International Benchmarking of Leakage from Water Reticulation Systems

CJ Seago*, RS Mckenzie*, R Liemberger***

*PO Box 1522, Brooklyn Square, 0075, Pretoria, South Africa, caryns@wrp.co.za

** PO Box 1522, Brooklyn Square, 0075, Pretoria, South Africa, ronniem@wrp.co.za

***Bahnhofstrasse 24, A-9020 Klagenfurt, Austria, roland@liemberger.cc

Abstract

The IWA methodology of determining and comparing leakage in water distribution systems is now generally accepted as world's best practice in many countries around the globe. This paper will evaluate the methodology in terms of how it is being used in practical situations and present the results from a number of Water Utilities throughout the world. Various issues of specific relevance to the South African situation are also discussed and some new software developments are presented.

Introduction

There is an increasing awareness around the world that water resources are limited and that careful management must be applied when dealing with this scarce resource. Water lost from potable water distribution systems remains a major concern, particularly in developing countries. The BENCKLEAK software was developed in 2000 through the South African Water Research Commission to provide a simple yet pragmatic approach to the evaluation of leakage from potable water distribution systems. The model proved to be very useful and numerous similar models have since been developed and customised for use in many other countries throughout the world. Such models are now used by many Water Utilities to assist them in evaluating their levels of leakage and non-revenue water using a standard and pragmatic approach.

Considerable progress has been made in the last few years regarding standard terminology and methodologies in terms of real losses from water distribution systems. In this regard efforts have been made worldwide by various individuals and organisations to assess levels of leakage and real losses in water distribution systems. This information is being collected and co-ordinated by one of the International Water Association's (IWA) sub-task forces and the preliminary results appear very promising.

This paper provides a brief outline of the standard IWA methodology for assessing real losses and discusses the Infrastructure Leakage Index (ILI) in some detail. It also summarises the data collected and collated to date from numerous Water Utilities around the world. The data have been collected by various leakage management specialists who have been working together for many years as part of a larger IWA initiative. The results are presented in a clear and concise manner and are both interesting and informative. They provide Water Utility managers with a target against which they can compare their own performances regarding leakage from their systems. Issues and suggested solutions unique to South Africa are also discussed. Latest developments with regard to leakage assessment are presented including some brief details of new software and the internet based data management system currently being developed for use in South Africa.

IWA Methodology and Performance Indicators

The IWA methodology of determining and comparing leakage in water distribution systems is now generally accepted as world's best practice. There has, however, been healthy debate regarding the use of various performance indicators and this is expected to continue for many years to come. South Africa has been one of the leading proponents of the use of the Infrastructure Leakage Index (ILI) (Lambert et al., 1999) as the main indicator for comparing levels of leakage amongst Water Utilities for the last ten years. In this regard, South African specialists have worked together with some of the leading specialists in the world to promote the use of a standard methodology to the complex issue of leakage assessment.

Infrastructure Leakage Index

The ILI is sometimes criticised for being too simplistic and not incorporating some of the key factors which can influence leakage from a water distribution system. The main points of discussion include:

- ILI values of less than 1.0 should not occur since this implies that the actual leakage is less than the theoretical minimum level of leakage.

- The Unavoidable Annual Real Loss (UARL) equation is too simplistic as it is based only on the length of mains, number of service connections, length of underground pipe from the mains to the point of metering and the average system pressure.

- The use of the ILI in cases where a Water Utility operates under either abnormally high or unusually low pressures.

- The use of the ILI for systems with less than 2000 connections.

- Updating of the ILI parameters as more reliable information becomes available.

While all of the above points are clearly valid concerns and can be debated at length, the ILI has proved to be extremely useful in South Africa even in many instances where it has been used outside the normally acceptable limitations. In such cases, it must obviously be used with caution and the results should be considered as indicative rather than totally rigorous. Some of the key issues addressed in the South African context are discussed below:

Bulk Storage: In response to the issue of over-simplification it should be noted that bulk storage is often a major source of leakage in many South African systems and has to be included in the overall water balance. The system input volume for many water supply systems in South Africa is measured before the bulk storage reservoirs and towers. For this reason Utilities are requested to provide their operational capacity of all bulk storage that occurs after the bulk system input meter. A volume is then assigned to the losses through bulk storage depending on how the Utilities rate the condition of their bulk storage. In this manner the losses from the storage facilities are included in the water balance and form part of the real loss calculation. It is important to only include bulk storage in the water balance if the system input volume is measured before the bulk storage.

Systems with less than 2 000 Connections: There has been considerable debate recently (Lambert, 2005) regarding the minimum size of zones that should be evaluated with the ILI calculation. In South Africa, many smaller systems have been included in cases where the areas are completely homogeneous and are fully residential in nature. While the results from such areas are not included in the international data set, they are nonetheless often found to be very useful. Smaller zones are often considered in South Africa and the ILI's derived in the usual manner can often help to identify key problem

areas within a larger zone. A typical example of such an analysis is provided in **Table 1** for a small Water Utility serving three relatively small towns.

Table 1. Input data for Emthanjeni Municipality, South Africa

Variable	Description	Units	Britstown	Hanover	De Aar
Lm	Length of mains	km	20	15	114
Ns	Number of service connections	no.	979	919	5485
D	Density of service connections	conns/km	49	62	48
P	Average operating pressure	m	20	38	30
T	% time system is pressurised	%	100	100	100
	Population served by the system	no.	4024	2695	26027
UARL	Unavoidable annual real losses	m^3/yr	8345	13 942	70 518
	Unavoidable annual real losses	litres/conn/day	23.4	41.5	35.2
INP	Total system input volume	m^3/yr	220 552	171 404	1 839 785
CON	Total authorised consumption	m^3/yr	123 369	137 104	1 465 865
AWL	Annual Water Losses	m^3/yr	97 183	34 300	373 920
%AL	% apparent losses	%	20	20	20
AL	Apparent losses	m^3/yr	19 437	6 860	74 784
ARL	Annual real losses	m^3/yr	77 746	27 440	299 136
	Consumption	litres/conn/day	345	409	732
ILI	Infrastructure Leakage Index		9.32	1.97	4.2

When the Water Utility was analysed as one combined area, the ILI value obtained was 4.5. This would most likely have been considered acceptable in the South African context where the average levels of leakage tend to be very high and anything lower than 5.0 tends to be ignored in preference of the areas with higher leakage. In this case, however, (as shown in the table), Britstown had an ILI of 9.3 which is considered unacceptable even in South Africa. While this figure is potentially unreliable to some extent since the area has less than 2 000 connections it proved most useful in directing the project team to a key problem area. On closer inspection it was found that Britstown had a serious billing problem due to a large number of new properties that had been added into the system but were not being billed properly. The issue was eventually addressed and the ILI decreased significantly as expected.

Acceptable Pressure Range: Various specialists have recently questioned the applicability of the ILI in areas with abnormally high pressures or unusually low pressures. The discussion has resulted in a proposed adjustment (Lambert, 2005) to the ILI calculation to incorporate a variable designed to adjust the ILI value in circumstances where the average system pressure is outside the normally accepted range (approximately 30m to 90m). While this proposed adjustment can help to manipulate the ILI for systems with unusual pressure conditions, the existing approach has proved most useful in a variety of systems (mainly in Asia) where very low pressures and intermittent supply are experienced. Once again, the ILI values obtained may not be totally reliable and are open to criticism in some respects. In such cases the ILI values obtained tend to be extremely large (often over 50) and as such are not suitable for general benchmarking with other data sets from around the world. The ILI is still, however, considered to be a useful indicator in its current form for identifying the areas with the highest leakage.

International Initiatives

The ILI as an Intervention Indicator

While it was recognised that several performance indicators are required when assessing water losses from a supply system, various new recommendations were recently (Australia, February 2005) proposed involving the use of the ILI as a key indicator for

excessive leakage in a system. The first set of values was suggested by Mr Tim Waldron from Wide Bay Water in association with Mr Allan Lambert with specific reference to the Australian water industry which boasts some of the lowest leakage levels in the world. The proposed guidelines are provided in **Figure 1**.

Proposed Minimum Leakage Activities Based on ILI Classification		ILI<1.5	1.5<ILI<2.0	2.0<ILI<2.5	2.5<ILI<3.0	3.0<ILI<3.5	ILI>3.5
	Management Action	Excellent	Good	Reasonable	Fair	Poor	Unacceptable
DO	Economic Pressure Management	Yes	Yes	Yes	Yes	Yes	Yes
YOU	Repair Policy Statement	Yes	Yes	Yes	Yes	Yes	Yes
NEED	Single Detection Intervention			Yes	Yes	Yes	Yes
THIS	Regular leak Detection Intervention				Yes	Yes	Yes
ACTION?	Peer Review of Leak Management Activities				Yes	Yes	Yes
	Formulate and Implement Action Plan						Yes

Notes:
1. Determine your ILI classification (eg) "Reasonable" 2.0<ILI<2.5
2. Look down chart to identify the management actions required for "reasonable" (ie) Economic Pressure Management, Repair Policy Statement, Single Direction Intervention
3. Wherever the word "yes" appears you must, as a minimum, implement these management actions

Figure 1: Proposed ILI classification for Australia (from Waldron and Lambert, 2005)

As can be seen from **Figure 1**, the ILI is being used as an indicator to highlight when specific remedial measures should be implemented. The higher the ILI value, the greater need for more comprehensive leakage reduction activities. An important issue that should be appreciated from **Figure 1** is the relatively low ILI values used in the assessment. Due to the relatively low levels of leakage experienced in Australian water supply systems, the ILI bands used in the analysis are very narrow and the overall ILI values relatively low. In many other countries with greater levels of leakage, it is necessary to look into a more comprehensive and flexible process where a greater range of ILI values can be accommodated.

To address water supply systems in countries with high levels of leakage and correspondingly high ILI values, a revised proposal was suggested by Liemberger (Liemberger, 2005). The proposed approach is shown in **Figure 2** and was first presented to the IWA Water Loss Task Force in February 2005. The approach was well received and was considered appropriate for use in both developed as well as developing countries.

Technical Performance Category		ILI	Litres/connection/day (when the system is pressurised) at an average pressure of:				
			10 m	20 m	30 m	40 m	50 m
Developed Countries	A	1 - 2		< 50	< 75	< 100	< 125
	B	2 - 4		50-100	75-150	100-200	125-250
	C	4 - 8		100-200	150-300	200-400	250-500
	D	> 8		> 200	> 300	> 400	> 500
Developing Countries	A	1 – 4	< 50	< 100	< 150	< 200	< 250
	B	4 – 8	50-100	100-200	150-300	200-400	250-500
	C	8 - 16	100-200	200-400	300-600	400-800	500-1000
	D	> 16	> 200	> 400	> 600	> 800	> 1000

Figure 2: Proposed use of ILI as PI in developed and developing countries (Liemberger, 2005)

As can be seen from **Figure 2**, different ILI ranges have been provided for developing and developed countries which was not necessary in the earlier Australian proposal. The proposal by Liemberger also attempts to classify the leakage levels within the Water Utilities into four categories based on the ILI value as follows:

A = Excellent – no specific intervention required.

B = Good – no urgent action required although should be monitored carefully.

C = Poor – requires attention.

D = Very Bad – requires immediate water loss reduction interventions.

It should also be noted, that unlike the Australian recommendations, Liemberger does not attempt to define the water loss reduction interventions required. It is assumed that the leakage management specialist will first identify the key problem areas after which the most appropriate interventions will be established to provide the greatest returns for the available budget.

International Data Set

As part of the IWA Water Leakage Task Force initiatives, several leakage management specialists agreed to gather data sets from around the world in order to establish a comprehensive international data set containing as many ILI estimates as possible. A simple template was developed to assist with the collection and standardisation of the data which was sent to leakage specialists who were willing to provide data sets from their investigations in different parts of the world. A total of 146 data sets were received from various countries, details of which are provided in **Table 2**.

Table 2 Summary of International data sets gathered

Country	Number of data sets	Country	Number of data sets	Country	Number of data sets
Australia	19	Greece	3	Philippines	1
Bulgaria	1	Hungary	2	Poland	1
Canada	2	India	1	Russia	1
Caribbean	2	Indonesia	1	South Africa	30
Chile	1	Ireland	1	Sri Lanka	5
Costa Rica	1	Italy	2	Turkey	5
Cyprus	1	Japan	1	UK	26
Czech Republic	4	Jordan	1	Ukraine	1
France	1	Malaysia	5	Vietnam	1
Germany	1	New Zealand	5	Wales	5
		North America	20		

The data sets range in size from the smallest with 2325 connections to the largest with nearly 2 million connections. Details of 50 selected data sets obtained are summarised in **Table 3.** It should be noted that the data provided in **Table 3** are presented in such a manner that the Utilities remain anonymous as agreed with certain Utilities when providing the information. The data are provided in numerically ascending order based on the ILI value.

Table 3. Details of International data sets gathered

Country	Data set no.	ILI	Density Conn. / km mains	Average pressure (m)	Consumption in litres / conn / day
Cyprus	1	1.2	70	45	529
New Zealand	2	1.2	57	56	639
Canada	2	1.3	79	56	1651
UK	1	1.3	53	48	500
Caribbean	2	1.3	25	75	460
Wales	2	1.4	67	52	478
New Zealand	1	1.4	52	74	1033
Canada	1	1.5	54	57	1619
England	1	1.5	70	44	540
Wales	1	1.8	23	55	498
Wales	4	2.1	27	55	521
Wales	5	2.1	49	53	489
Wales	3	2.3	47	53	526
Germany	1	2.4	31	45	474
France	1	2.5	51	38	779
Czech Republic	1	2.6	27	50	2182
Czech Republic	4	2.9	37	35	765
UK	1	3.0	8	38	2755
Sri Lanka	2	3.3	59	10	588
Czech Republic	3	3.4	27	45	1434
New Zealand	4	3.6	57	80	843
Japan	1	4.1	39	30	3174
Ireland	1	5.0	23	36	554
Hungary	2	5.7	57	45	1112
South Africa	1	5.7	43	50	1505
Czech Republic	2	6.7	27	30	627
Italy	2	7.1	55	40	894
Ukraine	1	9.0	37	35	2774
Greece	2	9.7	68	35	1766
South Africa	2	10.4	48	30	2200
Caribbean	1	10.5	95	38	607
Malaysia	1	10.8	60	28	1183
Sri Lanka	4	11.4	52	15	619

Country	Data set no.	ILI	Density Conn. / km mains	Average pressure (m)	Consumption in litres / conn / day
Hungary	1	15.3	41	45	2406
Italy	1	15.9	45	40	2407
Greece	1	16.1	136	30	425
Costa Rica	1	18.1	111	35	867
Malaysia	2	20.5	54	35	1382
Poland	1	20.6	27	55	1769
Bulgaria	1	24.4	39	60	2331
Malaysia	4	25.0	60	25	1840
Malaysia	3	26.3	78	25	1072
Jordan	1	27.0	57	40	548
Malaysia	5	27.1	64	35	1543
Sri Lanka	1	35.9	64	10	741
Sri Lanka	3	38.9	61	10	600
Sri Lanka	5	41.4	117	8	1167
Turkey	1	46.4	31	30	1754
Turkey	2	46.7	41	30	2556
Russia	1	70.9	27	45	6808

From the data sets analysed, it is often found that the ILI becomes unrealistically high in cases with intermittent supply. While this is an issue that must still be resolved, it is believed that part of the problem is due to the fact that once the pressure to an area is cut, much of the water left in the reticulation system gradually drains over a period of hours or even days – in effect, a system with one hour of pressurised supply every two days may have water in some parts of the system for up to 24 hours. For this reason an ILI based on one hour of "official" pressure may be misleading and it may be necessary to adjust the percentage of time pressurised in such cases.

The South African Perspective

South Africa is quite unusual in many respects and has a unique blend of both first and third world conditions. Highly developed and completely undeveloped areas often occur within the same Water Utility. One unusual feature evident in some parts of the country concerns areas of exceptionally high leakage which still receive an uninterrupted water supply at normal pressure. In most other developing countries, such high leakage would either not be tolerated or the residents would be forced to accept an intermittent supply to reduce the overall losses.

The debate surrounding the applicability of the ILI for areas of excessively low or high pressures is rarely a problem in South Africa which tends to offer normally acceptable pressures (approximately 50 m) in most Utilities throughout the country. The ILI values obtained from the various water suppliers in South Africa therefore provide a valuable indicator to determine whether or not a serious leakage problem exists in a specific Utility. Whether the ILI value is estimated to be 12 or 20 is not considered to be particularly important. The average ILI value for South African Utilities is in the order of 6 with the result that anything above 10 is considered to be very poor and worthy of attention, while a value of 4 or less is considered to be acceptable (for the time being). The ILI value is therefore used as a relatively rough indicator to highlight areas of particularly high leakage which can then be addressed using the limited funds available for leakage reduction.

Flat Rate Tariffs in townships

A problem experienced in South Africa is to some extent inherited by many Water Utilities due to the turbulent history of the country. The issue of flat-rate tariffs arises in many

township areas where water bills are sent to all consumers based on a fixed monthly tariff which in turn is calculated on the basis of an estimated average monthly use. A similar system exists in many parts of the world including the UK where flat rates, while not favoured by the government or Water Utilities, are still applied to large sections of the population. The major problem experienced in South Africa is the fact that the "estimated average consumption" on which the monthly account is based, tends to be significantly lower than the actual average consumption – often by a factor of 2 to 4.

For example, an area with 50 000 properties bills water on a flat rate of 40 kl per property per month. This equates to an annual consumption of 2 million kl. The bulk meter measuring the water entering the township, however, shows that the area is in fact using 7 million kl per annum. This suggests that 5 million kl per annum is not taken into account as part of the authorised consumption and/or the real losses in the local reticulation system downstream of the meter. Deciding exactly where the 5 million kl is being lost is normally a problem issue since it can either be through leaks (or normal use) in houses after the customer meter (which is not used in such situations). This would normally be considered as authorised unbilled. It could also occur through leaks on distribution mains in which case it would be considered as real water losses. In South Africa, it is normal practice to split the amount equally between real losses and the unbilled authorised consumption where no other information is available. In other countries, the split may be different and is often weighted 80/20 for the real losses and the after meter use respectively. If possible, a sample of water meters should be monitored in order to establish the true average household consumption after which the real losses can be easily established. It should also be noted, that some leakage specialists prefer to consider the additional water use after the meter as apparent losses rather than unbilled authorised. Once again this can be debated since there are often meters at each household connection although the monthly accounts are not based on the metered readings. In effect the meters are not used and can be considered as absent.

Revenue Water

Another issue pertinent to South Africa is the government's policy of providing a free basic water allowance to all properties. The current policy is to provide the first 6kl per property per month free of charge. It is reflected on the bills that are sent out and is therefore considered as billed-metered water. Although it is billed at a zero rate it must still be considered as revenue water. Often the step tariff structure is designed to cross-subsidise the zero rated water from the higher tariff water – this explains why the zero rated water is considered as revenue water although it generates no income. A project is currently underway in South Africa to gain a better idea of how this "free basic water" policy is affecting the profitability of Water Utilities.

Another issue is the high level of non-payment for water in certain areas. Again, the water is billed for but often payment is not received. For this reason, a request was made by the water regulator to add additional blocks onto the standard IWA water balance to reflect the water actually paid for compared to the water billed but not paid for. These two blocks would divide the revenue water into recovered revenue and un-recovered revenue.

Service Connections and Communal standpipes

Some input parameters required to calculate the ILI performance indicator have caused confusion and have required clarification in the past. One of these is the "number of service connections" which is required to calculate the UARL. The IWA Manual of Best Practice 'Performance Indicators for Water Supply Services' (Alegre et al., 2000) clearly defines a service connection as "*the authorised pipe connecting the main to the*

measurement point or the customer stop-valve, as applicable. Where several registered customers or individually occupied premises share a physical connection or tapping off the main, eg. apartment buildings, this will still be regarded as the one connection for the purposes of the applicable Performance Indicator, irrespective of the configuration and number of customers or premises".

Experience shows that most water suppliers do not know how many saddle connections they have and what proportion support one, two, four or eight properties. However, they do usually have information on the numbers of billed accounts, customer meters, or stands (the South African term for defined plots of land). It is also usually possible to count the number of stop-valves sited outside the stands, typically in the pavement. By considering a representative sample of service connection layouts for a particular system, it is possible to produce a correlation between one of these parameters (billed accounts, customer meters or stop-valves) and the number of service connections Ns (physical connections to the mains) for that particular system.

The South African situation is often relatively complex in this regard due to the mixture of very high income areas in close proximity to the very low income areas. For the average to high income areas, the number of properties is often used to establish the number of service connections. In the low income areas and informal settlements, the water is often provided through communal standpipes where a number of users obtain their water from a single tap connection. In such cases, the number of properties greatly exceeds the number of connections and it is therefore necessary to count the number of standpipes which provides a very realistic estimate of the number of service connections. The two extremes are shown in **Figure 3**.
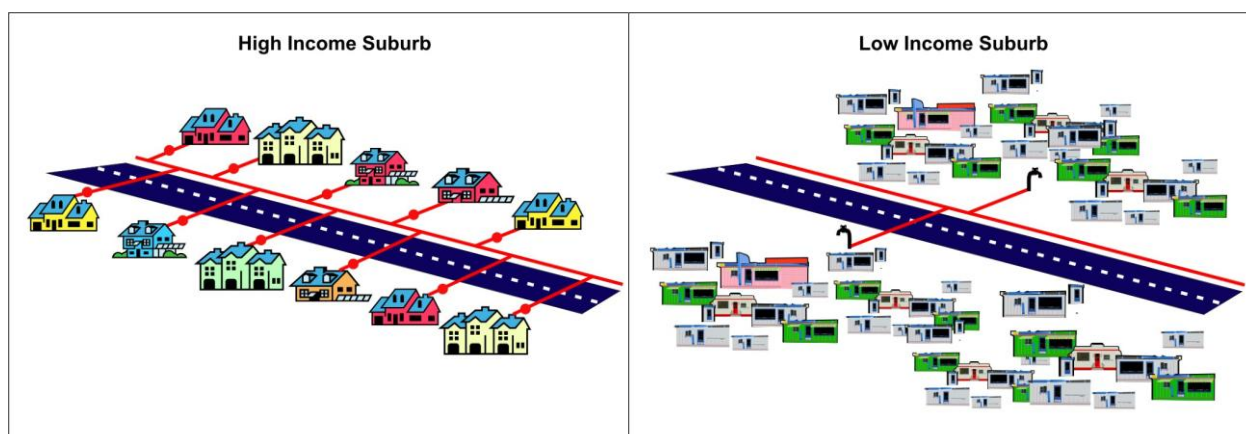

Figure 3: Illustration showing why "number of properties" should not be used in substitution for "number of. service connections" in an informal settlement.

Another issue concerning standpipes is that they are generally not metered and it is therefore necessary to estimate the water used from them in order to include it in the water balance. Some systems do include a bulk meter at the entrance to the low income and informal settlement areas and in such cases the total water use is known. This water is generally viewed as unbilled-unmetered in terms of the IWA standard water balance although some of the water will be lost through real losses before it is used at the tap.

Apparent losses

It is important that the estimate of apparent losses be realistic for the specific Utility being analysed since the apparent loss estimate has a direct impact on the ILI value. In South Africa, the initial approach of assuming 20% of the total real losses for apparent losses was realistic for many of the established high income areas but was overly optimistic for

the low income areas. Over-estimating the apparent losses will reduce the ILI value and some Water Utilities may therefore prefer to over-state their apparent losses rather than admitting to higher real losses. For this reason, a simple approach was used in South Africa to estimate to apparent losses for all Water Utilities in a standard manner.

The main parameters influencing the apparent losses in South Africa are illegal connections (theft of water), data transfer errors and meter inaccuracies. Water Utilities were therefore asked to classify their expected illegal connections as very high, high, average, low and very low. They were also asked to provide information on their water meters in terms of accuracy and age. Finally, they were asked to provide an estimate of the accuracy of their billing systems in terms of good, average and poor. The following table presents details of the approach used in South Africa to the estimate the apparent losses for the recent round of water audits. Where available, the Water Utilities provided actual data for the various components which are obviously preferable and more accurate than the estimates. It should be noted that the values suggested are relatively high when compared to the corresponding values used in many other countries. It has been found that the magnitude of the apparent losses in many South African Water Utilities are extremely high and the default values given in the table reflect this situation.

Table 4. Suggested apparent loss percentages for a typical South African system.

Illegal connections		Meter age and accuracy			Data transfer	
			Good water	Poor water		
Very high	10 %	Poor > 10 years	8 %	10 %	Poor	8 %
High	8 %					
Average	6 %	Average 5- 10 years	4 %	8 %	Average	5 %
Low	4 %					
Very low	2 %	Good < 5 years	2 %	4 %	Good	2 %

The suggested losses associated with meter under-registration were based on the fact that many parts of Europe have a compulsory replacement programme on all meters every five years. Most of the domestic meters in place in South Africa are similar to the European meters but there is rarely any standard replacement programme in effect. Many factors play a role in the accuracy of a meter, but were excluded in order to minimise the complexity of the procedure and only the water quality was considered which tends to be a dominant factor in the South African situation.

Software Developments

Many different software models have been developed to assist water utilities throughout the world to undertake the standard IWA annual water balance and to determine various performance indicators for leakage within the water distribution systems. The available models range from excel spreadsheets to complete Windows based packages. All of the models tend to be quick and efficient to use and the main differences are usually cosmetic or due to the various "bells and whistles" that are attached to the basic water balance calculation. Water Utilities can therefore select one of the existing models, some of which are available free of charge, or develop their own models from scratch. One such model that has recently been developed with considerable input from the authors of this paper as well as many other WDM specialists is the new Aqualibre model (Mckenzie and Liemberger, 2005).

AQUALIBRE is effectively an annual water-audit model based on the latest IWA best practice. It has been developed through close co-operation of numerous internationally recognised water loss managers from several countries and incorporates a host of features, some of which are not available on other water audit models. The 2005 version of the model is designed to evaluate the level of real losses occurring from a water

distribution system based on the traditional IWA top down water balance. This involves completing a basic water balance of water supplied to the system compared to water that can be accounted for in the usual manner. Having established the total losses from the system, the real losses are finally derived by reducing the total losses in accordance with the measured or estimated Apparent Losses. Each component of the calculation is undertaken in accordance with internationally accepted best practice as recommended by the IWA. This 'top-down' water balance provides the first estimate of the real losses from the system and the calculations are supported by a number of Performance Indicators which in turn are used by most water loss practitioners worldwide. The model also provides an alternative estimate of the annual real losses based on a 'bottom-up' approach which is based on the traditional Burst and Background Estimate (BABE) methodology. This optional assessment of the real losses is based on the number of bursts occurring in the system and the associated running times etc. While such information is often not collected by the water utility, it is a very valuable exercise which clearly highlights the key issues driving the real losses. The user may decide to omit the 'bottom-up' balance if no suitable burst data are available in which case the model performs as a standard 'top-down' water balance model.

The key features of AQUALIBRE include:

- A selection of 7 different units of measure for use in different countries where the standard metric units are not appropriate (see **Figure 4**);

- User defined confidence limits on all key variables included in the data sets;

- Splitting of mains into Trunk and Distribution which often have different pressure profiles;

- Ability to specify system pressures in a tabular format in order to derive the average system pressure;

- Differentiation between connections and customers in the calculations;

- Detailed reporting forms which can tailored to the users requirements;

- Both 'Top-Down" (see **Figure 5**) and 'Bottom-Up' water balances;

- Based on modern object orientated software design principles (DELPHI) which can be customised for a particular Client or country (i.e. language).
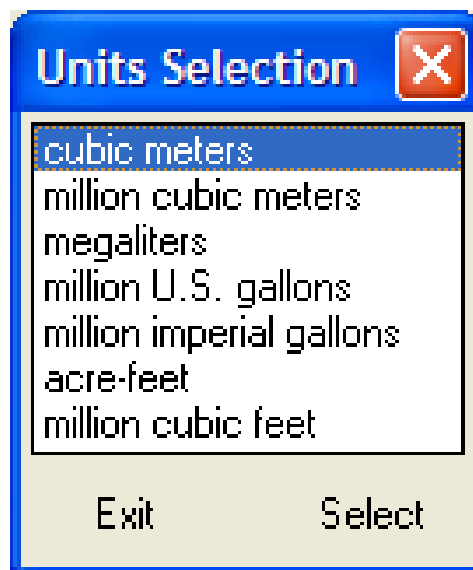
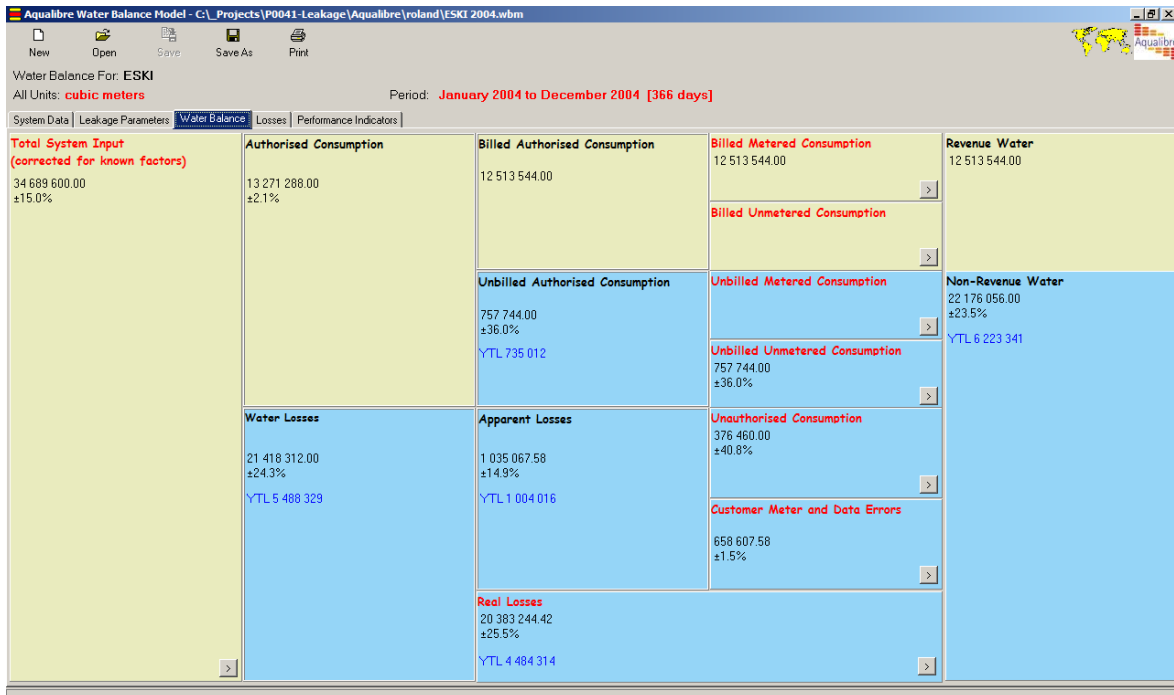

Figure 4: Units Available in Aqualibre

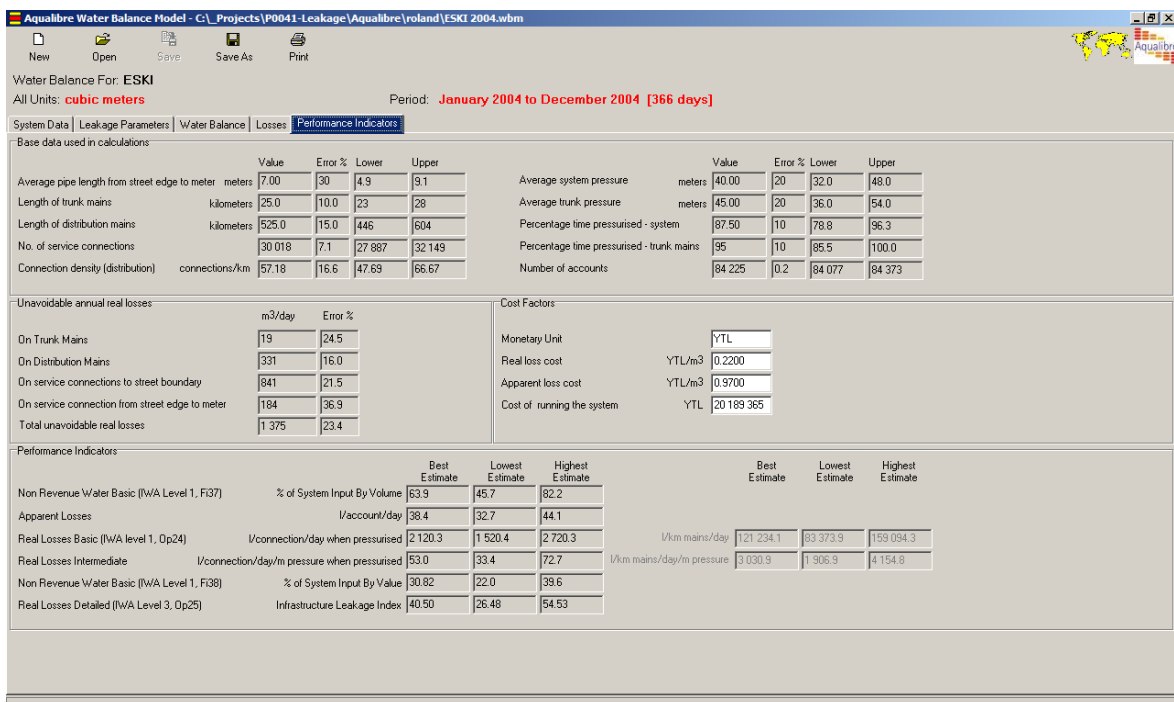Figure 5: Sample water balance screen from Aqualibre.

Figure 5: Sample output screen from Aqualibre

Another issue which is worthy of mention concerns the latest data capture system which has been developed by the South African Water Research Commission. The new system has been placed on a website to facilitate the data capture and processing of the annual water audit for all Water Utilities throughout the country. The system then calculates all performance indicators and represents the results graphically in a clear and concise manner. Each Water Utility can quickly see where it stands when compared to other Utilities that have entered their data. Utilities are provided with a specific login code which allows them to update their data as they wish and all results are presented in an anonymous manner. The key performance indicators are summarised on an output page which can be printed for reporting purposes.

Conclusions

The ILI has, in recent years, proved to be a very useful performance indicator when Benchmarking leakage in water distribution systems. Its relative simplicity and ease of use have enabled it to become widely used in many parts of the world where it has been introduced over the past 5 years.   In South Africa, it is the preferred indicator for the assessment of real losses and the country's regulator (department of Water Affairs and Forestry) in association with the SA Water Research Commission is promoting its use for benchmarking purposes.

While some aspects of the ILI are still being discussed and various enhancements are being implemented, it is nonetheless regarded as a very useful indicator to judge how a water distribution system is operating.   Although various limits on the use of the ILI have been proposed by it's original developer to safeguard the soundness of the results, the authors have found that it can still provide a useful indication of high leakage even when used outside the normally accepted limits. In such cases, the results must obviously be used with greater caution and cannot always be included in a larger data set for benchmarking purposes.

In summary, the authors have found that the ILI is a very helpful indicator which can be used to assist water utilities in identifying pockets of abnormally high leakage within a larger water distribution system. Identifying such areas is the first step in addressing a leakage problem and in this regard the ILI generally proves it's worth.

There have been various suggestions on how the ILI can be improved by refining certain coefficients or adding new terms in the underlying equations. While further improvement should never be discouraged, the authors remain comfortable with the ILI in it's current form and feel that there is no urgent need for change at this time.

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