Lies, Damn Lies and Leakage Statistics

Dave Pearson*

*Dave Pearson CEng is Special Project Manager for Leakage for North West Water in the UK

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Synopsis

Leakage has come to the attention of the general public and has received significant media attention in the UK over the last three years due to the intensity of the drought that started in June 1995. This public scrutiny has culminated in the government taking action in forcing mandatory targets on the water operating companies. These targets are imposed via the Regulator with significant implications if not achieved, either by fine or, in the extreme case, the loss of the licence to operate.

But how is leakage assessed, particularly in the UK, where a significant proportion of sales is not metered? This paper concentrates on the estimation and reporting of leakage in the UK, indicating the potential errors, and describes the work that is being carried out to improve these estimates.

Key Words : *Leakage, Water Balance, Regulation, Consumption*

Estimation of losses from a water supply system

The high level estimate of losses from a water supply network is assessed by carrying out a water balance between water put into supply less what is consumed by customers. This is a common method for assessing losses on a distribution system and used by all retail chains to assess their losses or wastage from supply to sales. Such stock taking exercises are usually carried out on a quarterly or annual basis, In the case of a water company in the UK such an exercise has to be carried out at least once a year and reported to Ofwat (the Regulator) as part of the annual statement known as the July Return. In practice companies will carry out water balance calculations on a more frequent basis in order to monitor performance.

Figure 1 shows the components used in carrying out such a water balance. In the UK the allowable components of the water balance are now laid down as part of the regulatory framework.

Components of the water balance

Distribution input

Distribution Input is measured at the output of the treatment works. This is net of any imports or exports to any other supply company.

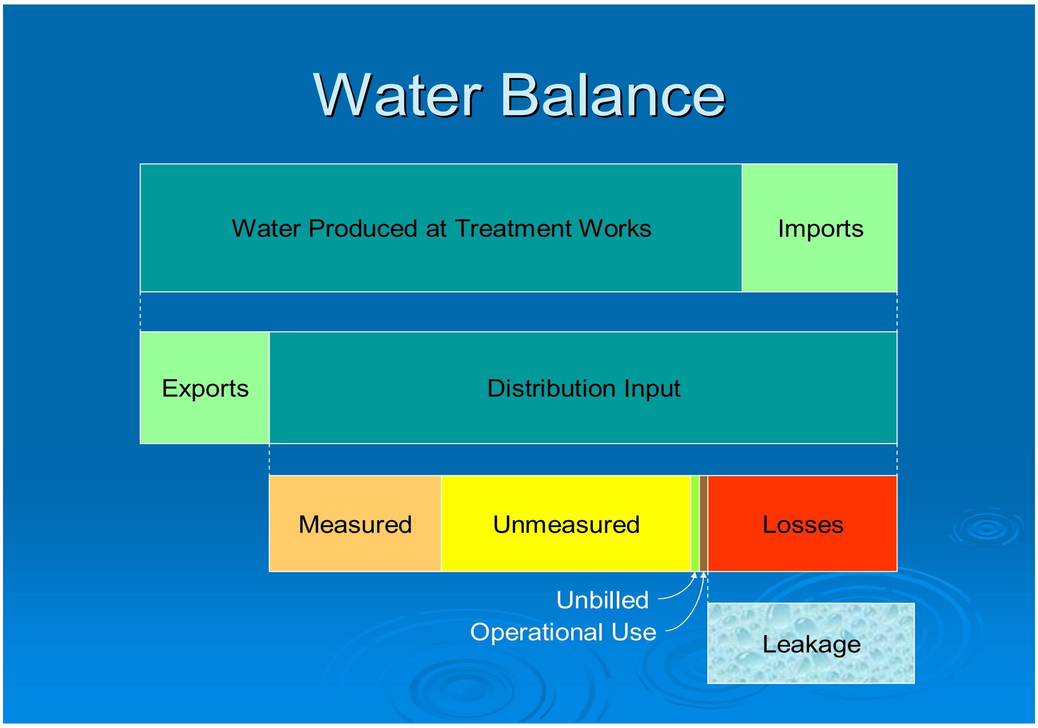

Figure 1 The top down water balance for assessing losses

Metered consumption

This is the consumption from the network measured through revenue meters. In the UK this is generally all the industrial and commercial premises. In the UK, there is often some minor non-household use which is still not metered; for example farm troughs and mixed premises such as a flat above a shop.

There is in increasing proportion of domestic premises paying for water based on a meter but even now the maximum penetration of metering in a water company in the UK into domestic premises is only some 35%.

Unmeasured consumption

This is consumption that is legitimately paid for but which is not measured. In the UK it has been the practice to collect water rates as part of the general rates. General rates were at the time collected based on a rateable value of a premise. This notional value, at which the premise could be let, generally reflects the size of the premises but there were some notable exceptions such as agricultural and religious buildings where rates were significantly lower than the norm.

This practice of collecting water rates with the general rates continued up until the formation of the water authorities in 1974. At this time the payment of water rates was split from the general rate but payment was still based on the rateable value of the property. Since 1974 water authorities and then water companies, offered the option for people to move onto meters. In 1991 local government stopped using rateable value to collect the general rate and since that date most water companies have had to compulsory install water meters into new premises but have continued with the old rateable value for existingpremises. Different companies have had differing policies on metering and the extent to which they encourage customers to move onto meters. This has resulted in a wide range of penetration between different companies.

In order for companies to estimate the volume consumed by unmeasured customers a fixed allowance per person known as the “per capita consumption” (PCC) is made. Population estimates are derived from the census information and used to estimate the total volume used.

Miscellaneous use

Miscellaneous use is an allowance for water taken from the system which is unbilled. This use can be legitimate or illegal. Examples of legitimate unbilled use are water taken for fire fighting or training and water taken for street cleaning and gully emptying. In that most companies do not bill themselves for water taken from potable water systems for use on their own sites then this is allowed for in this category. Some companies operate schemes for such things as standpipe operation and building water and the volumes would be allowed for in this category. Examples of illegal use would be unknown connections to the network as well as illegal use of bypasses or unmeasured fire main connections.

Operational use

Operational use is an allowance that can be made for water used as a necessary part of the duty of operating the system – such as water lost when flushing parts of the system, carrying out refurbishment work or emptying service reservoirs for inspection or cleaning.

Supply pipe losses

The losses assessed at this stage are all losses on the system. Some of these losses may occur on customer’s premises upstream of the meter or upstream of the point used to assess the PCC. In the UK, customers are responsible for the pipe , and hence any losses from it, from the street boundary. This is what is referred to as the point of delivery. It is therefore possible to split total losses into two components – those that are lost on the company’s network – known as distribution losses – and those lost on the customer’s network – known as supply pipe losses. It is not possible to directly measure supply pipe losses and even estimates are unreliable.

In the UK a number of cost efficiency measures used by the Regulator are expressed as a proportion of the water delivered. Improved performance in terms of efficiency will therefore be achieved with higher estimates of PCC and supply pipe loses.

Losses

After all the components are netted from the distribution input the remaining balance is referred to as losses – total losses if it includes supply pipe losses. It is deemed that this loss is equivalent to leakage. However as many of the components above are not measured then errors in these estimates or allowances come through into the losses figure; i.e. if PCC is underestimated then this would show through as higher losses and thereby imply higher leakage levels.

In some countries losses are split into real and apparent losses – where the real losses are those attributed to leakage, and apparent losses are those attributed to errors in the estimation of the components of the water balance. In the UK, companies are forced to include their primary assessment of errors in the relevant component and these are reported to the Regulator so that comparisons between companies can be made.

Method of assessment and ranges of allowances and estimates used in the UK

Metered consumption

It is generally accepted that revenue meters will under-record actual consumption. This is due to the fact that under normal operation the flow through the meter is well below the average accuracy range of the meter. This is particularly the case in the UK where most premises are fed from internal storage and these cisterns are refilled slowly through a ball valve. Meter accuracy will also deteriorate with time due to wear in the meter. It is also believed that meter installation arrangements lead to under-recording of actual consumption. An allowance can be made for this meter inaccuracy, referred to as meter under registration (MUR). The range in the UK is from 0% to 12%.

Unmeasured consumption

This is by far the most sensitive estimate. In the UK, the current range is 134 litres per head per day to 172 l/hd/d. In an attempt to understand whether there is any validity to such a wide range the Regulator is asking companies to set up their own domestic consumption monitors. In addition companies have to compare the PCC values they are using to the measured values from their metered customers.

Companies are using a number of different consumption monitors.

Household monitor

This involves the installation of a meter within a house but where the customer continues to pay based on rateable value. The intention is that the presence of the meter should not affect consumption habits. Accurate data on occupancy and use patterns can be obtained from surveys.

Small area monitor

This involves the installation of a meter on the supply to a number of houses – typically 25 to 100 houses. The size is limited so that leakage can be identified and repaired quickly. In this case households are unaware of the presence of the meter and consumption patterns should not be affected. However information on occupancy rate is impossible to collect and can lead to errors.

District meter monitor

In this case the meters used for leakage control – usually covering 500 to 2500 houses - are used. However in this case it is necessary to adjust for the leakage on the area and this leads to inaccuracies. With the larger size of area the errors due to estimates of the occupancy rate are reduced. It is essential for clean data that there is none or little industrial or commercial use on the area.

Miscellaneous and operational use

These, by their nature (numerous, diverse and relatively small consumptions on the network) are difficult to assess and provide reliable estimates. Generally speaking typical values are established by a statistical survey and then these are extrapolated to the company level. The range across the water companies is from 0% to 2.4% of distribution input for water taken unbilled and 0.1% to 1.5% for operational use.

Supply pipe losses

Estimating the proportion of water lost on the customer's part of the network is difficult. Although physical surveys were carried out in the UK as part of a major research project (Ref 1) these are only a random sample at any one point in time and are difficult to extrapolate or amend. In general companies use a computer model known as BABE (Burst and Background Losses Estimates - Ref 2) to estimate losses given company policy on detection and repair.

The range across the water companies is from 20% to 40% of total losses.

Water into supply

It is possible for a company to write down the value of water put into supply on the basis of meter over-registration. This may be due to meter installation or operating regime. The return to the Regulator does not specifically mention such an allowance. If such an allowance were being made it would have to be identified in the text to the return.

Changing allowances

Generally speaking the estimates that companies use were fixed at the time of privatisation in the company prospectus. Only if a company can show specific data to justify a different allowance, and an external certifier accepts this, can an allowance be changed. This means that at this stage companies are not called upon to justify their current values only any changes to that value.

Can leakage be measured directly?

It is clear to operating companies that losses is not a very useful measure in helping with the direct management of leakage. Just like an annual stocktaking exercise provides little information for a retail chain to manage and control its wastage. It will not provide information as to whether the loss is from their own staff or from shop lifting, nor whether the loss is from their stores or from their distribution depots. For this reason operating companies have to find ways of attempting to directly assessing leakage in a more accurate way in both the temporal and spatial sense. Only then can action be taken to address leakage and the impact measured.

The generally accepted method of providing a method of estimating leakage directly is to set up what are termed district metered areas (DMAs). DMAs range in size from a few hundred properties to a few thousand. The intention is to set up a discrete zone that can be monitored throughout the day and night by a minimum number of meters, preferably just one. On the assumption that the majority of flow at night will be leakage and allowing for what minor use there is, then leakage can be estimated.

Figure 2 shows a typical diurnal flow pattern obtained from a DMA and shows the low flow period in the early morning when leakage will be estimated.

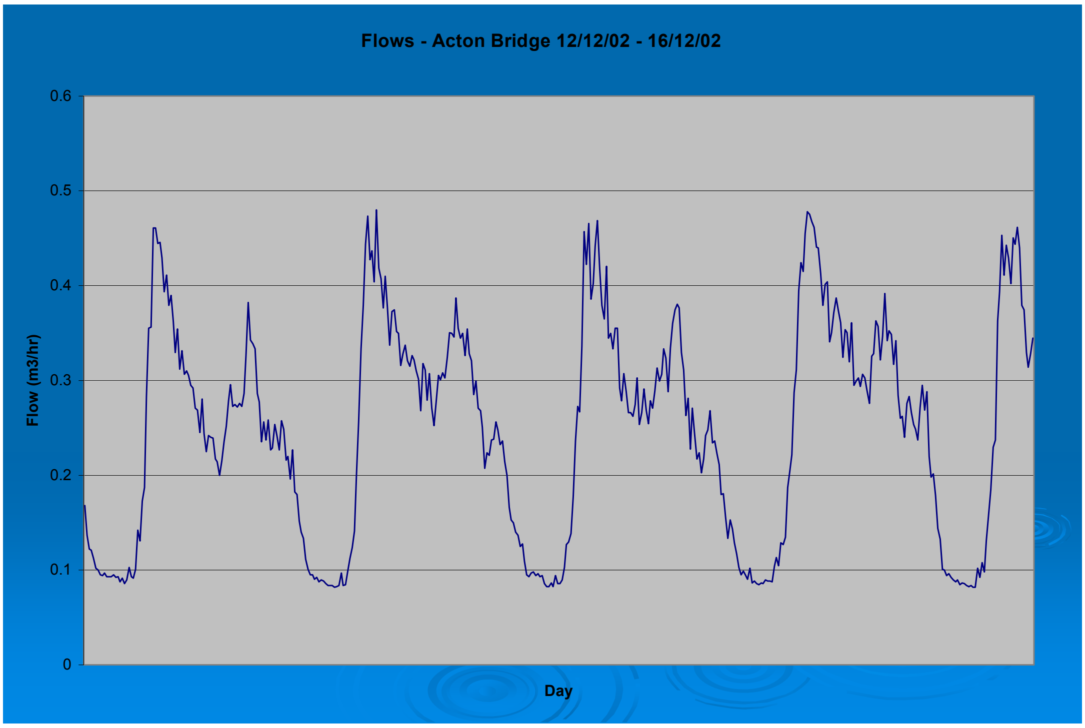

Figure 2 Typical diurnal flow pattern as measured on District Metered Area

DMAs have been set up by companies and operated for some years. However the original intention was to help in the management of leakage and not the direct measurement of leakage. In essence it was not essential that the absolute measurement was correct but that relative measurement showed that improvements were being made or leakage was being held. They also helped in the prioritisation of which area to investigate for leakage. However the Regulator seized upon this estimation of leakage and suggested that it could be used to assess leakage in a company area as a whole and for this to become one more component in the water balance. This would then act as a measure of confidence in the other components.

This aim, laudable as it may appear, however requires that the absolute value of leakage is accurate. This requirement was not there before. Now it is necessary to look at the process of estimating leakage from nightlines and the errors that may be involved in this estimation, particularly as there is no national standard for this methodology.

Nightline period

The minimum flow recorded can vary significantly on a DMA dependent on the time period and time of night at which it is measured. The shorter the time period over which the flow is measured the lower the flow, which is a reflection of variability in actual use. Variations in excess of 20% can be measured between 15min and 1 hour readings. Instantaneous readings show even greater variation.

Domestic use

Generally speaking domestic use is small, with a limited proportion of the population using water in the middle of the night between say 3 and 4 in the morning. However this use can vary significantly depending on the size of the DMA. With a very small DMA of a few hundred properties it is possible that within a short measurement period that there would be no domestic use. It would therefore be inappropriate to use a standard domestic allowance in this case. With larger DMAs the chance of domestic use increases until the mean domestic use can be used. Advice on the level of domestic use and the activity of houses is available (Ref 1).

Non-household use

The largest actual use at night is likely to be non-household. This can range from significant quantities being used by an industrial user that has a continuous process to very minor use such as automatic flushing urinals in commercial premises. It is possible to consider actual logging on a limited number of large users but this would be prohibitively expensive if considered for more than the top 1% of revenue meters. Consumption on the remainder has to be assessed. This can be done by using either standard allowances (Ref 1) or by using a sampling technique on the existing meter stock. Unfortunately this will give a limited sample and only at one point in time. It may have to be re-sampled on a regular basis in order to ensure validity. The UK is currently reviewing the methodology of this assessment in order to improve its confidence.

Hour to day factor

When leakage has been estimated during the time window in the middle of the night it is necessary to translate this to a volumetric loss over the day. For example if leakage is estimated during a one hour period in the middle of the night it may appear obvious to multiply by 24 hours in order to estimate the daily loss. However it is generally accepted that leakage varies with pressure (Ref 1). The higher the pressure the higher the leakage. At the time that leakage has been estimated then demand is at its lowest and hence the pressure at its highest. Therefore daily leakage will be less than 24 times the night time hourly rate. A figure of 20 hours has often been used. This was derived during studies in the early 1980s (Ref 3). However it is clear that this is a function of the topology of a DMA and it is not appropriate to use a standard factor. In fact with the advent of sophisticated time or flow modulated pressure control valves the whole diurnal-pressure profile can be inverted and hour to day factors in excess of 24 hours can apply.

Non-operational areas

At any time it is likely that a certain percentage of DMAs will not be operational. This may be due to technical problems associated with equipment failure or may be due to operational problems such as rehabilitation of the network. Rules need to be developed to decide on how to handle this missing data – either by bringing data forward or by estimating from other data.

Unmeasured areas

It is not possible to include every property within DMAs or a company may not have fully developed district metering. In this case it is necessary to estimate leakage on the un-monitored area. A company may choose to use the average of the leakage on the monitored area but is leakage likely to be the same?

Variations during the year

Once leakage is being assessed on a continuous basis on DMAs it is clear that there are variations from night to night in the nightline, that are not necessarily explained by all the factors above. It may be variations in actual use due to say summer use or other factors. It could be argued that a statistical method should be applied to this data to take out the stochastic variation and then estimate leakage by using a lower bound on this distribution.

Leakage upstream of DMAs

The process described above only measures leakage on DMAs. There can be, dependent on the nature of the supply company, a significant network upstream of these DMAs made up of aqueducts, trunk mains and service reservoirs. Monitoring of leakage on these parts of the network is notoriously difficult and susceptible to significant error.

Generally it is approached using one of the following methods:-

- by sampling a proportion of the network and scaling the remainder
- by using computer models such as BABE (Ref 2)
- by water balances between supply meters and DMA meters

In practice all have to be used to give confidence in the results. As leakage on DMAs has reduced by the extensive targeting methodologies that have been developed over the last five years, the proportion of leakage remaining on the upstream network has increased. This is bringing into focus the need to address leakage measurement on this part of the network.

Maximum likelihood estimation

Once an estimate for leakage has been derived it can be added as a component to the water balance – just like unmeasured consumption. With this estimate it may be that the components may add up to more than the distribution input or it may be less. This imbalance will indicate the confidence in the reliability of the estimates used in the various components. The Regulator has provided guidance on an approach to reconcile this imbalance. Provided the imbalance can be brought to within a few percent of the distribution input, then the imbalance can be re-distributed between all the components of the water balance in proportion to the company's estimate of the confidence of each component. This results in reducing distribution input, increasing leakage etc. The net effect is that although leakage is higher, looses will be lower than originally calculated.

Example of the assessment of losses - North West Water (UK)

North West Water (NWW) is one of the largest privatised water companies in the UK. It serves 6.7million people in the North West of England. The components in the water balance (post reconciliation) for NWW for the financial year 996/97 were:-

Distribution input	2176 Ml/d
Measured consumption (excl. SPL)	594 Ml/d
Unmeasured consumption (excl. SPL)	903 Ml/d
Supply pipe leakage	121 Ml/d
Miscellaneous use	18 Ml/d
Operational use	8 Ml/d
Distribution losses	532 Ml/d

There are many arguments why losses should not be expressed as a percentage of distribution input; however it is a measure that is used frequently by the media. This is in order to be able to reduce figures to a measure which, they believe, is understood by the general public and which can be used to compare different companies. These figures are shown in Table 1 below.

Application of sensitivity analysis to NWW

If the maximum allowances claimed by any UK company were used in the NWW water balance it would have the following affect:-

Measured consumption

If 12% meter under registration is assumed rather than the 3% currently used the metered consumption would increase by 49Ml/d

Unmeasured consumption

If a PCC of 172 l/hd/d were used instead of the assumption of 138 l/hd/d the unmeasured consumption would rise by 227Ml/d.

Miscellaneous and operational use

Changing these allowances from the ones currently assumed by NWW to the maximum i.e. 2.4% of distribution input for miscellaneous use and to 1.5% of distribution input for operational use would increase these allowances by 27Ml/d and 22Ml/d respectively.

Supply Pipe Losses

By changing the assumption of the split of total losses that can be attributed to customer supply pipe leakage to 40% of total losses then the allowance for supply pipe leakage will increase by 12Ml/d despite the dramatic reduction in total losses.

Net effect

The effect of applying these changes is showing in Table 1 below. The net effect is to reduce distribution losses from 532Ml/d to 195Ml/d or when expressed as percentages from 24% to 9%. A switch that can be made over night – by the stroke of a pen rather than major leakage detection effort!!!!

Item	Original		Change	Revised	
	Ml/d	%	Ml/d	Ml/d	%
Distribution input	2176	100	no	2176	100
Measured consumption (excl SPL)	594	27	+49	643	30
Unmeasured consumption (excl SPL)	903	41	+227	1130	52
Supply pipe loss	121	6	+12	133	6
Miscellaneous Use	18	<1	+27	45	2
Operational use	8	<<1	+22	30	1
Distribution losses :	532	**24**	-337	195	**9**

Table 1 Changes in the water balance components in a typical UK company

These changes are presented graphically in Figure 3.

Conclusions

Despite the fact that the UK has an agreed national methodology for reporting leakage which is audited by external certifiers, the figures rely on a significant number of assumptions and the methodology allows significant variation in the assumptions between companies. Until these variations are validated and can be explained by realistic demographic or topographic variations then the results have to be treated with caution and care. It is highly likely that they do not necessarily truthfully reflect the actual difference in leakage levels between companies.

The use of percentages only exaggerates these anomalies as the errors pass between the different components.

International comparisons become even more tenuous when consideration is made of the lack of standard terminology, methodology and measurement standards. Work on international comparisons will be published this year highlighting these anomalies (Ref 4).

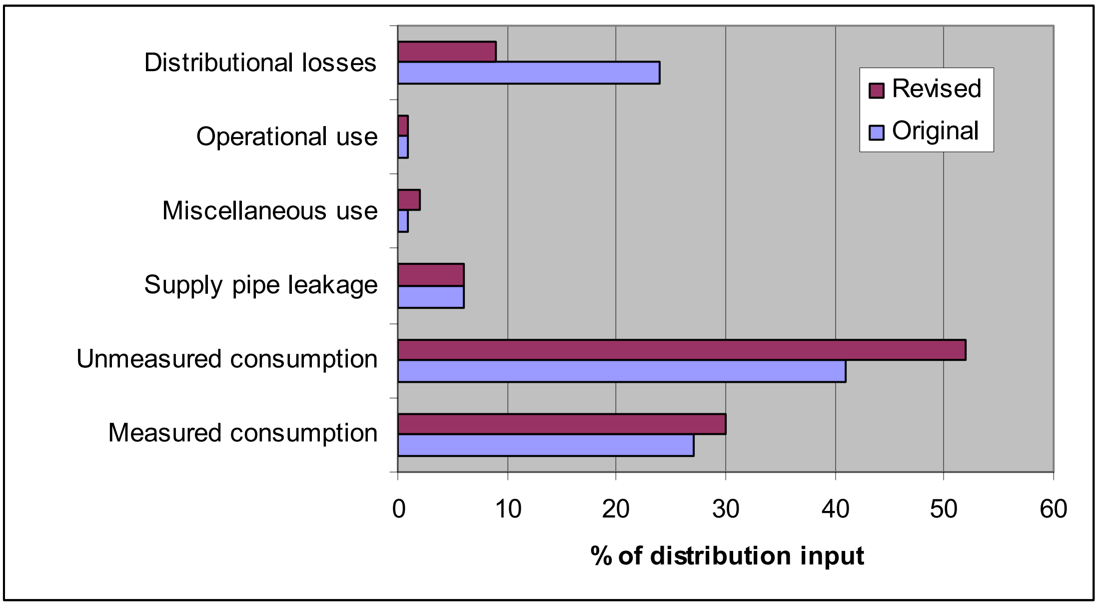

Figure 3 Impact of revising water balance assumptions

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