सत्यमेव जयते

Ministry of Housing and Urban Affairs
Government of India

Extent of Non-Revenue Water

TRAINING MANUAL

NIUA | C3
Climate Centre for Cities

ClimateSmart Cities Assessment Framework

Water Management

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Executive Summary

On one hand, cities are a significant contributor of carbon emissions aggravating climate change and on the other, cities are considerably impacted by climate disasters. The recently released Global Climate Risk Index 2021 ranks India as the 7th most affected country from climate related extreme weather events (storms, floods, heatwaves etc.). Further, studies indicate that poor planning and urban management are expected to cost Indian cities somewhere between $2.6 and $13 billion annually[1]. Cities are increasingly at the forefront of addressing both urbanization and climate change and to strengthen climate-sensitive urban development, a holistic understanding of the urban development from a climate lens is crucial. The ClimateSmart Cities Assessment Framework (CSCAF) launched in 2019 by the Ministry of Housing and Urban Affairs (MoHUA), Government of India aimed to address this gap. This first-of-its-kind assessment with 28 progressive indicators across 5 thematic areas helps cities to benchmark their development, understand the gaps and further prioritize climate relevant development.

With a focus on building local capacities to develop and adopt climate measures, the Climate Centre for Cities (C-Cube) at the National Institute of Urban Affairs (NIUA) initiated a series of training aligned to the thematic areas of CSCAF - Energy and Green Buildings, Urban Planning, Green Cover & Biodiversity, Mobility and Air Quality, Water Management, Waste Management. The focus of the training is to provide a step-by-step approach of conducting studies, assessments and stakeholder consultations, establishing committees, developing action plans and implementing relevant measures that not only makes the cities climate resilient but also helps them progress across the assessment of

[1]*Mani, M. et al., 2018. South Asia's Hotspots: The Impact of Temperature and Precipitation Changes on Living Standards, Washington D.C.: World Bank Group.*

CSCAF. This training focuses on the ‘non-revenue water management’ under the thematic areas of water management in the CSCAF.

According to the United Nations World Water Development Report 2019, the global demand for water is estimated to increase by 20% to 30% above current levels of water use by 2050[2]. Given that climate change is expected to create additional pressure on water resources, it becomes imperative to better manage existing water resources by reducing losses. Reducing Non-Revenue Water (NRW) is a powerful demand management instrument for urban local bodies in decreasing stress on existing resources. This module looks into the various aspects of NRW and how the extent of NRW can be reduced within cities.

The objective of this module is to build capacities of smart cities to understand and improve their performance with respect to the CSCAF indicator ‘extent of NRW’ by enabling them to undertake informed action to reduce the same. The training will be provided to select training institutes for further dissemination.

The focus of this module is the components of NRW. The module delves into the occurrence of water losses along the water distribution cycle, its causes and how to quantify these losses. The impact of NRW on existing water resource and power consumption is touched upon. The learnings from this module will enable cities to conduct water audits and formulate NRW reduction strategies to be implemented on ground to address the shocks and stresses climate change poses to cities.

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[2] *UNESCO World Water Assessment Programme (2019). The United Nations world water development report 2019: leaving no one behind. France*

Who is the training manual designed for?

What is the focus of the training manual?

How to make use of this manual?

What are the Learning outcomes of the training?

Scope and limitations of the training

The training module on the indicator 'Extent of NRW' is intended for Urban Local Bodies (ULBs), specifically the water utility department and other water service providers along with other development authority or parastatal officials involved in water management and water supply service delivery in urban areas. A basic understanding or water supply service delivery systems in urban areas is a prerequisite for various the stakeholders

The training module focuses on the various components of NRW and methods of NRW reduction to enhance resilience of ULBs by reducing water losses and the demand for electricity required for pumping water. The manual provides a brief description on the requirements for moving up the ladder under CSCAF. It also provides a detailed description of the water audit process needed to quantify the various components of NRW and identify relevant NRW reduction strategies to be adopted by ULBs.

This manual is to be used as a technical reference material which delves into details touched upon in the presentation with references to additional reading material to aid participants in following the training sessions.

The learning outcomes of this training is for cities to develop a better understanding of NRW and introduce effective ways for NRW reduction for better water management for addressing climate related risks. This training module would also equip cities in conducting water audits to establish the various water losses occurring within the water distribution system based on which relevant strategies can be formulated and implemented for NRW reduction.

As the training module is designed and developed as a 2 – hour online training session with interactive exercises for city officials its scope is limited to establish a basic understanding of NRW, requirements of the CSCAF indicator and outline of strategies for NRW reduction based on water audits.

Contents

List of Figures

List of Tables

Abbreviations

AMPLIFI	Assessment and Monitoring Platform for Liveable, Inclusive, and Future-ready urban India
BWSSB	Bangalore Water Supply and Sewerage Board
CEPT	Centre for Environment Planning and Technology
CPHEEO	Central Public Health & Environmental Engineering Organisation
CRDF	CEPT Research and Development Foundation
CSCAF	ClimateSmart Cities Assessment Framework
CWAS	Center for Water and Sanitation
DMA	District Metered Area
ESR	Elevated Storage Reservoirs
GHG	Greenhouse Gas
GIS	Geographic Information System
HIG	High Income Group
IWA	International Water Association
JICA	Japan International Cooperation Agency
JnNURM	Jawaharlal Nehru National Urban Renewal Mission
KPI	Key Performance Indicators
LAI	Local Action Indicators
LIG	Low Income Group
LPCD	Litres per Capita per Day
MIG	Middle Income Group
MLD	Millions of litre per day
MNF	Minimum Night Flow
MoHUA	Ministry of Housing and Urban Affairs
NIUA	National Institute of Urban Affairs
NRW	Non-Revenue Water
PAS	Performance Assessment Framework
SCADA	Supervisory Control and Data Acquisition
SLB	Service Level Benchmarks
MoUD	Ministry of Urban Development
UFW	Unaccounted for Water
ULB	Urban Local Body
UWSS	Urban Water Supply and Sanitation
WASH	Water, Sanitation and Hygiene
WDS	Water Distribution Station
WHO	World Health Organization
WTP	Water Treatment Plant

1

Non-Revenue Water

Non-Revenue Water (NRW) is defined as the difference between the volume of water introduced into the Water Distribution System (WDS) and the volume of water billed to end-users (Frauendorfer & Liemberger, 2010). It is water that is produced and introduced into the water distribution system but is "lost" before reaching the end-users due to leaks, theft or wastage (Duffy, 2016).

Figure 1: NRW definition

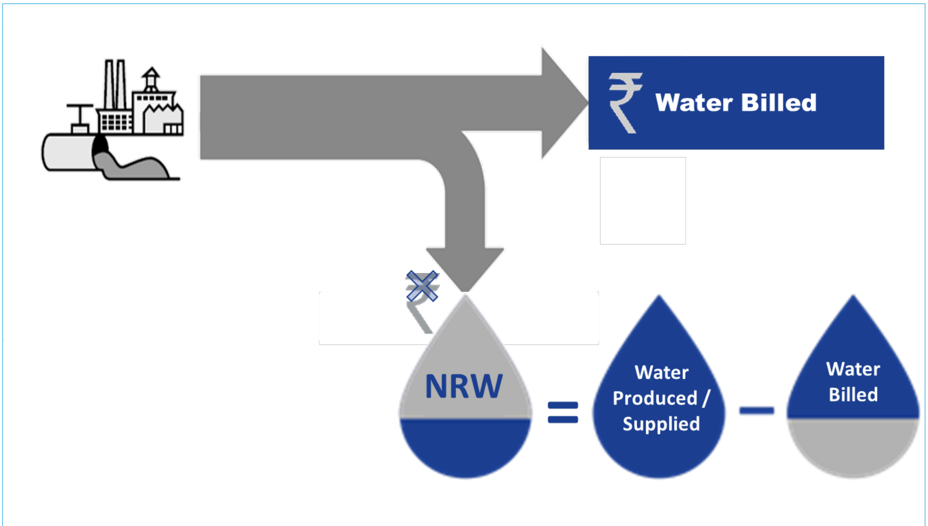


Image credits: Author, adapted from – AVK Saudi Arabia, Value in Every Drop, Stop Water Loss. https://www.avksvmc.com/en/water-supply/non-revenue-water and Introduction to NRW, Slide 34, https://slidetodoc.com/introduction-to-nrw-introduction-to-iwa-water-balance/

Water utilities in recent decades have noted chronic water losses as a significant challenge brought to the forefront due to rapid urbanisation of cities across the globe and negative impacts of climate change resulting in increasing demand but decreasing availability of water. A paper by R. Liemberger and A. Wyatt on 'Quantifying the global non-revenue water problem' (2019) estimated that the global volume of NRW is 346 million-cubic-meter per-day or 126 billion-cubic-meter per-day. The aggregate NRW globally is 30% of water system input volume and the cost value of the water lost amounts to 39 billion per year (Liemberger & Wyatt, 2019). If the global volume of NRW is reduced by one-third, the saved water would be sufficient for approximately 800 million people assuming 150 litre per capita (Liemberger & Wyatt, 2019).

Figure 2: Globally, why NRW is a concern.

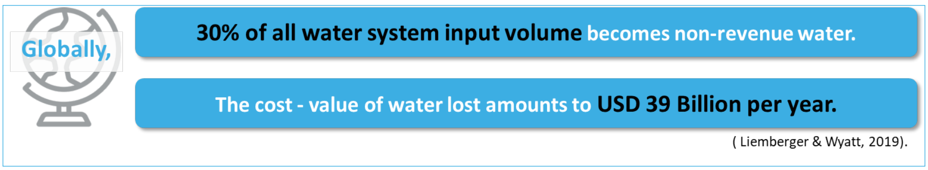


Image credits: Author, adapted from Liemberger & Wyatt, (2019) Quantifying the global non-revenue water problem. https://iwaponline.com/ws/article/19/3/831/41417/Quantifying-the-global-non-revenue-water-problem .

In India, the average NRW is around 38% and is above the global average (Varatharajan, 2020). In India, an estimated 600 million people face extreme to high water stress with around 200 thousand people dying every year due to lack of adequate access to safe water (NITI Aayog, GoI, 2018). By 2030, India's water demand is projected to be twice the available supply implying severe water scarcity (NITI Aayog, GoI, 2018) making it imperative to better manage available water resources and augment supply to ensure resilience to impending stresses and shocks.

Figure 3: In India, why NRW is a concern.

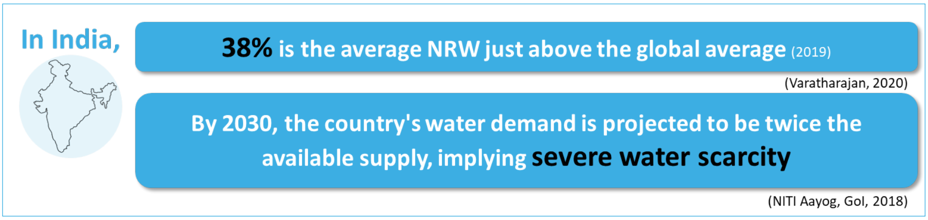


Image credits: Author, adapted from Nideshna Varatharajan (2020) World Water Day: India Tackling Water Utility Issues with Smart Water Meters. https://www.frost.com/frost-perspectives/world-water-day-india-tackling-water-utility-issues-with-smart-water-meters/ and NITI Aayog, GoI, (2018) Composite water management index: a tool for water management.

One of the strategies to tackle these challenges is to reduce NRW. This will not only improve the water utility service reliability but also decrease energy consumption, ensure equitable supply and will improve water quality. Reducing NRW would help the water utility move away from a vicious cycle of deteriorating water utility performance and also delay the need for capital intensive augmentation projects.

1.1 Water Distribution Cycle

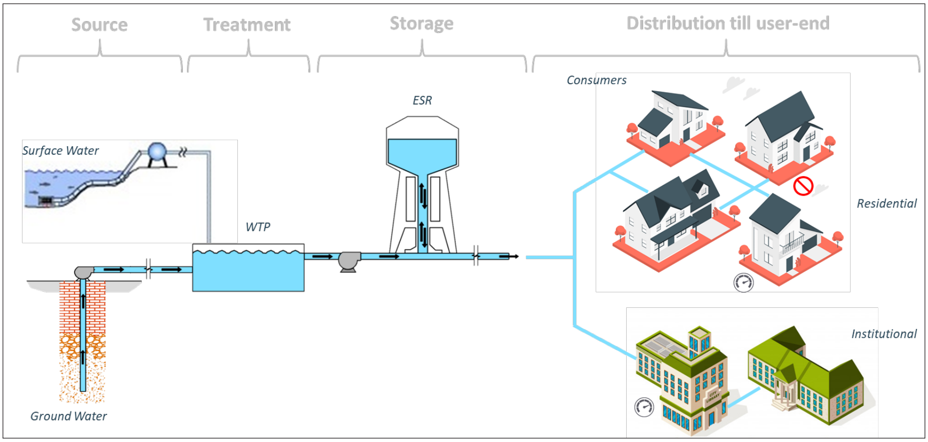
The water distribution cycle comprises the entire water supply service chain from the source to the end-user. The source of water can be surface sources such as rivers, lakes and other water bodies. The water from the source is transmitted through the transmission mains to the treatment plant where it is treated to ensure that the water meets drinking water standards as recommended by CPHEEO. Water from the treatment plant is then distributed to the end-users through a network of transmission and distribution lines and Elevated Storage Reservoirs and underground storage reservoirs.

1.2 Components of NRW

Water balance was defined by Lambert and Hirner as part of the International Water Association’s (IWA) Water Loss Task Force. It is recognised worldwide as an applied approach to assess water loss in a distribution system (Mastaller & Klingel, 2017). A water balance is established by determining the total volume of water added or subtracted from a water distribution system. It helps identify the components of NRW which include unbilled authorised consumption, and water losses which include real losses such as leakages[1] and apparent losses like metering inaccuracies.

[1] *Leakage is the unintentional loss of water from a distribution network ranging from a drip to a main break. (Sharma, 2008)*

Figure 4: Water distribution cycle.



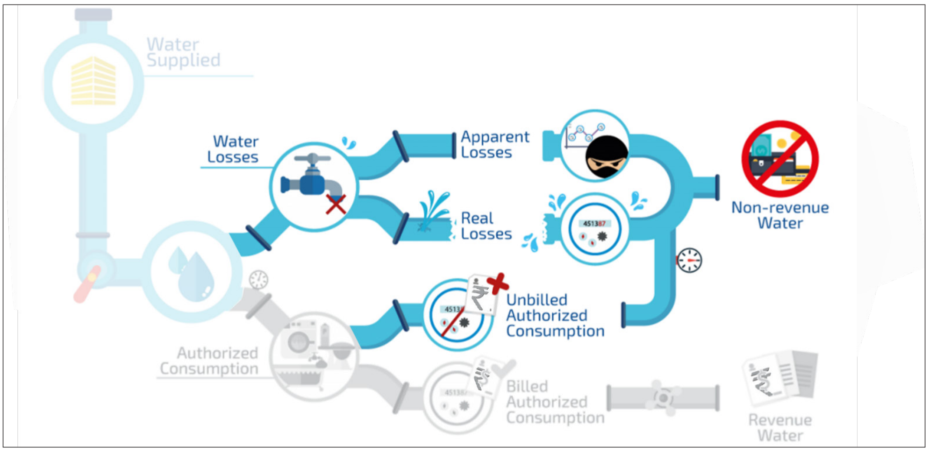


Image credits: Author.

The IWA water balance covers the entire water supply service chain of the water utility from the production of water to its treatment and distribution till the end-user.

Figure 6: IWA Water Balance Chart.

<table>
<tr><td rowspan="9">System Input Volume</td><td rowspan="4">Authorized consumption</td><td rowspan="2">Billed authorized consumption</td><td>Billed meter consumption</td><td rowspan="2">Revenue water</td></tr>
<tr><td>Billed un-metered consumption</td></tr>
<tr><td rowspan="2">Unbilled authorized consumption</td><td>Unbilled metered consumption</td><td rowspan="7">Non revenue water (NRW)</td></tr>
<tr><td>Unbilled un-metered consumption</td></tr>
<tr><td rowspan="5">Water losses</td><td rowspan="2">Apparent losses</td><td>Unauthorised consumption</td></tr>
<tr><td>Metering inaccuracy</td></tr>
<tr><td rowspan="3">Real losses</td><td>Leakages on transmission and / or distribution mains</td></tr>
<tr><td>Leakages and overflows at Utility's storage tanks</td></tr>
<tr><td>Leakage on services connections up to point of customer metering</td></tr>
</table>

Image credits: Lambert & Hirner (2000) Losses from water supply systems: standard terminology and recommended performancemeasures.https://waterfund.go.ke/watersource/Downloads/001.%20Losses%20from%20water%20 supply%20systems.pdf

The components of the IWA chart definitions as per the IWA blue pages (Lambert & Hirner, 2000):

- System Input Volume: the volume of water input to a transmission or distribution system.
- Authorised Consumption: the volume of metered or unmetered water consumed by registered customers and others who are authorised to do so by the service provider for domestic, commercial and industrial purposes.
- Unbilled Authorised Consumption: the volume of water where the consumer is authorised by the service provider to withdraw water but isn't billed for their usage.
- Water Losses: the total volume of water which doesn't reach the end-users.
- Real Losses: physical water losses up to the point of the customer.
- Apparent Losses: unauthorised consumption and all types of inaccuracies associated with production metering or customer metering.

Photo Credits: Jeremy Bezanger on Unsplash

2

CSCAF Indicators for Water Management

The ClimateSmart City Assessment Framework includes six indicators for Water Management which are:Water Resource Management

- Extent of Non-Revenue Water
- Wastewater Recycle and Reuse
- Flood/water stagnation risk management
- Energy efficient water management system
- Energy Efficient wastewater management system

These indicators help cities assess their present situation and guide them on implementing relevant climate actions with respect to water management (MoHUA, Government of India, 2020).

2.1. Extent of Non-Revenue Water Indicator

Climate change has significantly impacted the availability of water and is expected to create additional pressure on existing resources. In this context it becomes imperative to manage existing resources effectively. Reducing NRW by reducing water losses and the demand for electricity required for pumping and reducing GHG emissions will enhance climate resilience. NRW reduction is a powerful demand management instrument which decreases stress on existing water resources and provides a robust climate smart solution (MoHUA, Government of India, 2020).

The extent of NRW indicator signifies the extent of water produced which doesn't generate any revenue for the utility and is a useful performance benchmark. While NRW is calculated as the difference between the volume of water introduced into the distribution

Figure 7: CSCAF Indicators.

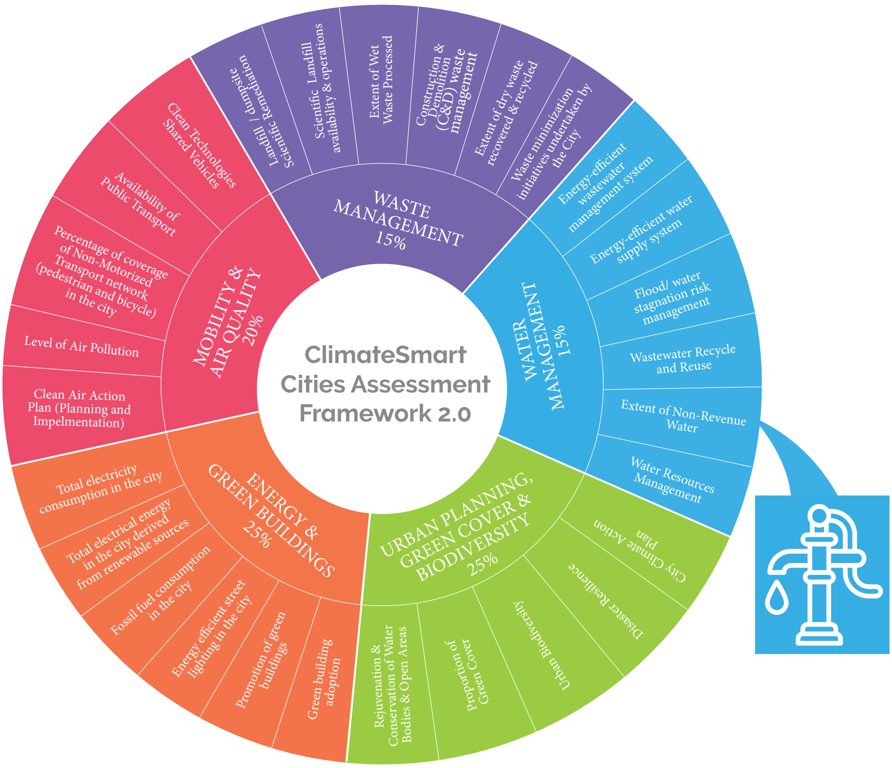


Image credits: C-Cube, NIUA (2020). Indicators of ClimateSmart Cities Assessment Framework 2.0. https://www.niua.org/csc/assets/pdf/CSCAF_2_Booklet.pdf system and the volume billed to the end-users. The extent is calculated as a percentage of NRW to the total volume of water introduced. NRW typically comprises consumption which is authorised but not billed, real losses such as leakages and apparent losses such as theft and metering inaccuracies.

Figure 8: Formula for extent of NRW.

$$\text{Extent of NRW} = \frac{(\text{Total water produced - Total water sold })*100}{\text{Total water produced}}$$

Image credits: Author.

CPHEEO recommends that cities should aim to reduce the extent of NRW to below 20%, after which it becomes significantly more difficult to further reduce it. The agencies responsible for measuring and reducing NRW include ULBs, water utility departments and water boards. NRW reduction provided numerous benefits such as, improved finances from increased water sales and reduced production, increased knowledge of the water distribution system and reduced risk in contamination.

2.2. Performance Evaluation Levels

Table 1: CSCAF indicator for Extent of NRW levels of action.

Develop-ment stages	1 Star	2 Stars	3 Stars	4 Stars	5 Stars
Levels	Level 1	Level 2	Level 3	Level 4	Level 5
Score	0	25	50	75	100
Progression Levels	NRW study is not conducted by the city	NRW study is conducted by the city and the most recent NRW of the city during 2016-20 is >40%	Most recent NRW of the city during 2016-20 is >30% to 40%	Most recent NRW of the city during 2016-20 is ≥20% to 30%	Most recent NRW of the city during 2016-20 is <20%
Data required	• Non-Revenue Water (NRW) report • Map of ward wise NRW as a .kml file (polygon geometry with attribute: percentage of NRW) (additional evidence)				

Credits: C-Cube, NIUA (2020). Indicators of ClimateSmart Cities Assessment Framework 2.0. *https://www.niua.org/csc/assets/pdf/CSCAF_2_Booklet.pdf*

2.3. Current Performance of cities

As per the ClimateSmart Cities Assessment Framework 2.0 - Cities Readiness Report 2021 it was observed that of the 126 participating cities only one city received five stars, while 23 cities performed relatively well with four stars (MoHUA, Governement of India and C-Cube, NIUA, 2021).

Figure 9: Performance of 126 cities in CSCAF assessment conducted in 2020

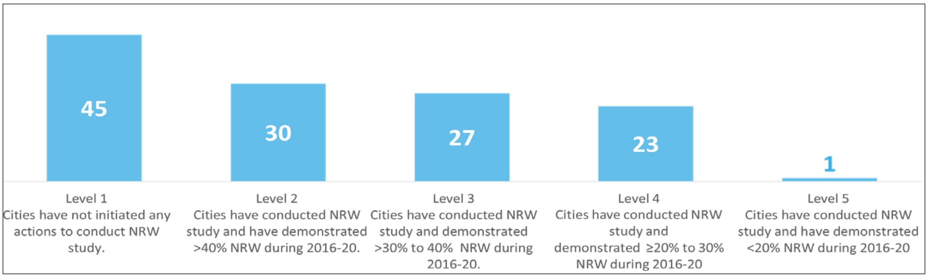


Image Credits: Author based on information from MoHUA, Government of India and C-Cube, NIUA (2021) Cities Readiness Report. https://heyzine.com/flip-book/31ddf6adfe.html#page/5

In order to move up the ladder cities should conduct regular water audits and prepare NRW reports, identify problem areas such as leakage points and illegal connections and undertake necessary actions to reduce the extent of NRW.

3

Service Level Benchmarking and Tools

Service level benchmarking was formulated in the context of needing to shift focus from infrastructure creation to delivery of service outcomes. Even though the urban sector is driving the growth of the economy and major rise in population in urban areas, it was observed that basic service levels were below desired levels. Service Level Benchmarking can be defined as a minimum set of standard performance parameters commonly understood and used by all stakeholders across the country (MoHUA, 2009). The Ministry of Housing and Urban Development (MoHUA) previously named the Ministry of Urban Development (MoUD) developed a Handbook for Service Level Benchmarking to identify a set of standard performance parameters for basic urban services such as water sanitation and solid waste management. A common minimum framework with indicators for each sector was identified for cities for monitoring and reporting along with guidelines on operationalising the same. The framework comprises 28 performance indicators, including nine indicators for water supply (MoHUA, 2009).

3.1. Service Level Benchmarks (SLB) for Water supply

A standardised set of key performance indicators related to urban management and service delivery were defined, measured and being reported on across urban areas by ULBs and other city-level parastatals. The standardisation is ensured by setting definitions and units along with data requirements and reliability of measurements (MoHUA, 2009).

Figure 10: SLB Handbook by MoHUA.

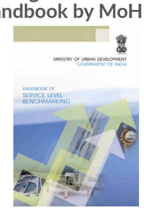


Image credits: MoHUA (2009). Handbook for Service Level Benchmarking. http://cpheeo.gov.in/upload/uploadfiles/files/Handbook.pdf

The water related Service Level Benchmarks (SLBs) focus on extent and accessibility to quality service while considering effectiveness of the system to manage the water supply network including aspects of financial sustainability. The following are the indicators for water services which includes the extent of NRW.

Table 2: SLBs for water supply services.

S.No.	Indicator	Benchmark
1	Coverage of water supply connections	100%
2	Per capita supply of water	135 LPCD
3	Extent of metering of water connections	100%
4	Extent of non-revenue water (NRW)	20%
5	Continuity of water supply	24 Hours
6	Quality of water supplied	100%
7	Efficiency in redressal of customer complaints	80%
8	Cost recovery in water supply services	100%
9	Efficiency in collection of water supply-related charges	90%

Credits: MoHUA (2009). Handbook for Service Level Benchmarking. ***http://cpheeo.gov.in/upload/uploadfiles/files/Handbook.pdf***

As per the SLB Handbook, the rationale for introducing 'Extent of NRW' indicator is to assess the financial sustainability of the water utility by reducing losses which can be utilized to meet excess demand and defer capital-intensive expenditure to enhance supply capacity. The benchmark value for NRW is 20% which has been achieved by most well-performing utilities in developed countries (MoHUA, 2009).

Table 3: Data requirement for measuring extent of NRW.

Data required	Unit	
a. Total water produced and put into the transmission and distribution system	Million litres per month	Daily quantities should be measured through metering, and records on the transmission and distribution system should be maintained. The total supply for the month should be based on the aggregate of the daily quantum.
b. Total water sold	Million litres per month	The actual volume of water supplied to customers who are billed for the water provided. Ideally, this should be the aggregate volume of water consumed as per which consumers have been billed.
NRW		NRW = [((a - b)/a)*100]

Credits: MoHUA (2009). Handbook for Service Level Benchmarking. ***http://cpheeo.gov.in/upload/uploadfiles/files/Handbook.pdf***

As per the SLB Handbook, the frequency of measurement of the indicator should be quarterly to be done at the ULB level. The highest and preferred level of reliability is given to those ULBs where quantity of water produced is computed based on bulk flow meter measurements at the bulk production points and metering is undertaken at key distribution nodes and the user-end for all categories of users (MoHUA, 2009). However, other methods of assessment along with their level of reliability are detailed out in the handbook. The benchmark value for NRW is 20% as the cost of reduction below the benchmark outweighs the benefits.

3.2. NRW Reduction Toolkit

In 2005, as part of the Government of India's urban reform agenda Jawaharlal Nehru National Urban Renewal Mission (JNNURM) efforts to strengthen and empower urban local bodies. This toolkit was prepared to assist ULBs in the NRW reduction process for the water supply service system. It details the water auditing process and calculating losses at various points of the water distribution system. The toolkit provides initial guidance to officials and policy makers in the water sector (MoHUA, 2012).

3.3. Performance Assessment System (PAS) Framework

The PAS framework draws on the Government of India's SLB framework combining it with various international and national efforts. It consists of Key Performance Indicators (KPIs) which are similar to the SLBs along with Local Action Indicators (LAIs) which contextualize the city's service requirement to better understand the results of the KPIs and inform action (CWAS, CRDF, CEPT University, 2011). NRW is one of the KPIs under the reform action theme and the following are the LAIs related to it. The complete list and definitions of the KPIs and LAIs is available in the 'Performance Measurement for Urban Water Supply and Sanitation – List and definitions of KPIs and Local Action Indicators'

(2011). The LAIs can be both quantitative and qualitative. Some examples of quantitative indicators include ‘Coverage of distribution network’, ‘% of identified illegal connections that are regularized’, and ‘Pump replacement’ (List of qualitative and quantitative indicators can be found in Annexure 1). The PAS framework is currently being applied to cities under the Smart City Mission and the results of the KPIs are hosted on the AMPLIFI dashboard where cities can compare results.

The AMPLIFI Dashboard (Assessment and Monitoring Platform for Liveable, Inclusive, and Future-ready urban India) hosted on the MoHUA website comprises data visualisations across various sectors including Water, Sanitation and Hygiene (WASH).

Figure 11: JNNURM NRW toolkit

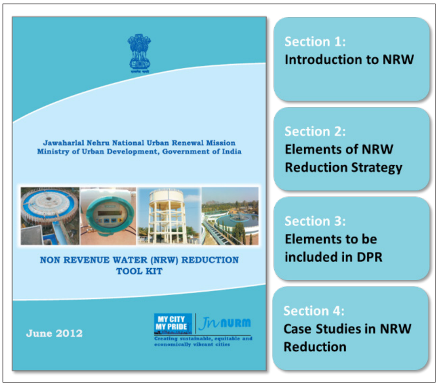
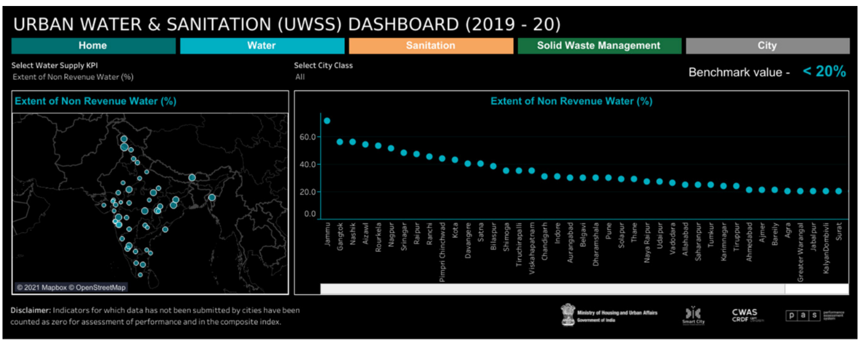


Image credits: MoHUA (2012). Non-Revenue Water (NRW) Reduction Toolkit. http://www.spml.co.in/Download/Reports/nrw-toolkit-final.pdf

Figure 12: Extent of NRW in Smart Cities on AMPLIFI dashboard.



Steps to view dashboard

http://amplifi.mohua.gov.in/ → Urban Water, Sanitation and Hygiene (WASH) Dashboard → Select Water tab → In Water Supply select ‘Extent of NRW’

Image credits: MoHUA, Government of India. AMPLIFI. Urban Water & Sanitation (UWSS) Dashboard (2019-20). http://amplifi.mohua.gov.in/

4

Impact of NRW on water and power

Most water utilities with high NRW fall into a vicious cycle where high levels of NRW lead to low levels of efficiency. The marketable product of a water utility is treated water, if a majority of this treated water is lost in the distribution cycle, the cost of water collection, treatment and distribution increases and the water sales decrease. This triggers the need for substantial capital expenditure programmes to meet ever-increasing demand which doesn't address the core problem (Frauendorfer & Liemberger, 2010). In order to improve efficiency and shift from the vicious cycle to a virtuous cycle, water utilities should prioritize NRW reduction strategies.

NRW has a significant impact on water availability, power consumption and cost-recovery in a city. In the following scenario based on a real case example we can see the impacts of NRW on the same.

Considering a case example of a particular city in which, the total quantum of water produced by the water utility is 320 MLD and the water billed to the end-users is 240 MLD. The city has an NRW of 25% which amounts to 80 MLD. The cost incurred by the water utility total to Rs.94 crores annually. This cost includes the cost of water which is Rs.45 crores, electricity charge for pumping water is Rs.30 crores and the salary for the staff and valve operators is Rs.16 crores and Rs.3 crores respectively. The cost incurred by the utility is Rs.125 per MLD.

Figure 13: Water Utility costs of a city.

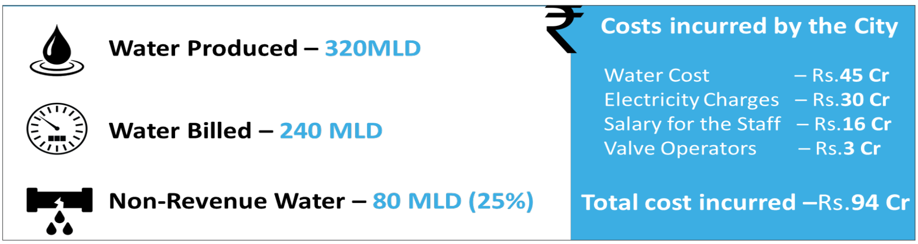


Image credits: Author adapted from The Indian Express (2016). Rajkot municipal commissioner proposes double water charges in budget 2016-17.

The total cost of electricity for pumping 320 MLD is Rs.30 crores annually including around Rs.7 crores being spent annually for pumping non-revenue water of 80 MLD. By reducing NRW the city could save the electricity cost incurred for pumping NRW and also generate revenue from the electricity currently being utilized for NRW elsewhere. The cost benefits to the city would be Rs.14 crore annually.

The city incurred a total cost of Rs.94 crores while the cost recovery through water charges Rs.22 crore which only accounts to 23%. The cost of purchasing water is approximately Rs.6000 per MLD and so the city would save Rs.17.5 crores by not purchasing the NRW from external sources along with the Rs.14 crore cost-benefit from savings and redistribution of electricity the total cost incurred on water supply to the city would reduce by 33%. The annual cost saved per MLD would be Rs.9.84 lakhs. Cities could make significant progress in terms of cost recovery in efforts made towards NRW reduction.

5

Water Audit

Water auditing is a method of quantifying water flows and quality in simple or complex systems, with a view to reduce water usage and save money on unnecessary water use (Sturman, Ho, & Mathew, 2005).

A water audit facilitates in detailing out the IWA Water Balance Chart and enables comparison of volumes of water treated and pumped to the volume billed to end-users. In the water auditing process, the estimated volume of losses due to leakage and inaccurate metering can be quantified. The water balance of the IWA methodology shows how to systematically track the volume of water under various components. The water balance tracks the supply of water from the source to the end-user from left to right and provides a format to quantify the volume of revenue and non-revenue water (Alliance for Water Efficiency, N.D).

The water audit will essentially answer questions like – 'how much water is being lost', 'where are losses occurring', 'why are losses occurring', 'what strategies need to be adopted to reduce losses' and 'how can these strategies be sustained to gain significant improvements'.

Before the water audit process is initiated the water service provider needs to establish a worksheet with the components of the IWA water balance chart. A time duration of the study period should be established while also defining the study boundary. The water audit includes a step-by-step process of establishing the volume of water under each component (CWAS, CRDF, CEPT University, N.D).

Figure 14: IWA Water Balance chart.

<table>
<tr><td rowspan="9">System Input Volume</td><td rowspan="4">Authorized consumption</td><td rowspan="2">Billed authorized consumption</td><td>Billed meter consumption</td><td rowspan="2">Revenue water</td></tr>
<tr><td>Billed un-metered consumption</td></tr>
<tr><td rowspan="2">Unbilled authorized consumption</td><td>Unbilled metered consumption</td><td rowspan="7">Non revenue water (NRW)</td></tr>
<tr><td>Unbilled un-metered consumption</td></tr>
<tr><td rowspan="5">Water losses</td><td rowspan="2">Apparent losses</td><td>Unauthorised consumption</td></tr>
<tr><td>Metering inaccuracy</td></tr>
<tr><td rowspan="3">Real losses</td><td>Leakages on transmission and / or distribution mains</td></tr>
<tr><td>Leakages and overflows at Utility’s storage tanks</td></tr>
<tr><td>Leakage on services connections up to point of customer metering</td></tr>
</table>

Image credits: Lambert & Hirner (2000) Losses from water supply systems: standard terminology and recommended performancemeasures.[*https://waterfund.go.ke/watersource/Downloads/001.%20Losses%20from%20water%20supply%20systems.pdf*](https://waterfund.go.ke/watersource/Downloads/001.%20Losses%20from%20water%20supply%20systems.pdf)

5.1. Steps for a water audit

Figure 15: Steps for a water audit

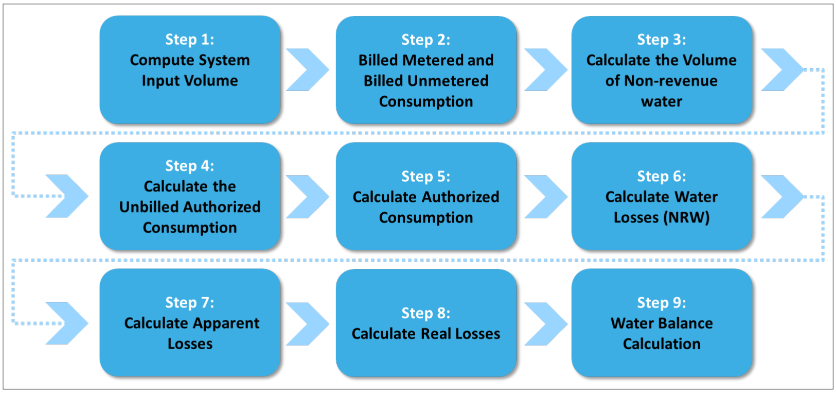


Image credits: Author adopted based on CWAS, CRDF, CEPT University. City Water Audit - Methodology and Outcome. https://pas.org.in/Portal/document/PIP%20Application/City%20Water%20Audit%20Methodology%20Final.pdf

5.1.1. Step 1: Computing System Input Volume

System input volume is the total volume of water introduced into the transmission system or purchased water from a concerned agency.

First, the various sources of water production need to be identified. These sources will include surface water sources like intakes at lakes or reservoirs, ground water sources and bulk purchase of water. The quantity of water from each source should be measured. This quantity of water withdrawn from different sources can be measured using flow meters, in case they haven't been installed, portable flow meters can be used. The quantity of bulk purchase of water will be available on the bill received from the concerned agency (CWAS, CRDF, CEPT University, N.D).

Figure 16: Intake well and portable flow meter

Image credits: 'Intake Well', Austin (2017). Designing, Constructing, Testing & Commissioning of Intake Well Cum Pump House, Water Treatment Plant. In Construction and Real Estate Blog. https://www.tendersontime.com/blogdetails/desingining-constructing-testing-commissioning-intake-well-cum-pump-house-water-treatment-plant-19885/ . 'Portable flow meter' CWAS, CRDF, CEPT University (ND). City Water Audit. Methodology and Outcome, Slide 10. https://pas.org.in/Portal/document/PIP%20Application/City%20Water%20Audit%20Methodology%20Final.pdf

5.1.2. Step 2: Estimating Billed Authorised Consumption

Billed Authorised Consumption is the volume of metered and non-metered water utilized by billed consumers. Billed metered consumption is quantified by identifying all the metered connections from the zonal or ward-wise ULB billing system records which will include the volume of metered water.

Billed unmetered consumption requires all unmetered connections to be identified. The quantum of unmetered use can be estimated by either test zone flow measurement or through representative sample survey method. Water meters can temporarily be installed during the measurement period (CWAS, CRDF, CEPT University, N.D).

The Test Zone Flow Measurement method is used to estimate unmetered billed quantity in a test zone and extrapolated at a city level. The selected test zone should include all housing categories from HIG, MIG, LIG and slums, availability of detailed distribution maps, consumer data such as number of connections and size of connections. The test zone should be small with about 50 to 60 service connections. Meters are installed at all connections in the test zone. Readings to be taken daily for a week and the pressure is recorded at a predetermined location and the losses are calculated in the test zone (CWAS, CRDF, CEPT University, N.D).

The Representative Sample Survey method samples according to water distribution zones. A base map with number of connections with size and type of connection to be identified. Samples from each zone to be taken considering average pressure keeping in mind the topography, supply timings and distance from ESRs. The selected samples should comprise of all types of end-users from different income groups, commercial and institutional buildings across the zone including slum households. The water received at the user-end can be established by installing temporary meters or through a bucket-stopwatch method. The total quantum of water is calculated by multiplying the number of connections with the average quantity of water received at the user-end (CWAS, CRDF, CEPT University, N.D).

5.1.3. Step 3: Calculate Non-Revenue Water

NRW is calculated by subtracting the volume of billed authorised consumption (computed in step 2) from the total system input volume (computed in step 1).

Figure 17: NRW formula.

$$\text{Non-Revenue water} = \underbrace{(\text{System Input Volume})}_{\text{Step 1}} - \underbrace{(\text{Revenue water})}_{\text{Step 2}}$$

Image credits: Author. Author adopted based on CWAS, CRDF, CEPT University. City Water Audit - Methodology and Outcome.https://pas.org.in/Portal/document/PIP%20Application/City%20Water%20Audit%2Methodology%20Final.pdf

5.1.4. Step 4: Compute Unbilled Authorized Consumption

Unbilled authorised consumption includes both metered and unmetered free supply. The unbilled metered consumption can be established by identifying all the connections at a zona or ward level and the consumption details obtained from ULB records.

Unbilled unmetered consumption includes government offices, schools, hospitals, and public toilets along with public stand posts and tanker supply to the under-served. The volume of unbilled unmetered consumption can be established by identifying the various connections. Consumption in government buildings and municipal properties is calculated based on standards prescribed by CPHEEO for that specific use. Quantum of water supplied from a public stand post can be extrapolated based on volumetric flow measurements from sample stand posts. The supply through water tankers in underserved areas can be computed by estimating number of trips and the capacity of the tankers (CWAS, CRDF, CEPT University, N.D).

5.1.5. Step 5: Calculate Authorised Consumption

The volume of water under authorised consumption is calculated as the sum of billed and unbilled consumption.

Figure 18: Authorised Consumption formula.

Authorized consumption = (Billed metered + Billed unmetered) + (Unbilled metered + Unbilled unmetered)

Authorized consumption = (Billed authorized consumption) + (Unbilled authorized consumption)

Image credits: Author. Author adopted based on CWAS, CRDF, CEPT University. City Water Audit - Methodology and Outcome. https://pas.org.in/Portal/document/PIP%20Application/City%20Water%20Audit%2Methodology%20Final.pdf

5.1.6. Step 6: Calculate water losses

Water losses are established by subtracting the authorised consumption (computed in step 5) from the system input volume (computed in step 1).

Figure 19: Computing water loss.

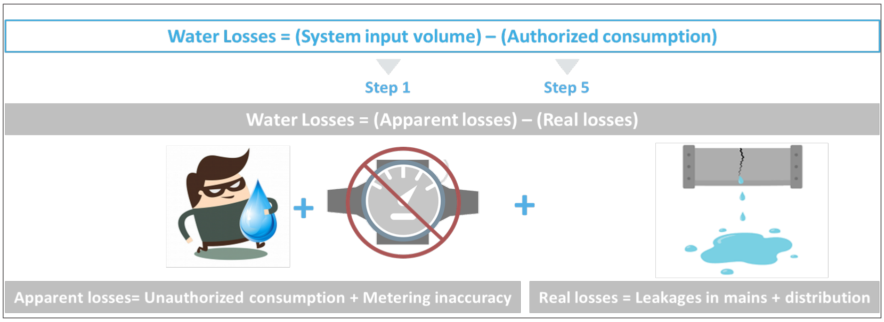


Image credits: Author. Author adopted based on CWAS, CRDF, CEPT University. City Water Audit - Methodology and Outcome.https://pas.org.in/Portal/document/PIP%20Application/City%20Water%20Audit%2Methodology%20 Final.pdf

5.1.7. Step 7: Computing Apparent Losses

Apparent losses include unauthorised consumption and all types of metering inaccuracies and data handling errors. Apparent losses are also known as commercial losses (CWAS, CRDF, CEPT University, N.D).

Unauthorised consumption is established through a detailed consumer survey in a selected test zone or through a sample survey by estimating the percentage of illegal connections and extrapolating this at the city level.

Metering inaccuracy is calculated through a sample survey of various metered installations at end users which should reflect various brands and age groups. The average meter inaccuracy value as a percentage of metered consumption should be established for different user groups.

5.1.8. Step 8: Calculating Real losses

Real losses also known as physical losses accounts for the total volume lost through different types of leaks, bursts[1] and overflows at the reservoir, the elevated-service reservoirs and service connections to the point of consumer metering.

Figure 20: Real loss formula.

Real Losses = (Water Losses) – (Apparent Losses)

Step 6 Step 7

Image credits: Author. Author adopted based on CWAS, CRDF, CEPT University. City Water Audit - Methodology and Outcome.https://pas.org.in/Portal/document/PIP%20Application/City%20Water%20Audit%2Methodology%20Final.pdf

5.1.9. Step 9: Assessment of Real losses

Potential water losses from the source to the user-end to be identified and the quantum of losses measured based on type. The methods of measurement of losses include bucket and stopwatch methods, portable ultrasonic flow meter, volumetric measurement and V-notch. The following are the potential sources of real losses and the method of quantifying the losses (CWAS, CRDF, CEPT University, N.D).

- Leaks at raw water transmission lines – measure volume at inlet and outlet of pipelines, leakage for valves needs to be surveyed and subtracted.
- Losses at the water treatment plant – measure volume at inlet and outlet of the treatment plant.
- Evaporation losses – losses to be calculated using the capacity curve after measuring the rate of evaporation.
- Leaks and seepage of reservoirs – drop test method to be employed to measure losses.
- Overflow of reservoirs – estimated based on frequency and flow rates.
- Leaks at distribution mains – volume of water to be measured at inlet and outlet of pipelines.
- Leakages from valves – to be quantified based on bucket and stop watch method.
- Leakage from service connections up to meter – established by deducting the leakage from mains and storage tank from total volume of real losses (CWAS, CRDF, CEPT University, N.D).

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[1] *Bursts are large openings caused in a network component due to excessive loads, high internal pressure, corrosion or a combination of factors. (Sharma, 2008)*

Figure 21: Methods used for measuring and estimating losses from discovered leaks.

Image credits: Author. Author adopted based on CWAS, CRDF, CEPT University. City Water Audit - Methodology and Outcome.https://pas.org.in/Portal/document/PIP%20Application/City%20Water%20Audit%2Methodology%20Final.pdf

5.2. Compute the volumes on a water balance chart

The quantum of losses estimated in various steps is to be computed in the IWA water balance chart and the percentage of different types of loss is to be established and the potential causes for these should be established based on field observations and network characteristics and conditions.

Figure 22: Water audit steps to detail out the IWA water balance chart.

<table>
<tr><td rowspan="9">System Input Volume
Step 1</td><td rowspan="4">Authorized consumption
Step 5</td><td rowspan="2">Billed authorized consumption
Step 2</td><td>Billed meter consumption</td><td rowspan="2">Revenue water</td></tr>
<tr><td>Billed un-metered consumption</td></tr>
<tr><td rowspan="2">Unbilled authorized consumption
Step 4</td><td>Unbilled metered consumption</td><td rowspan="7">Step 3
Non revenue water (NRW)</td></tr>
<tr><td>Unbilled un-metered consumption</td></tr>
<tr><td rowspan="5">Water losses
Step 6</td><td rowspan="2">Apparent losses
Step 7</td><td>Unauthorised consumption</td></tr>
<tr><td>Metering inaccuracy</td></tr>
<tr><td rowspan="3">Real losses
Step 8</td><td>Leakages on transmission and / or distribution mains</td></tr>
<tr><td>Leakages and overflows at Utility's storage tanks</td></tr>
<tr><td>Leakage on services connections up to point of customer metering</td></tr>
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Image credits: Author. Author adopted based on CWAS, CRDF, CEPT University. City Water Audit - Methodology and Outcome.https://pas.org.in/Portal/document/PIP%20Application/City%20Water%20Audit%2Methodology%20Final.pdf

6

NRW Reduction Strategies

The key to formulating an effective NRW reduction strategy is to develop a better understanding of the causes for NRW and its components. This is to be established as a part of the water audit, through a diagnostic approach by establishing network characteristics and understanding operation and management practices. Based on these characteristics and other local influencing factors, procedures can be tailored to tackle each component based on priority as part of the NRW reduction strategy (Farley & Liemberger, 2005). The following methods of NRW reduction can be adopted and integrated based on the local conditions to formulate an effective NRW reduction strategy. Some of the steps are a per-requisite of the other. An NRW reduction plan can be formulated identifying actions for addressing losses.

- Formation of an NRW cell
- Network mapping
- Leakage mapping
- Establishing District Metered Areas
- Leakage detection
- Supervisory Control and Data Acquisition (SCADA).

6.1. Formation of an NRW cell

An NRW cell established at the ULB level to carry out the monitoring and implementation of actions for NRW reduction. One of the key objectives of the NRW cell would be enhancing the efficiency in the transmission and distribution network to reduce physical losses by mapping, analysing and repairing leaks. Other key objectives include ensuring equity in distribution by regulating quantity and pressure across the city, achieving financial recovery by adopting appropriate metering and tariff policies and generating awareness around water conservation. The actions to be performed by the NRW cell include conducting periodic water audits, network mapping, leakage mapping and detection and augmentation of the network (Shah, 2011).

The NRW cell would comprise a decision maker such as the municipal commissioner or city engineer along with various civil engineers, electrical or mechanical engineers and instrumentation engineers to perform the day to day functions.

Figure 23: Structure of an NRW cell.

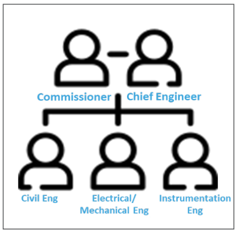


Image credits: Author.

6.2. Network mapping

Network Mapping involves preparing "as built" drawing of the existing water distribution network from the source to the end-user and carrying out hydraulic modelling of the distribution network. It requires plotting all the network information by combining older available drawings of the network from various water distribution stations and getting detailed information on the network from the valve operators. Network mapping enables the maintenance staff to establish accurate information on the location of water lines, valves, joints and flow meters which will save time and money while locating leaks and repairs. The network map is to be prepared on GIS and be linked to other databases such as property tax through which the service connection numbers can be linked to property numbers (Ceinsys Tech Ltd., ND).

Figure 24: GIS Network map hydraulic model of Amaravati (Dahasahasra, ND)

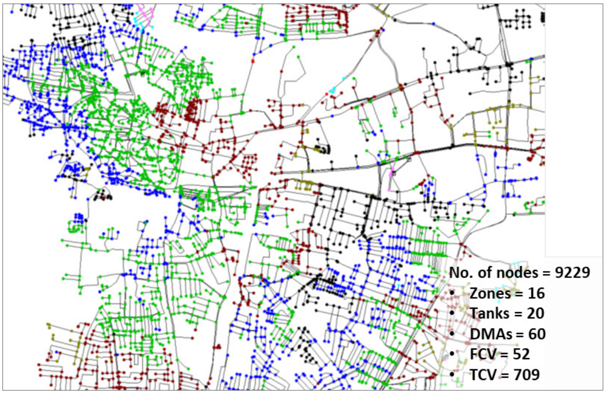


Image credits: Author. Sanjay Dahasahasra, Amravati City on Tap of 24X7 water supply. *https://mohua.gov.in/upload/uploadfiles/files/amravati.pdf*

6.3. Leakage mapping

Leakage management strategies can be categorised into passive leakage control also known as reactive control and active leakage control or proactive control. Passive Leakage Control is the method of addressing visible leaks identified due to bursts or drop in pressure reported by consumers or noted by field staff (Sharma, 2008).

Figure 26: Digit mobile application for leakage mapping. Complaints can be raised by clicking a photograph and geotagging the location by the citizens.

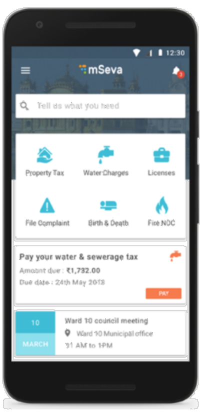
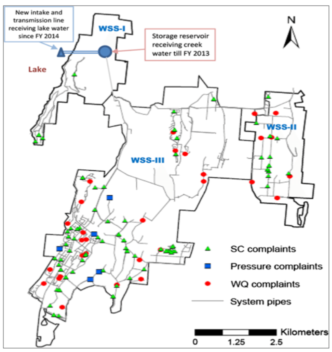


Image credits: Author

Figure 26: Leakage mapping. Pressure, water quality, and service connection complaints FY 2012 in different water supply systems @Okanagan Basin, Columbia.



Haider, Husnain & Sadiq, Rehan & Tesfamariam, Solomon. (2016). Risk-Based Framework for Improving Customer Satisfaction through System Reliability in Small-Sized to Medium-Sized Water Utilities. Journal of Management in Engineering. 32. 10.1061/(ASCE)ME.1943-5479.0000435.

Leakage mapping is a method of passive leakage control where water losses are addressed when the leak is visible or a problem is reported by the consumers which is mapped on the water distribution network map to identify the pipe condition.

The type of complaints include no water, low pressure, leakages on transmission, distribution or feeder lines and water quality issues. Mapping such information on a network will help in assessing actual pipe condition. Pipe refurbishment or replacement will be based on a number of complaints. The complaints may be received by a complaint redressal cell or through dedicated mobile applications.

6.4. Establishing District Metered Areas (DMA)

A District Metered Area (DMA) is an area of the distribution system defined by closure of valves and measurement of quantities of water entering or exiting the area (Khoa Bui, Marlim, & Kang, 2020). A DMA is created by separating a portion of the network hydraulically through a system of boundary valves and controlling and metering the water flowing in or out of the area. Water to a DMA is fed from a single point of entry and a meter chamber is built in the inlet of the DMA and flow is measured continuously. The factors influencing the design of a DMA are number of service connections which generally range from 500 to 3000 properties, ground elevation, pipe diameter, infrastructural performance indicators and cost of active leakage control (Gomes, Sousa, Muranho, & Marques, 2015). Within a DMA, pressure control valves are installed at one or more points and the analysis of water flow and pressure particularly at night helps identify leaks and calculate level of leaks in a DMA. Further, step tests[1] are conducted to pin-point the location of the leaks.

Figure 27: District Metered Area schematic diagram.

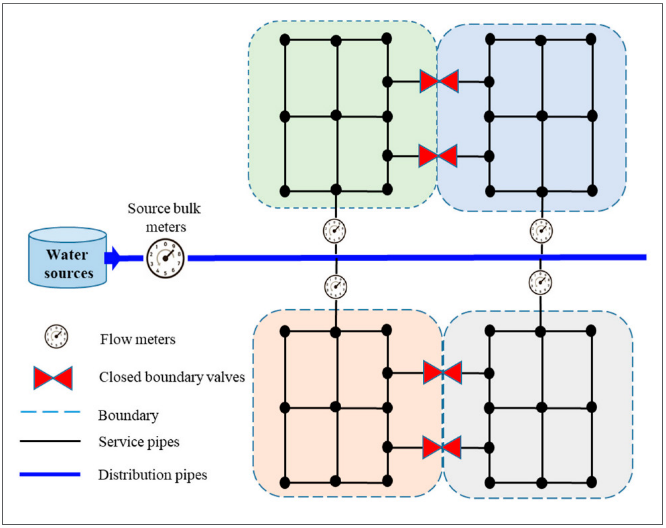


Image credits: Khoa Bui, Marlim, & Kang (2020). Water Network Partitioning into District Metered Areas: A State-Of-The-Art Review. In Water 12(4). https://doi.org/10.3390/w12041002 .

[1]*Step testing is the process of isolating portions of a network with portable water meters and checking for leaks*

The benefits of dividing a network into DMAs include substantially reducing NRW through active leakage control, rapidly being able to identify burst pipes, better control of water quality as there isn't mixing of water from other sources and the DMA would be protected from contamination and for those water distribution networks which supply water intermittently DMAs are a transition process to move towards continuous supply which will enable better pressure management. Some of the drawbacks include reduced network connectivity, suspension of water supply in case of bursts and deteriorating water quality due to decreased available flow paths (Khoa Bui, Marlim, & Kang, 2020).

6.5. Leakage detection

Leakage management strategies include active leakage control which refer to a set of procedures taken by the water utilities through a dedicated staff to monitor, repair and maintain leaks in the distribution network as a regular activity through regular surveys or by monitoring and managing DMAs. It is a method for identifying unreported water leakage in the distribution system. Leakage detection is a method of active leakage control for quantifying and localizing invisible leaks. Leak detection is the process of narrowing down or localisation of a leak to a particular section of a pipe network (Pilcher, et al., 2007). There are numerous techniques for leakage detection such as sub-division of DMAs into smaller areas, traditional step test method, sounding surveys or using acoustic loggers as a survey tool. Active leakage control is necessary to identify unreported leakage which gradually grows overtime and increases cost substantially. Through active leak control, the savings in water no longer lost due to leakage will outweigh the cost of leak detection and repair overtime (Georgia EPD, 2007).

Water leaks from the distribution pipes may sometimes not appear on the surface due to soil conditions resulting in invisible leaks which are more complicated to localize. In such cases, leak detection is carried out in isolated test zones or DMAs by observing night line flows during Minimum Night Flow (MNF) conditions. Minimum Night Flow (MNF) is an hourly average flow rate at the lowest consumption period which is typically between midnight and 4am (Maggs, ND). A target MNF rate based on an hourly average night flow rate is established based on MNF components such as customer night usage, unavoidable background leakage, exceptional customer night usage and bursts and leaks (Maggs, ND). Once the target is established, within the test zone or DMA if the apparent water consumption is higher than expected, an engineer is notified and will carry out a step test to identify the pipe stretch and pinpoint the leak using acoustic or ground penetrating radar equipment. Once the leak is pinpointed measures will be undertaken to repair the leak.

Figure 28: Leakage detection through MNF condition.

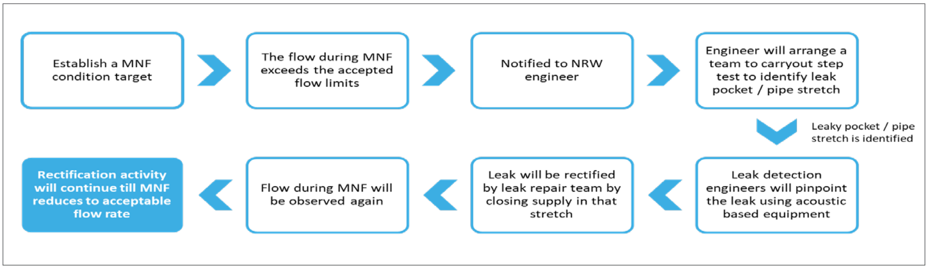


Image credits: Author.

The leakage detection devices include acoustic based equipment such as listening sticks, ground microphones and leak noise correlators and electromagnetic wave based equipment such as ground penetrating radars.

Figure 29: Leakage detection devices.

Image credits: Karthik Madhavan (2019). Suez attends to 700 leaks in water pipeline in last two weeks. The Hindu. https://www.thehindu.com/news/cities/Coimbatore/suez-attends-to-700-leaks-in-water-pipeline-in-last-two-weeks/article26433285.ece

6.6. Supervisory Control and Data Acquisition (SCADA)

SCADA is a distributed computer system used for monitoring and automation spread through-out the water distribution system. It consists of a system of software and hardware elements which control processes remotely, monitor, gather and process real-time data and record events (Inductive Automation, 2018).

Figure 30: SCADA monitoring interface at Ahmedabad.

Image credits: Smart Cities Council (2018). See, how SCADA system helps Ahmedabad water dept save Rs 6 cr on electricity bill. https://india.smartcitiescouncil.com/article/see-how-scada-system-helpsahmedabad-water-dept-save-rs-6-cr-electricity-bill

It enables direct interaction with sensors, valves, pumps and motors through a Human-Machine Interface software. The SCADA system allows real-time monitoring through sensors placed along the water supply service chain from the treatment plant, distribution stations and the distribution network and where necessary control relays can be installed on equipment like pumps and valves for remote operation.

SCADA can be installed at water treatment plants to monitor water levels and water quality to assess specific chemicals or toxins. In Elevated Storage Reservoirs (ESRs) to monitor water levels, automate pumps to decrease overflow and optimize electricity usage. Within the distribution network SCADA enables automatic monitoring and control of equipment in the distribution system.

Figure 31: SCADA applications.

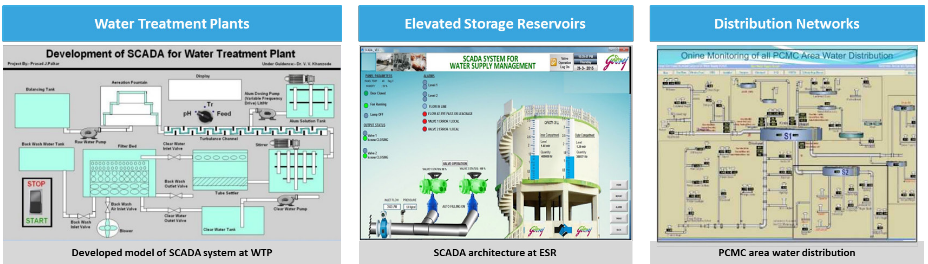


Image credits: Saurabh Varma (2016). SCADA for Water Supply Systems - Recktronic Devices & Systems, Pune, INDIA. https://www.youtube.com/watch?v=BrmuVpllzBA

Photo Credits: www.wallpaperflare.com

7

Case studies

7.1. NRW Reduction and Management in Surat

Surat Municipal Corporation undertook numerous initiatives to reduce NRW and maintain the level of NRW within the city at 15% (Shah, 2011). These initiatives include setting up of an NRW cell within their water utility department, conducting regular water audits, bringing in metering practices and leakage mapping.

The NRW cell was established in 2007 to ensure accountability and sustain implementation of actions to reduce and maintain NRW. The mandate of the NRW cell was to plan, develop, implement and monitor actions for NRW reduction (SMC, ND). The objectives of the NRW cell are

- Reducing physical losses by enhancing efficiency in transmission and distribution network
- Ensuring equity in distribution by regulating quantity and pressure.
- Achieve financial recovery through volumetric billing and adopting a metering policy
- Generating awareness for water conservation.

The NRW cell is headed by the commissioner and consists of six assistant engineers, one deputy engineer and a nodal officer. The execution repair work is carried out by civil engineers, instrumentation engineers, electrical and mechanical engineers. The Additional City Engineers both civil and electrical guide and supervise the activities of the cell. The financing for the project was from the Surat Municipal Corporation.

The activities carried out by the NRW cell include –

- Conducting periodic water audits (every 3 years) through a bidding process.
- Preparing a network map of the water distribution system
- Installing SCADA at the water treatment plant
- Identifying DMAs and setting up of approximately 50 DMAs and installing bulk meters, flow meters and related accessories as part of the comprehensive water audit.
- Leakage mapping and detection
- Repairing, rehabilitating and augmenting the network.

Leakage mapping was integral in NRW reduction. Leakages were identified based on plotting current and historical complaints from consumers on a network map. Complaints are received through helplines or their website and followed-up by ground level assessment by the corporation's hydraulic department. The leakage repairs are delegated to various levels based on the size of the pipes, for example –

- Leakage in pipe size >750mm is outsourced to private operators
- Leakage in pipe size between 500 – 750 mm addressed by the head municipal office
- Leakage in pipe size <500 mm addressed by the zonal offices (iMaCs, 2015).

Figure 32: Leakage mapping in central zone of Surat Municipal Corporation.

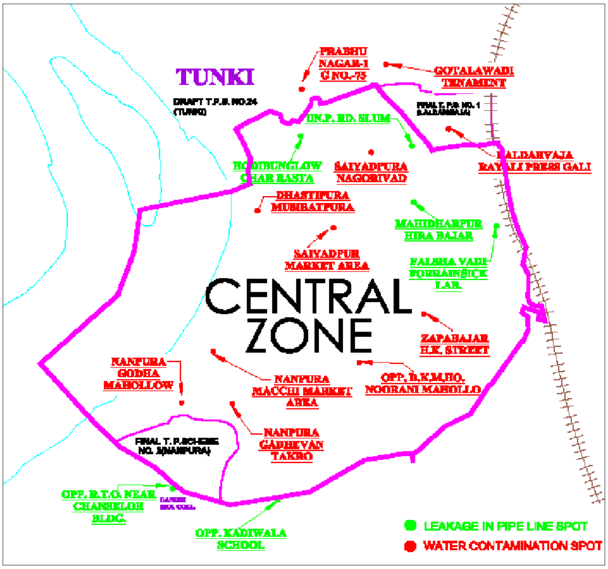


Image credits: Jatin Shah (2011). NRW Reduction and Management in Water Supply Distribution System. NIUA. https://www.niua.org/csc/assets/pdf/water/NRW-Reductions-and-Management-in-Water-Supply-Distribution-System-Surat.pdf

The leakage mapping exercise was carried out first in two zones and based on its successful implementation extended to other zones. As a result of the leakage mapping exercise, the leakage per kilometre length of the pipeline reduced, number of complaints from consumers reduced, tracking and follow up of complaints improved and increased leak repairs led to significant water savings (iMaCs, 2015).

Figure 33: Impact of leakage mapping in all zones.

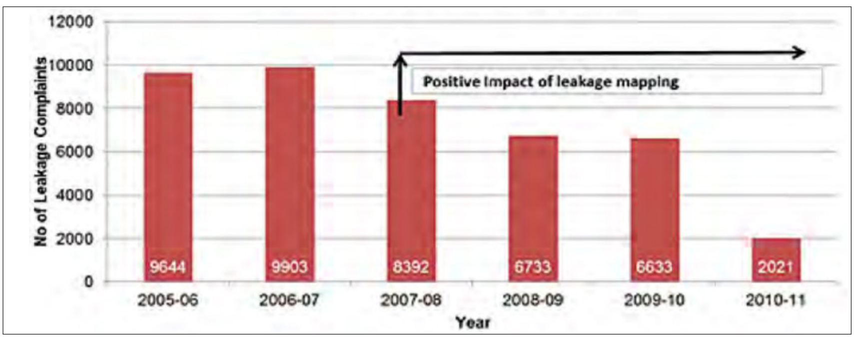


Image credits: iMaCs (2015). Compendium of Good Practices in Urban Water Supply and Sanitation in Indian Cities. NIUA. https://www.niua.org/pearl/sites/default/files/books/GP-IN2_WATSAN.pdf

7.2. NRW Reduction in Bangalore (Central Division – D1a)

The Bangalore Water Supply and Sewerage Board (BWSSB) in 2013 had undertaken the Improvement to Water Distribution System, Reduction in UFW & Leakage Control Project in the Central Division of BWSSB in Bangalore. The contract was formulated as a Performance-Based Construction and Maintenance model over a period of 8 years. The project was implemented in two phases, with design and construction as phase 1 and operation and maintenance in phase 2. The Japan International Cooperation Agency (JICA) financed the project (Lotthe, 2018). This project was a part of the Unaccounted for Water Project under which the ULB was divided into zones and demarcated for tendering to private contractors.

In Central Division, the area was divided into 43 DMAs comprising around 3000 connections where every consumer meter was inspected and more than 8500 visible and invisible leaks were detected through helium leak detection and repaired. The project resulted in reduction of UFW from 52% to 27% and increased the volume of water accounted to 35 MLD from 3 MLD in the central zone (Lotthe, 2018).

Figure 34: Progress in UFW reduction.

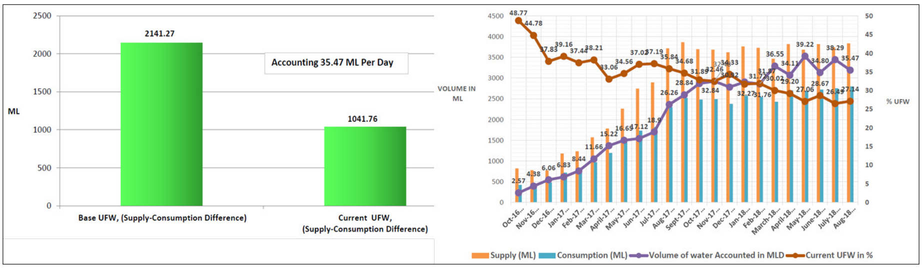


Image credits: Lotthe, J.-M. (2018). Cases study in India for Non-Revenue Water. Retrieved from Asian Development Bank - Asia Water Forum 2018: https://events.development.asia/system/files/materials/2018/10/201810-cases-study-india-non-revenue-water.pdf

8

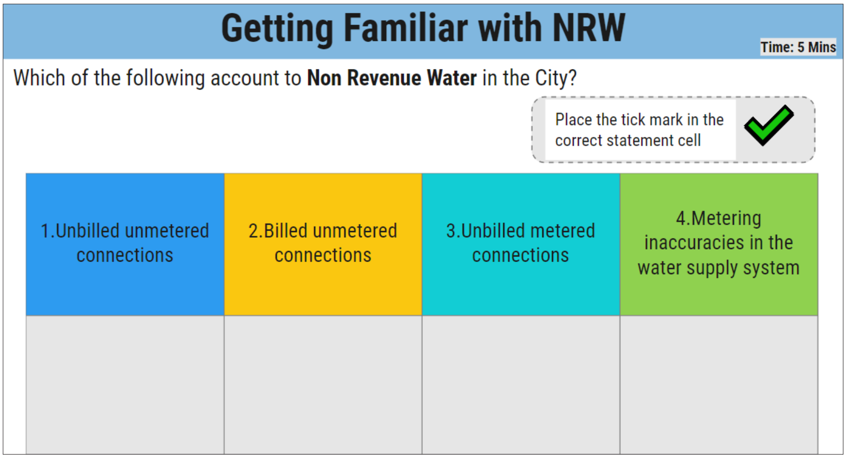
Exercises

A series of interactive exercises around the concepts related to NRW were developed to understand and discuss concepts, issues and methods. The interactive exercises were developed on Miro which enables interactions online.

Exercises for getting familiar with NRW

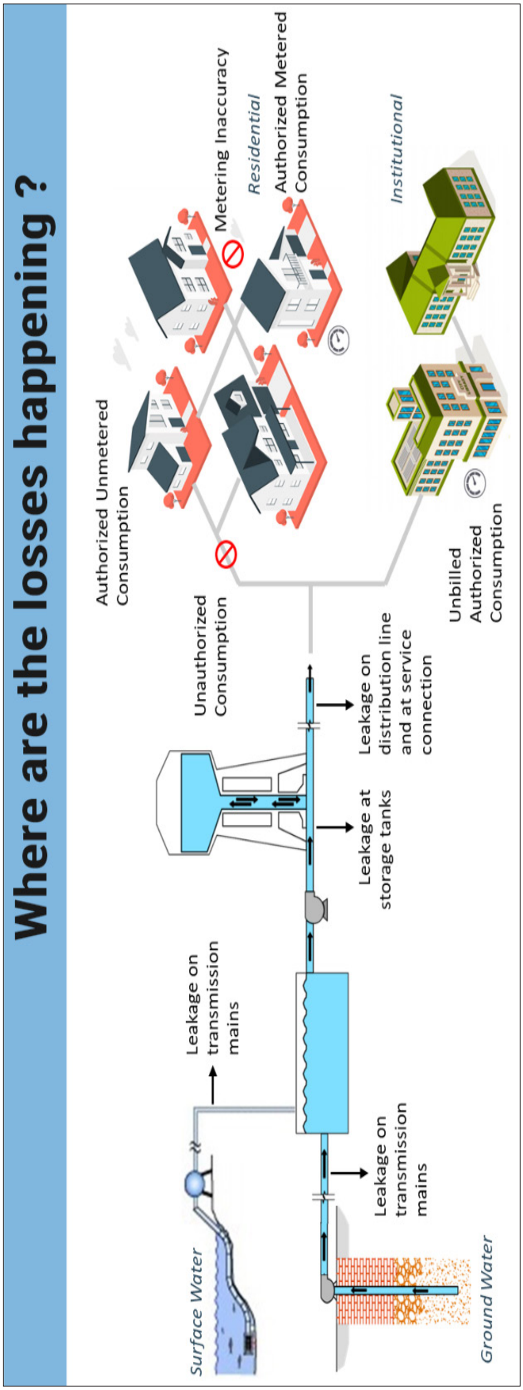
A series of five exercises were formulated in which the learnings from the latter exercises build on the former. The first exercise tests the understanding of the participants which components account for NRW. It includes various components like apparent losses, real losses and unbilled authorised connections which are further divided into sub-components which sound similar. In this exercise participants are required to identify all the components that account for NRW by placing the check mark in the appropriate box.

Figure 35: Exercise 1- Getting Familiar with NRW on Miro board



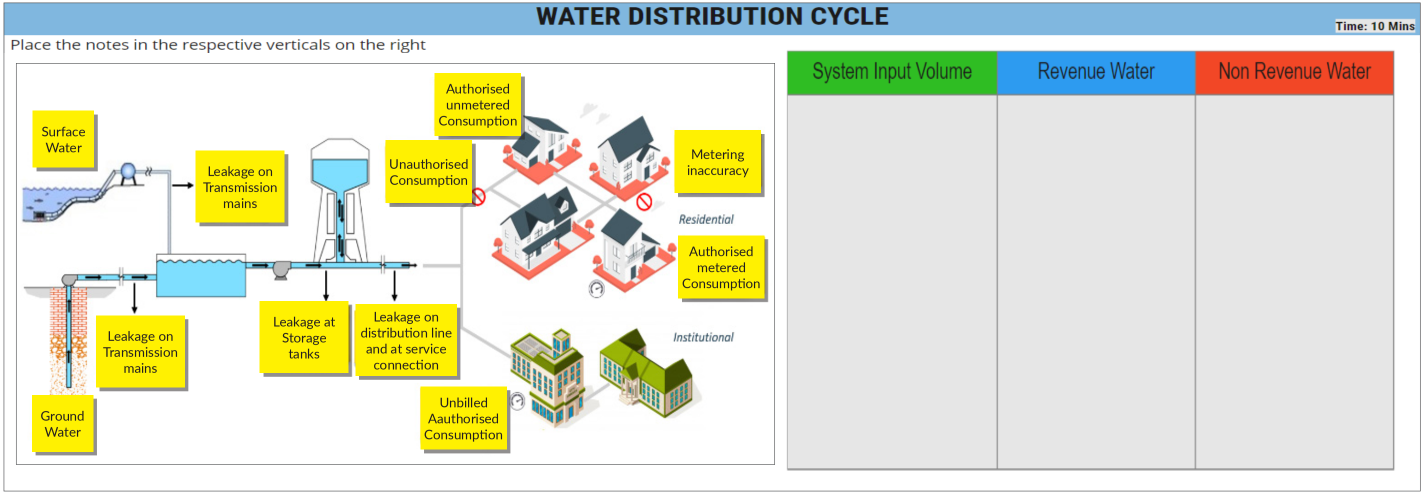
In the second exercise ‘Where are the losses happening?’ participants are required to identify where they the maximum losses occur within their city by placing the icon provided near the appropriate label. This exercise helps city officials reflect on the NRW within their city and delve into what the causes for the same could be.

Figure 36: Exercise 2 - ‘Where are the losses happening?’ on Miro board.



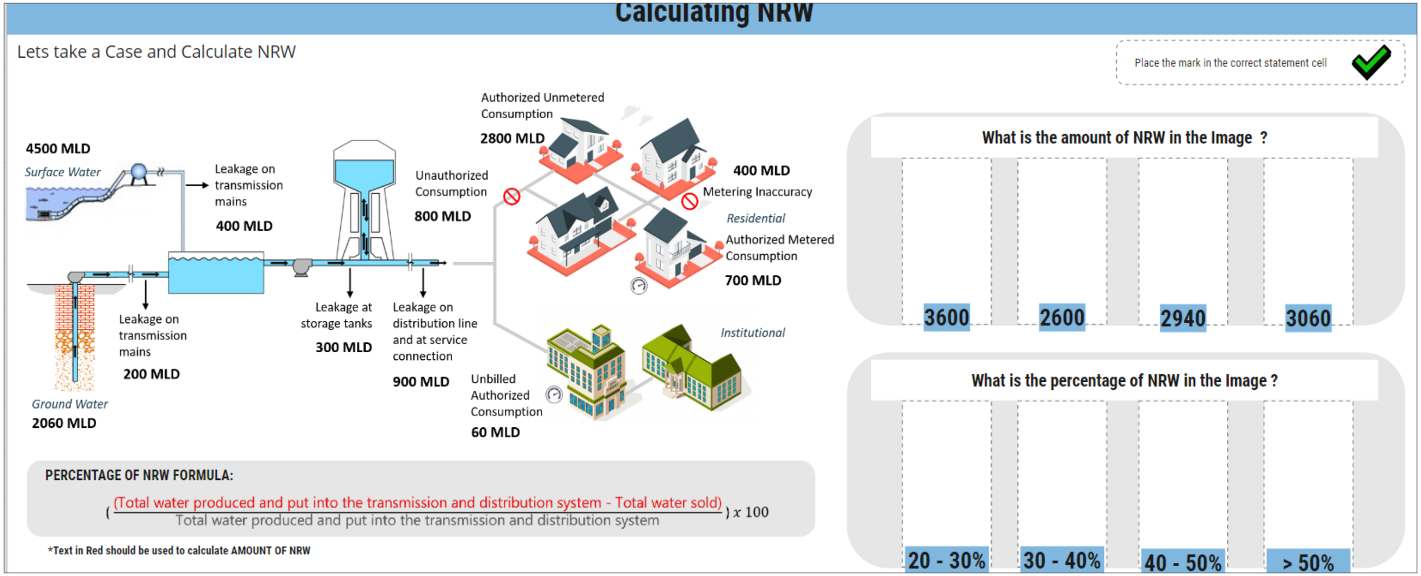
The third exercise is titled 'Identifying components of IWA chart along the water distribution cycle'. In this exercise, the participants are required to drag labels of the components in the IWA chart along the water distribution cycle and place the same in their respective columns based on what that label accounts to. Such as the label 'Surface Water' accounts to the system input volume and it should be placed appropriately. This exercise re-iterates the learnings on the components of NRW, revenue water and system input volume.

Figure 37: Exercise 3 - 'Water Distribution Cycle' on the Miro board.



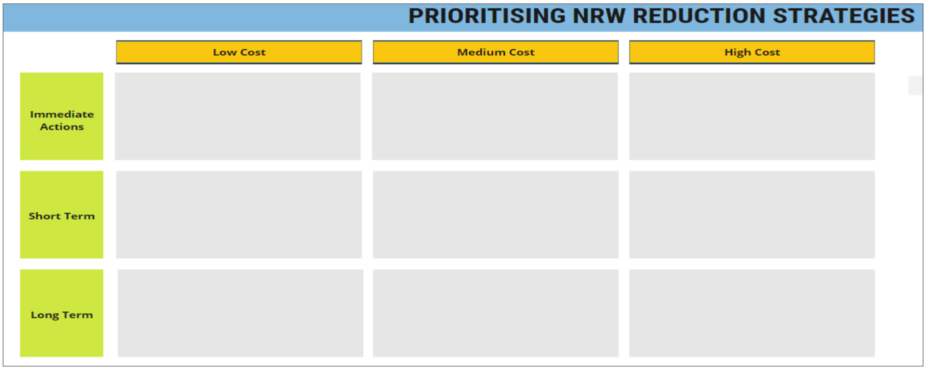
The fourth is building on the third in which the components of system input volume, revenue water and NRW have been identified. In this exercise participants are required to calculate NRW and also compute extent of NRW as a percentage of system input volume from the values provided along and place the check mark in the appropriate cell.

Figure 38: Exercise 4 - 'Calculating NRW' on Miro board.



In the fifth exercise, based on the learnings in the presentation, prioritize actions cities can undertake into immediate, short-term and long-term actions which also consider the repercussions in terms of cost. This exercise helps generate a discussion on how to plan actions for NRW reduction. The various activities that can be undertaken have been written on the blue labels while participants can add any other activities on the pink labels. These labels then have to be dragged and dropped in the appropriate boxes.

Figure 39: Exercise 5 - 'Prioritising NRW Reduction Strategies' on the Miro board.



The listed strategies include –

▪ Formation of an NRW cell	▪ Formation of DMAs.
▪ Reduction in free supply	▪ SCADA at WTPs
▪ Identification and regularization of illegal connections	▪ SCADA at reservoirs
▪ Repair valves and storage tanks.	▪ SCADA across the distribution network
▪ Replacement of pipelines.	▪ Augmentation of network
▪ Replacemwent of service connection meters	▪ Periodic water audits
▪ Network mapping by collating information from various sources.	▪ Metering of all service connections.
▪ Preparation of GIS based network maps	▪ Identification and metering of public taps.
▪ Leakage mapping	▪ Capacity building of officials.
▪ Leakage detection	▪ Create awareness about water conservation

Photo Credits: Samad Deldar on pexels

9

List of additional readings

9.1. Non-revenue water

1. **The issues and challenges of reducing non-revenue water**
   A report on the rising competition of scarce fresh water resources and the critical role of NRW management and the measures to be undertaken to address NRW.
   https://www.adb.org/sites/default/files/publication/27473/reducing-nonrevenue-water.pdf

2. **Quantifying the global non-revenue water problem**
   A paper on an update of global NRW estimates, its implications in terms of value of water and its impact in times of increased scarcity and climate change.
   https://iwaponline.com/ws/article/19/3/831/41417/Quantifying-the-global-non-revenue-water-problem

3. **Composite Water Management Index report by NITI Aayog.**
   The Composite Water Management Index (CWMI) was developed by NITI Aayog to bring in the spirit of competitive and cooperative federalism in the domain of water resource management.
   http://social.niti.gov.in/uploads/sample/water_index_report2.pdf

4. **Losses from Water Supply Systems: Standard Terminology and Recommended Performance Measures**
   A paper by the IWA's Water Losses Task Force with recommended terminology and preferred performance indicators for assessing the service delivery with respect to control over losses in the distribution system.
   https://waterfund.go.ke/watersource/Downloads/001.%20Losses%20from%20water%20supply%20systems.pdf

9.2. CSCAF Indicators for Water Management

1. **ClimateSmart Cities Assessment Framework 2.0 - Cities Readiness Report**
   This report is collates the performance of 126 cities with respect to the CSCAF framework which was developed and rolled-out by MoHUA to initiate sustainable urban planning and climate informed development actions across urban India.
   https://niua.org/c-cube/sites/default/files/Cities%20Readiness%20Report%20(High%20Res).pdf

2. **Best Practices Compendium: ClimateSmart Cities**
   The compendium provides a collection of promising case studies of successful actions undertaken for improving the climate action of cities both in India and globally.
   https://www.niua.org/csc/assets/pdf/imp-document/Best%20Practices%20Compendium_final.pdf

9.3. Benchmarking and Tools

1. **Improving urban services through Service Level Benchmarking**
   A flyer on the need for the Service Level Benchmarking (SLB), an initiative launched by MoHUA covering water supply, wastewater, solid waste management and storm water drainage in urban areas.
   https://mohua.gov.in/upload/uploadfiles/files/Flyer.pdf

2. **Handbook of Service Level Benchmarking**
   This is a handbook to facilitate the adoption of SLBs to municipalities for accounting current performance of utilities and taking up measures to improve their service delivery to citizens.
   http://cpheeo.gov.in/upload/uploadfiles/files/Handbook.pdf

3. **Non-Revenue Water (NRW) Reduction Toolkit**
   A toolkit developed by MoHUA under the JnNURM programme to strengthen ULBs and catalyse investments for urban infrastructure. It details the auditing water supply and calculating losses across the service chain.
   http://www.spml.co.in/Download/Reports/nrw-toolkit-final.pdf

4. **Performance Measurement for Urban Water Supply and Sanitation – List and definitions of KPIs and Local Action Indicators**
   A summary of the list of indicators based on the SLBs which are detailed to understand the performance of cities and pinpoint to actions to be initiated by ULBs.
   https://www.pas.org.in/Portal/document/PerformanceAssessmentDoc/pdf/List%20and%20Definition%20of%20LAIs_Jan%2018%202011.pdf

5. **Assessment and Monitoring Platform for Liveable, Inclusive, and Future-ready urban India (AMPLIFI) Dashboard.**
   http://amplifi.mohua.gov.in/

9.4. Impact of NRW on power and water resources.

1. **Rajkot municipal commissioner proposes double water charges in budget 2016-17**
   An article detailing an assessment of the water supply in Rajkot and its implications on the budget of the water supply department of Rajkot Municipal Corporation.
   https://indianexpress.com/article/cities/ahmedabad/rajkot-municipal-commissioner-proposes-do-double-water-charges-in-budget-2016-17/

9.5. Water Auditing

1. **Draft General Guidelines for Water Audit and Water Conservation.**
   A set of draft guidelines by the CWC and the CGWB on the definition and steps for conducting a water audit and the methods employed by various sectors.
   http://old.cwc.gov.in/main/downloads/DraftGuideline_Water_Audit.pdf

2. **City Water Audit Methodology and Outcome.**
   A detailed presentation by CWAS, CRDF, CEPT University on the methods to be used while conducting a water audit, the need to reduce NRW and the outcomes of conducting regular water audits.
   https://pas.org.in/Portal/document/PIP%20Application/City%20Water%20Audit%20Methodology%20Final.pdf

3. **Water Audit Manual**
   A manual developed by UN Habitat as part of a series on utility management for small towns to aid municipal authorities and urban service providers on delivering sustainable water supply services with a limited revenue base.

https://unhabitat.org/sites/default/files/download-manager-files/Water%20Audit%20Manual%20Volume%204.pdf

4. **Water Demand Management Strategy and Implementation Plan for Jabalpur**
   This document provides a comprehensive framework for developing a Water Demand Management Strategy and Implementation Plan for the city of Jabalpur involving institutional, financial and technical issues and is aimed at the efficiency improvements in management and utilization of water.
   https://unhabitat.org/sites/default/files/download-manager-files/Water%20Demand%20Management%20Strategy%20and%20Implementation%20Plan%20for%20Jabalpur.pdf

5. **Non-Revenue Water Assessment and Reduction Strategy for Tirupati**
   A Detailed Project Report prepared under the AMRUT mission aimed at reducing NRW in Tirupati.
   https://cdma.ap.gov.in/sites/default/files/Tirupati%20NRW%20DPR.pdf

9.6. NRW Reduction Strategies

1. **Leakage Management and Control**
   A best practice training manual on the techniques and institutional aspects in the leakage control programme aimed at professionals responsible for operation and maintenance of water supply systems.
   http://apps.who.int/iris/bitstream/handle/10665/66893/WHO_SDE_WSH_01.1_eng.pdf;jsessionid=7934317A34AC8633FEB3774D8EF806A9?sequence=1

9.7. Additional readings for Case Studies

1. **NRW Reduction and Management in Water Supply Distribution System in Surat.**
   https://www.niua.org/csc/assets/pdf/water/NRW-Reductions-and-Management-in-Water-Supply-Distribution-System-Surat.pdf

2. **Cases study in India for Non-Revenue Water presentation.**
   https://events.development.asia/system/files/materials/2018/10/201810-cases-study-india-non-revenue-water.pdf

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- Liemberger, R., & Wyatt, A. (2019, May 1). Quantifying the global non-revenue water problem. Retrieved from IWA Publishing: https://iwaponline.com/ws/article/19/3/831/41417/Quantifying-the-global-non-revenue-water-problem
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Annexure 1: Quantitative and Qualitative LAIs related to NRW under the PAS Framework

Table 4: Quantitative LAIs related to NRW under the PAS Framework.

Sl.No.	Quantitative Indicators
1	Coverage of distribution network
2	% illegal connections
3	% of identified illegal connections that are regularized
4	Percentage of estimated water demand over next 3 years to available supply from all current sources and immediate plans to augment through ongoing projects
5	Average pressure at WDS
6	Average pressure at consumer end
7	Days of supply
8	Pump replacement
9	Unit electricity cost of production of water supply
10	Per capita revenue expenditure
11	Average revenue per water connection
12	Per capita revenue income
13	% Losses from source to water treatment plant (WTP)

Sl.No.	Quantitative Indicators
14	% Losses from WTP to water distribution station (WDS)
15	% Losses from WDS to final consumption (includes both leakage on service connections and unauthorized consumption)
16	Pipe breaks per km length of network
17	% of network refurbished
18	% Authorized and unbilled consumption to total supply
19	Periodic monitoring and analysis of complaints
20	Total complaints in water supply per 1000 connections per year
21	% of meters that are functional
22	Annual cost of losses (real and apparent)
23	% of connections that are metered
24	Billed arrears to total billed demand

Credits: CWAS, CRDF, CEPT University (2011), Performance Measurement for Urban Water Supply and Sanitation – List and definitions of KPIs and Local Action Indicators. ***https://www.pas.org.in/Portal/document/PerformanceAssessmentDoc/pdf/List%20and%20Definition%20of%20LAIs_Jan%2018%202011.pdf***

Table 5: Qualitative LAIs related to NRW under the PAS Framework.

S.No.	Qualitative Indicators
1	Drive for identifying and regularizing illegal connections taken up
2	Regular annual assessment of available sources Reused supply water
3	Studies/ actions on detailed energy audits
4	Studies and actions for preliminary water audit
5	Presence of automated billing systems
6	Updating and linkage of connections with billing systems
7	Outsourcing collection systems

*Credits: CWAS, CRDF, CEPT University (2011), Performance Measurement for Urban Water Supply and Sanitation – List and definitions of KPIs and Local Action Indicators.*https://www.pas.org.in/Portal/document/PerformanceAssessmentDoc/pdf/List%20and%20Definition%20of%20LAIs_Jan%2018%202011.pdf

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Ministry of Housing and Urban Affairs
Government of India