



# CITY WATER AUDIT

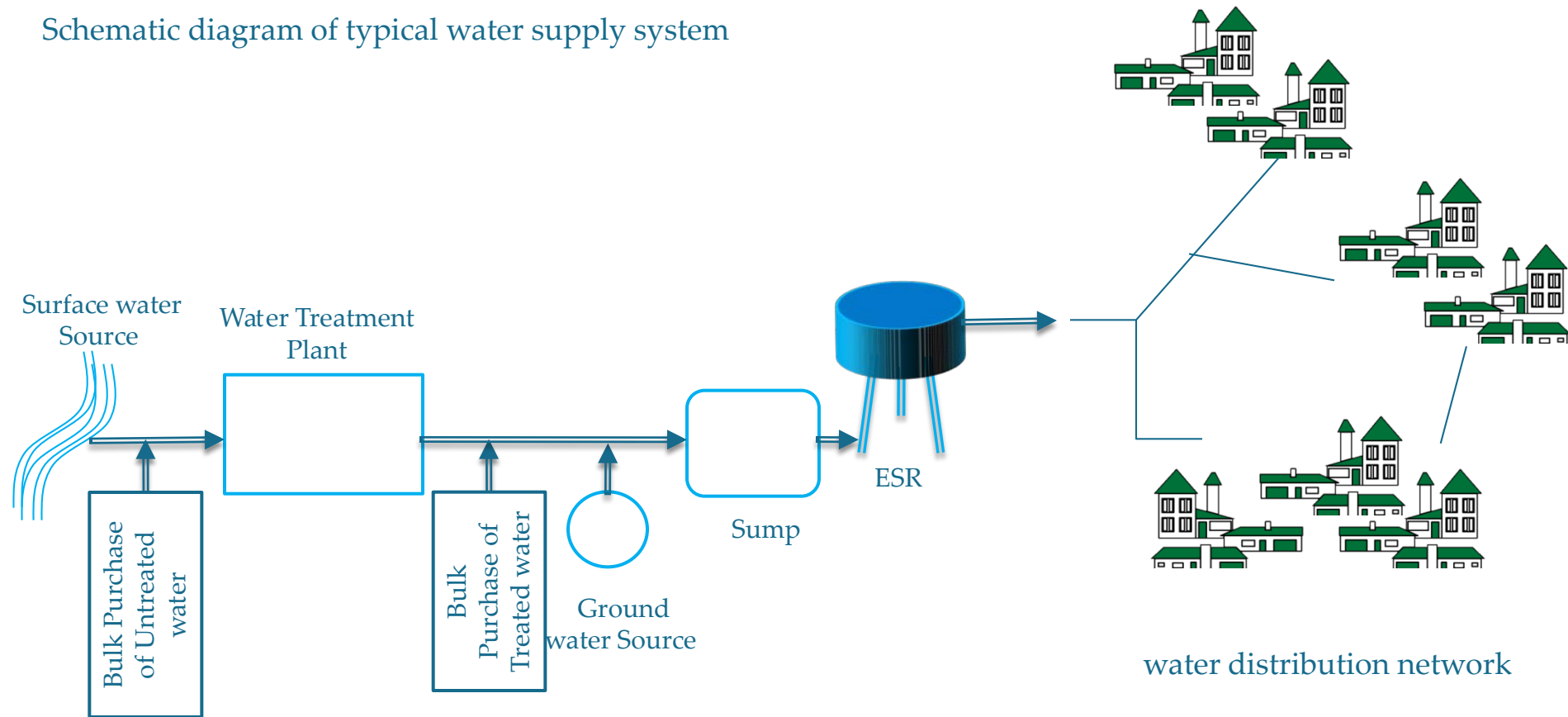
## *Methodology and Outcome*



# Introduction

# Schematic diagram of water supply system

Schematic diagram of typical water supply system

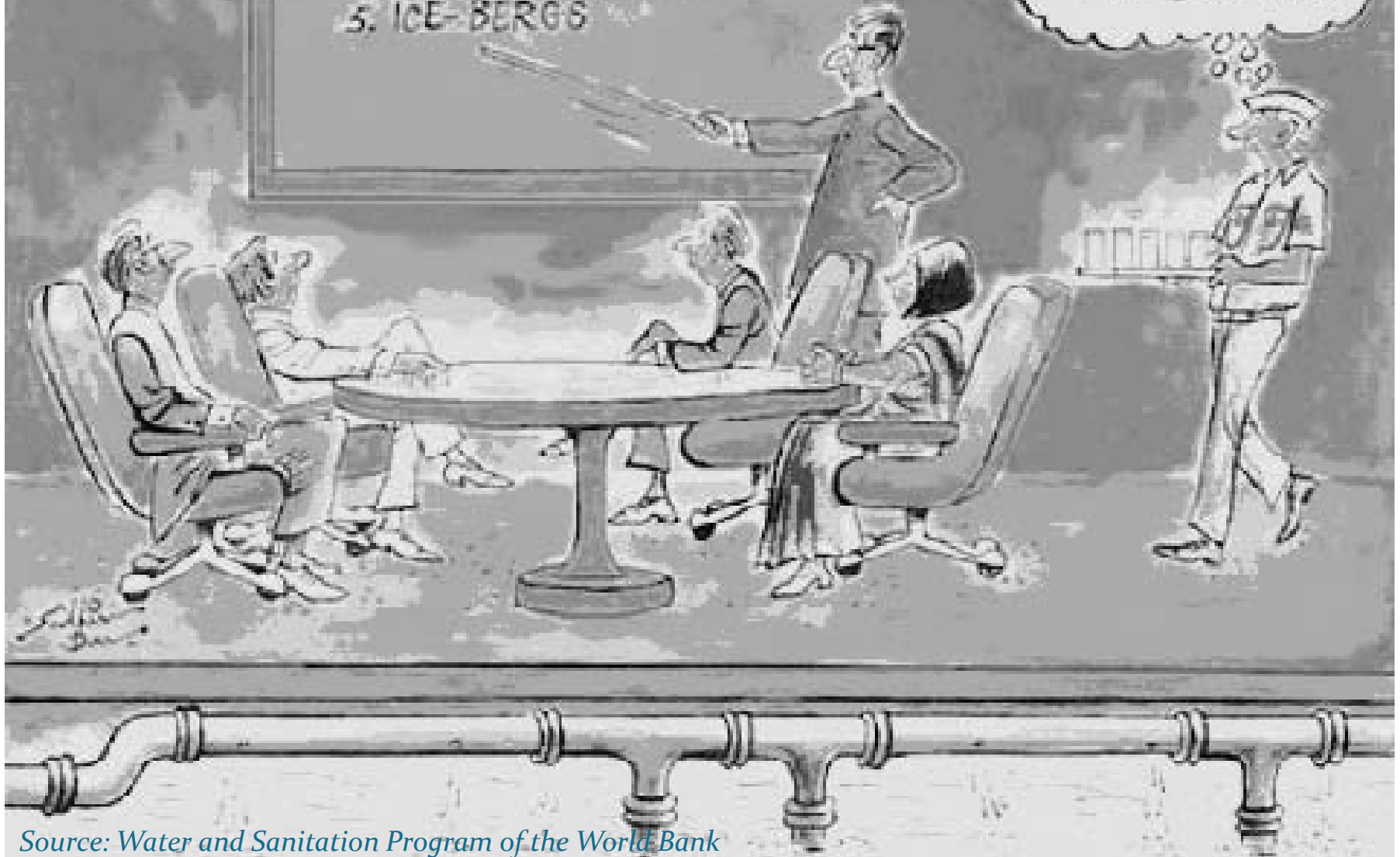


- ☐ Lack of metering
- ☐ Pipelines within the distribution network are interlinked
- ☐ Control of leakage on a routine, planned basis is impossible
- ☐ Routinely measure or assess adequacy of system pressure is impossible

# NEW SOURCES OF WATER

1. NEW DAMS
2. RIVER SHARING
3. RAIN-WATER HARVESTING
4. DESALINISATION
5. ICE-BERGS

JUST PLUG  
THE LEAKS!!



Source: Water and Sanitation Program of the World Bank

# To plug the leak

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- How much water is being lost?
- Where are losses occurring?
- Why are losses occurring?
- What strategies can be introduced to reduce losses and improve performance?
- How can we maintain the strategy and sustain the achievements gained?

# Water Audit Methodology

# Before the Audit

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- Establish a worksheet
- Set up a study period
- Define the study boundary

# IWA standard water balance chart

System Input Volume (A)	Authorised consumption (B <sub>1</sub> )	Billed authorised consumption (C <sub>1</sub> )	Billed meter consumption (D <sub>1</sub> )	Revenue water (E <sub>1</sub> )
			Billed un metered consumption (D <sub>2</sub> )	
	Water losses (B <sub>2</sub> )	Unbilled authorised consumption (C <sub>2</sub> )	Unbilled metered consumption (D <sub>3</sub> )	Non- Revenue Water (NRW) (E <sub>2</sub> )
			Unbilled unmetered consumption (D <sub>4</sub> )	
		Apparent losses (C <sub>3</sub> )	Unauthorised consumption (D <sub>5</sub> )	
			Metering inaccuracy (D <sub>6</sub> )	
		Real losses (C <sub>4</sub> )	Leakages on transmission and/ or distribution mains (D <sub>7</sub> )	
			Leakages and overflows at Utility's storage tanks (D <sub>8</sub> )	
			Leakage on services connections up to point of customer metering (D <sub>9</sub> )	



# Steps for water audit

## Task 1: System Input Volume (A)

*Volume of water entered into a transmission system and/or purchased water from concerned agency*

- Identify various sources of water production
  - ▣ Surface water: Intake of dam, river, lake or reservoir
  - ▣ Groundwater: Tube/bore wells
  - ▣ Bulk raw and/or treated purchase
- Measure the quantity from each sources
  - ▣ Quantity of water at various points need to be measured by flow meters. If flow meters are absent, measurements are done with portable ultrasonic flow meter
  - ▣ Quantity of bulk purchase water is generally available from water bill received by ULB

# Installation of portable flow meter

- While installing or using portable flow meter
  - It must be ensured that the minimum length of straight pipeline at upstream is 5 times the diameter of pipe and at downstream is 3 times the diameter of pipe without any bend, valves or joints
  - This is required to attain proper estimates of water flow in pipeline



# Steps for water audit

**Task 2: Billed Authorised Consumption**  
**( $C_1 = D_1 + D_2$ )**

*Volume of metered and non-metered water taken by billed consumers*

□ **Billed metered consumption ( $D_1$ )**

▣ Identify metered connections

▣ Measure quantum of metered use

- Zone/ward-wise billed metered water connections to be obtained from ULB's billing system and volume of metered water to be extracted from ULB records

# Steps for water audit

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## Task 2: Billed Authorised Consumption

### □ Billed unmetered consumption (D<sub>2</sub>)

- Identify unmetered connection
- Estimate quantum of unmetered use
  - Billed unmetered consumption can be calculated by:
    - Test zone flow measurement [like District Metered Area (DMA)] or
    - Representative sample survey method
  - Measurement can be done by installing water meter during measurement period

# Zone flow measurement

- Billed quantity is measured in various test zones and subsequently, extrapolated at city level
- Selection of test zone should be based on the following criteria:
  - It should cover all the housing category like HIG, MIG, LIG and Slums
  - Availability of detailed distribution maps
  - Availability of consumer data like number of consumers, size of connections, existing water meter details etc.
  - Preferably, smaller zones with about 50 to 60 house service connections
- If meters are already installed then check its accuracy and replaced inaccurate meters. If meters are not installed then installed meters in all connections
- Everyday take readings and calculate the losses in the test zone. Pressure is recorded on a predetermined location
- This exercise should be carry out for few days, mainly one week.

# Representative sample survey

- Sampling according to water distribution zones:
  - Number of connections in each zone should be arrived at according to their sizes using the base map and record of house connections
  - Samples should be taken from each water zone at an average pressure level by considering the topography and distance from the elevated reservoir and supply timings
  - Survey in each zone can be conducted using selected representative house connections for sample measurements. It must be ensured that samples should cover all the inhabited area and also slum households within city
  - Total quantum of water received can be calculated by multiplying number of connections with average quantity of water received at consumer ends for each water zone



# Representative sample survey

- Sampling according to wards
  - If the distribution system cannot be divided into water zones then samples should be taken at ward level
  - Number of connections in each ward can be multiplied with the average quantity of water received per connection to get the city level quantity of water received at consumer end



# Steps for water audit

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## Task 3: Calculate the volume of Non-Revenue Water (NRW)(E2)

*NRW is the difference between System Input Volume and Billed Authorised Consumption. NRW consists of Unbilled Authorised Consumption and Water Losses.*

$$\square \text{ Non-Revenue Water} = \text{System Input Volume} - \text{Revenue Water}$$



# Steps for water audit

## Task 4: Calculate the Unbilled Authorised Consumption ( $C_2 = D_3 + D_4$ )

*Unbilled authorised consumption covers metered and unmetered free supply*

### □ Unbilled metered consumption ( $D_3$ )

- Identify unbilled metered authorised connection
- Measure quantum of meter use
  - Zone/ward wise metered unbilled water connections and consumption details can be obtained from ULB

# Steps for water audit

## Task 4: Calculate the Unbilled Authorised Consumption

### □ Unbilled unmetered consumption (D4)

- Identify the unmetered authorised connections
  - This component typically includes items such as public stand post, tanker supply, government offices, schools, hospitals, gardens, public toilets etc.
- Measure quantum of unmetered authorised use
  - Water consumption in municipal property (municipal schools, offices, gardens etc.) is measured or calculated as per prescribed norms mentioned in Central Public Health and Environmental Engineering Organisation (CPHEEO) manual for specific use
  - Estimation of water supply from public stand post: volumetric flow measurement can be deployed for sample stand post
  - Water supply through tankers to unserved areas is calculated by estimating trips, capacity of tankers and estimating increase in tanker supply in summer seasons

# Steps for water audit

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## **Task 5: Calculate Authorised consumption (B<sub>1</sub>)**

*Authorised consumption includes billed and unbilled consumption*

- $\text{Authorised consumption} = \text{Billed authorised consumption (C}_1\text{)} + \text{Unbilled authorised consumption (C}_2\text{)}$

## **Task 6: Calculate water losses (B<sub>2</sub>)**

*Water losses includes apparent losses and real losses*

- $\text{Water losses} = \text{System input volume} - \text{Authorised consumption}$

# Steps for water audit

## Task 7: Calculate the apparent losses ( $C_3 = D_5 + D_6$ )

*Apparent losses also known as commercial losses which includes unauthorised consumption and all types of meter inaccuracy and data handling error*

### □ **Unauthorised consumption (D5)**

- ▣ Identify unauthorised connection and then estimate quantum of unauthorised use

From detailed consumer survey of selected test zone or by doing through sample survey, estimate percentage of illegal connections and from that estimate the unauthorised consumption

### □ **Metering inaccuracy (D6)**

- ▣ Estimate the inaccuracy of meters (D6)

Metering inaccuracy can be calculated through a sample survey across various meter installations at end users. The composition of the sample shall reflect the various brands and age groups of domestic meters. Based on the results of the accuracy tests, average meter inaccuracy values (as percentage of metered consumption) will be established for different user groups

# Steps for water audit

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## Task 8: Calculate real losses (C<sub>4</sub>)

*Real losses also known as physical losses. Volumes lost through all types of leaks, bursts and overflows on mains, service reservoirs and service connections, up to the point of customer metering*

$$\square \text{ Real losses} = \text{Water losses (B}_2\text{)} - \text{Apparent losses (C}_3\text{)}$$

# Steps for water audit

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## Task 9: Assessment of Real Losses

- Identify potential water losses like
  - ▣ Leaks at raw water transmission lines
  - ▣ Evaporation losses
  - ▣ Water treatment losses
  - ▣ Leaks/seepage of reservoirs
  - ▣ Overflows of reservoirs
  - ▣ Leaks at distribution mains
  - ▣ Leakages from valves and air valves
  - ▣ Leakages from services connections up to meter
- Measure or estimate quantum of losses by type (D7, D8,D9)

# Methods for real losses assessment

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The following methods has been used for measuring and estimating losses from identified leaks

- ❑ Bucket and stop watch methods
- ❑ Portable Ultrasonic Flow Meter
- ❑ Volumetric measurement
- ❑ Measurements by partially filled pipe, V-Notch etc.

# Assessment of real losses

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- Leaks at raw/treated water transmission lines: Measure inlet and outlet of pipelines; leakage from valves and air valves should be surveyed and subtracted
- Evaporation losses: Evaporation rate should be measured and with the help of capacity curve, losses should be calculated
- Water treatment losses: Inlet and outlet of treatment plant should be measured
- Leaks/seepage of reservoirs: Drop test should be carried out
- Overflows of reservoirs: Calculated based on frequency and flow rates
- Leaks of distribution mains: Measure inlet and outlet of pipelines
- Leakages from valves and air valves: Can be calculated using bucket and stop watch method
- Leakages from services connections up to meter: By deducting the mains leakage and storage tank leakage from the total volume of physical losses



# Template for water audit

Sr. no.	Item	Water Volume		
		Subtotal (MLD)	Total Consumption (MLD)	Percentage of Total Supply
1	At Head works		14.21	100
2	At Storage Reservoir		13.43	
3	At consumer end			
4	-Domestic -Non-Domestic Total	5.66 0.36	6.02	
5	Corrections- Low flow rate not recorded on meter		1.96	
A	Total corrected water use		7.98	56.16
6	Free water use	1.25		
B	Total authorised water use		1.25	8.80
7	Unauthorised consumption from illegal connections	0.15		
C	Total apparent loss		0.15	1.06
8	Loss of water from Source to GSR (Transmission Loss)	0.78		
9	Loss of water at storage tanks	0.12		
10	Loss of water in distribution system	3.88		
D	Total real loss		4.78	33.64

# Performance indicator for NRW

## Water Resources related indicators

- **% Authorised and Unbilled Consumption to Total Supply:**
  - Authorised and unbilled consumption is expressed as percentage of total water supply
  - This indicator is used for policy level decisions. For example, government offices also have to pay water bill, which is a policy level decision to curtail free supply
- **% Losses from Source to WTP:**
  - Amount of water losses from source to WTP is expressed as percentage of total water losses
  - This indicator is used for deciding the strategies for reduction of water losses
- **% Losses from WTP to WDS:**
  - Amount of water losses from WTP to WDS is expressed as percentage of total water losses
  - This indicator is used for deciding the strategies for reduction of water losses
- **% Losses from WDS to Final Consumption:**
  - Amount of water losses from WDS to final consumption is expressed as percentage of total water losses
  - This indicator is used for deciding the strategies for reduction of water losses

# Performance Indicator for NRW

## Indicators related to system operation

### □ Water Losses per Connection

- Usually water losses are presented as “Percentage by Volume” but this indicator is unsuitable for assessing the efficiency of operational management of water losses. So water loss in litres per service connection per day is the preferred basic operational Performance Indicator
- This indicator is useful for target setting and also use for comparisons between systems

### □ Real Losses per Service Connection per month per meter Pressure

- Real losses expressed in terms of annual volume lost per connection per average meter of pressure
- More useful indicator for comparing different utilities with systems operating at different pressures

### □ Water Losses per Mains Length

- Total losses expressed in terms of annual volume lost per length of mains
- This indicator is more useful to know the condition of Network. It does not include the affect of pressure relations in the pressure zone

# Performance indicator for NRW

## Indicators related to system operation

### □ Unavoidable Annual Real Losses (UARL)

- This indicator is used to estimate the lowest technically achievable real loss for well managed and maintained system with more than 5,000 service connections, connection density ( $N_c/L_m$ ) more than 20 per km, and average pressure more than 25 meters. The general equation for UARL is:  $(18 \times L_m + 0.8 \times N_c + 25 \times L_p) \times P$

Where,  $L_m$  – Length of Main (km);  $N_c$  – No of Connections;  $L_p$  – Total length of private pipe, property boundary to customer meter (km);  $P$  – Average pressure in meter

- This equation is based on the component analysis of real losses. The unit of this indicator is liters/day

### □ Infrastructure Leakage Index

- Ratio between the actual real losses and an estimate of the minimum real losses that could be technically achieved for the system operating pressure, average service connection length and service connection density
- It is an indicator of water supply system expressing the technical condition of the system from point of view of water losses. It also measures how effectively a utility is managing real losses under the current operating pressure regime

### □ Economical Level Leakage (ELL)

- The concept of ELL describes the equilibrium between the costs of leakage control and their benefits below which it is not cost effective to make further investments or to use additional resources to drive leakage down any further

# Performance indicator for NRW

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## Financial Water Losses Performance Indicators

### □ Annual Cost of Real Losses

- ▣ Real losses expressed in terms of production cost
- ▣ This indicator gives the money loss due real losses

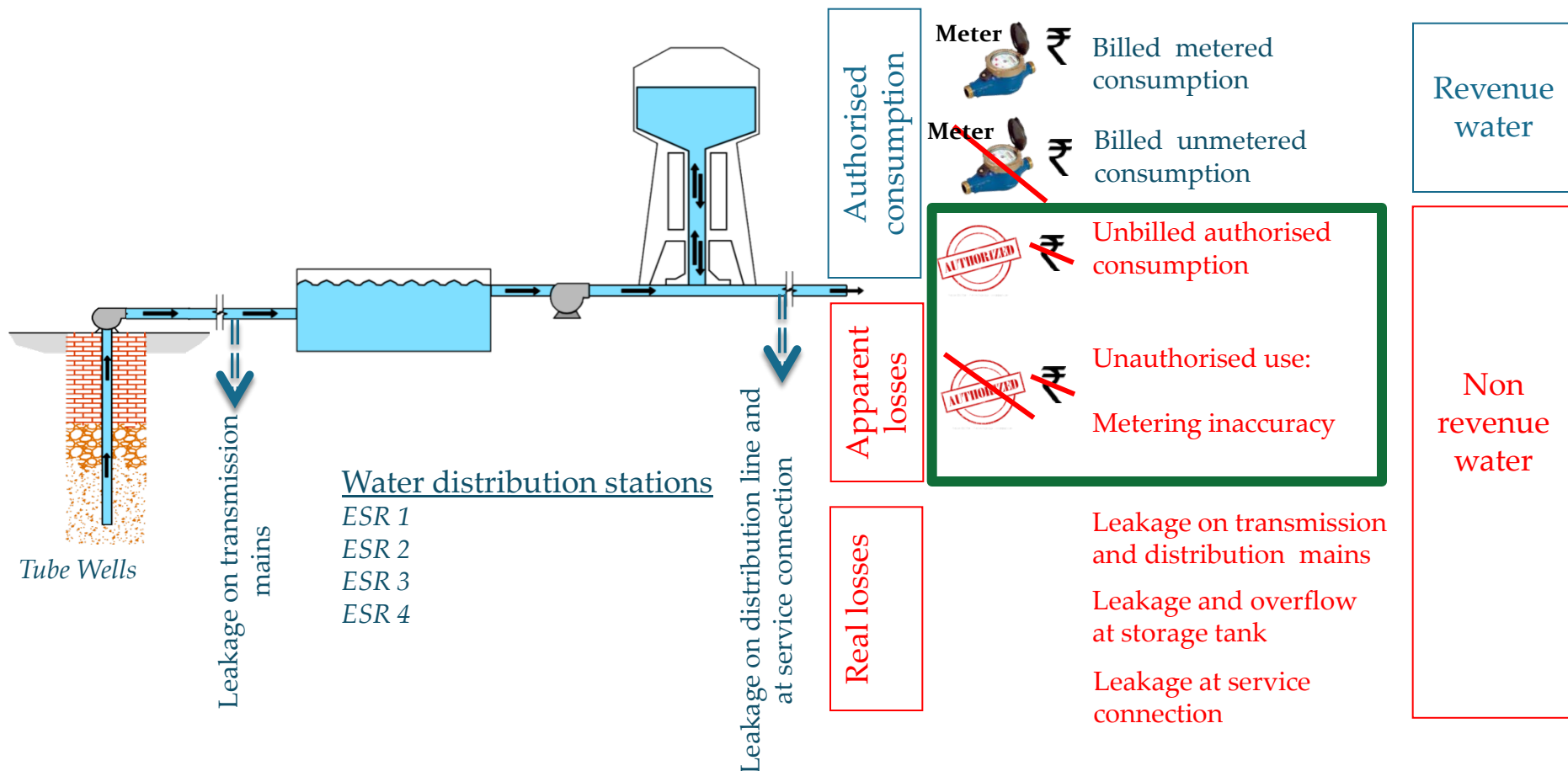
### □ Annual Potential Saving from Reducing Water Loss

- ▣ This indicator gives the amount of rupees saved due to reduction of water losses

# Strategies to Reduce NRW

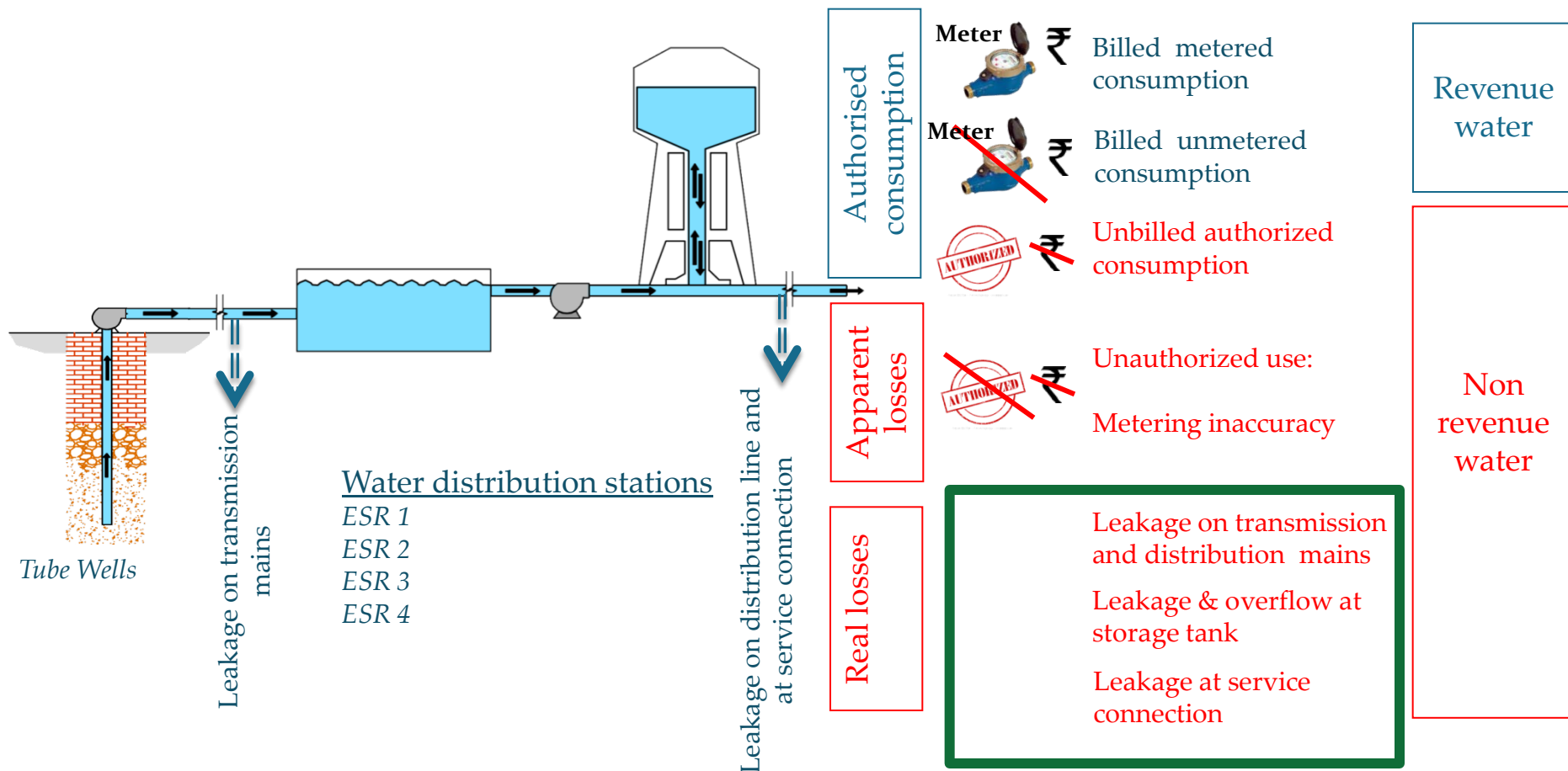
# NRW reduction

Reduction of these components will increase revenue



# NRW reduction

Reduction of these components will reduce expenditure and increase revenue (volumetric tariff)





# Measures to reduce NRW – Unbilled Authorised and Apparent Losses

## Losses

- Unbilled authorised consumption
- Illegal consumption
- Meter inaccuracy

## Improvement measures

- Start charging free supply
- Identify and then regularise illegal connection
- Prepare meter replacement plan

# Measures to reduce NRW – Real Losses

## Losses

- ❑ Leakage in transmission and distribution main
- ❑ Leakage and overflow at storage tank
- ❑ Leakage at service connection

## Improvement measures

- ❑ Repair leaking valves  
Repair or replace leaking pipelines
- ❑ Create awareness in staff  
Repair or rehabilitate storage tank
- ❑ Replace service connection
- ❑ Pressure management

# Cost of NRW reduction measures

	Low cost	Medium cost	High cost
Short term	Reduction in free supply		
	Regularisation of illegal connection		
	Repair valves and storage tank		
Medium term		Reduce customer meter inaccuracy	
Long term			Replacement of pipelines
			Replacement of service connection
			Pressure management

# Preliminary water audit

## *Case study of Kalol Municipality*

# Kalol Growth

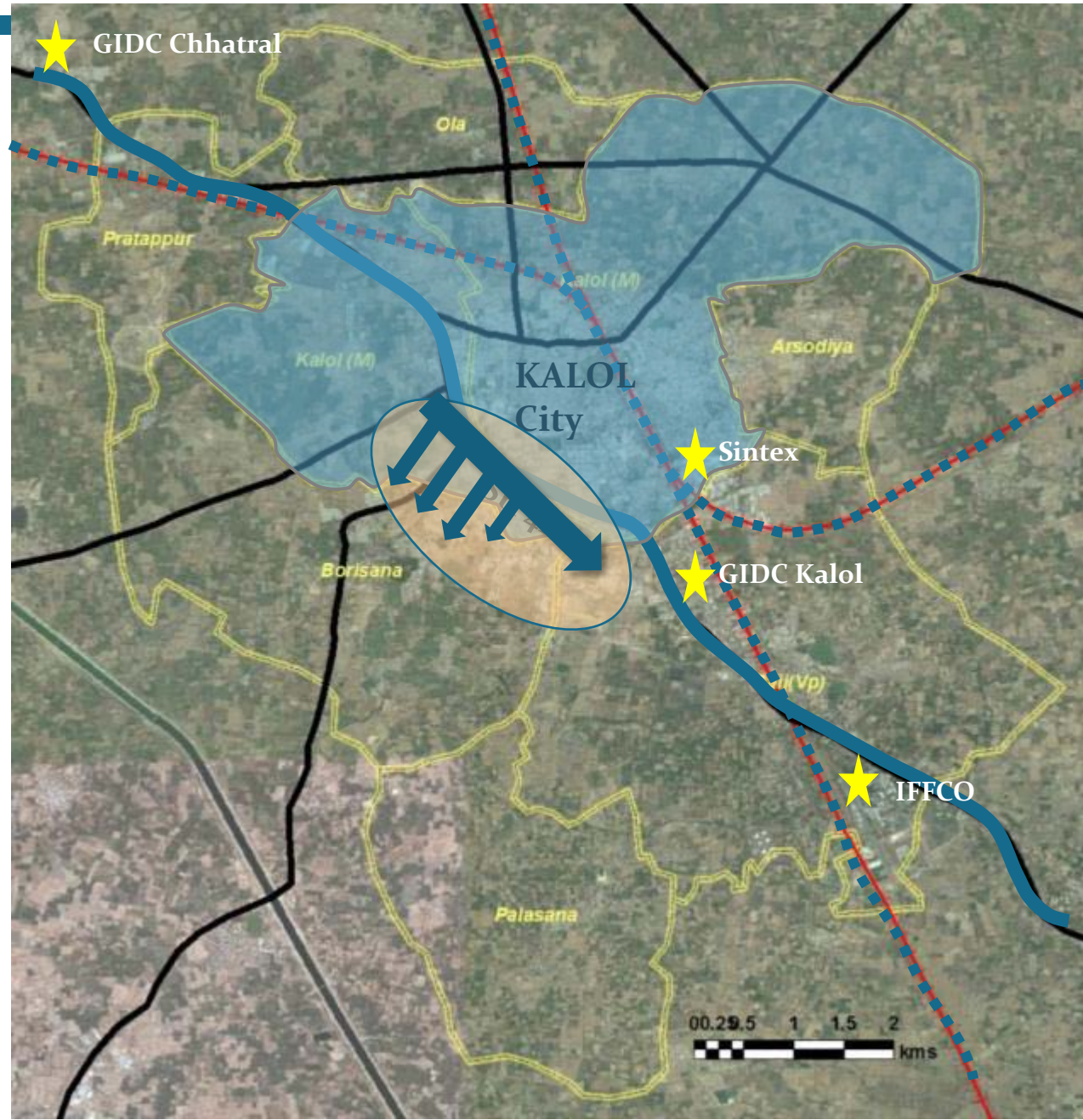
Population: Around 1.3 lakh

Percentage of slum population:  
22% of city population

City area: Around 17.24 sq. km

Major Industries located along  
the State Highway (SH 41)

SH 41 acting as Growth  
Corridor





# Good initiatives

## Newly Constructed WTP

Water Treatment Plant constructed by Gujarat Water Supply and Sewerage Board (GWSSB). Municipality purchases Bulk treated water from GWSSB.



# SLB Indicators-Water supply

Performance Indicators for Goal				
Sr. no.	Indicator	Unit	Value	Reliability
1	Coverage of water supply connections નળ જોડાણોનું વ્યાપ	%	52	C
2	Per capita supply of water માથાદિઠ પાણી પુરવઠો	lpcd	82	D
3	Continuity of water supply પાણી પુરવઠાની નિરંતરતા	hours	1.50 Hour	D
4	Quality of water supplied પાણી પુરવઠાની ગુણવત્તા	%	100	D
5	Cost recovery (O&M) in water supply services પાણી પુરવઠા સેવાની ખર્ચ વસુલાત	%	22	A+

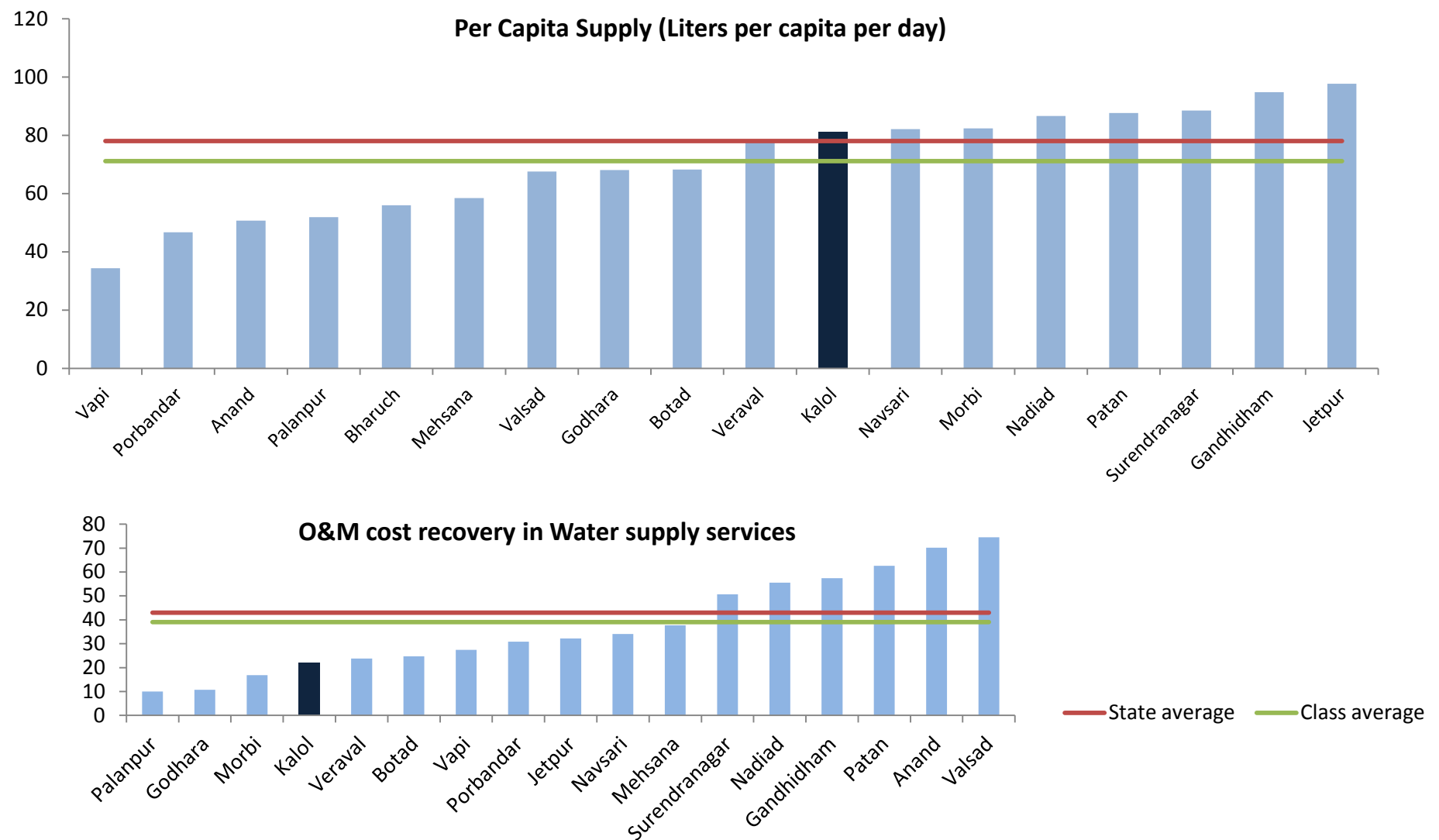
# SLB Indicators-Water supply

## Performance Indicators for Reforms

Sr. no.	Indicator	Unit	Value	Reliability
8	Coverage of water supply connections in 'slum settlements' સ્લમ વિસ્તારોમાં પાણી પુરવઠાનું વ્યાપ	%	33	D
9	Extent of non-revenue water બિન ઉપજાવ પાણીની માત્રા	%	46	D
10	Efficiency in redressal of customer complaints ગ્રાહક ફરિયાદ નિવારણની કાર્યક્ષમતા	%	100	O
11	Percentage of recruited staff to sanctioned staff નિયમિત કર્મચારી સંખ્યા મંજૂર રહેલ સંખ્યાની ટકાવારી	%	75	A
14	Efficiency in collection of water supply related charges પાણી પુરવઠા દર વસુલાતની ક્ષમતા	%	48	B

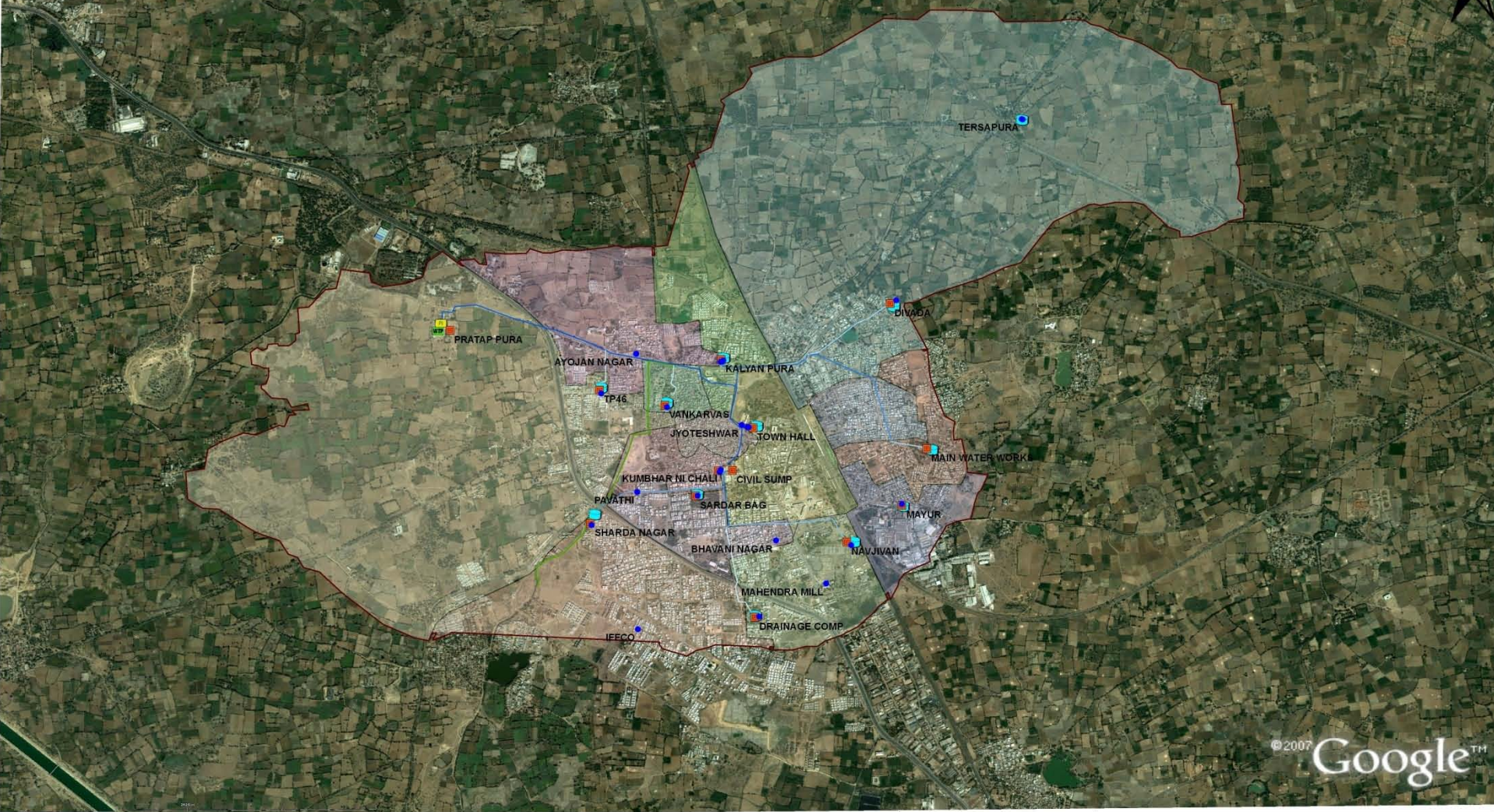


# Water supply indicators in Kalol





# Water Supply Main Distribution Network



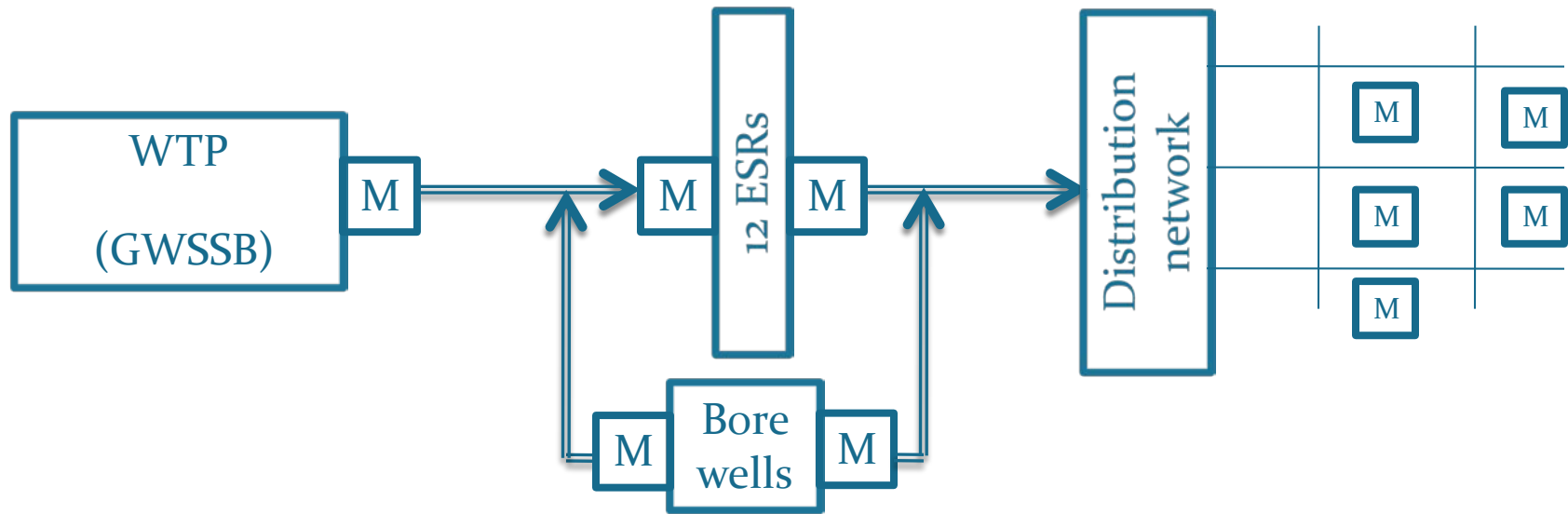
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PERFORMANCE ASSESSMENT SYSTEMS FOR URBAN WATER SUPPLY AND SANITATION IN GUJARAT	MAP TITLE	DRAWN BY	LEGEND	LEGEND	 <b>Center for Enviornment Plannning and Technology</b> Kasturbhai Lalbhai Campus, University Road, Navrangpura, Ahmedabad-380009
A Research Project in Association with Urban Management Centre (UMC)  <small>URBAN MANAGEMENT CENTRE in collaboration with ICMA</small> <small>This map is prepared as a part of an academic study at CEPT University. The boundaries and information in the map is used for representational purpose and no claim are made for its accuracy or authenticity. CEPT University is not responsible for any damages or other liabilities due to the accuracy, availability, use or misuse of the information provided herein.</small>	kalol	 ESR  SUMP  BOREWELL  WTP  MUNICIPAL BND  WARD BND	<b>WATERSUPPLY PIPELINE</b>  150  350 864  200  400  220  450  STROM WATER NATURAL DRAINAGE		





# Preliminary water audit



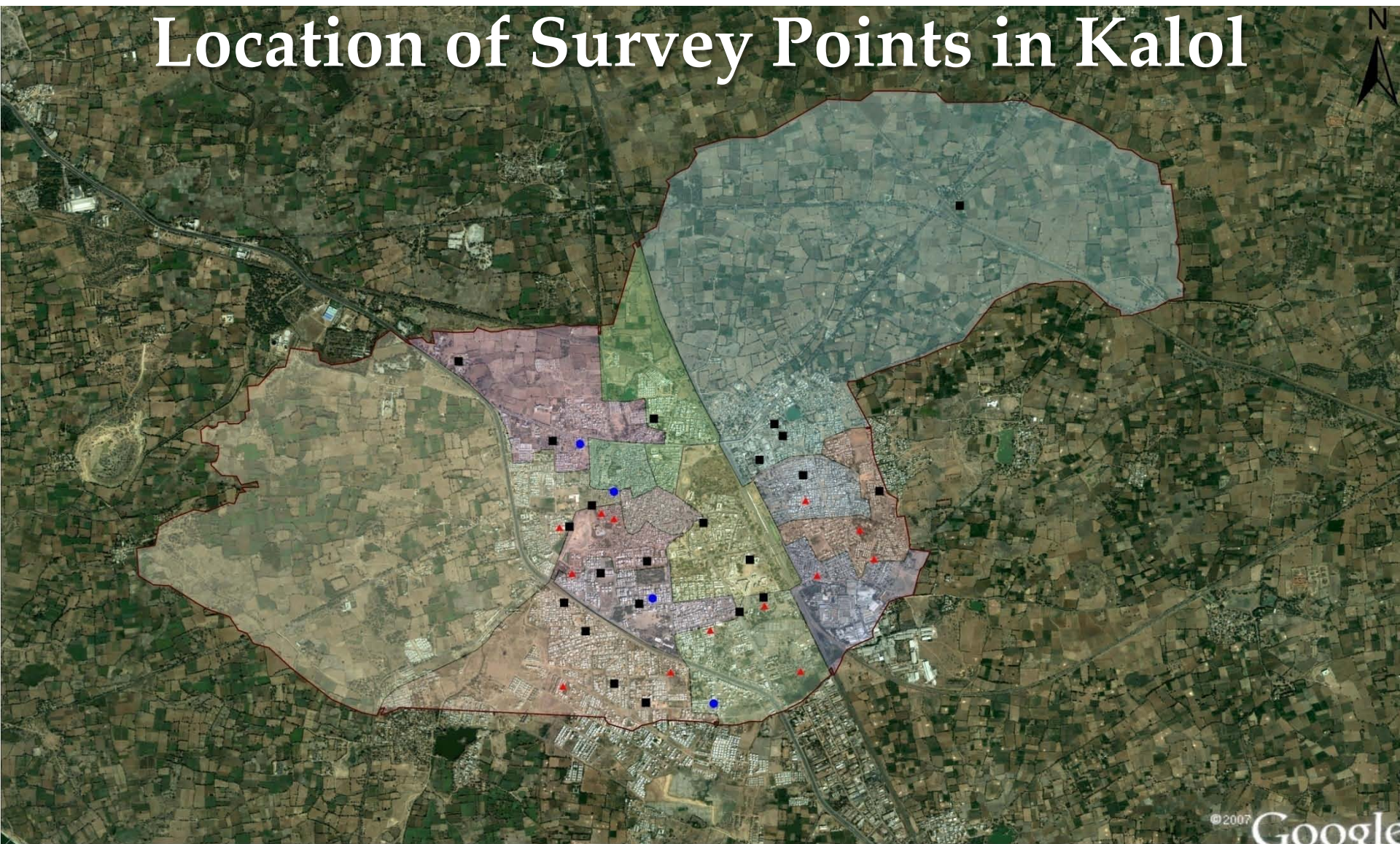
**Quantity measurement at Source, WTP, WDS** Using the portable ultrasonic flow meter, quantity at each level is measured. Cost of preliminary water audit is directly related with the number of measurement points.



For Kalol, measurement points at each level are:

WTP	1 measurement
Bore wells	21 measurement
ESRs inlet	12 measurement
ESR outlet	12 measurement



# Location of Survey Points in Kalol



<p>PERFORMANCE ASSESSMENT SYSTEMS FOR URBAN WATER SUPPLY AND SANITATION IN GUJARAT</p> <p>A Research Project in Association with Urban Management Centre (UMC)</p>  <p>URBAN MANAGEMENT CENTRE in collaboration with ICMA</p>	<p>MAP TITLE</p> <p>kalol</p>	<p>DRAWN BY</p>	<p>LEGEND</p> <p>SURVEY POINT</p> <ul style="list-style-type: none"> <li>● 1" CONNECTION</li> <li>▲ 3/4" CONNECTION</li> <li>■ 1/2" CONNECTION</li> <li>□ MUNICIPAL BND</li> <li>□ WARD BND</li> </ul>	<p>LEGEND</p>	 <p>Center for Environment Planning and Technology Kasturbhai Lalbhai Campus, University Road, Navrangpura, Ahmedabad-380009</p>
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# Calculation of NRW and Losses

Parameter	Actual Measurement
System Input Volume	17.3 MLD
Billed Quantity (Revenue Water)	9.26 MLD
NRW	46.32%

Categories of Losses	Actual Measurement	
Losses from source to WDS (leakage in transmission mains)	1.71 MLD	9.9%
Losses at WDS (leakage and overflows at storage tanks)	0.61 MLD	3.5%
Losses from WDS to Consumer (leakage on service connections and unauthorised consumption)	5.58 MLD	32.4%

# Kalol: Water balance chart

System input volume 6,299	Authorised consumption (54.2%) 3,414	Billed authorised consumption (53.7%) 3,381	Billed unmetered consumption (53.7%) 3,381	Revenue water (53.7%) 3,381
		Unbilled authorised consumption (0.5%) 33	Unbilled consumption (0.5%) 33	Non- revenue water (NRW ) (46.3%) 2918
	Water losses (45.8%) 2,885	Apparent losses (16.8%) 1,058	Un-authorised consumption (16.8%) 1058	
		Real losses (29%) 1,827	Leakage on service connections up to point of customers (15.6%) 980	
			Leakage on transmission mains (9.9%) 624	
			Leakage and overflows at utility's storage tanks (3.5%) 223	

Quantity are in “Million liters per year



# Income & Expenditure of Water supply services

Income (Rs.  
83,34,791)

Expenditure (Rs.  
3,75,29,849)

Special water tax  
(Rs. 51,47,940)

General water tax  
(Rs. 28,51,214)

Other (Rs. 3,35,637)

Narmada water  
charge (Rs.  
1,85,71,200)

Electricity (Rs.  
1,48,22,706)

Administration (Rs.  
31,09,547)

O&M Expenses (Rs.  
10,26,396)



# Financial Analysis: Kalol Water Supply

Income	In Rs
Special water tax #	51,47,940
Construction water fee	3,21,887
Water connection fee	13,750
General water tax #	28,51,214
Total	83,34,791

Expenditure	In Rs
Administration	31,09,547
O&M Expenses	10,26,396
Electricity*	1,48,22,706
Narmada water charge*	1,85,71,200
Total	3,75,29,849

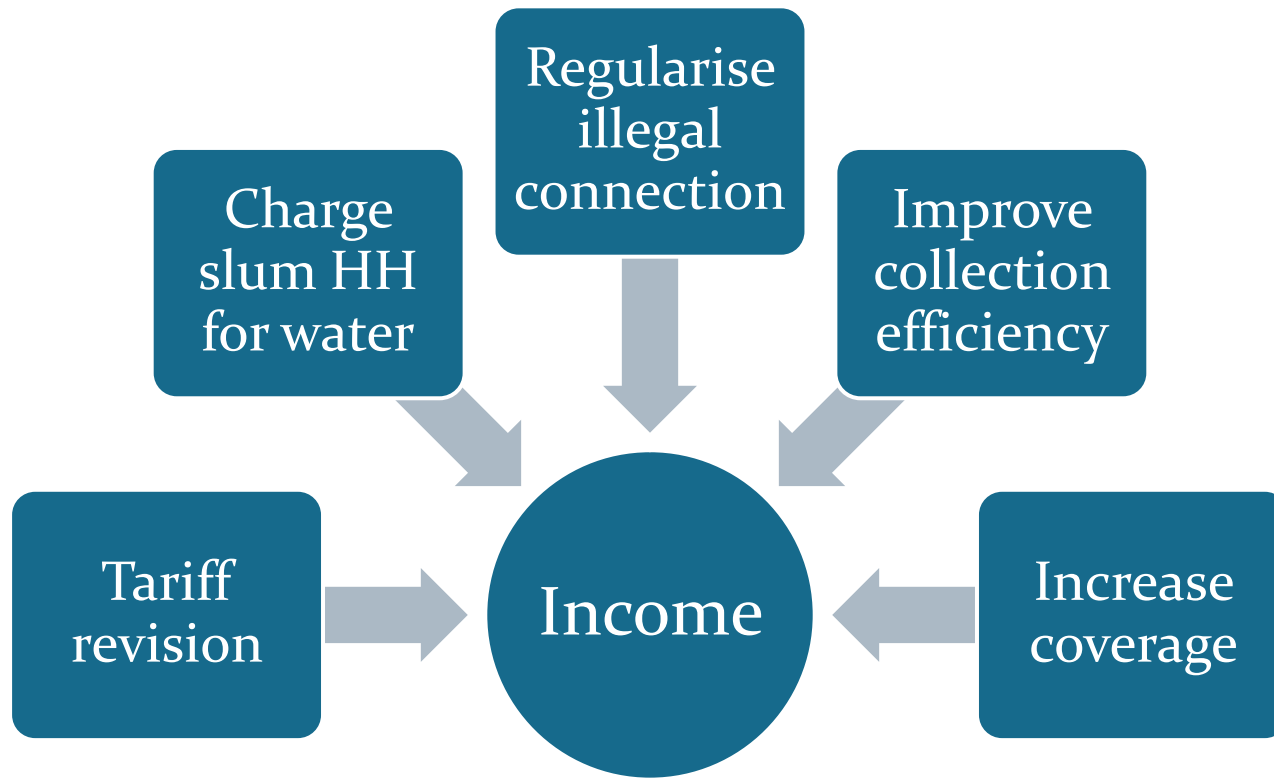
- Cost recovery (O&M) of water supply: 22 %
- Unit production cost: Rs. 5.96 per kilo liter
- Cost of NRW is Rs. 1.7 crore, which is 13% of total budgeted expenditure for year 2009 - 2010

*Revised actuals for year 2009 – 10 from the Budget Document (2010 – 2011)*

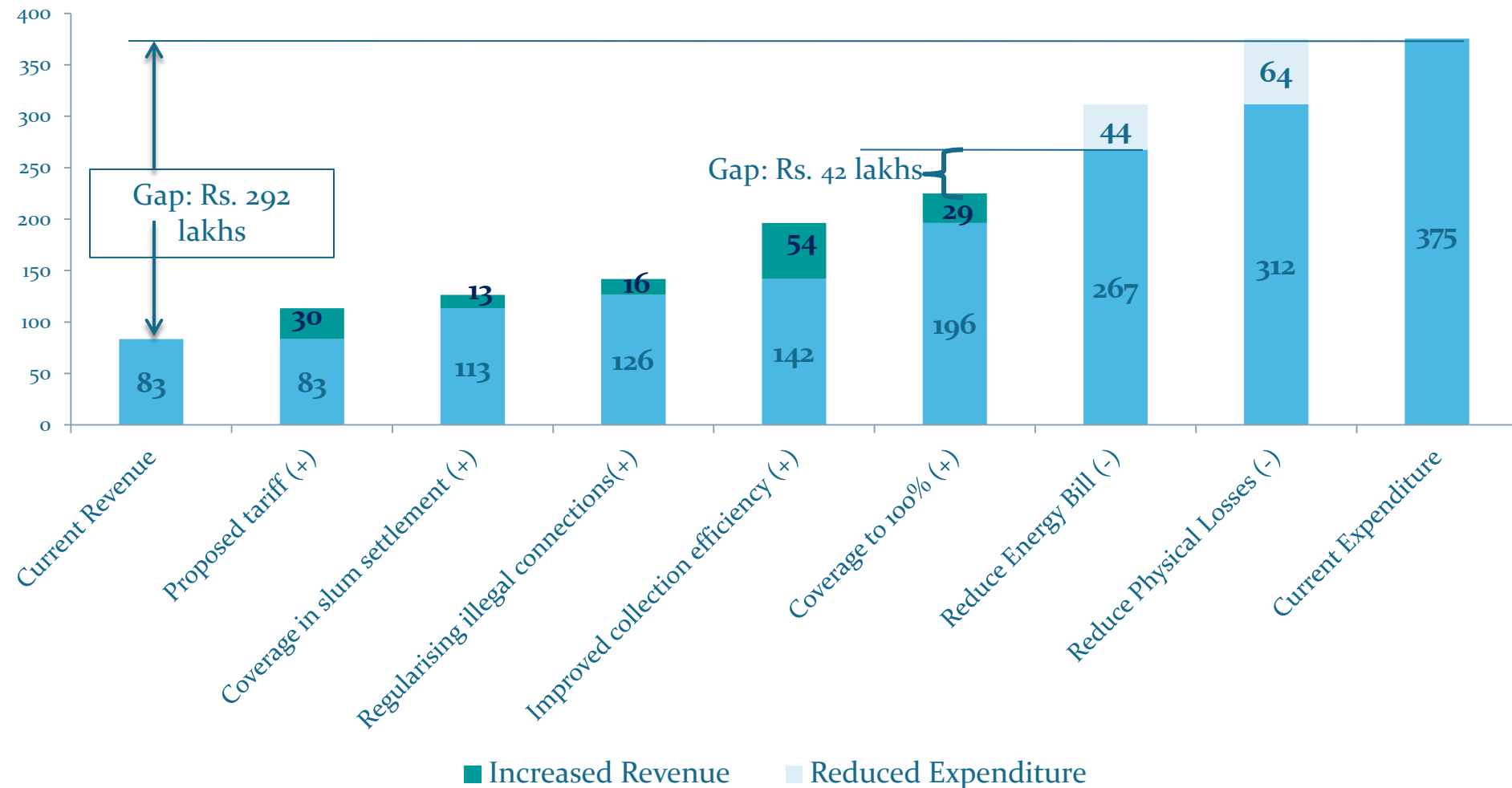
*# Values taken from DCB table*

*\* Electricity and Narmada water charge amount are actual payable amount*

# Actions to increase water supply Income



# Improvements areas for cost recovery - Kalol



Values are in Rs. Lakhs

# Urgent/Immediate steps for NRW measurement and reduction

- *Repair ESRs, leaking valves and reduce overflow of tanks:*
  - Kalyanpura, Divada, Sardanagar, Sardabag and Navjivan ESRs are leaking heavily and require immediate repair
  - Maintenance of valves and fittings **such as** tightening the loose bolts, positioning the gland packing, replacing the damaged parts of valves and fitting etc.
  - Staff's awareness to reduce overflow of storage tanks.
- *Identify and regularise illegal connections:*
  - Detect and then regularize illegal connections
  - Introduce a simpler and special procedure for giving connection to slum households
- *Establish water quantity data recording and processing system*

# Further studies to improve performance of WSS

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- Carry out energy audit
- Prepare system/network map and connections information
- Hydraulic modeling and creation of District Metered Areas (DMAs )
- Metering
- Develop a bankable project to reduce NRW

Thank You