Non-Revenue Water Assessment

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1.1 General

Why is Non-Revenue Water (NRW) assessment so important for any water utility? It is common knowledge that the NRW in any water utility is a percentage of the water volume pumped into the network - but this simple percentage figure just isn't sufficient to understand the water utility' problem and elaborate an appropriate reduction strategy.

Therefore it was necessary to apply the nowadays available methods and tools which had helped to establish a first baseline. The following pages provide a brief overview on the methodology and the related terminology.

1.2 Methodology

Twenty years ago, leakage management was more based on a process of 'guesstimation' than on precise science. This has changed dramatically, kick-started by the regulatory pressure on UK water companies to cut leakage. Significant advances have been made in the understanding and modeling of water loss components and on defining the economic level of leakage for individual system. Yet, despite some encouraging success stories, most water supply systems worldwide continue to have high levels of water losses, many of which are almost certainly higher than their economic level.

Part of the problem was the lack of a meaningful standard approach to benchmarking and reporting of leakage management performance. Surprisingly few countries have a national standard terminology and standard water balance calculation …and even then, they all differ from each other!

Being aware of the problem of different water balance formats, methods and leakage performance indicators, the International Water Association (IWA) has developed a standard international water balance structure and terminology.

This standard format has meanwhile been adopted (with or without modifications) by national associations in a number of countries (for example Canada, Germany, Australia, New Zealand and South Africa and most recently the American Water Works Association (AWWA).

This standard methodology is described in this paper which also includes a number of important leakage management definitions.

1.2.1 The Standard Water Balance

The level of water losses can be determined by conducting a Water Audit (North American Term) with the results shown in a Water Balance (International Term). To be consistent with the new international terminology, the term Water Balance has been used in this report.

A Water Balance is based on measurements or estimations of water produced, imported, exported, used and lost. Whilst most water utilities are able to provide estimates of water produced, imported, exported and consumed, they are less able to quantify the different components of water lost.

Water utilities around the world have always established water balances in one or the other way. But unfortunately, a wide diversity of formats and definitions is used, often within the same country. So it was (and still is) virtually impossible to compare UfW, NRW, leakage or water losses of different utilities.

Being aware of the problem of different water balance formats and methods, the IWA has developed a standard international water balance structure and terminology, as already mentioned above. This form was generated drawing on the best practice of water utilities from many countries. Figure 1 below shows the IWA standard water balance.

<table>
<tr><td rowspan="9">System Input Volume</td><td rowspan="4">Authorized Consumption</td><td rowspan="2">Billed Authorized Consumption</td><td>Billed Metered Consumption (including water exported)</td><td rowspan="2">Revenue Water</td></tr>
<tr><td>Billed Unmetered 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 Unmetered Consumption</td></tr>
<tr><td rowspan="5">Water Losses</td><td rowspan="2">Apparent Losses</td><td>Unauthorized Consumption</td></tr>
<tr><td>Metering Inaccuracies</td></tr>
<tr><td rowspan="3">Real Losses</td><td>Leakage on Transmission and/or Distribution Mains</td></tr>
<tr><td>Leakage and Overflows at Utility's Storage Tanks</td></tr>
<tr><td>Leakage on Service Connections up to point of Customer metering</td></tr>
</table>

Figure 1: Standard IWA Water Balance

1.2.2 Water Balance Definitions

In the following, all terms used in Figure 1 above are listed in hierarchical order – as one would read the water balance form from left to right. Some of the terms are self-explanatory but are still listed and briefly explained in order to having a complete list available.

System Input Volume

The volume of treated water input to that part of the water supply system to which the water balance calculation relates – either from own production facilities or bulk supplies from others. If problems with production meters are know, relevant corrections will be made to the System Input Volume.

Authorized Consumption

The volume of metered and/or unmetered water taken by registered customers, the water supplier and others who are implicitly or explicitly authorized to do so by the water supplier, for residential, commercial and industrial purposes. It also includes water exported across operational boundaries.

Authorized consumption may include items such as fire fighting and training, flushing of mains and sewers, street cleaning, watering of municipal gardens, public fountains, frost protection, building water, etc. These may be billed or unbilled, metered or unmetered.

Water Losses

The difference between System Input and Authorized Consumption. Water losses can be considered as a total volume for the whole system, or for partial systems such as transmission or distribution schemes, or individual zones. Water Losses consist of Real Losses and Apparent Losses.

Billed Authorized Consumption

Those components of Authorized Consumption which are billed and produce revenue (also known as Revenue Water). Equal to Billed Metered Consumption plus Billed Unmetered Consumption.

Unbilled Authorized Consumption

Those components of Authorized Consumption which are legitimate but not billed and therefore do not produce revenue. Equal to Unbilled Metered Consumption plus Unbilled Unmetered Consumption.

Apparent Losses

Includes all types of inaccuracies associated with customer metering as well as data handling errors (meter reading and billing), plus unauthorized consumption (theft or illegal use).

Note: Over-registration of customer meters, leads to under-estimation of Real Losses. Under-registration of customer meters, leads to over-estimation of Real Losses.

Real Losses

Physical water losses from the pressurized system and the utility's storage tanks, up to the point of customer use. In metered systems this is the customer meter, in unmetered situations this is the first point of use (stop tap/tap) within the property.

The annual volume lost through all types of leaks, bursts and overflows depends on frequencies, flow rates, and average duration of individual leaks, bursts and overflows.

> Note: Although physical losses, after the point of customer use, are excluded from the assessment of Real Losses, this does not necessarily mean that they are not significant or worthy of attention for demand management purpose.

Billed Metered Consumption

All metered consumption which is also billed. This includes all groups of customers such as domestic, commercial, industrial or institutional and also includes water transferred across operational boundaries (water exported) which is metered and billed.

Billed Unmetered Consumption

All billed consumption which is calculated based on estimates or norms but is not metered. This might be a very small component in fully metered systems (for example billing based on estimates for the period a customer meter is out of order) but can be the key consumption component in systems without universal metering. This component might also include water transferred across operational boundaries (water exported) which is unmetered but billed.

Unbilled Metered Consumption

Metered Consumption which is for any reason unbilled. This might for example include metered consumption by the utility itself or water provided to institutions free of charge, including water transferred across operational boundaries (water exported) which is metered but unbilled.

Unbilled Unmetered Consumption

Any kind of Authorized Consumption which is neither billed nor metered. This component typically includes items such as fire fighting, flushing of mains and sewers, street cleaning, frost protection, etc. In a well run utility it is a small component which is very often substantially overestimated. Theoretically this might also include water transferred across operational boundaries (water exported) which is unmetered and unbilled – although this is an unlikely case.

Unauthorized Consumption

Any unauthorized use of water. This may include illegal water withdrawal from hydrants (for example for construction purposes), illegal connections, bypasses to consumption meters or meter tampering.

Customer Metering Inaccuracies and Data Handling Errors

Apparent water losses caused by customer meter inaccuracies and data handling errors in the meter reading and billing system.

Leakage on Transmission and/or Distribution Mains

Water lost from leaks and bursts on transmission and distribution pipelines. These might either be small leaks which are still unreported (e.g. leaking joints) or large bursts which were reported and repaired but did leak for a certain period before that.

Leakage and Overflows at Utility's Storage Tanks

Water lost from leaking storage tank structures or overflows of such tanks caused by e.g. operational or technical problems.

Leakage on Service Connections up to point of Customer Metering

Water lost from leaks on service connections from (and including) the tapping point until the point of customer use. In metered systems this is the customer meter, in unmetered situations this is the first point of use (stop tap/tap) within the property. Leakage on service connections might be reported bursts but will predominately be small leaks which do not surface and which run for long periods (often years).

Revenue Water

Those components of Authorized Consumption which are billed and produce revenue (also known as Billed Authorized Consumption). Equal to Billed Metered Consumption plus Billed Unmetered Consumption.

Non-Revenue Water

Those components of System Input which are not billed and do not produce revenue. Equal to Unbilled Authorized Consumption plus Real and Apparent Water Losses.

(Unaccounted-for Water)

Because of the widely varying interpretations and definitions of the term 'Unaccounted for Water', the IWA strongly recommends not to use this term any more – an if it is used at least to be defined like Non-Revenue Water.

1.2.3 Selected Water Loss Management Definitions

This section covers some of the most important water loss management terms – important for the understanding of the entire approach. Unlike the water balance definitions, they are in alphabetical order.

Active Leakage Control (ALC)

ALC is the policy a water utility implements if it decides to pro-actively search for hidden leaks. ALC in its most basic form consists of regular sounding (e.g. listening to leak noise on fire hydrants, valves and curb stops with listening sticks or electronic devices).

Awareness Duration

Awareness Duration is the average time from the occurrence of a leak until the water utility becomes aware of its existence. The awareness time is influenced by the type of applied ALC policy.

Background Losses

Background losses are individual events (small leaks and weeps) that will continue to flow, with flow rates too low to be detected by an active leakage control campaign unless either detected by chance or until they gradually worsen to the point that they can be detected.

Bursts

Events with flow rates grater than those of background losses and therefore detectable by standard leak detection techniques. Bursts can be visible or hidden.

BABE Concepts

The Bursts And Background Estimates (BABE) concepts were developed by the UK National Leakage Initiative between 1991 and 1993. The concepts were the first to model physical leakage objectively, rather than empirically, thus permitting rational planning management and operational control of strategies for their reduction.

Component Analysis

Determination and quantification of the components of real losses in order to calculate the expected level of real losses in a distribution system. The BABE concepts were the first component analysis model.

Current Annual Real Losses (CARL)

The volume of water lost from all kind of leaks (Bursts and Background Losses) during the (annual) reporting period. This includes water lost from (still) hidden bursts as well as from bursts which were found and repaired during the year. It also includes possible losses at the utility's storage tanks and is equal to the component Real Losses of the Annual Water Balance.

District Metered Area (DMA)

Hydraulically discreet part of the distribution network, ideally with one but sometimes with two or more inflow points equipped with bulk meters. District metering involves the permanent monitoring of minimum night flows into DMAs. It is a leakage management technique targeted at reducing the awareness time for new leaks.

Excess Losses

A component based real loss analysis is used to determine the part of real losses which is in 'excess' of all other leakage components. The volume of Excess Losses represents the quantity of water lost by leaks that are not being detected and repaired with the current leakage control policy.

Fixed and Variable Area Discharge path (FAVAD)

Losses from fixed area leakage paths vary according to the square root of the system pressure, whilst discharges from variable area paths vary according to pressure to the power of 1.5. As there will be a mixture of fixed and variable area leaks in any distribution system, loss rates vary with pressure to a power that normally lies between the limits of 0.5 and 1.5.

The simplest versions of the FAVAD concept, suitable for most practical predictions, are

$$\text{Leakage Rate L (Volume/unit time) varies with Pressure}^{N1}$$

or

$$L1/L0 = (P1/P0)^{N1}$$

The higher the N1 value, the more sensitive existing leakage flow rates will be to changes in pressures. The FAVAD concepts have for the first time allowed accurate forecasting of the increase or decrease of Real Losses due to a change in pressure. In distribution systems with a mix of pipe materials, N1 values might be in the order of 1 to 1.15. Therefore a linear relationship can be assumed initially until are carried out to derive better data.

Hidden Losses

Alternative term for Excess Losses

Infrastructure Leakage Index (ILI)

The ILI is a measure of how well a distribution network is managed (maintained, repaired, rehabilitated) for the control of real losses, at the current operating pressure. It is the ratio of Current Annual volume of Real Losses (CARL) to Unavoidable Annual Real Losses (UARL).

$$ILI = CARL / UARL$$

Being a ratio, the ILI has no units and thus it facilitates comparisons between countries that use different measurement units (metric, U.S., or imperial).

Leakage Management

Leakage Management can be classified into two groups:

- Passive (reactive) Leakage Control

- Active Leakage Control (ALC)

Leakage Modeling

Leakage modeling is a methodology to analyze 24h inflow and pressure data of a hydraulically discreet part of the distribution system. Using the FAVAD principles and the results of the N1 Step Test the measured inflow can be split into:

- Consumption; and
- Leakage; and further into:
    - Background Losses
    - Bursts (= losses which can be recovered)

Leak Duration

The length of time for which a break runs is split, in the BABE concepts, into three separate time components - awareness, location and repair - the duration of each of which is separately estimated and modeled; Leak Duration equals Awareness plus Location plus Repair Time.

Location Duration

For reported leaks and bursts, this is the time it takes for the water utility to investigate the report of a leak or break and to correctly locate its position so that a repair can be carried out. For Unreported Leaks and Bursts, depending on the ALC method used, the location duration may be zero since the leak or break is detected during the leak detection survey and therefore awareness and location occur simultaneously.

Minimum Night Flow (MNF)

The Minimum Night Flow in urban situations normally occurs during the early morning period, usually between around 02:00 and 04:00 hours. The MNF is the most meaningful piece of data as far as real loss levels are concerned. During this period, consumption is at a minimum and therefore real losses are at the maximum percentage of the total flow. The estimation of the real loss component at Minimum Night Flow is carried out by subtracting an assessed amount of legitimate night consumption for each of the customers connected in the zone being studied.

Passive Leakage Control

Passive Leakage Control is practiced in many water utilities – whether economically justified or not. Passive Leakage control is reacting to Reported Bursts or pressure drops, usually reported by customers or noted by the utility's own staff while carrying out other duties. This method can only be justified in areas with plentiful and very low cost supplies. Under normal circumstances, the overall level of leakage will continue to rise under Passive Leakage Control.

Pressure Management

Pressure Management is one of the fundamental elements of a well designed leakage management strategy. Pressure Management is best undertaken in conjunction with district metering. Pressure Management does not necessarily require dramatic pressure reduction, sometimes good results can be achieved with stabilizing pressures at slightly lower levels or reducing excessive (and unnecessary) night pressures.

Pressure Reducing Valve (PRV)

Pressure Reducing Valves are traditionally understood as devices to be used in case of excessively high pressures, e.g. in systems with widely varying altitudes. In the case of Pressure

Management, PRVs are to be understood as control devices used to reduce, regulate and manage operating pressures.

Recoverable Leakage

Equivalent to Hidden or Excess Losses.

Repair Time

The time it takes a water utility to organize and affect the repair once a leak has been located.

Reported Bursts

Reported Bursts are those events that are brought to the attention of the water utility by the general public or the water supply organization's own operatives. A break or a leak that, under urban conditions, manifests itself at the surface will normally be reported to the water supply organization whether or not it causes nuisance such as flooding.

Unavoidable Annual Real Losses (UARL)

Real Losses cannot be totally eliminated. The volume of Unavoidable Annual Real Losses (UARL) represent the lowest technically achievable annual Real Losses for a well-maintained and well-managed system.

Equations for calculating UARL for individual systems were developed and tested by the IWA Water Losses Task Force, allowing for:

- background leakage – small leaks with flow rates too low for sonic detection if non-visible
- reported leaks and bursts – based on frequencies, typical flow rates, target average durations
- unreported leaks and bursts – based on frequencies, typical flow rates, target average durations
- pressure/leakage rate relationships (a linear relationship being assumed for most large systems)

The UARL equation recommended requires data on four key system-specific factors:

- Length of mains
- Number of service connections
- Location of customer meter on service connection
- Average operating pressure

Unreported Bursts

Unreported bursts are those that are located by leak detection teams as part of their normal everyday active leakage control duties. These bursts go undetected without some form of active leakage control.

1.2.4 Establishing the top-down water balance

Ideally, all components of the water balance should be quantified over the same designated period, usually 12 months, and expressed in volumetric terms. This quantification is of course much easier in fully metered systems, but it is also possible to establish reasonable accurate water balances in systems with largely unmetered consumption (as in England and Wales).

1.2.4.1 Step 1 – Determining System Input Volume

When the entire system input is metered, the calculation of the annual system input should be a straight forward task. The regular meter records have to be collected and the annual quantities of the individual system inputs calculated. This includes own sources as well as imported water from bulk suppliers.

Ideally the accuracy of the input meters is verified, using portable flow measuring devices. If discrepancies between meter readings and the temporary measurements are discovered, the problem has to be investigated and, if necessary, the recorded quantity has to be adjusted to reflect the real situation. It is recommended that as well as verifying the accuracy of the meters, the whole of the data recording chain from the meter to the SCADA archive is checked when testing the input meters.

It is also recommended to assess the general accuracy of all individual meters, for example using the manufacturer's manuals and specifications. These figures are required should a 95% confidence limit analysis be carried out but will be also useful to get a general idea of the accuracy of the AWB even without a 95% analysis.

Should there be some unmetered sources the annual flow has to be estimated by using any (or a combination) of the following:

- temporary flow measurements using portable devices
- reservoir drop tests
- analysis of pump curves, pressures and average pumping hours

1.2.4.2 Step 2 – Determining Authorized Consumption

Billed Metered Consumption

The calculation of the annual billed metered consumption goes hand in hand with the detection of possible billing and data handling errors, information later on required for the estimation of apparent losses.

Consumption of the different consumer categories (e.g. domestic, commercial, industrial) have to be extracted from utility's billing system and analyzed. Special attention shall be paid to the group of very large consumers.

Annual billed metered consumption information taken from the billing system has to be processed for meter reading time-lag to ensure that the billed metered consumption period used in the audit is consistent with the audit period.

The general accuracy of the various makes of domestic and non-domestic consumption meters shall also be determined for a possible 95% confidence limit analysis. This product and type of meter related accuracy must not be confused with meter under-registration to be dealt with separately.

Billed Unmetered Consumption

Billed unmetered consumption can be obtained from the utility's billing system. In order to analyze the accuracy of the estimates, unmetered domestic customers should be identified and monitored for a certain period, either by the installation of meters on those non-metered connections or by measuring a small area with a number of unmetered customers. The latter has the advantage that the customers are not aware that they are metered and so they will not change their consumption habits.

In the unlikely case that non-domestic customers are unmetered, detailed surveys have to be carried out to check the accuracy of the estimated billed consumption figures.

Unbilled Metered Consumption

The volume of unbilled metered consumption has to be established similar to that of billed metered consumption.

Unbilled Unmetered Consumption

Unbilled unmetered consumption, traditionally including water used by the utility for operational purposes, is very often seriously overestimated. This might be caused by simplifications (a certain % of total system input) or overestimates on purpose to 'reduce' water losses.

Components of unbilled unmetered consumption shall be identified and individually estimated, for example:

- mains flushing: how many times per month? for how long? how much water?
- fire fighting: has there been a big fire? how much water was used?

It is always surprising what a small component the unbilled unmetered but authorized consumption turns out to be - especially compared to traditional (over)estimates.

1.2.4.3 Step 3 – Estimating Apparent Losses

Unauthorized Consumption

It is difficult to provide general guidelines of how to estimate unauthorized consumption. There is a wide variation of situations and knowledge of the local situation will be most important to estimate this component. Unauthorized consumption can include:

- illegal connections
- misuse of fire hydrants and fire fighting systems
- vandalized or bypassed consumption meters
- corrupt practices of meter readers
- open boundary valves to external distribution systems (unknown export of water).

All in all, the estimation of unauthorized consumption is always a difficult task and should at least be done in a transparent, component based way so that the assumptions can later easily checked and/or modified.

Customer Metering Inaccuracies and Data Handling Errors

The extent of customer meters inaccuracies, namely under- or over registration, has to be established based on tests of a representative sample of meters. The composition of the sample shall reflect the various brands and age groups of domestic meters. Tests are done either at the utility's own test bench, or by specialized contractors. Large customer meters are usually tested on site with a test rig. Based on the results of the accuracy tests, average meter inaccuracy values (as % of metered consumption) will be established for different user groups.

Data handling errors are sometimes a very substantial component of apparent losses. Many billing systems are not up to the expectations of the utilities but problems often remain unrecognized for years. It is possible to detect data handling errors and problems with the billing system by exporting billing data (of say the last 24 months) and analyzing it using standard database software.

The detected problems have to be quantified and a best estimate of the annual volume of this component has to be calculated.

1.2.4.4 Step 4 – Calculating Real Losses

The annual volume of real losses is the balance between the system input and:

- all consumption elements;
- water exported; and
- apparent losses.

1.2.4.5 Step 5 – Estimating Real Loss Components

To accurately split real losses into its components will only be possible with a detailed component analysis. However, a first estimate can be made using a few basic estimates.

Leakage on Transmission and/or Distribution Mains

Bursts on distribution and especially transmission mains are primarily large events – they are visible, reported and normally repaired quickly. By using data from the repair records, the number of leaks on mains repaired during the reporting period (usually 12 months) can be calculated, an average flow rate estimated and the total annual volume of leakage from mains calculated as follows:

number of reported bursts x average leak flow rate x average leak duration (say 2 days)

and then a certain provision for background losses and so far undetected leaks on mains can be added.

Leakage and Overflows at Utility's Storage Tanks

Leakage and overflows at storage tanks are usually know and can be quantified. Overflows can be observed and the average duration and flow rate of the events estimated. Leakage of storage tanks can be calculated by making a level drop test with in and outflow valves closed.

Leakage on Service Connections up to Point of Customer Metering

By deducting mains leakage and storage tank leakage from the total volume of real losses, the approximate quantity of service connection leakage can be calculated. This volume of leakage includes reported and repaired service connection leaks as well as hidden (so far unknown) leaks and background losses from service connections.

1.2.5 Performance Indicators

Performance Indicators (PI) are used in may sectors of industry, including the water industry. As long as PIs are only used within a utility, for example to set targets for departments or work groups, they can be self-defined. But for all other purposes, for example as soon as PIs are used to compare utilities' performances or for regulation, it is important to have standardized indicators, calculated according to a clearly defined methodology and using standard definitions, particularly in respect to water audits and water loss PIs.

Probably the most important issue is the problematic approach of using % UfW, or % NRW as a performance indicator for water losses. Since the level of water losses, both real and apparent, is a very important efficiency issue for water utilities across the world, one would assume that accurate performance indicators are used for benchmarking, international performance comparison, or target setting. But unfortunately this is widely not the case - utility managers, consultants and regulators continue to use a very inappropriate indicator when talking about water losses. With the exception of the UK water industry, water losses (as well as Unaccounted-for Water (UfW), Non-Revenue Water (NRW) and leakage) are still quoted as % of System Input (or water production), although % water losses are a very misleading indicator.

The new and most advanced real loss indicator (recommended by the IWA and the AWWA Water Loss Control Committee) is the ILI, the Infrastructure Leakage Index. The development of the ILI started in 1997 when Allan Lambert realized the need for a real loss performance indicator which would allow international comparisons between systems with very different characteristics, e.g. intermittent supply situations; low and high pressure systems; differences in consumption levels and so on. Therefore, in these early days, the ILI (nowadays Infrastructure Leakage Index), was the abbreviation of International Leakage Index.

The ILI, in the first few years known to only to a few insiders, is now widely accepted and used by practitioners around the world, as it best describes the efficiency of the real loss management of water utilities. However, regulators, funding agencies, media and, last but not least, utility managers in most countries continue to use percentage figures and are too often unaware of how misleading these are.

The ILI is a measure of how well a distribution network is managed (maintained, repaired, rehabilitated) for the control of real losses, at the current operating pressure. It is the ratio of **C**urrent **A**nnual volume of **R**eal **L**osses (CARL) to **U**navoidable **A**nnual **R**eal **L**osses (UARL).

ILI = CARL / UARL

Being a ratio, the ILI has no units and thus facilitates comparisons between countries that use different measurement units (U.S., metric or imperial). But what are unavoidable losses and how are they calculated? Leakage management practitioners around the world are well aware that Real Losses will always exist - even in new and well managed systems.

It is just a question of how high these unavoidable losses will be. Without going into details the most 'user friendly' versions of the UARL equation require data on four key-system specific parameters:

- Length of mains
- Number of service connections
- Location of the customer meter on service connection (relative to the property boundary)
- Average operating pressure (when the system is pressurized)

The Current Annual Real Losses can easily be derived from the Standard Water Balance. But what about the ***unavoidable*** losses?

The complex initial components of the UARL formula were converted to a ‘user friendly’ pressure-dependent format for practical use:

UARL (liters/day) = (18 x Lm + 0.8 x Nc + 25 x Lp) x P

where Lm = mains length (km); Np = number of service connections; Lp = total length of private pipe, curb-stop to customer meter (km); P = average pressure (m).

Whilst the length of mains and number of service connections normally are known to a water utility, the distance between the property line and meter seems to be a troublesome figure to obtain. But fortunately, in some 50% of situations world-wide customer meters are located close to the property line and Lp is effectively zero. In the remaining cases, where customer meters are located some distance after the property line, it is relatively easy to estimate the average and total length of underground pipe from the property line to customer meters by inspecting a quite small random sample of service connections.

The ILI can perhaps be best envisaged from Figure 2 below, which shows the four components of leakage management. The large square represents the _current annual volume of real losses_ (CARL), which is always tending to increase, as the distribution networks grow older. This increase however can be constrained by an appropriate combination of the four components of a successful leakage management policy. The black box represents the _unavoidable annual real losses_ - the lowest technically achievable volume of real loses at current operating pressure.

The ratio of the CARL (the large square) to the UARL (the black box), is a measure of how well the three infrastructure management functions - repairs, pipelines and asset management, active leakage control - are being undertaken. And this ratio is the ILI. Although a well managed system can have an ILI of 1.0 (CARL = UARL), this does not necessarily have to be the target as the ILI is a purely technical performance indicator and does not take economic considerations into account.

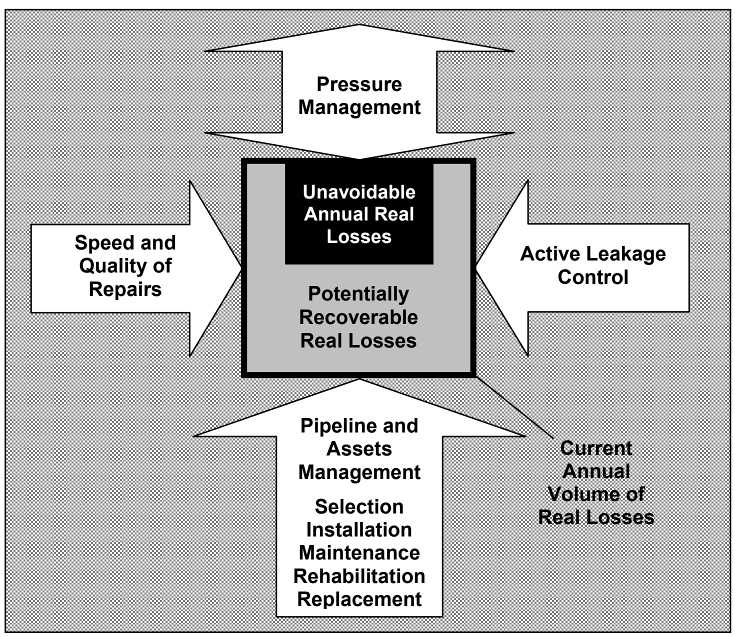

Figure 2: The four components of a successful leakage management policy

1.2.5.1 Recommended Real Loss Performance Indicators

In accordance with the IWA's Best Practice Manual, the PIs are categorized by Function and by Level, defined as follows:

Level 1 (basic): A first layer of indicators that provide a general management overview of the efficiency and effectiveness of the water undertaking.

Level 2 (intermediate): Additional indicators, which provide a better insight than the Level 1 indicators; for users who need to go further in depth.

Level 3 (detailed): indicators that provide the greatest amount of specific detail, but are still relevant at the top management level.

Function	Level	Performance Indicator	Comments
Financial: NRW by Volume	**1** (Basic)	Volume of NRW **[% of System Input Volume]**	Can be calculated from simple water balance, not too meaningful
Operational: Real Losses	**1** (Basic)	**[liters/service connection/day]** or:	Best of the simple 'traditional' performance indicators, useful for target setting, limited use for comparisons between systems
		[liters/km of mains/day] *(only if service connection density is < 20/km)*	
Operational: Real Losses	**2** (Intermed.)	**[liters/service connection/day/m pressure]** or:	Easy to calculate Indicator if the ILI is not known yet, useful for comparisons between systems
		[liters/km of mains/day/m pressure] *(only if service connection density is < 20/km)*	
Financial: NRW by cost	**3** (Detailed)	Value of NRW **[% of annual cost of running system]**	Allows different unit costs for NRW components, good financial indicator
Operational: Real Losses	**3** (Detailed)	**Infrastructure Leakage Index (ILI)**	Ratio of Current Annual Real Losses to Unavoidable Annual Real Losses, most powerful indicator for comparisons between systems

Figure 3: Recommended Indicators for Real Losses and Non-Revenue Water