Water Loss Management in in Distribution Systems: An Overview

By Sam Kayaga

(Materials adapted from Saroj Sharma's lecture**)**

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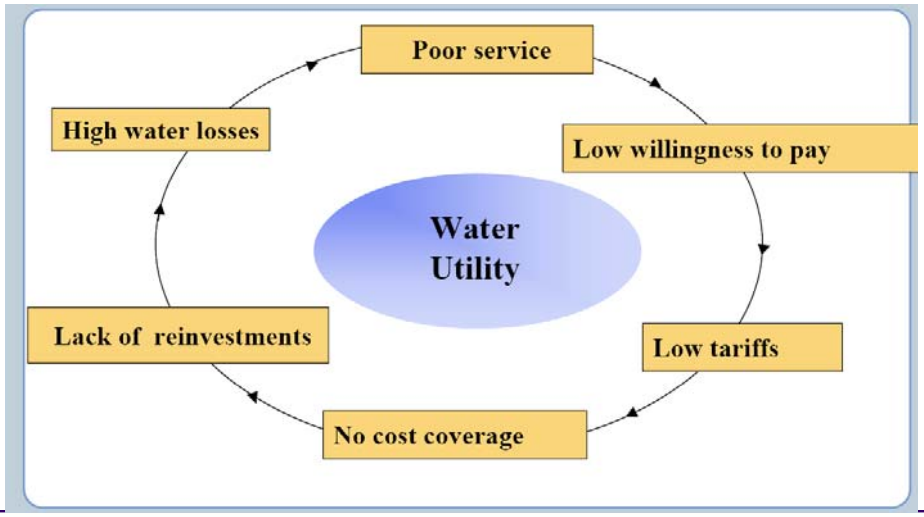
The vicious cycle of high water losses



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General steps for managing water losses

Step 1: Analysis of network characteristics and operating practices

Step 2: Quantification water losses

Step 3: Use of appropriate tools and mechanisms to find solutions

IF YOU CANNOT MEASURE, YOU CANNOT MANAGE!

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Unaccounted-For-Water vs Non-Revenue Water

- Unaccounted-for water (UFW) is
  - the difference between the volume of water delivered into a network and the volume of water that can be accounted for by legitimate consumption
- Non-revenue water (NRW) is
  - the difference between the volume of water delivered into a network and billed consumption.
- NRW = "Net production" – "Revenue water"
  = UFW + water which is accounted for, but no revenue is collected (i.e. unbilled authorized consumption)

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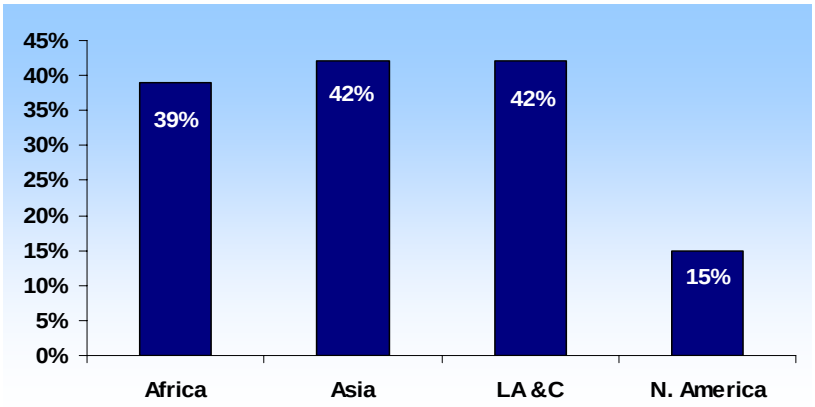
Mean UFW in Large Cities



Source: **Global Water Supply and Sanitation Assessment 2000 (WHO-UNICEF)**

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UFW in Some Southern African Cities

City	Percentage of connections that are metered (%)	Unaccounted for water (%)
Luanda, Angola	40	60
Gaborone, Botswana	100	20
Kinshasa, Democratic Republic of the Congo	76	47
Maseru, Lesotho	97	32
Port Louis, Mauritius	100	45
Maputo, Mozambique	100	34
Windhoek, Namibia	100	11
Greater Victoria, Seychelles	100	26
Mbabane, Swaziland	100	32
Dar Es Salaam, Tanzania	10	60
Lusaka, Zambia	44	56
Harare, Zimbabwe	85	30

Source: Handbook for the Assessment of Catchment Water Demand and Use: HR Wallingford and DFID, UK (2003)

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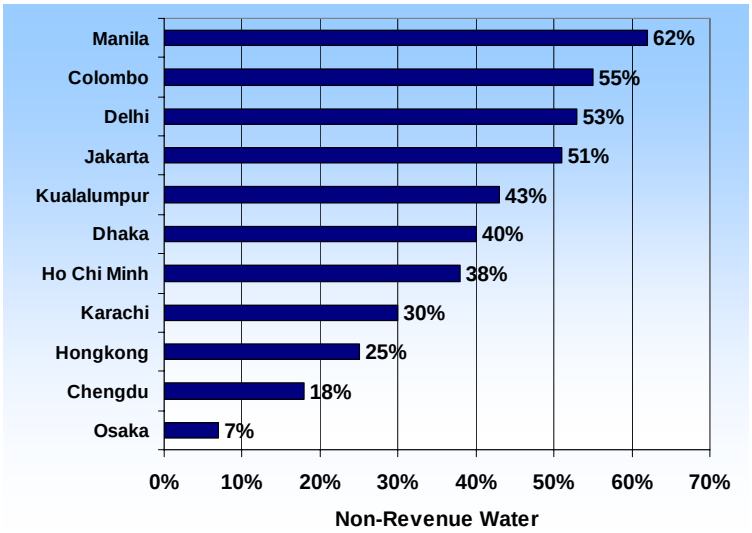
Non-revenue Water in Some Asian Cities



Source: Water in Asian Cities, ADB (2004)

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'IWA Best Practice' Water Balance and Terminology

System Input Volume	Authorized Consumption	Billed Authorized Consumption	Billed Metered Consumption	Revenue Water
			Billed Unmetered Consumption	
		Unbilled Authorized Consumption	Unbilled Metered Consumption	Non Revenue Water
			Unbilled Unmetered Consumption	
	Water Losses	Apparent Losses	Unauthorized Consumption	
			Customer Meter Inaccuracies and Data Handling Errors	
		Physical Losses	Leakage on Transmission and Distribution Mains	
			Leakage and Overflows from the Utilities Storage Tanks	
			Leakage on Service Connections up to the Customer Meter	

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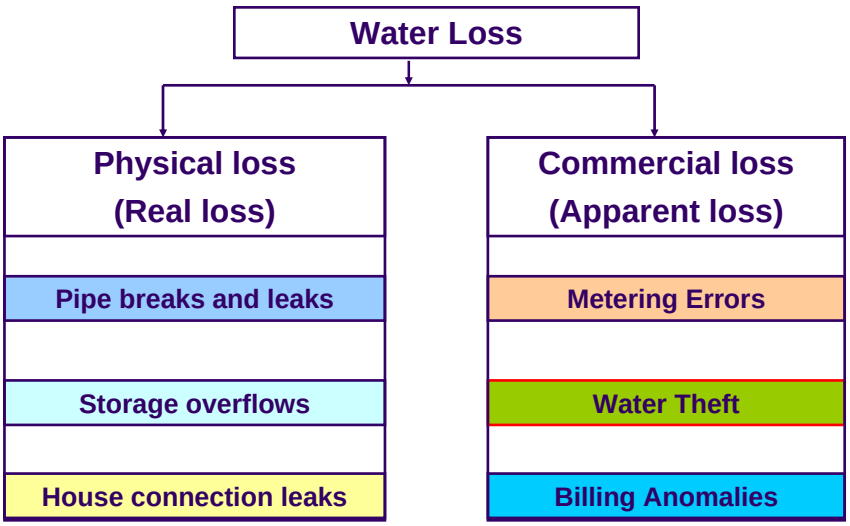
How is water lost?



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A 10-metre-long section of a key thoroughfare in north-end Toronto is seen on April 26, 2006 after sinking into its foundation. Heavily-travelled Sheppard Avenue West (between Bathurst and Senlac) was weakened by a break in a water main. Police say all four lanes, just east of a bridge straddling the West Don River, sunk about three metres.

(CP Photo/Toronto Star - Ron Bull)

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Calculating Water Loss

Water loss is expressed as

- a percentage of net water production (delivered to the distribution system)
- as m^3/day/km of water distribution pipe network (specific water loss)
- Others
  - m^3/day/connection
  - m^3/day/connection/m of pressure

-Water loss as % of net water production is the most common.

-It could be misleading for systems with different net productions with same amount of real & apparent losses.

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What is an Acceptable Water Loss?

1. It is a compromise between the cost of reducing water loss and maintenance of distribution system and the cost (of water) saved.
2. AWWA Leak detection and Accountability Committee (1996) recommended 10% as a benchmark for UFW.
3. UFW levels and action needed

< 10%	Acceptable, monitoring and control
10-25%	Intermediate, could be reduced
> 25%	Matter of concern, reduction needed

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Components of Water Losses (1)

- Good understanding of the relative weights of different components is important for development of a sound water loss reduction program.

Country/City	Year	Components of UFW (%)		
		Physical	Commercial	Total
Singapore	1989	4	7	11
Spain, Barcelona	1988	11	12	23
Colombia, Bogota	1991	14	26	40
Costa Rica, San Jose	1990	21	25	46

Source: Water and Wastewater Utility Data – 2nd Edition 1996 (WB)

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Components of Water Losses (2)

Component of UFW (%)		Bangdung (Indonesia)	Chonburi (Thailand)	Petaling Jaya (Malaysia)
Physical Losses	Trunk mains, distribution system	21	2	2
	Service connections	10	34	17
Non-physical loss	Illegal connections	6	2	2
	Under registration and Billing	6	8	15
Total UFW %		**43**	**46**	**36**

Source: (Thiadens, 1996)

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Unavoidable Annual Real Losses (UARL)

- It is impossible to eliminate all real losses from a distribution system
  - some losses are "unavoidable"
  - some leakages are believed to be undetectable (too small to detect) or uneconomical to repair
- An estimate of Unavoidable Annual Real Losses (UARL) can help to evaluate the feasibility of real loss minimization (provides better understanding of real loss components).

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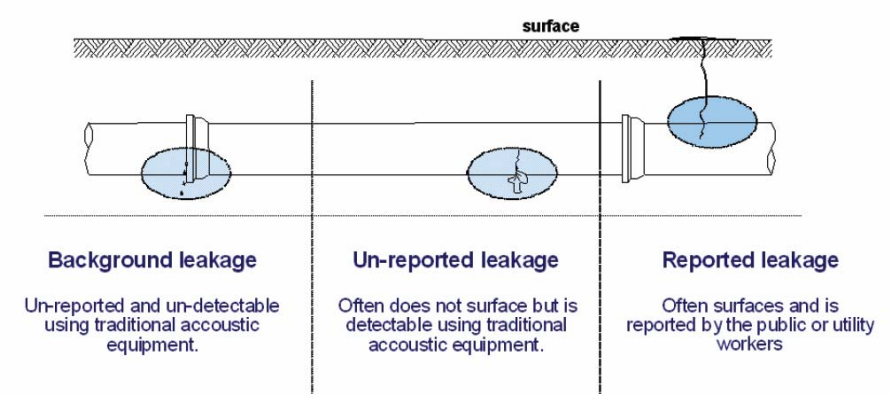
Unavoidable Annual Real Losses (UARL)

- **The UARL is computed based on Background and Burst Estimates (BABE) concept.**



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UARL – Background (1)

- Based on a statistical analysis of international data, including 27 diverse water supply systems in 19 countries, a method of predicting UARL has been developed and tested for application to systems with:
  - average operating pressure of between 20 and 100 metres;
  - density of service connections between 10 and 120 per km of mains;
  - customer meters located 0 and 30 metres from the edge of the street.

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Unavoidable Annual Real Losses (UARL)

UARL (L/day) = (18 x Lm + 0.80 x Nc + 25 x Lp) x P
where

Lm = Length of mains in km

Nc = Number of service connections

Lp = Total length in km of underground connection pipes (between the edge of the street and customer meters)

P = Average operating pressure in m

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UARL in litres/service connection/day for customer meters located at edge of street

Density of of Connections Nc/Lm (per km mains)	Average Operating Pressure (P) in Metres				
	20	40	60	80	100
20	34	68	112	146	170
40	25	50	75	100	125
60	22	44	66	88	110
80	21	41	62	82	103
100	20	39	59	78	98

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The Infrastructure Leakage Index (ILI)

- **A better indicator**
- **Describes the quality of infrastructure management**
- **Is the ratio of *Current Annual Real Losses* to *Unavoidable Annual Real Losses***

$$ILI = \frac{CARL}{UARL}$$

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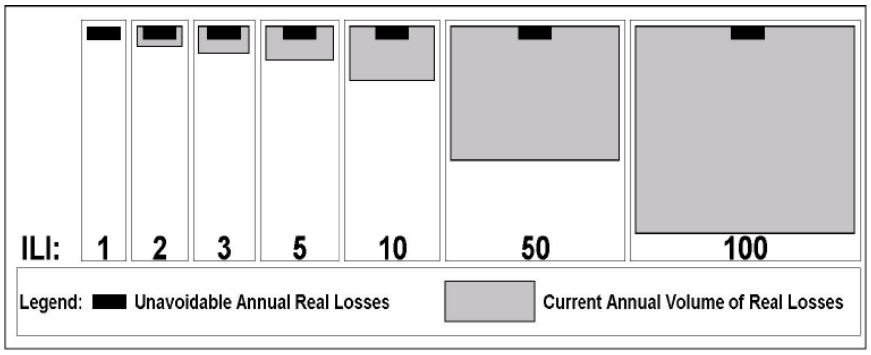
The Infrastructure Leakage Index (ILI) - 2



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World Bank Institute Banding System to Interpret ILIs

- **ILI is classified into Bands A to D**
- **Different limits for developed & developing countries**
- **Each Band has a general description of performance**
- **Each Band suggests a range of recommended activities**

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WBI Banding System to Interpret ILIs

Developing countries	Developed countries	BAND	General description of real loss performance management categories
ILI Range	ILI Range		
< 4	< 2	A	Further loss reduction may be uneconomic unless there are shortages; careful analysis is needed to identify cost effective improvement
4 to <8	2 to <4	B	Potential for marked improvements; consider pressure management, better active leakage control practices, and better network maintenance
8 to <16	4 to <8	C	Poor leakage record; tolerable only if water is plenty and cheap; even then analyze level and nature of leakage and intensify leakage reduction efforts
16 or more	8 or more	D	Very inefficient use of resources; leakage reduction programs imperative & high priority

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WBI Recommended Activities

WBI Recommendations for BANDS	A	B	C	D
Investigate pressure management options	Yes	Yes	Yes	
Investigate speed and quality of repairs	Yes	Yes	Yes	
Check economic intervention frequency	Yes	Yes		
Introduce/improve active leakage control		Yes	Yes	
Identify options for improved maintenance		Yes	Yes	
Assess Economic Leakage Level	Yes	Yes		
Review burst frequencies		Yes	Yes	
Review asset management policy		Yes	Yes	Yes
Deal with deficiencies in manpower, training and communications			Yes	Yes
5-year plan to achieve next lowest band			Yes	Yes
Fundamental peer review of all activities				Yes

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Comparison of real loss performance indicators

Source: Liemberger and McKenzie (2005)

Indicator	Vietnam	Indonesia	Sri Lanka
L/conn./day	866	430	519
L/conn./day/m pressure	72	38	48
ILI	79	31	39
NRW (%)	42%	40%	46%

The % losses do not reflect the huge difference in leakage performance of three systems.

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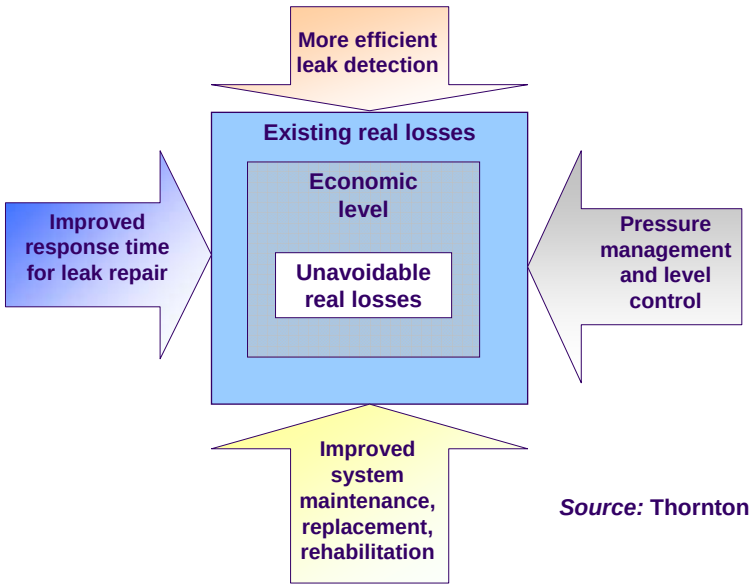
Four components of an active real loss management program



Source: **Thornton (2002)**

Suggested apparent loss percentages for a typical water distribution system in South Africa

Illegal connections		Meter age and accuracy			Data transfer	
			Good water quality	Poor water quality		
Very high	10 %	Poor > 10 years	8 %	10 %	Poor	8 %
High	8 %					
Average	6 %	Average 5- 10 years	4 %	8 %	Average	5 %
Low	4 %					
Very low	2 %	Good < 5 years	2 %	4 %	Good	2 %

Source: Seago *et al.* (2004)

Rule of thumb = apparent losses is 20% of total water losses

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The Apparent Loss Index (ALI)

- **Similar to the concept of ILI, an index for apparent loss has been recommended by IWA task force.**

$$\text{Apparent Loss Index (ALI)} = \frac{\text{Apparent Loss}}{5\% \text{ of Water Sales}}$$

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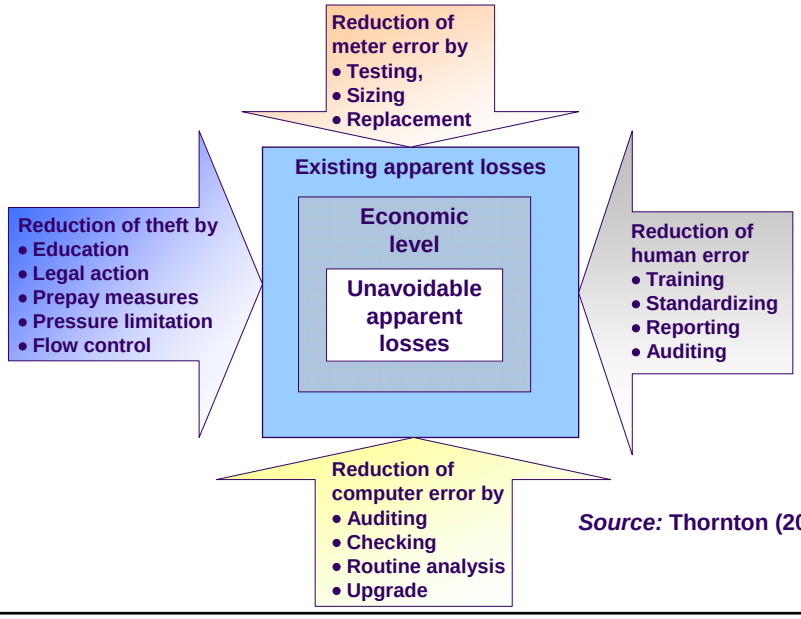
Four components of an active apparent loss management program



Source: Thornton (2002)

IWA recommended performance indicators

Function	Level	PI	Remarks
Financial: NRW by volume	Basic	Volume of NRW as % of system input volume	Can be calculated from simple water balance
Financial: NRW by cost	Detailed	Value of NRW as % of annual cost of running system	Allows different unit costs for NRW components
Inefficiency of use of water resources	Basic	Real loss as % of system input volume	Unsuitable for assessing efficiency of management of distribution system
Operational: Real losses	Basic	m^3/service line/day, when system is pressurized	Best "traditional" basic performance indicator
Operational: Real losses	Detailed	Infrastructure Leakage Index	Ratio of CARL to UARL

Source: Adapted from Thornton (2002)

Guideline for Water Loss Level

Source: Gerhard Zimmer (Experiences from KfW funded programs)

- For systems with per capita consumption of less than 150 l/day the general rule for water loss level is:

Good condition of system	< 250 Litre/connection /day
Average condition	250 - 450 Litre/connection/day
Bad condition of system	> 450 Litre/connection/day

- Another guideline for the water loss level is the "Benchmark" Litre/km mains/day:

Good condition of system	< 10,000 Litre/km main/day
Average condition	10,000 – 18,000 Litre/km main/day
Bad condition of system	> 18,000 Litre/km main/day

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