Performance Based Contracts in Non-Revenue Water Reduction Programs

March 2017

Session 2: Basics in Non-Revenue Water Reduction

WORLD BANK GROUP Water

PPIAF Enabling Infrastructure Investment

www.wsp.org | www.worldbank.org/water | www.blogs.worldbank.org/water | @WorldBankWater

Why is NRW Management So Important?

- Reducing NRW delivers multiple benefits:
  1. Improves customer service levels – higher pressures and/or better continuity and/or expanded coverage
  2. Enhances asset lives and utility management – if NRW reduction leads to 24/7
  3. Improves utility financial performance (and/or reduces local government subsidies) by reducing costs and increasing revenues
  4. Makes cities more competitive when accompanied by service improvement
  5. Improves climate resilience by reducing demand on scarce water resources
  6. Reduces emission of GHGs – less energy/m3 delivered

This is not a "win win" (W^2) - it is a "win win win win win win" (W^6)

1

PPIAF Enabling Infrastructure Investment

WORLD BANK GROUP Water

Content

Non Revenue Water, The International Water Association (IWA) Water Balance, The Economic level of Leakage

PPIAF Enabling Infrastructure Investment | WORLD BANK GROUP Water

Non Revenue Water

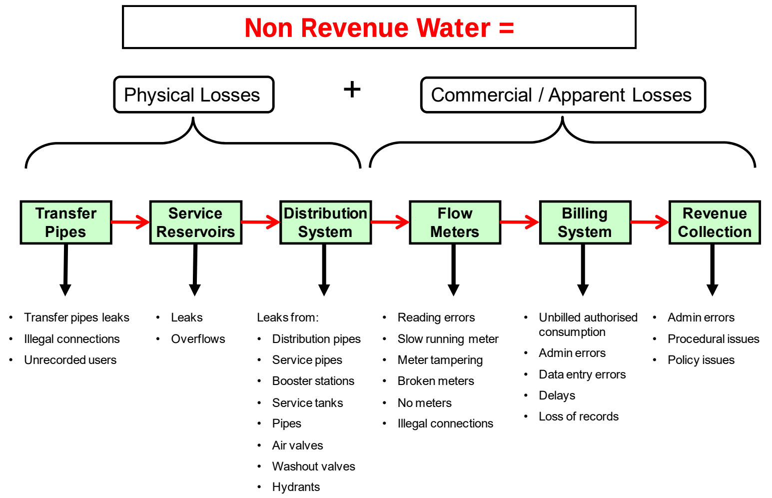
The volume of water supplied into the network that does not generate sales revenue

Usually expressed in:

- m^3/day; or
- % of $1 - \frac{\text{Water Volume Sold}}{\text{Water Volume Produced}}$

PPIAF Enabling Infrastructure Investment | WORLD BANK GROUP Water

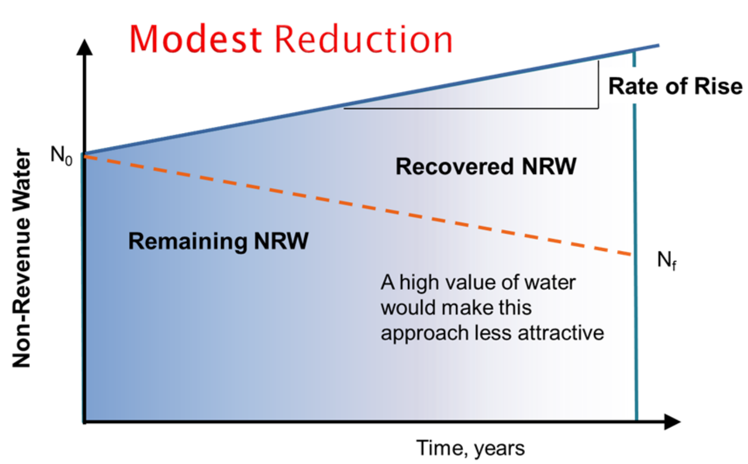
Areas of Non Revenue Water



PPIAF Enabling Infrastructure Investment

WORLD BANK GROUP Water

The Nature of NRW



PPIAF Enabling Infrastructure Investment

WORLD BANK GROUP Water

Some Reasons for High NRW

- Lack of management focus
- Lack of understanding or awareness
- Lack of staff motivation and incentives
- Lack of skills and training
- Poor construction standards – especially service connections
- Absence of technology for Active Leakage Control
- Others that are specific to a utility, area or country

Institutional Factors

- Denial by managers that physical losses are the main problem
- Insufficient or incomplete network zoning
- Insufficient attention to commercial loss reduction
- Absence of a powerful NRW department
- Absence of an NRW management strategy

International Water Association – Water Balance

- **The International Water Association (IWA) gives best practice for calculating NRW using a 'Water Balance'**
- **The IWA methodology is generally considered the standard for reporting NRW**
- **It is typical to use this methodology to baseline and calculate the NRW reduction for each DMA in a network system**
- **Further details are on the web-site** *www.iwahq.org*

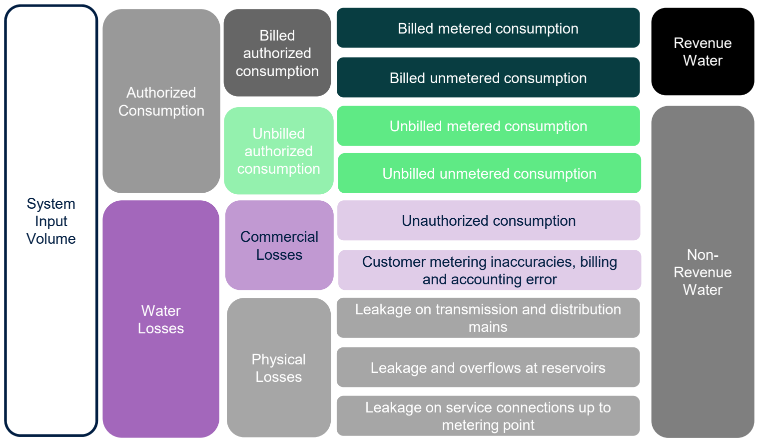
PPIAF Enabling Infrastructure Investment
WORLD BANK GROUP Water

Water Balance: Scope and Goal

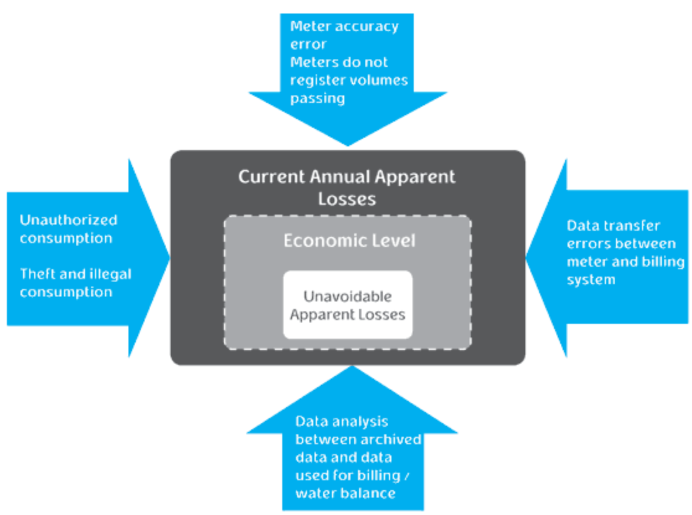
- The Water Balance Identifies:
  - The volume of water lost
  - Where the water is lost from
  - The value of the loss
  - The business case for reducing the loss
- The goal is to help the utility select and implement programs to reduce and sustain water losses and manage the utility as an efficient business

PPIAF Enabling Infrastructure Investment
WORLD BANK GROUP Water

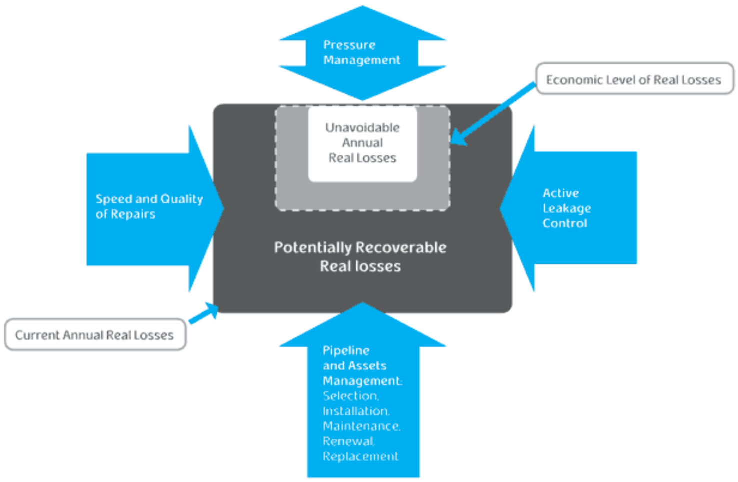
IWA Water Balance (Simplified)



Apparent Losses



Physical Losses

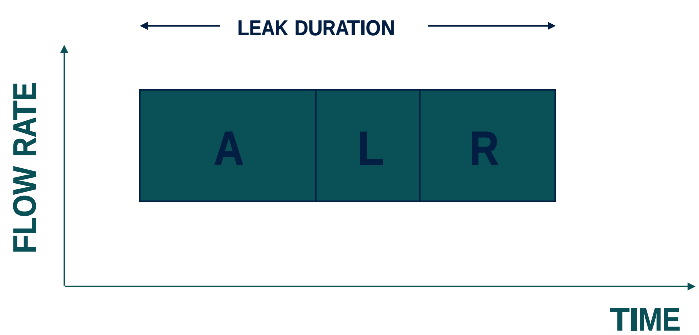


PPIAF Enabling Infrastructure Investment

WORLD BANK GROUP Water

The Effect of Time

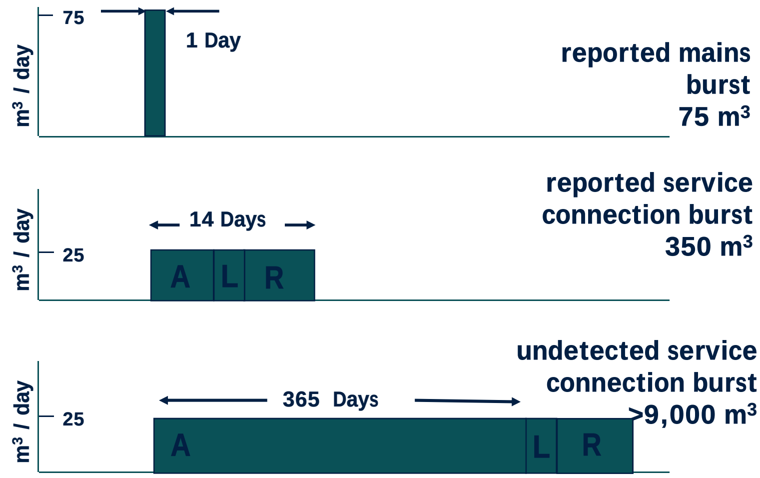
Leak Volume =
Awareness + Location + Repair Time x Flow Rate



PPIAF Enabling Infrastructure Investment

WORLD BANK GROUP Water

Time Makes The Difference



PPIAF Enabling Infrastructure Investment — WORLD BANK GROUP Water

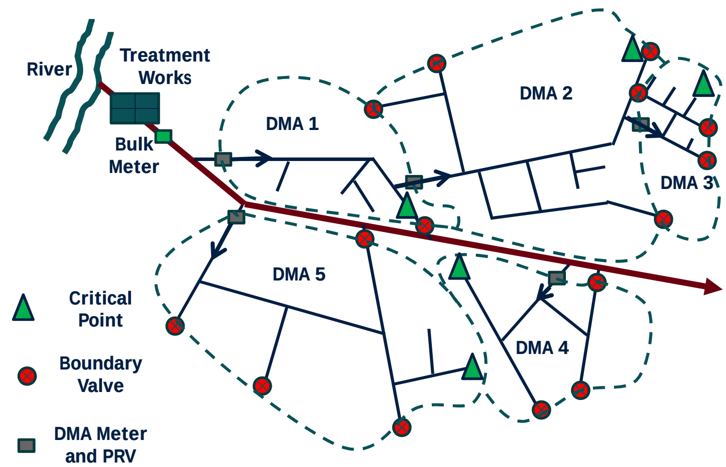
Why DMA Management?

A lot of money and resources is spent to establish DMAs

Money **Resources** **DMA**

PPIAF Enabling Infrastructure Investment — WORLD BANK GROUP Water

Example of DMAs



PPIAF Enabling Infrastructure Investment

WORLD BANK GROUP Water

Why DMA Management?

By dividing a large, complex network into smaller metered areas, we can:

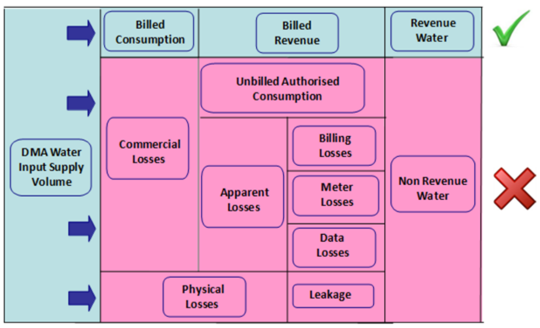
1. Monitor and prioritize leak reduction
2. Prioritise Commercial Loss reduction
3. Manage water pressure to meet Customer requirements
4. Target the most cost effective areas for capital investment
5. Allocate ownership and sense of pride to Caretakers responsible for managing and operating the DMA

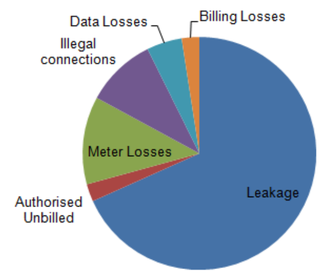
PPIAF Enabling Infrastructure Investment

WORLD BANK GROUP Water

NRW Components in Each DMA

- We need to calculate the DMAs' water balance components
- This allows us to prioritise our efforts to reduce NRW
- Using on-site measurements and experience, we will calculate / estimate the:
  - Leakage, and
  - Commercial Loss components





PPIAF Enabling Infrastructure Investment

WORLD BANK GROUP Water

Economic Level of Leakage

The Economic Level of Leakage (ELL) is . . . :

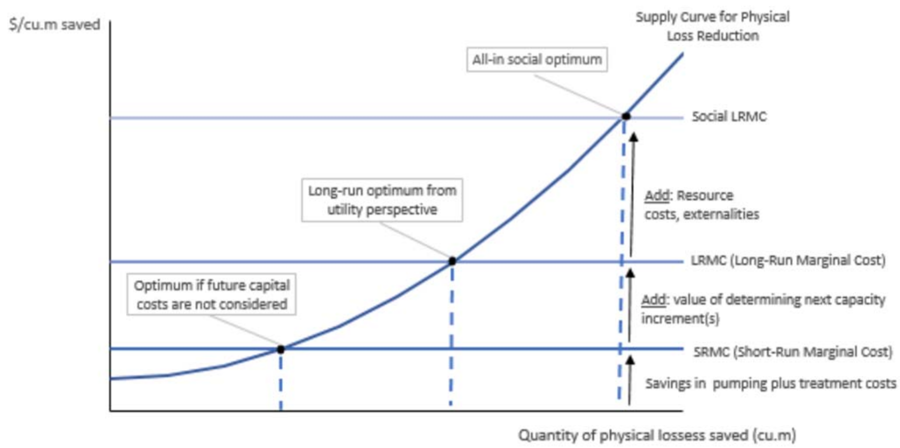
' . . . .the level of leakage at which any further reduction would incur costs greater than the benefits derived from the savings'

- In theory, the ELL would serve as the water company's leakage target
- In practice, it is extremely difficult and time consuming to calculate the ELL; it is specific to each water company and even to each DMA
- Consequently, best international practice for leakage target setting uses the easier performance indicators of:
  1. Infrastructure Leakage Index (ILI); and
  2. Volume of Leakage per Service Connection per Day
- Calculating these leak performance indictors enables DMAs to be prioritised for proactive leak reduction activities
- It allows leakage targets to be easily set

PPIAF Enabling Infrastructure Investment

WORLD BANK GROUP Water

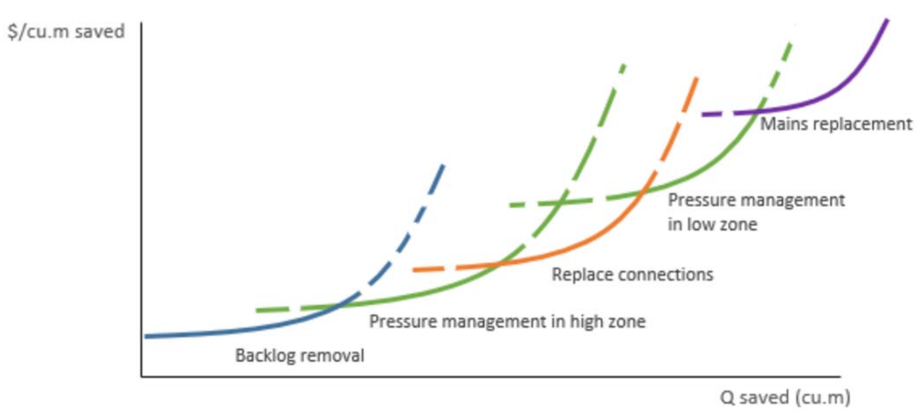
The Value of Water



PPIAF Enabling Infrastructure Investment

WORLD BANK GROUP Water

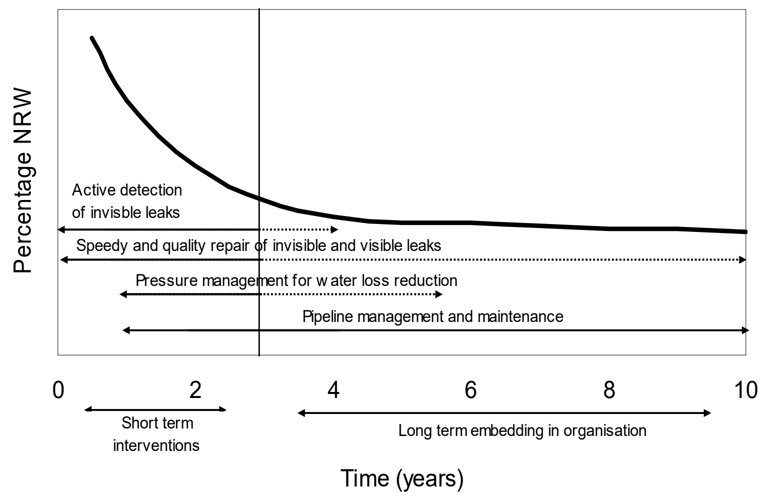
The Cost of NRW Management



PPIAF Enabling Infrastructure Investment

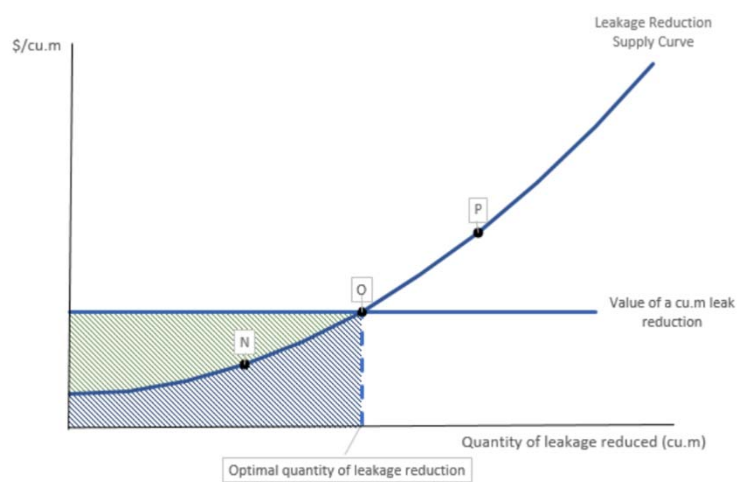
WORLD BANK GROUP Water

The Timing of Activities



PPIAF Enabling Infrastructure Investment
WORLD BANK GROUP Water

Optimization



PPIAF Enabling Infrastructure Investment
WORLD BANK GROUP Water

Method 1 – Infrastructure Leakage Index (ILI)

- Infrastructure Leakage Index (ILI) is the ratio of:

"actual leakage" vs "best possible minimum leakage"

Referred to as MAAPL – Minimum Achievable Annual Physical Losses

Referred to as CAPL – Current Annual Volume of Physical Losses

- It is the international indicator for water network efficiency
- An ILI of 4 is comparable with an efficient water company
- It can also be used to compare leakage performance across DMAs

"Best possible minimum leakage" is calculated by:

On distribution pipes (Lm) =	18 litres/km mains/day/metre of pressure +
On service connections (Nc) =	0.8 litres/service connection/day/metre of pressure (property boundary) +
On customer supply pipes (Lp) =	25 litres/km/day/metre of pressure (to customer meter)

PPIAF Enabling Infrastructure Investment — WORLD BANK GROUP Water

Method 1 – Infrastructure Leakage Index (ILI)

Data required to calculate Minimum Achievable Leakage:

DMA Data	Units	Source
Total length of pipe (Lm)	Km	Measured from GIS maps
Number of connections (Nc)	Number	Billing database
Total Service connection length (Lp)	Km	Estimate
Average DMA pressure	Metre	Logger data
Minimum Achievable Annual Volume of Physical Losses	m^3 / day	Calculation

On distribution pipes (Lm) =	18 litres/km mains/day/metre of pressure +
On service connections (Nc) =	0.8 litres/service connection/day/metre of pressure (property boundary) +
On customer supply pipes (Lp) =	25 litres/km/day/metre of pressure (to customer meter)

PPIAF Enabling Infrastructure Investment — WORLD BANK GROUP Water

Method 1 – Infrastructure Leakage Index (ILI)

Example calculation for Minimum Achievable Leakage of a DMA:

DMA Data	Value	Units
Total length of pipe (Lm)	4.81	Km
Number of connections (Nc)	1,196	Number
Total Service connection length (Lp)	3.6 (each at 3m)	Km
Average DMA pressure	11.7	Metre
Minimum Achievable Annual Volume of Physical Losses	13.20	m^3 / day

Min Leakage = [(18x 4.81 x11.7) + (0.8 x 1,196 x 11.7) + (25 x 3.6 x 11.7)]/1000

Min Achievable Leakage for DMA = 13.20 m^3/day

On distribution pipes (Lm) =	18 litres/km mains/day/metre of pressure +
On service connections (Nc) =	0.8 litres/service connection/day/metre of pressure +
On customer supply pipes (Lp) =	25 litres/km/day/metre of pressure (to customer meter)

PPIAF Enabling Infrastructure Investment — WORLD BANK GROUP Water

Method 1 – Infrastructure Leakage Index (ILI)

Evaluating Infrastructure Leakage Index

$$\text{Infrastructure Leakage Index} = \frac{\text{Actual Leakage}}{\text{Minimum Achievable Leakage}}$$

ILI Range	Band	Leakage Reduction
< 4	A	Further loss reduction may be uneconomical
4 to < 8	B	Lower priority
8 to < 16	C	Medium Priority
≥ 16	D	High Priority

PPIAF Enabling Infrastructure Investment — WORLD BANK GROUP Water

Method 1 – Infrastructure Leakage Index (ILI)

Evaluating Infrastructure Leakage Index

	DMA 1	DMA 2	DMA 3	DMA 4	DMA 5	DMA 6
Actual Leakage	776	180	51	92	400	210
Minimum Possible Leakage	13.2	14.9	17.1	16.4	11.4	14.6
ILI	59	12	3	6	35	14
Category	D	C	A	B	D	C

ILI Range	Band	Leakage Reduction
< 4	A	Further loss reduction may be uneconomical
4 to < 8	B	Lower priority
8 to < 16	C	Medium Priority
≥ 16	D	High Priority

PPIAF Enabling Infrastructure Investment

WORLD BANK GROUP Water

Guideline Targets for ILI

Technical Performance Category		ILI	Physical Losses [Litres/connection/day] (when the system is pressurised) at an average pressure of:				
			10 m	20 m	30 m	40 m	50 m
Developed Countries	A	1 - 2		< 50	< 75	< 100	< 125
Developed Countries	B	2 - 4		50-100	75-150	100-200	125-250
Developed Countries	C	4 - 8		100-200	150-300	200-400	250-500
Developed Countries	D	> 8		> 200	> 300	> 400	> 500
Developing Countries	A	1 - 4	< 50	< 100	< 150	< 200	< 250
Developing Countries	B	4 - 8	50-100	100-200	150-300	200-400	250-500
Developing Countries	C	8 - 16	100-200	200-400	300-600	400-800	500-1000
Developing Countries	D	> 16	> 200	> 400	> 600	> 800	> 1000

PPIAF Enabling Infrastructure Investment

WORLD BANK GROUP Water

Conclusion

- NRW is a well developed area but global losses are still high, solution?

A reinvigorated public sector
Or
The private sector (skills and equipment)
+
Performance based contracts (incentives)

PPIAF Enabling Infrastructure Investment

WORLD BANK GROUP Water

Further Questions? Contact us

Gerard Soppe
Sr. Water and Sanitation Specialist
gsoppe@worldbank.org

Jemima Sy
Sr. Infrastructure Specialist
(Private Sector Development)
jsy@worldbank.org

WORLD BANK GROUP Water

www.wsp.org | www.worldbank.org/water | www.blogs.worldbank.org/water | @WorldBankWater

Physical Losses (Leakage)

Leakage is the water escaping from the distribution network before reaching the customer

This is usually in the form of leaks from the:

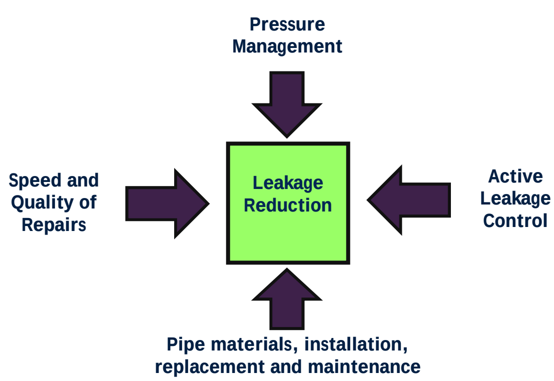
- **Transfer and distribution pipes;**
- **Joints and fittings including air valves, hydrants etc;**
- **Service reservoir floors and walls;**
- **Reservoir overflows; and**
- **Service connections up to the point of customer boundary or meter**

PPIAF Enabling Infrastructure Investment

WORLD BANK GROUP Water

The Four Approaches to Leak Reduction

Prioritise Leak Reduction Approach



PPIAF Enabling Infrastructure Investment

WORLD BANK GROUP Water

Key Components of Commercial Loss

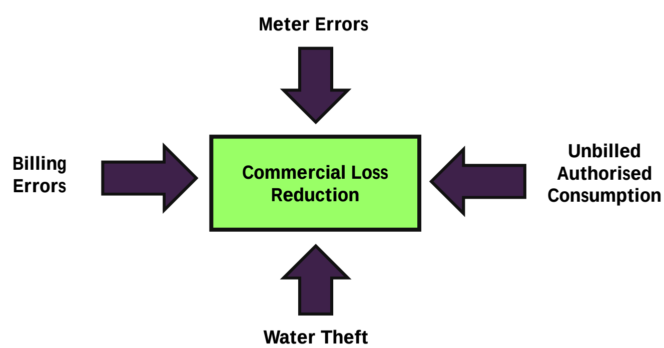
Commercial Loss	Component
Unbilled Authorised Consumption	**Unbilled Authorised Consumption:** • E.g. fire water, sewer cleaning, pipe flushing etc)
Apparent Losses	**Unauthorised Consumption:** • Billing errors e.g. legitimate connection where billing team not informed, or no action taken (intentional and accidental) • Permanent or temporary meter bypass • Illegal connections
	Revenue Meter Inaccuracies and Data Handling Errors: • Volume under-recorded by revenue meter due to its condition • Over-sized revenue meters • Meter tampering (water theft) • Meter reader and customer collusion (water theft) • 'Fictitious' readings (water theft) • Data handling errors

PPIAF Enabling Infrastructure Investment

WORLD BANK GROUP Water

The Four Approaches to Leak Reduction

Prioritise Commercial Loss Approach

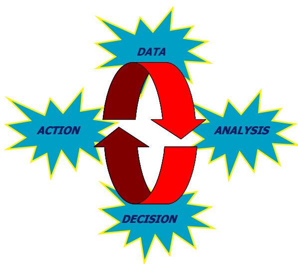


PPIAF Enabling Infrastructure Investment

WORLD BANK GROUP Water

Importance of Accurate and Reliable Data

- Measuring and collecting accurate and reliable data is critical
- We must have confidence that the water balance is accurate
- Otherwise we may waste money chasing non-existing water losses
- And our benchmark and NRW reduction progress will be in doubt
- Best practice is to allocate owners who will be responsible for collecting and reporting data



- **Review the correct Data**
- **Do the correct Analysis**
- **And you will make the correct Decision**
- **And take the correct Action**
- **NRW will reduce**

PPIAF Enabling Infrastructure Investment

WORLD BANK GROUP Water

Example DMA Data to Collect and Analyze

NRW Component	Example Data to Collect and Analyse For each DMA
DMA Water Supply Volume	Flow data from DMA meter
Billed water consumption	Billing database
Unbilled Authorised Consumption	Fire hydrants, pipe flushing, fountains etc
Illegal connections	Check GIS property number v actual property in DMA v billing database
Billing and data handling errors	Same as illegal connections Check billing database against actual meter readings
Meter Tampering	Analyse information from meter reading / meter replacement team
Revenue meters errors	Sample each age of meter and test accuracy Check meter is sized correctly Check meter is installed correctly
Leakage	DMA night line and legitimate night time consumption

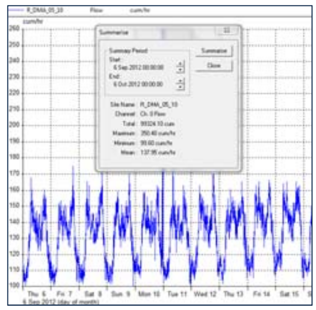
PPIAF Enabling Infrastructure Investment

WORLD BANK GROUP Water

DMA Water Supply Input Volume

The volume of water entering a DMA over a fixed period of time

- Try to coincide the period of time with the DMA billing period
- Calculated by:
  - ➢ Physically reading the DMA meter at the start and end of the period
  - ➢ Analysing the flow data at the office (if meter fitted with GPRS / SMS)



PPIAF Enabling Infrastructure Investment

WORLD BANK GROUP Water

DMA Billed Water Consumption

The volume of billed water in a DMA over a fixed period of time

- Billed volume taken from the monthly billing database
- Try and read the customer meters on the same day

DMA	Month	Customer ID	Name	Address	Water Meter Size	Last reading	New Reading	Last Meter Read Date	New Meter Reading Date	Days of Period	Metered Consumption
05-01	12	10142370091	DOAN NGOC KHOA	DIEN BIEN PHU	15	627	671	16/11/2011	15/12/2011	29	44
05-01	12	10202930229	TRAN THI TUYET XINH	THANH THAI	15	204	204	27/10/2011	28/11/2011	32	0
05-01	12	10243320151	VU HUY TU	CC 830 SU VAN HANH	15	137	143	08/11/2011	08/12/2011	30	6
05-01	12	11011020010	LAI SAN MIEN	PHU THO	15	921	958	21/10/2011	21/11/2011	31	37
05-01	12	11011020011	LUU HONG NGOC	PHUTHO	15	1345	1397	21/10/2011	21/11/2011	31	52
05-01	12	11011020020	CHUA SUNG DUC	HONG BANG	15	2407	2469	21/10/2011	21/11/2011	31	62
05-01	12	11011020022	NG NGOC SANG	(SAN CHUA SUNG DUC)	15	608	726	21/10/2011	21/11/2011	31	118
05-01	12	11011020029	LE ANH TUAN	PHU THO	15	1189	1236	21/10/2011	21/11/2011	31	47
05-01	12	11011020030	CHENH A CAU	PHU THO	15	73	85	21/10/2011	21/11/2011	31	12
05-01	12	11011020040	NGUYEN AN MY	PHU THO	15	139	167	21/10/2011	21/11/2011	31	28
05-01	12	11011020041	NG BINH MINH	PHU THO	15	1106	1153	21/10/2011	21/11/2011	31	47
05-01	12	11011020050	DO TO	PHU THO	15	0	50	21/10/2011	21/11/2011	31	104
05-01	12	11011020060	TRAN AN TRAN	PHU THO	15	2415	2454	21/10/2011	21/11/2011	31	39
05-01	12	11011020070	LIEN CHIEU DUC	PHU THO	15	36	43	21/10/2011	21/11/2011	31	7
05-01	12	11011020071	NG THI HOANG	PHU THO	15	971	971	21/10/2011	21/11/2011	31	0
05-01	12	11011020075	HOANG VAN TAM	PHU THO	15	1052	1077	21/10/2011	21/11/2011	31	25

PPIAF Enabling Infrastructure Investment

WORLD BANK GROUP Water

Unbilled Authorized Consumption

What is Unbilled Authorised Consumption?

- Water legitimately consumed but not billed
- Cannot be reduced unless there is a change in policy
- Still should be metered as part of the water balance
- This can be:
  - Water fountains
  - Pipe and sewer flushing
  - Water bowsers
  - Watering parks and gardens / sprinklers
  - Public drinking fountains
  - Fire fighting – e.g. hydrants

PPIAF Enabling Infrastructure Investment

WORLD BANK GROUP Water

Illegal Connections

Illegal connections are Customers who have connected to the water network without notifying the water company; these can be:

1. Permanent connections to properties; or
2. Temporary connections for building, construction sites etc

- Loss of revenue to the water company
- Connections are likely to be poor quality – often leaking and source of contamination
- Encourages others to illegally connect

PPIAF Enabling Infrastructure Investment

WORLD BANK GROUP Water

Reducing Illegal Connections

- For each DMA, take a copy of the billing database, and GIS plan showing all properties and their reference number
- Walk the DMA; check the GIS plan is up to date and billing database accurate
- Identify properties that mismatch with the GIS plan and billing database
- Identify properties not on billing database; investigate and take action
- Update the GIS plan and billing database

Billing and Data Handling Losses

Billing and data handling losses generally comprise:

1. Legal connections not recorded on the billing database (accidental or on purpose)
2. Data errors between the meter reading and the customer's bill
3. Billing errors due to broken / tampered customer meters

Broken customer meters

To complete the water balance, we have to identify the 'lost' water volume from billing and data handling errors

Reducing Billing Errors

- Using the same methodology for reducing illegal connections, identify legal connections not on the billing database
- Audit the end-to-end processes and make improvements (if any) for:
  - Meter read to the bill being paid
  - Estimated readings
  - Replacing meters
  - Billing reports
- Rotate meter readers to avoid customer collusion
- Use hand held meter reading devices to avoid data errors

Spot billing minimises data handling errors.

Hand held printed bill

PPIAF Enabling Infrastructure Investment

WORLD BANK GROUP Water

Meter Tampering

Meter tampering is customers illegally altering the revenue meter so they pay less money; common methods are:

1. Inserting a pin or needle to stop the totaliser moving
2. Blocking the meter inlet or chamber
3. Placing a powerful magnet to break the magnetic coupling of impellors and gears
4. Reversing the meter
5. Temporary removal of the meter
6. Hitting the meter hard – some meters now come with an impact warning system
7. Cutting or damaging the impellor

To complete the water balance, we have to identify the reduced consumption of these tampered meters

PPIAF Enabling Infrastructure Investment

WORLD BANK GROUP Water

Examples of Meter Tampering

Pipe used to partially bypass water meter.

Water meter removed and replaced with straight pipe.

Meter magnet

PPIAF Enabling Infrastructure Investment

WORLD BANK GROUP Water

What is the Impact of Meter Tampering

Water is being consumed without the full volume being measured and billed

- Loss of revenue to the water company
- Encourages others to tamper meters

Reducing the risk of meter tampering:

- Select good quality meters that have anti-tampering devices
  - Impact alarms
  - Magnet proof
  - Toughened bodies and dial
  - Meter seals
  - Non return valves

The Elster V100
has all these features

PPIAF Enabling Infrastructure Investment

WORLD BANK GROUP Water

Reducing Meter Tampering – Proactive Approach

For each DMA:

- Set alarms in the billing system for:
  - Large variations in monthly consumption
  - Substantially reduced consumption compared to similar occupied households
- Establish an anonymous and free telephone number for reporting suspect meter fraud
- Enforce and prosecute customers who have committed meter fraud (this may also include plumbing / meter installation companies)
- Identify those DMA with frequent meter tampering for targeted publicity, education and enforcement
- Train the meter readers on how to detect tampered meters
- Regularly and randomly rotate meter readers

PPIAF Enabling Infrastructure Investment — WORLD BANK GROUP Water

Reducing Meter Tampering – Reactive Approaches

1) Billing database Showing occupied properties with no billed consumption

Customer ID	Consumption Norm ($4m^3$ x occ rate)	Meter Status Code	Billed Consumption (m^3)
11011020166	16	4	0
11011041260	16	4	0
11011041350	8	4	0
11011061020	4	4	0
11011061252	24	4	0

2) Exceptionally Low Consumption for Investigation

	No. of meters registering 50% or less of the Normal Consumption			
Consumption Norm (4m3 x occ rate)	1 m^3/month	2 m^3/month	3 m^3/month	4 m^3/month
4 m^3	36	27		
8 m^3	38	24	28	1,878
12 m^3	52	37	37	2,841
16 m^3	93	72	63	4,995
20 m^3	45	35	36	2,585

It can be seen that 3 m^3/month or less is unusual and should be investigated for fraud or meter error

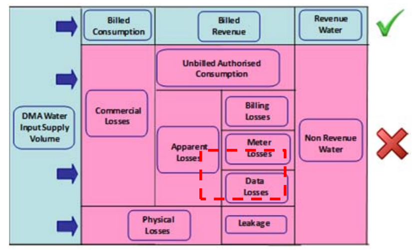
It can be seen that 4 m^3/month is common

PPIAF Enabling Infrastructure Investment — WORLD BANK GROUP Water

Revenue Meter Errors

Meter errors are produced by the following:

1. Incorrect sizing
2. Their Class
3. Their condition:
   - Age
   - Water quality
   - Maintenance regime
4. Incorrect installation



Impact of meter errors:

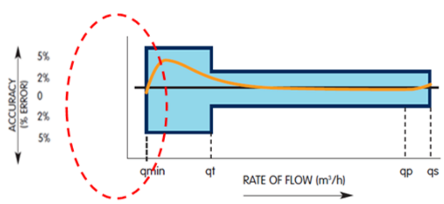
1. Almost all meter errors result in them under-reading
2. The meters will read less than the actual water volume being consumed;
3. Consequently, a proportion of the consumed water is not billed to the customer – loss in revenue

PPIAF Enabling Infrastructure Investment

WORLD BANK GROUP Water

Meter Errors – Incorrect Size (too big)

1. Over-sized meters result in under-reading as the meter cannot detect low flows



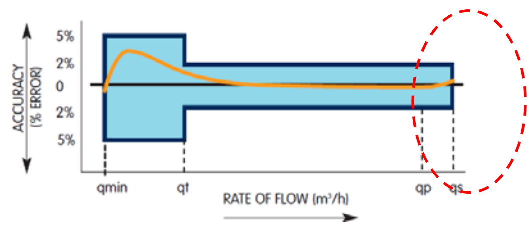
This 150mm meter should have been 80 mm; it under-reads by 15%

PPIAF Enabling Infrastructure Investment

WORLD BANK GROUP Water

Meter Errors – Incorrect Size (too small)

- Under-sized meters also result in under-reading as the meter becomes damaged at high flows



- Electro-Magnetic meters have a better tolerance to size than mechanical meters:
  - ➢ No moving parts to damage
  - ➢ Wider flow range

PPIAF Enabling Infrastructure Investment

WORLD BANK GROUP Water

Meter Errors – Class

- There are four types of ISO meter classes: - A, B, C and D
- A = least accurate and D = most accurate for measuring low flows
- A = least expensive and D = most expensive
- It is important to measure low flows where customers have private water tanks – e.g. Vietnam

Meter Class	Q nominal	Q min
Class A	1.5 m^3/hour	60 litres / hour
Class B	1.5 m^3/hour	30 litres / hour
Class C	1.5 m^3/hour	15 litres / hour
Class D	1.5 m^3/hour	11.25 litres / hour

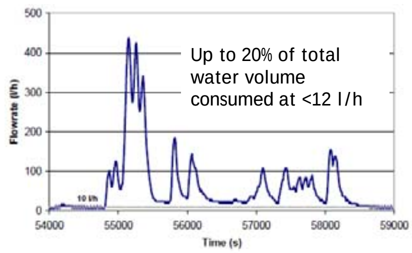
PPIAF Enabling Infrastructure Investment

WORLD BANK GROUP Water

Meter Error – Low Flow Class

Example meter error from a Class C revenue meter

Meter Class C	Low Flow Accuracy Error
< 12 l/h	100% under read
12 to 30 l/h	15% under-read
30 to 120 l/h	5% under-read



PPIAF
Enabling Infrastructure Investment

WORLD BANK GROUP
Water

Meter Errors – Condition Due to Age

- The older a meter is, the more it will under-read water volume
- The mechanics start to wear, causing increased friction
- The rate of deterioration is dependent on water quality and meter type
- The meters will reach a point where the loss in revenue justifies the cost of meter replacement
- The replacement age is different for each water company, as it is also a function of water tariff
- The economic age of replacement is typically between 5 and 12 years

PPIAF
Enabling Infrastructure Investment

WORLD BANK GROUP
Water

Meter Errors – Condition Due to Age

We need to:

- Determine the average accuracy of customer meters due to their age
- Identify whether the meter replacement policy is economically justified

Methodology:

- Remove a sample of working revenue meters for each age group
- Test the meter accuracy on a calibration testing machine
- Use the results to extrapolate the average meter under-read across each DMA; for example:

Age (years)	No. of Meters April 2010	Proportion	% Under Read	Consumption (m^3)	Under read (m^3)
0 - 5	7,868	33%	2%	212,442	4,248.8
6 - 10	5,957	25%	2%	160,858	3,217.2
11 - 15	5,538	23%	4%	149,545	5,981.8
16 - 20	2,391	10%	16%	64,555	10,328.7
>20	2,149	9%	30%	58,035	17,410.4
Total	**23,904**	**100%**	**5%**	**NRW**	**41,187**

PPIAF Enabling Infrastructure Investment   WORLD BANK GROUP Water

Meter Errors – Maintenance Regime

Meters operating in poor quality water require frequent filter cleaning to remove deposits:

- Blockages and mineral deposits cause meters to under-read
- Inaccuracy measured using same method as for age
- Does the water company use and clean meter filters?

PPIAF Enabling Infrastructure Investment   WORLD BANK GROUP Water

Meter Errors – Incorrect Installation

- Meters require upstream and downstream straight length pipes to provide uniform velocity profile
- In general:

Meter Type	Upstream Straight Length	Downstream Straight Length
Electro-Magnetic	3 x pipe diameter	2 x pipe diameter
Mechanical	10 x pipe diameter	5 x pipe diameter

- Insufficient straight length distance can result in both over-read and under-read errors (typically 2 to 5% error)
- An estimate for meter error will be required for the water balance

PPIAF Enabling Infrastructure Investment

WORLD BANK GROUP Water

Meter Errors – Incorrect Installation

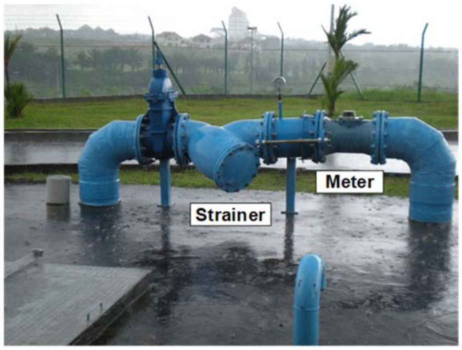
Wrong

Right

PPIAF Enabling Infrastructure Investment

WORLD BANK GROUP Water

Meter Issues – Factory Meter Example



Size and Installation:

- Meter oversized (300mm)
- Insufficient straight lengths
- Meter damaged by air in pipe
- Under-reads (this example by 7,000m^3/month)
- Significant revenue loss
- Contributes to NRW
- Customer unaware of his true water consumption

PPIAF Enabling Infrastructure Investment

WORLD BANK GROUP Water

Meter Errors – Mounting Position Errors

- Domestic meters are sensitive to their mounting position
- Using Single Jet Meters as an example

Meter Class	Horizontal Position	45º Position	Vertical Position
Class B	- 1.2%	- 4.5%	- 7.9%
Class C	+ 1.3%	- 2.9%	- 6.0%

- Volumetric meters are generally unaffected by mounting position
- An estimate for meter error will be required for the water balance

PPIAF Enabling Infrastructure Investment

WORLD BANK GROUP Water

Meter Error Action Plan

#	Potential Meter Issue	Action
1	Meter Size	• Survey sample meters • Prioritise under-reading meters for replacement • If required, establish procedure for sizing new meters
2	Meter Age	• Establish age of meters • Sample different age meters for accuracy • Develop a prioritised and economic meter replacement programme
3	Meter Maintenance	• Take sample meters from different areas • Establish extent of meter blockages • Identify best economic policy – reactive or proactive maintenance
4	Meter installation	• Survey meter installations and evaluate • Identify any large industrial meters for re-locating • If required, establish standard meter installation designs
5	Meter Mounting	• Survey meter mountings and evaluate • If required, establish standard meter installation designs

Calculating DMA Leakage

There are two methods to calculate DMA leakage:

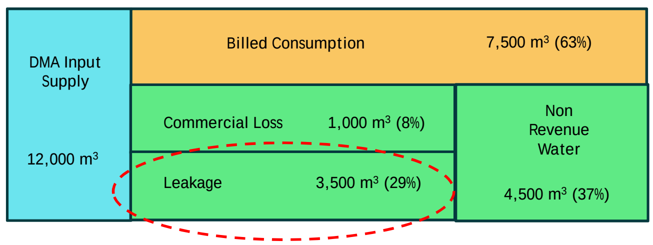
1. Top-Down – subtract the Commercial Losses from the NRW
2. Bottom-Up – Measure the Minimum Night Flow and subtract the Legitimate Night Flow; then apply a pressure correction factor

- Top-Down method is easier to calculate, but less accurate as many of the Commercial Loss components are estimated
- Bottom-Up method requires complex measurement, but gives an accurate leakage figure

Best practice is to use both methods and compare as a 'check'

Calculating Leakage Using the Top-Down Method

1. Measure the monthly water into and out of the DMA to calculate the DMA input supply volume
2. Calculate the billed water volume for that period
3. Calculate the NRW by subtracting the billed volume from the supply volume
4. Estimate the Commercial Losses in the DMA
5. Subtract the Commercial Losses from the NRW to calculate leakage



PPIAF Enabling Infrastructure Investment

WORLD BANK GROUP Water

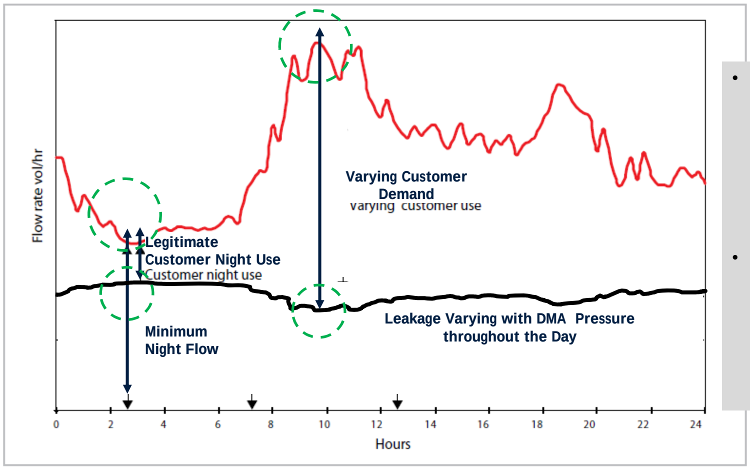
Estimating Commercial Loss for the Top-Down Method

Commercial Loss Component	Data Source and Assumptions	Estimated NRW (m^3/day)	Estimated NRW (%)
Unbilled Authorised Consumption	Billing department; fire hydrants metered when flushing	120	1%
Billing Errors	Billing database checked against GIS and walked DMA – no errors	0	0%
Illegal Connections	Average value from GIS / DMA and billing database check	50	0.4%
Meter inaccurate – age	Meter sample calibration test (meters average under read of 5%)	375	3.1%
Meter inaccurate –class	Class B meters under read test	150	1.3%
Meter inaccurate – size	Large revenue meter audit	0	0%
Meter inaccurate - installation	Meter audit – meters installed correctly	0	0%
Meter inaccurate - Tampering	Data taken from meter repair / calibration workshop	225	1.9%
Data Handling Errors	Meter reading audit	80	0.7%
Commercial Loss		1,000	8.3%

PPIAF Enabling Infrastructure Investment

WORLD BANK GROUP Water

Calculating Leakage Using the Bottom-Up Method



- Peak demand = lowest DMA pressure = lowest level of daily leakage
- Night demand = highest DMA pressure = highest level of daily leakage

PPIAF Enabling Infrastructure Investment

WORLD BANK GROUP Water

Calculating Leakage Using the Bottom-Up Method

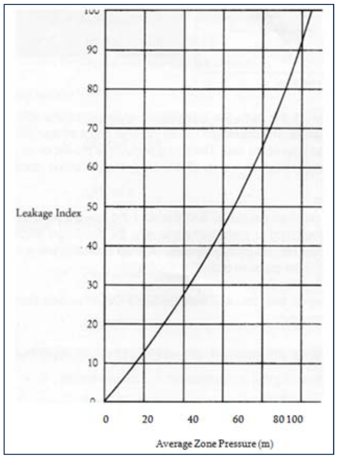
- Identify the Minimum Night Flow (MNF) from the logged DMA meter
- The MNF is the lowest hourly average flow into the DMA over a 24-hour period
- Identify typical Legitimate Night Flow (LNF)
  - ➢ Domestic customers – toilet flushing, washing machines etc; use a standard legitimate night time factor, or measured sample
  - ➢ Large exceptional commercial users (>500 l/h) – manually night time read or log the meter
- Calculate the Net Night Flow: NNF = MNF – LNF
- Leakage is proportional to pressure, so we need to adjust the NNF to represent the average leakage through the day
- Apply a pressure correction factor; typically:
  - ➢ average daily DMA pressure / MNF pressure

The calculated volume is the DMA leakage

PPIAF Enabling Infrastructure Investment

WORLD BANK GROUP Water

Pressure and Leakage Relationship



- The relationship between pressure and leakage is almost linear
- A 10% decrease in pressure can produce a 10% decrease in leakage
- Reducing pressure is the most cost effective method for reducing leakage

PPIAF Enabling Infrastructure Investment

WORLD BANK GROUP Water

Calculating Leakage Using the Bottom-Up Method – Example

Minimum Night Flow into DMA (MNF)	**= 13 m^3/hour**
Number of domestic connections in DMA	= 500
Average DMA occupancy rate	= 5
Legitimate Domestic Night Use factor Note 1	= 1.7 litres / person / hour
Legitimate Domestic Night Use = 500 x 5 x 1.7 / 1000	= 4.25 m^3/hour
Measured Exceptional Night Use	= 1 m^3/hour
Night leakage (L_0) = 13 – 4.25 – 1	= 7.75 m^3/hour
Measured night pressure ($P_{0)}$)	= 25 metres
Measured average DMA pressure (P_1)	= 15 metres
Therefore average DMA leakage (L_1) = 7.75 x (15/25)	= 4.65 m^3/hour
Or, average DMA leakage (L_1)	**= 3,348 m^3/month**

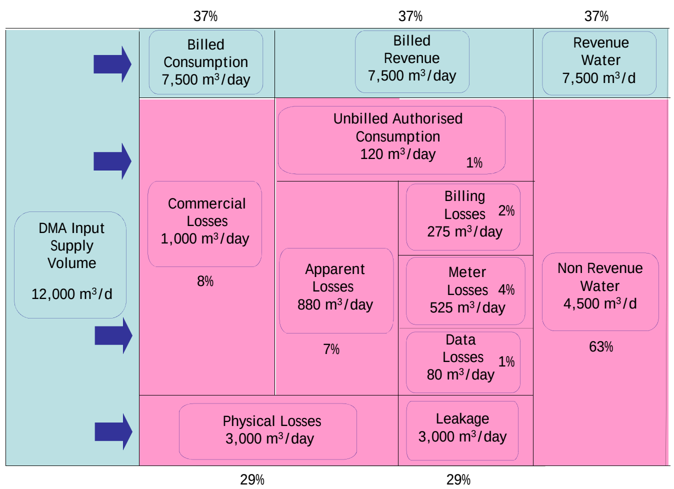
Note 1 – IWA Standard Factor

Compares well with the Top-Down leakage result of 3,500 m^3/month

PPIAF Enabling Infrastructure Investment

WORLD BANK GROUP Water

Completed IWA Water Balance

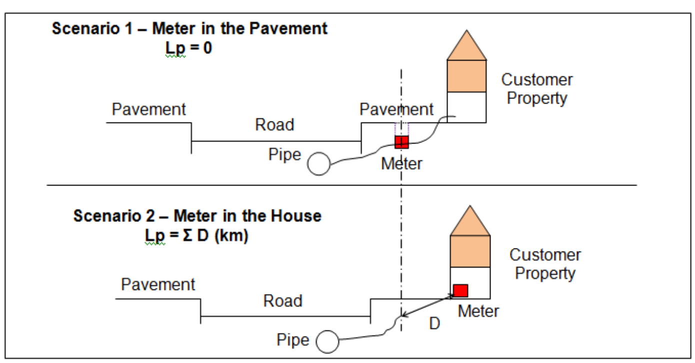


PPIAF Enabling Infrastructure Investment

WORLD BANK GROUP Water

Measuring Customer Supply Pipe Length

Lp is the sum of the pipe lengths from the property boundary to the customer meter



Easier to estimate an average distance 'D' for the DMA (Lp = Σ D)

PPIAF Enabling Infrastructure Investment

WORLD BANK GROUP Water

Method 1 – Infrastructure Leakage Index

Evaluating Infrastructure Leakage Index

	DMA 1	DMA 2	DMA 3	DMA 4	DMA 5	DMA 6
Actual Leakage	776	180	51	92	400	210
Minimum Possible Leakage	13.2	14.9	17.1	16.4	11.4	14.6
ILI	59	12	3	6	35	14
Category	D	C	A	B	D	C

ILI Range	Band	Leakage Reduction
< 4	A	Further loss reduction may be uneconomical
4 to < 8	B	Lower priority
8 to < 16	C	Medium Priority
≥ 16	D	High Priority

PPIAF Enabling Infrastructure Investment — WORLD BANK GROUP Water

Method 2 – Leakage / Connections / Day

Evaluating the Leakage / Connections / Day

- Simply divide the DMA daily leakage by the number of service connections
- Then reference the performance category from the average DMA pressure
- Example - if the average DMA pressure is 10 m:

NRW Management Performance Category	NRW in litres/connection/day when the system is pressurised at an average DMA pressure of:				
	10m	20m	30m	40m	50m
A1	<55	<80	<105	<130	<155
A2	55-110	80-160	105-210	130-260	155-310
B	110-220	160-320	210-420	260-520	310-620
C	220-400	320-600	420-800	520-1000	620-1200
D	>400	>600	>800	>1000	>1200

PPIAF Enabling Infrastructure Investment — WORLD BANK GROUP Water

Method 2 – Leakage / Connections / Day

Evaluating the Leakage / Connections / Day

	DMA 1	DMA 2	DMA 3	DMA 4	DMA 5	DMA 6
Actual Leakage	776	180	51	92	400	210
# of Connections	1,196	1,515	1,603	1,652	1,298	1,573
Leakage / connection	648	119	32	56	308	133
Category	D	B	A1	A2	C	B

NRW Management Performance Category	NRW in litres/connection/day when the system is pressurised at an average DMA pressure of:				
	10m	20m	30m	40m	50m
A1	<55	<80	<105	<130	<155
A2	55-110	80-160	105-210	130-260	155-310
B	110-220	160-320	210-420	260-520	310-620
C	220-400	320-600	420-800	520-1000	620-1200
D	>400	>600	>800	>1000	>1200

PPIAF Enabling Infrastructure Investment — WORLD BANK GROUP Water

Leakage Target Setting Using ILI

	DMA 1	DMA 2	DMA 3	DMA 4	DMA 5	DMA 6
Actual Leakage	776	180	51	92	400	210
Leak Reduction Volume	700	90	0	0	330	120
Target leakage (m^3/day)	76	90	51	92	70	90
Minimum Possible Leakage	13.2	14.9	17.1	16.4	11.4	14.6
ILI	6	6	3	6	6	6
Category	B	B	A	B	B	B

ILI Range	Band	Leakage Reduction
< 4	A	Further loss reduction may be uneconomical
4 to < 8	B	Lower priority
8 to < 16	C	Medium Priority
≥ 16	D	High Priority

PPIAF Enabling Infrastructure Investment — WORLD BANK GROUP Water

Leakage Target Setting Using L/C/D of Pressure

	DMA 1	DMA 2	DMA 3	DMA 4	DMA 5	DMA 6
Actual leakage	776	180	51	92	400	210
Number of connections	1,196	1,515	1,603	1,652	1,298	1,573
Target leakage (m^3/day)	700	90	0	0	334	117
Leakage after project	76	90	51	92	66	93
Leakage / connection	63	59	32	56	51	59
Category	**A2**	**A2**	**A1**	**A2**	**A2**	**A2**

NRW Management Performance Category	**NRW in litres/connection/day when the system is pressurised at an average DMA pressure of:**				
	10m	**20m**	**30m**	**40m**	**50m**
A1	<55	<80	<105	<130	<155
A2	55-110	80-160	105-210	130-260	155-310
B	110-220	160-320	210-420	260-520	310-620
C	220-400	320-600	420-800	520-1000	620-1200
D	>400	>600	>800	>1000	>1200