WHAT IS THE INFRASTRUCTURE LEAKAGE INDEX (ILI) AND HOW DID WAITAKERE CITY COUNCIL MANAGE TO ACHIEVE AN ILI OF 1.0?

By Richard Taylor, Assets and Network Manager, EcoWater, Waitakere City Council

Abstract: *This paper explains the relatively new performance indicator for real water losses (from water supply distribution systems) called the 'Infrastructure Leakage Index (ILI)' and how Waitakere City Council, through a number of initiatives and management practices over a 18 year period, has achieved and maintained an Infrastructure Leakage Index of close to 1.0, which is a world class ranking.*

The traditional water loss performance indicator 'percentage water loss' is a very poor indicator of real water losses. In this paper an explanation is given of meaningful performance indicators for real water losses such as 'litres/connection/day' and the ILI. A comparison of international data is provided.

Waitakere City Council, over the past 18 years, has implemented operational and management practices which have been very successful in reducing water loss to the point where it has achieved what is accepted as a world class ranking. These practices include setting up water supply distribution zones, an effective 'real time' monitoring system (using telemetry), setting leakage thresholds for each water supply zone, targeted leak detection work, pressure management to both reduce and stabilise water supply pressures, ongoing commitment to pressure control, monitoring and leakage reduction, and use of new leak detection technologies.

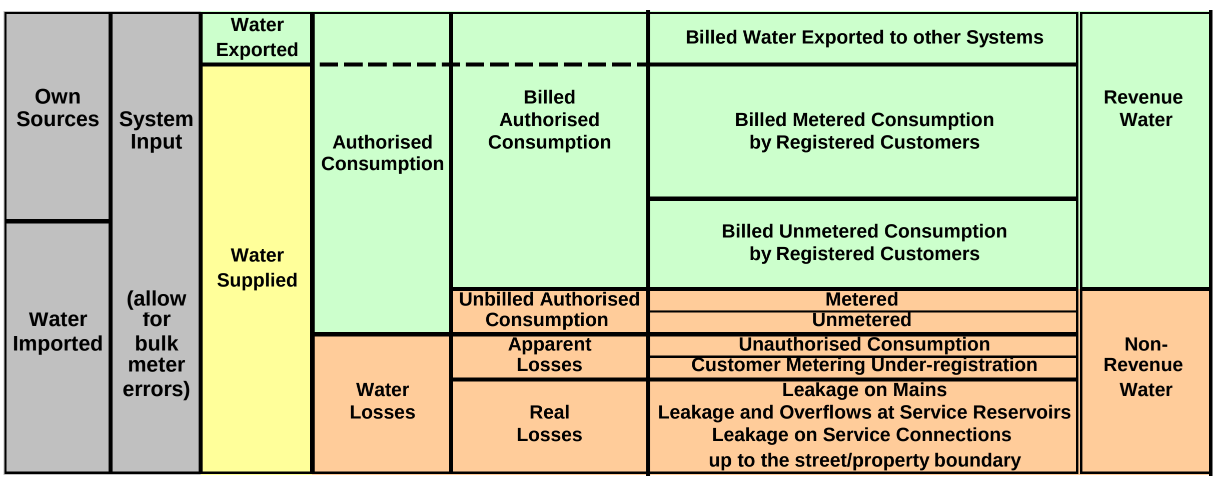
The practices above cannot be considered in isolation to the management structure, systems, processes and scale of operations at Waitakere City, and the paper also discusses the relevance of these matters to the successful management of a water supply distribution system.

Introduction

The Infrastructure Leakage Index (ILI) is a performance indicator of real (physical) water loss from the supply network of water distribution systems. The ILI was developed by the International Water Association (IWA) Water Loss Task Force (WLTF) and first published in 1999. It has been applied in at least 50 countries worldwide. The measure is included in the New Zealand *BenchlossNZ* Manual (and software) which outlines performance indicators for Non Revenue Water and its components in New Zealand. *BenchlossNZ* was developed as a New Zealand Water and Wastes Association (NZWWA) project, managed by a workgroup from the Water Supply Managers Group, a NZWWA subgroup. I was the leader of this workgroup, and international consultants (Allan Lambert and Dr Ronnie McKenzie) were engaged on this project to bring the New Zealand industry up to date with international thinking on water loss. Internationally accepted terminology and performance measures, as developed by the WLTF, are included in *BenchlossNZ.* An update of *BenchlossNZ* was completed in February 2008. The *BenchlossNZ* Manual explains why 'Percentage water loss' is a very poor indicator of water loss, as it is relates water loss to consumption, and should not be used. Litres/service connection/day is a good performance indicator of real water losses for a typical urban water system, however ILI goes one step further allowing the performance of urban water systems worldwide to be compared using a simple dimensionless performance indicator.

In order to explain and calculate the ILI as a performance measure, the components and terminology relating to the water balance of a water supply system needs to be explained. The water balance categorises all water use so that 'real' water losses from the supply network can be identified. The diagram below shows the water balance. The various components are identified in the table. In simple terms, water supplied to a network can be classified as either 'Revenue Water' i.e. water sold, or 'Non-Revenue Water'. The latter includes the components 'Unbilled

Authorised Consumption' (such as water used for maintenance purposes – for flushing, cleaning of service reservoirs etc. and water used by the Fire Service) and 'Apparent Losses' comprising unauthorised consumption (such as unauthorised use from fire hydrants and illegal water connections) and under-registration of customers' water meters. The remaining component of Non-Revenue water is 'Real Losses' which represents the actual water losses from the water distribution network. In systems where not all customers have their water use 'metered', the volume of 'Revenue Water' is estimated and can be unreliable, giving rise to greater uncertainty of the overall water balance. This is dealt with in *BenchlossNZ* by using confidence ratings for each component used in the calculations to arrive at confidence limits (95% confidence range) for the performance measures calculated. The 95% confidence limits for unmetered domestic consumption could be typically +/- 30% which gives rise to a high level of uncertainty with the performance measure, including ILI. In regions where water use is highly seasonal and also unmetered, carrying out a water balance for the 'low and steady' water use period of the year can result in a much lower 95% confidence range for calculated performance measures such as ILI. In Auckland, all water use is metered, and relatively accurate calculations for water loss can be determined; typically the calculated ILI has a 95% confidence limit of approximately +/- 10%. Metering and billing of customer use tends to reduce water consumption, including private leakage, but ultimately, this metering does not change the volume of real water losses occurring in the water distribution system; it only changes (reduces) the 95% confidence limits for the calculation of real losses.



Water Balance Diagram extracted from the *BenchlossNZ* Manual

Calculation of Infrastructure Leakage Index (ILI)

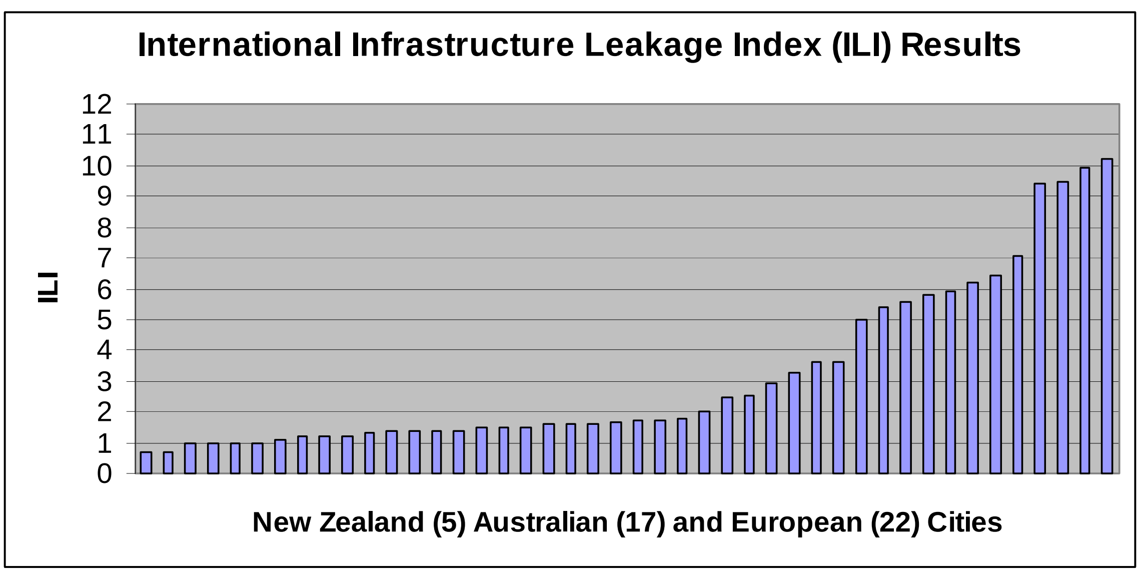
The Infrastructure Leakage Index is calculated as follows:

$$ILI = \frac{\text{Current Annual Real Losses (CARL)}}{\text{Unavoidable Annual Real Losses (UARL)}}$$

A full explanation of how the UARL is calculated and what it represents is documented in the *BenchlossNZ* manual. In New Zealand, where customer meters are located at the property boundary, the UARL for a network can be readily established based on a simple formula using the length of watermains (Lm), the number of service connections (Nc), and the average pressure (P). The formula is generally applicable for networks where (Nc + Lm/20) exceeds 3000. The UARL however, also allows for the average water supply pressure a system operates at, and therefore the ILI represents the level of water loss from a supply system (excluding leakage from private water systems) while allowing for the supply pressure of the system. For example, at a given ILI, a system operating at a high average pressure will have a greater actual volume of real losses compared to an equivalent system operating at a lower average pressure. This means that the ILI is a very useful indicator [comparative method] for 'metric benchmarking', comparing the performance of systems with different operating pressures and connection densities due to topographical and other relevant considerations. Real water losses can in most cases however, be reduced in a network using pressure management techniques as outlined below, and the performance indicator 'litres/service connection/day' is recognised in *BenchlossNZ* as being the preferred performance measure for 'process benchmarking'; to set targets and track reductions in real losses due to combinations of initiatives of pressure management, active leakage control, speed and quality of repairs and infrastructure management.

The ILI for 44 water systems, including 5 systems from New Zealand and 17 from Australia is shown in the graph below. An ILI of 1.0 is not common and has been described by Allan Lambert as being 'world class' in terms of water loss. Waitakere City Council has achieved an ILI of 1.0, and continues to maintain this level of performance for water loss through a range of initiatives implemented since 1990; these initiatives are outlined below. It should be noted that an ILI of less than 1.0 is achievable; UARL is based on a quantitative formula using clearly specified system parameters (for background leakage, numbers of reported and unreported bursts, flow rates, durations etc) and performance, and if local parameters are less, then an ILI of less than 1.0 is possible. However, many apparently low ILI's turn out, on investigation, to be due to systematic water balance errors or wide confidence limits.

In general terms, the most 'appropriate' ILI for a distribution system will be based on economics (related to water availability, the cost of producing and distributing treated water, and the cost of reducing water loss), the strategic direction of the water supply organisation (the importance of sustainability), the ability to implement water loss reduction measures (such as physical factors and affordability - to implement monitoring systems, effective maintenance and renewal programmes etc).



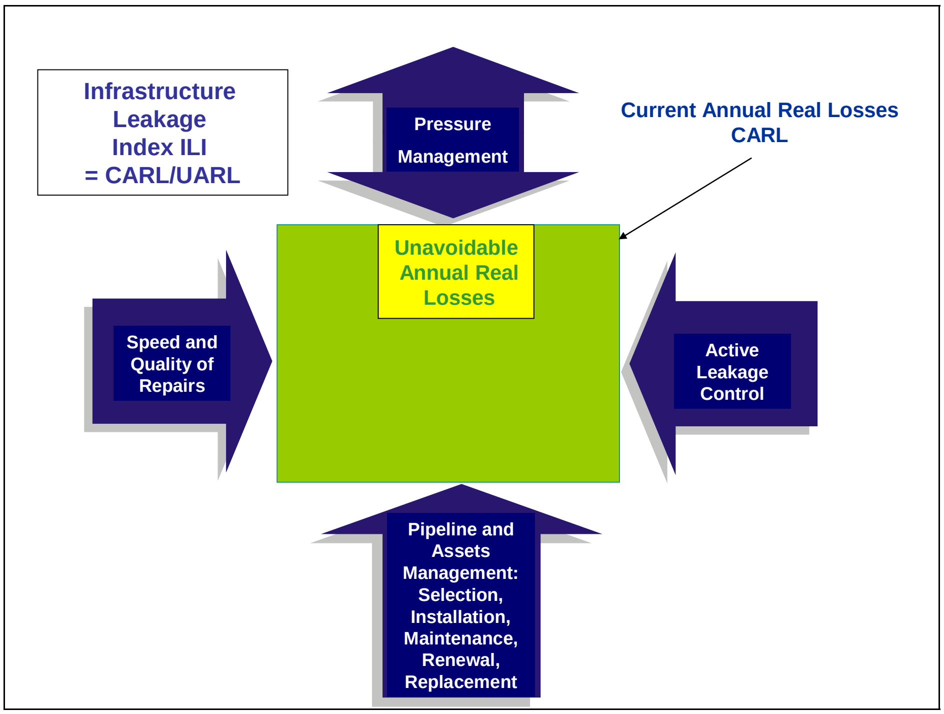
ILI International dataset for developed countries provided by Allan Lambert and Dr Ronnie McKenzie

Four Key Factors Influencing Water Losses in Distribution Systems

The four key factors which influence real water losses in distribution systems are:

- The speed and quality of repairs;
- Pipeline and Asset Management - Renewal of the water network
- Active leakage control; and
- Pressure management.

These factors, along with a representation of ILI, are shown in the diagram below. The green coloured box represents the amount of current annual real water losses in a water system (CARL), the yellow box represents the volume of unavoidable annual real losses (UARL). The ratio of these two components is the ILI for the system.



It is evident that pressure management affects both CARL and UARL, and as previously mentioned, ILI is effectively independent of ‘supply pressure’. ILI measures how well real losses are being managed at the current pressure, but it does not imply that the current pressure is the optimal pressure.

Initiatives Implemented at Waitakere City Council (WCC)

The initiatives implemented in Waitakere City since 1990 which have contributed to reducing water losses are covered below, and relate one way or other, to these four factors above.

<u>Setting Up and Monitoring of Discrete Supply Areas</u>
In 1988 when I joined Council, the water supply network was operated as an ‘open’ network without any deliberate zoning of discrete supply areas for monitoring purposes. Bulk water to Waitakere City is supplied through approximately 30 ‘bulk supply points’ (BSP’s) where bulk

water supplied by Watercare Services Limited is metered for invoicing purposes. These BSP's are ideal monitoring points, and in 1990 and 1991, two important measures were put in place.

Firstly, the BSP's were monitored via telemetry system. Telemetry systems were relatively new in New Zealand at the time, and Waitakere City Council (WCC) was installing telemetry at wastewater pump stations to monitor overflow alarms. I realised the potential of adding BSP monitoring to the telemetry system at relatively low cost, by utilising pulse units on the helix flow meters located at the BSP. This was implemented as a national 'first' in the early 1990's and provided real time flow information from bulk supply points located across the city.

Secondly, the water supply network was divided into discrete supply areas, so monitoring of flows into each area could be monitored using the real time flow information from one or more BSP's. Seventeen water supply areas were initially set up, and the flow monitoring was very successful. Accurate minimum night flows into each supply area could be monitored, giving rise to the next important initiative; targeted leak detection.

Active leakage Control: Targeted and Performance Based Leak Detection

Prior to 1990 WCC had a 'common' yet very 'expensive' leak detection programme. A team of contracted leak detection staff would methodically work right across the water supply network using acoustic equipment to listen on all water fitments (meters, valves, hydrants) to locate leakage. This was costing approximately $250,000 pa at the time.

The real time monitoring of minimum night flows (MNF provided the opportunity to identify supply areas (or zones) with high leakage rates. High leakage rates were deemed to be those where MNF in a zone exceeded 5 litres/connection/hour, and leak detection work would be 'triggered' in a zone when MNF exceeded 9 litres/connection/day. A zone could also be split into a number of sub-zones for several hours at a time during the night, and the MNF monitoring used to identify the parts of the zone with the highest leakage, thus speeding up the leak location process. The process of targeting leak detection efforts in zones where MNF's were highest, reduced leak detection costs to under $100,000 pa while achieving better results.

Hence, the efficiency and effectiveness of leak detection work, to reduce water loss from the network, was significantly enhanced by the setting up of discrete supply areas where minimum night time flows (which are used to monitor leakage levels) could be monitored 'real time'.

Furthermore, in the mid 1990's we changed our leak detection contract from being a straight 'methodology' based contract where the contractor was paid for leak detection work carried out (i.e. paid per kilometre of watermain surveyed etc) to one where up to 50% of the payment due for leak surveying work was performance based i.e. dependent on the 'actual reduction in MNF' achieved after the leaks found were repaired, based on telemetry monitoring. Hence rather than paying a leak detection contractor for 'going through the motions of acoustic surveying' and providing a leak list for repair, the contractor has an incentive to find the worst leaks, and to find them quickly using whatever technology or methodology available. The leak detection contractor is requested to carry out leak detection in a zone where high MNF's are present, and having a performance based leak detection contract ensures a good outcome from the leak detection work;

the leaks are either located and repaired, or the MNF is accounted-for by investigation work by the contractor.

Pressure Management

In 1993 and 1994 Auckland experienced a water shortage, where the regional (Watercare's) storage volume fell to just over 30%. All opportunities to reduce water use and water losses were explored and implemented wherever possible. Pressure reduction was identified as one of these measures, and in 1994, as an emergency measure, pressure reducing valves were installed at most BSP's in Waitakere City. Supply pressures were reduced 'overnight', with the consent of the Fire service, and additional water savings were achieved.

After significant rainfall later in 1994, the water shortage was over, and supply pressures were restored. It was then that WCC decided to progress with a 'managed' pressure reduction programme, and between 1996 and 1999, supply pressures were reduced across two thirds of the city, with the average supply pressure reduced from 720kPa to 540kPa, and the number of water network 'sectors' (or district metered areas) increased to 34. This programme was carried out with the cooperation of the Fire Service, and WCC made special effort to ensure fire sprinkler systems were not adversely affected. This programme had multiple benefits (refer paper by Taylor and Pilipovic 2002) including a further reduction in the amount of water loss from the network, and a reduction in watermain break frequency.

The success of a pressure management programme as outlined above is however dependent on an ongoing commitment to monitoring supply pressures and ensuring the satisfactory performance of the pressure reducing valves. If this commitment is not made, water losses will increase due to variable and increasing water pressures in the network arising from poor pressure reducing valve performance. WCC has implemented an inspection and preventative maintenance programme to ensure pressure reducing valves are well maintained and operate at the target pressure with minimal pressure variability.

Speed and Quality of Repairs

Another aspect of maintaining a low level of water losses is the speed and quality of repairs. In WCC there is a high awareness of water wastage by residents, and leaks are reported to Council's 24 hour Call Centre. Due to the mostly clay soils in the city, water leaks generally surface and are readily visible. WCC's maintenance contractor has a good record of responding to, and repairing leaks quickly. Leaks are not left 'unrepaired' as to do so would result in serious complaints from the public.

Recently WCC implemented a 'real time' reporting system for maintenance work whereby the response and repair times for all faults are recorded 'real time' on our Hansen Asset Management System (AMS).

Asset Management System and Renewal programme

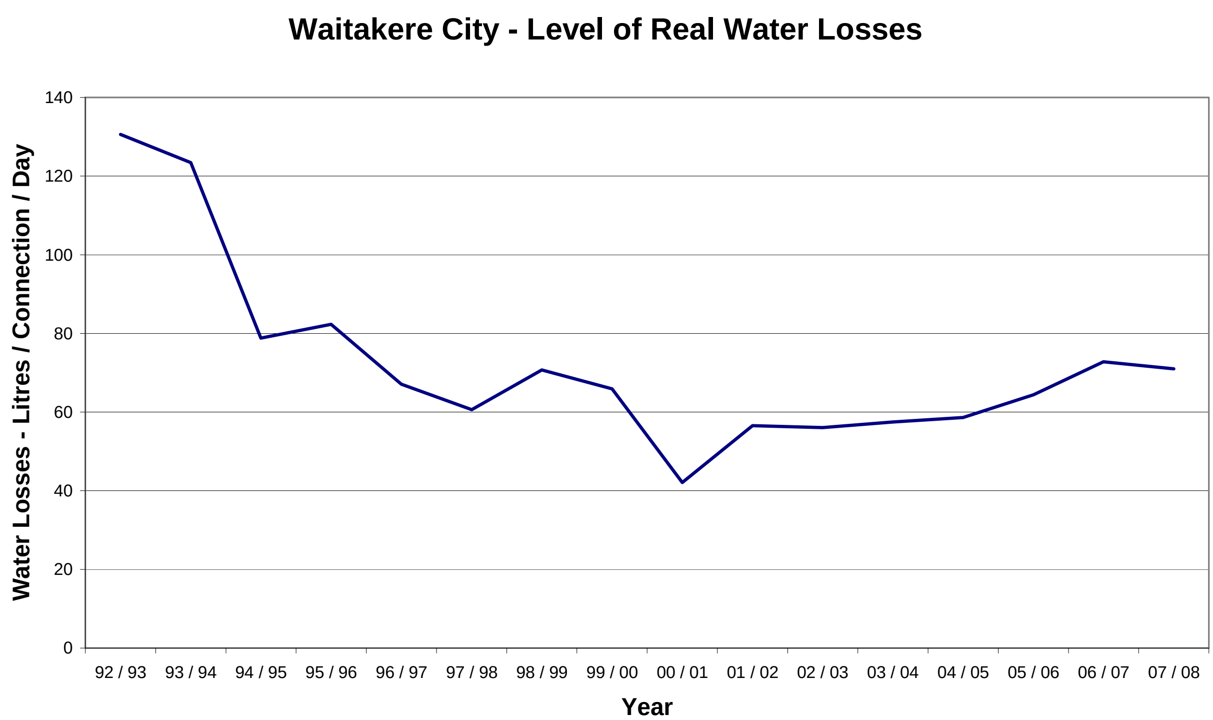
Further to the real time reporting mentioned above, when repair work is carried out, the nature of the fault and asset information, including asset condition, is recorded directly into the Hansen AMS. This provides the information necessary to identify sections of watermain requiring replacement due to poor asset performance and/or condition. An ongoing watermain renewal programme ensures watermains (including associated valves, hydrants and service connections) in very poor condition are replaced before water loss from such sections of main becomes an issue.

Enhanced Pressure Initiatives

One enhanced pressure management initiative carried out recently was the replacement of the pump units at a water pump station with lower energy use and lower ‘head’ pumps, which while providing the necessary service level, also resulted in much lower pressure fluctuations in the network on pump startup and pump stop. The extent of leakage caused by pressure fluctuations is difficult to quantify, but we know from experience that these types of pressure variations definitely result in higher loss rates and higher watermain break frequencies.

Water Loss Performance / Results

The extent of the reduction in water loss in the Waitakere City network since 1990 is shown in the graph below (shown in terms of litres per connection per day water loss), and highlights the effectiveness of the measures introduced. This reduction is water loss represents an annual saving of approximately $700,000 per annum. The payback period for the capital investment carried out was less than 3 years. As mentioned above, the performance indicator ‘litres/service connection/day’ is the preferred performance measure for ‘process benchmarking’i.e. to track reductions in real losses due to combinations of water loss reduction initiatives.



Graph showing reduction in Real Water Losses in Waitakere City since 1992/93

Management Aspects

Apart from the technical aspects outlined above, it is important to mention the other characteristics which contribute to such change. Some of these are covered below.

Culture for Change

In 1991 Waitakere City declared itself the first ‘Eco City’ in New Zealand and took seriously the sustainable management principles covered in the 1991 Earth Summit at Rio de Janeiro. In addition to this, Waitakere City Council had, and still has, a culture promoting innovation and change. The council’s mission statement was stated as the words; open, dynamic, just. These factors cannot be underestimated in terms of facilitating the investment and change necessary to implement the measures outlined above.

Catalyst for Change

Often there needs to be a catalyst for change, and in our case the 1993 water shortage provided the impetus to focus strongly on water loss reduction, which triggered the implementation of pressure management in the city. A further catalyst was the opportunity to work with Allan Lambert, an international water loss consultant who came to Auckland as a speaker at the Water 2000 conference, and who subsequently spent time with the water staff at Waitakere City Council. This was a great learning time for staff where the understanding of water loss and performance measures for water loss was greatly enhanced.

Commitment to Change

As mentioned in the section on pressure management, commitment is very important. The water loss reduction initiatives outlined above span almost 20 years, and the ongoing commitment by both management and staff to reducing and maintaining a low level of water loss cannot be underestimated. Often in organisations commitment to an objective is lost either due to staff turnover or other priorities taking place. In our case, three key staff have been committed throughout this period to the objective of reducing water losses, and this has contributed significantly to the achievements made.

Structure for Change

The structure of the water industry in terms of the ‘wholesale/retail’ split in the Auckland region, and the ‘size’ of Waitakere City as a retailer has facilitated the changes made to reduce water losses. Monitoring of flows into the local water distribution system was facilitated by the number of metered bulk supply points located in the city. The size of Waitakere’s network meant that a few ‘empowered’ staff were able to implement change in an organisation which encouraged innovation. The structure of the water industry in my view facilitated the change necessary to achieve the low water loss reduction figures successfully.

Summary

The Infrastructure Leakage Index is a very useful performance indicator for comparing water loss between water distribution systems. It has been applied in more than 50 countries. Waitakere City Council has achieved outstanding results in reducing water loss since 1990 by implementing a number of initiatives which have reduced water losses to achieve an ILI of 1.0 which is considered to be a ‘world class’ standard.

Acknowledgements

I would like to thank Allan Lambert, international water loss consultant from the United Kingdom for his involvement with Waitakere City Council water supply staff since 2000. Also to acknowledge Allan Lambert and Ronnie McKenzie for their role in developing the BenchlossNZ manual and software for the New Zealand Water and Wastes Association. Thanks also to my colleagues at Waitakere City Council; Tony Miguel, Group Manager Asset Management and Zoran Pilipovic, Water Supply Planning Engineer, for their commitment and contribution to the initiatives carried out to date.

References

BenchlossNZ Manual and Software (February 2008 version), available from the New Zealand Water and Wastes Association.