Leakage Determination Using Nightline Methodology

The Company has continued to improve the quality of the data used to obtain robust company-specific data to underpin this leakage appraisal. The sources of this data are detailed in the following sections.

Netbase Leakage Management System

The Crowder & Co. Netbase leakage management system has been used to provide base leakage data for the return. Netbase provides several important facilities that ensure consistent and reliable data provision:

- Determination of minimum night flows in accordance with the UKWIR methodology.
- Automated extraction of daily summary data from the Radcom, PMAC, TRD Scada database and Wisdom logger databases with data validation and exception reporting.
- Daily updates and reporting of DMA leakage levels for active leakage control purposes.
- Powerful and flexible reporting facilities.
- Extensive data validation checks.

Netbase is the repository of all leakage data for each DMA and WWMD (Waste Water Meter District). Mains, fittings, service pipes, properties, network boundaries and the network configuration are imported directly into Netbase from the corporate Smallworld GIS. Customer billing data, metered consumptions, property types, SIC codes and administrative boundary data are imported directly into Netbase from the corporate data warehouse. Time series flow and pressure data for all DMA's and logged customers is obtained by direct interrogation of the Radcom, PMAC, TRD Scada database and Wisdom logger databases and summary data is stored in Netbase. The summary data is validated and data failing validation is flagged as inoperable in Netbase.

Minimum night flows are determined using the UKWIR 7-day rolling average 50 percentile method for a minimum rolling hour determined between 00:00 – 06:00hr. Non-household night use data is allocated at property level, based on the SIC code and annual billed volume. Household night use and exceptional night use are also allocated at property level. Zone-specific ICF, hour to day ratio and AZNP's have been determined and weighted company specific values are used in the leakage calculation. Calculation of the hour to day ratio and AZNP data is now done in Netbase.

Exceptional Night Use

The Company has undertaken a detailed survey of commercial and industrial properties within DMA's to identify those customers with exceptional night use, typically defined as greater than 500 l/hr.

There are currently 121 supply points classified as exceptional night users. Where a customer's night use is found to be a significant component of the minimum night flow into a DMA, the Company has installed flow loggers to ensure that variations in the exceptional night use are taken account of in the night flow method of leakage calculation. These loggers are either connected to some form of telemetry or are manual downloaded on a monthly basis.

Non-household Night Use

The Company has continued to develop the non-household night use study with Tynemarch Systems Engineering in order to provide a robust auditable basis for legitimate non-household night use. The methodology has been revised to accommodate the UKWIR methodology and to make use of the full 4-5-digit SIC code that the Company has now purchased. The methodology also now includes separate analyses for metered and unmetered non-household customers. The analysis was undertaken using all survey data now available from two survey periods.

The sample data were modelled against the annual consumption applicable at the time of the survey using the UKWIR power law relationship. All valid sample data from the two survey periods were used, with the following constraints:

A maximum limit of 750 l/hour was placed on any contributing sample
The model was not applied to any meters recording more than 1000 l/hour (8760 m3/year) because above this value the data are distributed too thinly.

Both these constraints yield models that are conservative estimates of mean night use. An additional 38 random samples were taken during 2006-07 and the final sample set used in the modelling comprised a total of 2,058 valid samples, and the assessed population of meters is 27,475.

The modelling resulted in stratification into 10 new industry groups, based on the SIC code categorisation. Values of the "a" and "b" parameters in the power law relationship were determined for each strata and input to Netbase with a look-up table detailing the SIC codes within each strata. The modelled average of night use for metered customers is 23.05 litres/property/hour.

The night use of unmeasured customers has been modelled by making best use of the measured population. For this modelling, a maximum ABV threshold for the sampled population was set at 1000 m3/year and the maximum night use was set at 300 litres/hour. The measured sample data were re-modelled using these constraints and average values developed for each of the strata(strata for application to unmeasured properties within Netbase according to the SIC code. The modelled average of night use for

unmeasured customers has been estimated at 8.83 litres/property/hour using this methodology.

Household Night Use

The Company has continued to develop the use of Socrates night flow analysers to obtain a more accurate understanding of household night use. The Socrates analysers are designed to distinguish short term, intermittent, use from leakage by using pulse interval timing and a high scanning rate. This enables Socrates to separate out peaks and troughs of legitimate night use from what would normally appear to be the minimum night flow when logged at a 15-minute interval. Socrates analysers have been used on the Company's consumption monitor meters to obtain an accurate, representative, estimate of household night use.

Socrates is designed to remove variations in the high resolution flows recorded that are not due to variations in the demand, but are due to a combination of errors inherent in the measuring system, surge flow effects and oscillating flow effects. These variations are removed by interpolation and autocorrelation to determine the optimum averaging period for each specific meter installation and measurement site. Socrates uses both transient flow and pressure data for these calculations. The optimum averaging period varies from 15 seconds to 120 seconds, depending on the type of meter and the meter location in the distribution system. The output from Socrates is a nightly minimum derived for each night, based on an analysis of the flows over the 2 hour minimum flow period.

Socrates attempts to penetrate through all short-term usage events to what is termed the core night flow. The core flow is made up of continuous night use and leakage. Continuous night use is defined as, for example, leaking taps and plumbing losses. The continuous night use component varies significantly from night to night. To ensure that the continuous night use component is minimised, Socrates analysers are installed for a period of at least 30 consecutive nights on any meter, ensuring a minimum of 15-18 days of valid data is obtained.

The household legitimate night use has been determined using the Socrates Effective Minima analysis. This analysis relies on the fact that leakage flows will not reduce over time (unless a burst has been repaired). The minimum in the data set is adopted until the data point of the effective minimum is reached. After this data point, a new minimum is identified and adopted and allocated back to the data point following the original minima. This process continues until the end of the data set is reached. Any data sets affected by burst repairs during the logging period are excluded from the analysis. The following formula is then applied:

Night use = 2 hourly night flow - effective minimum allocated for night.

During 2006-07 a consultant has undertaken further analysis of the household night use data set. Year specific analysis methods were assessed as well as a long term “all years” estimate. For the night use assessment of 2006-07 an allowance based on 30% trade was used, this appears not only to provide a balanced result but also carries the lowest confidence interval. The average figure of 2.39 litres/property/hour is populated in Netbase through 6 Water Use Class strata. The WUC stratification applied at DMA level provides a more specific allowance based on the composition of the DMA, which can benefit the process of active leakage control.

Average Zone Night Pressure

The average zone night pressure (AZNP) has been determined for each zone using direct measurement and an assessment in Netbase, which uses the inlet pressure of a DMA. These methods has been used to determine the AZNP for zones covering 95.0% of all company properties. The height of all properties in the GIS database has been determined by interpolation of the OS 1:10000 digital terrain model. The average height of each particular zone is determined from this data and the pressure is logged from a hydrant at an elevation close to the average height for a period of 7 days. The average night pressures recorded are adjusted for any height difference between the hydrant and the average zone height to determine the AZNP. The determination of the AZP point in Netbase is the same as the methodology applied in GIS. For the 2006-07 assessment the AZNP for 24.8% of the company properties was determined using the Netbase methodology. This percentage will increase over time when the AZNP has to be reassessed after pressure regimes changes in DMAs, and instead of direct measurement Netbase will be used to determine the new AZNP.

A company property-weighted AZNP has been calculated from the zonal data to be 46.38 m.

Hour to Day Ratio

The hour to day ratio has been determined for each zone by using the UKWIR spreadsheet, and calculations in Netbase. Hourly averages of the pressures recorded for the AZNP determination are entered into the UKWIR sheet for a 24 hour period, which determines the hour to day factors for each zone for the FAVAD theory power law exponents of N1=0.5 and N1=1.5. The zonal hour to day ratio is determined from these parameters using the zone specific level of background losses and bursts. As per the AZNP calculation, the HDF calculation has now been incorporated into Netbase using the inlet pressures into a DMA, thus avoiding the need for direct measurement in the future. The company, property weighted, hour to day ratio is 23.33.

Service Reservoir Losses

A standing test is performed on all Service Reservoirs as part of the routine structural inspection programme. The interval between inspections is

generally no more than every four years for an individual compartment. There has been a marginal increase of the average Service Reservoir losses during 2006-07.

Trunk Main Losses

All Trunk Mains are normally inspected for leakage through an annual programme of route tracing with sounding on valves and fittings. For sixty six trunk main systems a water balance is calculated through logging of all inlets and outlets. The balance is initially used to highlight any large meter errors or inaccuracies within the balance. The balance is resolved to within +/- 5%, after which the balance is deemed stable. This year further work was undertaken and all but four trunk mains balances were run. This is a change from last year when it was only attempted to solve balances which historically did not balance. The majority of the balances can now be automatically run through Netbase, 23 of the balances were within tolerance for 2006-07 and have been used for the direct leakage estimation.

The volume of leakage from trunk mains is determined in two ways.

1. Where the balance is resolved to within +/-5%, and the length of the main has been inspected for leaks during the past 2-3 years, the number of leaks found constitutes the reported level of leakage for this particular trunk main system. An estimate of the duration of each leak is made based on when the leak was found, when the main was last inspected, and when the leak was repaired. An estimate of the flow rate is made from a photograph (where provided) of each leak and based on four categories of leak – weeping stop tap (<500 l/hr), broken supply pipe (1200 l/hr), distribution main burst (8000 l/hr), trunk main burst (volume to be determined from graph).

2. Where a trunk main system is not within balance, or the balance has not been refreshed in the current reporting period, the leakage for this trunk main is based on a traditional non-specific method. The method uses the length of main and multiplies by a static factor derived from Report 26 of 150 l/km/yr of age/day.

Bristol Water are pursuing improvements to systems that will allow the move away from the old method of losses based on length of main and toward the specific method that takes account of real leakage, and promotes maintenance of the trunk main system. Maintenance schedules within the trunk mains department have changed and every trunk mains is now walked on a 3 year frequency (this was every 12-18 months). The methodology has been amended to reflect this change and balances within +/- 5% will now be used for direct leakage determination if the main has been walked in the past 2-3 years.

Background level of leakage

Background losses determination is based around BABE (Burst And Background Estimation) theories as described in ‘Managing Leakage’.

The background level of leakage has been assessed in night flow monitored areas by examining the best achieved night flow losses, based on a rolling 7-day minimum night flow. The Infrastructure Correction Factor (ICF) is a value obtained by calculating the ratio of an area's background losses to those calculated using England and Wales nominal average values. This approach has been used to calculate the ICF for each DMA. No further update of the ICF figures has been done during 2006-07 and the company global ICF figure remains unchanged at 0.871.

The level of background losses is dependent on the size (number of connections and length of mains) and condition of the system (ICF), and the average system pressure (Average Zone Night Pressure and Hour to Day Factor).

Maximum Likelihood Estimation (MLE)

Overview

The figures quoted in the sections above are unadjusted for Maximum Likelihood Estimation (MLE). The MLE adjustment re-assigns any difference there may exist between the water balance determination of total leakage (top down), and the estimate of leakage from component analysis of DMA nightlines (bottom up). Where a difference exists it is re-distributed among the components of the water balance based on the confidence intervals associated with each component.

Confidence intervals are based around the expected accuracy of each component and reflect the likely error range associated with each component.

95% Confidence intervals

The reconciliation between Net Consumption (including losses) and distribution input is 3.32 Ml/d.

This difference has been redistributed as follows:

Line	Component	95 % conf interval	Explanation	Value determined (Ml/d)	MLE Redistribution (Ml/d)
1	Measured household	+/-3	Derived from metered sources	33.71	+0.10
2	Measured non household	+/-3	Derived from metered sources	65.48	+0.19
4	Unmeasured	+/-	Detailed calculations	133.57	+1.31

	household	10	give high accuracy, although extrapolation to company level reduces confidence.		
5	Unmeasured non household	+/- 30	Some assumptions, and extrapolation method increase uncertainty	4.16	+0.12
16	Operational use	+/- 10	Some element of estimation in some components of this line	1.75	+0.02
17	Legal unbilled	+/- 50	Reliant on Fire Service to make correct records. Some element of estimation.	0.56	+0.03
18	Illegal unbilled	+/- 50	Element of estimation in calculations	0.48	+0.02
25	Leakage	+/- 30	Detailed calculations but the number of components that make up this figure increases uncertainty	43.43	+1.28
26	Distribution Input	+/- 0.9	Derived from combined meter error on DI meters	286.10	-0.26

Summary and confidence grading

The leakage target for Bristol Water for reporting period 2006-07 is 54 Ml/d. Following MLE adjustment the level of leakage for the same period is reported as 53.56 Ml/d.

The difference seen in the water balance was 3.32 Ml/d, which represents –1.16 **%** error across the balance, and 3.82**%** error over the final leakage figure. This is a significant improvement in water balance reconciliation item compared with the 2005-06 submission when the error in the water balance was –1.69%

The main focus during 2007-08 will be to continue work not yet finalised as part of the leakage control and management strategy plan for 2006-07.

- Finalise the review of unmeasured Household PCC sample set of area monitors. This work was started in 2004-05. Incorporation of PCC calculation into Netbase5.
- Continue proactive revenue meter exchange programme, and reassess the Meter Under Registration calculation for commercial and domestic meters.
- Continue progress on trunk mains reconciliation project and meter verification studies.
- Continue to work on improving the supply pipe leakage calculation, implement where feasible the

recommendations and data from the collaborative supply pipe leakage project.

- Review of the smaller water balance components, in particular the Legally and Illegally unbilled use components.
- Optimise the DMA monitoring and configuration where possible.

No major changes have been made to the calculation methodology, and the confidence grades remain unchanged.

Line	Description	Confidence Grade
11	Estimated water delivered per unmeasured non household	B4
12	Per capita consumption (unmeasured household excluding SP leakage)	A3
29	Total Leakage	A3