Applicable background minimum night flow for leakage management of small district metered areas in Korea

H. Lee*, S. Chung*, M. Yu*, J. Koo*, I. Hyun and H. Lee*****

*Department of Environmental Engineering, University of Seoul, 90, Jeonnong-dong, Dongdaemun-gu, Seoul, Korea (E-mail: *peacho210@yahoo.co.kr; shinho@ene.uos.ac.kr; myong@uos.ac.kr; jykoo@uos.ac.kr*)

**Department of Civil and Environmental Engineering, Dankook University, San-8, Hannam-dong, Yongsan-gu, Seoul, Korea (E-mail: *ihhyun@dankook.ac.kr*)

***Water Resources and Environmental Engineering Division, Korea Institute of Construction Technology, 2311, Daehwa-dong, Ilsan-gu, Goyang, Gyonggi-do, Korea (E-mail: *hdlee@ kict.re.kr*)

Water Science & Technology: Water Supply **Vol 5 No 3–4 pp 181–188**

Abstract In case of Seoul city in Korea, the level of water leakage from any distribution system is evaluated by comparison of measured minimum night flows (NFMs) with a fixed allowable leakage level. However, infrastructure condition of District Metered Areas (DMAs) could be misjudged, because characteristics of the system are not considered properly. Therefore the components of NFM were estimated in residential and business DMAs by using data of night uses collected by modified option A test and real losses from water balance analysis. A new background minimum night flow equation was developed by the components of NFM. Applicability of the equation was tested on various revenue water % residential and business DMAs. As a result, it is concluded that the new background night flow developed in this study is more reasonable in Korea and could be used to judge whether the DMAs have economically recoverable unreported bursts prior to leakage detection activity.

Keywords Allowable leakage; background minimum night flow; leakage detection; minimum night flow

Introduction

Seoul city in Korea has set the allowable leakage level at 1 m^3/hr km for distribution pipes. Concentrative leakage detection and repairing activities are repeated until the NFM reaches this level (Office of Waterworks, 2000). However, the allowable leakage can overestimate or underestimate present leakage level, because it only considers total length of mains and communication pipes and ignores other important factors. It is difficult to identify the existence of unreported bursts in distribution network using current allowable leakage level unless including night uses, because night flows contain considerable amount of night uses influenced by different life and business style of customers. To use NFMs well, residents' lifestyle and pattern of water consumption should be considered corresponding to the national or local situation rather than the criterion suggested in the UK, because the lifestyle of Korea differs from that of the UK. Therefore, more rational criterion should be developed involving background losses and night uses considering the local characteristics of DMA: pressure; number and type of service connections; and length of mains. The objective of this study was to develop a reasonable background minimum night flow equation with considering the characteristics of DMA, through minimum night flow analysis of the UK Water Industry and water balance analysis.

Minimum night flow analysis of the UK water industry

Figure 1 shows how components of NFM contribute to the series of NFMs which would be measured in an individual DMA over a period of a year. NFM analysis is based on calculation of the components as shown in Table 1 (McKenzie, 1999; McKenzie and Wegelin, 2002).

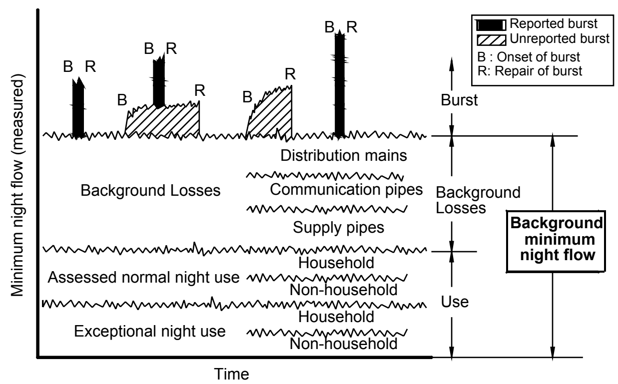

Figure 1 Components of minimum night flow

Measured NFM is standardized to 1 hour and 50 m pressure with the Sampling Duration Correction Factor (SDCF) and Pressure Correction Factor (PCF) as shown in Figures 2 and 3. NFM can identify the existence of unreported bursts in distribution network by comparison with background minimum night flow (WRC, 1994).

Method

Suitability test of conventional two criteria on NFMs

As shown in Figure 4, NFMs were measured during the minimum demand period (0:00 4:00 am) with an ultrasonic flow meter installed at the inlet point of each residential and business DMAs with various revenue water % of system input volume (RW %), covering ranges of 50–60%, 60–70%, 70–80%, 80–90% and over 90%. Allowable leakage of Seoul city, Korea was tested for its suitability by comparing measured NFMs with the criterion. And background NFM of UK was tested whether it can be applied in Korea directly without any modification.

Development of new background minimum night flow equation

Assessed normal night uses. Normal customer night uses were estimated from sample survey checking night flow delivered to externally metered households and non-households in small DMAs (named A, B, C, D, E and F) from January to November by modified option A test. Modified option A test was that external meters outside properties were individually read twice overnight and any measured night flow delivered to individual properties except supply pipe background losses was categorized as customer night use as shown in Table 2.

Table 1 Components of minimum night flows

Components		Definition
Exceptional night uses		Night uses exceeding 500 L/hr (criterion of bursts)
Assessed normal night uses	Household	Night flows used by household
	Non-household	Night flows used by non-household
Background losses	Mains	Collective sum of numerous minor leaks and seepages from valve, joints, hydrant on mains
	Communication pipes	Collective sum of numerous minor leaks and seepages from stop-taps, meters, boundary boxes on communication pipes
	Supply pipes	Collective sum of numerous minor leaks from dripping taps and overflows from lavatory cisterns and roof tanks

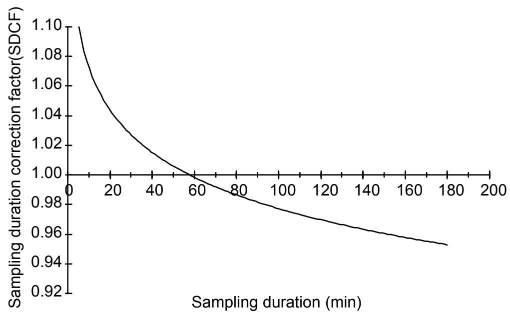

Figure 2 Sampling duration correction factor (SDCF)

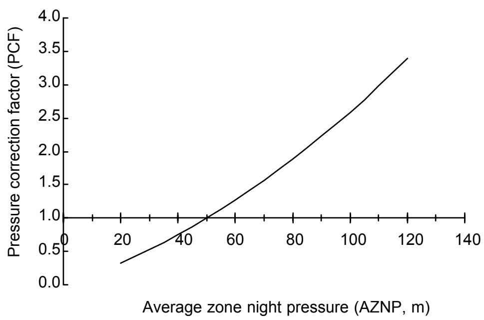

Figure 3 Pressure correction factor on night flow standard duration of 1 hr

For considering characteristics of DMAs which have different patterns of night flows, DMAs are classified into two groups: residential (A, B, C and D); and business (E and F) according to ratio of water consumption by each type of business. Especially in business DMAs, non-household night uses were estimated according to four groups classified by types of business. Group I is general type of business working at daytime, group II is public bath working for 24 hours, group III is leisure activities and group IV is accommodation. Local characteristics of residential and business DMAs are shown in Table 3.

Background losses. Supply pipes background losses were estimated by carrying out a modified option A test on the previously mentioned DMAs. Those values which have similar revolving speed of tell-tale on meters showing difference of less than 10 seconds/revolution were classified into supply pipe background loss even though

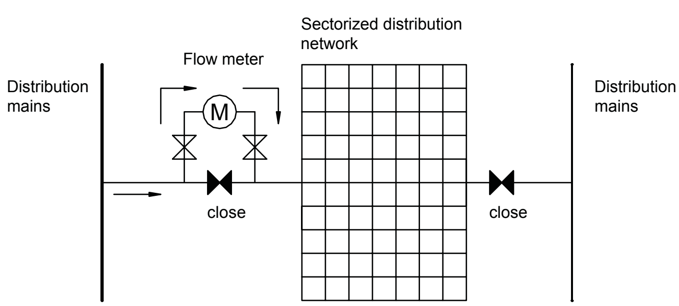

Figure 4 Measurement of minimum night flow at sectorized distribution network

Table 2 Classification of revolving 'tell-tale' on the meter

Revolution of tell-tale 1st	2nd	Classification
X	X	No customer night uses (by no difference of 1st and 2nd read figures)
O	O	Customer night uses (by difference of 1st and 2nd read figures)
O	X	Customer night uses (by difference of 1st and 2nd read figures)
X	X	Customer night uses (by difference of 1st and 2nd read figures)
O	O	Supply pipes background losses* (by difference of 1st and 2nd read figures)

X: 'Tell-tale' on the meter is not revolving; O: 'Tell-tale' on the meter is revolving slowly.
O: 'Tell-tale' on the meter is revolving fast (within 1 second while taking a round).
*: Difference of two readings was considered as supply pipes background losses in case that difference of revolving time is within 10 seconds.

the tell-tales were revolving in both of readings (1st and 2nd) at night. This was a modification of option A test used in the UK.

Mains and communication pipes background losses were difficult to estimate from night flows measured in small DMAs, because the number of DMAs was limited in this study. Therefore they were estimated by three methods: considering figures suggested by UK Water Industry (Method 1), real losses extracted from nationwide statistics data of high ranking (low real losses) 10% areas (Method 2) and 20% areas (Method 3).

Applicability test of new background minimum night flow equation. Applicability was tested by comparing measured NFMs with new background NFM in various RW % DMAs. It was reviewed on residential and business DMAs.

Results and discussion

Suitability test of conventional two criteria on NFMs

NFMs measured in various RW % DMAs exceeded both criteria of UK and Seoul city even in well maintained DMAs (5, 8, 9) showing RW over 90% as shown in Figure 5. Neither of the two conventional criteria was suitable to apply because the background NFM for the UK was estimated too low compared with that of Korea and allowable leakage of Seoul city considered local characteristics insufficiently.

Development of new background minimum night flow equation

Each component of minimum night flow was estimated as shown in Table 4. A new background NFM equation was composed by using each component of NFM as coefficients of the equation, as shown in Equations 1 and 2.

$$\text{New background minimum night flow in residential DMAs}$$
$$= \text{NFCUE} + C_1N_\text{h} + C_2N_{\text{non}-\text{h}} + [(C_3N_\text{h} + C_4N_{\text{non}-\text{h}} + C_5L + C_6N) \times P^*] \quad (1)$$

where NFCUE is the exceptional night uses (L/conn·hr), C_1 is the assessed normal household night uses (L/conn·hr), C_2 is the assessed normal non-household night uses (L/conn·hr), C_3 is the household supply pipes background losses (L/conn·hr), C_4 is the non-household supply pipes background losses (L/conn·hr), C_5 is the mains background losses (L/km·hr), C_6 is the communication pipes background losses (L/conn·hr), L is the Length of mains (km), N is the number of service connections, N_h is the number of household service connections, $N_\text{non-h}$ is the number of non-household service connections, and $P*$ is the pressure correction factor.

Table 3 Local characteristics of DMAs

Characteristics	DMAs	Residential DMAs				Business DMAs							
		A	B	C	D	E				F			
Number of connections	Household	1,050	3,791	1,283	727	733				210			
	Non-household	175	351	158	168	240 (i)	3 (II)	41 (III)	22 (IV)	145 (I)	0 (II)	2 (II)	90 (IV)
Mains (km)		8.031	32.891	8.392	9.745	11.326				7.332			
Communication pipes (km)		4.631	11.766	4.098	5.241	3.776				5.051			
Connections density (conn/m)		0.153	0.126	0.172	0.092	0.092				0.061			
Pressure correction factor		1.328	0.849	1.747	0.753	1.690				1.187			

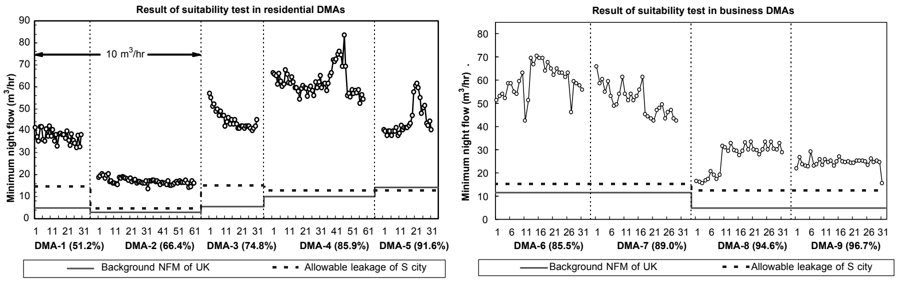

Figure 5 Result of suitability test in residential and business DMAs

Since non-households were divided into four groups in the business DMAs, coefficients of the four groups were estimated separately. Therefore $C_2N_{\text{non-h}}$ can be calculated as shown in Equation 2.

$$C_2N_{\text{non}-\text{h}} = [C_{2\alpha}N_\alpha + C_{2\beta}N_\beta + C_{2\gamma}N_\gamma + C_{2\delta}N_\delta] \tag{2}$$

where $C_{2\alpha}$ is the assessed normal non-household night uses of group I (L/conn·hr), $C_{2\beta}$ is the assessed normal non-household night uses of group II (L/conn·hr), $C_{2\gamma}$ is the assessed normal non-household night uses of group III (L/conn·hr), $C_{2\delta}$ is the assessed normal non-household night uses of group IV (L/conn·hr), N_α is the number of non-household service connections of group I, N_β is the number of non-household service connections of group II, N_γ is the number of non-household service connections of group III, and N_δ is the number of non-household service connections of group IV.

Applicability test of new background minimum night flow equation

New background NFMs (Methods 1, 2 and 3) in the residential and business DMAs judged the distribution network with over RW 90% (DMA 5, 8 and 9) to be mostly satisfactory as shown in Figure 6, while the two criteria of UK and Seoul city judged the same sites to be 100% unsatisfactory as shown in Figure 5. Unsatisfaction occurred sometimes but not continuously as shown in Figure 7. The occasional events (unsatisfaction which was changed to satisfaction automatically after sometime without taking any action) implies that it was caused by exceptional night uses rather than unreported bursts.

New background NFMs of the residential DMAs with RW 50–60%, 60–70%, 70–80% and 80–90% were unsatisfactory, as measured NFMs continuously exceeded the new background NFMs during the measured period. In case of business DMAs, unsatisfaction % increased as RW % decreased. The satisfaction % of business DMAs (DMA 6) was shown higher than that of residential DMAs (DMA 4) in spite of similar RW %, because sufficient allotment of night uses was made in order to cover frequently occurring exceptional night uses, in business DMAs.

According to the result of applicability test, therefore, it was concluded that the new background minimum night flow developed in this study was more reasonable for Korea and could be used for judging DMAs whether there were unreported bursts recoverable economically prior to leakage detection activity.

In comparison with new background NFMs developed from different techniques estimation (Method 1, 2 and 3) of mains and communication pipes background losses, three equations appeared satisfactory (or unsatisfactory) with a shade of difference during the study period. Therefore, it seemed that differences between methods were very small and it was meaningless to select the most reasonable equation among them. Assessed normal night uses have to be considered properly rather than to be excluded, because those yield

Table 4 Estimation of new background minimum night flow

Components of minimum night flow	New background minimum night flow	
	Residential DMAs	Business DMAs
Assessed normal night uses (L/conn·hr)	15	
Household	17	35
Non-Household		357
I		117
II		177
III		
IV		
Supply pipes background losses (L/conn·hr)		
Household	10	
Non-household	13	
Mains background losses (L/km·hr)		
Method 1	40	
Method 2	88	
Method 3	56	
Communication pipes background losses (L/conn·hr)		
Method 1	3	
Method 2	3	
Method 3	5	

great influence upon minimum night flow. New background minimum night flow equation should be applied by determining most proper coefficients considering local characteristics as well as financial aspect at the state of the art in order to avoid misuse of the background NFM.

Customer night uses for non-households was classified into four groups in this study and target areas were limited to several DMAs of three cities. However, if more detailed grouping and obtaining more datasets from the broad range of DMAs are available, better background minimum night flow equations would be developed.

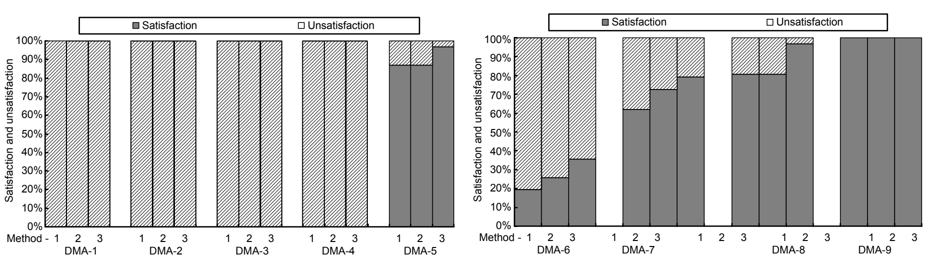

Figure 6 Satisfaction percentage by new background NFMs in residential and business DMAs

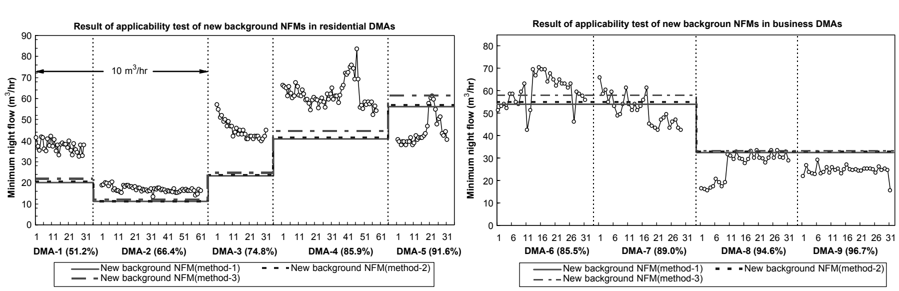

Figure 7 Result of applicability test of new background NFMs in residential and business DMAs

Conclusions

NFMs measured in various RW % DMAs were compared with conventional two criteria of the UK Water Industry and Seoul city in Korea for suitability test. As a result, two criteria were thought to be too conservative to apply them economically in Korea, as measured NFMs in well maintained DMAs exceeded both criteria.

The components of NFM were estimated in residential and business DMAs by using modified option A test and real losses from water balance analysis. A new background minimum night flow equation was developed for each component of NFM.

New background minimum night flows (Method 1, 2 and 3) judged the well-maintained residential and business DMAs to be mostly satisfactory while the two criteria of UK and Seoul city judged the same sites to be 100% unsatisfactory. Therefore, it was concluded that the new background minimum night flow developed in this study was more reasonable in Korea and could be used for judging DMAs whether there are unreported bursts recoverable economically prior to leakage detection activity.

It seemed that differences between different basis of estimation (Method 1, 2 and 3) were very small and night flows were more strongly influenced by night uses than by background losses. Therefore, assessed normal night uses must be considered properly rather than excluded because those wield great influence upon minimum night flow.

Acknowledgements

This research was supported by a grant (4-2-2) from the Sustainable Water Resources Research Center of 21st Century Frontier Research Program.

References

McKenzie, R.S., Wegelin, W. (2002). Leakage reduction through pressure management in South Africa, IWA Managing Leakage Conference, Cyprus.

McKenzie, R.S (1999), *Development of a Standardized Approach to Evaluate Burst and Background Losses in Potable Water Distribution Systems: SANFLOW User Guide*, South African WRC, Report TT 109/99

Office of Waterworks (2000). *White Paper on Revenue Water policy in Seoul*, Seoul Metropolitan Government, Seoul, Korea.

WRC (1994). *Managing Leakage Report Series*, Engineering and operations committee: Water Research Centre.