

The service pipe – a forgotten asset in leak detection

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Introduction

In a distribution network the length of service pipes may approach or exceed the length of mains. Although service pipes are of small diameter and leaks run with restricted flow rates, they can contribute significant volumes to overall leakage, particularly as the leak may be on customer premises and run undetected for many months. Service pipes are often accorded less priority in leak detection and repair activities than the more obvious and larger bursts arising from distribution mains. A similar observation may be made of asset renewals where mains are often replaced without corresponding replacement of the private or public part of the service pipe.

Both leakage and asset investment policy would benefit from a clearer understanding of the proportion of losses occurring through the service pipe and distribution mains.

There are few published studies on service pipe leakage. Those references that are available (WRc/WSA/WCA, 1994), (Lambert, 1999) do not indicate that substantial field studies have been carried out and there is much reliance on small studies carried out in the UK over 10 years ago even for international approaches.

This paper is based on recent research on service pipes that was funded by UK Water Industry Research Ltd (UKWIR, 2005).

UKWIR study

The UKWIR study was part of an ongoing programme of research across all areas of the water industry. The main study objective was to improve the assessment of leakage on the private service pipe (beyond the edge of the street). Such assessments are required by the government regulator in the UK as part of leakage reporting. Improved knowledge of service pipe leakage would also improve leak detection targeting and inform asset replacement strategies.

The service pipe presents particular issues in the UK where the section between the customer premises and the street is owned by the customer, but the emphasis is on the water company to deal with leakage and few customers are measured at the boundary of the street. UK service pipes typically are a single connection feeding a single property, although many older properties may be jointly served by a single connection.

Detailed examination carried out in the UK presents an opportunity to apply the results to other countries, irrespective of their particular arrangements of ownership and metering. Countries with universal metering at the property boundary (and responsibility for downstream leakage placed on the customer) need also to account for customer-side leakage when considering water resources.

A further benefit arising from this review is the potential to understand leakage mechanisms from a different perspective. Probably uniquely in studies of this nature, detailed and long term individual leak life histories were examined and provided the basis for some development of established methodologies to accommodate better service pipe issues. The resulting developments have wider application outside the area of service pipes.

BABE methodology

The bursts and background estimates (BABE) methodology has been used in leakage estimation and is now incorporated within the IWA leakage methodology to determine unavoidable annual real losses (UARL) and the Infrastructure Leakage Index (ILI) (Lambert, 1999).

The volume lost in a burst can be assessed as:

$$\text{Volume} = \text{Average Flow Rate} * \text{Average Duration} * \text{Frequency}$$

Other leakage that is not an identifiable burst is labelled as background leakage.

It is clear from observations of the application of this method that background leakage represents a substantial proportion of the overall estimate in many networks.

The BABE approach forms a sound basis for estimation of leakage as it potentially separates identified leakage burst events (which are managed by policy and technology) from background leakage at the sub-event level (which are a function of network infrastructure condition). The BABE approach was used as the basis of the UKWIR study.

Issues with the BABE methodology

The following issues arise from the BABE approach, and are applicable to all parts of the network.

Definitions – the literature is vague on the separation of bursts and background leakage. The potential benefits of the separation described above are then lost. There is also a possibility of double counting or omission of leakage depending on the means used to determine the parameter values.

Durations – company estimates of duration are reasonable from the point of awareness of the burst, but the time from the start of the leak to awareness is difficult to estimate directly.

Estimates of durations can be based on policy (e.g. for leaks found by active leakage control (ALC) half the interval between sweeps is commonly used). Other factors extend the duration beyond this estimate. For example, there is an assumption of 100% success in finding service pipe leaks during an ALC sweep. This is rarely the case, and any leaks not found are likely to remain until the next sweep, extending the average interval. A “detection success factor” is therefore required to account for this effect in the analysis.

This and other identified factors extend estimates of burst durations significantly when compared with previous approaches. For example in the UARL estimates not only is a six monthly ALC sweep assumed, it is also assumed to be 100% successful in finding all leaks and that there will be no significant delays to repair. On private service pipes it may take considerable time to effect a repair on private property depending on the legislative framework available and other customer management factors.

Frequencies – frequencies of burst breakout are unknown, only frequencies of repairs are available. Whilst repair frequency data may be reliably gathered, any network not in a steady state (e.g. with a backlog of repairs developing or being cleared) requires additional estimation to develop the true breakout frequency.

Flow rates – the only observable flow rate in the absence of special studies is the flow rate on leak discovery (the terminal flow rate). This is not necessarily the average flow rate required for the BABE equation if bursts are assumed to grow. Previous studies have used terminal flow rate data as the average burst flow rate. A “burst shape factor” is therefore introduced to accommodate the difference.

Pressure – there are no significant issues with the concept of pressure correction and previous comprehensive research has been carried out in this area (summarised in Lambert, 2000) and was applied for the study. It is essential to the methodology that all experimental flow measurements are corrected to give parameter values at standard 50 m pressure and that all applications of the methodology are corrected back to local pressures.

Engineering considerations

For the service pipe, as for distribution mains, it is to be expected that both burst frequency and background leakage on the pipe run will be proportional to the length of pipe under consideration (other factors being equal). This is consistent with parameters used for distribution mains.

Additionally for the service pipe it is to be expected that there will be an element of leakage which can be expressed “per connection” related to fittings such as stop taps and meters. This is analogous to mains fittings such as hydrants.

Between the private and company elements of the service pipe, the development of bursts is expected to be similar in nature for a given size of pipe (i.e. the frequency of leaks and the growth patterns are expected to be similar). Similar arguments can be applied for the background leakage element.

On the private part of the service pipe there may be additional means of detection (e.g. external meters) that will affect the overall duration of the burst, but these and other differences can be accommodated in the analysis.

The limited range of diameters for most service pipes is of advantage in this analysis as the effect of diameter variations on the scale of leakage is minimised. Large diameter connections to non-household properties may need special consideration. If there is enough information about the private and company service pipe asset (e.g. pipe materials) then differences can be modelled, but this is rarely the case in the UK.

Any revised approaches to service pipe leakage should account for and exploit these engineering considerations. In particular consistency is expected in model structure and parameter values on private and company service pipe leakage.

Data reviewed

Several sets of data were made available for the UKWIR project as detailed below. Whole company burst repair job databases were also available.

Flow rate measurements on burst repair

Samples of flow measurement obtained during burst repairs on the private service pipe were made available to the study. All service pipes supplied a single property only. Measurements were taken at the boundary from an existing or temporarily fitted meter.

The burst repair data provided information for the assessment of terminal flow rates against a variety of pipe materials.

Snapshot studies

Several snapshot studies were made available. These studies carried out intensive leakage control effort in sectors of around 1,000 properties with detailed recording of bursts found and flow rate estimation.

The snapshot studies provided details of the bursts running in an area and the effectiveness of different ALC methods in finding the bursts. The leakage found included mains, company and private service pipe leaks and internal property plumbing losses.

Long-term small sector flow and pressure data

Long term flow and pressure data in small sectors of 20-100 properties were provided allowing full burst life history analysis of 76 burst events. The small size of the area allowed individual bursts to be identified and tracked. Service pipes reviewed included both single and multiple property connections. All areas were isolated after the sector meter and contained no boundary connections.

The small sectors provided data for the assessment of leak durations, terminal flow rates, burst growth and background leakage estimates. Private and company service pipe leakage and distribution mains and fittings leakage was observed. Over 5.3 million property-days of data were available with each sector being recorded for between 18 months to 5 years. 76 burst life histories were available from around 100 sectors. Property age, and hence pipework age, ranged from less than 10 years to over 100.

Critically for the small sector data, the monitor had not been used as a detection resource to identify leakage (it was used for estimates of unmeasured household customer demand). The bursts observed were therefore unaffected by the observations made and could be taken to be representative of burst life histories across the company.

Not all bursts could be matched to repair events. Bursts which were identified as mains bursts were eliminated. Two outlier events were also eliminated as the volumes were an order of magnitude larger than other bursts. The remainder of the unidentified bursts were of similar characteristics to the identified company and private service pipe bursts. None of these groups could be proved to be statistically different from any other and it was felt appropriate to use all the bursts in the analysis.

Results

Durations

The duration of the bursts was estimated using the small sector data from the point when the burst was identifiable above the background flows until repair. The average duration of the bursts observed was 339 days. The means of identification of the burst (reported, unreported) was not available and so separate average durations could not be determined from the data.

The duration estimate is consistent with the longer durations assumed from the earlier discussion.

Duration/frequency relationships

From an estimate of the durations and frequencies of bursts, a prediction of the number of bursts running at any point in time can be made.

Area snapshot studies indicated that higher numbers of bursts were running than could be predicted by assuming the shorter durations used in previous estimates. As the frequency of burst repairs was assumed reliable, this pointed to longer durations than previously assumed reinforcing the evidence from the small sector studies.

Burst flow rates

Terminal flow rates in the small sector monitor averaged around 450 l/h at 50 m pressure. This was supported by the burst repair data where an average of 560 l/h at 50 m pressure was obtained correcting from an assumed company pressure of 35m (detailed pressure data was not available). The largest burst in either set did not exceed 1500 l/h.

The small sector monitor allowed observation of burst growth as illustrated in Figure 1 below. A burst shape factor was calculated; this being the average burst flow rate divided by the terminal burst flow rate. From the limited 76 bursts available a shape factor of 0.65 was determined (standard deviation 0.3). The average burst flow rate from the small sector monitor was therefore 0.65×450 or approximately 300 l/h. This compares to 1600 l/h used for the UARL estimates.

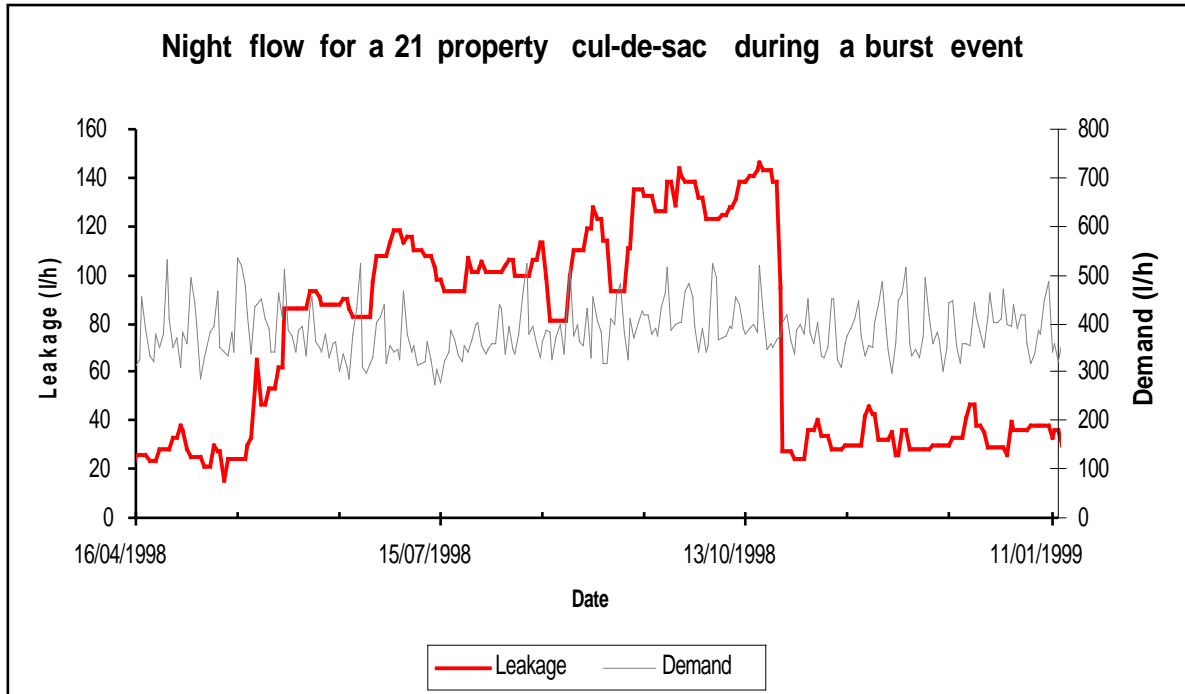


Figure 1 Illustration of burst growth on a small sector monitor

Flow rate / duration relationships

The fundamental assumption of the average leakage volume being the product of the average durations and average flow rates only holds if the components are independent. This may not be the case if, for example, bursts become larger over time. Evidence of a burst shape factor of less than 1 indicates that burst flow rates become larger when running for longer durations and therefore may not be independent.

There were insufficient burst numbers in the small sector data set to prove independence or disprove non-independence and further work is needed. Certainly the higher service pipe burst flow rates quoted in previous UK research may be indicative of bursts running for longer duration than is currently experienced.

Background leakage

Estimates of background leakage for the small sector monitors could be made in the periods between bursts. Estimates of service pipe and mains length were scaled from plans to allow models of background leakage to be tested.

Several models were defined using the UARL principles. The data set of over 80 small sectors was not sufficiently robust to allow new parameters to be determined. The preferred model was developed to accommodate both the length and per connection elements of service pipe leakage and used the following allowances:

Table 1 Background losses components estimated from the small sector monitor

Background component at 50 m pressure	l/h
Mains (/km mains)	20
Service pipe (/km pipe)	33.3
Service pipe (/property)	0.6

The mains “per km” allowance is unchanged from the UARL approach. The private service pipe “per km” allowance is equivalent to the UARL parameter for service pipes after the edge of the street. The company “per km” element of the service pipe uses the same estimate on a typically shorter length.

The service pipe “per property” allowance was determined by modelling from the available data set after fixing the above parameters. The overall allowance for the company service pipe to the edge of the street is reduced from the UARL parameters when the “per km” and “per property” allowances are combined.

This model is consistent based on the engineering considerations detailed earlier. However it probably understates the background leakage as the metering used in the monitors was likely to be under-registering flows. The varying age of the infrastructure should also be accommodated in the model, but insufficient data were available to permit modelling.

The data were not sufficient to suggest a change to the established IWA parameter values. Further research is necessary with more accurate metering at low flows to improve the estimates and to confirm the modelling approach suggested here.

Separation of policy/technology from condition/serviceability of assets

Previous approaches have not dealt with the separation of bursts and background leakage in a consistent manner. For example, if the background for an area is defined as the lowest level of leakage that has historically been achieved, this will be affected by the emergence of a more intensive leak location policy or a new technology allowing bursts to be detected at a lower threshold. In addition some studies to determine background leakage levels were carried out following sector leak detection which is significantly more intensive than routine effort.

There are advantages in separating bursts and background leakage in a manner which allows consistent analysis for leakage and infrastructure renewals. By defining the burst as starting at the point when it emerges from background leakage the following consequences flow:

- Bursts and background flows are separated
- Background is independent of policy and is a function of condition /serviceability only
- The condition/serviceability element of bursts is the frequency
- For the initial part of the duration the burst will be undetectable by the level of technology applied. The threshold will change as technology changes.
- The remainder of the duration will be a period where the burst is detectable but not detected until reported or ALC effort is applied and will therefore be dependent on policy.

The following figure illustrates this for a single burst life history.

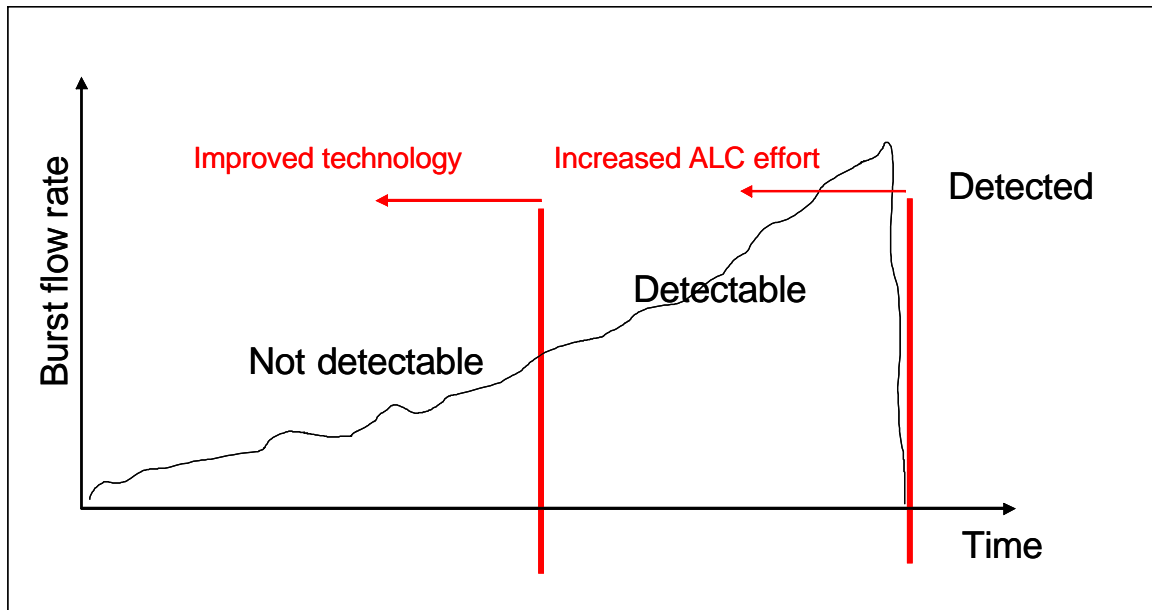


Figure 2 Burst growth relationship with policy and technology

A view of background leakage based on the lowest achievable level would probably contain some elements of bursts that are at the “not detectable” stage. These will be variable in extent depending on factors such as the size of the area, with larger areas masking bursts. By separating bursts and background leakage, estimates can be made independent of the area of application.

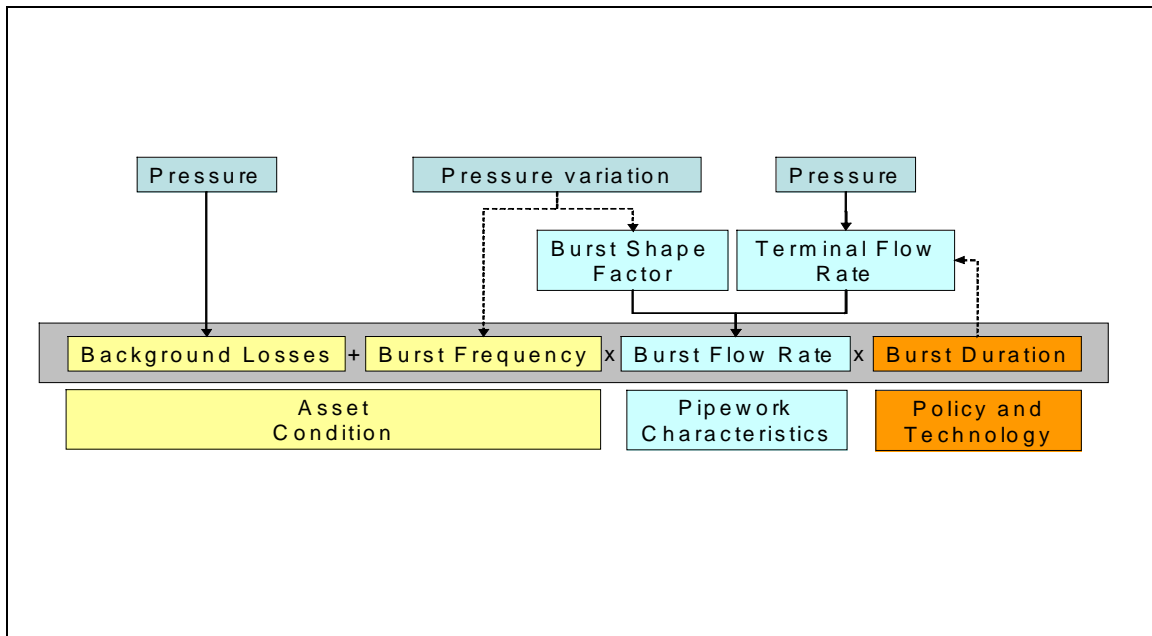


Figure 3 BABE equation with underlying factors

Figure 3 expresses the BABE equation with its links to underlying factors identified when used with bursts and background losses separated. The link between burst frequency and pressure is related more to pressure variation and pressure variation may also influence the burst shape factor.

Some workers apply an infrastructure condition factor (ICF) to background leakage. The ICF appears to have two functions:

- To account for the condition of the infrastructure relative to the assumed condition that was used to derive the reported default data.
- To account for the effects of policy and the efficacy of detection or repair activities. The factor scales the background leakage to include the best achieved levels which include bursts that were running but were not detectable, detectable but not actually detected, or detected but not economic to fix.

It would be more advantageous to separate these into the defined components so that the impacts of condition and policy could be more reliably assessed.

The introduction of a correction for condition presumes that the condition of the networks providing the original experimental data was known (It is directly analogous to the pressure correction.). This is unlikely to have been the case in the original research and the parameter values quoted probably reflect the UK infrastructure condition at the time the data was gathered.

Further work

The available data sets are sufficient to develop a consistent conceptual approach, but are limited in providing detailed parameter values.

In addition, the estimates of background leakage currently available are limited by issues of meter under-registration and further effort using higher specification metering would be of benefit. Given the contribution of the background leakage element to service pipe leakage, further work would remove some of the uncertainties surrounding this area. Background leakage models could be developed that accommodate varying infrastructure condition. Significant further study is required before a reliable set of parameters can be developed.

Work in the UK is continuing and some more detailed field work is being carried out. The UKWIR report details data collection approaches that will provide a robust set of data for analysis and it is recommended to any organisations undertaking field work.

Conclusions

Significant progress has been made towards a service pipe leakage assessment approach that is consistent with both engineering concepts and leakage control policy. However, there remain many areas where further work is necessary to allow firm conclusions to be made.

The work is also consistent with the IWA leakage methodology and provides further development of elements of the methodology. Further concepts have been introduced covering such areas as burst shape factors and detection success factors and allowing improved analysis. The separation of infrastructure condition factors from aspects of policy and technology will allow more informed management of distribution networks.

The use of long-term small sector monitors has wider application, particularly if the monitor does not affect leakage detection activities in the area observed. By observing a single burst on a small sector, more detailed analysis and simulation can be carried out. It would be of interest to locate other organisations internationally with similar small sector or other service pipe data sets for comparison to the UK results. The results of international studies could then be used to input to the IWA leakage methodologies.

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