Some Examples of European Water Loss Targets, and the Law of Unintended Consequences

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Abstract

During their international water loss studies, the authors have worked in or with countries where the recommended guidelines or targets set by national organisations for water losses can have unforeseen, and presumably unintended, consequences.

In some European countries there is a 'matrix' system approach to Water Loss performance guidelines, but a simple analysis shows that a scaling parameter (mains length), that is used as the basis for the matrix method, cancels out. Some guidelines are seen to be based on %s by volume, with significant discontinuities at the internal boundaries of the matrix, resulting in anomalous interpretation of performance in water loss management.

In Malta, the traditional use of %s by volume, and losses per km of mains, for target setting changed in 2006. In Austria, a performance classification scheme based on Infrastructure Leakage Index (ILI), losses per service connection and the World Bank Institute Banding System have recently been introduced. Increasing use of ILI and losses per service connection in Italy, Croatia and Serbia are noted.

Introduction

For many years, the most widely used performance indicators in Europe for Non-Revenue Water and Real (Physical) losses have been percentages, and 'per km of mains'. The numerous problems with using percentages for benchmarking and setting targets have been well documented and will not be repeated in detail in the paper, except to say that both for at least 15 years, both the German DVGW and the UK Economic Regulator (Office of Water Services – OFWAT) have recommended against the use of percentages (Refs 1, 2).

The use of 'per km of mains' also suffers from the fact that, in developed countries, only a relatively small proportion of the annual volume of Non Revenue Water and Real Losses occurs from the mains. This statement may appear counter-intuitive to those who think that mains bursts are the principal cause of leakage – but a simple component analysis calculation will show that if mains bursts are repaired promptly, they usually represent less than 10% of Real Losses. The majority of Real Losses volume usually arises from service connections leaks, except at very low connection densities.

Leak flow rates also vary with average pressure P to the power N1, where N1 may vary between 0.5 and 1.5, but can be assumed to have an average close to 1.0 for systems with mixed pipe materials. So the logical forms of equations relating Real Losses (RL) to mains length (Lm) and number of service connections (Ns) are:

RL (litres/day) = (A x Lm + B x Ns) x P ………….(1a)
RL (litres/km mains /day) = (A + B x Ns/Lm) x P … …..(1b)
RL (litres/service conn/day) = (A x Lm/Ns + B) x P ……… …..(1c)

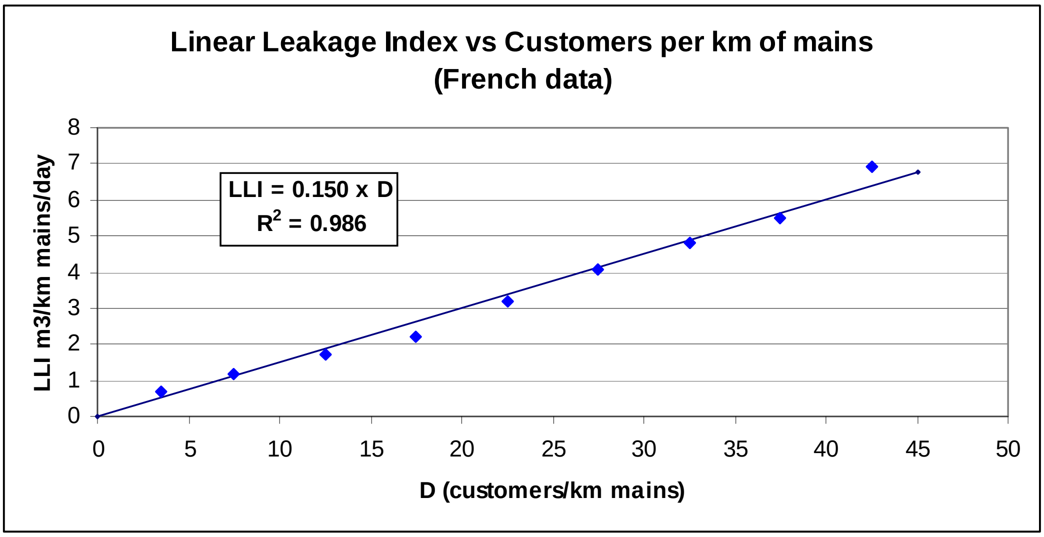
where A and B are coefficients and Ns/Lm is the density of connections, per km of mains. Values of the coefficients A and B can be obtained by either:

a) linear regression, using equation 1b or 1c, of data from Utility systems
b) use of BABE component analysis models allowing for background leakage, burst frequencies (reported and unreported), average flow rates, durations etc.

How much leakage occurs on mains? The Cemagref Study

Figure 1, from Ref 3, shows an example of using linear regression and Equation 1b, for grouped data from 2000 water suppliers and 15,296 systems in 69 French counties. The Linear Leakage Index is the principal indicator used to quantify the evolution of leakage levels in France, and is approximately equivalent to Non-Revenue Water (in IWA standard terminology) expressed as m^3/km of mains/day.

Figure 1: LLI vs Customers/km of mains (French data)



The derived relationship for this graph, LLI = 0.150 x D, with a high correlation coefficient, appears to support the use of 'losses per km' as a performance indicator. However, the scaling factor 'per km' appears in the denominator of both the X and Y parameters, and if we multiply both LLI and D by 'km', we obtain

NRW (m^3/day) = 0.150 x Customers

or NRW = 150 litres/customer/day for all connection densities

The authors of Ref. 1 correctly conclude that 'the length of mains isn't taken into account to explain the level of non-revenue water'. But in fact, the more substantial question to be answered here is:

> ***How can it be considered logical to use losses per km of mains as the principal indicator for leakage levels, when a comprehensive analysis of national data shows that the losses are overwhelmingly related to service connections, irrespective of connection densities***?

The second method of assessing the coefficients A and B in equations 1a, 1b and 1c is to use BABE component analysis models allowing for background leakage, burst frequencies (reported and unreported), average flow rates, durations etc. The equation for Unavoidable Annual Real Losses (Ref. 4) is perhaps the best-known international example of this type of approach. For systems with meters at the property line the UARL equation is:

UARL (litres/km/day) = (18 + 0.8 x Ns/Lm) x P

where Lm is in km and P is in metres.

Figure 2a compares the UARL equation for Real Losses at 3 different pressures (30, 50 and 70 metres) and the Cemagref Study NRW data, both in litres/km/day vs Density of Connections. The ‘French’ line for NRW lies above the ‘UARL’ lines for Real Losses, for all connection densities greater than 15 per km. It could be concluded from Figure 2a that:

a) if Utilities set targets ‘per km mains’, and invest heavily in mains renewals, it appears possible to achieve lower ‘per km’ values of the Coefficient A than the 18 litres/km/day/metre of pressure used in the UARL formula

b) however, if Utilities do not recognise that most losses (both real and apparent) on most systems are associated with service connections, they miss significant opportunities to reduce both NRW and Real Losses

Figure 2a: Losses per km mains/day, UARL and Cemagref data

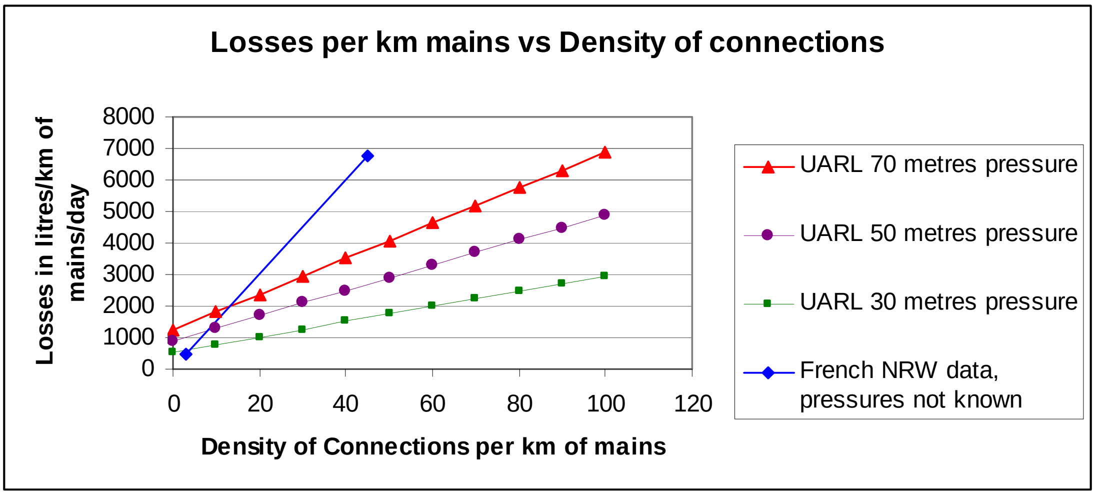
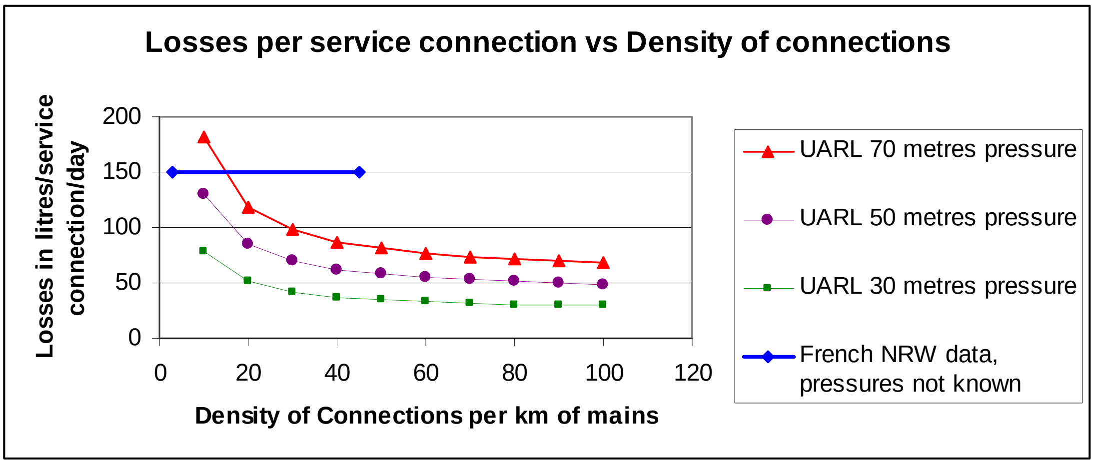


Figure 2b shows the same data sets as Figure 2a, but with the Y-axis in litres/service connection/day. The ‘French’ line for NRW lies above the ‘UARL’ lines for Real Losses, for all connection densities greater than 15 per km, and reinforces conclusions (a) and (b) above.

Figure 2b: Losses per service connection/day, UARL and Cemagref data



Some European approaches to use of ‘per km of mains’

Countries that use ‘per km of mains’ for performance indicators or target setting need somehow to take into account the substantial losses that occur from service connections; as density of connections increases, NRW and Real Losses will increase (see Equation 1b and Figure 2a).

In European countries, this has been approached in several different ways:

a) relate losses per km to connections/km or customers/km, or
b) relate losses per km to consumption per km of mains (implying a general relationship between density of connections and consumption), or
c) relate losses per km to system input volume per km of mains (implying a general relationship between density of connections and system input volume)

and then show the relationship in the form of a stepped graph or table.

The following examples will show that, in all three cases above, the effect of using ‘per km’ as a denominator, for both the dependent and independent variable, means that mains length is not essential for defining a relationship. Also, more importantly, the use of the ‘stepped’ approach introduces significant anomalies at the ‘step’ points, which may not be evident to the user of these methods.

Relating NRW/km to Customers/km: an example from a French Public Agency

Ref. 3 states that, in France, for public agencies, the urban/rural character is defined according to the density of customers (as in Figure 1 and Figure 2a). However, instead of using an equation or graph with a continuous rising line to set reference values for Utilities to achieve, a ‘stepped’ graph is used. In Figure 2a, the criteria for ‘acceptable’ losses defined by Laboratoire GEA (2006) (as reported in Ref. 3) are shown in terms of Linear Leakage I vs Customers/km, with the line representing the Cemagref equation added for comparison. These relationships can easily be converted into NRW in litres/service connection/day as shown In Figure 2b.

Figure 2a: LLI vs Customers/km, Example of ‘Stepped’ approach

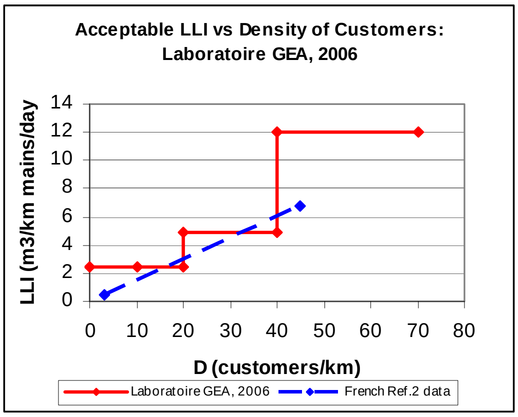
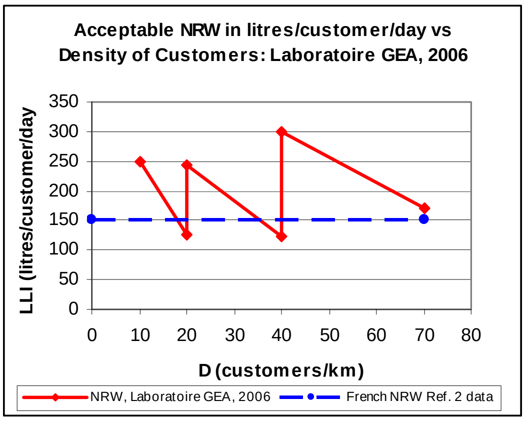


Figure 2b: NRW litres/conn/day vs Customers/km, stepped approach



It is immediately apparent from these graphs that the ‘stepped’ approach introduces significant inconsistencies at the ‘step’ points. For example, to be ‘acceptable’:

- a system with 39 customers/km needs LLI < 5, and < 128 litres/customer day
- a system with 40 customers/km needs LLI < 12, and < 293 litres/customer day

so a 5% increase in connection density can more than double allowable NRW!

Relating NRW/km to Consumption/km: FNCCR for French Water Companies

Criteria for Network Performance Classification suggested by Federation Nationale des Collectivites Concedantes et Regies (FNCCR) at a 2003 seminar (Ref. 5) are representative of many similar tables used in France by Administrations and private operators. Network Type is classified by consumption in m^3/km mains/day, using the Linear Consumption Index (Indice Lineaire de Consommation) ILC , as follows:

Urban: ILC > 30 m^3/km/day; ***Intermediate***: 10< ILC< 30; ***Rural:*** ILC < 10 m^3/km/day

For the 3 different network types, the performance in managing losses is assigned to one of the following four classifications in Table 1

Worrying; Mediocre; Almost Satisfactory*; or *Satisfactory

according to the Linear Losses Index (Indice Lineaire de Perte) (ILP) in m^3/km/day.

Table 1: Performance Classification according to FNCCR proposal (2003)

ILC	Network Type	FNCCR Network classification according to its ILP			
m3/km/d		Worrying	Mediocre	Almost satisfactory	Satisfactory
ILC<10	rural	ILP > 5	3 <ILP<5	2<ILP<3	ILP < 2
10<ILC<30	intermediate	ILP > 11	8<ILP<11	6<ILP<8	ILP<6
ILC>30	urban	ILP > 16	13<ILP<16	10<ILP<13	ILP<10

The information in Table 1 can also be presented as a stepped graph similar to Figure 2a, with ILC as the X-axis. However, it is more interesting to use the Table 1 data to create Figure 3, which shows ILP as a % (of ILP + ILC), vs ILC.

Figure 3: FNCCR Proposed Classification expressed in an alternative form

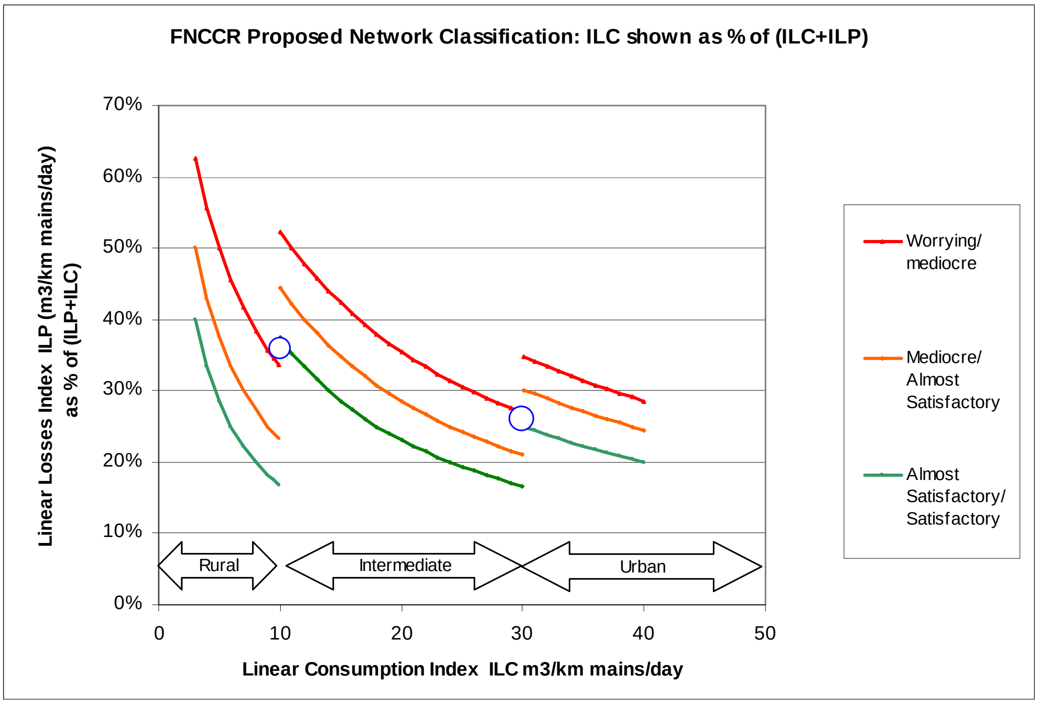


Figure 3 shows that Table 1 basically represents a relationship in which assessment of performance is based on % losses which decrease as the consumption increases, with significant discontinuities at the 'step' points. At the points shown by blue circles, a small increase or decrease in consumption could result in the Utility performance being changed; for example, from:

- 'Satisfactory' to 'Worrying' (or vice versa) at ILC = 10 m^3/km/day
- 'Mediocre' to 'Almost Satisfactory' (or vice versa) at ILC = 30 m^3/km/day

Relating NRW/km to Network Input Rate: German DVGW 392

DVGW W392 (2003) (Ref. 6) provides a Table based on 'experiences', as an 'orienting frame' to show 'points of reference' for real losses per km. The supply structure (metropolitan, urban, rural), categorised according to the Specific Network Input Rate (SNIR), which could be between 2000 and 40000 m^3/km/annum, is principally the basis for this classification.

For the 3 different supply structures, the performance in managing Real Losses is assigned to a ***Low; Medium*** or ***High*** classification according to the Specific Loss in m^3/km/hr. The criteria in Table 2 can be used to create Figure 4, which shows Real Losses as a percentage of Specific Network Input Rate.

Table 2: Performance Classification according to DVGW 392 (2003)

Classification of Water Losses	Supply Structure		
	Area 1 (metropolitan) SNIR >15000 m3/km*a	Area 2 (urban) SNIR 5000-15000 m^3/km*a	Area 3 (rural) SNIR < 0.57 m^3/km*a
Low Water Losses	< 0.10	< 0.07	< 0.05
Medium Water Losses	0.10 - 0.20	0.07 - 0.15	0.05 - 0.10
High Water Losses	> 0.20	> 0.15	> 0.10

Figure 3: DVGW Performance Classification expressed in an alternative form

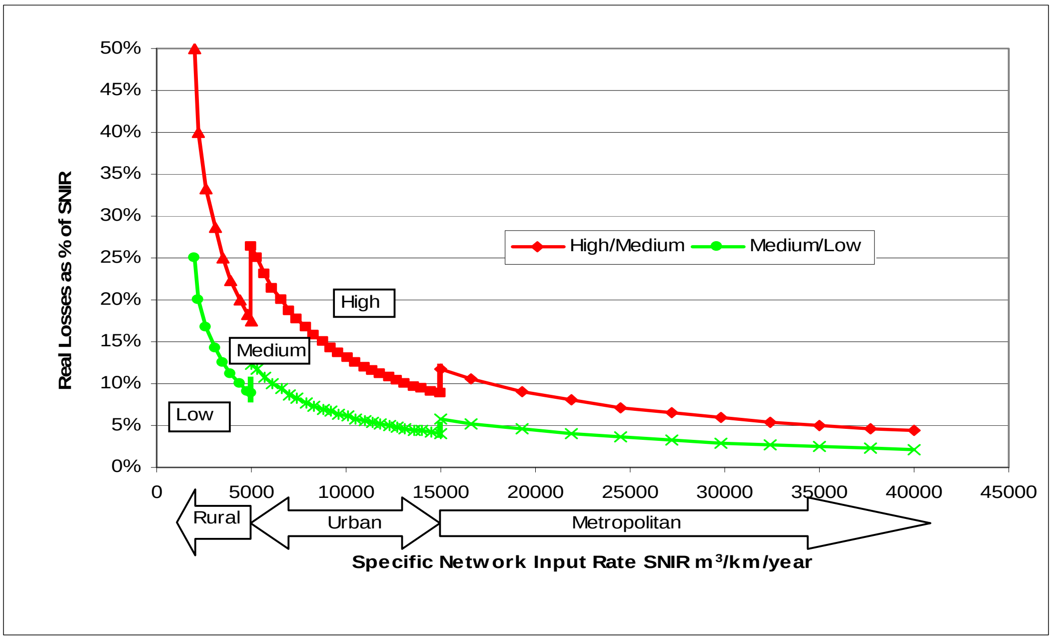


Figure 4 shows that, as with the French FNCCR system, the DVGW Table 2 basically represents relationships in which the descriptions of performance are based on losses as a % of System Input Volume, rather than on losses per km of mains as a technical measure. The % losses decrease as the SNIR increases, with discontinuities at the 'step' points. The decrease with increasing SNIR is attributed in W392 in general to:

- the increase of service connection density with System Network Input Rate
- systems with a high System Network Input Rate being influenced by more diverse, and higher, loads and stresses than rural systems

Malta

Prior to the publication of the IWA Best Practice Performance Indicators in 1999, Water Services Corporation of Malta used %s by volume and losses/km mains/day to record performance in managing Real Losses in WSC annual reports. As these were both recognised as being inappropriate for a Utility with low consumption and high connection density, the PI used since 2006 by WSC and its regulator has been the Infrastructure Leakage Index ILI. WSC has also developed a 'Snapshot' ILI calculated from night flows to target active leakage control efforts (Ref. 7).

Austrian OVGW W63 (2009)
An Austrian Benchmarking study by OVGW (four projects since 2003) identified the problems associated with use of %s and km of mains as performance indicators for Real Losses management. An alternative classification scheme was introduced as part of the updating of the National Standard OVGW W63, in 2009 (Ref. 8)

The revised Austrian approach used two IWA recommended performance indicators – litres/service connection/day, and Infrastructure Leakage Index ILI – together with the World Bank Institute Banding System shown in Table 3 below. The approach is as follows:

- Current Annual Real Losses (CARL), calculated from a standard annual water balance, are expressed in litres per service connection/day
- Unavoidable Annual Real Losses (UARL) are calculated from the IWA UARL formula for systems where meters are located after the property line
- The Infrastructure Leakage Index (ILI) is calculated as CARL/UARL
- The ILI is classified as A, B, C or D based on the World Bank Institute Banding System for developed countries (Table 3); OVGW has added the terms 'very low' to 'very high' and deleted reference to pressure management in Category B

Table 3: ILI Classification scheme for OVGW W63, 2009

ILI	category	assessment
< 2	A	**very low to low water losses**: Further loss reduction may be uneconomic; detailed analyses are recommended before setting further measures
2 – 4	B	**medium level of water losses**: potential for marked improvements; optimisations in active leakage control practices, and better network maintenance
4 – 8	C	**high level of water losses**: analyse level and nature of leakage and intensify leakage reduction efforts
> 8	D	**very high water losses**: analyse level and nature of leakage; extensive leakage reduction programs imperative and of high priority

Because the OVGW W63 calculates UARL in litres/service connection/day, and the IWA approach recommends that real losses are expressed 'per km of mains' for systems with less than 20 connections/km, OVGW W63 uses a table based on the DVGW system for connection densities less than 20 per km. This can be avoided if the UARL is calculated in litres/day, using equation 1a rather than equation 1c.

Italy
Italian Water Utilities currently calculate the water balance for each of their water systems according to Decree n° 99/97 (1997), which introduced a standard water balance method and terminology and also defined some performance indicators for real losses; principally m^3/km mains/year and % of System Input volume.

However, since 2005, official training workshops regarding water loss reduction activities run by FederUtility (Italian Water Works Association) promote the IWA WLTF approach and the use of the more meaningful performance indicators ILI and litres/service connection/day. Many Utilities and some regulators (Region Emilia Romagna, Region Piedmont) now apply the IWA methodology.

West Balkans
In Croatia, NRW % by volume is still used as the main indicator regarding water losses. However, from mid 2009 the Association of Water Utilities in Croatia started

promotion activities and advising water utilities to start to use the IWA WLTF methodology with ILI as main indicator.

In Serbia, NRW % by volume is also still used but a national effort is now being made to promote the IWA methodology. This involves pilot case studies, education and use of ILI as the main performance indicator. It will be supported on many levels including government, local municipalities and universities, and by an international non-profit organization specializing in capacity building for water loss reduction activities.

Concluding Comments

Within continental Europe, percentages and losses per km of mains have been the traditionally preferred measures for assessing performance in management of water losses. Outside Europe, real losses are increasingly being expressed in litres per service connection per day, or as Infrastructure Leakage Index ILI.

For developed countries, losses on mains are now known to be a relatively small proportion of real losses. Attempts in Europe to relate losses/km of mains/day to density of customers/km, consumption/km and system input/km, with ‘stepped’ relationships, have been shown in this paper to produce significant anomalies which can confuse, rather than inform, performance assessment. In Malta, the ILI replaced %s and losses per km of mains for target setting in 2006. In 2009, the Austrian OVGW W63 moved from using %s and losses per km of mains as their key performance indicators, to a transparent approach based on ILI as the decisive PI and the World Bank Institute Banding System. Regulators and Utilities in Italian provinces are also starting to use ILI as their principal performance indicator for Real Losses, with similar positive interest in Croatia and Serbia .

The time has surely come to at least question whether users of the traditional European performance indicators - both Utilities and National organisations – truly understand the implications and unintended consequences of the anomalies that are built into the present European systems that use %s by volume and ‘stepped’ values of losses per km of mains to assess their water loss management performance.

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