5 MLD**. The total losses found in the Karelibaug water-supply system from **source to households** is **11.85 MLD**. The cost of these water losses are estimated to be **22 lakhs per month** which is beared by VMC.

Table 5 Cost of NRW losses for VMC

	Cost of water to VMC for Karelibaug
Cost of 1 kl water to VMC per day	Rs. 6.47 per day
Cost of water loss per day (source to HHs)	Rs. 48,525 per day
Cost of water loss per month (source to HHs)	Rs. 22 lakhs per month

Note: Calculations done based on cost of water per kL provided by VMC, 2022

2.2. Key observations from the water audit process

- SCADA phase 1 have digitized the water source to OHT network, hence water supplied from source is measured on daily basis. SCADA phase 2 involves digitization of OHT to consumer end network which would help to track water losses. Also connecting the valves in SCADA, would help in smooth functioning of water distribution and detect in operation of the valves.
- Fatehpura and Hathikhana area receive mix of water supply from Karelibaug OHT and from Warasia booster pump. There is no count of the water received from Warasia booster.
- Various complaints were received from the consumers regarding water quality and pressure during the water audit. Sometimes the keyman forgets to close the valve which results to overflowing of water from consumer tanks.
- To maintain water pressure due to topographical differences, in areas like Fatehpura, Hathikhana, Nagarwada, and Sadhana Nagar have booster pumps installed. In one of the area named Hathikhana water theft was observed as water pressure was not achieved at higher end. Most of the people were using motors for drawing the water from the pipes directly. It was noted that more than 100 motors were running at a single time.
- It was noted during the non-supply hours, water level of the tank reduces. Within a span of 2.3 hours, gap of 2 ft. twice a day calculates up to 1MLD water loss daily.
- Unaccounted water usage can be inferred from the citizen survey due to absence of metering at consumer end.

- Most of the consumers do not having a ball cock in the underground tank as well as overhead tank. Hence over drawing of water is noted.
- Many consumers use submersible pumps to suffice their water demands. The water works department do not have data regarding the pumps, and hence extra water pumped out is not known.
- It is observed that water is supplied for more than two hours are observed in Vrindavan, Vijay Nagar, Sreedhar duplex, 2500 houses in bright school lane and EMF staff quarters due to political interference.
- The annual maintenance contract for maintenance of pipeline and valves is INR 50 lakhs per annum. But it has been observed that under the contract only pipeline leakage work is taken care off.
- It was narrated that about 50 people are working in the Karelibaug OHT area to maintain the water supply. However, at present only 20/25 people are working.

3. Recommendations and way forward

Based on the observations made during the basic water audit and its results, a few key suggestions for improved measurement of NRW as well as for its reduction have been identified. The city will be able to save considerably by reducing its NRW losses**:**

- **Repair the leakages at the OHT, valves and distribution lines** - Vadodara Municipal Corporation must urgently reduce its non-revenue water losses by repairing the leakages at the Karelibaug overhead tank. According to water audit results, 11% water losses are reported at the OHT. This includes regular monitoring of valves at the OHT and replace them. Valves which are kept open for extensive hours should also be monitored regularly to avoid water losses. Leakages in distribution lines should be repaired immediately.

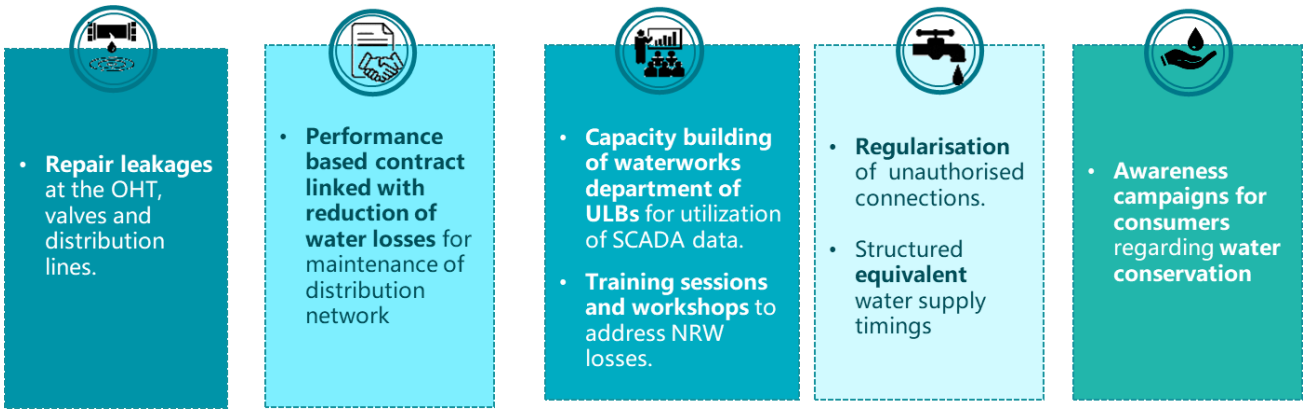
- **Performance based contract linked with reduction of water losses for maintenance of distribution network**- VMC can link its contracts with reduction of water losses for all the OHTs and distribution network. Payment of the private contractor can be managed by linking it to performance. Such initiatives have been successful in countries like Vietnam where cities like Ho Chi Minh and Hanoi during its six years' time span, this PBC project was able to save 122 MLD of water, ameliorated the supplying reliability, connected more customers to the network, and saved more than US$100 million of capital expenditures by reforming and restoring the water network. (IWA, 2019)

- **Regularise unauthorised connections** - Illegal withdrawal of water from distribution lines is one of the reasons resulting in low or even negative pressure. Almost 4% of the water losses are due to unauthorised connections in few areas. However, VMC officials mention that there might be more unauthorised connections. The city should carry out a drive to identify these connections and should regularise them to reduce NRW losses. This will also avoid illegal use of booster pumps and result in improved performance of the water distribution network.

- **Capacity building of staff members**- Though the city has installed SCADA and flow meters at the distribution stations, it is observed that there is a gap in monitoring of this data by

the water supply department. The operating staff should be trained to read, monitor and utilise SCADA data appropriately. This will help in pro-active measures for NRW loss reduction for current and future prospects.

- **Citywide water audit as a next step-** VMC should undertake city wide water audit for all its water distribution stations, valves and pipelines in the distribution network to reduce NRW losses. This can be done in phases where the city undertakes the audit for all the distribution stations followed by assessing the network losses as required.



Annexure

Annex 1: Losses at OHT

The following are the details of the overhead tank and different sizes of the pipes.

Size of Overhead Tank

Volume: 20 Mtr x 15 Mtr x 6 Mtr = 18,00,000 Ltrs. = 1.8 MLD

85 ft height the tank was repaired last year only as there were leakages at 3 places.

Size of pipes

- 24 inches, 20 inches, 16 inches, 18 inch, 12 inches, -- 7 Kms. Long lines to distribute the water at different locations. The pipes are made up of CI (Cast Iron) and/or DI (Ductile Iron). The repairing of the pipe is being made by the Dy. Engineer concerned if it is upto 250 mm, and 250 mm and more would be repaired by ward office.
- 8 inches, 6 inches, and 4 inches pipe = 11 Kms to distribute to each residential/house, commercial etc.

Annex Table 1 Calculated water losses at OHT level

Table 1 Loss at OHT water level					
Sr.No	**Date**	**Time**	**foot**	**Water Loss (liter)**	**Remark**
1	17.1.22	12	13	1560000	Day
2		9	11	1320000	Night
3	18.1.22	12	12	1440000	Day
4		8	10	1200000	Night
5	19.1.22	12	12	1440000	Day
6		8	13	1560000	Night
7	20.1.22	12	12.9	1548000	Day
8		8	10	1200000	Night
9	21.1.22	12	13	1560000	Day
10		8	9	1080000	Night
11	22.1.22	12	13	1560000	Day
12		8	11.3	1356000	Night
13	23.1.22	12	8	960000	Day
14		8	5.6	672000	Night
15	**Total**			**18456000**	
16	Average of 7 Days			2636571.43	
17	Leakage MLD			0.16	
18	**% Leakage Loss**			**11%**	

Annex 2: Losses at Valves

- There are approximately 103 Nos. of valves having a size of 20 inches, 16 inches, 12 inches, 10 inches, 8 inches, 6 inches, 4 inches.
- As and when required the contract is being placed to repair the valves. Generally, the valve has defects either in nut replacement, guide ring and holding clamp, the spindle, adjustment in pin, and the vendors for valves are Kirloskar, Jupiter and Kartar.
- The measurement was taken at Amit Nagar Circle, by taking out the water from the leakage valve with DG set pump (Primer) and stopwatch methodology it was calculated the loss as under:
- 3-inch diameter pipe, the time taken to replace the water from leakage chamber (having a valve) 11 minutes 25 seconds.
- 0.628 M^3 x 11 Minutes = 6809 Litres. Of water. The same procedure was allotted at Sangam Char Rasta and similar results were also achieved.

Annex Table 2 : Water leakages at Valve locations

Table 2 Leakage In valves			
Sr. No	**Parameter**	**Unit**	**Value**
1	Diameter of Drainpipe (3")	Meter	0.08
2	Time of drain water in Minute (5 Min)	Hours	0.08
3	Length of Pipe (15 ft)	Meter	4.57
4	Volume of Drain Water (m3)	m3	0.02
5	Volume of Drain Water (liter)	Liter	20.84
6	Drain water for 20 minutes	Liter	416.79
7	Drain Water for 60 Mins	Liter	1250.37
8	Drain water for 103 valves	Liter	128787.7
9	Loss in MLD	MLD	0.13
10	Loss per 25 MLD		0.01
11	% Loss		0.52%

Annex 3: Losses at pipelines

- These pipes are required to be repaired/replaced for the leakages for the above-said locations and this is to be done 2 to 3 times a year.
- The repairing works take a minimum of 4 hours to replace/repair the pipe. The losses are being counted only for 4 hours in the above said six numbers of pipes which were repaired twice last and considering the losses of water is being calculated as given hereunder:
- 1000 Ltr. / Hour x 6 Nos. of locations x 2 times in a year x 4 hours = 48000 ltrs This is no doubt unavoidable condition because of old laying of lines of Cast Iron or otherwise. Many times, when they come to know the leakages, the nearest valve is being closed for stopping water.
- The cost of repairing is around Rs. 50 lakhs per annum. However, the losses in water are being stopped manually to save the water.
- The survey has been carried out to find the leakages in the valve of individual areas. For that the during morning and evening the operation by the operator at different locations has been observed. It is observed that there are water leakages due to opening and closing of the valves by the operators. The following are the some of the photographs which helps to understand the leakages during opening and closing operation of the valve.

Annex Figure 1 Valve conditions in OHT command area

Near Karelibaug Overhead Tank Char Rasta (18 inches)

Opposite Indrapuri Pumping Station (18 inches)

Near Muktanand Teen Rasta (18 inch)

Near Swaminarayan Mandir, Karelibaug (16 inch)

Near Sangam Char Rasta(16 inch)

Opposite Vrundavan Township (12 inches)

Annex 4: Zone wise timings of water distribution

Zone	Timing for Zone for water supply	Area of water supply
Morning Session		
1	6 to 7 am	Tulsiwadi, Jwaharnagar, Kala kunj, OHT to Sangam Char Rasta, Fatehpura.
2	7 to 8 am	Dhaval Hospital, Samvad Char Rasta, Samvad Quarters, Navnit Park, Saajanand Char Rasta
3	8 to 9.30 am	Sangam Char Rasta to Harni Road, Vrundavan township, Krishna Leela Society
4	9 to 11.10 am	Sangam Char Rasta to Subhash Park, Harijan Tekra, Amrapali Society (9 to 10.30 am)
5	11 to 12.10 am	Amitnagar, Bhavna Park, Ajitha Nagar, Krishnaveli Society,
Evening Session		
6	4 TO 5 pm	Jyoti Park, Anandnagar, Suvidha Park, OHT to Muktanand (3.50 to 6.20 pm Bright School Lane, Feeder Line)
7	5 to 6 pm	Deepika Society Part III, Shanti Park, Akshatha Society, Kunika Society
8	6 to 7 pm	Ambalal Park, Ayodhya Nagar
9	7 to 8.15 pm	Amrapali Narendra Park, Vithalkrupa Society,

Annex 5: Average water supply of each zone of Karelibaug based on household water audit

Zone	Area (sq km)	Estimated no of connections	Duration of water supplied per day (in minutes)	Average volume of water supplied per connection (in litres)	Total volume of water supplied in each zone (in MLD)
1	0.7	3051	60 min	549	1.7
2 (A)	0.4	1874	60 min	582	1.1
2 (B)	0.1	262	60 min	480	0.1
3	0.5	2049	90 min	544	1.1
4	0.4	1874	60 min	439	0.8
5	0.7	2877	130 min	843	2.4
6	1.1	4882	60 min	396	1.9
7	0.4	1831	60 min	781	1.4
8	1.5	6408	60 min	546	3.5
9 (A)	0.3	1177	130 min	682	0.8
9 (B)	0.6	2485	130 min	718	1.8
Total	**6.60**	**28770**	-	**588.0**	**16.7**

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