THE IWA WATER LOSS TASK FORCE
Water 21 - Article No 2

Assessing Non-Revenue Water and its Components: A Practical Approach

- This article, by ALLAN LAMBERT, is the second in a special series of articles for *Water21* by the IWA Water Loss Task Force, highlighting practical developments over the last decade in managing water losses in public water supply distribution systems.

The scope of this series of articles 'A Practical Approach to Water Loss Reduction' was outlined in the June 2003 issue of Water21. (Brothers 2003).

An annual water balance is normally used to assess Non-Revenue Water (NRW) and its components. Unfortunately, because of the wide diversity of formats and definitions used for such calculations, previous attempts at national and international comparisons of performance in NRW management and performance have been open to considerable doubt.

IWA Task Forces recently produced an international 'best practice' standard approach for Water Balance calculations (Figure 1), with definitions of all terms involved, as the essential first step in practical management of water losses (Hirner and Lambert, 2000; Alegre et al, 2000).

Figure 1: the IWA 'best practice' standard water balance

<table>
<tr><td rowspan="9">System Input Volume (corrected for known errors)</td><td rowspan="4">Authorised Consumption</td><td rowspan="2">Billed Authorised 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 Authorised 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>Unauthorised Consumption</td></tr>
<tr><td>Customer 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>

Abbreviated definitions of principal components of Figure 1 are as follows:

- System Input Volume: the annual input to a defined part of the water supply system

- Authorised Consumption: the annual volume of metered and/or non-metered water taken by registered customers, the water supplier and others implicitly or explicitly authorised to do so. It includes water exported, and leaks and overflows after the point of customer metering.
- Non-Revenue Water (NRW): the difference between System Input Volume and Billed Authorised Consumption.
- NRW consists of Unbilled Authorised Consumption and Water Losses
- Water Losses: the difference between System Input Volume and Authorised Consumption, consisting of Apparent Losses and Real Losses
- Apparent Losses consists of Unauthorised Consumption and metering inaccuracies
- Real Losses: the annual volumes lost through all types of leaks, bursts and overflows on mains, service reservoirs and service connections, up to the point of customer metering.

IWA Task Forces have recommended that use of the term 'Unaccounted for Water' (UFW) be discontinued (Alegre et al 2000), because of widely varying interpretations of the term worldwide.

The components of the water balance should always be calculated and expressed as volumes before attempting to calculate performance indicators. The separation of Non-Revenue Water into components – Unbilled Authorised Consumption, Apparent Losses and Real Losses – should always be attempted.

Where national standards are being reviewed, or proposed for the first time, the IWA 'best practice' water balance should be the first logical choice, as it can be used as the basis for both national and international performance comparisons. Where an alternative published well-defined national format for water balance already exists (e.g. in England & Wales), the components should be re-ordered into the IWA standard approach before attempting international performance comparisons.

The IWA 'best practice' Water Balance is rapidly gaining international acceptance, and has already been adopted or promoted (with minor variations) by:

- DVGW (Germany), Australia (Water Services Association and Queensland Environmental Protection Agency), Malta Water Services Corporation and its regulator, South African Water Research Commission, New Zealand Water and Waste Association, American Water Works Association, and the Canadian Federation of Municipalities and National Research Centre.
- Utilities and/or consultants working in Austria, Brazil, Cyprus, Ghana, Jordan, Kazakhstan, Malaysia, Oman, Palestine, Saudi Arabia, the United Kingdom, Uzbekistan, and the countries mentioned above.
- Thornton (2002), and Farley and Trow (2003), in recently published books

Checking the reliability of water balance calculations

All metered or assessed input data to the Water Balance are subject to errors and uncertainty, to a greater or lesser extent. These errors accumulate in the calculated volumes of NRW and Real Losses. For highly sectorised systems with continuous night flow measurements, the Real Losses volume can be independently checked by 'bottom-up' calculations based on analysis of night flows (Ofwat,2001), but that calculation also has errors and uncertainties.

Another method of assessing Annual Real Losses from first principles is Component Analysis. In this approach, annual volume of real losses is assessed using numbers, average flow rates and average run-times of different types of leaks and bursts (background, reported and unreported) on different parts of the distribution infrastructure. A calibrated component analysis model is also useful for evaluating alternative leakage management options.

Introducing 95% confidence limits to Water Loss calculations

Irrespective of which method or methods are used to evaluate water losses, uncertainty will always exist in the calculated values of NRW, Apparent Losses and Real Losses. A practical approach is to dealing with uncertainty is to attempt to quantify it. Uncertainty calculations have been standard practice for many years in hydrological measurements such as gauging of river flows, but until recently been not been used in water loss calculations.

Software now exists for Water Balance calculations with provision for entering 95% confidence limits for all data entry items, and automatic calculation of 95% confidence limits for NRW and Real Losses (e.g. NZWWA 2002; Paracampos and Thornton 2002; Liemberger and McKenzie 2003). The use of 95%iles simply means that calculations made with approximate data have wider confidence limits than calculations made with more reliable data. Table 1 demonstrates the application of 95% confidence limits to a simplified IWA standard water balance.

Component of IWA Standard Water Balance	Megalitres/ year	95% Confidence Limits	Standard Deviation	Variance
System Input Volume	**6117**	**+/- 2%**	***61***	***3721***
Billed Authorised Consumption	**5200**	**+/- 1%**	***26***	***676***
Non-revenue Water	***917***	***+/- 15%***	***69***	***4397***
Unbilled Authorised Consumption	**80**	**+/- 50%**	***20***	***400***
Water Losses	***837***	***+/- 17%***	***71***	***4997***
Apparent Losses	**111**	**+/- 50%**	***23***	***529***
Real Losses	***726***	***+/- 20%***	***74***	***5526***

Entered values ***Derived values***

Table 1: An IWA Standard Water Balance with 95% Confidence Limits

If it is considered necessary to improve the reliability of NRW or Real Losses estimates, the 'Entered Value' component with the greatest Variance should be the priority (in Table1 this would be the System Input Volume).

UNAVOIDABLE ANNUAL REAL LOSSES (UARL)

Real Losses cannot be eliminated totally. The lowest technically achievable annual volume of Real Losses for well-maintained and well-managed systems is known as Unavoidable Annual Real Losses (UARL). Figure 2 shows the relationship between Current Annual Real Losses (CARL) from an IWA water balance – represented by the large rectangle - and UARL (the smaller rectangle). Using the four methods of leakage management (the four arrows), Real Losses can be controlled, but (at the current operating pressure) cannot be reduced any further than the UARL.

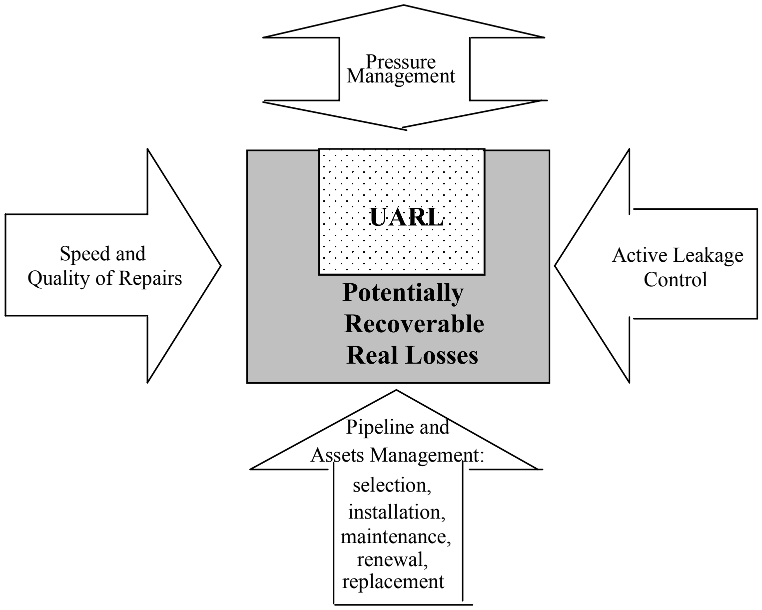

Figure 2: The four basic methods of managing Real Losses

System-specific values of UARL can be assessed using a formula developed by the IWA Water Losses Task Force. (Lambert et al, 1999). Data required for this assessment are the number of service connections Nc, the length of mains Lm (km), the length of private pipes (Lp in km) between the street:property boundary and customer meters, and the average operating pressure (P metres). The general equation for UARL is

UARL (litres/day, when system is pressurised) = (18 x Lm + 0.8 x Nc + 25 x Lp) x P …(1)

This equation, based on component analysis of Real Losses for well-managed systems with good infrastructure, has proved to be robust in diverse international situations (Lambert and McKenzie, 2002), and is the most reliable predictor yet of 'how low could you go' with real losses for systems with more than 5000 service connections, connection density (Nc/Lm) more than 20 per km, and average pressure more than 25 metres.

For example, the water balance in Table 1 relates to a system with Lm = 603 km, Nc = 16,359 service connections, Lp = 0 km of private pipe (customer meters being at the street/property boundary), and P = 65 metres. Using equation (1), the UARL for this system can be quickly assessed as 1556 m^3/day, 568 Ml/year, which can then be compared with the current annual real losses of 726 Ml/year +/- 20% from Table 1.

The UARL formula is a practical user-friendly tool for assessing a system-specific lower limit for the annual volume of Real losses that would be technically achievable at the current operating pressure, with world 'best practice' for speed and quality of repairs, active leakage control and pipeline and assets management, if economics is not a constraint (i.e. for systems where water is scarce or has very high marginal costs). UARL values have now been calculated for several hundred diverse systems world-wide (Lambert, 2003), but are being achieved by only a few of the world's best leakage practitioners.

UARL is used in the calculation of a new and important performance indicator, the Infrastructure Leakage Index (ILI), which is the ratio of CARL to UARL. Performance indicators will be discussed in a later article in this series.

In the next article in the series, Julian Thornton, Leader of the Pressure Management Team in the IWA Water Loss Task Force, will outline the practical approach to 'Managing Leakage by Managing Pressure'.

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References

Alegre H., Hirner W., Baptista J.M. and Parena R. (2000) *Performance Indicators for Water Supply Services. IWA Manual of Best Practice*. ISBN 900222272

Brothers, K.J (2003). *A practical approach to Water Loss Reduction*. Water21, June, 54-55

Farley M and Trow S (2003). *Losses in Water Distribution Networks: A practitioner's guide to Assessment, Monitoring and Control.* IWA Publishing.ISBN 1 900222 116, www.iwapublishing.com/template.cfm?name=isbn1900222116

Hirner W and Lambert A.(2000): *Losses from Water Supply Systems: Standard Terminology and Recommended Performance Measures*. IWA Website, www.iwahq.org.uk/bluepages

Lambert A., Brown T.G., Takizawa M. and Weimer D. (1999) *A Review of Performance Indicators for Real Losses from Water Supply Systems.* AQUA, Vol. 48 No 6. ISSN 0003-7214

Lambert A. (2002). *International Report on Water Losses Management and Techniques: Report to IWA Berlin Congress, October 2001*. Water Science and Technology:Water Supply 2(4)

Lambert A. and McKenzie R (2002*): Practical Experience in using the Infrastructure Leakage Index.* Proceedings of IWA Conference 'Leakage Management: A Practical Approach' in Lemesos, Cyprus. ISBN 9963-8759-0-4

Liemberger R and McKenzie R, 2003. Aqualibre: A New Innovative Water Balance Software. IWA/AWWA Conference on Efficient Management of Urban Water Supply, Tenerife, April 2003. Copies of paper available from http://www.bws-austria.com/startpage/nrw.htm

New Zealand Water & Wastes Association (2002). *'Benchmarking of Water Losses in New Zealand (Incorporating the User Manual for the BenchlossNZ Software: Version 1A)'*. User Manual ISBN 1-877134-35-X; ISBN for CD is 1-877134-39-2. water@nzwwa.org.nz

Office of Water Services (2001). *Leakage and the Efficient Use of Water*. ISBN 1 874 234 80 9 Website www.ofwat.gov.uk/ofwat/

Paracampos F and Thornton J*: SABESP's experience in applying the IWA water loss, a field experience.* Proceedings of IWA Conference 'Leakage Management: A Practical Approach' in Lemesos, Cyprus. ISBN 9963-8759-0-4

Thornton J. (2002) Water Loss Control Manual. McGraw Hill. ISBN 0 07 137434 5