European Commission

EU Reference document Good Practices on Leakage Management WFD CIS WG PoM

Case Study document

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Table of Contents

List of terms and abbreviations

Term or abbreviation	Explanation
AL[1]	Apparent Losses
ALC	Active Leakage Control
AR	Asset Renewal
AZP	Average Zonal Pressure
AZNP	Average Zonal Night Pressure
BL	Background Leakage
BFm	Annual Burst Frequency (mains, per 100 km/year)
BRs	Annual Burst Frequency (service connections, per 1000 SCs/year)
CARL	Current Annual Real Losses
CROW	Independent Dutch Knowledge Organisation on infrastructure, public space, and traffic and transport
DI	Distribution Input volume (similar to SIV)
DMAs	District Metering Areas
DZ	Distribution Zone
EC	European Commission
EIF	Economic Intervention Frequency (for Active Leakage Control)
ELL	Economic Level of Leakage
FTE	Full Time Equivalent (staff numbers)
GPKL	Dutch Platform Cable and Pipe from the Dutch municipalities
GSDI	Good System Design and Installation

[1] The simplified IWA Water Balance used for the case studies can be found in Figure 8 of Section 6.1 and in Appendix B.1 of the EU Reference document *Good Practices on Leakage Management*. The terms and abbreviations used in this Water Balance are listed. All terms relating to the Water Balance and components are for potable water only.

Term or abbreviation	Explanation
ILI	Infrastructure Leakage Index
IM	Infrastructure Management
Klic-online	Digital system about the location of cables and pipes
KLO	Cable and Pipe Consultation
KPI	Key Performance Indicator
LoL	Level of Leakage
MARP	Minimum Annual Reference Pressure
MCoALC	Marginal Cost of Active Leakage Control
$MCoW_{WSP}$	Marginal Cost of Water for the WSP
Ml/d	Mega litres (million litres) per day
MNF	Minimum Night Flow
NEN	Dutch Normalisation Institute
Network[2]	Mains only
NRR	Natural Rate of Rise (of unreported leaks)
NRW	Non-Revenue Water
O&M	Operation & Maintenance
PCC	Per Capita Consumption
PESTLE	Acronym for Political, Economic, Social, Technological, Legal and Environmental
PHC	Per Household Consumption
PM	Pressure Management
PMAs or PMZs	Pressure Managed Areas or Pressure Managed Zones
PMI	Pressure Management Index
PoM	Programme of Measures
RBMP	River Basin Management Plan
REE	Resource and Economic Efficiency of Water Distribution Networks in the EU
RRul	Rate of Rise of Unreported Leakage
RL	Real Losses
SELL	Sustainable Economic Level of Leakage
SIV	System Input Volume
SQR	Speed and Quality of Repairs
System[2]	Mains and service connections
TCMD	Thousand metre cubed per day
UAC	Unbilled Authorised Consumption
UARL	Unavoidable Annual Real Losses
UKWIR	United Kingdom Water Industry Research
WAFU	Water Available For Use (raw water resources available to the WSP)
WE	Water Exported
WFD	Water Framework Directive
WI	Water Imported
WION	Law Information exchange Underground Networks
WL	Water Losses (= Apparent Losses and Real Losses)
WLTF	Water Loss Task Force
WLSG	Water Loss Specialist Group
WOA	Water Operations Area
WS	Water Supplied (excluding Water Exported)
WSP	Water Service Provider
WRZ	Water Resource Zone
WTW	Water Treatment Works

[2] In different European countries, the words 'network' and 'system' can have different meanings, which can lead to errors of interpretation. In most European countries 'network' relates only to main length, and does not include service connections. 'System' includes both mains and services.

Leakage management from Water Utility point of view

Contribution of Bambos Charalambous.

The annual volume of treated water leaking from a distribution system is an important indicator of the evolution of water distribution efficiency, in individual years and as a trend over a period of years. High and increasing annual volumes of leakage indicate ineffective planning and construction, and low operational maintenance activities. With the increasing international trend towards sustainability, economic efficiency and environmental protection, the topic of water supply system leakage is high-profile. This is especially so during times of water scarcity or drought, when consumers are asked to reduce their own consumption of water in order to maintain continuity of supply. Failure to quickly repair visible leaks is highly damaging to a Utility's reputation.

To the general public, media and politicians, high leakage levels in water distribution networks are generally perceived as waste and inefficiency on the part of the water service providers and damaging to the environment. But what is a 'high' or 'low' level of leakage often depends on the choice of performance indicator, and leakage statistics tend to be selectively used as weapons by those seeking to justify a pre-conceived viewpoint. So it is little wonder that some Utilities choose indicators which appear to show their performance in the best possible way, or use favourable (rather than neutral or unfavourable) options and assumptions in leakage calculations. There are remarkably few countries worldwide in which Utilities publish attributed and independently audited water balance figures. Also, few people are aware that almost all assessments of system leakage, however derived, are subject to a quantifiable range of uncertainty, even in fully metered systems (see Maltese Case Study Malta WSC). So use of performance bands has merit, compared to quoting performance indicator figures which seem to be precise, but aren't.

When water service providers have no option but to impose reductions on customers' consumption during water shortages, there is an immediate reduction in metered revenue, an increase in operational costs, and the effective unit value of leakage equates to the retail price of water. Introduction of rotational (intermittent) supply may seem to non-specialists to be an obvious way to save water, but this actually results in long-term damage to the infrastructure, lower than expected savings, higher leakage rates in subsequent years, and substantial additional operational costs (see Cypriot Case Study Lemesos).

Water services providers often offer the defence that they are operating as efficiently as they can, given their specific circumstances, and that further increases in efficiency to reduce levels of leakage would require increased tariffs that are always politically unpopular. So investments needed for improved Pressure Management and leakage efficiency must compete with other priorities for Operating and Capital funds from revenues, and must be based on a sound financial case of costs and benefits.

Pressure Management is defined by the WLSG as 'the practice of managing system pressures to the optimum levels of service ensuring sufficient and efficient supply to legitimate uses and customers, while:

- reducing unnecessary or excess pressures
- eliminating transients and faulty level controls
- reducing the impact of theft

all of which cause the distribution system to leak unnecessarily'.

As there are many different methods of Pressure Management, they are classified by the WLTF as being Basic, or Intermediate, or Advanced.

The practical approaches developed by the WLTF and WLSG since 2006 for predicting Pressure Management benefits now not only include reduction of leak flow rates, but also reduction of burst frequency and repair costs, ways to estimate increase of extension of residual asset life, reduction of consumption and other benefits (see the Table 1 in Section 4.2 of the EU Reference document). These practical approaches have provided economic justification with much reduced payback periods for capital investment in many hundreds of additional Pressure Management schemes internationally since 2006, resulting in lower leak flow rates and leak frequencies, which in turn facilitate other leakage management activities as part of a virtuous circle of activity.

The appropriate budget for Active Leakage Control is highly dependent upon the value placed on leakage, and the Rate of Rise of unreported leakage. Utilities purchasing expensive bulk water or using desalination can therefore usually justify increased leakage control activity compared to Utilities with their own sources. Rate of Rise of unreported leakage varies widely from Zone to Zone, even within a single Utility, from almost zero (all leaks surface) to almost 100% (no leaks surface). Economic intervention frequencies can vary from once every 6 years to several times per year, so budgets need to be based on local data rather than generalised assumptions.

The larger the Utility and the lower the level of leakage, the more difficult it is to reduce leakage quickly in response to a drought or an emergency. In many European Utilities, both water resources availability and consumption vary widely during the year, and from year to year, so leakage management activity should also be linked to variations in seasonal consumption and short or medium term availability of water resources. This can also be an important aspect of a sustainable leakage control policy, with increased effort during periods of potential or actual scarcity, and lesser effort during times of plenty. Where there are large variations in seasonal peak demands, some flexibility in standards of service for pressure can also be a useful facility.

Provision of a free facility for the public to report leaks, and clear short target repair times for all leaks, are essential elements of a sustainable leakage management policy. Failure to repair visible leaks promptly will attract justifiable criticism of the Utility.

Taking all of the above factors into account, Water Utilities should ensure efficient, long-run operation of existing assets, employing high level of workmanship and materials in the daily maintenance operations. Operational efficiency must be improved through the adoption of the lowest cost use of inputs (labour, energy, water and materials) in the daily operations of the Utility. The optimum combination amongst the above inputs must be sought by the Water Utility in order to strive towards sustainability.

Ongoing assessment and tracking of leakage levels is a fundamental part of a Non-Revenue Water Strategic Plan. A water audit is used to determine Real and Apparent Water losses through the performance of a “top-down” water balance for the whole system and large sub-systems, for overview reporting. This is supplemented by Night Flow analysis in individual Pressure Managed Areas (PMAs) and District Metered Areas (DMAs), which provides a ‘fast track’ notification of new leaks.

Figure 1 – Properties with roof storage tanks on Cyprus.

In systems with many unmetered properties (e.g. UK) or relatively high apparent losses due to customer meter under-registration for properties with roof storage tanks (Cyprus, Malta, some parts of Italy, Spain and Portugal) the leakage component of minimum Night Flows, coupled with 'Night-Day Factors' (which allow for variations in daily pressure profiles) can also be used to provide an assessment of annual real losses volume.

Many countries within Europe now use versions of the IWA Water Balance (with local variations which may be significant), but some European countries use different formats. So a simplified IWA Water Balance for potable water (Appendix B.1 of the EU Reference document) is used to ensure standardised assessments of annual leakage volumes in the Case Studies.

Good practices on leakage management by utilities

Every Water Utility has unique characteristics and losses and a variety of tools, techniques and methodologies must be available in the leakage practitioner's tool kit. Case study accounts of individual Water Utility experiences are an important way to communicate that a particular method or approach is feasible and has succeeded in a given setting. Referencing a case study account of a successful water loss control programme is an effective way for a Water Utility manager to enhance his/her case when making a proposal for a new project or a change in rationale. It is very effective in gaining support for a proposal to provide evidence that a similar programme has been carried out in an efficient and economic manner.

The case studies prepared for the EU Reference document *Good Practices on Leakage Management* are presented in this separate document.

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What can be learned from each case study account?

1 Austrian Case Study: Small systems

Out of the 2.354 Austrian municipalities 2.128 have less than 5.000 inhabitants. Because of this structure Austria has about 5.500 water utilities (OVGW 2014):

- About 1.900 municipal utilities.
- About 165 water associations.
- About 3.400 water cooperatives.

More than 5.000 of these utilities have less than 3.000 service connections and can be considered as 'very small utilities'; around 4.500 of these utilities have less than 1.000 service connections. A significant number of utilities serve less than 100 service connections. These small structures are common in most parts of Austria, especially in the Alpine regions and also in other rural regions, which belong mainly to the Danube River Basin.

You should read this Case Study account to learn more about:

- The conclusion in the Final REE Report, which states that high leakage of over 50% in small Alpine systems would not be exceptional. From the analysis of very small systems in Austria we learn the opposite is true, as it seems to be easier to achieve very low leakage (ILI < 1) in such systems, which are similar to individual DMAs. Reasons for low leakage in small systems are described in the Case Study.
- The guidelines developed by WLTF members between 2005 and 2009, which show that, for a lower limit of 3.000 service connections, the UARL standard formula is supported by the Austrian data and a number of practical considerations which are listed in the Case Study. The additional influence of low pressure and pipe materials on UARL are being investigated using data from larger systems with lower pressures than are available in Austria.
- Burst frequency on mains, and on services, which are also important indicators of system infrastructure condition, and are widely used in Austria. Combining water loss and failure rates gives an indication about the effectiveness of water loss management and supports decision making regarding required actions such as improvements in Active Leakage Control, Pressure Management and rehabilitation.

2 Austrian Case Study: Salzburg

This case study deals with the successful long-term management of the historical grown water supply network of the city of Salzburg in Austria. Parts of the network are more than 100 years old, but water losses and failure rates are low compared to international values. The good condition of the pipe network and the high service quality provided to the clients are a result of a consequent asset management strategy using innovative network monitoring and asset management tools.

You should read this Case Study account to learn more about:

- Maintaining water supply assets in good condition, a requirement of Austrian Water Law. Salzburg AG has implemented a sustainable asset management strategy and uses innovative rehabilitation software to ensure efficient asset renewal.
- Salzburg AG's water loss management strategy, which is similar to many other utilities in Austria. It follows OVGW guideline W 63 (2009) which includes principles of the IWA water loss management strategy. Beside network zoning of the core zones, which can be temporarily sub-divided, sections with permanent DMAs, permanent noise logging and basic Pressure Management are key measures alongside innovative infrastructure management practices. Salzburg achieves very low leakage levels with an ILI of 1,1 in 2013.

- The focus on annual maintenance activities of distribution system fittings, which are carried out for about 20% of the network per year, and combined with additional Active Leakage Control checks for small detectable leaks.

3 Belgian Case Study: De Watergroep

De Watergroep is a major Belgian Water Company, active in Flanders. Founded in 1913 as 'NMDW', it was renamed in 1987 as 'VMW' and then as 'De Watergroep' in 2013. The source water is 53% groundwater, 22% surface water and 25% bulk imports of potable water, and there are also exports of potable water to adjacent Utilities. De Watergroep has very low consumption of only 300 litres per service connection per day.

You should read this Case Study account to learn more about:

- How a consistent companywide approach is essential for efficient network and NRW management in a large Utility with multiple individual systems.
- The importance of data management within a complex and widespread distribution system.
- How low (or high) consumption adversely influences perception of leakage management performance when % of System Input Volume is used to compare performance or set targets. More meaningful performance indicators are now available; ILI was developed for comparisons between systems; litres/connection/day or m^3/km mains/day are appropriate for tracking progress in individual systems (but not for comparing different systems).

4 Bulgarian Case Study: Dryanovo and Razgrad

Most of Bulgaria experiences very high NRW, Apparent Losses and Real Losses. A tendency of reduced water consumption exists in the region due to customers' savings, closure of industrial production, etc. as well as reductions in the served population, payment of water taxes and repayment of long-term credit. So there is a lack of funds for rehabilitation.

However, some Utilities are starting to tackle the problems systematically. This Case Study contains two examples showing how the powerful combination of pressure management and Active Leakage Control in DMAs, applied in sequence, can achieve sustainable reductions in volumes of leakage in Bulgaria.
The Dryanovo example covers 12 DMAs recently established in a small town (1.470 service connections, 38,2 km mains). Razgrad is a pilot project to demonstrate benefits in 4 DMAs (716 service connections, 13 km mains) out of 24 existing DMAs in a city with 5.251 service connections and 116 km mains.

You should read this Case Study account to learn more about:

- How utilities with high leakage and few resources in Bulgaria can, with small capital investments based on knowledge and professional application of IWA practical concepts, deliver significant positive results in water loss reduction, providing a strong foundation for further gains.
- How the measurement of pressures, and application of Pressure Management in conjunction with Active Leakage Control in DMAs, is fundamental to the success of this approach.
- How the setting of targets and monitoring of leakage reduction using % of System Input Volume seriously under-estimates actual achievements (by a factor of 3 in the Dryanovo Case), and provides a disincentive for Utilities to implement effective leakage control and reduce excessive consumption and apparent losses.

5 Croatian Case Study: Pula

Waterworks Pula supplies the cities of Pula and Vodnjan, and municipalities Medulin, Ližnjan, Marčana, Barban, Svetvinčenat and Fažanu, in the south cape of the Istria peninsula in Croatia with a population of 75.000 and during the summer months an additional 100.000 tourists. The company has 32 reservoirs (32.313 m^3 capacity), 70 pumping units, 12 pump stations, 11 braking chambers, 17 water treatment plants, 25.657 service connections with 46.882 metered customers, 2.402 hydrants, and 928 km of mains of different sizes and materials.

You should read this Case Study account to learn more about:

- The importance of early recognition of water loss management as a result of a dedicated strategy initiated over 10 years ago.
- How a successful reduction and control of leakage requires goals, vision and commitment for continuous implementation.
- How an open minded management board emphasized the importance of company management, own personnel knowledge improvement and new technologies implementation.

6 Cypriot Case Study: Lemesos

The Water Board of Lemesos, established in 1951, is a semi-government Utility (Legal Person governed by Public Law) run by a Board of Directors appointed by the Council of Ministers and local Municipality appointees. The Board aims exclusively to ensure the supply of sufficient quantity water of good quality and to meet both the households' needs and its consumers' commercial and industrial requirements. The main concern and cornerstone of operations is the best possible service offered to its consumers. Lemesos, on the south coast of the island, is the second largest town of Cyprus. Ground levels in the 100 km^2 supply area fall from 450 meters at the foothills, to sea level.

You should read this Case Study account to learn more about:

- The problems of managing leakage under severe water shortage and intermittent supply conditions.
- Using Pressure Management and Active Leakage Control, from year 2002 to year 2007, to reduce leakage to ILI < 2,0.
- Being aware of how intermittent supply damages infrastructure and increases leakage in subsequent years.

7 Danish Case Study: VCS Denmark Odense

VCS Denmark is a Danish water and wastewater company with more than 150 years of operational experience in water supply and wastewater management - and a strong tradition for innovation. VCS Denmark is the third largest water and wastewater company in Denmark, operating 7 waterworks, 8 wastewater treatment plants and 3.400 km of water and wastewater pipeline networks. VCS Denmark is known as a frontrunner in the Danish water and wastewater sector. We have supplied the city of Odense with clean drinking water since 1853. Today VCS Denmark is a modern water and wastewater company with approximately 200 employees.

You should read this Case Study account to learn more about:

- How VDS Denmark has reached such low water losses with an ILI of 0,7.
- The effect of taxes on network water losses and potable water.
- The influences of system design, Pressure Management and Active Leakage Control.

8 English Case Study: Anglian Water

Anglian Water is one of 19 privately owned water companies in England and Wales, regulated by a number of organisations, which supplies water to approximately 2 million households. Rainfall in most of the Company's area is significantly less than the national average; it is classed as an area of severe water stress with many wetland and conservation sites of national and international importance. Anglian Water operates 450 Distribution Zones (DZs) with 1.800 DMAs covering 37.232 km water mains, of which 24% are actively pressure managed. About 75% of households and almost all non-households are metered.

You should read this Case Study account to learn more about:

- The way the economic regulator, Ofwat, requires an annual total leakage KPI in Ml/d based on a standard water balance and agrees targets based on a sustainable economic level of leakage (SELL in Ml/d) every 5 years. Environment Agency requires zonal leakage values to be incorporated into Water Resource management Plans, again every 5 years.
- The way the Company's supply-demand balance is at risk from growth, climate change and the reductions in deployable output that are planned to restore abstraction to sustainable levels. The Company has to manage risks from drought, deteriorating raw water quality and the impact of cold, dry weather on its distribution system and customer supply pipes. In response, a flexible and adaptive plan has been developed that commits to reducing leakage and consumption.
- The plan to increase coverage of Pressure Management from 24% to circa 50% within 5 years in order to reduce average zone pressure (AZP) from 44m to 38m (13% reduction).

9 French Case Study: Beaune

Beaune is a small town in central eastern France of 22.500 inhabitants and of an area of 31 km^2. The drinking water supply network of Beaune supplies 6.350 customers via 150 km of pipes. Beaune has the particularity to be located between the hills and the plain of the Saône so that its unique resource is the resurgence of a small stream. In addition to being restricted, this resource requires a complete water treatment (removal of pesticides and limestone, disinfection), hence leakage reduction is a strong issue to Beaune. This issue led Veolia Water, through the renewal of the public service contract with the Conurbation authority of Beaune Côte et Sud in 2009, to commit to progressively and significantly improve the efficiency of the network up to reach a target of 80% in 2016 (network efficiency was equal to 70% in 2009). Network efficiency is a French performance indicator.

You should read this Case Study account to learn more about the first results of the Veolia Water action plan (implemented in 2009-2010) comprising:

- Deployment of an Advanced Metering Infrastructure.
- Establishment of permanent DMAs and supervision.
- Installation of permanent acoustic noise loggers.

10 French Case Study: Bordeaux

The studied system is the water supply system of CUB (Communauté Urbaine de Bordeaux). The CUB and its delegate Lyonnaise des Eaux provide the consumers of 22 cities with high quality underground water resources. The system includes 103 water intake points, 3.132 km water mains (aqueducts included), 130 treatment plants and 49 reservoirs. The whole water production system is monitored and controlled remotely 24 hours a day by the operation centre.

You should read this Case Study account to learn more about:

- How leakage in Communaute Urbaine de Bordeaux was reduced from 10,8 to 7,5 Mm^3 (ILI 3,2 to 2,5) between 2008 and 2013.
- How advanced Pressure Management and sectorisation created improved network conditions for achieving sustainable lower levels of leakage.
- How the current strategy focuses on efficient Active Leakage Control and prioritising the renewal of service connections, which are the most deteriorated part of the system and the source of 90% of all leaks.

11 German Case Study: Munich

Leakage control has a long history in German water supply, starting with first rules of the German Technical and Scientific Association for Gas and Water (DVGW) in 1986. These rules have been revised several times, the last update is still under revision right now.

The city of Munich is the capital of the state of Bavaria. It is situated at the river Isar, a tributary of the Danube river. With a resident population of 1,5 Million it is the third largest city in Germany. Population growth is proposed to about 1% per annum. Stadtwerke München GmbH (SWM) is the utility of the City of Munich for energy and water supply, urban transport und telecommunication.

You should read this Case Study account to learn more about:

- The German DVGW technical rules on Water Loss in Guideline W392.
- Groundwater quality protection through compensation payments to organic farmers and constructors, as an alternative to abstraction charges, to keep water quality so good that no water treatment is necessary.
- Leak detection in an area of sands and gravels with very high permeability, where only large leaks show at the surface, even with relatively high pressures.
- The importance of careful construction and design of infrastructure to minimise occurrence of new leaks.

12 Italian Case Study: Iren Emilia

Iren group is a major Italian multi-utility active in water, gas, energy and waste disposal, operating in the provinces of Turin, Genoa, Parma, Piacenza and Reggio Emilia in the northern part of Italy. The company was founded in 2010 by the merger of several companies in the area and serves a total of more than 2,5 million inhabitants. Water systems in Reggio Emilia province are managed by Iren Emilia. The 28 water systems in Iren Emilia supply 45 municipalities with 475.000 inhabitants through 4.940 km of mains.

You should read this Case Study account to learn more about:

- How Iren Emilia has learnt and applied the IWA concepts, since 2005, to reduce leakage (by 50%, to an average ILI of 2,5), burst repairs (by 33%) and use of electricity (by 20%) in 14 discrete systems in Reggio Emilia.
- Why implementing Pressure Management before (or during) the creation of DMAs, rather than afterwards, would have been a more efficient strategy.
- Why the implementation of technological solutions is only part of the real solution, which is all about managing Utility people to perform, by empowering them with the responsibility, training, practical tools and proven techniques, motivating them to perform, and inspiring them to believe that they can make a difference.

13 Maltese Case Study: Malta WSC

The Water Services Corporation is the national water operator for all three Maltese islands. Wholly government owned, it is responsible for both water and waste water operations.

The problem of leakage has been holistically tackled since the intermittent supply problems of the mid-nineties. Almost all customers use indirect plumbing systems with large roof storage tanks, which create major meter under-registration quantified by detailed studies as being around 20% or more.

You should read this Case Study account to learn more about:

- How major reductions of leakage on the Maltese Islands since 2001 using IWA methods has resulted in 2-out-of-5 desalination plants being scrapped.
- How leakage was reduced from an ILI close to 20 in the mid-nineties to an ILI of 2,1 by 2013 (>600 to 70 litres/connection/day). This was achieved by a combination of Pressure Management and Active Leakage Control in small DMAs.
- Using snapshot ILIs from night flows to target ALC interventions and regulatory targets – and how smart metering installation is in progress to address high apparent losses.

14 Portuguese Case Study: Lisbon

The largest and oldest water utility in Portugal, Empresa Portuguesa das Águas Livres (EPAL), SA is a limited liability company, with 100% public capital, owned by the Águas de Portugal group. EPAL undertakes the extraction, treatment and distribution of potable water, encompassing both bulk supplies to around three million people in 34 municipalities and direct supply to more than half a million people in the city of Lisbon. This case study relates to the Lisbon distribution network, which receives treated water via EPAL's bulk supply network from the principal water source at Castelo de Bode, some 120 kilometres north of the city. The distribution network encompasses around 1.450 kilometres of mains, divided into five pressure zones and supplying in excess of 340.000 clients.

You should read this Case Study account to learn more about:

- Active leakage control 'find and fix' in DMAs with 'WONE' data analysis.
- Identifying pressure management opportunities that may exist in the EPAL Lisbon distribution network.
- How EPAL reduced leakage by 200 m^3/hour (500 to 178 litres/connection/day) between 2005 and 2013.

15 Scottish Case Study: Scottish Water

Scottish Water (SW) is the statutory water and wastewater services provider for the whole of Scotland, covering an area over 79.000 square kilometres (a third of the area of Great Britain), supplying 4,9 million population with drinking water through 48.000 kilometres of water pipes from 241 water treatment works. Households are not metred; all non-households are and there is market competition.

You should read this Case Study account to learn more about:

- The way in which a publically owned organisation with a one-to-one relationship with its regulator, and relatively plentiful low cost water, has outperformed the annual leakage targets agreed with the regulator with reported annual leakage reducing by 48% from 1.104 Ml/d in 2006 to 575 Ml/d in 2013.
- The process involved in estimating a sustainable economic level of leakage (SELL) for each of the 230 water resource zones and how the SELL varies considerably when reported in term of standard performance measures.
- The extensive pressure management programme combined with 96% coverage of district metering which has contributed to the reduced leakage, and which aims to further reduce average operating pressure to 40 metres. Current coverage of pressure management is 56% of the network with a weighted average pressure of 44,8 metres.

16 Serbian & Croatian Case Study: Mentoring

The Western Balkan region (Slovenia, Croatia, Bosnia and Herzegovina, Montenegro, Serbia, Macedonia and Kosovo) has around 500 water distribution systems serving some 20 million people. All utilities are public and under the control of national regulators. Individual distribution systems of separate municipalities and towns are relatively small, other than the capital cities. For example, Croatia has some 150 utilities supplying water to 4,3 million people, 20% of whom live in the capital city of Zagreb, and similar situations occur in the other countries.

The economic downturn in the 1990s due to numerous reasons had a negative impact on water infrastructure condition and leakage due to war damages, lack of preventive maintenance, limited or zero investments in rehabilitation, low revenue due to low water tariff, slow economic recovery, etc. Water resources availability and capacity are generally adequate, so leakage is not usually considered an issue of high importance by managements and workforce with little experience of modern leakage management.

You should read this Case Study account to learn more about:

- How a mentoring approach is beneficial, particularly for small utilities, for bridging the gap due to lack of national/regional educational good practices in leakage management.
- The main topics of interest in the mentoring approach for utilities regarding water loss management. These were: skills in use of leak detection equipment, free software for PIs calculation in local language, better understanding of pressure management benefits, DMAs, accurate and frequent flow and pressure measurements, operation of networks and apparent losses.
- How, in the light of rising capacities of employees (competencies, skills, responsibilities), mentoring of water utilities has proved a positive option in the West Balkan region, leading toward water loss reduction and increased system efficiency.

Summary Tables on the Case Study accounts

This section presents on the following five pages a summary table for:

- The context for each Case Study account.
- The Water Utility or system(s) context on infrastructure and leakage control.
- The assessment of annual leakage volume.
- The energy, economic and regulatory context.
- The assessment of annual leakage performance.

Note that it is important in any review of bursts that the level of ALC is taken into account. This to avoid the misconception that the asset condition is deteriorating when in fact there are more staff on the ground finding leaks. That is why some bursts rates look high; for those utilities the bursts rate has been reducing due to clearing the backlog.

Note on quality control: whilst the Drafting Group members have carried out numerous checks on the data contained in this Section, the reliability of the information and data contained in the Case Studies remains the responsibility of the Case Study authors.

Summary table Case Studies: Context for Case Study account

Country	River Basin / Sub-basin	Utility	Case Study title	Case Study nr.	Abundant water resources		Potable Water, Own Sources				Potable water, Bulk Supplies	
					At the Basin level?	For Utility all year every year?	Surface water	Ground water	Springs	Desal ination	Bulk Imports	Bulk Exports
Austria	Various	54 with < 10k services	Small Systems	1	Yes	Mostly	No	Yes	Yes	No	Some	Some
Austria	Danube	Salzburg AG Wasser	Salzburg	2	Yes	Yes	No	Yes	Yes	No	Yes	Yes
Belgium	Flanders	De Watergroep	De Watergroep	3	No	No	Yes	Yes			Yes	Yes
Bulgaria	Danube/Yantra	ViK Gabrovo - Dryanovo Region	Dryanovo City	4	No	No	Minor sources	Minor sources	Minor sources	No	Yes	No
	Danube/ Russenski Lom	Vodosnabdyavane Dunav EOOD - Razgrad	Razgrad Pilots		No	No	Minor sources	Minor sources	Minor sources	No	Yes	No
Croatia	Istrian	Vodovod Pula	Pula	5	No	No	Yes	Yes	Yes	No	Yes	Yes
Cyprus	Cyprus	Lemesos Water Board	Lemesos	6	No	No	Yes			Yes	Yes	No
Denmark		VCS Denmark	Odense	7	Yes	Yes	No	Yes	No	No	No	No
England	Anglian	Anglian Water	Anglian Water	8	No	No	Yes	Yes	Yes	No	Yes	Yes
France	Adour/Garonne	Communaute Urbaine de Bordeaux	Bordeaux	10	Yes	Yes		Yes			No	Yes
Germany	Danube/Isar	SWM GmbH	Munich	11	Yes	Yes	No	Yes	No	No	No	No
Italy	Reggio Emilia	Iren Emilia	Reggio Emilia	12	Yes	Yes				No		
Malta	Malta	Malta WSC	Malta WSC	13	No	Yes	No	Yes	No	Yes	No	No
Portugal	Targus	EPAL S.A.	Lisbon	14	Yes	Yes	Yes	Yes	Yes	No	No	Yes
Scotland	Scotland	Scottish Water	Scottish Water	15	Yes	Yes	Yes	Yes	Yes	No	No	No

Summary table Case Studies: Utility or system(s) context

Case Study		System size and density of connections			Underground service length, main to meter	Average Pressure	Annual Frequency of Repairs		Average Speed of repairs		Pressure management?	DMAs and Active Leakage Control?
		Service Conns	Mains length	Service conns			Mains	Services	Mains	Services	Basic, Intermediate or Advanced	
Country	Case Study title	nr.	km	per km	metres/conn	metres	/100 km	/k conns	days	days		
Austria	Small Systems (median)	1 396	50	27	12	50	7,5	3,8			Mostly basic	Mostly ALC
Austria	Salzburg	20 130	539	37	16	46	16,5	3,7	1,5	2,5	Basic	Yes
Belgium	De Watergroep	1 108 042	30 834	36	9	38	15,0	2,0	0,5	1,0	Basic, Int.	Yes
Bulgaria	Dryanovo City	1 470	38,2	39	5	41,5	60	21	1	7	Basic, Int.	Yes
	Razgrad Pilots	716	13,0	55	9	45			1	7	Basic, Int.	Yes
Croatia	Pula	25 657	928	28	10	40	26	5	1	2	Basic, Int, Adv	Yes
Cyprus	Lemesos	53 040	1 020	52	8	40	21	22	1	1	Int, Advanced	Yes
Denmark	Odense	33 230	994	33	15	30	1,8	1,2	4 hrs	4 hrs	Int, Advanced	Yes
England	Anglian Water	1 842 088	38 076	48	approx. 7 *	44	12,9		2,3	5,7	Advanced	Yes
France	Bordeaux	201 001	3 093	65	5	37	12	14	3	1,7	All types	Yes
Germany	Munich	130 000	3 380	39	15	60	7,0	2,5	1 to 30	1 to 30	Basic	Yes
Italy	Reggio Emilia	94 410	4 941	19	25	43,7	16	20	2	2	Int, Advanced	Yes
Malta	Malta WSC	140 00	2 300	61	7	35	24	53	0,5	2,5	Int, Advanced	Yes
Portugal	Lisbon	87 815	1 448	61	approx. 8 *	51,2	38,2	8,4	1,0	1,0	Basic	Yes
Scotland	Scottish Water	2 305 449	52 354	44	approx. 7 *	44,8	24,5	3,2	1,8	3,7	Advanced	Yes

Note: * UK and Portuguese service lengths are estimated

Summary table Case Studies: Assessment of annual leakage volume

Case Study		Requires bulk Metering of			District Metering	Customer metering		UAC, Apparent Loss Estimates			Leakage derived from	
		Own sources	Bulk Imports	Bulk Exports		Non-Residential	Residential	UAC	Theft	Meter	Water Balance	Night Flows
Country	Case Study title							% of metered consumption				
Austria	Small Systems	Yes	Some	Some	Yes	100%	100%	0% to 20%	0% to 1%	0.5% to 2%	Yes	For ALC
Austria	Salzburg	Yes	Yes	Yes	Yes	100%	100%	0,43%	0,00%	0,50%	Yes	For ALC
Belgium	De Watergroep	Yes	Yes	Yes	Yes	100%	100%	1,25%	0,25%	3,00%	Yes	For ALC
Bulgaria	Dryanovo City	Yes	Yes	No	Yes	100%	100%	10% of System Input Volume			Yes	Yes
	Razgrad Pilots	Yes	Yes	No	Yes	100%	100%	10% of System Input Volume			Yes	Yes
Croatia	Pula	Yes	Yes	Yes	Yes	100%	100%	0,25%	1%	2%	Yes	For ALC
Cyprus	Lemesos	No	Yes	No	Yes	100%	100%	1,00%	0,20%	4,50%	Yes	For ALC
Denmark	Odense	Yes	No	No	Yes	100%	100%	0,50%	0,20%	0,00%	Yes	For ALC
England	Anglian Water	Yes	Yes	Yes	Yes	100%	75%	5,10%	incl. in UAC	3,50%	Yes	Yes, and ALC
France	Bordeaux	Yes		Yes	Yes	100%	100%	0,5%	0,2%	2,0%	Yes	For ALC
Germany	Munich	Yes	No	No	Yes	100%	100%	0,5%	0,2%	2,0%	Yes	For ALC
Italy	Reggio Emilia	Yes	No	No	Yes	100%	100%	0,47%	0,68%	6,95%	Yes	Yes, and ALC
Malta	Malta WSC	Yes	Yes	Yes	Yes	100%	100%	0,2%	1,0%	51.5%*	No	Yes, and ALC
Portugal	Lisbon	Yes	Yes	Yes	Yes	100%	100%	0,50%	0,20%	4,05%	Yes	Yes, and ALC
Scotland	Scottish Water	Yes	N/A **	N/A **	Yes	100%	0%	13,40%	0,00%	4,50%	Yes	Yes, and ALC

Notes:

* Malta — Estimate of meter under-registration also contains billing errors, billng system being replaced by smart meters
** Scotland — Scottish Water has no imports or exports

Summary table Case Studies: Energy, economic and regulatory context

Case Study		Annual Energy used for		Unit value of leakage		Assessed Unit Valuations of leakage takes account of						
		Production, Treatment	Distribution, Pumping	Average	Highest	Water resource unit cost	Bulk Import unit cost	Production, treatment unit cost	Distribution, pumping unit cost	Taxes	Specific Regulator (Utility subject to regulation?)	Public Affordability Net Monthly Median Wage k€
Country	Case Study title	Million kWh	Million kWh	Euro/m³	Euro/m³							
Austria	Small Systems											1,82
Austria	Salzburg	3,34		< 0,1 to 0,35		Yes	Yes	Yes	Yes	No	Water Laws	1,82
Belgium	De Watergroep	80,0				Yes	Yes	Yes	Yes		Yes	1,81
Bulgaria	Dryanovo City			0,47		0,01	Yes		Yes		Yes	0,24
	Razgrad Pilots										Yes	0,24
Croatia	Pula	6,67		0,90*	1,05*	0,4	0,3	0,5		0,4*	Yes	0,73
Cyprus	Lemesos	2,5		0,65	0,69	Yes			Yes			1,41
Denmark	Odense	2,90		0,27	1,09**	Yes	No	Yes	Yes	Yes	Yes	2,22
England	Anglian Water			0,81****		Yes	Yes	Yes	Yes	N/A ***	Yes	2,08
France	Bordeaux			0,472		0,38		0,05	0,04			1,72
Germany	Munich										Water Laws	1,77
Italy	Reggio Emilia	22		0,08	0,17	No	No	Yes	Yes		Yes	1,34
Malta	Malta WSC	95		1,59	2,01	Yes	N/A	Yes	Yes	Yes	Yes	0,95
Portugal	Lisbon	115,8 (total)		0,05	0,10	Yes	N/A	Yes	Yes	Yes	Yes	0,69
Scotland	Scottish Water			0,59****		Yes	N/A	Yes	Yes	N/A ***	Yes	2,08

Notes:

* Croatia	Pula	Value of leakage estimated for 2015 with new added Tax (varies with ILI ranges, likely to be 0.4 Euro/m3 for Pula ILI)
** Denmark	Odense	Value of leakage rises to 1,09 Euro/m3 if Water Loss exceeds 10%
*** UK		Taxes are not volume related for Scottish Water and Anglian Water
**** UK		Using 1,25 Euro per pound sterling

Summary table Case Studies: Assessment of annual leakage performance

Case Study		KPIs for targets and tracking progress				KPIs for internal/external leakage comparisons					Assessed value of leakage	
									Repair frequency		Average	Highest
Country	Case Study	Leakage Mm^3/year	litres/conn /day	m^3/km mains/day	litres/ billed property/ day*****	UARL Mm^3/year	ILI	Average pressure metres	Mains per 100 km/year	Services per 1000 conns/yr	Euro/m^3	Euro/m^3
Austria	Small Systems median		85	2,4			1,0	50	7,5	3,8		
Austria	Salzburg	0,62	84	3,1	84	0,54	1,1	46	16,5	3,7	< 0,1 to 0,35	
Belgium	De Watergroep	28,09	70	2,5	61	21,94	1,3	38	15	2		
Bulgaria	Dryanovo City	0,183	340	13,1	137	0,032	5,8	42	60	21	0,48	
	Razgrad Pilots	4,73	2.470	112		0,11	41	45			0,25	
Croatia	Pula	1,71	183	5	100	0,6	2,9	40	26	5	0,90**	1,05**
Cyprus	Lemesos	2,46	127	6,6	77	0,97	2,5	40	21	22	0,69	
Denmark	Odense	0,41	34	1,1	23	0,41	0,7	30	1,8	1,2	0,27	1,09***
England	Anglian Water	70,34	105	5,1	95	N/A	approx. 1,5 *	44	12,9		0,81****	
France	Bordeaux	7,55	103	6,7	83	3	2,5	35	12	14	0,47	
Germany	Munich	11,50	243	9,4	242	4,4	2,6	60	7	2,5		
Italy	Reggio Emilia	8,47	246	4,7	92	3,43	2,5	43,7	16	20	0,08	0,17
Malta	Malta WSC	3,96	78	4,7	43	1,9	2,1	35	24	53	1,59	2,01
Portugal	Lisbon	5,71	178	10,8	45	1,97		51,2	38,2	8,4	0,05	0,1
Scotland	Scottish Water	209,88	249	11,0	227	N/A	approx. 4 *	44,8	24,5	3,18	0,59****	

Notes:

* UK		ILIs have been estimated from MLE reported leakage values and other available data
** Croatia	Pula	Value of leakage estimated for 2015 with new added Tax (varies with ILI ranges, likely to be 0.4 Euro/m3 for Pula ILI)
*** Denmark	Odense	Value of leakage rises to 1,09 Euro/m3 if Water Loss exceeds 10%
**** UK		Using 1,25 Euro per pound sterling
*****		The number of billed properties is always likely to exceed the number of services connections, so leakage in litres/connection/day will frequently be significantly lower than litres/billed property/day.

1 Austrian Case Study: Small Utilities

Contribution of Joerg Koelbl, Blue Networks e.U. & Allan Lambert (August 19, 2014).

The EC Report 'Resource and Economic Efficiency of Water Distribution Networks in the EU' (October 2013) concluded that high leakage of around 50% would not be exceptional in small or medium size urban communities located in the mid or upper regions of catchments with readily available access to good quality mountain water resources gravitating to them from above where they incur minimum treatment and distribution costs. Alpine regions of Italy, Austria, Slovenia, Croatia, Romania, the Pyrenees and highlands of Scotland were mentioned as typical examples.

The actual situation identified during consulting and research activities in Austria was quite different from the EC Report (2013) conclusion. In adoption of the ILI and litres/connection/day as the most appropriate leakage KPIs in Austria (OVGW W 63 guideline, 2009), most Austrian utilities achieve very low levels of leakage (ILI close to or slightly less than 1,0), while individual very small Austrian utilities can achieve even lower leakage levels. This Case Study presents water loss assessment results for small Austrian urban and rural systems and briefly examines reasons as to why low leakage levels can occur in these communities.

1.1 Structure of Austrian Water Utilities

Statistics Austria (2014) categorizes Austria's urban regions as follows:

- 6 urban regions with more than 100.000 inhabitants in the core zone.
- 9 medium-sized urban regions with 40.000 to 100.000 core zone inhabitants, and
- 18 small urban regions with fewer than 40.000 inhabitants in the core zone.

Out of the 2.354 Austrian municipalities 2.128 have less than 5.000 inhabitants. Because of this structure Austria has about 5.500 water utilities (OVGW 2014):

- About 1.900 municipal utilities.
- About 165 water associations.
- About 3.400 water cooperatives.

Approximately more than 5.000 of these utilities have less than 3.000 service connections and can be considered as 'very small utilities'; around 4.500 of these utilities have less than 1.000 service connections. A significant number of utilities serve less than 100 service connections. These small structures are common in most parts of Austria, especially in the Alpine regions and also in other rural regions, which belong mainly to the Danube River Basin (Table 1).

Country	Basin / Sub-basin	Water service provider	Other key stakeholders
Austria	Danube River Basin (96%), Rhine, Elbe	Various	Various

Table 1 – Geographical context of described small Austrian utilities

1.2 Water Loss Situation of small Austrian Utilities

While a significant number of small utilities achieve low losses, there have of course also been single situations where losses have been high and no proper water loss management was implemented. Figure 2 shows ILI data from three different years (all less than 10.000 service connections). According to the Austrian banding system most of the utilities achieve low (ILI < 2) and medium (2 < ILI < 4) losses and a significant number of very small utilities achieves ILIs below 1. The reasons for these low ILIs are various and are discussed in the following sections of this Case Study.

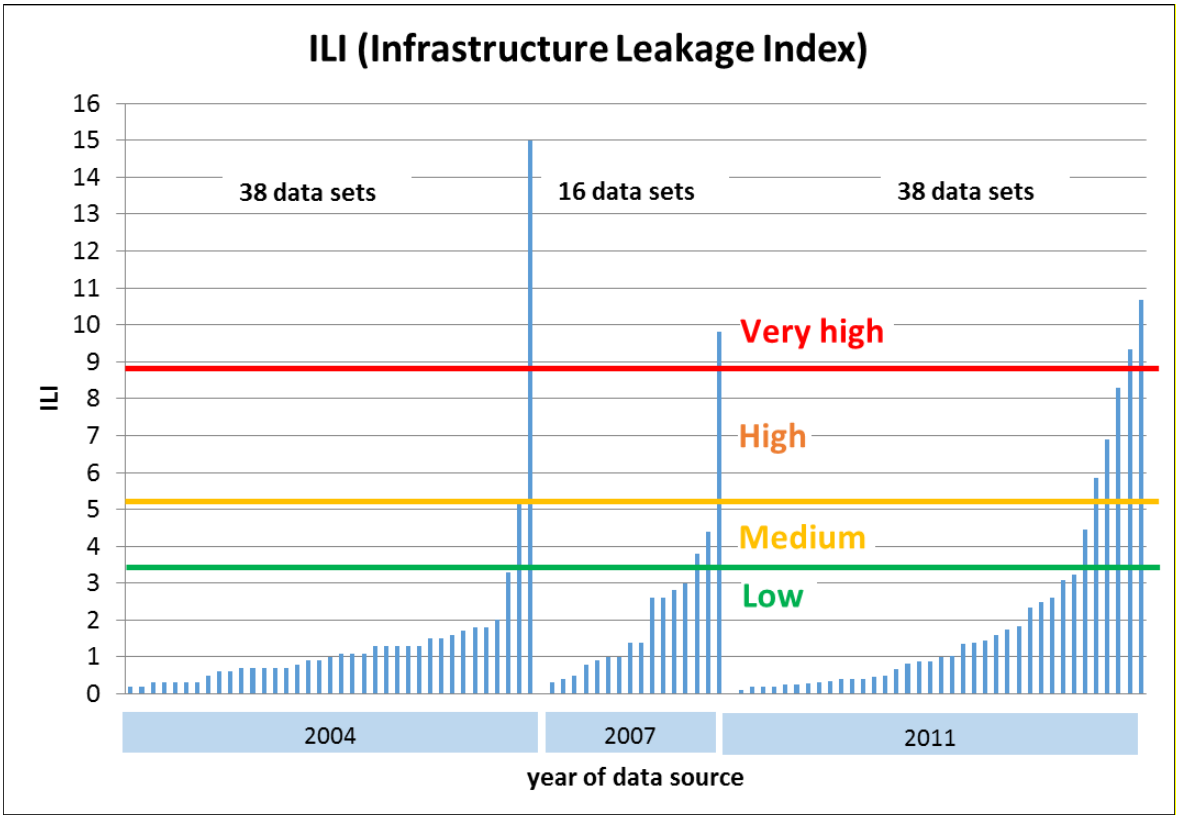

Figure 2 – ILIs from three different years (banding according to OVGW W 63 guideline, 2009; data source: OVGW benchmarking).

Beside water losses, failure rates are also an important indicator for network condition. Combining water loss and failure rates gives an indication about the effectivity of water loss management and supports the decision making regarding required actions such as improvements in active leakage control, pressure management and rehabilitation. For example if failure rates are low but losses are high the water loss management is not effective. In case failure rates and losses are high and active leakage control and maintenance does not lead to a reduction in leakage then in situations where pressure reduction is not an issue, often only rehabilitation could improve the situation (compare Koelbl et al. 2012).

Figure 3 shows mains and services failure rates in relation to the average system pressure. The banding according OVGW guideline W 100 (2007) shows that most of the systems have failure rates in the 'low' and 'medium' range. This situation is typical for systems in good condition. Main reasons for that are use of good quality materials, good system design and good installation quality. Also the average age of many small Austrian systems is relatively low (see Figure 4).

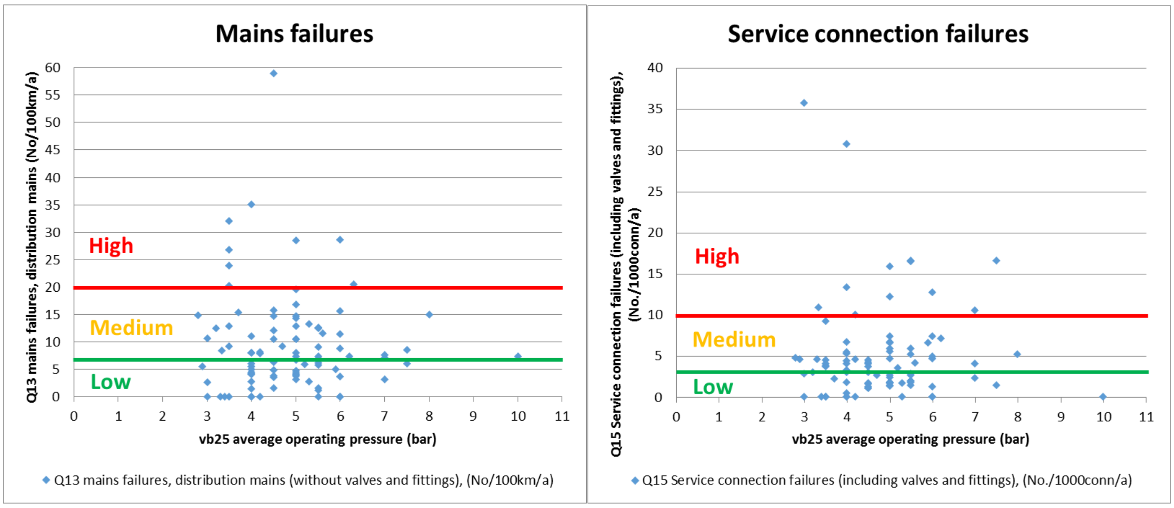

Figure 3 – Failure rates, per km and per connection and pressure (data source: OVGW benchmarking, banding according OVGW W 100 guideline).

Experience shows that scatter graphs plots of this type are not suitable for trying to establish any kind of general relationships between pressure and bursts even for very large areas, as there are many other factors involved. Each zone has its own unique relationship between burst frequency and pressure for mains, and another for services, which vary over time. Therefore options for pressure management need to be investigated for individual systems.

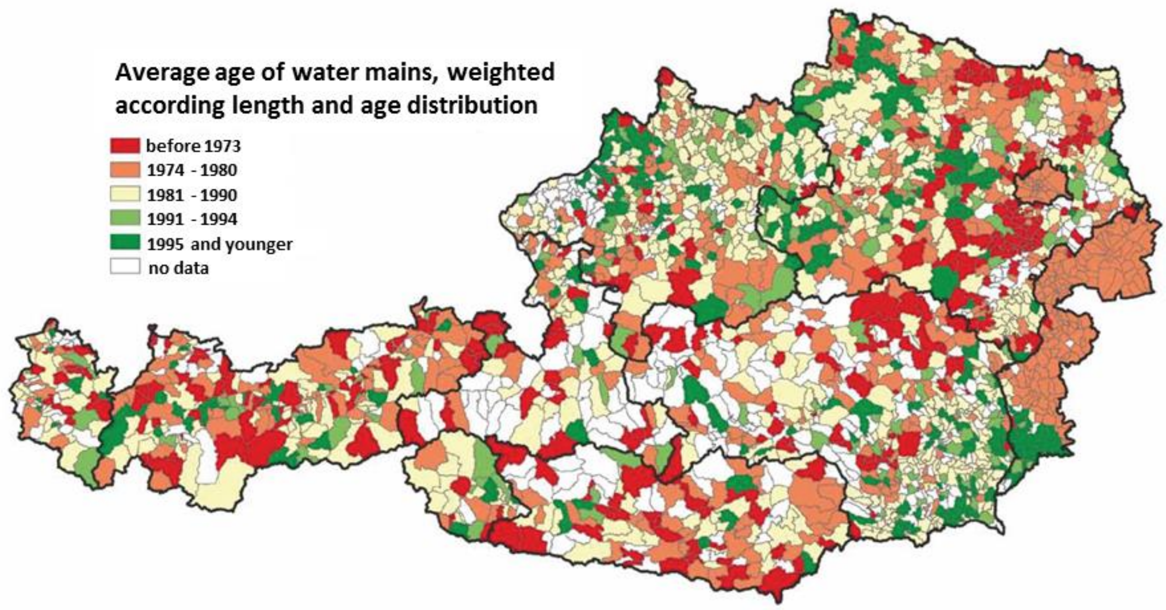

Figure 4 – Average age of water mains, weighted according length and age distribution (source: BMLFUW / Kommunalkredit Public Consulting 2012).

1.3 Overview of leakage reduction measures implemented at small Austrian Water Utilities

Table 2 summarises the measures taken on leakage assessment and reductions in typical small Austrian Utilities. Any system with less than 3.000 service connections was considered to be a very small system, where network monitoring is easy when reliable system input metering is installed.

Implemented measure on leakage assessment and reduction	Yes	No
Reliable Bulk Supply Metering	mostly	not in very small systems
Reliable District Metering	mostly	not in very small systems
Reliable Customer Metering	mostly	not in very small systems
Good System Design and Installation	√	
Effective Management of Excess Pressure and Pressure Transients	√	
Speed and quality of repairs	√	
Active Leakage Control at an economic frequency	mostly	not in very small systems
Sectorisation and/or District Metering Area formation	√	
Asset Renewal: service connections	√	
Asset Renewal: mains	√	
Leakage Indicators used	**Typical ranges of values**	
% of system input volume (not recommended according OVGW W 63 guideline, but still common)	5 to >30%	
l/conn/day	50 to 300	
m³/km/h (specific loss)	<0,05 to 0,40	
ILI (only advanced utilities, not standard yet)	<1 to 4	

Table 2 – Typical leakage reduction measure(s) at small Austrian Water Utilities.

1.4 Explanations for low leakage levels in Small and Medium sized Austrian Utilities

The following list outlines reasons why very low leakage levels (ILI significantly less than 1,0) may be calculated in some small supply systems:

- *Low System pressure, influence on pressure-sensitive background leakage*: this is unlikely to be the reason in Austria as few utilities operate at less than 40 metres average pressure. Also Austrian systems are designed to avoid excessive pressure and pressure transients.
- *Possible under-recording of bulk/district meters* at low flows in small direct pressure systems due to large maximum to minimum flow range.
- *Confidence limits for Real Losses calculation*: in many water balances of small Austrian systems the Unmetered Unbilled Authorised Consumption component for public fountains, municipal irrigation water etc. can be significant. By limiting the analysis to small systems with metered UAC, and assuming that potable water supplied volume is ±2%, meter lag errors are small and billed metered consumption is within ±1%, and the other components of NRW are very small, for a typical system with 1.000 service connections and an ILI of 1,0 the confidence limits for the calculated Real Losses of 7% of Water Supplied (a typical Austrian small systems figure) are around ±20%. Assuming the UARL calculation is within ±10%, the ILI is within ±22%. This does not explain ILIs less than 0,78 for systems with 1.000 service connections.
- *Statistical variation* of relatively rare events in small samples, based on binomial or similar statistical analysis, influences analysis of night flows in small systems.
- *Influence of system size related to benefits of DMAs*: the UARL formula has a lower limit for system size of around 3.000 service connections (Lambert, 2009), to allow for the large statistical variation, year on year, of relatively few burst events with differing flow rates in small systems.
- *Rapid Identification of an Unreported Burst or Leak*: in a single stand-alone DMA, there are no problems with leaking boundary valves, so it is usually possible to see quite easily from night flow measurements in a direct pressure system when:
    - An unreported mains burst has occurred in a Zone with less than around 3000 services.

  - An unreported service pipe leak (≥ 0,5 m^3/hour) has occurred in a Zone with less than around 1.000 services.
  - There is temporarily zero night consumption in a residential Zone with less than around 1.000 people, so the whole night flow consists of leakage.
- *System age*: Many small Austrian systems are less than 30 years old and the conditions of infrastructure in younger systems are good (see Figure 4).
- *Influence of installation quality*: In general OVGW certified and quality proofed material is used and construction and installation quality is high due to available standards and guidelines, and proper supervision of the construction phase.
- *Economic driver in bulk supply systems*: When more expensive water is purchased from bulk supply systems, the economic frequency of Active Leakage Control interventions is likely to be higher, speed of repair quicker, and economic leakage levels lower.

1.5 General explanations for low ILIs in Small Systems and Zones

The UARL parameters in the ILI formula were developed for historically grown, large, well-managed urban systems, and it is known and recognised that some systems can achieve calculated ILIs below 1,0 due to combinations of the reasons described in this paper.

The original international lower limit for calculating UARL in 2001 was 5.000 service connections - this was to avoid statistical 'noise' due to changes in low numbers of bursts from year to year. As UARL was proving popular to use in DMAs, the lower limit was reduced in 2005 to 3.000 service connections, recognising that in zones with good infrastructure it's possible to get ILIs slightly less than 1,0. Following further pressure to reduce lower limits, the zone size was reduced in 2009 to NC +20xLm > 3.000, to cover zones with low connection densities.

Before seeing the Austrian benchmarking data the following was predicted:

a) That if less than 3.000 SCs, unreported mains bursts could be easily 'seen' in a DMA night flow and targeted.
b) That if less than 1.000 SCs, unreported service pipe bursts could also be easily seen and targeted.
c) That if less than 1.000 people (500 SCs?) in a Zone, leakage could be directly measured over short periods between consumption events.

Figure 5 shows Austrian ILI data > 2 from the years 2007 and 2011. It can be seen, that in the range of very small utilities (less than 3.000 service connections) ILIs less than 1 are common. The dark blue line in the diagram represents an approximate lower boundary of expected ILI values according to this data and the assumptions described above.

The drop of ILIs in the low service connection range can be seen as evidence for supporting the existing lower limits for system size when calculating Unavoidable Annual Real Losses (UARL) and ILI in Zones with low leakage.

As the ILI is widely used internationally now, and many Utilities wish to use it for small systems and average pressures as low as 25 metres, the authors are currently developing an approach which will enable the 1999 standard UARL formula to be approximately adjusted for average pressure (and pipe materials), and also for small systems (Lambert, Koelbl & Fuchs-Hanusch, 2014, in draft). However, it must always be remembered that the confidence limits for such very low leakage, calculated from Water Balance, can easily reach ±50%, so an adjustment of the International Performance Category banding system for very low ILIs in lower pressure systems and small systems may be the most practical approach.

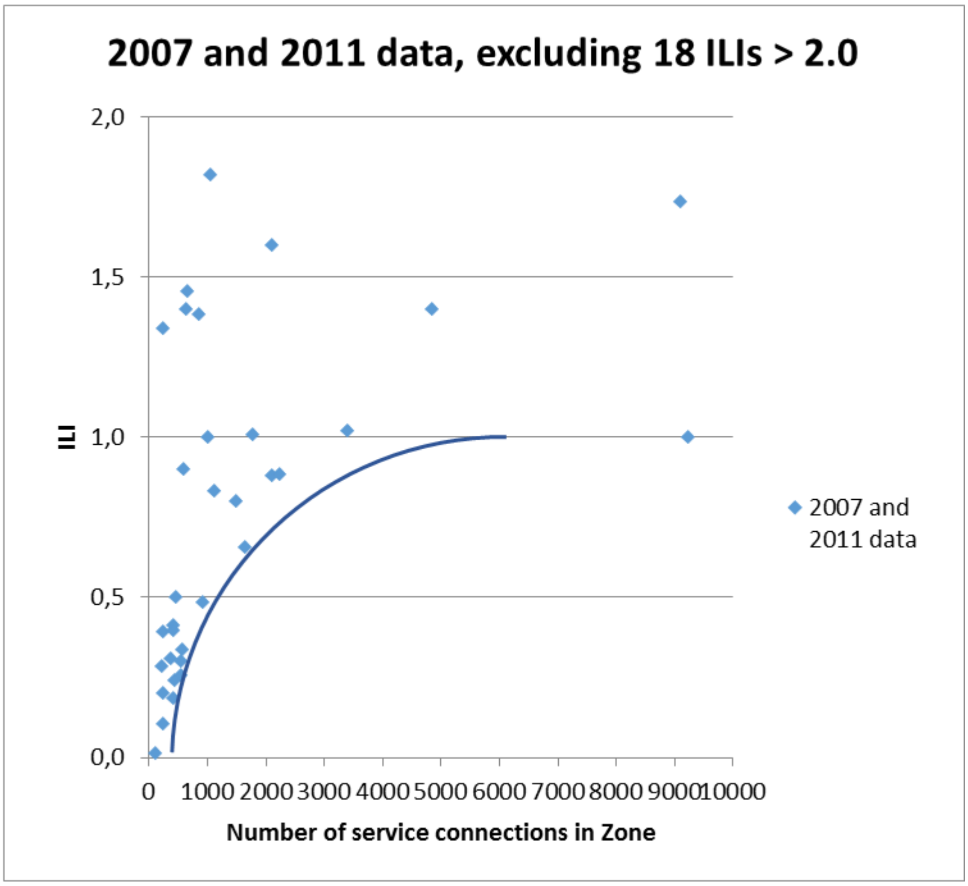

Figure 5 – Selected small system ILIs (data source: OVGW benchmarking).

1.6 Acknowledgements

The authors wish to express their sincere thanks to the Austrian Association of Gas and Water (OVGW) for providing access to selected Austrian benchmarking data. Special thanks go to Daniela Fuchs-Hanusch (Graz University of Technology) for extracting and preparing the raw data from different benchmarking years.

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2 Austrian Case Study: Salzburg

Contribution of Joerg Koelbl, Blue Networks e.U. (August 26, 2014).

This case study deals with the successful long-term management of the historical grown water supply network of the city of Salzburg in Austria (compare Koelbl 2011). Parts of the network are more than 100 years old, but water losses and failure rates are low compared to international values. The good condition of the pipe network and the high service quality provided to the clients are a result of a consequent asset management strategy using innovative network monitoring and asset management tools.

2.1 Details Salzburg AG and water supply system of Salzburg

Salzburg's water supply system has a long tradition, dating from roman times to renewal and enlargement of the network in the decades after World War II. Today Salzburg AG, a multi-utility infrastructure provider in the city and province of Salzburg (water, power, district heating, natural gas, tele-communication and public transport services), uses two main groundwater resources and bulk imports from a trans-regional bulk supply system as emergency resource. Two large water reservoirs serve four main zones of the city (3.900 to 5.900 service connections) by gravity, and seven small higher zones via pumping stations. The 484,1 km of mains, average age 40 years, are mainly cast iron and ductile iron and partly fibre cement, steel, concrete and plastic. 23% of the 332,6 km of service connections are zinc-coated steel pipes which have been installed up to the 1960s, and 70% are PE, which has replaced all lead and copper service connections and is used for all new service connections. The average supply pressure is around 4,6 bar (maximum 6,5 bar) and 98% of the population is connected to the public water supply system. Table 41 and Figure 6 provide some more details of the water production system and distribution network of Salzburg.

Country	Basin / Sub-basin	Water service provider	Other key stakeholders
Austria	Danube River Basin	Salzburg AG	Municipality of Salzburg, Regional Government of Salzburg, Energie AG

Table 3 – Geographical context of Salzburg AG

Characteristic	Value year 2013
Population	155.382
Number of billed properties (residential and non-residential)	20.130
Number of service connections (main to first meter)	20.130
Average length of underground service connections	16,4 m
Length of trunk mains	54,71 km
Length of distribution mains	484,1 km
Average operating pressure	46 m
% of time system is pressurised	100% of year
% of total mains length subject to active pressure management	0%
Annual volume of potable water supplied (excluding exports)	11.451.527 m^3/year
Average time from location of mains leaks to shutoff or repair	1,5 days
Average time from location of service leaks to shutoff or repair	2,5 days
Leaks on mains (number per 100 km/year)	16,5 No/100km/year
Leaks on service connections (number per 1000 connections/year)	3,73 No/1000/year
% of system having active leakage control interventions each year	100 %
Number of water treatment plants	5
Number of pumping stations	6
Number of distribution reservoirs	9

Characteristic	Value year 2013
Total number of staff	2.001
Staff directly involved in water operations	49
Average consumer price (excluding 10% VAT)	€ 1,468/m^3
Average unit costs of water resource	<0,10 - 0,25 €/m^3
Average unit costs of production and distribution	<0,10 €/m^3
Highest unit cost of production and distribution	<0,10 €/m^3
Energy usage	3.343 million kWh/year

Table 4 – Details water production system and distribution network of Salzburg AG.

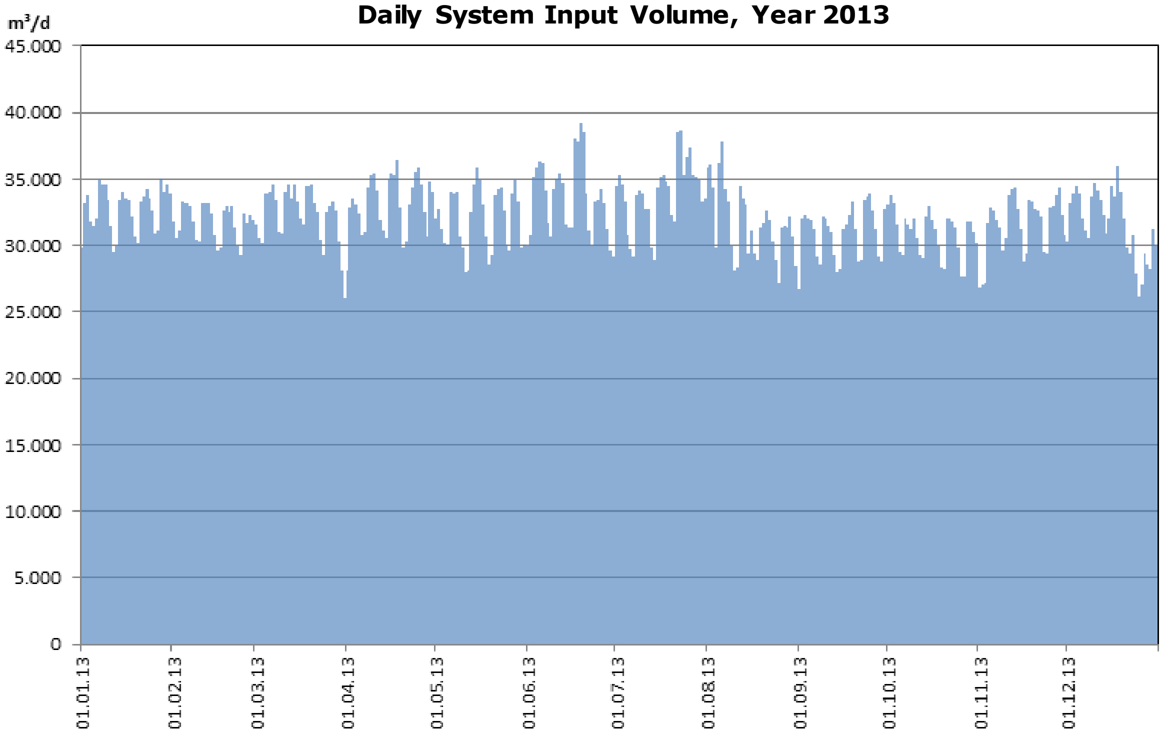

Figure 6 – System input volume of Salzburg AG in m³/d.

A Water Balance in simplified IWA Water Balance format is enclosed in Section 2.9 at the end of this Case Study.

2.2 Details context Salzburg AG

Table 42 provides an overview about the context of Salzburg AG's water supply situation.

Relevant factor	Yes	No
Abundant water resources at a basin level?	√	
Limited measures required to improve water status to achieve WFD objectives?		
River Basin Management Plan (RBMP) completed?		
Active quantity management incorporated in the RBMP?		
RBMP harmonised with other key socio-economic and land use planning documents prior to adaptation and incl. financing plans?		
Abundant water resources for water service provider all year every year?	√	
Water resources of good chemical quality (low or no treatment)?	√	
Water resources located at topographical levels above the level of the customer base (low or no energy costs)?		√
Are the economics of density reasonable (> 20 connections per km)?	√	
Cost effective investment and operating conditions?	√	

Relevant factor	Yes	No
Distribution network designed for ease of operation and maintenance without maximum pressure stresses?	√	
Pressure Management implemented throughout the system?	basic	
District Metering implemented throughout the system?	partially	
Good quality of the network installation (materials selection and workmanship at the time of installation)?	√	
Water pricing limitations?	√	
Conflicting socio-economic needs and/or historical legacy?		√
Public affordability constrains?		√
Ability- / willingness-to-pay constraints?		√
Benefitting from EU Funds to finance significant water supply (and urban wastewater) treatment investments?		√
Specific Regulator (Utility subject to regulation)?		√

Table 5 – Specific context within Salzburg AG is operating.

- Austrian National (ON), European (EN) and international (ISO) standards as well as a set of guidelines provided by the Austrian Association for Gas and Water (OVGW) guarantee good quality of network installation, operation and maintenance.
- Salzburg's water supply system is well designed in terms that there are no excessive network pressures and no pressure stress and use of good quality material for construction and repair work.
- The average operating pressure is about 4,6 bar. Basic pressure management is implemented by network zoning, which avoids unnecessary high pressures and water surges. As the main reservoirs are situated slightly too high, the system input pressure from the reservoirs to the supply zones is controlled by reducing pressure by 0,5 bar during night hours.
- Salzburg AG uses two main groundwater resources, which are protected by adequate ground water protection areas and provide water in excellent quality, which does not need to be treated. In addition eight (8) springs provide water which requires disinfection only (UV and/or flocculation filtration). As emergency resource imports from a trans-regional bulk supply system are available.

2.3 Overview leakage measures and indicators implemented at Salzburg

Water losses are maintained on a low level. Table 43 gives an overview of the water loss management frame work in Salzburg.

Implemented measure on leakage assessment and reduction	Yes	No
Reliable Bulk Supply Metering	√	
Reliable District Metering, where implemented	√	
Reliable Customer Metering	√	
Good System Design and Installation	√	
Effective Management of Excess Pressure and Pressure Transients	√	
Speed and quality of repairs	√	
Active Leakage Control at an economic frequency	√	
Sectorisation and/or District Metering Area formation	partially	
Asset Renewal: service connections	√	
Asset Renewal: mains	√	
Annual Volume of Real Losses (Level of Leakage, CARL)		**Value**
CARL (2013 data)		605,311 m^3/year
Leakage Indicators used at Salzburg AG		**Value**
Infrastructure Leakage Index (ILI)		1,14
Losses per connection per day		84 l/conn/d
Losses per mains length		0,13 m^3/km/h
Non-Revenue Water as % of system input volume		6,3 %

Table 6 – Implemented leakage measures and indicators in Salzburg.

Key issues of information shown in Table 6 are:

- Regarding district metering, all system input volumes and all zones are metered. The four large zones are too large to be considered as DMAs, therefore only large bursts can be identified through system input metering; but the small zones are fully functional DMAs.
- Combining annual maintenance of distribution system fittings with an additional check for small detectable leaks are carried out for about 20 % of the network per year (see Chapter 'Details proven leakage reduction measures').
- Maintaining the water supply assets in good condition is a requirement by the Austrian Water Law. Salzburg AG has implemented a sustainable asset management strategy and uses innovative rehabilitation software to ensure an efficient asset renewal.

2.4 Details strategy, monitoring methods and leakage indicators

Before explaining strategies for water loss management the network conditions are explained briefly. Two criteria are mainly characterising the condition of a pipe network: physical water losses and failure rates. The failure dynamics of a network is influenced by several parameters such as (OVGW W 63, 2009): structure of the network (e.g. rural or urban), type of soil and soil movements, traffic load, excavations near pipes, pressure variations, water surges, operating pressure and service connection density.

Also the qualities of the used pipe materials, fittings and the construction procedures are affecting the lifetime and failure dynamics essentially. Therefore, Salzburg AG uses only high quality material with OVGW (Austrian Association for Gas and Water) approval. This might lead to slightly higher investment costs but pays back multiple in long-term because of lower failure rates and therefore lower operation and maintenance costs due to less repair demand and lower water losses.

The condition of Salzburg's pipe network in general is very good considering the heterogenic material and age structure, which is normal for historically grown networks. Actual failure rates of mains are around 16,5 failures per 100 km mains per year, which is close to other Austrian urban systems and low in international comparison. The most critical pipe group is mains of cast iron with a failure rate (average between 2010 and 2013) of 30,7 per 100 km per year. Recently installed pipe materials like ductile iron new, PE and steel new, representing a third of mains with an average age of 14 years, have no or very few failures. Most likely basic causes for the failures are fatigue, ground motion, traffic load and frost damages.

Water loss performance indicators are evaluated regularly and according to OVGW W 63 (2009), the Austrian water loss guideline. Water losses for the total network are classified as low with an ILI of about 1,14 (Table 6). Real losses per connection are about 84 l/conn/day. On the one hand this is due to 100% customer metering and good payment moral of clients and on the other hand the physical losses are low. The multi-utility approach with one bill for several services of Salzburg AG is an advantage for the payment moral and increases the customer satisfaction with the provided infrastructure services. The low physical losses indicate a well maintained network and are a consequence of the water loss management and rehabilitation strategy.

Salzburg AG's water loss management strategy is similar to many other water utilities in Austria. It is in accordance with OVGW guideline W 63 (2009) and is in principal also based on the IWA water loss management strategy, including active leakage control, the repair process, pressure management and infrastructure management.

2.5 Details proven leakage reduction measure(s)

Regarding active leakage control Salzburg AG uses a mixed methodology of network monitoring and routine inspection campaigns. The network is divided into four main zones (each of them about 120 km of mains) and seven small zones. Each of these zones is permanently metered and the flow data are transferred to a central control room. On daily basis the night minimum input of each zone is evaluated. In addition to the zone measurements, Salzburg AG has implemented permanent noise logging technology stepwise as most of the network consists of metallic pipes. While at the beginning only the main traffic routes were equipped with permanent noise loggers, since 2013 the whole network is covered by 300 permanent noise loggers. The noise loggers are read by the cars of the maintenance teams according to their daily routes and on demand. At least every logger is read once a month. In case there is an increasing trend in night minimum input, leak detection campaigns are initiated. For the purpose of step testing the four main zones can be easily divided into 15 small temporary zones. For leak detection and pinpointing all common leak detection technologies are available. In case one or more of the noise loggers give an indication for leakage, the leak detection is focused on a small area and location time is kept short.

In addition to the on-demand leak detection, also routine leak detection campaigns are carried out every year to detect small leakages which are not detectable by the network monitoring system. During these campaigns all fittings are investigated by listening sticks. According to the Austrian standard ON B 2539 every year about 20% of the network is investigated.

Out of a total number of 80 main failures 16 have been identified by noise loggers only (20%). 8 out of 75 service connection failures were identified by noise loggers only (11%). Reported failures are not included in these figures. In addition 26 not fully closed (leaking) hydrants have been detected. In total about 50 leaks have been identified by noise loggers in the first year the system has been in place. These leaks would not have been detected as single leaks by flow monitoring and would most probably have been leaking until the next routine leak detection campaign (every 5 years).

Speed and quality of repair is a must to keep water losses low. With the multi-utility structure, which means there is one maintenance team for water, natural gas and district heating networks, run times of leaks are kept short. For repairs only high quality material is used and relevant repair standards are followed.

Infrastructure management

Infrastructure management includes a very broad field of tasks and is therefore described in more detail. In general, infrastructure management activities are long-term measures. One aspect is the general configuration of the supply system and the technical equipment in use. The central tasks of infrastructure management are the duties of maintaining all kind of assets: wells, springs and water treatment facilities, storage tanks, pumping stations and also the supply network, including all kinds of valves and joints, hydrants and flow meters.

One of the core questions in infrastructure management is: Which pipes should be replaced and which pipes should be repaired? The questions for the optimal replacement time of a pipe is not easy to answer and requires intensive analyses of failure behaviour, expected lifetimes of pipes as well as cost analyses, besides replacement activities triggered by overall reconstructions of streets and/or other media. During the last years Salzburg AG participated in a research project, where a Pipe Rehabilitation Management Software (PiReM) has been developed.

This decision support tool allows long-term and mid-term planning of rehabilitation measures based on individual calibrated aging behaviour of pipe groups. Several relevant costs like repair and rehabilitation costs but also socio-economic costs of construction sites can be considered. However, the basis for a software based rehabilitation planning is a detailed asset and failure documentation. All assets of Salzburg AG are recorded in a GIS system (Geographic Information System). The GIS system also includes detailed failure documentation according to the Austrian guideline OVGW W 100 (2007).

On basis of failure data the aging behaviour of different pipe groups can be analysed and critical pipe groups can be identified. Combined with cost data for repair and replacement, economic models for short and long term periods allow finding the optimal rehabilitation time for each pipe section.

A long-term rehabilitation plan defines the rehabilitation needs for a 10 to 20 years scope. In combination with economical and technical criteria priority plans for pipe rehabilitation with 3 to 5 years scope can be deduced from the long-term plan. The fine tuning of definite annual rehabilitation measures is done by coordination of street reconstruction and measures of other pipe infrastructures. This leads to cost optimization of rehabilitation budgets and decreases the repair costs if the most critical pipe groups are removed systematically. However, there is enough flexibility to shift rehabilitation measures within a timeframe of a few years if this leads to cost benefits.

2.6 Evaluation of further options for pressure management

Pressure management is a very sensitive topic in Austria. Concerning pressure management it has to be mentioned that the pressure management philosophy in central Europe, especially in Austria, Germany and Switzerland, is clearly different from the IWA philosophy. In these countries pressure reduction under a level of 30 m to 40 m service pressure head (3 to 4 bars) is seen as an urgent and temporary measure in a system of poor infrastructure condition and it is seen more as a fight against symptoms rather than against the real cause.

The Austrian OVGW W 63 (2009) guideline describes the following: '…*following the valid Austrian legal and technical standards pressure management is not allowed as a substitute for maintenance of affected network sections*…' and '…*it has to be noted that ON B 2538 (note: defines minimum service pressures for different operating conditions) and OVGW W 77 (note: guideline for firefighting requirements) have to be followed in order to ensure a proper supply of water even during extra ordinary operating conditions*…' and "…*in general facilities have to be designed that enough pressure is provided but no over pressure can be generated*…'.

According to ON B 2538 the minimum operating pressure is 3 bar under normal operation condition and 1,7 bar for firefighting condition (for higher buildings it is more). This means that extensive pressure management as it is practised in other countries is not a big issue in Austria. In general systems are designed for pressure ranges of 4 to 5 bar.

As described above, Salzburg's average operating pressure is about 4,6 bar and basic pressure management is implemented by network zoning and time controlled pressure reducing by 0,5 bar in the core zones during night hours, which is required in order to avoid exceeding 6 bar at pressure relief valves of boilers. At the moment no further options for more advanced pressure management are taken under consideration.

2.7 Results and recommendations

Salzburg AG is an excellent example that it is possible to maintain historically grown networks in good condition, achieving both, low failure rates and low water losses. Following key success factors for a sustainable network management can be summarised:

- High quality materials need to be used and highest construction standards applied to ensure low failure rates and keep operation costs low. A strong commitment to related guidelines and high level standards is essential for quality assurance. Also the requirement of proper supervision of construction works and quality checks, e.g. pressure tests of pipes before starting asset operation need to be addressed.
- An adequate network monitoring system is essential. Without monitoring it is not possible to become aware of failures and take corrective actions in time.
- Regular monitoring and adequate effort in reducing water losses by quick and consequent repair is important for a successful water loss management.
- For proper asset management, it is required to perform regular assessments of the network condition with a detailed documentation of all failures. A comprehensive asset and failure data base is a precondition for reliable analyses of network aging behaviour and rehabilitation planning.
- The aim of long-term cost optimisation and minimised lifecycle costs can only be achieved with long-term service contracts. Short-term O&M contracts are often counterproductive, because the operator’s main concern is maximizing profit then comes the aspect of sustainability. From the viewpoint of Salzburg AG as an owner and operator, the long-term scope in asset management is crucial for cost optimisation.
- To ensure sufficient financial capabilities, long-term cost recovery is required. Therefore, cost recovering tariffs and a minimised ratio of non-revenue water are necessary.
- Another key success factor is the commitment to a continuous improvement process. This requires permanent performance analyses, orientation at national and international benchmarks and the implementation of improvement measures. Salzburg AG has been benchmarked as a best practice utility in the Austrian water supply sector and is regularly participating in national and international benchmarking projects on utility and process level.

In conclusion, it becomes clear that an integrated approach considering all the described factors is necessary to ensure sustainability in a network management. This aspect is the basis to conserve water supply networks for future generations.

The Water Balance for Salzburg follows in Section 2.9 at the end of this Case Study.

2.8 References

Austrian Water Law (WRG 1959 idF BGBl. I Nr. 98/2013). The Austrian Federal Ministry of Agriculture, Forestry, Environment and Water Management (BMLFUW), Vienna, Austria.

Koelbl, J. (2011): *Sustainable network management practices*. Conference Proceedings IWA Efficient 2011, Jordan.

OeNorm B 2538 (2002): *Transport-, Versorgungs- und Anschlussleitungen von Wasserversorgungsanlagen – Ergänzende Bestimmungen zu ÖNORM EN 805* (English: Long-distance district and supply pipelines of water supply systems – Additional specifications concerning ÖNORM EN 805). Austrian Standard, Österreichisches Normungsinstitut, Vienna, Austria.

OeNorm B 2539 – OVGW W 59 (2005): *Technische Überwachung von Trinkwasserversorgungsanlagen*. (English: Austrian standard for technical inspection of water supply systems). Österreichisches Normungsinstitut, Vienna, Austria.

OVGW W 63 (2009): *Water Losses in Water Supply Systems: Assessment, Evaluation and Measures for Water Loss Reduction*. OVGW directive, OVGW, Vienna, Austria.

OVGW W 77 (2013): *Provision of fire water*. OVGW directive, OVGW, Vienna, Austria.

OVGW W 100 (2007): *Water Supply Pipelines – Operation and Service*. OVGW directive, OVGW, Vienna, Austria.

2.9 Water Balance Salzburg AG

SIMPLIFIED IWA WATER BALANCE CALCULATIONS		Salzburg AG, Austria	Whole System	# Conns =	20.130
Period of Water Balance from 01.01.2013	to 31.12.2013	365 days	Mm^3	1000 m^3/day	lit/conn/day
POTABLE WATER VOLUME INPUT FROM UTILITY TREATMENT WORKS			9,798	26,8	1334
Potable Water Imported to this system			3,128	8,6	426
SYSTEM INPUT VOLUME (Potable Water)			12,926	35,4	1759
Potable Water Exported from this system			1,474	4,0	201
Potable WATER SUPPLIED TO THIS SYSTEM			11,452	31,4	1559
Billed Metered Consumption			10,697	29,3	1456
Billed Unmetered Consumption			0,036	0,1	5
NON-REVENUE WATER NRW			0,719	2,0	98
Unbilled Authorised Consumption	0,43%	of Billed Metered Consumption	0,049	0,1	7
WATER LOSSES			0,670	1,8	91
Unauthorised Consumption	0,00%	of Billed Metered Consumption	0,000	0,0	0
Customer Metering Inaccuracies	0,50%	of Billed Metered Consumption	0,053	0,1	7
APPARENT LOSSES			0,053	0,1	7
CURRENT ANNUAL REAL LOSSES CARL			0,616	1,7	84
Information entered by	Joerg Koelbl	08.08.2014	Contact	koelbl@bluenetworks.at	

Enter data for your system in yellow cells. Check the default %s in the purple cells, and change them if you have better information which will improve the reliability of the calculation. Add comments in the Comments Box below.

Comments:

Guideline maximum default %s for assessed components of Non-Revenue Water are shown below:			
If higher figures are claimed they should have been validated by Utility Specific data			
Unbilled Authorised Consumption	0,50%	of Billed Metered Consumption	excluding Water Exported
Unauthorised Consumption	0,20%	of Billed Metered Consumption	
Customer Metering Inaccuracies: Direct pressure systems	2,00%	of Billed Metered Consumption	
Customer Metering Inaccuracies: Roof storage tanks	5,00%	of Billed Metered Consumption	
Customer Metering Inaccuracies are positive for under-recording, negative for over-recording.			

Potable Water Produced from Utility Treatment Works 9,80 Mm3	System Input Volume SIV (Potable Water) 12,93 Mm3	Potable Water Exported WE 1,47 Mm3			
		Potable Water Supplied WS 11,45 Mm3	Billed Authorised Consumption (excluding Water Exported) Metered 10,70 Mm3 Unmetered 0,04 Mm3		
Potable Water Imported to this System 3,13 Mm3			Non -Revenue Water NRW 0,72 Mm3	Unbilled Authorised Consumption UAC 0,05 Mm3	
				Water Losses WL 0,67 Mm3	Apparent Losses AL 0,05 Mm3
					Real Losses RL 0,62 Mm3

Salzburg AG, Austria
Whole System
01.01.2013
to
31.12.2013

Infrastructure Parameter			Performance Indicators for Leakage					
Distribution mains length	484,1	km	1273	m^3/km/year	3,5	m^3/km/day	0,15	m^3/km/hour
Trunk and Distribution mains length	538,8	km	1144	m^3/km/year	3,1	m^3/km/day	0,13	m^3/km/hour
Service Connections (to 1st meter)	20130	Number	30,6	m^3/conn/yr	84	l/conn/day	'per hour' is influenced by Night-Day Factor NDF	
Density of Connections	37,4	No/km	↑ Use PIs above this row to track leakage in individual systems ↑ ↓ Use PIs below this row to compare leakage between systems ↓					
Length of underground Service	16,4	m/conn	Current Annual Real Losses CARL				0,62	Mm^3/year
Connections, Main to first meter	330,1	km	Unavoidable Annual Real Losses UARL				0,54	Mm^3/year
Average Operating Pressure	46,0	metres	Infrastructure Leakage Index ILI =				1,1	
Annual Repair Frequencies: Mains (UARL)	13,0	/100 km	16,5	per 100 km		which is	1,3	x UARL frequency @ 50m
Annual Repair Frequencies: Connections (UARL)	4,7	/k conns	3,7	per 1000 conns		which is	0,8	

Comments: High Income Country, ILI in Leakage Performance Category A1, Total consumption was 1759 lit/conn/day (for (SIV) or 1559 for WS, Real losses were 84 litres per connection per day. Exports from this system, so %s based SIV and WS differed.

↓ PIs based on %s are for comparison only, not recommended ↓	
Leakage as % of System Input Volume SIV	4,8%
Leakage as % of Water Supplied, excluding exports	5,4%

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3 Belgian Case Study: De Watergroep

Contribution of Gisèle Peleman and Maarten Torbeyns (Brussels, 2014).

3.1 Details De Watergroep and Whole system

De Watergroep is a major Belgian Water Company, active in Flanders. Founded in 1913 as 'NMDW', it was renamed in 1987 as 'VMW' and then as 'De Watergroep' in 2013. The source water is 53% groundwater, 22% surface water and 25% bulk imports of potable water, and there are also exports of potable water to adjacent Utilities.

The geographical context of De Watergroep is shown in Table 7, and the system characteristics in Table 8. De Watergroep serves an increasing number of smaller systems on the outskirts of larger cities and in the countryside, and has one of the lowest levels of consumption (around 300 litres/service connection/day) in Western Europe.

The water price does not include the cost for treatment of the waste water.

Country	Basin / Sub-basin	Water service provider	Other key stakeholders
Belgium	Flanders	De Watergroep	

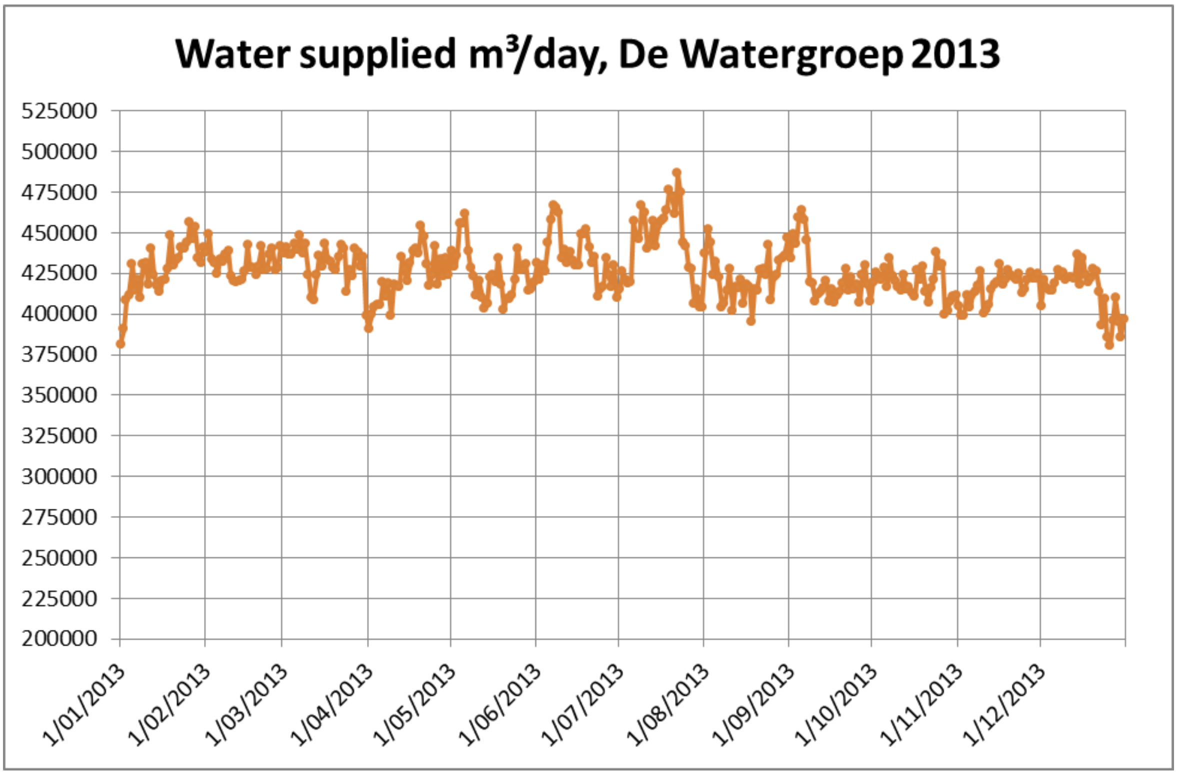
Table 7 – Geographical context of De Watergroep

Characteristic	Value
Population	2,86 million
Number of billed properties (residential and non-residential)	1.224.101
Number of service connections (main to first meter)	1.108.042
Average length of underground service connections	9 m
Length of trunk mains	4.871 km
Length of distribution mains	25.963 km
Average operating pressure	38 m
% of time system is pressurised	100 % of year
% of total mains length subject to active pressure management	100 %
Annual volume of potable water supplied (excluding exports)	155,497 Mm^3/year
Average time from location of mains leaks to shutoff or repair	0,5 days
Average time from location of service leaks to shutoff or repair	1 days
Leaks on mains (number per 100 km/year)	15 No/year
Leaks on service connections (number per 1000 connections/year)	2 No/year
% of system having active leakage control interventions each year	
Number of water treatment plants: Ground water 50, Surface 5	55
Number of pumping stations	185
Number of distribution reservoirs: Water towers 82, reservoirs 74	156
Total number of staff	1.455
Staff directly involved in water operations	900
Average consumer price: Water excluding waste water costs	1,66 €/m^3
Energy usage	80 million kWh/year

Table 8 – Details water supply system and distribution network De Watergroep, 2013

The graph below shows the typical daily variation of potable water supplied in m^3/day for the year 2013. The values in the graph are calculated without the net flow out of the 74 service reservoirs and 82 water towers.

This means that the real daily factors are substantially higher than shown in the graph, because De Watergroep has big storage volumes for peak consumption. The total storage capacity is 395.000 m³. Consumption is highest in summer and varies with temperature.



A Water Balance in simplified IWA Water Balance format can be found at the end of this Case Study.

3.2 Details context De Watergroep

In Flanders, which is densely populated, water availability is rather low. Consequently, ground water and surface water extraction is subject to strict authorizations. Population density and industrialization have an impact on water quality, which necessitates treatment, especially for surface water.

Relevant factor	Yes	No
Abundant water resources at a basin level?		√
Limited measures required to improve water status to achieve WFD objectives?		√
River Basin Management Plan (RBMP) completed?	√	
Active quantity management incorporated in the RBMP?		√
RBMP harmonised with other key socio-economic and land use planning documents prior to adaptation and incl. financing plans?	√	
Abundant water resources for water service provider all year every year?		√
Water resources of good chemical quality (low or no treatment)?	√	√
Water resources located at topographical levels above the level of the customer base (low or no energy costs)?		√
Are the economics of density reasonable (> 20 connections per km)?	√	
Cost effective investment and operating conditions?	√	
Distribution network designed for ease of operation and maintenance without maximum pressure stresses?	√	

Relevant factor	Yes	No
Pressure Management implemented throughout the system?	√	
District Metering implemented throughout the system?	√	
Good quality of the network installation (materials selection and workmanship at the time of installation)?	√	
Water pricing limitations?	√	
Conflicting socio-economic needs and/or historical legacy?		√
Public affordability constraints?		√
Ability- / willingness-to-pay constraints?	√	
Benefitting from EU Funds to finance significant water supply (and urban wastewater) treatment investments?		√
Specific Regulator (Utility subject to regulation)?	√	

Table 9 – Specific context within which De Watergroep is operating.

De Watergroep has very strict technical regulations to ensure the quality of the materials and the installation.
The ground level varies between 1 m and 288 m which causes high pressure in some regions which can't be divided into subzones for technological reasons.

3.3 Overview leakage measures and indicators implemented

De Watergroep uses an IWA Water Balance for assessing Non-revenue water and leakage. The whole system is managed through 4 large sub-systems, with a total of 282 permanently monitored DMAs. Night flows are used to target priorities for active leakage control interventions.

Within such a widely spread transmission and distribution system, imports and exports of water are common. Basic and advanced pressure management is achieved by provision of supply by gravity through 156 water towers and service reservoirs and by pumping with variable speed drive pumps, resulting in an average system pressure of around 38 metres.

The type of pressure management adopted (basic, intermediate or advanced) depends on the specific situation of each area. Typical pressure management activities include:

- Reduce pressure transients using measures to combat water hammer and cavitation; air vessels are dimensioned by hydraulic modelling and calculation of transients with specific software (Wanda).
- Analyse network behaviour using calibrated network analysis models with InfoWorks WS.
- Install pressure reduction valves and/or variable speed drive pumps.

Network management is supported by an accurate GIS system and a permanent SCADA system.

Implemented measure on leakage assessment and reduction	Yes	No
Reliable Bulk Supply Metering	√	
Reliable District Metering	√	
Reliable Customer Metering	√	
Good System Design and Installation	√	
Effective Management of Excess Pressure and Pressure Transients	√	
Speed and quality of repairs	√	
Active Leakage Control at an economic frequency	√	
Sectorisation and/or District Metering Area formation	√	
Asset Renewal: service connections	√	
Asset Renewal: mains	√	
Annual Volume of Real Losses (Level of Leakage, CARL)	**Value**	
2013	28 Mm^3/year	

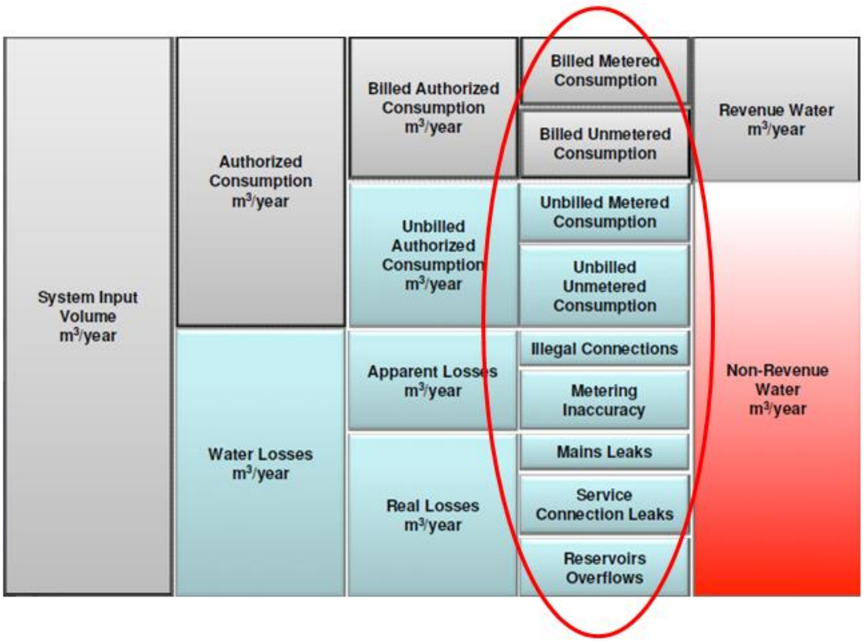
Leakage Indicators used at *De Watergroep*	Value
ILI: adopted in 2014 for internal/external performance comparisons	1,30
m^3/km mains/day: traditionally used in Belgium up to now	2,5
Litres/service connection/day: for tracking individual systems	70
% of System Input Volume: currently required by Regulator	17,1%
% of Water Supplied	18.1%

Table 10 – Implemented leakage measures and indicators at De Watergroep.

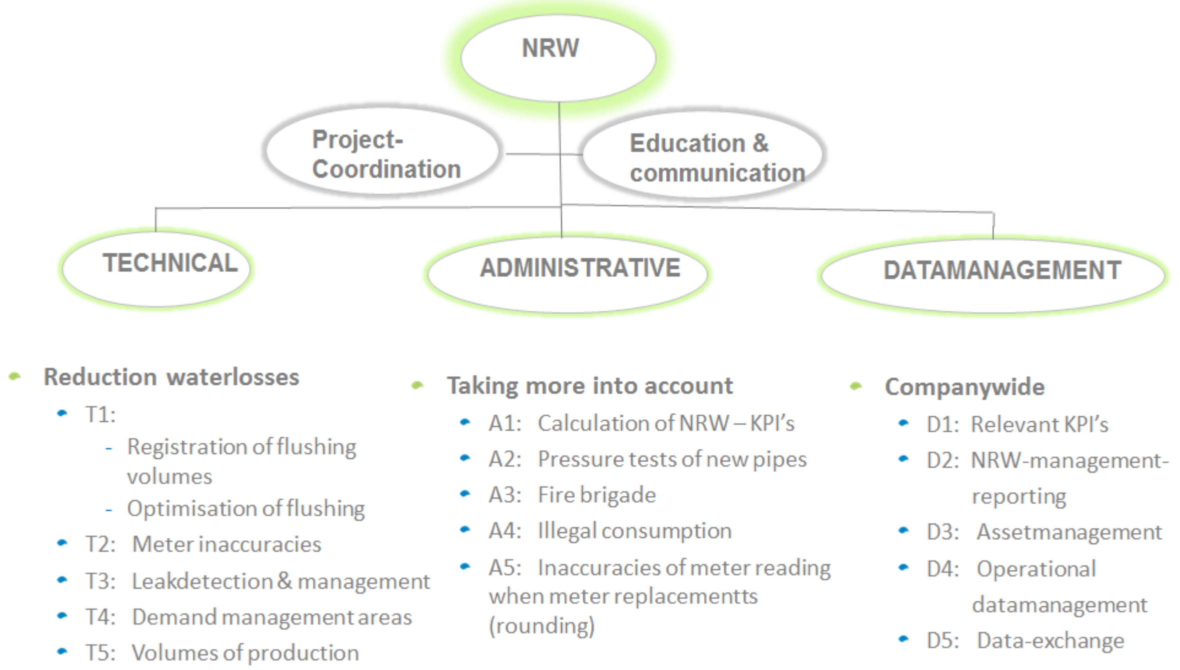
3.4 Details strategy, monitoring methods and leakage indicators

De Watergroep's vision is focused on sustainable management of people and resources. Lowering NRW fits perfectly within this vision because sustainable management of water also implies sustainable management of energy and chemicals required for the production of drinking water.

Since De Watergroep has a complex, geographically extensive network infrastructure for production, storage, supply and distribution of the necessary drinking water, coordination of all initiatives for integrated management of NRW is thus essential. Therefore, a company-wide project structure was introduced, in which all aspects of good NRW management are studied and addressed, with particular emphasis on cooperation and coordination.



For the completion of the project structure, the IWA Water Balance was taken as the baseline so no issue is overlooked: all components of water balance, see graph above, must be handled by someone. That's why the project-based approach below was formed:



Besides project coordination and education & communication, three large groups devote themselves to one specific theme:

1. The technical group looks for ways to reduce water losses.
2. The administrative group emphasizes increased water awareness, like reducing unauthorized consumption, unmetered connections and stopped meters.
3. The data management group mainly concentrates on a company-wide and coordinated approach to the different databases. All information which can currently be found in the databases of GIS, Arcado, InfoWorks WS, Octopus and telemetry together represent a wealth of information which can provide us with insight on our water pipe network.

Within each of these three groups, there are five active working groups focusing on one aspect (see graph above). These working groups feature employees from across the company. Thus, anyone who can play a role in bringing down the NRW figures is involved in this project.

Various methods applied for monitoring

The network system is segmented into permanently monitored DMAs, in order to assess and quantify potential water losses per sub-zone. Night flow measurements are used for targeting leakage in DMAs. Every night the water supplied between 2h and 3h is compared with a normal consumption of 3 l/h per property. Big industrial customers get their own known consumption for more accuracy. Where targeted consumption is exceeded ALC is used to localise the leak.

Every service connection is metered and every customer meter is replaced each 16 years.

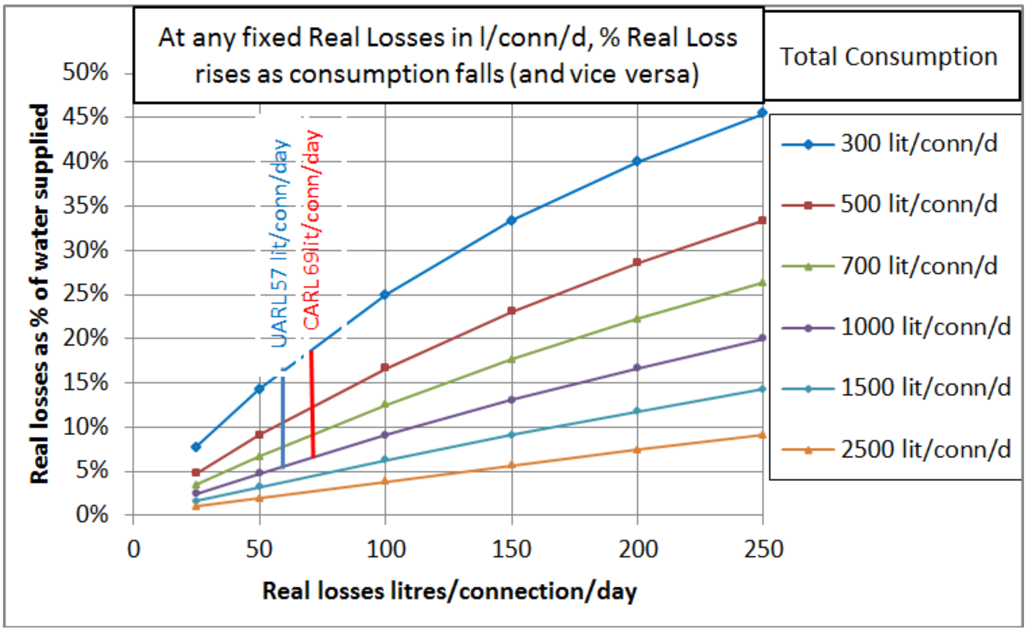
Implemented leakage performance indicators

De Watergroep contributes to the European benchmarking study and has also contributed ILI data for its 4 large sub-systems to a recent European data set collated by WLSG members.

Despite implementing pressure management and active leakage control using multiple DMAs with night flow measurements, De Watergroep has been subject to persistent criticism for having NRW of around 20% of System Input Volume, which is significantly more than many urban Water Utilities in Belgium and Europe. In its constant search to reduce leakage, De Watergroep organised a 2-day Workshop in December 2013 by IWA WLSG specialists who had been assisting Iren Emilia to achieve significant reductions.

Deficiencies of % of SIV for performance comparisons, tracking changes in leakage and setting targets were explained (Appendix B.2), and also to a wider audience of AquaFlanders Utilities in March 2014. The graph below shows:

- De Watergroep low consumption (300 litres/connection/day) is a major cause of the leakage of 17% of System Input Volume or 17.9% of Water Supplied.
- If consumption was 1.000 litres/connection/day or more, typical for a large urban area, current leakage would represent 7% or less of System Input Volume.
- Unavoidable Annual Real Losses for De Watergroep, calculated from the IWA Formula, are 57 litres/connection/day, so even if De Watergroep achieved an ILI of 1,0 their leakage would still be 12% of SIV and their NRW 15% of SIV.



Using ILI, which was developed by the 1st IWA WLTF for technical comparisons, it became possible to compare the 4 sub-systems. This fair comparison is a motivation for people working on the reduction of leakages.

3.5 Details proven leakage reduction measure(s)

De Watergroep					
Year	Population (mlj)	Billed properties (mlj)	Water Supplied (mlj m³)	consumption (l/conn/day)	ILI
1990	2.40	0.83	132	366	
1998	2.60	1.00	140	350	1.01
2009	2.74	1.14	151	307	1.40
2013	2.86	1.23	155	300	1.28

De Watergroep serves an increasing population, while consumption per consumer has decreased. The performance of the network in terms of leakage has always been good, thanks to strict quality standards in the construction of new pipelines and connections and fast repair of leaks. However, the biggest challenge for De Watergroep is to avoid leakage increases, which are due partly to aging pipes, the increasing number of customers, and to network infrastructure expansion. To achieve this, efforts in terms of NRW management must be intensified. When creating new DMAs, pressure management at the initial phase will be taken into account.

In one of the four sub-systems, the introduction of permanent metered DMAs, daily analysis of night consumption, and active leakage control was already initiated 20 years ago. This systematic approach is paying off, as evidenced by an ILI of 0,63 in this sub-system in 2013.

3.6 Evaluation of further options for pressure management

The average pressure of 38 m is rather high which make further options for pressure management appropriate. This average pressure of 38 m has different reasons:

- A ground level that varies between 1 m and 288 m.
- De Watergroep supplies water in a wide spread distribution system with long trunk mains for outlying regions without their own sources of water or possibilities for imports.

Now that the influence of pressure on leak flow rates and burst frequencies can be predicted with some confidence using IWA WLSG concepts, a systematic re-evaluation of average and maximum pressures has started, and cost-effective opportunities for intermediate and advanced pressure management will be sought.

De Watergroep already has a step-by-step plan and budget to increase the number of permanently measured DMAs from 282 to 325.

3.7 Results and recommendations

The Water Balance for De Watergroep follows in Section 3.9 at the end of this Case Study.

For a large company like De Watergroep with a huge, complex, widely spread transmission and distribution system, it is essential that everyone is involved in NRW management, from the worker on the field to the management team.

A well-thought project structure in which each activity has a place, and in which all aspects of the water balance are handled, is essential. This way, NRW is a live issue within the company and everyone is encouraged to reflect and be aware of the problem. That’s why it’s extremely important that training at all levels is organized to raise awareness and to sharpen the understanding of this issue.

The introduction of representative KPIs contributes to a fair comparison between the different sub-systems, which is a motivation to continue to actively work on leakage reduction.

For such a large water company the importance of accurately collecting and combining data on losses due to leakage to derive information is widely recognized. For example, keeping separate track and analysing breaks and leaks on mains and service connections is very important to implement targeted improvement actions.

On the other hand, data can be combined using a data warehouse. Thus, for example, complaints can be immediately geographically linked to the corresponding GIS asset, real-time pressure measurements can be compared with the network modelling to detect abnormal values that may indicate the existence of leaks. By analysing the combined data, a decision support system can be built for just-in-time asset management.

Above all, we must keep one thing in mind: doing nothing means going backwards!

3.8 References

European Environment Agency (2009): *Water resources across Europe — confronting water scarcity and drought*. EEA Report No 2/2009

P.F. Boulos, K.E. Lansey and B.W. Karney (2006): *Comprehensive Water Distribution Systems Analysis Handbook for Engineers and Planners.* AWWA / MWH, ISBN-13: 978-0974568959.

Lambert, A., B. Charalambous, M. Fantozzi, J. Kovač, A. Rizzo and S. Galea St John (March 2014): *14 Years' Experience of using IWA Best Practice Water Balance and Water Loss Performance Indicators in Europe.*

Hamilton, S. and B. Charalambous (July 2013): *Leak Detection – Technology and Implementation*, IWA Publishing, ISBN: 978-1-78-040470-7.

3.9 Water Balance De Watergroep

DATA COLLECTION WORKSHEET FOR CASE STUDIES, BEST PRACTICE ON LEAKAGE REDUCTION					Version 2e	23-09-2014	by ILMSS Ltd
THIS WORKSHEET IS USED TO CALCULATE NON-REVENUE WATER AND ASSESS COMPONENTS NON-REVENUE WATER							
Colour coding:	Data entry	Essential data entry	Default Values	Calculated Values	Data from another Worksheet		
SIMPLIFIED IWA WATER BALANCE CALCULATIONS		De WaterGroep	Whole System		# Conns =	1.108.042	
Period of Water Balance from	01-01-2013	to 01-01-2014	365	days	Mm^3	1000 m^3/day	lit/conn/day
Enter data for your system in yellow cells. Check the default %s in the purple cells, and change them if you have better information which will improve the reliability of the calculation. Add comments in the Comments Box below.	POTABLE WATER VOLUME INPUT FROM UTILITY TREATMENT WORKS				122,434	335,4	303
	Potable Water Imported to this system				41,729	114,3	103
	SYSTEM INPUT VOLUME (Potable Water)				164,163	449,8	406
	Potable Water Exported from this system				8,666	23,7	21
	Potable WATER SUPPLIED TO THIS SYSTEM				155,497	426,0	384
	Billed Metered Consumption				121,518	332,9	300
	Billed Unmetered Consumption				0,000	0,0	0
	NON-REVENUE WATER NRW				33,979	93,1	84
	Unbilled Authorised Consumption	1,25%	of Billed Metered Consumption		1,519	4,2	4
	WATER LOSSES				32,460	88,9	80
	Unauthorised Consumption	0,25%	of Billed Metered Consumption		0,304	0,8	1
	Customer Metering Inaccuracies	3,00%	of Billed Metered Consumption		3,646	10,0	9
	APPARENT LOSSES				3,949	10,8	10
	CURRENT ANNUAL REAL LOSSES CARL				28,511	78,1	70
Information entered by	Gisèle Peleman	20-08-2014	Contact		gisele.peleman@dewatergroep.be		
Comments:							

Guideline maximum default %s for assessed components of Non-Revenue Water are shown below:				
If higher figures are claimed they should have been validated by Utility Specific data				
Unbilled Authorised Consumption		0,50%	of Billed Metered Consumption	excluding Water Exported
Unauthorised Consumption		0,20%	of Billed Metered Consumption	
Customer Metering Inaccuracies	Direct pressure systems	2,00%	of Billed Metered Consumption	
	Roof storage tanks	5,00%	of Billed Metered Consumption	
	Customer Metering Inaccuracies are positive for under-recording, negative for over-recording.			

Potable Water Produced from Utility Treatment Works 122,43 Mm3	**System Input Volume SIV (Potable Water)** 164,16 Mm3	**Potable Water Exported WE** 8,67 Mm3			**De WaterGroep** / **Whole System** / **01-01-2013** to **01-01-2014**
		Potable Water Supplied WS 155,50 Mm3	**Billed Authorised Consumption (excluding Water Exported)** — **Metered** 121,52 Mm3; **Unmetered** 0,00 Mm3		
Potable Water Imported to this System 41,73 Mm3			**Non -Revenue Water NRW** 33,98 Mm3	**Unbilled Authorised Consumption UAC** 1,52 Mm3	
				Water Losses WL 32,46 Mm3	**Apparent Losses AL** 3,95 Mm3
					Real Losses RL 28,51 Mm3

Infrastructure Parameter				**Performance Indicators for Leakage**					
Distribution mains length		25963,0	km	1098	m^3/km/year	3,0	m^3/km/day	0,13	m^3/km/hour
Trunk and Distribution mains length		30834,0	km	925	m^3/km/year	2,5	m^3/km/day	0,11	m^3/km/hour
Service Connections (to 1st meter)		1108042	Number	25,7	m^3/conn/yr	70	l/conn/day	'per hour' is influenced by Night-Day Factor NDF	
Density of Connections		35,9	No/km	↑ Use PIs above this row to track leakage in individual systems ↑ / ↓ Use PIs below this row to compare leakage between systems ↓					
Length of underground Service		9,0	m/conn	Current Annual Real Losses CARL				28,51	Mm^3/year
Connections, Main to first meter		9972,4	km	Unavoidable Annual Real Losses UARL				21,94	Mm^3/year
Average Operating Pressure		38,0	metres	Infrastructure Leakage Index ILI =				1,30	
Annual Repair Frequencies	Mains (UARL)	13,0	/100 km	15,0	per 100 km		which is	1,2	x UARL frequency @ 50m
	Connections (UARL)	3,7	/k conns	2,0	per 1000 conns		which is	0,5	
				↓ PIs based on %s are for comparison only, not recommended ↓					
				Leakage as % of System Input Volume SIV				17,4%	
				Leakage as % of Water Supplied, excluding exports				18,3%	

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4 Bulgarian Case Study: Dryanovo and Razgrad

Contribution of Metodi Indzhov (Dryanovo), Stoyan Ivanov (Razgrad) and Mircho Tanev (AQUAPARTNER Ltd.) – August 14, 2014

Most of Bulgaria experiences very high NRW, Apparent Losses and Real Losses. A tendency of reduced water consumption exists in the region due to customers' savings, closure of industrial production, etc. as well as reductions in the served population, payment of water taxes and repayment of long-term credit. So there is a lack of funds for rehabilitation. However, some Utilities are starting to tackle the problems systematically. This Case Study contains two examples showing how the powerful combination of pressure management and Active Leakage Control in DMAs, applied in sequence, can achieve sustainable reductions in volumes of leakage in Bulgaria. It also demonstrates that the current Bulgarian National Practice of requiring calculations of NRW and Water Losses in terms of % of System Input Volume substantially underestimates actual achievements in reduction of water losses.

The Dryanovo example covers 12 DMAs recently established in a small town (1.470 service connections, 38,2 km mains). Razgrad is a pilot project to demonstrate benefits in 4 DMAs (716 service connections, 13 km mains) out of 24 existing DMAs in a city with 5.251 service connections and 116 km mains).

Country	Basin / Sub-basin	Water service provider	Other key stakeholders
Bulgaria	Danube / Yantra river	„ViK" Gabrovo - Dryanovo Region	51% State property; 49% Municipal property
Bulgaria	Danube / Russenski Lom river	"Vodosnabdyavane Dunav" EOOD - Razgrad	100% State property

Table 11 – Geographical context of Dryanovo and Razgrad.

4.1 Details Water Utilities and distribution networks

VIK Gabrovo – Dryanovo Region

The water supply system of the small city of Dryanovo was built in 1950, then partially reconstructed and extended during 1979-1982 with a 6.500 m³ service reservoir, with outlets through asbestos-cement and steel mains to two high level Zones (A and B), and also to a pressure-reduced Low Zone which is part of Zone B. Three very small Pilot Zones (with 17, 84 and 81 service connections) were created between 1997 and 2004, and 27% of the system has been rehabilitated since 2004. A leakage management program between 2011 and 2013 involving pressure management in conjunction with the creation of 9 more small DMAs for Active Leakage Control has reduced the 2010 Non-Revenue Water volume of 0,670 Mm^3 by 0,487 Mm^3 (73%); ILI has fallen from 20 to 5,8.

Characteristic	Value
Population	7.316
Number of billed properties (residential and non-residential)	3.657
Number of service connections (main to first meter)	1.472
Average length of underground service connections	5,34 m
Length of trunk and distribution mains	38,218 km
Average operating pressure	41,5 m
% of time system is pressurised	100% of year
% of total mains length subject to active pressure management	100%
Annual volume of potable water supplied (excluding exports)	0,494 Mm^3/year
Average time from location of mains leaks to shutoff or repair	1 days
Average time from location of service leaks to shutoff or repair	7 days

Characteristic	Value
Leaks on mains (number per 100 km/year)	60/year
Leaks on service connections (number per 1000 connections/year)	21/year
% of system having active leakage control interventions each year	100%
Number of water treatment plants	0
Number of pumping stations	0
Number of distribution reservoirs	1
Total number of staff	33
Staff directly involved in water operations	14
Average consumer price	€ 0,74/m^3
Average unit costs of water resource	€ 0,01/m^3
Average unit costs of production and distribution	€ 0,47/m^3

Table 12 – Details water production system and distribution network Dryanovo 2013

Assessment of Unbilled Authorised Consumption and Apparent losses is a problem in much of Bulgaria; 2006 Bulgarian regulations assume these to be 10% of System Input Volume, so calculations of reductions in water losses are largely based on night flow measurements in DMAs. Simplified Water Balances for Dryanovo City, 2010 to 2013, are shown below. It is evident from the lowest line that even though consumption (Billed Water) is reasonably constant from year to year, changes in % of System Input Volume significantly underestimate true progress in water loss reduction.

Dryanovo Water Balance Annual Volumes expressed in Mm^3				**Performance Indicators**		
Year	System Input Volume (SIV)	Billed Water (BW)	Water Losses (NRW)	Water Losses	ILI for Water Losses	Average Pressure
	Mm^3	Mm^3	Mm^3	% of SIV		Metres
2010	0,995	0,325	0,670	67,3%	20,0	44,7
2011	0,896	0,321	0,575	64,2%	16,8	44,7
2012	0,693	0,335	0,358	51,7%	11,5	40,6
2013	0,494	0,331	0,183	37,0%	5,8	41,6
Change 2010 to 2013	-0,501	-0,014	-0,487		-14,2	3,1
% change from 2010	**-50%**	**-4%**	**-73%**	**-30%**	**-71%**	**-7%**

"Vodosnabdyavane Dunav" EOOD – Razgrad Demonstration Project

This joint project, by an AQUAPARTNER Ltd team and the team of "Vodosnabdyavane Dunav" EOOD, Razgrad, was designed to demonstrate possibilities for delivering real and positive results in water loss reduction by water companies in Bulgaria with relatively few resources, using the proven IWA practical approaches. A previous joint project in 2004 to 2007 under a Dutch governmental initiative managed by AQUAPARTNER and Aquanet Ltd (Netherlands) had created a network analysis model (EPANET) and established 24 DMAs and a pilot Zone to assess Water Losses, all linked to a SCADA system.

Razgrad has 5.251 service connections and 116km mains. The Water Balance for 2010 (see Section 4.9) using the Bulgarian Guidelines assumption that Apparent Losses are 10% of System Input Volume, assesses Real Losses as 4,73 Mm^3/year, or:

- IWA indicators: 2.470 litres/connection/day, ILI 41,4.
- Bulgarian Guidelines indicators: 4,7 m^3/km/hour, 67% of System Input Volume.

These figures represent very high leakage, whichever performance indicator is used.

The demonstration project comprises four of the 24 DMAs (Kooperativen Pazar, Largo 1, Largo 2 and Parkova) concentrated in the central parts of the town with 13 km of mains and 716 service connections serving 5.928 people. A great deal of the required data – 24-hour data on water input volumes, pressures downstream and upstream of the DMA chambers – were obtained through SCADA, and the project was completed within 3 months.

At the start of the demonstration project, the total minimum night flow of the 4 DMAs, was 32,4 l/s. Because of the high apparent losses, the 'consumption' component of night flow is difficult to assess reliably for both water balance and night flow analysis. However, reductions in minimum night flow can be reasonably assumed to represent reductions in hourly night leakage achieved in the 4 DMAs through a systematic application of the various stages of analysis, preparation and application of an appropriate water loss reduction programme, and in particular, the application of Pressure Management (PM) in conjunction with Active Leakage Control (ALC) in DMA Kooperativen Pazar.

4.2 Details context Water Utilities and distribution networks

Details context Dryanovo

The management of NRW and leakage has been greatly improved between 2010 and 2013. The responses in the table below relate to the improved situation in 2013.

Relevant factor	Yes	No
Abundant water resources at a basin level?		No
Limited measures required to improve water status to achieve WFD objectives?		No[3]
River Basin Management Plan (RBMP) completed?	Yes	
Active quantity management incorporated in the RBMP?		No
RBMP harmonised with other key socio-economic and land use planning documents prior to adaptation and incl. financing plans?	Yes	
Abundant water resources for water service provider all year every year?		No
Water resources of good chemical quality (low or no treatment)?	Yes	
Water resources located at topographical levels above the level of the customer base (low or no energy costs)?		No
Are the economics of density reasonable (> 20 connections per km)?	Yes	
Cost effective investment and operating conditions?		No
Distribution network designed for ease of operation and maintenance without maximum pressure stresses?	Yes	
Pressure Management implemented throughout the system?	Yes	
District Metering implemented throughout the system?	Yes	
Good quality of the network installation (materials selection and workmanship at the time of installation)?		No
Water pricing limitations?	Yes	
Conflicting socio-economic needs and/or historical legacy?		No
Public affordability constrains?	Yes	
Ability- / willingness-to-pay constraints?		No
Benefitting from EU Funds to finance significant water supply (and urban wastewater) treatment investments?		No[4]
Specific Regulator (Utility subject to regulation)?	Yes	

Table 13 – Specific context within which Dryanovo is operating.

[3] Only some WFD objectives are followed.
[4] EU funding during the next program period 2014-2020.

A tendency of reduced water consumption exists in the region due to customers' savings, closure of industrial production, etc. as well as reductions in the served population, and payment of water taxes and long-term credit. So there is a lack of funds for rehabilitation. 96% of system input volume is a bulk supply from the Reservoir – Dam Yovkovtsi (Veliko Tarnovo).

Details context Razgrad

The first activities for water loss reduction started long ago with the establishment of 24 DMAs. Practically water loss reduction began with night flow measurements and ALC in the 4 DMAs, mentioned above in section 4.1.

Relevant factor	Yes	No
Abundant water resources at a basin level?		No
Limited measures required to improve water status to achieve WFD objectives?		No[3]
River Basin Management Plan (RBMP) completed?	Yes	
Active quantity management incorporated in the RBMP?		No
RBMP harmonised with other key socio-economic and land use planning documents prior to adaptation and incl. financing plans?	Yes	
Abundant water resources for water service provider all year every year?		No
Water resources of good chemical quality (low or no treatment)?	Yes	
Water resources located at topographical levels above the level of the customer base (low or no energy costs)?		No
Are the economics of density reasonable (> 20 connections per km)?	Yes	
Cost effective investment and operating conditions?		No
Distribution network designed for ease of operation and maintenance without maximum pressure stresses?	Yes	
Pressure Management implemented throughout the system?	Yes	
District Metering implemented throughout the system?	Yes	
Good quality of the network installation (materials selection and workmanship at the time of installation)?		No
Water pricing limitations?	Yes	
Conflicting socio-economic needs and/or historical legacy?		No
Public affordability constrains?	Yes	
Ability- / willingness-to-pay constraints?		No
Benefitting from EU Funds to finance significant water supply (and urban wastewater) treatment investments?		No[4]
Specific Regulator (Utility subject to regulation)?	Yes	

Table 14 – Specific context within which "Vodosnabdyavane Dunav" - Razgrad is operating.

The Municipality of Razgrad will apply for funding from the Operational Program for Environment for the period 2014 – 2020. Thus it expects to be able to rehabilitate a big part of the water supply network as a result of which the water losses will be reduced.

4.3 Overview leakage measures and indicators implemented

Dryanovo

By 1997 a 6.500 m³ service reservoir served two high level Zones (A and B), and a pressure-reduced Low Zone of two small pilot DMAs within Zone B. An additional small Pilot Zone was created in 2004, then 9 more small DMAs and 17 pressure measurement points were established between 2011 to 2013.

A combination of further basic pressure management (reducing pressures in the Zones and DMAs by amounts between 6 and 45 metres as numbers of leaks were detected and repaired using Active Leakage Control) has reduced the 2010 Non-Revenue Water volume by 73%, from 0,670 to 0,183 Mm^3 in 2013. The ILI (calculated for NRW, which is higher than ILI for leakage) reduced from 20 to 5,8. However, NRW calculated as a % of System Input Volume (required by Bulgarian National Regulations) reduced by only 30% (67% to 37%), hiding the scale of the achievements.

Additional pressure management since 2010 consisted of creating DMAs designed to reduce average pressures; then when leaks were identified and repaired, further reductions in pressure were made to prevent pressure rising. Overall, average pressure was reduced by 7%, from 44,7 metres in 2010 to 41,5 metres in 2013.

During rehabilitation of the service connections 676 of them have been renovated and the water meters have been replaced as well. 796 SCs are still of old pipes. About 28% of the mains are changed with new pipes.

Implemented measure on leakage assessment and reduction	Yes	No
Reliable Bulk Supply Metering	√	
Reliable District Metering	√	
Reliable Customer Metering	√	
Good System Design and Installation	√	
Effective Management of Excess Pressure and Pressure Transients	√	
Speed and quality of repairs	√	
Active Leakage Control at an economic frequency	√	
Sectorisation and/or District Metering Area formation	√	
Asset Renewal: service connections	Some	
Asset Renewal: mains		√
Annual Volume of Real Losses (Level of Leakage, CARL)	Value	
2013	0,183 Mm^3/year	
Leakage Indicators used at Dryanovo	Value	
ILI (calculated using NRW volume, so over-estimates true leakage ILI)	5,8	
NRW as % of System Input Volume	37,0%	
Average Pressure	41,5 m	

Table 15 – Implemented leakage measures and indicators at Dryanovo in VIK.

Razgrad

The table below summarizes the situation for the City of Razgrad in 2010. The funding isn't enough for the rehabilitation of the network. Regarding asset renewal of service connections and mains, only repairs of the bursts and leaks can be considered. Plans for replacement of any specific figures for km of mains and numbers of service connections don't exist due to lack of finance.

Implemented measure on leakage assessment and reduction	Yes	No
Reliable Bulk Supply Metering	√	
Reliable District Metering	√	
Reliable Customer Metering		√
Good System Design and Installation		√
Effective Management of Excess Pressure and Pressure Transients	√	
Speed and quality of repairs	√	
Active Leakage Control at an economic frequency	√	
Sectorisation and/or District Metering Area formation	√	
Asset Renewal: service connections		√
Asset Renewal: mains		√
Annual Volume of Real Losses (Level of Leakage, CARL)	Value	
2010	4,73 Mm^3/year	

Leakage Indicators used at Razgrad	Value
ILI (calculated using NRW volume, so over-estimates true leakage ILI)	41,4
NRW as % of System Input Volume	67,0%
Average Pressure	45 m

Table 16 – Implemented leakage measures and indicators at "Vodosnabdyavane Dunav" - Razgrad.

4.4 Details of strategy, monitoring methods and leakage indicators

Dryanovo

The Manager of VIK Gabrovo – Dryanovo Region assisted in developing the strategy, which was based on IWA WLTF Manuals, the EPANET 2 software User Manual and more than 20 other sources on Water Loss Management. The methodology used for hydraulic dimensioning of the modelled system included:

- Updating ACAD for each part of Dryanovo mains - type, diameter and length of pipes; estimated elevation of network junctions and reservoir elevations.
- Estimating service connections numbers, type, diameter (≤ 1", > 1"), and identifying large consumers.
- Dimensioning of sections of the network was used to estimate junction flows and their input in EPANET 2. Distribution of billed water quantities was based on average flow rate for service connection cross-sectional area in each Zone.

Simulations of the water supply network were made using average monthly billed water quantity for output data. The difference between billed quantity and supplied water quantity (Non-Revenue Water) was assumed to represent water loss. The Bulgarian language version of CheckCalcs software, distributed free of charge in Bulgaria by AQUAPARTNER was used to calculate Water Balances and performance indicators. In the base year, 2010, ILI was 20,0, average pressure 44,7 metres, and water loss 67,4% of Water Supplied.

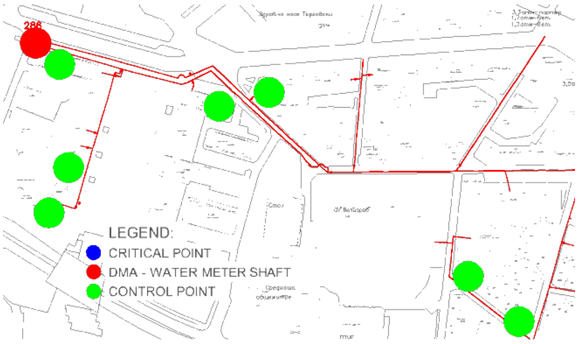
Priorities were identified to establish 17 pressure management points (only 2 existed previously) and to increase the number of DMAs to 12. Hydraulic simulations and calculations were made, and water losses assessed from water balance were compared with measured average 24 hour consumption, minimum night flow and pressure data during day and night. Over the next 3 years, the additional DMAs were gradually established.

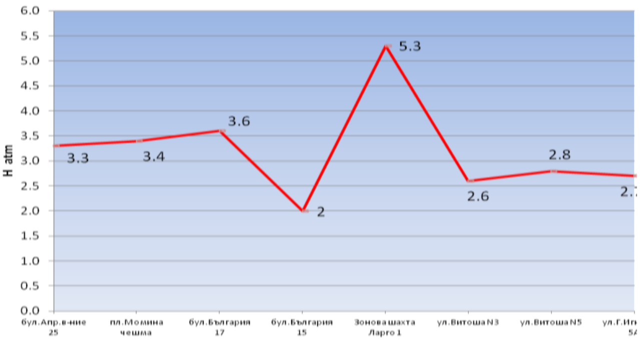
Razgrad

The methods of the International Water Association (IWA) were applied, to a great degree, in the 4 DMAs in the demonstration project for a period of 3 months.

Qualified specialists of the water operator and AQUAPARTNER surveyed the water supply network and its accessories: state of network, working stop valves, location of water pipelines, number of service connections, fire hydrants and other accessories.

Bulk meters were tested in a licensed metrological laboratory to rule out any error. DMA monitoring included 24-hour monitoring of minimum night flow (MNF) and pressure data obtained by means of SCADA, upstream and downstream of the DMA inlet chamber. Pressure measurements were also taken at the Critical Point, and other control points within the DMA, both before and after each significant project step.

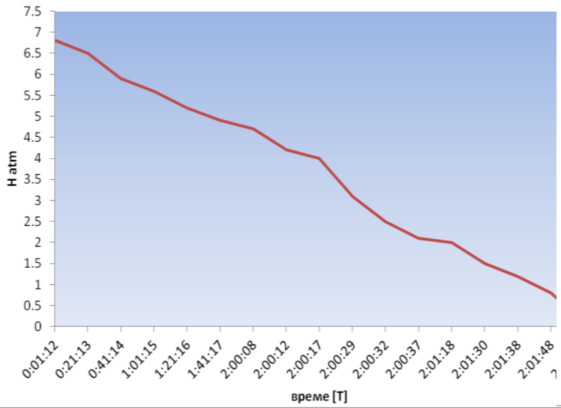


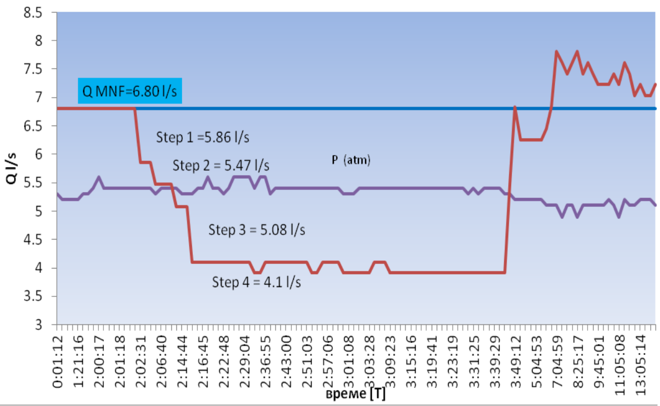


Control points where pressure is measured

Pressures at Control points

An annual Water Balance was then calculated for each DMA for March 2010 to March 2011, using Bulgarian Guideline assumption, and the ILI was calculated using the Bulgarian language version of the CheckCalcs free software. Within the scope of the performed Active Leakage Control, a Zero Pressure Test was conducted to confirm the isolation of the DMA from adjacent DMAs, followed by a step test using SCADA to identify sub-areas with highest leakage.



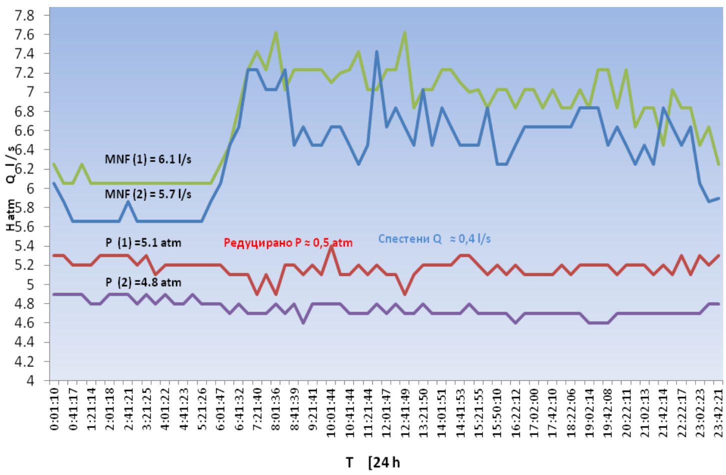


Zero Pressure Test Graph

Step Test Graph

Teams trained to search the water supply network for hidden leaks identified 6 leaks in four areas. After repairs the minimum night flows in the areas reduced by 5.9 l/s.

Analyzing the rise in the free pressure, had been monitored systematically before and after the leaks repair. The downstream pressure of the DMAs chambers of Kooperativen Pazar DMA and Largo DMA 1 were reduced by 5 metres and 3 metres. This additional pressure control down to the minimum acceptable for the DMAs resulted in further 0,8 l/s decrease in night flow, to 6,7 l/s.



Pressure reduction, Kooperativen Pazar DMA

In the detailed study of the Kooperativen Pazar DMA (Paskalev, A. et al, 2011), it is interesting to note that the average pressure at the pressure control points rose by an average of 2,5 metres after the leak repairs, but the inlet pressure then could be reduced by 5 metres whilst maintaining the minimum pressure at the critical point. This effect, also been seen in high leakage systems in Brazil, may be attributed to a reduction in frictional head losses in the mains at the lowered total flow rates.

4.5 Details of proven leakage reduction measures at Dryanovo and Razgrad

Those responsible for the post-2010 leakage management strategy in Dryanovo and Razgrad knew that simply identifying and repairing leaks causes average pressure to increase, which then results in further detectable leaks and increases in background (undetectable) leakage. However, by quickly reducing the average pressure after leak detection and repair, by between 3 and 45 metres in different DMAs, standards of service for minimum pressure to customers can be maintained, while securing the elimination of the detected leaks, and additional reductions in background (undetectable) leakage could be gained. The results of this policy over the period 2010 to 2013 in Dryanovo can be seen in the table below. The aggregate minimum night flow in the 4 DMAs in the Razgrad Demonstration Project was reduced from 32,4 litres/second to 25,7 litres/second.

Billed Water volume (consumption) in Dryanovo remained almost unchanged, but Water Losses volume was reduced by 487 Mm^3 (73%) in three years. ILI (calculated for Water Losses rather than leakage) was reduced from 20 to 5,8 – the ILI for leakage alone will be lower than this – and average pressure was reduced by 7% from 44,7 to 41,5 metres. It is probable that, without the means to measure pressure and to make selective reductions in pressure when establishing DMAs and undertaking major leak repairs and ALC interventions, much less progress would have been made in reducing water losses in Dryanovo. This, and the Razgrad data, are clear examples which demonstrate that, where leakage is concerned, 'every metre of pressure counts'.

Reduction of maximum pressures can also be expected to reduce numbers of leak repairs. The table below shows repairs and frequencies for mains and services in Dryanovo, year by year from 2010 onwards. The 2013 frequencies for mains (60 per 100 km/year) and services (21 per 1000 service connections/year) can both be classified as high or very high, confirming the deteriorated condition of much of the infrastructure.

Dryanovo Mains and Services Repairs: Annual Numbers and Frequencies

Year	Mains Repairs			Service Connection Repairs		
	Mains Length km	Repairs Number	Frequency /100 km/year	Services Number	Repairs Number	Frequency /k SCs/year
2010	38,1	19	50	1469	30	20,4
2011	38,1	25	66	1469	32	21,8
2012*	38,1	29	76	1469	35	23,8
2013	38,1	23	60	1469	31	21,1
Change 2010 to 2013	0	4	10,5	0	1	0,7
% change from 2010	**0%**	**21%**	**21%**	**0%**	**3%**	**3%**

The simplified prediction method for pressure:burst frequency relationships in Appendix B.3 would suggest that for high leak frequencies with pressure reduction of 7%, a reduction in 2010 leak numbers of around 10% (1,4 x 7%) might be expected. However, interpretation of the data is influenced by an increase in bursts (particularly on distribution mains) in 2012 during a severe winter, and repairs of a backlog of unreported bursts prior to 2010; a clearer set of data may emerge in 2014 and 2015.

4.6 Evaluation of further options for pressure management

Dryanovo

By any standards, the DMAs in Dryanovo are very small, varying from 11 to 369 service connections (average 110 SCs). When all of the 12 DMAs have been established and running for some time, further options for pressure management may be limited to small reductions, here and there, when opportunity arises through reduction of leakage, for example when very badly leaking mains and services are replaced.

Razgrad

The purpose of the demonstrative project was to show how pressure management and active leakage control can be more effective in achieving greater sustainable reductions in leakage when implemented together in systems with high leakage. The results are intended to stimulate more of this type of joint activity, and only 4 of the 24 DMAs have been checked in the demonstration study.

4.7 Results and recommendations for both Dryanovo and Razgrad

A simplified Water Balance for Dryanovo for 2010 to 2013 was shown in Section 4.1. The Water Balance for Razgrad follows in Section 4.9 at the end of this Case Study.

The initiators of the Dryanovo Case Study had the purpose to show that with small capital investments the difficult and constant struggle for water losses management can be started, and that construction today may become the foundation of the introduction of the newest technologies tomorrow. The Razgrad joint project was also designed to demonstrate the possibilities for delivering real and positive results in water loss reduction by water companies in Bulgaria with relatively few resources using the professionalism of the operating team.

In Dryanovo, the water loss has been reduced by 0,487 Mm^3 (73%) and ILIs reduced from 20 to 5,8 in 3 years. The use of % of System Input Volume for setting targets and tracking progress has been shown yet again to greatly under-estimate the true progress. Appendix B.2 outlines the well-known problems of using % of SIV for setting targets, tracking performance and performance comparisons.

Dividing the water supply network into 12 DMA provides monthly information to the Water Utility Manager – Dryanovo Region about every DMA and the whole network. If underground leakage exists in a particular DMA then daily, night measurements and simulations are made through which the risky sections are marked in order to be examined and rehabilitated. The obtained results confirm that the methodology used for hydraulic dimensioning is reliable enough to determine junction inflow for input into the EPANET 2 program.

Based on the results obtained, the Dryanovo team consider that ILI is an appropriate index for status monitoring of the water supply network and DMAs, and that the minimum number of service connections in a DMA can be reduced to less than 100 (a question of the terrain, technical feasibility and economic justification).

The originator of the ILI, who has reviewed this Case Study, considers that this conclusion may well be appropriate for targeting rehabilitation in very small systems with high leakage provided that options for pressure management, active leakage control and speed and quality of repairs have been applied to their fullest extent.

The Razgrad Demonstration study shows that the creation of DMAs is not sufficient on its own to effectively manage leakage; a combination of ongoing pressure management with Active Leakage Control is required to secure the full benefits of leak detection and repair.

4.8 References

Indzhov, M.A., et al (2013): *Inexpensive approach to water loss management in the internal water distribution network (IWDN) of the town of Dryanovo*.

Paskalev, Dr A., S. Ivanov and M. Tanev (2011): *Water loss reduction in Razgrad demonstrative project through active leakage control, pressure management and the relationship between pressure management and leakage: The case of Kooperativen Pazar DMA.*

CheckCalcs – Bulgarian Version, AQUAPARTNER EOOD, Sofia.

4.9 Water Balance Razgrad (Year 2010)

DATA COLLECTION WORKSHEET FOR CASE STUDIES, BEST PRACTICE ON LEAKAGE REDUCTION							Version 2e	23-09-2014	by ILMSS Ltd
THIS WORKSHEET IS USED TO CALCULATE NON-REVENUE WATER AND ASSESS COMPONENTS NON-REVENUE WATER									
Colour coding:	Data entry	Essential data entry	Default Values		Calculated Values		Data from another Worksheet		
SIMPLIFIED IWA WATER BALANCE CALCULATIONS			Bulgaria		Razgrad			# Conns =	5.251
Period of Water Balance	from	01-01-2010	to	31-12-2010	365	days	Mm^3	1000 m^3/day	lit/conn/day

Notes	Item	%	Basis	Mm^3	1000 m^3/day	lit/conn/day
Enter data for your system in yellow cells. Check the default %s in the purple cells, and change them if you have better information which will improve the reliability of the calculation. Add comments in the Comments Box below.	POTABLE WATER VOLUME INPUT FROM UTILITY TREATMENT WORKS			7,110	19,5	3710
	Potable Water Imported to this system			0,000	0,0	0
	SYSTEM INPUT VOLUME (Potable Water)			7,110	19,5	3710
	Potable Water Exported from this system			0,000	0,0	0
	Potable WATER SUPPLIED TO THIS SYSTEM			7,110	19,5	3710
	Billed Metered Consumption			1,780	4,9	929
	Billed Unmetered Consumption			0,000	0,0	0
	NON-REVENUE WATER NRW			5,330	14,6	2781
	Unbilled Authorised Consumption	0,00%	of Billed Metered Consumption	0,000	0,0	0
	WATER LOSSES			5,330	14,6	2781
	Unauthorised Consumption	20,00%	of Billed Metered Consumption	0,356	1,0	186
	Customer Metering Inaccuracies	13,60%	of Billed Metered Consumption	0,242	0,7	126
	APPARENT LOSSES			0,598	1,6	312
	CURRENT ANNUAL REAL LOSSES CARL			4,732	13,0	2469
Information entered by	A.Lambert	18-07-2014	Contact	anyone@anywhere.com		

Comments: Water balance data copied from Bulgarian CheckCalcs by Silvyia Nikolova, AQUAPartner, 20th November 2011. Unbilled Authorised Consumption and Apparent Losses default %s used total 10% of System Input Volume in accordance with Bulgarian Regulations Guidance. Customer metering inaccuracies estimated % adjusted to give same Current Annual Real Losses, allow for more detailed assessment in Bulgarian CheckCalcs.

Guideline maximum default %s for assessed components of Non-Revenue Water are shown below:				
If higher figures are claimed they should have been validated by Utility Specific data				
	Unbilled Authorised Consumption	0,50%	of Billed Metered Consumption	excluding Water Exported
	Unauthorised Consumption	0,20%	of Billed Metered Consumption	
Customer Metering Inaccuracies	Direct pressure systems	2,00%	of Billed Metered Consumption	
	Roof storage tanks	5,00%	of Billed Metered Consumption	
	Customer Metering Inaccuracies are positive for under-recording, negative for over-recording.			

		Potable Water Exported WE **0,00 Mm3**				**Bulgaria** **Razgrad** **01-01-2010** **to** **31-12-2010**
Potable Water Produced from Utility Treatment Works **7,11 Mm3**	**System Input Volume SIV (Potable Water)** **7,11 Mm3**	**Potable Water Supplied WS** **7,11 Mm3**	**Billed Authorised Consumption (excluding Water Exported)** **Metered** **1,78 Mm3** **Unmetered** **0,00 Mm3**			
Potable Water Imported to this System **0,00 Mm3**			**Non -Revenue Water NRW** **5,33 Mm3**	**Unbilled Authorised Consumption UAC** **0,00 Mm3**		
				Water Losses WL **5,33 Mm3**	**Apparent Losses AL** **0,60 Mm3** **Real Losses RL** **4,73 Mm3**	

Infrastructure Parameter				**Performance Indicators for Leakage**						
Distribution mains length		116,0	km	40792	m^3/km/year	111,8	m^3/km/day	4,66	m^3/km/hour	
Trunk and Distribution mains length		116,0	km	40792	m^3/km/year	111,8	m^3/km/day	4,66	m^3/km/hour	
Service Connections (to 1st meter)		5251	Number	901,1	m^3/conn/yr	2469	l/conn/day	'per hour' is influenced by Night-Day Factor NDF		
Density of Connections		45,3	No/km	↑ Use PIs above this row to track leakage in individual systems ↑ ↓ Use PIs below this row to compare leakage between systems ↓						
Length of underground Service Connections, Main to first meter		9,0	m/conn	Current Annual Real Losses CARL				4,73	Mm^3/year	
		47,3	km	Unavoidable Annual Real Losses UARL				0,11	Mm^3/year	
Average Operating Pressure		45,0	metres	Infrastructure Leakage Index ILI =				41,4		
Annual Repair Frequencies	Mains (UARL)	13,0	/100 km		per 100 km		which is	0,0	x UARL frequency @ 50m	
	Connections (UARL)	3,7	/k conns		per 1000 conns		which is	0,0		
Comments:				↓ PIs based on %s are for comparison only, not recommended ↓						
				Leakage as % of System Input Volume SIV				66,6%		
				Leakage as % of Water Supplied, excluding exports				66,6%		

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5 Croatian Case Study: Pula

Contribution of Jurica Kovač, (August 25, 2014).

5.1 Details Waterworks Pula and System

Waterworks Pula supplies the cities of Pula and Vodnjan, and municipalities Medulin, Ližnjan, Marčana, Barban, Svetvinčenat and Fažanu, in the south cape of the Istria peninsula in Croatia with a population of 75.000 and during the summer months an additional 100.000 tourists. The company has 32 reservoirs (32.313 m^3 capacity), 70 pumping units, 12 pump stations, 11 braking chambers, 17 water treatment plants, 25.657 service connections with 46.882 metered customers, 2.402 hydrants, and 928 km of mains of different sizes and materials.

Waterworks Pula sources are different types of well fields located throughout Istria peninsula and around the city of Pula. Water is transported from the remote well fields by trunk mains, and local well fields also directly supply the city of Pula and surrounding places. Waterworks Pula uses four main water supply systems which differ in their origin, type and technical features, types of water intake and different technological solutions for purification. Almost 95% of the Pula area is covered by the system of public waterworks. The water supply transport and distribution network commenced in 1860 and the average pipeline age today is more than 50 years. Quality of the drinking water is mostly satisfactory. The volume of NRW in Waterworks Pula has been reduced by 48,5% since 2004. Detailed data on Pula system for the year 2013 are represented in the tables Table 17 and Table 18.

Country	Basin / Sub-basin	Water service provider	Other key stakeholders
Croatia	Istrian	Vodovod Pula ltd. (Waterworks Pula)	City of Pula, Town Vodnjan, municipalities of Barban, Ližnjan, Marčana, Medulin and Svetvinčenat

Table 17 – Geographical context of Waterworks Pula.

Characteristic	Value
Population	75.000 175.000 during summer
Number of billed properties (residential and non-residential)	46.882
Number of service connections (main to first meter)	25.657
Average length of underground service connections	10 m
Length of trunk mains	92 km
Length of distribution mains	836 km
Average operating pressure	40 m
% of time system is pressurised	100% of year
% of total mains length subject to active pressure management	30%
Annual volume of potable water supplied (excluding exports)	8.534 Mm^3
Average time from location of mains leaks to shutoff or repair	1 day
Average time from location of service leaks to shutoff or repair	2 days
Leaks on mains (number per 100 km/year)	26
Leaks on service connections (number per 1000 connections/year)	5
% of system having active leakage control interventions each year	70
Number of water treatment plants	17
Number of pumping stations	12
Number of distribution reservoirs	32
Total number of staff	159
Staff directly involved in water operations	159

Characteristic	Value
Average consumer price	€ 0,97/m^3
Average unit costs of water resource (from 1.1.2015.)	€ 0,40/m^3
Average unit costs of production and distribution	€ 0,50/m^3
Highest unit cost of production and distribution	€ 0,65/m^3
Energy usage	6,67 million kWh/year

Table 18 – Details water production system and distribution network Pula (2013)

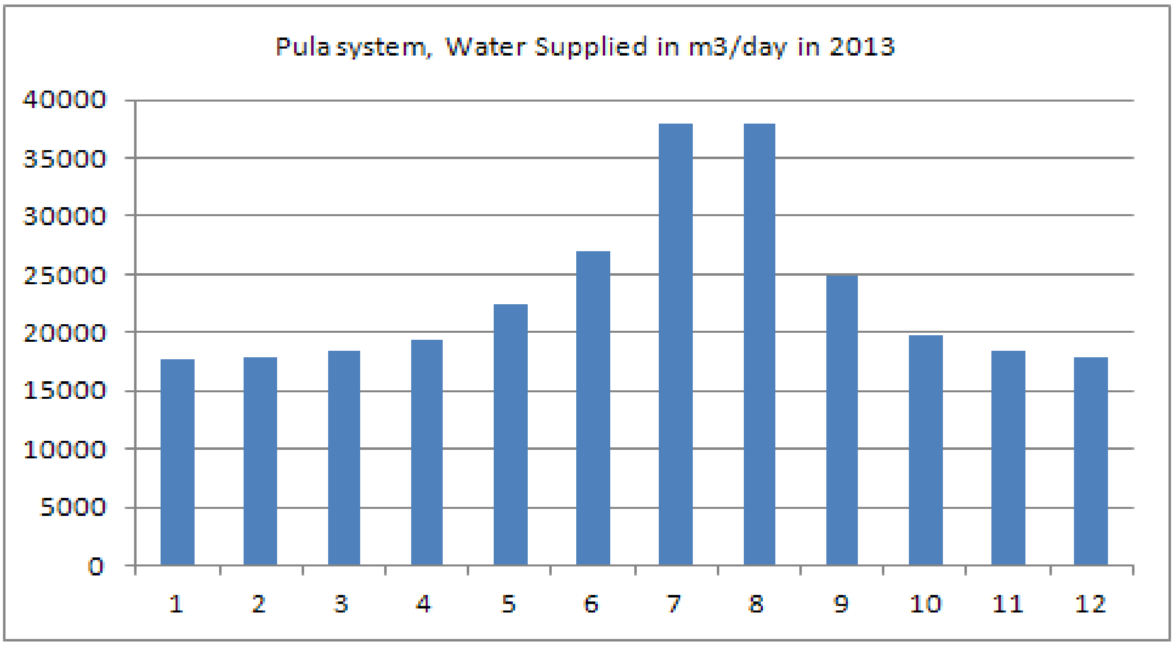


Figure 7 – Seasonal variation of daily treated water supplied (excluding exports).

A Water Balance in simplified IWA Water Balance format is enclosed in Section 5.9.

5.2 Details context Waterworks Pula

Today, average age of the pipelines in the system is around 50 years (precise age data cannot be defined for almost 25% of the pipelines). A special characteristic of this system is the intensive tourist activity during summer months when the population is increased by more than 130%. This change in the water demand influences the construction of the system which needs to be adopted for large variations in the consumption and therefore, system maintenance is made much more difficult.

Relevant factor	Yes	No
Abundant water resources at a basin level?		x
Limited measures required to improve water status to achieve WFD objectives?	x	
River Basin Management Plan (RBMP) completed?		x
Active quantity management incorporated in the RBMP?		x
RBMP harmonised with other key socio-economic and land use planning documents prior to adaptation and incl. financing plans?		x
Abundant water resources for water service provider all year every year?		x
Water resources of good chemical quality (low or no treatment)?	x	x
Water resources located at topographical levels above the level of the customer base (low or no energy costs)?	x	x
Are the economics of density reasonable (> 20 connections per km)?	x	
Cost effective investment and operating conditions?	x	

Relevant factor	Yes	No
Distribution network designed for ease of operation and maintenance without maximum pressure stresses?	x	
Pressure Management implemented throughout the system?	x	
District Metering implemented throughout the system?	x	
Good quality of the network installation (materials selection and workmanship at the time of installation)?	x	
Water pricing limitations?	x	
Conflicting socio-economic needs and/or historical legacy?	x	
Public affordability constrains?		x
Ability- / willingness-to-pay constraints?	x	
Benefitting from EU Funds to finance significant water supply (and urban wastewater) treatment investments?		x
Specific Regulator (Utility subject to regulation)?	x	

Table 19 – Specific context within which Waterworks Pula is operating.

Efficient management of the system can be seen in the fact that special attention is given to the quality of the materials used (special control standards and warehouse state tracking are defined). The water supply system of Waterworks Pula is one of the few in the region which introduced full control in 100% of the system through DMA zones.

Water supply of the area covered by Waterworks Pula is derived from four water supply systems which differ in the origin, type and technical features of pumping, types of water intake and different technological solutions for purification:

- The wells in City of Pula – dug and drilled wells.
- Rakonek system– source.
- Gradole system– source.
- Butoniga system– surface water (accumulation).

Most of the systems are supplied with water by gravity; water is pumped into tanks and then distributed towards consumers by gravity**.** However, there is a source in the city of Pula from which water is being directly pumped into the system.

5.3 Overview leakage measures and indicators implemented at Pula Utility

An organised approach towards dealing with leakages in Waterworks Pula started in 2003 when the "Water supply network leakage reduction programme" was designed and officially initiated. Since the very beginning the programme had a clear understanding of the division between real and apparent loss, and several measures and activities for achieving results. The specified deadlines and goals (at that point used the indicator % of NRW, resulting in reduced NRW from an initial 34% to 25% over a 10 year period. However, the main leakage indicators according to the IWA methodology (CARL, ILI) have been used for the last couple of years.

One of the most important strategy segments is the system and leakage control with the implementation of hydraulic valves for pressure regulation. 19 pressure regulation zones have been formed in the system so far and they cover approximately 30% of the total length of the water network The peripheries and rural areas of the system are covered but the city of Pula, being the most urbanised area, does not have advanced pressure regulation. Every year new pressure regulated areas are added, and existing ones are renewed. Contemporary hydraulic valves for pressure regulation are being used, with the regulation of pressure according to current flow (or with the application of special solutions which enable increased pressure for firefighting activities). Regular activities of measuring and controlling pressure in the system are conducted.

Implemented measure on leakage assessment and reduction	Yes	No
Reliable Bulk Supply Metering	√	
Reliable District Metering, where implemented	√	
Reliable Customer Metering	√	
Good System Design and Installation	√	
Effective Management of Excess Pressure and Pressure Transients	√	√
Speed and quality of repairs	√	
Active Leakage Control at an economic frequency	√	
Sectorisation and/or District Metering Area formation	partially	
Asset Renewal: service connections	√	
Asset Renewal: mains	√	
Annual Volume of Real Losses (Level of Leakage, CARL)		**Value**
CARL (2013 data)		1,71 Mm^3/year
Leakage Indicators used at Waterworks Pula		**Value**
Infrastructure Leakage Index (ILI)		2,9
CARL in litres / service connection /day		183 l/conn/d
NRW in %		23%

Table 20 – Implemented leakage measures and indicators at Waterworks Pula.

5.4 Details strategy, monitoring methods and leakage indicators

Since 2003 a leakage control strategy has been implemented. In the first years of implementation the priorities were acquisition and application of instruments and equipment for leakage detection. Other activities have also been initiated like introduction of DMA areas, pressure regulation in certain areas, regular system restoration (approximately 2% of the mains and service connections is reconstructed yearly). Leakage control has been organised using a special service team for leakage control fieldwork (2 teams with 4 workers in total). Special emphasis has been put on the quality and applicability of data regarding the system and their analysis, for which purpose specially adapted programmes based on a GIS platform are being used.

IT based on GIS has been recognised as one of the key parts of the strategy and programme of leakage control. The reason lies in the fact that this chosen solution for the first time enables the development of a unique IT system which is capable of covering all work processes within the utility company. In order to reduce losses employees of Waterworks Pula today use the following GIS software:

- GIS - Basic module: This is a standard GIS programme which provides a complete database on water supply that is available in every workplace. System information is regularly updated and controlled.
- GIS Module for valve closure: This module has the ability to simulate hydraulic conditions, and after it has been designated to a location on the water supply network it proposes which valves should be closed, and finds all consumers which will thereby remain without water. The module distinguishes parts of the network and consumers who will unconditionally and completely remain without water and parts of the network which will have water until the water tank is emptied. It significantly speeds up work during interventions in repairing losses.
- GIS Records of failures module: The program follows the procedure from the point of notification of failure to the records of completed works on its repair. The strategy of the water supply system rehabilitation is based on the collected records of failures.
- GIS module for linking technical and business information systems: Placing all the consumers into certain space (location, information about consumers) created a connection between the business and technical information system. This module enables the connection of system information with data about consumers (water consumption) and thus helps in monitoring the state of the system, but also for the search of possible illegal users.

- GIS Module for controlling and managing losses: The module registers DMA zones which represent units of supervision and managing losses. The module provides daily monitoring of minimum night flow by DMA areas thanks to an established link with existing systems of remote monitoring and the SCADA system (measurements of flow and pressure are visualised and further processed in a GIS application).

IWA Water Balances can be calculated for the entire system and for each DMA zone. The ability to monitor trends in water consumption readouts collected during the year (monthly, quarterly) is important for an effective control of water loss. It is also possible to make analysis and comparison of key parameters i.e. IWA "Snapshot ILI" indicator in certain DMAs in order to identify priorities for action in the search for leaks. In recent years, an intensive implementation of the IWA methodology began precisely with the aim of introducing a large number of indicators which will allow a better understanding of the situation and planning of future improvements.

The Pula water distribution system is divided into 157 zones; 147 DMA zones, and 10 virtual zones in the city of Pula (the zones cover 100% of the system). Virtual zones were developed from experience considering the complexity of the city network. Where the distribution network is ring-shaped it is difficult to create standard DMA zones because of the need to close a large number of boundary valves and use many measurement locations or, create very large zones what would reduce efficiency in finding leaks. Creating virtual zones and estimating the position of measuring installations are based on test measurements in winter and summer periods. Based on this, measurements have been set on pipelines with large day-night fluctuations in flow, mostly pipelines with larger profile. Sizes are determined according to the current state of water supply or according to the possibilities of avoiding investment in the construction of the water supply network, and meeting the criteria of hydraulics according to the terrain. The sizes of the DMA zones in the city of Pula are from 5 to 15 km, while in other parts DMA zones are adapted to the size of the settlement and are from 2 to 10 km.

Activities on the control and reduction of apparent water losses

The problem of apparent loss was recognised from the very beginning of dealing systematically with water loss and since then the situation is continuously improving. The following measures and activities can be emphasised:

- The program of monitoring water consumption and selecting the optimum meter for certain categories of consumers.
- The annual audit plan of measurement of large consumers and specific consumers (firefighting use).
- Control Program (daily, weekly) of water meters with high consumption.
- Monthly records of water consumption for system maintenance.
- Sealing of all water meters (theft protection).
- The prosecution of all types of water theft.
- The introduction of remote reading of water meters of larger consumers.

Human resources and working conditions

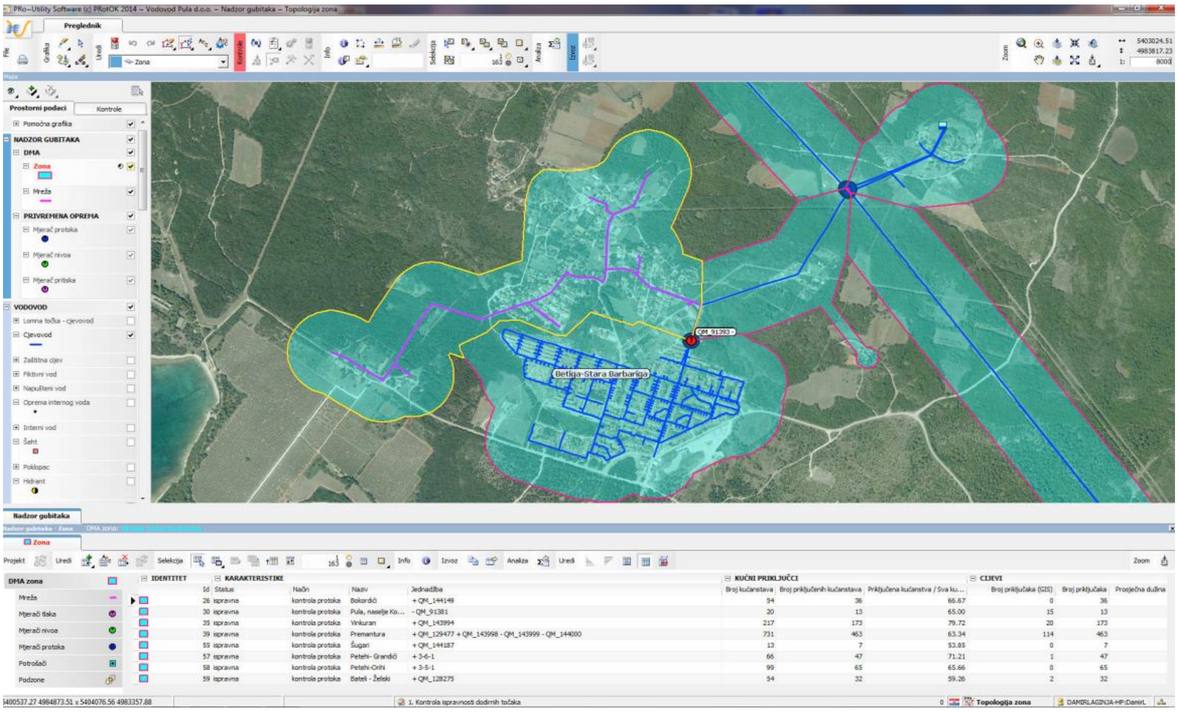
Equipping, organising and training personnel (trainings, seminars, conferences, literature, etc.) for activities of leakage detection are part of the regular annual improvement program and are identified from the beginning as a key element of the strategy. The management of the company has a clear understanding that only trained, organised and motivated people can achieve results, and technology is only a tool that can help in that.

5.5 Details proven leakage reduction measure(s)

An important part of the approach in managing leakage for these systems is the reduction of leakage in Spring before the influx of summer visitors. Targeted night-time acoustic testing of pipelines is carried out extensively each year in May and June; the oldest parts of the system and elsewhere where frequent leaks were detected are necessarily examined. These tests are conducted by a team for leakage detection and another team works during the day to resolve reported leaks. The rest of the year two teams cover the activities of reported leakages and unreported leakages i.e. monitoring the DMA zones (and testing in zones when an increase in the minimum night flow is noticed).

Most of the DMA and PMA zones were introduced into the system of remote monitoring and analysis of indicators. What is special in Waterworks Pula is the application of so-called virtual zones which are applied in system areas where the introduction of standard DMA zones is technically complex and financially overwhelming (with closed boundary valves and a small number of measured input / output). In this way the most complex part of the urban system is monitored, covering 70km of pipelines i.e. 8% of the total network. For virtual zones insertion flow meters are used which also perform pressure measurement and detection of noise in the appearance of leaks (these instruments cover only selected reference sites where it is possible to notice that leaks have occurred in the virtual zone). Further improvements of control in virtual zones will be the introduction of permanent (or frequent occasional) monitoring for leaks using noise loggers. In other parts of the system standard DMA zones are applied (92% of the network covered) thereby using one to two measured and remotely monitored locations.

Considering the large number of DMAs (and related measuring locations) and limited workforce, it was very important and beneficial to use advanced IT solutions based on GIS applications. The following screenshot shows what a DMA zone looks like when visualised in a GIS application for tracking losses in the system. This application was developed based on Waterworks Pula specifications by a Croatian company specialised in GIS solutions.



Systematic approach and continuity in action have proven to be effective, which is evident from the data on the reduction of losses in recent years.

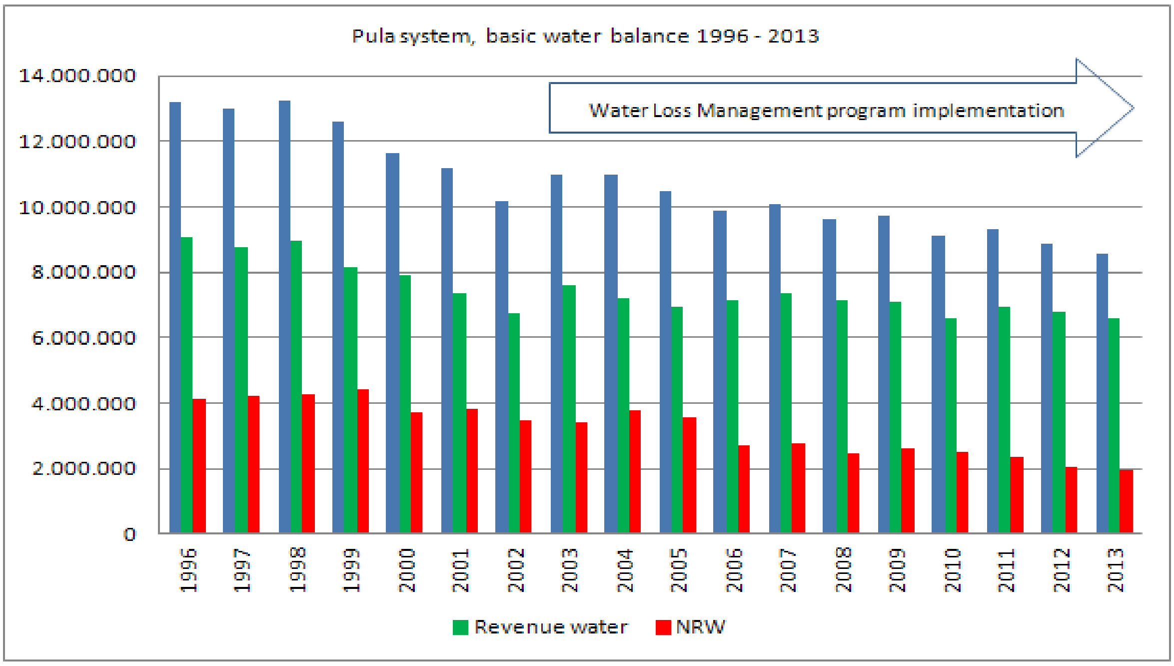


Figure 8 – Results of the Water Loss Management Programme at Pula (1996-2013).

Comments and results of the implementation process

From 2005 to 2007 investments were made in basic equipment for loss analysis (mobile ultrasonic flow meter, correlator, pressure loggers) where a relatively small investment produced an initial reduction in NRW. From 2007 to 2013 continuous investments were made in the zoning system by installing control measurements with remote controls, investments in GIS applications and by creating DMA zones. With this further investment a continuous reduction in loss is evident. Investments regarding the upgrading of SCADA, installation of measuring and noise meters in the city of Pula area are 25 electromagnetic flow, pressure and noise meters, installation of 150 control water meters and remote monitoring of flow and pressure on water meters and updates of the GIS modules, total cost approximately € 700.000.

From 2004 till 2013 NRW was reduced from 34,5% to 22,8%. Considering problems in presenting losses in %s Waterworks Pula introduced use of other indicators based on IWA methodology (ILI, CARL in litres/service connection/day) and for 2013 ILI was 2,9 (among the best waterworks in Croatia). The volume of NRW in 2004 was 3,77 Mm^3, and in 2013 it was 1,94 Mm^3, making a difference of 1,83 Mm^3 (48,5% savings in volume), but making also a financial impact by reducing expenses for more than € 700.000 in one year!

From the above we can see that the funds that were invested in a couple of years in the development of the system are being returned through savings in water losses and through reduction of the cost of managing and maintaining the system.

Legislation and financial framework

According to the Law on Financing Water Management (regulated by government agency Croatian waters) since 1st January 2015 the base for calculating fees for water use is the quantity of abstracted water in m^3 (which will additionally increase the production cost of water).

The previous regulations that were in force failed to initiate care for reducing losses and loss control in the water supply system, namely provisions regulated the collection of fees for water use based on the quantity of water supplied to the final consumer. In practice this meant fees based on invoiced amounts of water. This way of charging neglected the problem of water losses in water supply systems, so we had cases where the ratio of abstracted and delivered water was over 70% in some systems in Croatia.

The current Law on Water and the Law on Financing Water Management prescribes the fee for water use based on volumes of abstracted water and beginning of such a calculation starts with 1st January 2015. In 2014 this new higher fee was introduced to costs of water delivered (causing increase of consumer price) but from 2015 all NRW will be subject of new fee obligation, and thus it is clear that attention is paid to the issue of reducing losses in water supply systems. Also in preparation is part of this new regulations that should specify the correction coefficients and coefficients of acceptable technical loss, and by which methodology should the loss in water supply systems be calculated. This means that different fee categories would be used (lower fee for small losses and greater fee for large losses). Intention is to use IWA methodology and ILI banding categories according to the World Bank Institute Leakage Performance Categories. Important issue for this solution is current lack of accurate data in most of the utilities (length of mains, number and length of service connections, average pressure), but new regulation will create conditions to force necessary improvements.

5.6 Evaluation of further options for pressure management

Pressure control is recognised as an effective measure for water loss control, by reducing leak flow rates but also decreasing the frequency of appearance of new leaks. Continued surveillance of zone flow and pressure data provides data for analysis of the potential for the introduction of pressure control. In the coming period there are three basic priorities (indicators) for the introduction of new pressure control zones:

- Excessive pressure (based on specific zone measurements at key locations).
- The frequency of occurrence of new leaks (leaks statistics and repair).
- PVC pipes older than 20 years, which show the highest sensitivity to pressure evident in the increased number of leaks).

An important part of the activities of pressure control is controlling the operational validity of the equipment with the use of remote monitoring, and analysis with the use of indicators in zones according to the IWA methodology. The continuing improvement of applied technology - introduction of advanced pressure control by applying dynamic pressure changes according to current flow rate.

5.7 Results and recommendations

The Water Balance for Waterworks Pula follows in Section 5.9 at the end of this Case Study.

From presented experience in Waterworks Pula following results can be emphasized:

- Dedicated investments and organisational changes (for example mentioned seasonal dedicated night time acoustic surveys) with clear focus on water loss control and reduction proved to be reasonable and beneficial (NRW in volume reduced by 48% in 10 years, all financial investments already paid-back through savings).
- Implementation of DMAs increases capabilities and reduces time in daily management of water leakages (water distribution systems 100% covered with DMAs, 157 zones in total).

- Understanding influence of pressure helps in water loss management (30% of the network under pressure regulation).
- Understanding apparent losses issue and implementation of corrective actions.
- Use of adequate IT solutions improved maintenance activities and network understanding (applied specially developed and customised GIS applications).
- Recognised importance of own workforce (organisation, clear responsibilities, communication, education).

Recommendations for further improvements:

- Further expansion of pressure control (and improvement of existing installations).
- Use of noise loggers for leak detection (mobile swift and permanent installations with remote readouts).
- Use of Automatic Meter Reading of customers' water meters (better and faster understanding of consumption patterns – especially considering seasonal fluctuations due to tourists).
- Improvement of water consumption measurements (meters with higher accuracy).
- Proactive use of IT solutions (continuous improvements of current GIS tools).
- Active involvement of utility management board in monitoring and planning of water loss management.
- Continuing programs of network rehabilitation (keeping current rate of 2%/year) and use of high quality materials.
- Support in own staff education and further introduction of organisational improvements and rewarding systems.

5.8 References

Habenšus I. and Ž. Mrđen (2014): *Problems for water suppliers with regard to the implementation of the new base for the calculation of fees for the water supplied*. Association of Water Utilities in Croatia, Conference in Cavtat, Croatia, October 2014.

Baćun A., Kovač J. et al (2012): *GIS software module for leakage monitoring and analyses*. International conference Water Loss Europe 2012, Ferrara, Italy, May 23-25.

5.9 Water Balance Pula System (year 2013)

DATA COLLECTION WORKSHEET FOR CASE STUDIES, BEST PRACTICE ON LEAKAGE REDUCTION					Version 2e	23-09-2014	by ILMSS Ltd
THIS WORKSHEET IS USED TO CALCULATE NON-REVENUE WATER AND ASSESS COMPONENTS NON-REVENUE WATER							
Colour coding:	Data entry	Essential data entry	Default Values	Calculated Values	Data from another Worksheet		
SIMPLIFIED IWA WATER BALANCE CALCULATIONS		Pula, Croatia	Whole System		# Conns =	25.657	
Period of Water Balance	from 01-01-2013	to 31-12-2013	365	days	Mm³	1000 m³/day	lit/conn/day

Enter data for your system in yellow cells. Check the default %s in the purple cells, and change them if you have better information which will improve the reliability of the calculation. Add comments in the Comments Box below.

Component	%	Basis	Mm³	1000 m³/day	lit/conn/day
POTABLE WATER VOLUME INPUT FROM UTILITY TREATMENT WORKS			4,553	12,5	486
Potable Water Imported to this system			4,002	11,0	427
SYSTEM INPUT VOLUME (Potable Water)			8,555	23,4	914
Potable Water Exported from this system			0,034	0,1	4
Potable WATER SUPPLIED TO THIS SYSTEM			8,521	23,3	910
Billed Metered Consumption			6,592	18,1	704
Billed Unmetered Consumption			0,000	0,0	0
NON-REVENUE WATER NRW			1,929	5,3	206
Unbilled Authorised Consumption	0,25%	of Billed Metered Consumption	0,016	0,0	2
WATER LOSSES			1,913	5,2	204
Unauthorised Consumption	1,00%	of Billed Metered Consumption	0,066	0,2	7
Customer Metering Inaccuracies	2,00%	of Billed Metered Consumption	0,132	0,4	14
APPARENT LOSSES			0,198	0,5	21
CURRENT ANNUAL REAL LOSSES CARL			1,715	4,7	183

Information entered by	Jurica Kovac	18-08-2014	Contact	jurica.lovac@mail.com

Comments:

Guideline maximum default %s for assessed components of Non-Revenue Water are shown below:				
If higher figures are claimed they should have been validated by Utility Specific data				
	Unbilled Authorised Consumption	0,50%	of Billed Metered Consumption	excluding Water Exported
	Unauthorised Consumption	0,20%	of Billed Metered Consumption	
Customer Metering Inaccuracies	Direct pressure systems	2,00%	of Billed Metered Consumption	
	Roof storage tanks	5,00%	of Billed Metered Consumption	
	Customer Metering Inaccuracies are positive for under-recording, negative for over-recording.			

		Potable Water Exported WE 0,03 Mm3			
Potable Water Produced from Utility Treatment Works 4,55 Mm3	**System Input Volume SIV (Potable Water)** 8,56 Mm3	**Potable Water Supplied WS** 8,52 Mm3	**Billed Authorised Consumption (excluding Water Exported)** Metered 6,59 Mm3; Unmetered 0,00 Mm3		
Potable Water Imported to this System 4,00 Mm3			**Non -Revenue Water NRW** 1,93 Mm3	**Unbilled Authorised Consumption UAC** 0,02 Mm3	
				Water Losses WL 1,91 Mm3	**Apparent Losses AL** 0,20 Mm3
					Real Losses RL 1,71 Mm3

Pula, Croatia
Whole System
01-01-2013
to
31-12-2013

Infrastructure Parameter				**Performance Indicators for Leakage**					
Distribution mains length		836,0	km	2051	m³/km/year	5,6	m³/km/day	0,23	m³/km/hour
Trunk and Distribution mains length		928,0	km	1848	m³/km/year	5,1	m³/km/day	0,21	m³/km/hour
Service Connections (to 1st meter)		25657	Number	66,8	m³/conn/yr	183	l/conn/day	'per hour' is influenced by Night-Day Factor NDF	
Density of Connections		27,6	No/km	↑ Use PIs above this row to track leakage in individual systems ↑ ↓ Use PIs below this row to compare leakage between systems ↓					
Length of underground Service Connections, Main to first meter		10,0	m/conn	Current Annual Real Losses CARL				1,71	Mm³/year
		256,6	km	Unavoidable Annual Real Losses UARL				0,60	Mm³/year
Average Operating Pressure		40,0	metres	Infrastructure Leakage Index ILI =				2,9	
Annual Repair Frequencies	Mains (UARL)	13,0	/100 km	26,0	per 100 km		which is	2,0	x UARL frequency @ 50m
	Connections (UARL)	3,8	/k conns	5,0	per 1000 conns		which is	1,3	

Comments:	↓ PIs based on %s are for comparison only, not recommended ↓	
	Leakage as % of System Input Volume SIV	20,0%
	Leakage as % of Water Supplied, excluding exports	20,1%

6 Cypriot Case Study: Lemesos

Contribution of Bambos Charalambous.

6.1 Details Water Board of Lemesos and Lemesos

The Water Board of Lemesos, established in 1951, is a semi-government Utility (Legal Person governed by Public Law) run by a Board of Directors appointed by the Council of Ministers and local Municipality appointees. The Board aims exclusively to ensure the supply of sufficient quantity water of good quality and to meet both the households' needs and its consumers' commercial and industrial requirements. The main concern and cornerstone of operations is the best possible service offered to its consumers.

Lemesos, on the south coast of the island, is the second largest town of Cyprus. Ground levels in the 100 km^2 supply area fall from 450 meters at the foothills, to sea level. Ductile iron trunk mains supply water by gravity to nine major pressure zones, each with a dedicated storage reservoir, which in turn supply 60 DMAs, some of which are also individually pressure-controlled. This strategic design has enabled average pressure to be reduced to 40 metres. All customers are metered and all properties have roof tanks.

Country	Basin / Sub-basin	Water service provider	Other key stakeholders
Cyprus	Lemesos	Water Board of Lemesos (WBL)	Water Development Department (WDD)

Table 21 – Geographical context of Water Board of Lemesos (2013).

Characteristic	Value
Population	158.000
Number of billed properties (residential and non-residential)	87.640
Number of service connections (main to first meter)	53.040
Average length of underground service connections	8 m
Length of trunk mains	200 km
Length of distribution mains	820 km
Average operating pressure	40 m
% of time system is pressurised	100% of year
% of total mains length subject to active pressure management	90%
Annual volume of potable water supplied (excluding exports)	13.177 Mm^3/year
Average time from location of mains leaks to shutoff or repair	1 day
Average time from location of service leaks to shutoff or repair	1 day
Leaks on mains (number per 100 km/year)	21/year
Leaks on service connections (number per 1000 connections/year)	22/year
% of system having active leakage control interventions each year	100
Number of water treatment plants	1
Number of pumping stations	10
Number of distribution reservoirs	21
Total number of staff	111
Staff directly involved in water operations	70
Average consumer price	€ 1,00/m^3
Average unit costs of water resource	€ 0,65/m^3
Average unit costs of production and distribution	€ 0,69/m^3
Highest unit cost of production and distribution	€ 0,92/m^3
Energy usage	2,5 million kWh/year

Table 22 – Details water production system and distribution network WBL.

The graph below shows the potable water supplied by the Water Board of Lemesos (WBL) for the year 2013. It shows typical annual variations in the consumption pattern, varying from 38.000 m^3/day on average during the winter months of December – January reaching an average of about 50.000 m^3/day on average in the summer months of June – August.

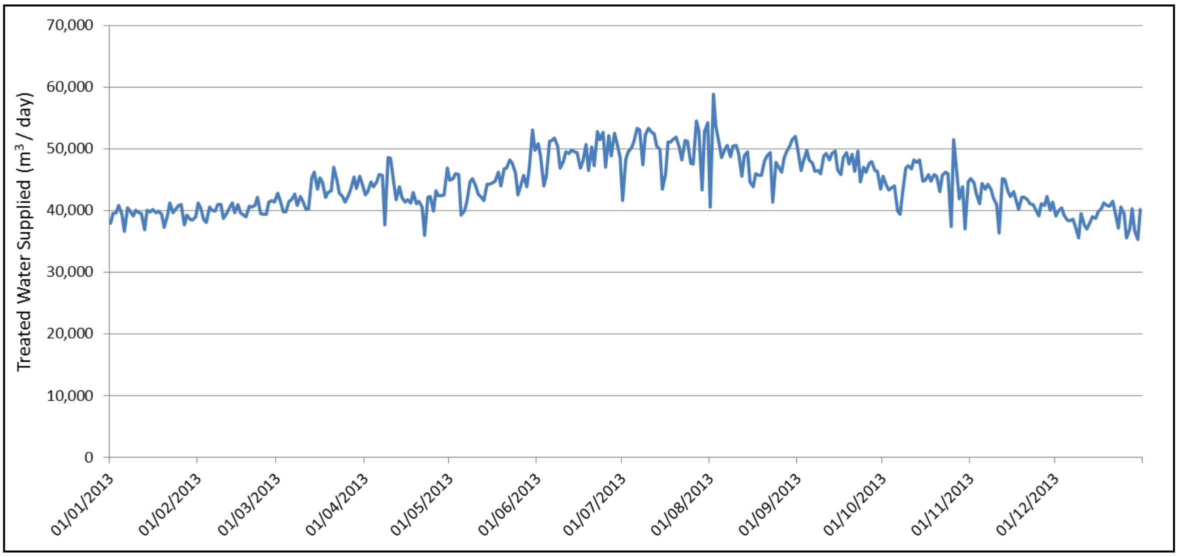


Figure 9 – Water supplied by WBL for the year 2013 in m^3/day.

The specific purpose of this Case Study is to demonstrate the adverse effects of intermittent supply, during droughts. Graphs of aggregate minimum night flows before and after two years of intermittent supply are shown in Section 6.7.

A Water Balance in simplified IWA Water Balance format is enclosed in Section 6.9 at the end of this Case Study.

6.2 Details context Water Board of Lemesos

Precipitation (460 mm annual average, 1971-2010) is confined to November to May, and often two or three or sometimes up to six consecutive dry years are observed. The water resources of Cyprus have been highly developed with the most economically viable projects already implemented, and further exploitation of remaining scarce water resources will be extremely costly. With this in mind the government has adopted a comprehensive and holistic approach to water management encompassing the conjunctive use of surface and ground water, addressing in parallel the interrelation between domestic and irrigation water demands.

Relevant factor	Yes	No
Abundant water resources at a basin level?		√
Limited measures required to improve water status to achieve WFD objectives?	√	
River Basin Management Plan (RBMP) completed?	√	
Active quantity management incorporated in the RBMP?	√	
RBMP harmonised with other key socio-economic and land use planning documents prior to adaptation and incl. financing plans?		√
Abundant water resources for water service provider all year every year?		√
Water resources of good chemical quality (low or no treatment)?		√
Water resources located at topographical levels above the level of the customer base (low or no energy costs)?		√

Relevant factor	Yes	No
Are the economics of density reasonable (> 20 connections per km)?	√	
Cost effective investment and operating conditions?	√	
Distribution network designed for ease of operation and maintenance without maximum pressure stresses?	√	
Pressure Management implemented throughout the system?	√	
District Metering implemented throughout the system?	√	
Good quality of the network installation (materials selection and workmanship at the time of installation)?	√	
Water pricing limitations?	√	
Conflicting socio-economic needs and/or historical legacy?	√	
Public affordability constrains?	√	
Ability- / willingness-to-pay constraints?	√	
Benefitting from EU Funds to finance significant water supply (and urban wastewater) treatment investments?		√
Specific Regulator (Utility subject to regulation)?		√

Table 23 – Specific context within which Water Board of Lemesos is operating.

In order to eliminate the dependency of the towns and tourist centres on annual rainfall and in view of the increasing water demand the Government constructed seawater desalination plants serving each town.

Rota cuts had to be implemented in the 1997 to 2000 drought. By 2007, Water Board of Lemesos had reduced leakage to under 92 litres/connection/day (ILI 1,96) by creating additional pressure managed DMAs, but in the 2008 and 2009 drought, water cuts were imposed nationally on irrigation and public water Utilities, and intermittent supply had to be introduced again, despite tankering of water by ship from Athens to maintain reduced domestic supplies.

Cyprus is progressing towards full implementation of the European Union (EU), Water Framework Directive. The EU Water Framework Directive (WFD) sets out the basis for achieving a vision for water management and Cyprus is totally committed to the efficient and effective implementation of its principles and provisions.

6.3 Overview leakage measures and indicators implemented at WBL

The development of the distribution network took place in an organised fashion with new areas of supply being incorporated into their respective pressure zones, strictly governed by the areas ground contours. Each pressure zone is subdivided into DMAs, a total of 60 are currently operating, which have a single metered source with physical discontinuity of pipe work at boundaries.

Pressure management has been practically applied to the DMAs with fixed downstream pressure being the basic form of pressure control. Where possible further pressure control has been applied using advanced techniques such as flow modulation, multi-point control or critical point control thus driving leakage to even lower levels.

Leakage interventions are based on Minimum Night Flow monitoring in each DMA prioritising according to the value of water being lost in each DMA and the number of Equivalent Service Pipe Bursts present. Speed and quality of repair policy is such that almost all leaks are fixed on the same day. Interventions are also focused on apparent losses such as meter under registration, stopped meters and illegal connections.

Implemented measure on leakage assessment and reduction	Yes	No
Reliable Bulk Supply Metering	√	
Reliable District Metering	√	
Reliable Customer Metering	√	

Implemented measure on leakage assessment and reduction	Yes	No
Good System Design and Installation	√	
Effective Management of Excess Pressure and Pressure Transients	√	
Speed and quality of repairs	√	
Active Leakage Control at an economic frequency	√	
Sectorisation and/or District Metering Area formation	√	
Asset Renewal: service connections	√	
Asset Renewal: mains	√	
Annual Volume of Real Losses (Level of Leakage, CARL)	**Value**	
2013	2,46 Mm^3/year	
Leakage Indicators used at *Water Board of Lemesos*	**Value**	
Litres per connection per day	127	
ILI	2,5	

Table 24 – Implemented leakage measures and indicators at Water Board of Lemesos.

6.4 Details strategy, monitoring methods and leakage indicators

The Water Board of Lemesos operates a well-organised water supply system, which is imperative for the proper management of the network. The network zoning and DMA design and the application of pressure reduction has produced favourable results with both background leakage and locatable losses being reduced. Furthermore the frequency of new reported leaks was reduced through the reduction of Pressure Management.

The DMAs vary in size from 50 to 7.000 properties with the average size being approximately 3.000 properties. Distribution main diameters within the DMAs vary between 100mm and 250mm and where possible, interconnecting ring systems within the DMAs have been formed to minimize head loss at peak demands.

The Water Board of Lemesos has maintained records of its operational activities since 1963, which include production of water from sources, distribution through district meters and consumption from consumer meters. Meter readings at water sources (boreholes and treatment plant) are connected via a SCADA telemetry system to the control room. This enables continuous monitoring of the water source outputs and accurate recording of flows. Likewise storage reservoir outlet meters are monitored on SCADA providing the same ability to observe trends as well as to record daily, weekly, monthly and yearly totals.

As all the trunk mains, made of ductile iron, are purely dedicated to transferring water from sources to the storage reservoirs, it is possible to carry out a water balance between production meters and storage reservoirs outlet meters. The results show that on a yearly basis the difference between the production meters and reservoir outlet meters is less than 1% which is considered to be negligible and is attributed to meter registration errors.

Distribution of water to the DMAs is effected through dedicated ductile iron mains from the storage reservoirs. Each network zone has its own dedicated storage reservoir supplying the DMAs within the specific zone. Each DMA has a single feeding point, which is metered. With this arrangement it is possible to carry out a water balance between the storage reservoir outlet meter and the DMA meters. The results show that on a yearly basis the difference is about 2%, which is attributed to meter inaccuracies. Therefore it could safely be assumed that all real water losses are within the DMAs.

In 2002 the Water Board of Lemesos embarked on the redesign of its network management creating smaller and more manageable DMAs with continuous flow and pressure monitoring as well as pressure control. The key factors for good DMA design (Water Loss Task Force, 2004) formed the basis of the redesign. These were:

- Minimum variation in ground level across the DMA.
- Easily identified boundaries that are robust.
- Area meters correctly sized and located.
- Single entry point into the DMA.
- Discrete DMA boundaries.
- Pressure optimised to maintain standard of service to customers.
- Degree of difficulty in working in urban area.

The variation in ground levels across the supply area was examined and particular attention was given to the influence of the pressure within the DMAs. Main highways and physical features such as streams were chosen to form discrete boundaries between DMAs. A single entry point into the district was chosen where a meter chamber was constructed to house the district meter, a pressure reducing valve and a pressure sensor. It must be stressed that the implementation of the redesign was not an easy task due to the difficulties and restrictions imposed in executing works in built up areas. These works involved inter alia, the construction of new district meter chambers, laying new lengths of pipeline and installation of new telemetry system for continuous monitoring of flow and pressure.

The redesign process yielded DMAs of smaller, more manageable size with physical pipework discontinuity between DMAs. In order to verify that all interconnecting pipes between DMAs were located and isolated, a zero pressure test was carried out which involved closing the valve at the inlet to the DMA thus isolating the DMA and observing that the pressure within the DMA dropped immediately indicating that all interconnecting pipes were isolated. This test was usually carried out between 02:00 and 04:00 in the morning in order not to inconvenience consumers.

For the effective operation of the DMAs, a reliable continuous monitoring system was established gathering flow data used for Minimum Night Flow (MNF) analysis in order to assess leakage. For this purpose each district meter is equipped with a programmable controller which is powered in most cases by solar energy panels providing a cheap and effective solution. The continuous monitoring of the district meters combines information technology and telecommunication networks to transfer the data via the World Wide Web.

Between 2002 and 2007, leakage was reduced from 138 to 92 litres/connection/day, and ILI from 2,66 to 1,96. During the creation of 14 additional pressure managed DMAs in Pressure Zones 1 and 2 in 2005, WLTF prediction methods for reductions in background leakage were confirmed, and reported leaks were reduced by 45% on mains and 40% on service connections (in line with initial international prediction methods developed by WLTF in 2006).

After intermittent supply had to be used again to combat the water shortages in 2008 and 2009, Water Board of Lemesos prepared and published a detailed post-event analysis of this event in what is normally a well-managed continuously pressurised distribution system. This has important lessons for any Utility contemplating similar actions in drought. Adverse effects on the of the distribution system integrity, leakage levels and costs, are discussed and quantified below.

6.5 Details proven leakage reduction measure(s)

The leakage reduction measures applied by the Water Board of Lemesos are solely based on the IWA Water Loss Task Force four leakage control strategies to reduce Real Losses, namely: active leakage control, pressure management, speed and quality of repairs and targeted renewal of infrastructure. These had to be balanced in order to achieve the most cost effective leakage programme which reduced leakage to an economically, environmentally and socially acceptable level as indicated in Section 6.4. This approach is well tested and has been applied around the globe with extremely positive results for utilities.

A permanent leak detection team which focused solely on leak detection activities was established and the latest technology available in leak detection equipment was procured to improve the efficiency of the full time leakage staff in detecting leaks under difficult situations. This equipment included leak noise correlators, leak noise loggers and electronic sounding equipment. Suitable transport for the leakage team was made available. The basic leak detection techniques applied included:

- Locate (Leak Noise Loggers).
- Localise (Leak noise correlators).
- Pin-point (Ground microphone.

Coupled with the Active Leakage Control the Water Board of Lemesos placed great emphasis in minimising the awareness time of a leak. This was achieved by having a smaller more manageable size DMAs which are continuously flow monitored with data sent on a daily basis to the control centre. As and when leaks are picked up by the Leakage Engineer monitoring the Minimum Night Flows, the Active Leakage Control team is deployed to survey the DMA which takes about 3-4 days on average. This has been an important point in the design of the DMAs, to have continuous flow monitoring and a reasonably small size DMA so that any new leak appearing will be a substantial proportion of the Minimum Night Flow, thus easily recognisable, and a relatively small size DMAs thus locating the leak in a very short period of time.

It should also be emphasised that both the backlog leak detection activities and the permanent Active Leakage Control resulted in the requirement for enhanced leak repair capability. The key to effective leak control was not just the detection of outstanding leaks, but that the leaks were repaired in a timely manner whilst ensuring good quality. Once a burst or leak has been located, the rapid shutoff and repair of the leak is a fundamental aspect of leakage management. To achieve this the Water Board of Lemesos set up a priority procedure for repairing both reported and detected leaks. The target is to repair leaks within 24 hours.

Clearly the quality of materials and workmanship adopted for the repair was also of importance. A poor quality repair will often mean that a leak will re-occur within hours or days of the mains being re-pressurised and effectively, the leak repairs are not sustainable and leaks that are supposedly repaired will continue to run. It was essential that the quality of materials and workmanship employed by the Water Board of Lemesos were of the highest standard.

The physical relationship between leakage flow rates and pressure is well proven. Consequently, by lowering pressure to the absolute minimum required to maintain an adequate level of service to all customers, 20m at the customer's water meter, within the distribution network, it was possible to reduce the leakage rates from all types of leaks with extremely positive results as indicated in Section 6.4 of this Case Study.

The Water Board of Lemesos replaced old pipelines which were repeatedly presenting problems. The decision to replace pipelines was based on leak clustering data thus targeting the section of the network with the worst record in breaks.

In the longer term, Active Leakage Control procedure at the Water Board of Lemesos includes monitoring of leakage levels in the DMAs. After all the leaks in the DMAs were repaired, a period of monitoring and maintenance began. During this period, the flow into the zone was continually monitored and analysed using software based on Background and Bursts component analysis. Of course it was inevitable that new leaks occurred within the zones and it was necessary at some point to carry out further leak detection surveys and repair exercise.

The point at which subsequent interventions took place was determined separately for each DMA using this method. For each zone, an intervention (entry) level for losses was set and whenever this level was reached due to the natural rate of rise of leakage, a leak detection and repair exercise was carried out to bring the leakage level back down to the original baseline or exit level. The long-term average leakage level for each DMA would lie between the intervention (entry) and exit levels that are set.

This concept of regular intervention into each DMA determined by the setting of intervention (entry) and exit levels would ensure sustainability of the results achieved during the backlog leak detection exercise over a long period of time. It will also ensure that leak detection resources are efficiently utilised in finding leaks in those DMAs where the greatest number of leaks exist and can be found. It will avoid the wasteful allocation of resources to leak detection exercises in DMAs where there may be little or no leakage.

6.6 Evaluation of further options for pressure management

Management of pressure is a key factor in an effective leakage management policy. This has long been recognised by the Water Board of Lemesos and all DMAs are equipped with PRVs to reduce pressure where possible and to control and stabilise pressure in DMAs where pressure reduction is not practicable. Advanced pressure management techniques such as flow and time modulation and critical point control are used with extremely beneficial results. Further pressure management options are now very limited.

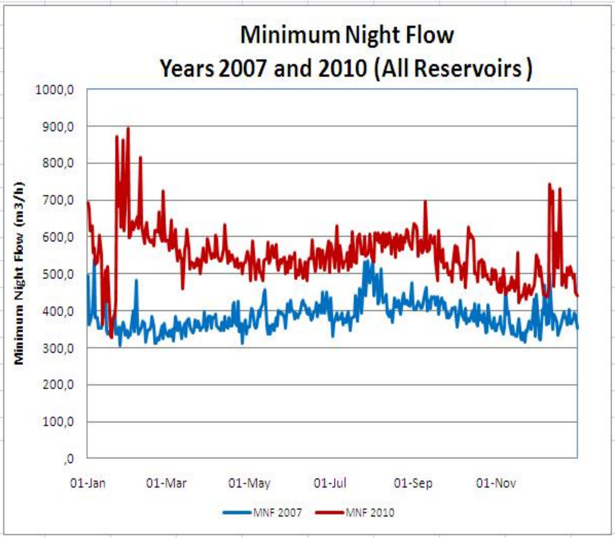
6.7 Results and recommendations

The Water Balance for 2013 follows in Section 6.9 at the end of this Case Study.

Numbers of reported pipe breaks increased substantially during the period of intermittent supply in 2008 and 2009. A comparison for 20 District Metered Areas showed a 300% increase in mains breaks and a 200% increase in service connection repairs between 2007 and 2010, the year after the measures were lifted.

A significant number of unreported breaks, caused by frequent emptying and refilling of the network, did not surface as the network was not pressurized for any significant length of time; nor was there opportunity to locate these by active leakage control without water in the mains. Minimum Night Flow in all DMAs had increased by 164 m^3/hour (see graph).

1 January to 30 December				
	2007	2010	Difference	
Zone 1	5,185,434	5,808,271	622,837	
Zone 2	5,150,320	5,497,431	347,111	
Zone 3	939,659	1,073,681	134,022	
Z4 Ag.Phila	180,690	152,175	-28,515	
Zone 5	141,591	114,837	-26,754	
Zone 6	83,118	134,086	50,968	
Zone 7	20,759	21,509	750	
Total (m^3)	11,701,571	12,801,990	1,100,419	9.40%
MNF (aver.)	385	549	164	m^3/h (period)
Consumers	60,730	66,684	5,954	
Night use	103	113	10	m^3/h
	392,419	430,892	38,473	m^3 (period)
Background losses & Bursts	5,914	9,149	3,235	m^3 (per day)
	1,969,454	3,046,663	1,077,210	m^3 (period)
	16.83%	23.80%	6.97%	
Night use + Background losses & Bursts	2,361,873	3,477,555	1,115,683	m^3 (period)



The table adjacent to the graph shows that, after adjustment for night use by consumers, the MNF increase represented a 1,08 Mm^3/year (55%) increase in annual leakage. This is more than the annual average volume of water saved (0,80 Mm^3) by intermittent supply during 2008 and 2009.

The Table below provides further evidence to substantiate the increase in leakage caused by the intermittent supply measures. This shows an increase of 12,8% in the System Input Volume for the year 2010 compared with year 2007 without a corresponding increase in customer consumption, which was slightly less than in 2007.

Year	System Input Volume	Customer Consumption
2007: Before Intermittent Supply	Base line 0%	Base line 0%
2008: Intermittent Supply	-17,5%	-9,2%
2009: Intermittent Supply	-9,1%	-8,9%
2010: After Intermittent Supply	+12,8%	-1,2%
2011: Continuous supply	+7,6%	+2,1%
2012:Continuous supply	+5,6%	+2,3%
2013: Continuous supply	+2,0%	+6,0%

Lemesos: System Input Volume vs. Customer Consumption.

The problem of this additional leakage continues to burden the Utility. By 2013, leakage of 127 litres/connection/day had still not fully returned to 2007 levels, and it would not be at all surprising if intermittent supply has increased undetectable background leakage at joints and fittings. So even when the backlog of additional leaks have been found and successfully repaired, the extra leakage caused by the intermittent supply will result in an extra demand on water resources in subsequent years, advancing the onset of the next period of shortage, with a higher base level of leakage in the distribution system.

The implementation of intermittent supply has a direct financial cost to the water utility, which has been assessed as follows for the two years of intermittent supply:

- Loss of revenue due to reduced sales of water: €0,300 million
- Additional costs of staff overtime: €0,365 million
- Cost of repairing additional pipe breaks: €0,325 million

€0,995 million, €0,50 million/year

These short term and relatively easily quantified costs are substantially exceeded by the additional bulk purchase costs (€1,6 million) for the additional post-drought leakage of 1,84 Mm^3 in 2010 to 2013, which only gradually reduces after 2010, but may not disappear completely due to higher background leakage caused by damage to joints and fittings. Consider also that numerous complaints were received from disgruntled consumers regarding quality problems and lack of pressure during intermittent supply. Intermittent supply caused serious disruption and upheaval to daily activities of people whether these were at home or at work, which has not been included in this analysis.

It is evident from the data and information presented in this case study that although intermittent water supply may seem to have been a solution to a water shortage situation in overall terms, the water balance was adversely affected. Supplying less quantity in an intermittent manner causes such deterioration to the network that when continuous supply is re-established additional quantities are lost through increased leakage, which in fact places an added financial burden on the utility.

Intermittent supply operation clearly has a detrimental effect on the integrity of good networks. The amount of water 'saved' is later 'lost' and in greater quantities through increased levels of leakage. Such operational conditions should be avoided especially in systems that have been designed for continuous supply. Over the past 15 years, this and other international experiences by WLTF members have led to the conclusion that it is definitely preferable to operate a distribution system continuously, even at low pressures, than to operate intermittent supply – which has led to the successful implementation of 24:7 policies in India. The fall in ground levels across many Lemesos DMAs limited the use of this option, which has been used in parts of Brazil during drought.

It has also been shown that domestic demand is this case was inelastic and quantities of water saved by customers were very small. Structured conservation programmes, introduced as part of an overall strategy for water conservation, may have achieved better results.

6.8 References

Lambert A., B. Charalambous, et al (2014): *14 years' Experience of using IWA Best Practice Water Balance and Water Loss Performance Indicators in Europe*. IWA Specialised Conference 'Water Loss 2014", Vienna, Austria. Conference Proceedings.

Charalambous B. (2011): *The effects of Intermittent Supply on Water Distribution Networks*. IWA Efficient 2011 Conference, Dead Sea, Jordan, Proceedings.

Charalambous, B. (2007): *Effective Pressure Management of District Metered Areas*. IWA Specialised Conference "Water Loss 2007", Bucharest, Romania. Proceedings pages 241-255.

Charalambous, B. (2005): *Experiences in DMA redesign at the Water Board of Lemesos, Cyprus*. Specialised Conference on Leakage, Halifax, Nova Scotia, Canada. Proceedings pages 403-413.

6.9 Water Balance Water Board of Lemesos

DATA COLLECTION WORKSHEET FOR CASE STUDIES, BEST PRACTICE ON LEAKAGE REDUCTION					Version 2e	23-09-2014	by ILMSS Ltd
THIS WORKSHEET IS USED TO CALCULATE NON-REVENUE WATER AND ASSESS COMPONENTS NON-REVENUE WATER							
Colour coding:	Data entry	Essential data entry	Default Values	Calculated Values	Data from another Worksheet		

SIMPLIFIED IWA WATER BALANCE CALCULATIONS		Lemesos WB, Cyprus	Whole System			# Conns =	53.050	
Period of Water Balance	from 01-01-2013	to 31-12-2013	365	days		Mm³	1000 m³/day	lit/conn/day
Enter data for your system in yellow cells. Check the default %s in the purple cells, and change them if you have better information which will improve the reliability of the calculation. Add comments in the Comments Box below.	POTABLE WATER VOLUME INPUT FROM UTILITY TREATMENT WORKS					0,000	0,0	0
	Potable Water Imported to this system					13,177	36,1	681
	SYSTEM INPUT VOLUME (Potable Water)					13,177	36,1	681
	Potable Water Exported from this system					0,000	0,0	0
	Potable WATER SUPPLIED TO THIS SYSTEM					13,177	36,1	681
	Billed Metered Consumption					10,120	27,7	523
	Billed Unmetered Consumption					0,000	0,0	0
	NON-REVENUE WATER NRW					3,057	8,4	158
	Unbilled Authorised Consumption	1,20%	of Billed Metered Consumption			0,121	0,3	6
	WATER LOSSES					2,936	8,0	152
	Unauthorised Consumption	0,20%	of Billed Metered Consumption			0,020	0,1	1
	Customer Metering Inaccuracies	4,50%	of Billed Metered Consumption			0,455	1,2	24
	APPARENT LOSSES					0,476	1,3	25
	CURRENT ANNUAL REAL LOSSES CARL					2,460	6,7	127
Information entered by	Bambos Charalambous	25-07-2014		Contact		bcharalambous@cytanet.com.cy		

Comments: Properties in Cyprus have roof tanks, so customer meter under-registration is higher than for direct pressure plumbing systems. The Customer Metering Inaccuracies error of 4.5% is based on field tests which were carried out to determine the meter under-registration based on the customer meters installed in the system. These meters were of the volumetric type Class "C" and Class "D".

Guideline maximum default %s for assessed components of Non-Revenue Water are shown below:				
If higher figures are claimed they should have been validated by Utility Specific data				
	Unbilled Authorised Consumption	0,50%	of Billed Metered Consumption	excluding Water Exported
	Unauthorised Consumption	0,20%	of Billed Metered Consumption	
Customer Metering Inaccuracies	Direct pressure systems	2,00%	of Billed Metered Consumption	
	Roof storage tanks	5,00%	of Billed Metered Consumption	
	Customer Metering Inaccuracies are positive for under-recording, negative for over-recording.			

		Potable Water Exported WE 0,00 Mm3				Lemesos WB, Cyprus Whole System 01-01-2013 to 31-12-2013
Potable Water Produced from Utility Treatment Works 0,00 Mm3	System Input Volume SIV (Potable Water) 13,18 Mm3	Potable Water Supplied WS 13,18 Mm3	Billed Authorised Consumption (excluding Water Exported) Metered 10,12 Mm3 Unmetered 0,00 Mm3			
Potable Water Imported to this System 13,18 Mm3			Non -Revenue Water NRW 3,06 Mm3	Unbilled Authorised Consumption UAC 0,12 Mm3		
				Water Losses WL 2,94 Mm3	Apparent Losses AL 0,48 Mm3	
					Real Losses RL 2,46 Mm3	

Infrastructure Parameter			Performance Indicators for Leakage					
Distribution mains length	820,0	km	3000	m³/km/year	8,2	m³/km/day	0,34	m³/km/hour
Trunk and Distribution mains length	1020,0	km	2412	m³/km/year	6,6	m³/km/day	0,28	m³/km/hour
Service Connections (to 1st meter)	53050	Number	46,4	m³/conn/yr	127	l/conn/day	'per hour' is influenced by Night-Day Factor NDF	
Density of Connections	52,0	No/km	↑ Use PIs above this row to track leakage in individual systems ↑ ↓ Use PIs below this row to compare leakage between systems ↓					
Length of underground Service	8,0	m/conn	Current Annual Real Losses CARL				2,46	Mm³/year
Connections, Main to first meter	424,4	km	Unavoidable Annual Real Losses UARL				0,97	Mm³/year
Average Operating Pressure	40,0	metres	Infrastructure Leakage Index ILI =				2,5	
Annual Repair Frequencies — Mains (UARL)	13,0	/100 km	21,0	per 100 km		which is	1,6	x UARL frequency @ 50m
Annual Repair Frequencies — Connections (UARL)	3,5	/k conns	22,0	per 1000 conns		which is	6,2	

Comments:	↓ PIs based on %s are for comparison only, not recommended ↓	
	Leakage as % of System Input Volume SIV	18,7%
	Leakage as % of Water Supplied, excluding exports	18,7%

7 Danish Case Study: VCS Denmark Odense

Contribution of Erling Nissen and Steen Jakobsen.

7.1 Details VCS Denmark

VCS Denmark is a Danish water and wastewater company with more than 150 years of operational experience in water supply and wastewater management - and a strong tradition for innovation. VCS Denmark is the third largest water and wastewater company in Denmark, operating 7 waterworks, 8 wastewater treatment plants and 3.400 km of water and wastewater pipeline networks. VCS Denmark is known as a frontrunner in the Danish water and wastewater sector. We have supplied the city of Odense with clean drinking water since 1853. Today we are a modern water and wastewater company with approximately 200 employees.

Table 26 shows the technical key figures for VCS Denmark water supply.

Country	Region / City	Water service provider	
Denmark	South Denmark / Odense	VCS Denmark	

Table 25 – Geographical context of VCS Denmark.

Characteristic	Value
Population	160.000
Number of meters	49.384
Number of service connections (main to first meter)	33.230
Average length of underground service connections	15 m
Length of trunk mains	185 km
Length of distribution mains	818 km
Average operating pressure	30 m
Average age of the pipeline network	28 years
% of time system is pressurised	100 % of year
Annual volume of potable water supplied	9,1 Mm^3/year
Average time from location of mains leaks to shutoff or repair	4 hours
Average time from location of service leaks to shutoff or repair	4 hours
Leaks on mains (number per 100 km/year)	1,8 No/year
Leaks on service connections (number per 1000 connections/year)	1,2 No/year
Number of water treatment plants	7
Number of pumping stations	14
Number of distribution reservoirs	2
Total number of staff	200

Table 26 – Details water production and distribution *VCS Denmark*

Figure 10 on the next page shows the water volume pumped out per year and the number of inhabitants supplied. In the late seventies some parts of the water-consuming industry left the city of Odense, but also environmental awareness and especially the high costs of water and wastewater in Denmark are the reason for this development with strongly declining water consumption. It is not only in the city of Odense but generally throughout Denmark, that we see this development (in Denmark both water and wastewater are charged after the water meter). Figure 11 on the next page shows the development of the price for water and waste water per m^3.

Household consumption has declined from 153 l/day/inhabitant in 1994 to 101 l/day/inhabitant in 2013 in the city of Odense.

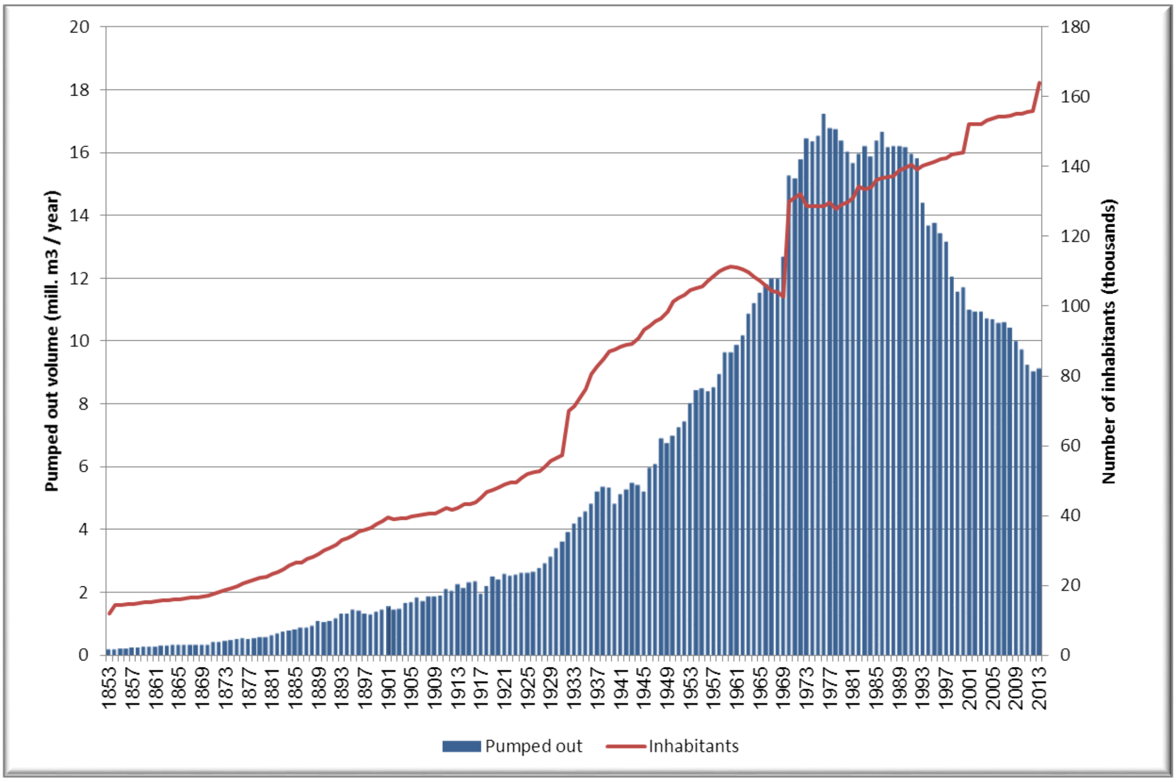


Figure 10 – Development pumped out volume and inhabitants VCS Denmark.

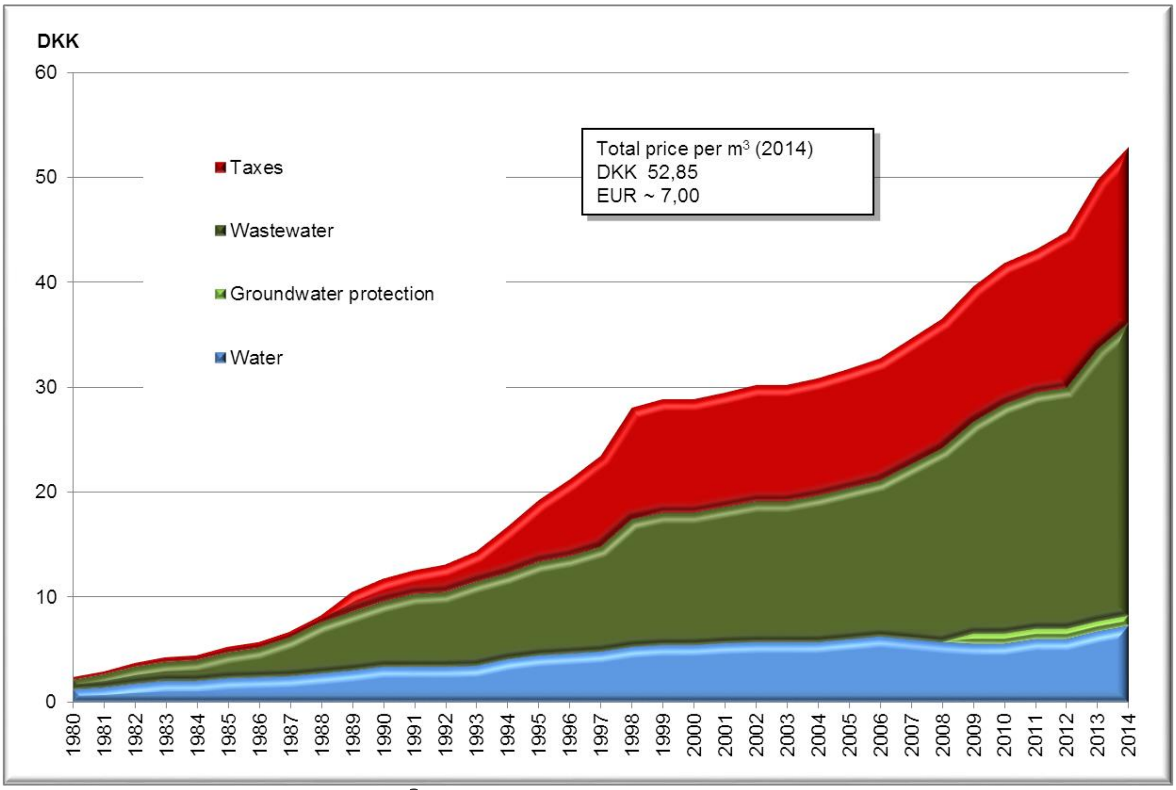


Figure 11 – Development in m^3 price 1980-2014.

These conditions, with decreasing consumption and a growing distribution network, in conjunction with the Danish legislation to water companies limiting maximum loss to 10% of the abstracted water (water loss above 10% would lead to an additional tax of

6.13 DKK per m^3), is of course a challenge for the Danish water companies, but also the reasons they are searching for all possibilities to reduce the water loss. In Denmark there must be one meter per property. Old buildings with apartments can do with a meter for the entire property. The water loss is calculated as pumped amount – sold amount.

7.2 District zoning of water network and rehabilitation

VCS Denmark have since the start of 1993, as the first water company in Denmark, carried out a district zoning of the pipeline network from a big inter-connected network system, into a ring connected main network and a unified supply system divided in district metering areas (DMAs). The purpose of dividing the supply net into DMAs can be summarized as follows:

- Registration of district consumption, instantaneous and totals.
- Leakage detection of pipe bursts and pressure registration/surveillance.
- Unified distribution system with a possibility to limit pollution by closing and if necessary then changing over the supply for the DMA.
- Controlled water distribution in the DMA (no unmetered zones).
- Trunk mains as long unbroken stretches without branch connections (prepared for NO DIG renovation).
- Data for a network simulation program.

The idea for the district zoning was created in connection with a pipeline network analysis carried out in 1991-1992. The network analysis was initiated with the purpose to get a documented basis to make a plan of action for the future rehabilitation of the pipeline network. The main elements in this plan were as follows:

- Renewal of worn pipes in accordance with fixed net analytic criteria.
- Minimization of losses due to leakage in the pipeline network.
- Zoning of the pipeline network in districts.
- Development of a SCADA system for the distribution network.
- Initiation of a gate valve activating program.

At the end of 1998, the first 21 DMAs had been equipped with district measuring devices and connected to a new developed SCADA system. The DMAs communicate with the SCADA system by GPRS (General Packet Radio Service) mobile Internet services. To-day there are 63 DMAs in function and the SCADA system covers in total more than 95 % of the supply system.

Average figures for a district at VCS Denmark
2.150 inhabitants supplied
140.000 m^3 annual consumption
650 meters
460 service connections
11 km water mains

Figure 12 on the next page shows the principle of the new design of the distribution system. The green lines are trunk mains (no service connections). The red and blue lines are distribution mains.

By establishing of a district, all ring connections are “cut off” and a main connection from the nearest main pipe is established. The supply is hereby changed to a unified system whereby the water from the main pipe is distributed in the district according to the branch principle.

At the inlet to the district, a metering manhole is established equipped with the necessary measuring devices for district monitoring. Out of consideration for the security of supply an alternative supply pipe connection (emergency supply) is established to the district. This will normally be closed.

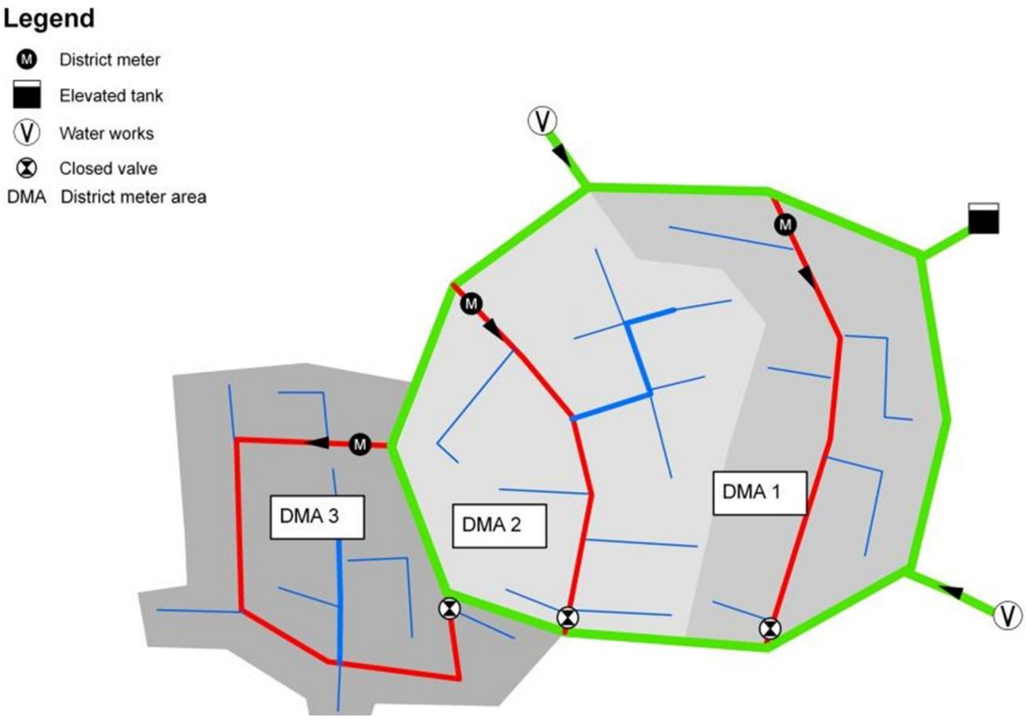


Figure 12 – Principle for the district zoning of the supply system.

It is very easy to perform leak detection using "step test" by opening and closing the valves on the red distribution mains and checking the night flow on SCADA system.

Figure 13 – District meter manhole (left) and installation cabinet for district meter.

In order to measure the lowest consumption at night accurately enough to be used for leakage control, the pipes are reduced both outside and inside the manhole and most of the districts are equipped with a 50 mm meter.

VCS Denmark has renewed and relocated 267 km of mains from 1990 to 2013. The figure below shows that it is mainly old cast iron mains replaced by PE pipes.

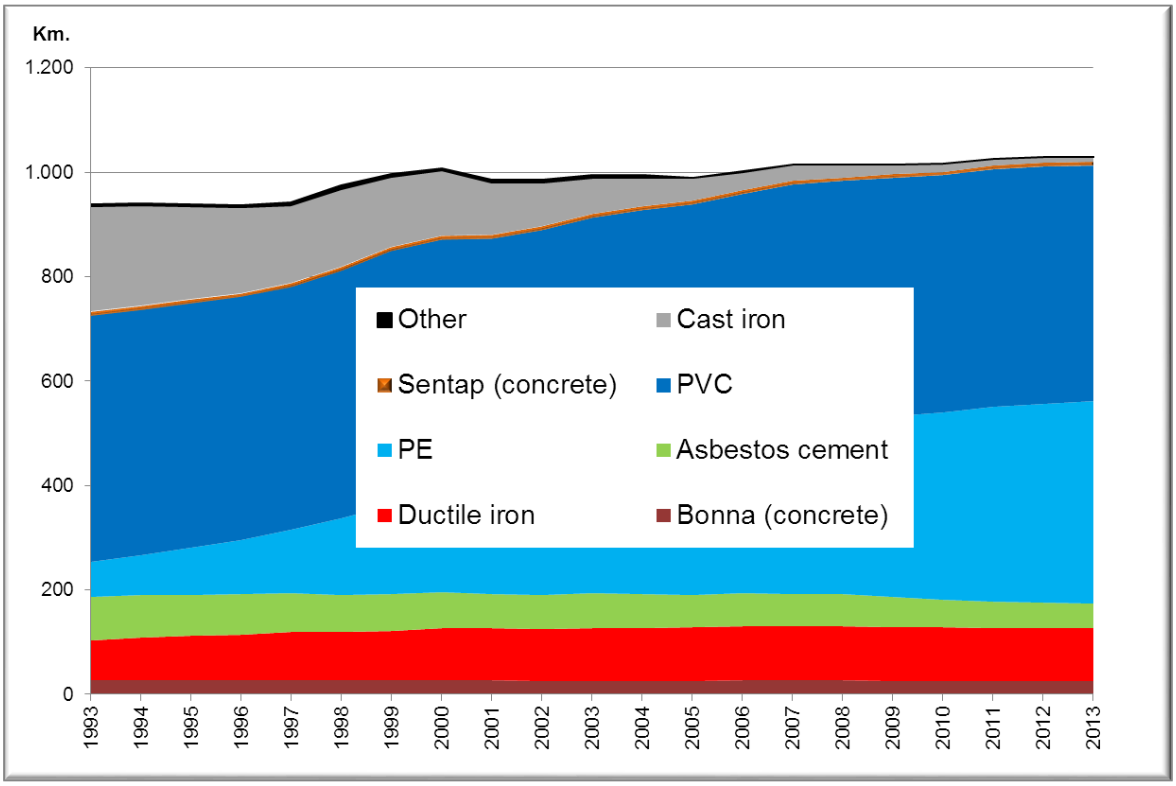


Figure 14 – Development in pipe materials 1993 - 2013.

The aim for VCS Denmark is to get a fully welded distribution system with as few mechanical connections as possible. When we renew our part of the service pipe, we offer the homeowner a subsidy, free pipe and welding, if they also renew the private part of the service pipe, and more than 90% of homeowners accept and do so.

7.3 The effect of the district zoning and rehabilitation

The effect from the district zoning and the rehabilitations program is clearly seen on the burst registry and the amount of water loss. Figure 15 on the next page shows the burst registry and causes of burst from 1986 to 2013. It shows also that it took some years before the effect of the rehabilitations program were evident.

Figure 16 shows the total loss of water from 1995 – 2013 and also here it is clear to see the effect. Apparent losses in Odense are minimal, so leakage is almost the same as water losses.

Figure 17 shows that there is a very good correlation between the number of burst/repairs and the water loss.

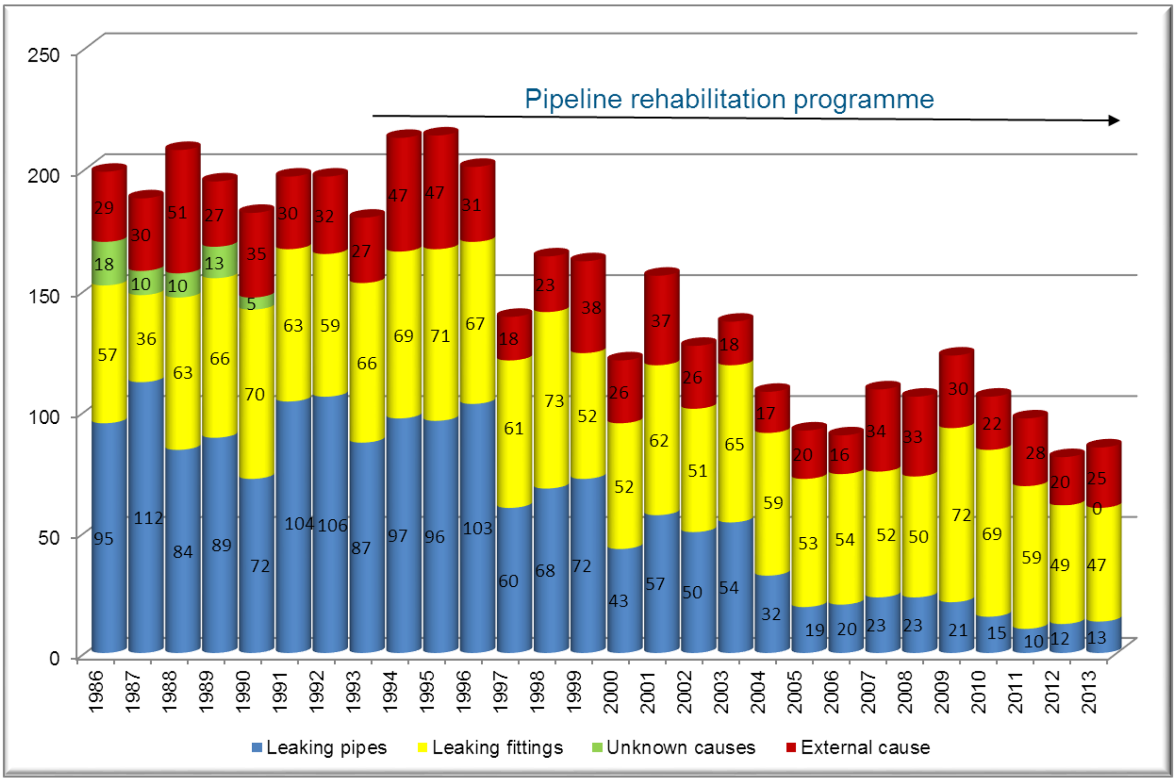


Figure 15 – Number of repairs 1986 – 2013.

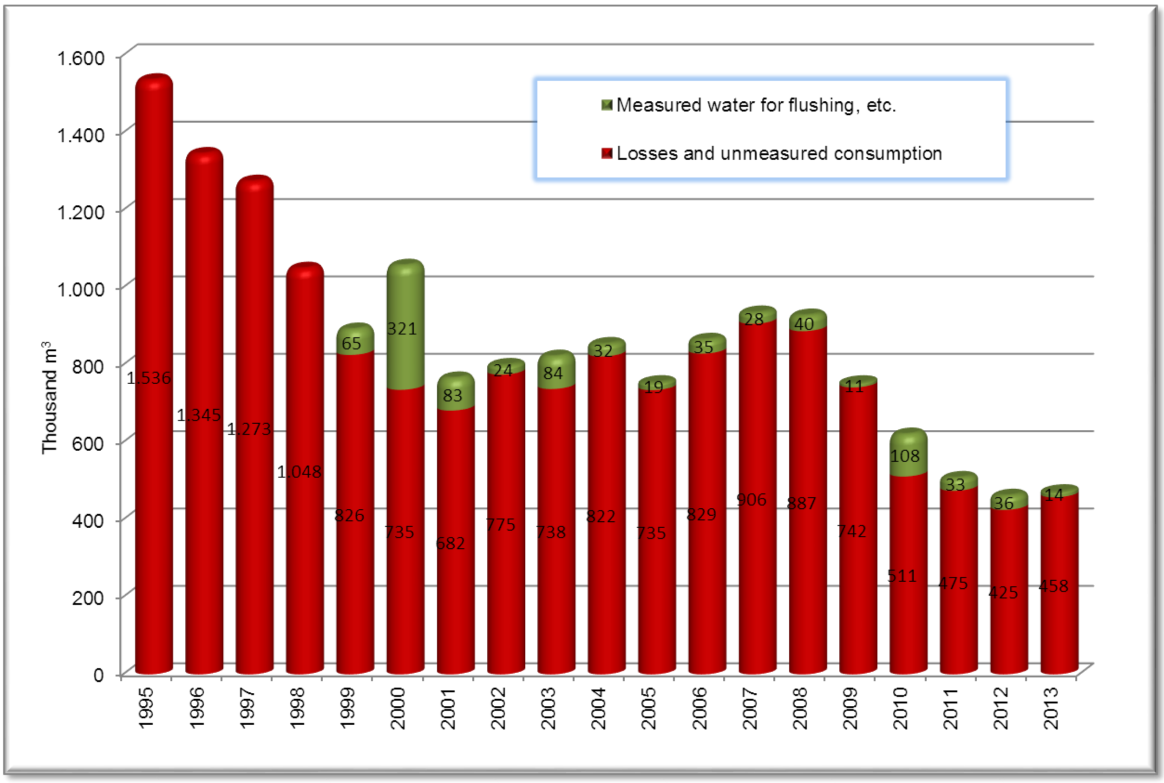


Figure 16 – Water loss 1995 - 2013.

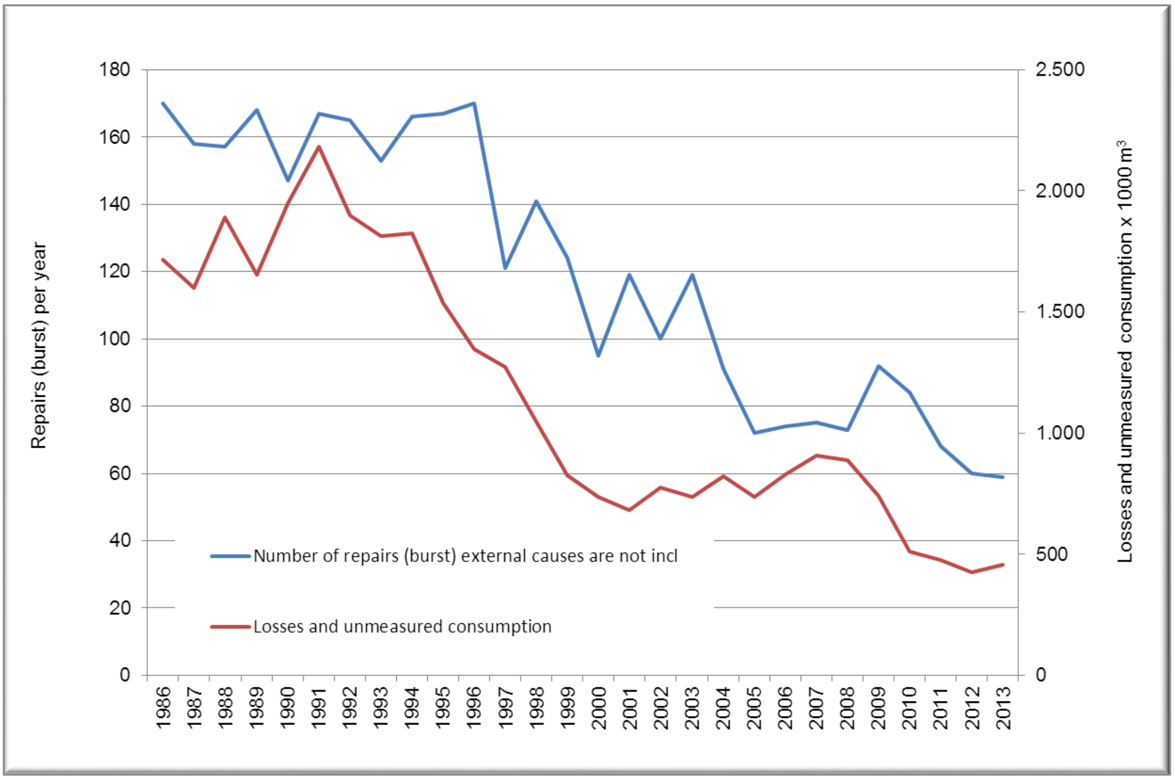


Figure 17 – Water loss and repairs (burst) 1986 – 2013.

Implemented measure on leakage assessment and reduction	Yes	No
Reliable Bulk Supply Metering	√	
Reliable District Metering	√	
Reliable Customer Metering	√	
Good System Design and Installation	√	
Effective Management of Excess Pressure and Pressure Transients	√	
Speed and quality of repairs	√	
Active Leakage Control at an economic frequency	√	
Sectorisation and/or District Metering Area formation	√	
Asset Renewal: service connections	√	
Asset Renewal: mains	√	
Annual Volume of Real Losses (Level of Leakage, CARL)	**Value**	
2013	0,41 Mm^3/year	
Leakage Indicators used at VCR Denmark	**Value**	
ILI	0,7	
NRW as % of System Input Volume	4,5%	
m^3/km of mains/day	1,1	
Average Pressure	30 m	

Table 27 – Implemented leakage measures and indicators at VCS Denmark.

7.4 Design of pressure zones at VCS Denmark

The topography in the supply area varies from -2 m to 105 m above sea level. VCS Denmark design the pressure zones so that the costumers have from 20 to 50 m water pressure at ground level. That results in relatively many small pressure zones but it also means that the average pressure in the network can be sustained at approximately 30m. VCS tries to avoid pressure reducing valves due to the loss of energy. In the supply area there are 13 small pressure zones with a population from around 60 to a few thousand inhabitants, and two zones with approximately 100.000 and 50.000 inhabitants. It is in the two large zones that the district zoning has been established.

7.5 Dynamic pressure control

The pressure zone with approximately 50.000 inhabitants are supplied form 5 booster stations and one waterworks. Previously the pressure was maintained from one central booster station, and fixed pumps on the other booster stations were switched on after a scheme based on experience of the consumption pattern in the zone.

In 2013 Schneider Electric developed a new module for network simulation program AQUIS in cooperation with VCS Denmark. The network model calculated, on the basis of online values from the DMAs and the boosters stations, the optimum pressure that the 5 booster stations and waterworks must provide, to keep a pressure of minimum 20m anywhere in the network. The model calculates these set points every 5 minutes and sends them to the SCADA system which regulates the pumps in the booster stations and the waterworks. This dynamic control make a smoother regulation and the pressure is generally lower in the entire network. Because the model calculates at online values it adapts constantly and automatically changes the consumption pattern. The lower pressure and the smooth regulation will result in fewer bursts, less leakage and save energy.

7.6 Results and further steps

The aggregate Water Balance for VCS Denmark follows in section 7.7 at the end of this Case Study.

The results shown in Section 7.3 of this Case Study are is mainly due to the active leakage control in the DMAs and the replacement of the old fragile cast iron pipes but also the spirit of the company and by the staff who always are willing to try new approaches that can help in the right direction, have had an influence. The low water loss in general is also a result of the relatively low pressure in the network, that is made possible by the strategy for design of the pressure zones.

Further steps includes a pilot project that VCS Denmark has initiated about installation of electronic meters by all costumers in an DMA. One of the objective of this project is to gain experience of how to get the best benefits out of the new opportunities, also for leakage detection in the network.

Another project that VCS Denmark is involved in deals with updating a program that utilizes all the data that is available in the GIS system and all other systems about the distributions network, such as pipe material, dimension, age, length, burst statistics, actual burst, cost for renewal, social costs and all other relevant information that can be obtained. The program will form a ranking, budget and other decisions such as e.g. how big an amount water loss you want, provide the best offer for how much, where and when to renew mains and illustrate the consequences of the choices you have made in a report.

7.7 Water Balance VCS Denmark (year 2012)

DATA COLLECTION WORKSHEET FOR CASE STUDIES, BEST PRACTICE ON LEAKAGE REDUCTION					Version 2e	23-09-2014	by ILMSS Ltd
THIS WORKSHEET IS USED TO CALCULATE NON-REVENUE WATER AND ASSESS COMPONENTS NON-REVENUE WATER							
Colour coding:	Data entry	Essential data entry	Default Values	Calculated Values	Data from another Worksheet		

SIMPLIFIED IWA WATER BALANCE CALCULATIONS		Denmark	Odense		# Conns =	33.230	
Period of Water Balance	from 01-01-2012	to 01-01-2013	366	days	Mm³	1000 m³/day	lit/conn/day
Enter data for your system in yellow cells. Check the default %s in the purple cells, and change them if you have better information which will improve the reliability of the calculation. Add comments in the Comments Box below.	POTABLE WATER VOLUME INPUT FROM UTILITY TREATMENT WORKS				9,133	25,0	751
	Potable Water Imported to this system				0,000	0,0	0
	SYSTEM INPUT VOLUME (Potable Water)				9,133	25,0	751
	Potable Water Exported from this system				0,000	0,0	0
	Potable WATER SUPPLIED TO THIS SYSTEM				9,133	25,0	751
	Billed Metered Consumption				8,661	23,7	712
	Billed Unmetered Consumption				0,000	0,0	0
	NON-REVENUE WATER NRW				0,472	1,3	39
	Unbilled Authorised Consumption	0,50%	of Billed Metered Consumption		0,043	0,1	4
	WATER LOSSES				0,429	1,2	35
	Unauthorised Consumption	0,20%	of Billed Metered Consumption		0,017	0,0	1
	Customer Metering Inaccuracies	0,00%	of Billed Metered Consumption		0,000	0,0	0
	APPARENT LOSSES				0,017	0,0	1
	CURRENT ANNUAL REAL LOSSES CARL				0,411	1,1	34
Information entered by	Erling Nissen	25-07-2014	Contact				
Comments:							

Guideline maximum default %s for assessed components of Non-Revenue Water are shown below:				
If higher figures are claimed they should have been validated by Utility Specific data				
	Unbilled Authorised Consumption	0,50%	of Billed Metered Consumption	excluding Water Exported
	Unauthorised Consumption	0,20%	of Billed Metered Consumption	
Customer Metering Inaccuracies	Direct pressure systems	2,00%	of Billed Metered Consumption	
	Roof storage tanks	5,00%	of Billed Metered Consumption	
	Customer Metering Inaccuracies are positive for under-recording, negative for over-recording.			

Potable Water Produced from Utility Treatment Works 9,13 Mm3	**System Input Volume SIV (Potable Water)** 9,13 Mm3	**Potable Water Exported WE** 0,00 Mm3			**Denmark**
					Odense
					01-01-2012
					to
					01-01-2013
		Potable Water Supplied WS 9,13 Mm3	**Billed Authorised Consumption (excluding Water Exported)** Metered 8,66 Mm3; Unmetered 0,00 Mm3		
Potable Water Imported to this System 0,00 Mm3			**Non -Revenue Water NRW** 0,47 Mm3	**Unbilled Authorised Consumption UAC** 0,04 Mm3	
				Water Losses WL 0,43 Mm3	**Apparent Losses AL** 0,02 Mm3
					Real Losses RL 0,41 Mm3

Infrastructure Parameter			**Performance Indicators for Leakage**					
Distribution mains length	818,0	km	504	m³/km/year	1,4	m³/km/day	0,06	m³/km/hour
Trunk and Distribution mains length	994,0	km	415	m³/km/year	1,1	m³/km/day	0,05	m³/km/hour
Service Connections (to 1st meter)	33230	Number	12,4	m³/conn/yr	34	l/conn/day	'per hour' is influenced by Night-Day Factor NDF	
Density of Connections	33,4	No/km	↑ Use PIs above this row to track leakage in individual systems ↑ ↓ Use PIs below this row to compare leakage between systems ↓					
Length of underground Service	15,0	m/conn	Current Annual Real Losses CARL				0,41	Mm³/year
Connections, Main to first meter	498,5	km	Unavoidable Annual Real Losses UARL				0,59	Mm³/year
Average Operating Pressure	30,0	metres	Infrastructure Leakage Index ILI =				0,7	
Annual Repair Frequencies: Mains (UARL)	13,0	/100 km	1,8	per 100 km		which is	0,1	x UARL frequency @ 50m
Annual Repair Frequencies: Connections (UARL)	4,5	/k conns	1,2	per 1000 conns		which is	0,3	
Comments:			↓ PIs based on % are for comparison only, not recommended ↓					
			Leakage as % of System Input Volume SIV				4,5%	
			Leakage as % of Water Supplied, excluding exports				4,5%	

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8 English Case Study: Anglian Water

Contribution of Stuart Trow and Sean McCarthy.

8.1 Details Anglian Water

Anglian Water is one of 10 privately owned regional water and sewerage companies in England and Wales. There are a further 9 water only companies, all of which are regulated by a number of organisations. For leakage management, Ofwat requires an annual total leakage key performance indicator (KPI) in mega litres per day (Ml/d) based on a standard water balance and agrees annual targets based on a sustainable economic level of leakage (SELL in Ml/d) every 5 years. Environment Agency requires zonal leakage values to be incorporated into Water Resource Management Plans, again every 5 years.

Anglian Water supplies water to approximately 2 million households in East Anglia, the adjacent areas of the South East, Midlands, Yorkshire, Humberside and to households in Hartlepool, a town in the north east of England. Rainfall in most of the Company's supply area is significantly less than the national average; it is classed as an area of severe water stress with many wetland and conservation sites of national and international importance. Anglian Water operates 450 Distribution Zones (DZs) with 1.800 DMAs (virtually total coverage) covering 38.076 km of trunk and distribution mains, of which 24% are actively pressure managed. Flows and pressure are logged, recorded and analysed in the Company's bespoke ILPM (integrated leakage and pressure management) database. About 75% of households (the highest proportion of any UK water company) and almost all non-households are metered. Over 50% of the network is subject to direct pumping which costs £8 million per annum in energy.

Country	Basin / Sub-basin	Water service provider	Other key stakeholders
United Kingdom	Largely the Anglian River Basin, with some overlap into neighbouring regions	Anglian Water	Water Service Regulation Authority (Ofwat), and the UK Environment Agency

Table 28 – Geographical context of Anglian Water (AW).

Characteristic	Value
Population	4.541.561
Number of billed properties (residential and non-residential)	2.026.297
Number of service connections (main to first meter)	1.842.088
Average length of underground service connections	Not recorded
Length of trunk mains	844 km
Length of distribution mains	37.232 km
Average operating pressure	44 m
% of time system is pressurised	100%
% of total mains length subject to active pressure management	24%
Annual volume of potable water supplied (excluding exports)	1.100 Ml/d 401 million m^3/year
Average time from location of mains leaks to shutoff or repair	2,3 days
Average time from location of service leaks to shutoff or repair	5,7 days
Leaks on mains (number per 100 km/year)	12,9 No/year
Leaks on service connections (number per 1000 connections/year)	Not recorded
Number of water treatment plants	140
Number of pumping stations	
Number of distribution reservoirs	330 incl. WT
Total number of staff	3.952
Unit value of leakage	€0,81/m^3

Table 29 – Details water production system and distribution network of AW.

The graph below shows the trend in regional distribution system input (DI in Ml/d) over the past 8 years, showing the correlation with high and low temperature periods, and the number of burst mains. A key challenge of managing leakage in the UK is to take account of an increase in leakage in winter due to frost damage and ground movement, and in late summer due to ground movement following dry spells. The winter of 2010/11 was particularly difficult due to the concentration of burst mains and services in a short period of time. The summer of 2013 was also a challenge, when the peak in DI was caused by a combination of increased leakage and increased customer use.

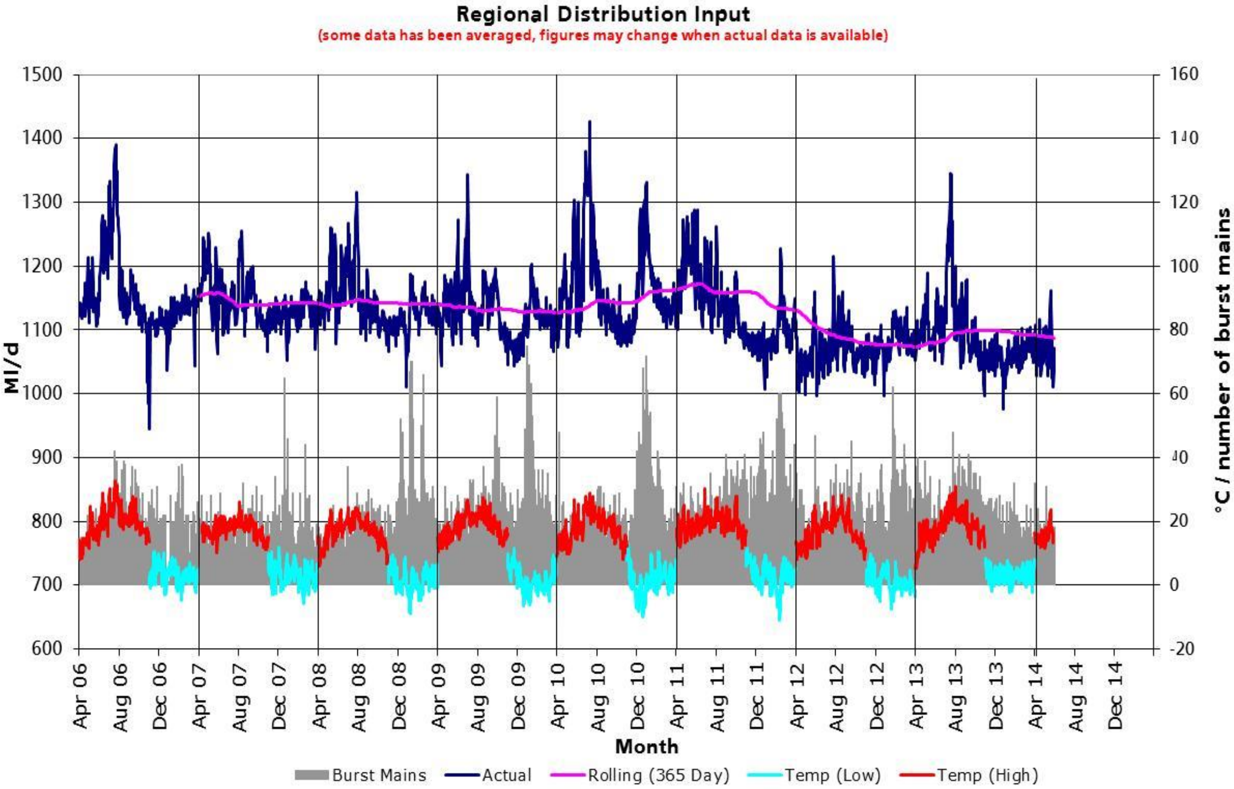

Figure 18 – Trend in regional distribution input for the years 2006 to 2014 in Ml/d.

8.2 Details context Anglian Water

Over the next 25 years, the Company's supply-demand balance is at risk from growth, climate change and the reductions in deployable output that are planned to restore abstraction to sustainable levels. In the worst case, the impact could approach the equivalent of approximately 50% of the water put into supply in 2012/13. The Company also has to manage risks from drought, deteriorating raw water quality and the impact of cold, dry weather on its distribution system and customer supply pipes.

In response, a flexible and adaptive plan has been developed that commits to reducing leakage and consumption by at least 139 Ml/d. It also increases the volume of water traded and transfers resources from areas of surplus to areas of deficit. The demand management measures that will be delivered are cost-beneficial, while the supply-side schemes are the most cost-effective of a large number of alternative options.

Leakage in Anglian Water has been stable for several years with matures leakage management systems, processes and organisation structure.

Relevant factor	Yes	No
Abundant water resources at a basin level?		X
Limited measures required to improve water status to achieve WFD objectives?		X
River Basin Management Plan (RBMP) completed?	X	
Active quantity management incorporated in the RBMP?	X	
RBMP harmonised with other key socio-economic and land use planning documents prior to adaptation and incl. financing plans?	X	
Abundant water resources for water service provider all year every year?		X
Water resources of good chemical quality (low or no treatment)?	In places	
Water resources located at topographical levels above the level of the customer base (low or no energy costs)?		X
Are the economics of density reasonable (> 20 connections per km)?	X	
Cost effective investment and operating conditions?	X	
Distribution network designed for ease of operation and maintenance without maximum pressure stresses?		X
Pressure Management implemented throughout the system?	X	
District Metering implemented throughout the system?	X	
Good quality of the network installation (materials selection and workmanship at the time of installation)?	X	
Water pricing limitations?	X	
Conflicting socio-economic needs and/or historical legacy?	X	
Public affordability constrains?	X	
Ability- / willingness-to-pay constraints?	X	
Benefitting from EU Funds to finance significant water supply (and urban wastewater) treatment investments?		X
Annual Volume of Real Losses (Level of Leakage, CARL)	**Value**	
Total leakage including customer supply pipe losses (Mm^3)	70,34	
Distribution leakage excluding customer supply pipe losses (Mm^3)	56,42	
Leakage Indicators used at Anglian Water	**Value**	
Total Leakage by m^3/per km of main/day	5,1	
Total Leakage Litres/property/day	95	
Total Leakage Litres/connection/day	105	
Total Leakage Ml/d	192,72	

Table 30 – Specific context within Anglian Water is operating.

Water pricing is set every 5 years by Ofwat based on Asset Management Plans (AMPs) prepared by the Company and reviewed by external assurance providers. They are also subject to scrutiny by Customer Challenge groups and willingness to pay is taken into account. Water Resource Management Plans (WRMPs) are prepared for each resource zone (RZ), taking account of the demand forecast, the forecast supply demand balance over a 25 year period, the environmental water quality impacts and sustainability, and all the intervention options available.

Total leakage is calculated using an MLE (Maximum Likelihood Estimation) technique based on the top down water balance, and a bottom up analysis of night flow data from DMAs.

8.3 Strategy adopted, and methods and PIs developed at Anglian Water

In AMP6 for the period 2015 to 2020, the Company will deliver the following combination of cost-beneficial demand management measures and cost-effective supply-side schemes:

- A reduction in leakage from the current 2014-15 SELL of 211 Ml/d to 172 Ml/d.
- The installation of 85.000 household meters, with switching on demand or change of occupancy. This is in addition to 76.000 meter optants and around 1.500 selective (compulsory) meter installations.

- Completion of 180.000 water efficiency audits with free fitting of water saving devices.
- Relocating one of the intakes on the River Wensum, restoring favourable hydro-ecological conditions in the river.
- Transferring additional resources into the Hunstanton RZ, restoring sustainable abstraction to the North Norfolk Chalk.

In addition, the Company will start detailed planning for the delivery of a scheme that will remove the threat of rota-cuts and standpipes for customers in the Ruthamford system. Subject to feasibility and affordability, the rest of this scheme will be delivered in AMP7.

In developing the plan, Anglian Water had to take account of uncertainty in the current assessments of climate change, growth in demand and sustainability reductions:

- Around 15% of the current and future supply-demand challenge will be managed through baseline water efficiency and leakage reduction savings. This is communicated in the "Love Every Drop" campaign and strategy: http://www.anglianwater.co.uk/about-us/our-progress.aspx.
- Around 17% will be managed using the cost-beneficial demand management measures and cost-effective schemes that are planned to deliver in AMP6.
- For the remaining 67% of the challenge, the Company will need to plan for the delivery of additional resources, transfers, trading as well as possible further reductions in consumption and leakage. This work will be planned, in large part, through the AMP6 Water Resources East Anglia project.

Overall, this plan will deliver a flexible and adaptive water resource management strategy for the region, which increases resilience to the effects of drought, climate change and growth. The approach is affordable and sustainable, and balances the future needs of water abstractors, customers and the environment.

8.4 Evaluation of further options for pressure management

Anglian Water has a strategy to deliver a pressure optimisation programme over the next 5 years. Key drivers for this are:

- The Company had experienced a drought which had resulted in a risk to customer supplies.
- Although Anglian Water has one of the lowest levels of leakage in the UK; customer engagement has shown that leakage is still considered to be too high and that they are willing to pay for further reductions.
- To reduce overall costs by improving efficiency and reviewing the balance between capital expenditure and ongoing operating costs.
- The benefits of pressure management in terms of burst rate reduction and reduction in DI are now better understood.

Following a review of the benefits accruing from the schemes completed to date, and their costs, new schemes generated will comprise pressure management across large zones as well as DMAs. It is acknowledged that small reductions in pressure over large areas are more effective than larger reductions in small areas. Anglian Water will focus on areas with the highest operating costs. The high degree of network pumping means that pump control schemes are likely to be a key element of the investment strategy.

The initial corporate targets for the next planning period as follows:

- To increase coverage of pressure management to circa 50% within 5 years.
- To reduce average zone pressure (AZP) from 44 m to 38 m (13% reduction) in the same period.

- To be a major enabler to contribute to leakage target of 172 Ml/d (11% reduction).
- To improved serviceability by reducing mains burst numbers by 30%.
- To save in excess of £8 million Totex (cumulative operating costs and capital.
- To reduce operational carbon by reducing energy consumption.

8.5 Results and recommendations

Anglian Water has developed an Optimised Water Networks (OWN) strategy to make full advantage of the benefits of advanced pressure management and has reorganised to make the transition.

The Company advocated an holistic view in which leakage control and pressure management are considered together taking account of internal and external drivers to develop a sustainable economic strategy. Significant external drivers include the impact of climate change, the need for customer engagement in water efficiency measures.

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9 French Case Study: Beaune

Contribution of Nicolas Rondard and Marion Clauzier (June 13, 2014).

9.1 Overview leakage reduction measures implemented at Beaune

Beaune is a small town in central eastern France of 22.500 inhabitants and of an area of 31 km^2. The drinking water supply network of Beaune supplies 6.350 customers via 150 km of pipes. Beaune has the particularity to be located between the hills and the plain of the Saône so that its unique resource is the resurgence of a small stream. In addition to being restricted, this resource requires a complete water treatment (removal of pesticides and limestone, disinfection), hence leakage reduction is a strong issue to Beaune.

This issue led Veolia Water, through the renewal of the public service contract with the Conurbation authority of Beaune Côte et Sud in 2009, to commit to progressively and significantly improve the efficiency of the network up to reach a target of 80% in 2016 (network efficiency was equal to 70% in 2009). Network efficiency is a French performance indicator defined as following:

$$E = \frac{V_{\text{authorised consumption}} + V_{\text{sold to other services}}}{V_{\text{produced}} + V_{\text{purchased to other services}}} \ (\%)$$

To do this, Veolia Water implemented in 2009-2010 an action plan comprising:

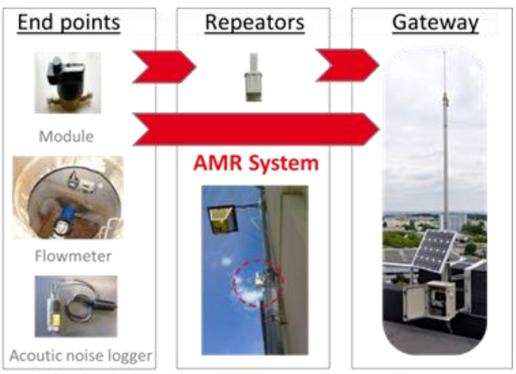
- Deployment of an Advanced Metering Infrastructure.
- Establishment of permanent DMAs and supervision.
- Installation of permanent acoustic noise loggers.

Implemented measure on leakage assessment and reduction	Yes	No
Reliable Bulk Supply Metering		
Reliable Customer Metering	√	
Good System Design and Installation		
Effective Management of Excess Pressure and Pressure Transients		
Speed and quality of repairs		
Active Leakage Control at an economic frequency	√	
Sectorisation and/or District Metering Area formation	√	
Asset Renewal: service connections		
Asset Renewal: mains		

Table 31 – Implemented leakage reduction measure(s) at Beaune.

9.2 Details proven leakage reduction measures Beaune

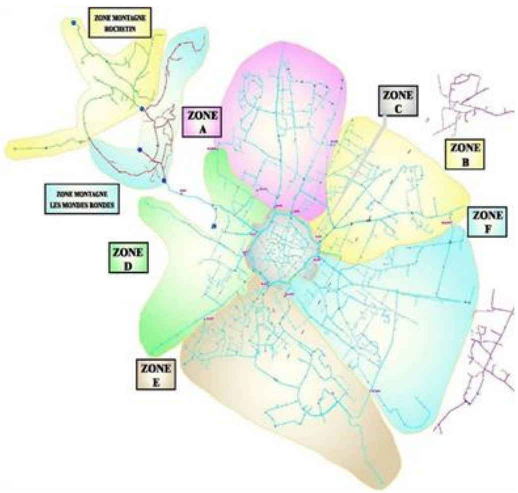
Deployment of an Advanced Metering Infrastructure



The radio communication network has been deployed with Homerider Systems technology (868 MHz band) to collect daily data from 6,350 customer meters equipped with radio module. Data are relayed by repeaters to 3 concentrators and then send via GSM/GPRS to Homerider servers for processing and presentment.

This Automatic Meter Reading system has many advantages for customers such as alarms for potential leakage, back flow incidents and abnormal consumption, and the possibility to monitor their consumption on the Internet.

Establishment of permanent DMAs and supervision

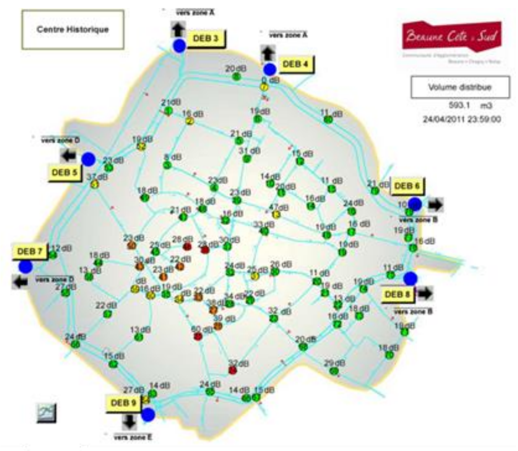


After outline planning of the DMAs, DMA design has been validated using a hydraulic model of the network. This model enabled to analyse boundary valves closure effects on flow distribution through this highly meshed network and so to adjust DMA boundaries while preserving supply security, water quality and fire-fighting, and finally to size flow meters.

The network has been divided into 8 zones of homogeneous distribution, with an average linear of 20 km each. 15 electromagnetic flow meters with remote reading were installed to measure the supplied volumes on each of these zones.

DMA management ensures a daily monitoring of the network efficiency of each zone. The joint analysis of night flows, supplied volumes and consumptions allows the operator to guide quickly leak detection operations.

Installation of permanent acoustic noise loggers



In addition to DMAs establishment, 80 acoustic noise loggers were installed on the city centre old network in order to rapidly and accurately locate leaks in this area. These devices, placed in key holes, listen during the night the noise of the pipes, noise intensity information and confidence factor are daily transmitted through the remote management system. Results are then analysed by means of synoptic maps, dashboards and noise histograms in order to confirm the identification of leaks by noise loggers and/or to identify new ones.

Results

Thanks to these actions, Beaune network efficiency increased by 11 points between 2010 and 2011. In 2012, despite a period of strong frost at the beginning of the year (the number of leaks repaired on pipes doubled between 2012 and the average of the previous years), network efficiency slightly increased compared to 2011. Implementation of DMAs and acoustic noise loggers coupled to AMI has made it possible to react quickly in a targeted way to the emergence of new leaks.

Figure 19 shows the results of the leakage reduction measures in Beaune over the period 2009 up to and including 2012. Leakage reduction results in resource efficiency.

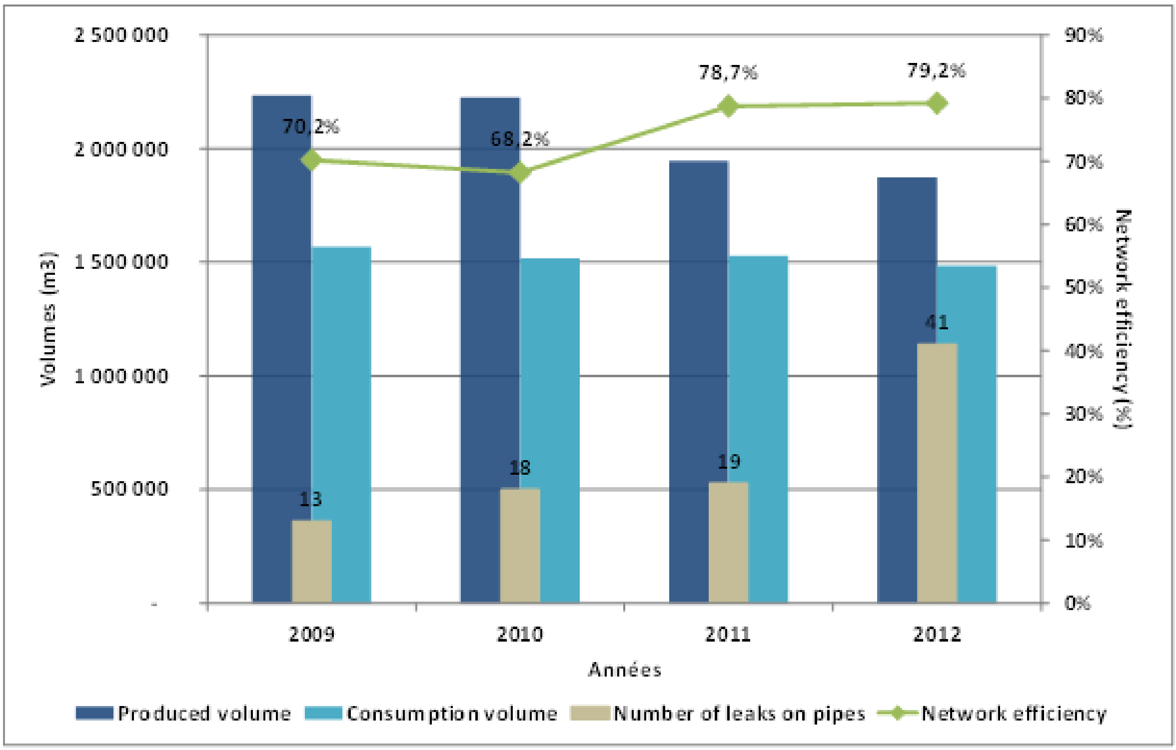


Figure 19 – Results of leakage reduction measures in Beaune (2009-2012).

Regarding the resource, this efficiency in the detection and repair of leaks led to get withdrawal savings of 325.000 m^3/year, which are equivalent to 80 days of water consumption for the city of Beaune. Besides, it generated energy savings of pumping of 250.000 kWh/year and a decrease of the needs in plant reagents.

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10 French Case Study: Bordeaux

Contribution of CTD (Centre Technique Distribution), CIRSEE, Suez Environment.

10.1 Details Communauté Urbaine de Bordeaux (CUB)

The studied system is the water supply system of CUB (Communauté Urbaine de Bordeaux). The CUB and its delegate Lyonnaise des Eaux provide the consumers of 22 cities with high quality underground water resources. The system includes 103 water intake points, 3.132 km water mains (aqueducts included), 130 treatment plants and 49 reservoirs. The whole water production system is monitored and controlled remotely 24 hours a day by the operation centre.

Country	Basin / Sub-basin	Water service provider	Other key stakeholders
France	Adour-Garonne	Lyonnaise des Eaux	

Table 32 – Geographical context of CUB.

Characteristic	Value
Population	724.224
Number of billed properties (residential and non-residential)	246.390
Number of service connections (main to first meter)	201.001
Average length of underground service connections	5 m
Length of trunk mains	185 km
Length of distribution mains	2.909 km
Average operating pressure	37 m
% of time system is pressurised	100 %
% of total mains length subject to active pressure management	33 %
Annual volume of potable water supplied (excluding exports)	47,56 Mm^3
Average time from location of mains leaks to shutoff or repair	3 days
Average time from location of service leaks to shutoff or repair	1,7 days (public)
Leaks on mains (number per 100 km/year)	12 leaks/100km/year
Leaks on service connections (number per 1000 connections/year)	14 No/year
% of system having active leakage control interventions each year	113%
Number of water treatment plants	130
Number of pumping stations	-
Number of distribution reservoirs	50
Total number of staff	700
Average consumer price	€ 3,47/m^3
Average unit costs of water resource	€ 0,38/m^3
Average unit costs of production and distribution	€ 0,0911/m^3
Energy usage	25 million kWh/year

Table 33 – Details water production system and distribution network of CUB.

Figure 20 shows seasonal variation of treated water supplied (excluding exports) in m^3/month.

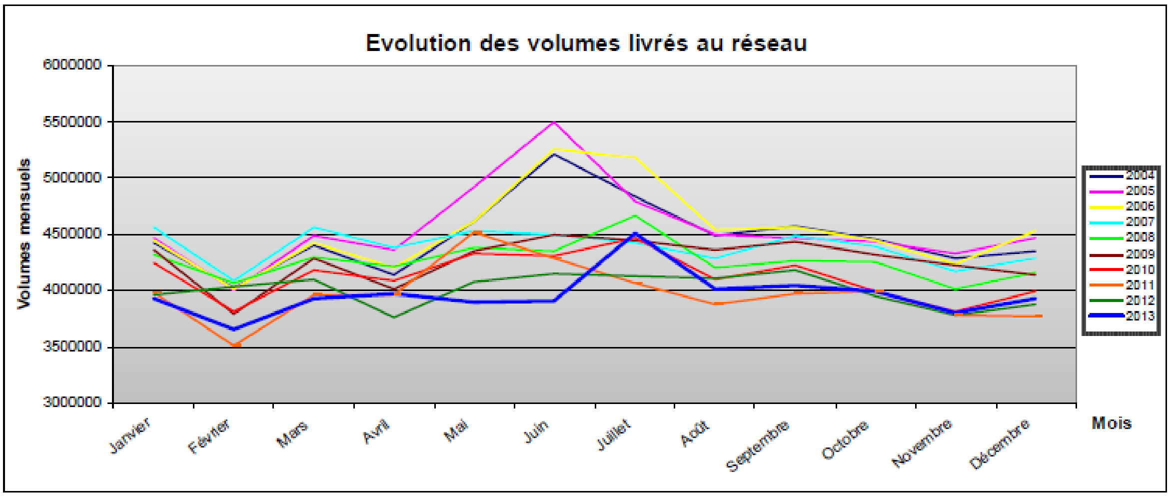


Figure 20 – Water supplied by CUB for the years 2004 to 2013 in m^3/month.

A water balance in simplified IWA Water Balance format is enclosed in Section 10.9 at the end of this Case Study.

10.2 Details context CUB

The CUB via its delegate Lyonnaise des Eaux guarantees water supply with high quality underground water. Among the 103 water intake points, water is extracted from deep wells at 92 points. These days, the CUB has no water quantity and quality problem, however these resources are very fragile, often due to pollutions.

Relevant factor	Yes	No
Abundant water resources at a basin level?	√	
Limited measures required to improve water status to achieve WFD objectives?		
River Basin Management Plan (RBMP) completed?	√	
Active quantity management incorporated in the RBMP?	√	
RBMP harmonised with other key socio-economic and land use planning documents prior to adaptation and incl. financing plans?	√	
Abundant water resources for water service provider all year every year?	√	
Water resources of good chemical quality (low or no treatment)?	√	
Water resources located at topographical levels above the level of the customer base (low or no energy costs)?		√
Are the economics of density reasonable (> 20 connections per km)?	√	
Cost effective investment and operating conditions?	√	
Distribution network designed for ease of operation and maintenance without maximum pressure stresses?	√	
Pressure Management implemented throughout the system?	√	
District Metering implemented throughout the system?*		√
Good quality of the network installation (materials selection and workmanship at the time of installation)?	√	
Water pricing limitations?	√	
Conflicting socio-economic needs and/or historical legacy?		√
Public affordability constrains?		√
Ability- / willingness-to-pay constraints?		√
Benefitting from EU Funds to finance significant water supply (and urban wastewater) treatment investments?		√
Specific Regulator (Utility subject to regulation)?	√	

Table 34 – Specific context within CUB is operating.

10.3 Overview leakage measures and indicators implemented at CUB

The basis of leakage reduction measures implemented within the CUB is a combination of:

- Sectorisation for monitoring volume distribution in large areas and minimum night flows in smaller and more degraded areas. The sectorisation follows a segmentation from larger to smaller zones in order to prioritise the operational workload.
- Classic leak detection using correlators. On the zones that cannot be sectorised, leak research is implemented in order to cover the length at least four times a year. Leak detection teams have a set of very challenging objectives: a maximum of 4km by leak and a large length of leak detection to cover.
- Permanent acoustic leak detection is also implemented for the sub-zones which are identified as leak zones. Nowadays 20% of the network is permanently monitored acoustically.
- Leak repair with the shortest delay possible. The intervention teams are well organised in order to repair the leaks as soon as possible. The objective is to repair leaks within 12 h for big mains (>300mm), 3 days for all the diameters and 1,7 days for service connections in public domain.

The CUB contract has set the objective of performance. If the minimal contract level is not maintained, fees are applied to the delegate. Therefore a large set of measures are implemented to ensure this performance, even if this means deploying a non-economic group of actions in terms of NRW.

Implemented measure on leakage assessment and reduction	Yes	No
Reliable Bulk Supply Metering	√	
Reliable District Metering		√
Reliable Customer Metering	√	
Good System Design and Installation	√	
Effective Management of Excess Pressure and Pressure Transients	√	
Speed and quality of repairs	√	
Active Leakage Control at an economic frequency		√
Sectorisation and/or District Metering Area formation	√	
Asset Renewal: service connections	√	
Asset Renewal: mains		√
Annual Volume of Real Losses (Level of Leakage, CARL)	**Value**	
CARL	7,55 Mm^3/year	
Leakage Indicators used at *Utility*	**Value**	
ILI	2,5	
Leakage rate (leaks/km/year) on pipes	0,12	
Leakage rate (leaks/1000 conn./year) on service connections	14,04	

Table 35 – Implemented leakage measures and indicators at CUB.

10.4 Details strategy, monitoring methods and leakage indicators

The leakage monitoring is based on a segmentation strategy aiming to ensure the right measurement of the "in" and "out" volume of sub-zones by increasing the reliability of bulk water and sector meters and to find rapidly the leaks whenever/wherever they occur.

The whole system is under monitoring permanently using a sectorisation of adapted zone level and with adapted indicators to be monitored. The sectorisation implemented throughout the system consist in:

- 14 large zones (50 to 300 km network, 10.000 to 200.000 connections).
- 40 medium size zones (20 to 100 km with less than 10.000 connections).

- A 3rd level sectorisation is under progress for required areas (where leak rate is higher and assets are classified as degraded according to their function, material, age, etc.).
- Based on the results of asset assessment and leakage detection, step test is used for more precise leaks localisation in some of permanent sectors.

10.5 Details proven leakage reduction measure(s)

The CUB previous strategy was successfully oriented towards pressure modulation. The ongoing strategy now aims to monitor and control the network using sectorisation and leak research. The investigated length using classic leak detection is now the same as before the sectorisation but efficiency is now much more higher (in 2011 in average 3,8 km were investigated per leak detected against 7,1 km investigated before finding a leak in 2008). This is because the areas of research are now prioritised thanks to sectorisation.

10.6 Evaluation of further options for pressure management

The whole system is divided by 8 pressure zones. The average service pressure is 37m. In order to reduce the volume of losses pressure management was implemented for 4 zones covering in total 1.030 km network (33% of total length) since 2009.

A feedback study showed obvious benefits from pressure management in the first two modulated zones:

- Zone 1. Average reduction of 1 bar in daytime and 2 bar in the night for 660 km of network and an initial distributed volume of 37.000 m^3/day.
- Zone 2. Average reduction of 1 bar in daytime and 2 bar in the night for 200 km of network and an initial distributed volume of 10.200 m^3/day.

The results of these zones showed:

- A large decrease on the leak rate:
  - On zone 1: On service connections a reduction from 23 leaks per 1000 connections to 14 leaks per 1000 connections, so a 44% reduction. On water mains a reduction from 0,15 leaks per km to 0,13 leaks per km.
  - On zone 2: On service connection a reduction from 20 leaks per 1000 connections to 7 leaks per 1000 connections, so a 53% reduction. On water mains for the second zone benefits were not found, on the contraire leaks on mains passed from 0,14 leaks per km to 0,17 leaks per km. The reason to explain this odd evolution was the climatic changes that affected strongly the iron water main in the second zone (65% of Cast Iron).
- A volume of losses and therefore a distributed volume decrease of 19%.
- No significant effect on the consumption in the modulated areas.

Pressure modulation was a very good way to optimise the CUB performance. NRW level reduced from 20,39% in 2009 to 18,56% in 2010 and finally 15,61% in 2011. However this improvement was not only achieved with pressure modulation, the replacement of black polyethylene connections was also very beneficial during these years, which is a very important issue at the moment.

Nowadays a pilot site is identified in one of the others pressure zones for an advanced modulation solution but large projects such as the ones presented above are no longer viable.

10.7 Results and recommendations

The Water Balance for CUB follows in Section 10.9 at the end of this Case Study.

CUB started in 2009 a long process with the aim of reducing NRW using pressure modulation. Through this process a better performance was obtained and the volume of losses has decreased considerably. All of the most widely used indicators chart the successful reduction of annual water losses from around 10,8 million m^3 or 22% of System Input Volume (SIV) in 2008 to 7,5 million m^3 and less than 16% of SIV in 2013, with the ILI being reduced from 3,2 to 2,5 in the same period and the leak rate on service connections from almost 25 leaks/1000 connections to around 14 leaks/1000 connections. The CUB is today an international example of best practices in pressure modulation with results easily compared to those obtained by the most efficient European companies. Pressure modulation is still a big challenge for the CUB, next steps are to optimise pressure pumping on pumped supplied areas.

Today the objectives are both to optimise the level of monitoring and the existing sectorisation, and to continue an asset management strategy (especially for water connections).

Regarding the asset management plan, the strategy for now has been to prioritise the renewal of water connections by area. This is because water connections represent 90% of all leaks and some of them have deteriorated physical condition according to condition assessment results. However the impact of the asset condition has proven to be quite important, so the utility is now building a renewal policy for all type of assets.

As for sectorisation the aim is to create an specialised team dedicated entirely to valve management, night flow analysis and directing leak detection following the sectorisation results.

10.8 References

CUB (2012): *Politique de l’eau Eau & Assainissement CUB*.

CUB (2012): *Modulation de pression sur le réseau de la CUB, Note de retour d’expérience*.

10.9 Water Balance CUB (year 2012)

DATA COLLECTION WORKSHEET FOR CASE STUDIES, BEST PRACTICE ON LEAKAGE REDUCTION					Version 2e	23-09-2014	by ILMSS Ltd
THIS WORKSHEET IS USED TO CALCULATE NON-REVENUE WATER AND ASSESS COMPONENTS NON-REVENUE WATER							
Colour coding:	Data entry	Essential data entry	Default Values	Calculated Values	Data from another Worksheet		

SIMPLIFIED IWA WATER BALANCE CALCULATIONS			Anytown		Whole System		# Conns =	201.001
Period of Water Balance	from	01-01-2012	to	01-01-2013	366	days	Mm³	1000 m³/day	lit/conn/day
Enter data for your system in yellow cells. Check the default %s in the purple cells, and change them if you have better information which will improve the reliability of the calculation. Add comments in the Comments Box below.	POTABLE WATER VOLUME INPUT FROM UTILITY TREATMENT WORKS						48,767	133,2	663
	Potable Water Imported to this system						0,000	0,0	0
	SYSTEM INPUT VOLUME (Potable Water)						48,767	133,2	663
	Potable Water Exported from this system						1,291	3,5	18
	Potable WATER SUPPLIED TO THIS SYSTEM						47,476	129,7	645
	Billed Metered Consumption						38,379	104,9	522
	Billed Unmetered Consumption						0,513	1,4	7
	NON-REVENUE WATER NRW						8,584	23,5	117
	Unbilled Authorised Consumption	0,50%	of Billed Metered Consumption				0,192	0,5	3
	WATER LOSSES						8,392	22,9	114
	Unauthorised Consumption	0,20%	of Billed Metered Consumption				0,077	0,2	1
	Customer Metering Inaccuracies	2,00%	of Billed Metered Consumption				0,768	2,1	10
	APPARENT LOSSES						0,844	2,3	11
	CURRENT ANNUAL REAL LOSSES CARL						7,548	20,6	103
Information entered by	CTD-Cirsee-Suez Environnemen		25-07-2014		Contact		cdt@suez-env.com		

Comments:

Guideline maximum default %s for assessed components of Non-Revenue Water are shown below:				
If higher figures are claimed they should have been validated by Utility Specific data				
	Unbilled Authorised Consumption	0,50%	of Billed Metered Consumption	excluding Water Exported
	Unauthorised Consumption	0,20%	of Billed Metered Consumption	
Customer Metering Inaccuracies	Direct pressure systems	2,00%	of Billed Metered Consumption	
	Roof storage tanks	5,00%	of Billed Metered Consumption	
	Customer Metering Inaccuracies are positive for under-recording, negative for over-recording.			

Potable Water Produced from Utility Treatment Works	System Input Volume SIV (Potable Water)	Potable Water Exported WE			
		1,29 Mm3			
		Potable Water Supplied WS	Billed Authorised Consumption (excluding Water Exported)		
			Metered 38,38 Mm3		
48,77 Mm3	48,77 Mm3	47,48 Mm3	Unmetered 0,51 Mm3		
Potable Water Imported to this System			Non -Revenue Water NRW	Unbilled Authorised Consumption UAC 0,19 Mm3	
			8,58 Mm3	Water Losses WL	Apparent Losses AL 0,84 Mm3
0,00 Mm3				8,39 Mm3	Real Losses RL 7,55 Mm3

Anytown
Whole System
01-01-2012
to
01-01-2013

Infrastructure Parameter			Performance Indicators for Leakage					
Distribution mains length	2909,0	km	2602	m³/km/year	7,1	m³/km/day	0,30	m³/km/hour
Trunk and Distribution mains length	3093,0	km	2447	m³/km/year	6,7	m³/km/day	0,28	m³/km/hour
Service Connections (to 1st meter)	201001	Number	37,7	m³/conn/yr	103	l/conn/day	'per hour' is influenced by Night-Day Factor NDF	
Density of Connections	65,0	No/km	↑ Use PIs above this row to track leakage in individual systems ↑ ↓ Use PIs below this row to compare leakage between systems ↓					
Length of underground Service	5,0	m/conn	Current Annual Real Losses CARL				7,55	Mm³/year
Connections, Main to first meter	1005,0	km	Unavoidable Annual Real Losses UARL				3,00	Mm³/year
Average Operating Pressure	37,0	metres	Infrastructure Leakage Index ILI =				2,5	
Annual Repair Frequencies: Mains (UARL)	13,0	/100 km	12,0	per 100 km		which is	0,9	x UARL frequency @ 50m
Annual Repair Frequencies: Connections (UARL)	3,1	/k conns	14,0	per 1000 conns		which is	4,5	

Comments:	↓ PIs based on %s are for comparison only, not recommended ↓	
	Leakage as % of System Input Volume SIV	15,5%
	Leakage as % of Water Supplied, excluding exports	15,9%

11 German Case Study: Munich

Contribution of Thomas Prein (August 14, 2014).

11.1 Details Stadtwerke München GmbH (SWM)

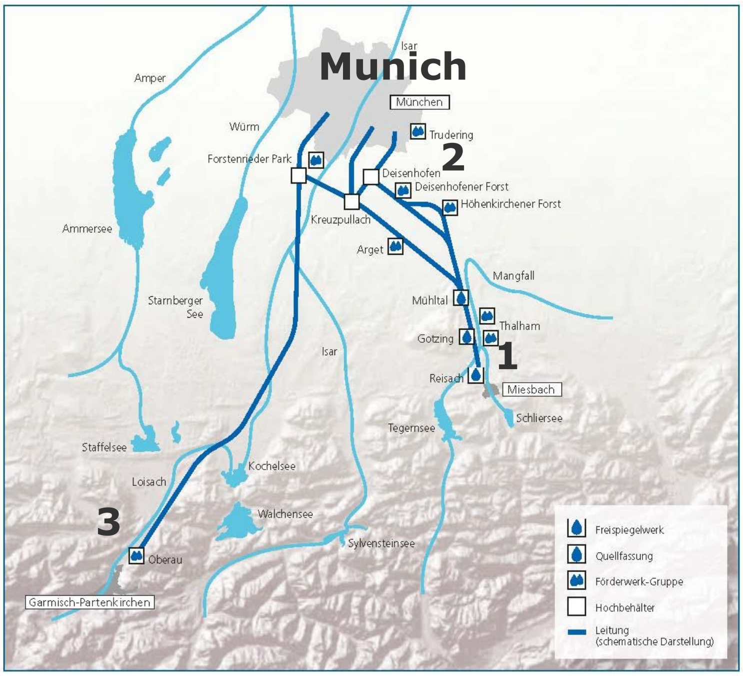
Leakage control has a long history in German water supply, starting with first rules of the German Technical and Scientific Association for Gas and Water (DVGW) in 1986. This rules have been revised several times, the last update is still under revision right now. These rules are briefly summarised in Section 11.8 at the end of this Case Study.

The city of Munich is the capital of the state of Bavaria. It is situated at the river Isar, a tributary of the Danube river. With a resident population of 1,5 Mio it is the third largest city in Germany. Population growth is proposed to about 1% per annum. Stadtwerke München GmbH (SWM) is the utility of the City of Munich for energy and water supply, urban transport und telecommunication.

Drinking water (ground water) is collected at the foot of the Bavarian alps, about 50 km south of Munich. To meet the requirements of 1,5 million people in an environmentally responsible way, the city and SWM have developed three supply catchment areas over the years:

1. The Mangfalltal valley.
2. The Schotterebene.
3. The Loisachtal region.

These ground water catchment areas complement one another perfectly and provide Munich with some of the best drinking water in Europe from the alpine uplands.



Country	Basin / Sub-basin	Water service provider	Other key stakeholders
Germany	Danube/Isar	SWM	City of Munich

Table 36 – Geographical context of SWM.

Water quality is very good, so no treatment of raw water is necessary. The water may directly be fed into the transport pipelines towards Munich. Large pipelines transport the drinking water towards large undergrounds reservoirs south of the city. Water is stored in three large underground reservoirs with a total capacity of some 200.000 m³. These reservoirs are connected by pipelines, so water may be exchanged. From the reservoirs drinking water is supplied to the urban distribution network via several large main pipelines.

The three catchment areas provide abundant amount of fresh water to serve the cities need. If one of the catchment areas cannot provide water, i.e. due to technical problems, the two remaining catchment areas are able to meet the demand.

In case of failure of one of the reservoirs or of one of the main pipelines, water supply may be kept up by two of the three catchment areas or reservoirs.

The topographical level of the catchment areas and the reservoirs is high above the level of the customer base, so pumping stations are not necessary. Water is running by gravity from the catchment area via the reservoirs to the customers. New large pipelines have been constructed during the recent period to bring the water to the city by gravity and save the water quality during the transport. Energy support is only needed for the well pumps in the Loisachtal and Schotterebene catchment areas.

Characteristic	Value
Population	1.500.000
Number of billed properties (residential and non-residential)	app. equal to service connections
Number of service connections (main to first meter)	130.000
Average length of underground service connections	15 m
Length of trunk mains	180 km
Length of distribution mains	3.200 km
Average operating pressure	50-70 m
% of time system is pressurised	100 % of year
% of total mains length subject to active pressure management	0 %
Annual volume of potable water supplied (excluding exports)	91 Mio m^3/year
Average time from location of mains leaks to shutoff or repair	1-30 days
Average time from location of service leaks to shutoff or repair	1-30 days
Leaks on mains (number per 100 km/year)	6-8 No/year
Leaks on service connections (number per 1000 connections/year)	2-3 No/year
% of system having active leakage control interventions each year	100
Number of water treatment plants	none
Number of pumping stations	none
Number of distribution reservoirs	3
Total number of staff	9.000
Staff directly involved in water operations	app. 300
Average consumer price	€ 1,58/m^3
Average unit costs of water resource[5]	€ 0,00/m^3

Table 37 – Details water production system and distribution network SWM.

Figure 21 shows the variation of daily water consumption in terms of difference of mean value of the year 2013. Figure 21 also includes the course of maximum daily temperature of 2013 as well as holiday times. With this information, periods of high consumption may be explained as well as periods with low consumption. Hot seasons result in a high consumption, but holiday times, especially during summer, in low consumption.

Figure 22 shows variation of the daily water consumption during a characteristic summer day. The percentage given in the graph is the part of the daily consumption in that hour, so total of percentage over 24 hours shows the daily consumption.

A simplified IWA Water Balance in Section 11.9 at the end of this Case Study has been used to calculate the leakage performance indicators for SWM.

[5] See explanation of "compensation costs" in section 11.2.

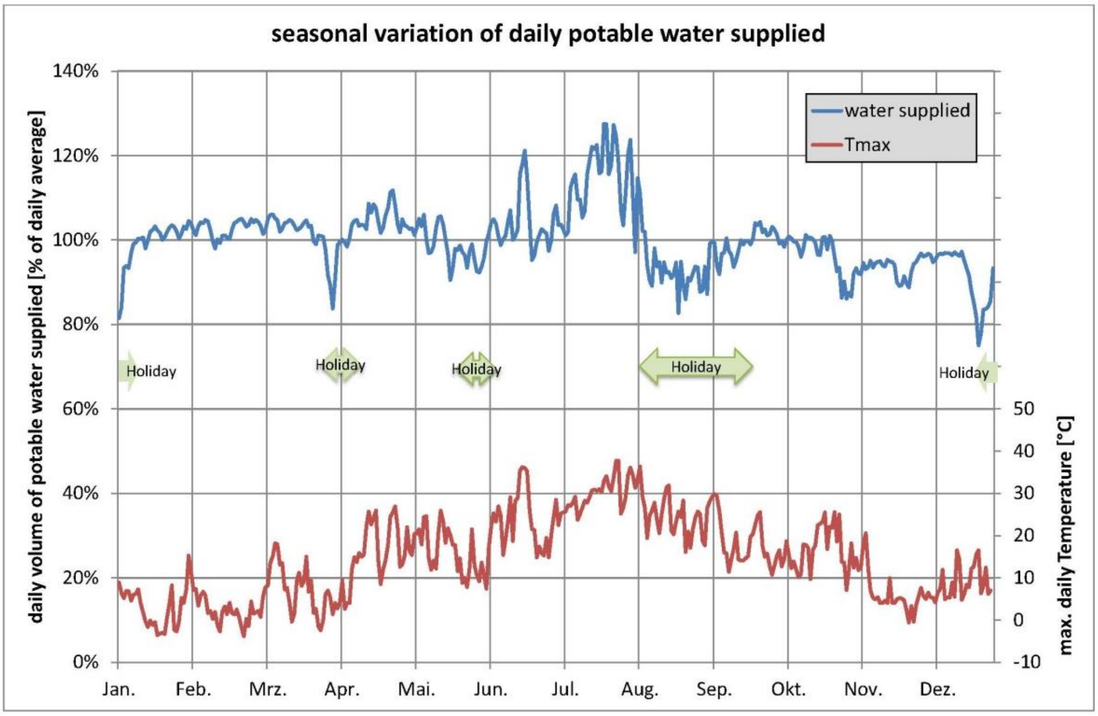


Figure 21 – Seasonal variation of daily potable water supplied by SWM.

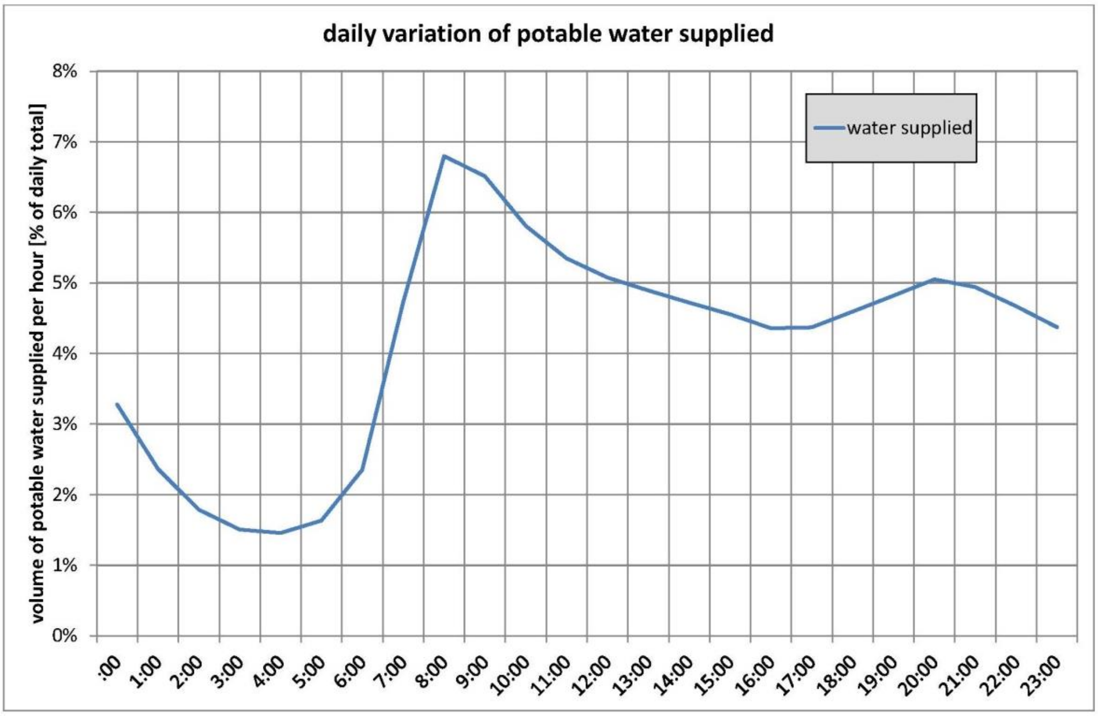


Figure 22 - Variation of daily water consumption during a characteristic summer day.

11.2 Details context SWM

Securing raw water quality is carried out by defining water protection areas which limits land use, e.g. construction of buildings, use of land or farming may be forbidden or restricted. In case of restrictions mostly additional measures for ground water protection are necessary.

Compensation costs

SWM (utility) has to pay for compensation of additional expenditures that has to be carried out by farmers or constructors to secure water quality, e.g. additional sealing of tanks for farm slurry to prevent infiltrating to ground water. To maintain the good quality (chemical and biological) of the drinking water resources, SWM support farmers in the catchment areas to practise organic farming. SWM owns plots of land in the catchment areas, which are leased to farmers for organic farming. SWM also supports farmers in marketing their organic products. Similar guidelines exists for forestry in the catchment area. This helps to maintain water quality and to avoid the necessity of treating the water. SWM spends a lot of money for this kind of water protection instead paying for water abstraction (that has to be paid by the utilities in other parts of Germany). Expenses for this kind of water protection is about € 0,50/m³.

The locations of all water supply assets in the Mangfalltal valley have been given the status of designated water protection areas. Over 1.800 hectares of forest ensure a balanced hydrological regime in the drinking water supply catchment area. SWM also launched the "organic farmers" initiative in 1992, which promotes organic farming in the water supply catchment area of the Mangfalltal valley.

Relevant factor	Yes	No
Abundant water resources at a basin level?	√	
Limited measures required to improve water status to achieve WFD objectives?		√
River Basin Management Plan (RBMP) completed?	√	
Active quantity management incorporated in the RBMP?	√	
RBMP harmonised with other key socio-economic and land use planning documents prior to adaptation and incl. financing plans?	√	
Abundant water resources for water service provider all year every year?	√	
Water resources of good chemical quality (low or no treatment)?	√	
Water resources located at topographical levels above the level of the customer base (low or no energy costs)?	√	
Are the economics of density reasonable (> 20 connections per km)?	√	
Cost effective investment and operating conditions?	√	
Distribution network designed for ease of operation and maintenance without maximum pressure stresses?	√	
Pressure Management implemented throughout the system?		√
District Metering implemented throughout the system?	√	
Good quality of the network installation (materials selection and workmanship at the time of installation)?	√	
Water pricing limitations?	√	
Conflicting socio-economic needs and/or historical legacy?		√
Public affordability constrains?		√
Ability- / willingness-to-pay constraints?		√
Benefitting from EU Funds to finance significant water supply (and urban wastewater) treatment investments?		√
Specific Regulator (Utility subject to regulation)?	√	

Table 38 – Specific context within SWM is operating.

With the above mentioned measures to protect the groundwater resources in the supply catchment areas (e.g. by funding organic farming or restricting land use) SWM contributes to the good chemical status of the water bodies in this area. Customer prices are calculated by the utility, but have to be approved by the authorities. This may be considered as a kind of limitation of price. All investments are financed by income from water price without any funding.

11.3 Overview leakage measures and indicators implemented at SWM

Leakage detection in Munich takes place under difficult conditions. The subsoil in Munich is characterized by gravel and sand with a very high permeability. Therefore, pipe burst do not always appear at the surface if the burst doesn't have a large discharge. Small and long running leakages will not appear, so there's a need for regular activities for detection. For that reason SWM has established a system of control activities.

Implemented measure on leakage assessment and reduction	Yes	No
Reliable Bulk Supply Metering	√	
Reliable District Metering	(√)	
Reliable Customer Metering	√	
Good System Design and Installation	√	
Effective Management of Excess Pressure and Pressure Transients	√	
Speed and quality of repairs	√	
Active Leakage Control at an economic frequency	√	
Sectorisation and/or District Metering Area formation	(√)	
Asset Renewal: service connections	√	
Asset Renewal: mains	√	
Annual Volume of Real Losses (Level of Leakage, CARL)		**Value**
CARL Mio m^3/year		11-12
Leakage Indicators used at SWM		**Value**
Assumed specific real losses (m^3/h*km)		0,4-0,5

Table 39 – Implemented leakage reduction measure(s) at SWM.

Customer consumption is metered as well as the input in the system.

The distribution network is constructed over a long period, resulting in different materials in the different periods of construction. Most of the pipes are steel and cast iron, excepted the service connections which are from polyethylene since a long time.

11.4 Details strategy, monitoring methods and leakage indicators

A well done construction of the distribution network is the basis of a long lasting system of good quality, which guaranties few leakage. For that reason SWM takes a lot of effort in planning and building the network. That includes:

- Take care of good and secure bedding of pipes:
  - Backfill without stones.
  - Gravel and sand with adequate grain size.
- Use of materials of well-known quality for construction and rehabilitation:
  - Steel pipes (large dimensions, main distribution).
  - Cast iron pipes (distribution).
  - Polyethylene pipes (connection, no dig rehabilitation).
- Control of construction work.

Within the operation cycle we secure safe and cost efficient operation by:

- Control of distribution network in short intervals.
- Cathodic Corrosion protection of distribution network (steel pipes only).
- Screening of the pipe network to identify section of bad quality.

- Destroyed pipe section are examined at the utilities laboratories.
- A Evaluation tool for state of pipe based on measurement of Cathodic Corrosion protection is used to measure condition of steel pipes.

All information is used to evaluate the state of the pipe section and to develop a rehabilitation strategy, if necessary (see section 11.5). The replacement of pipes in case of failure or bad condition is done with modern long life material. Any replacement and also new construction are considered under aspects of Life Cycle Costs (LCC). LCC comparison of different materials and/or methods of construction include construction and operating costs as well as rehabilitation and demolishing costs.

On the other hand there are still a lot of different materials in a long lasting supply system, that has been build up over the years from long time ago. SWM studies which of the pipes is still working properly and which has to be replaced soon. This knowledge is aggregated in a maintenance program.

11.5 Details proven leakage reduction measure(s) at SWM

SWM uses a system of:

- Maintenance by scheduled activities.
- Maintenance by condition of pipe section.
- Maintenance by occurrence of failure.

Except the last one, which is determined by the occurrence, different methods are used to define the right time of handling. Methods for network control used by SWM are:

- Inspection of the pipe network. The complete pipe network is inspected by electric-acoustic detection once a year. This will give hints of leakage, that has to be examined with a more specific method.
- Cathodic Corrosion protection. Cathodic Corrosion protection is not only used for protection, but is also used to find out the actual condition of pipes. Regular measurements show the development of the situation versus time of usage. From this data the change of the condition may be calculated by using a software tool, developed by SWM. By defining a "rehabilitation" level, sections may be defined for the rehabilitation table.
- Collecting data on damages in the network. Several damages in a certain time will indicate a diminishing quality of the material. These knowledge is used in combination with information of one or more of the above mentioned methods.

Asset renewal is part of the strategy to maintain a well working system. To identify the most important sections of the network to be renewed, all information are put in relation. From a set of key indicators a ranking for rehabilitation has been established:

- Optic information during construction works, e.g. for additional connection pipes.
- Information of construction material: certain material is known to be less durable under certain conditions.
- Conditions of pipes (subsoil, groundwater, load or additional load by changed conditions, e.g. construction works, traffic load).
- Damages in the section during a time period, especially if more failures with the same or similar reasons.
- Evaluation of Cathodic Corrosion protection, increasing electric energy for protection is a symptom for a diminishing quality.

From this information a table with a ranked renewable list is created, which is basis for operational work. These list is the working guide.

Planning the pipe network is done by utilities staff as well as supervision of the construction work. Construction work is done by third parties, having a lot of experience and providing an adequate equipment for necessary works. This guaranties a good quality of work and is the base for good system design and installation.

In case of failure first aid is done by own staff, sometimes with support of third party companies (e.g. civil engineering). If reconstruction will last for longer times or preparation works are necessary, support of third parties is usual. Destroyed pipes sections are examined at the utilities laboratory, especially if the materials quality is known to be restricted in certain circumstances.

Measuring the customers consumption is necessary in Germany for a reliable billing. The meter has to be adjusted by an authorized department (that could be a utilities department). In most cases consumption of the connection pipe is measured, which is identical with the building and is billed to the owner of the building. Distribution to the customers inside the building is done by the owner and not the utility.

At this time there are only a few district metered areas in the network. Increasing these areas might be considered useful if leakage has to be decreased further.

11.6 Evaluation of further options for pressure management

There is no pressure management in the SWM water supply network. The supply network of SWM is divided into three sections, each of them providing a pressure of 50-70 m according to geographical situation. From the point of view of SWM there is no need for pressure management at present.

11.7 Results and recommendations

The Water Balance for SWM follows in Section 11.9 at the end of this Case Study.

SWM is making a lot of efforts to maintain or improve the quality of the water supply network. These efforts include:

- Evaluation system for the network. Based on the results of regular inspection of the network an evaluation system is established, that will identify the measures and the necessary financial investments.
- Ranking of pipe sections for rehabilitation. Technical requirements and financial opportunities will gathered and a ranking of the most important projects will be compiled in a table.
- Annual rehabilitation of pipe sections according to the ranking. Each year a budget for rehabilitation will be set up according the rehabilitation table. If large incidents require additional expenses a special budget is created.

11.8 Update DVGW W392 and W400

Leakage control has a long history in Germany, which starts with W391 "Water loss in water distribution systems" in 1986, followed by the first edition of W392 in 2003. W392 will be revised in 2014 or 2015. W392 (2003) defines principles for inspection, maintenance and rehabilitation. This rule has to be seen in combination with W400, which defines principles for planning and construction of water supply networks as well as activities on the basis of inspection of the condition of networks. This rules are basics for economical service and lifetime.

W392 (2003) defines controlling of water loss as a goal for hygienic, safety, economic and ecological reasons. A low level of water loss is a key figure for good condition of the water supply network and cost efficient service. W392 defines the water balance of the water supply network according the table below.

<table>
<tr><td rowspan="11">System Input Q_N</td><td rowspan="4">Network output Q_A</td><td rowspan="2">Billed Q_{AI}</td><td>Billed and measured</td><td rowspan="2">Billed supplied water Q_{IR}</td></tr>
<tr><td>Billed, not measured</td></tr>
<tr><td rowspan="2">Not billed Q_{AN}</td><td>Not billed, measured</td><td rowspan="9">Not billed supplied water Q_{NR}</td></tr>
<tr><td>Not billed, not measured</td></tr>
<tr><td rowspan="7">Water loss Q_V</td><td rowspan="3">Apparent water loss Q_{VS}</td><td>Measuring difference, time lags</td></tr>
<tr><td>Unavoidable loss</td></tr>
<tr><td>Water theft</td></tr>
<tr><td rowspan="4">Real water loss Q_{VR}</td><td>Feeding network</td></tr>
<tr><td>Water reservoir (storage)</td></tr>
<tr><td>Main an d distribution network</td></tr>
<tr><td>Connection pipes</td></tr>
</table>

From the water balance the specific real water loss is calculated, which indicated the level of water loss according the table below.

$$q_{VR} = \frac{Q_{VR}}{8760 * L_N}\left[\frac{m^3}{h * km}\right]$$

Level of real water loss	Structure of network		
	City	Town	Rural
Low level	< 0,10	< 0,07	< 0,05
Medium level	0,10 – 0,20	0,07 – 0,015	0,05 – 0,10
High level	> 0,20	> 0,15	> 0,10

According to the level of real water loss, inspection cycles are defined from every 6 years to once a year. The approach to define water loss figure q_{VR} is a German key indicator for the quality of the distribution network.

Revision of W392, which is under construction now, will have a shift towards international key figures to describe water loss. Therefore the ILI (Infrastructure Leakage Index), defined by the International Water Association (IWA) will be introduced into German technical rules. Calculation of ILI will follow international guidelines.

The key indicator q_{VR} as described in the W392 (2003) will exist alongside the international ILI.

DVGW W400-1 Bl.1 provides measures for inspection and maintenance according to the condition of the network. Main information to describe the condition is water loss and damage figures. For illustration some of the tables are shown below (on the next page).

	Damages per km and year	
	Mains and distribution pipes	Connection pipes
Low	< 0,1	< 5
Average	0,1 to 0,5	5 to 10
High	> 0,5	> 10

With these indicators activities may be considered as below:

Leakage	**Damages**	**Inspection**	
Very high	High/Average/Low	Special measures for reduction	
High/Average/Low	High	Every 3 years	Special measures for reduction
High	Else	Every 3 years	Every 3 years
Else	Else	Every 6 years	Every 6 years
Low	Low	Every 12 years	By occurrence

The rules are still under discussion, changes might be in future rules.

Reference

Fantozzi, M., A.O. Lambert and R. Liemberger (2010): *Some Examples of European Water Loss Targets, and the Law of Unintended Consequences*. IWA Specialised Conference 'Water Loss 2010', Sao Paolo, Brazil, June 2010.

11.9 Water Balance SWM (year 2011)

DATA COLLECTION WORKSHEET FOR CASE STUDIES, BEST PRACTICE ON LEAKAGE REDUCTION					Version 2e	23-09-2014	by ILMSS Ltd
THIS WORKSHEET IS USED TO CALCULATE NON-REVENUE WATER AND ASSESS COMPONENTS NON-REVENUE WATER							
Colour coding:	Data entry	Essential data entry	Default Values	Calculated Values	Data from another Worksheet		
SIMPLIFIED IWA WATER BALANCE CALCULATIONS			SWM Munich	Whole System		# Conns =	130.000
Period of Water Balance	from 01-01-2011	to 31-12-2011	365	days	Mm^3	1000 m^3/day	lit/conn/day
Enter data for your system in yellow cells. Check the default %s in the purple cells, and change them if you have better information which will improve the reliability of the calculation. Add comments in the Comments Box below.	POTABLE WATER VOLUME INPUT FROM UTILITY TREATMENT WORKS				105,000	287,7	2213
	Potable Water Imported to this system				0,000	0,0	0
	SYSTEM INPUT VOLUME (Potable Water)				105,000	287,7	2213
	Potable Water Exported from this system				0,000	0,0	0
	Potable WATER SUPPLIED TO THIS SYSTEM				105,000	287,7	2213
	Billed Metered Consumption				91,000	249,3	1918
	Billed Unmetered Consumption				0,000	0,0	0
	NON-REVENUE WATER NRW				14,000	38,4	295
	Unbilled Authorised Consumption	0,50%	of Billed Metered Consumption		0,455	1,2	10
	WATER LOSSES				13,545	37,1	285
	Unauthorised Consumption	0,20%	of Billed Metered Consumption		0,182	0,5	4
	Customer Metering Inaccuracies	2,00%	of Billed Metered Consumption		1,820	5,0	38
	APPARENT LOSSES				2,002	5,5	42
	CURRENT ANNUAL REAL LOSSES CARL				11,543	31,6	243
Information entered by	Thomas Prein	04-08-2014		Contact	prein.thomas@swm.de		
Comments:							

Guideline maximum default %s for assessed components of Non-Revenue Water are shown below:				
If higher figures are claimed they should have been validated by Utility Specific data				
	Unbilled Authorised Consumption	0,50%	of Billed Metered Consumption	excluding Water Exported
	Unauthorised Consumption	0,20%	of Billed Metered Consumption	
Customer Metering Inaccuracies	Direct pressure systems	2,00%	of Billed Metered Consumption	
	Roof storage tanks	5,00%	of Billed Metered Consumption	
	Customer Metering Inaccuracies are positive for under-recording, negative for over-recording.			

		Potable Water Exported WE 0,00 Mm3			SWM Munich Whole System 01-01-2011 to 31-12-2011
Potable Water Produced from Utility Treatment Works 105,00 Mm3	System Input Volume SIV (Potable Water) 105,00 Mm3	Potable Water Supplied WS 105,00 Mm3	Billed Authorised Consumption (excluding Water Exported) Metered 91,00 Mm3 Unmetered 0,00 Mm3		
Potable Water Imported to this System 0,00 Mm3			Non -Revenue Water NRW 14,00 Mm3	Unbilled Authorised Consumption UAC 0,46 Mm3	
				Water Losses WL 13,55 Mm3	Apparent Losses AL 2,00 Mm3 Real Losses RL 11,54 Mm3

Infrastructure Parameter			Performance Indicators for Leakage					
Distribution mains length	3200,0	km	3607	m^3/km/year	9,9	m^3/km/day	0,41	m^3/km/hour
Trunk and Distribution mains length	3380,0	km	3415	m^3/km/year	9,4	m^3/km/day	0,39	m^3/km/hour
Service Connections (to 1st meter)	130000	Number	88,8	m^3/conn/yr	243	l/conn/day	'per hour' is influenced by Night-Day Factor NDF	
Density of Connections	38,5	No/km	↑ Use PIs above this row to track leakage in individual systems ↑ ↓ Use PIs below this row to compare leakage between systems ↓					
Length of underground Service	15,0	m/conn	Current Annual Real Losses CARL				11,54	Mm^3/year
Connections, Main to first meter	1950,0	km	Unavoidable Annual Real Losses UARL				4,40	Mm^3/year
Average Operating Pressure	60,0	metres	Infrastructure Leakage Index ILI =				2,6	
Annual Repair Frequencies — Mains (UARL)	13,0	/100 km	7,0	per 100 km		which is	0,5	x UARL frequency @ 50m
Annual Repair Frequencies — Connections (UARL)	4,5	/k conns	2,5	per 1000 conns		which is	0,6	
Comments:			↓ PIs based on %s are for comparison only, not recommended ↓					
			Leakage as % of System Input Volume SIV				11,0%	
			Leakage as % of Water Supplied, excluding exports				11,0%	

12 Italian Case Study: Iren Emilia

Contribution of Marco Fantozzi and Francesco Calza.

12.1 Details Iren Emilia and *14 Systems*

Iren group is a major Italian multi-utility active in water, gas, energy and waste disposal, operating in the provinces of Turin, Genoa, Parma, Piacenza and Reggio Emilia in the northern part of Italy. The company was founded in 2010 by the merger of several companies in the area and serves a total of more than 2.500.000 inhabitants. Water systems in Reggio Emilia province are managed by Iren Emilia, (previously ENIA Utility, which was created from three smaller Utilities in 2005).

The 28 water systems in Iren Emilia supply 45 municipalities with 475.000 inhabitants through 4.940 km of mains. Data in Table 40 and Table 41 include all 28 water systems, but those which are small and located in hilly areas have been grouped as one system 'Vari Montagna'. So 14 managed systems are shown in the Case Study graphs.

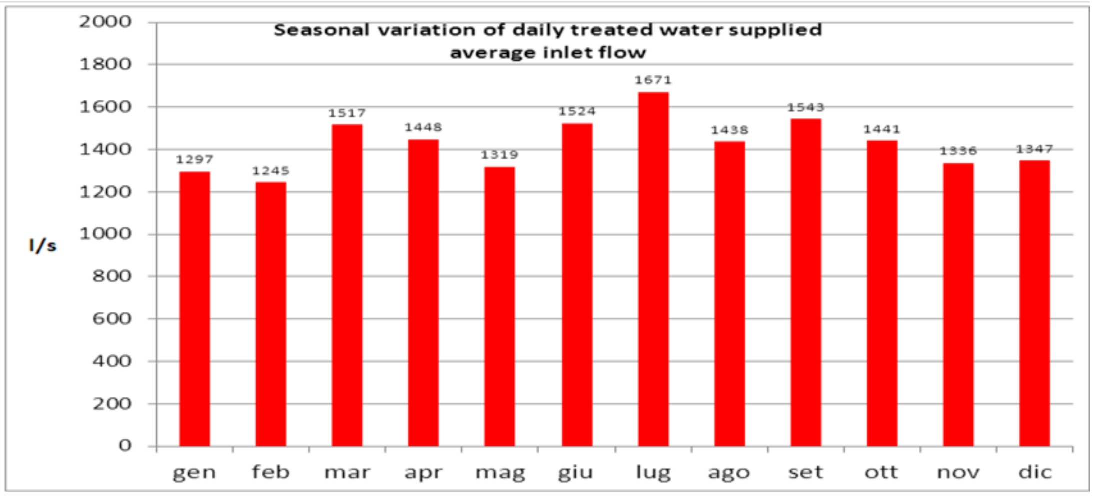
Country	Basin / Sub-basin	Water service provider	Other key stakeholders
Italy	Reggio Emilia Province	Iren Emilia (formerly ENIA)	

Table 40 – Geographical context of Iren Emilia.

Characteristic	Value
Population	475.000
Number of billed properties (residential and non-residential)	250.725
Number of service connections (main to first meter)	94.410
Average length of underground service connections	25,3 m
Length of trunk mains	606,2 km
Length of distribution mains	4.334,8 km
Average operating pressure	43,7 m
% of time system is pressurised	100 % of year
% of total mains length subject to active pressure management	39,2 %
Annual volume of potable water supplied (excluding exports)	44.488,5 Mm^3/year
Average time from location of mains leaks to shutoff or repair	2 days
Average time from location of service leaks to shutoff or repair	2 days
Leaks on mains (number per 100 km/year)	15,9 No/year
Leaks on service connections (number per 1000 connections/year)	20,2 No/year
% of system having active leakage control interventions each year	35%
Number of water treatment plants	7
Number of pumping stations	107
Number of distribution reservoirs	257
Total number of staff	320
Staff directly involved in water operations	143
Average consumer price	€2,18/m^3
Average unit costs of water resource	€ 0/m^3
Average unit costs of production and distribution	€ 0,08/m^3
Highest unit cost of production and distribution	€ 0,17/m^3
Energy usage	22 million kWh/year

Table 41 – Details water production and distribution Iren Emilia, 14 systems.

The graph below shows the typical monthly variation of potable water supplied in litres/sec for the year 2013. Consumption is lowest in November to February, before increasing in March/April around Easter, followed by a slight reduction in May before peaking again in June to October.



A simplified IWA Water Balance format in Section 12.9 at the end of this Case Study has been used to calculate the leakage performance indicators for the aggregated 14 Systems in Iren Emilia in Table 43 below.

12.2 Details context Iren Emilia

ENIA began to introduce sectorisation and active leakage control in the mid-1990s, and was the first Italian Utility to adopt and begin to implement, in 2004, the IWA WLTF best practices and techniques. Since then they have consistently improved the efficiency of their leakage management, reducing bursts, leakage and energy consumption year by year.

Relevant factor	Yes	No
Abundant water resources at a basin level?	X	
Limited measures required to improve water status to achieve WFD objectives?		X
River Basin Management Plan (RBMP) completed?	X	
Active quantity management incorporated in the RBMP?	X	
RBMP harmonised with other key socio-economic and land use planning documents prior to adaptation and incl. financing plans?	X	
Abundant water resources for water service provider all year every year?	X	
Water resources of good chemical quality (low or no treatment)?	X	
Water resources located at topographical levels above the level of the customer base (low or no energy costs)?		X
Are the economics of density reasonable (> 20 connections per km)?	X	
Cost effective investment and operating conditions?	X	
Distribution network designed for ease of operation and maintenance without maximum pressure stresses?	X	
Pressure Management implemented throughout the system?	X	
District Metering implemented throughout the system?	X	
Good quality of the network installation (materials selection and workmanship at the time of installation)?	X	
Water pricing limitations?	X	
Conflicting socio-economic needs and/or historical legacy?		X
Public affordability constrains?		X
Ability- / willingness-to-pay constraints?	X	
Benefitting from EU Funds to finance significant water supply (and urban wastewater) treatment investments?		X
Specific Regulator (Utility subject to regulation)?	X	

Table 42 – Specific context within Iren Emilia is operating.

Topography varies significantly in the province of Reggio Emilia, and around 80% of water supplies are pumped. Pressure management is being progressively applied (now to 39% of the network) and has produced remarkable results. However, for technical reasons, it will not be possible to apply it to 100% of the networks.

The strict control of materials and quality of installation has helped to improve the condition of the infrastructure over time. The progressive implementation of pressure management and "no dig" replacement techniques also substantially contributed to the achievements.

12.3 Leakage measures and indicators implemented at Iren Emilia

In the mid-1990s, Iren Emilia's predecessor (ENIA) started to sectorise networks and undertake Active Leakage Control. In 2003 they started to apply the holistic approach of best practices and techniques developed by the IWA WLTF and WLSG. This section of the Case Study demonstrates the progress that has been achieved to date, which is continuing to reduce leakage, energy use and bursts.

Pressure management has, to date, been applied to 39,2% of water distribution system. The target is to apply it to 56% of water distribution system by end of year 2016. The type of pressure management adopted (basic, intermediate or advanced) depends on the specific situation of each area. Typical pressure management activities include:

- Check zone for pressure transients using high frequency sampling data loggers.
- Analyse network behaviour using calibrated network analysis models.
- Design pressure management, choose type of management to optimise customer service and return of investment (including prediction of leak reduction and bursts frequency reduction).
- Design and size pressure reduction valves and/or variable speed drive pumps.

Actually Iren Reggio Emilia manages 103 pressure management zones, 60 of which are characterized by fixed reduction (as head loss is very limited during the 24 hours). 18 zones have a night/day pressure regulation while in the remaining 25 zones pressure is modulated according to flow variations or predefined pressure values at the critical point in order to better respond to daily and significant seasonal variations.

Implemented measure on leakage assessment and reduction	Yes	No
Reliable Bulk Supply Metering	X	
Reliable District Metering	X	
Reliable Customer Metering	X	
Good System Design and Installation	X	
Effective Management of Excess Pressure and Pressure Transients	X	
Speed and quality of repairs	X	
Active Leakage Control at an economic frequency	X	
Sectorisation and/or District Metering Area formation	X	
Asset Renewal: service connections	X	
Asset Renewal: mains	X	
Annual Volume of Real Losses (Level of Leakage, CARL)	**Value**	
2013	8,47 Mm^3/year	
Leakage Indicators used at *Utility*	**Value**	
ILI: used by Reggio Emilia regulator and now requested by new Italian National regulator	2,50	
Litres/service connection/day (IWA, if > 20 conns/km)	246	
% of Distribution Input (Italian Decreto 99, 8 June 1997 P.I. "R4")	19,0%	
m3/km mains/day (Italian Decreto 99, 8 June 1997)	4,7	

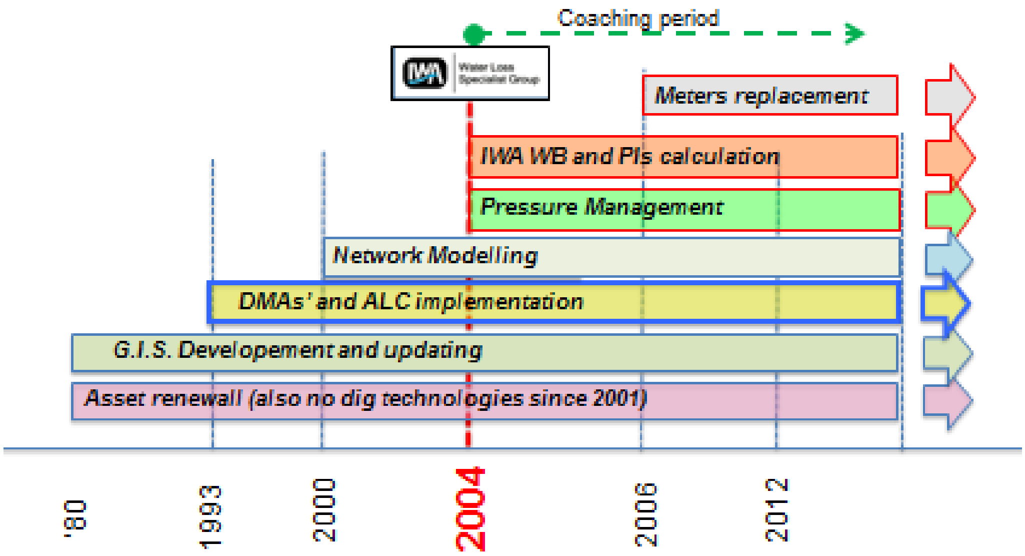
Table 43 – Implemented leakage measures and indicators at Iren Emilia's 14 Systems.

12.4 Details strategy, monitoring methods and leakage indicators

All of the leakage reduction and assessment measures listed in Table 4 have been implemented to a greater or lesser extent, only the accuracy of customer meters lags the other activities, because the Italian regulations for replacement of customer meters have not been as strict as in some other European countries. In Iren, and also in most Italian utilities, under registration of customers meters has been underestimated so far due to lack of regulations. In the last few years due to increased attention to this topic, and after publication of results of meters tests, more and more utilities (including Iren) started a meters replacement plan. In addition the Italian regulator introduced in 2014 a new requirement for control/replacement of customers meters after 13 years (in case of static meters) or after 10 years for turbine, volumetric, etc.

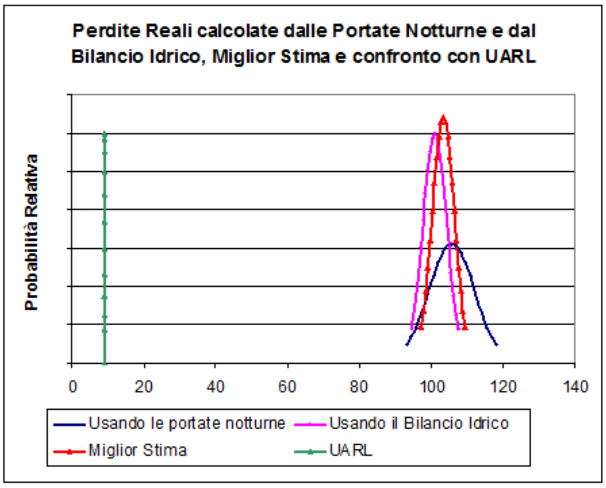
From the mid-1990s, ENIA started to sectorise networks and undertake Active Leakage Control. During the period 1993 to 2010, 348 District Metered Areas covering 94% of the mains were created for targeting Active Leakage Control activities. However, by 2003, even with around 60% of the DMAs created, and 60% of the system having been checked by ALC, population and electricity consumption for water supply were continuing to rise.

In 2003 ENIA started to apply the holistic approach of best practices and techniques developed by the IWA WLTF and WLSG, which includes: speed and quality of repairs, pressure management, active leakage control, and renewal of assets in appropriate combinations for each system. Since then, remarkable progress has been achieved.



Implementation of NRW strategy in Iren Reggio Emilia

Since 2004, the ENIA team have been mentored and provided with 'as required' technical support by WLTF members Fantozzi and Lambert. An early initiative requested by ENIA was a software (STIPERZENIA) which would compare 'top-down' and 'bottom-up' calculations of real losses for each DMA, with confidence limits, to enable anomalous assumptions or situations to be easily identified, and progress in leakage reduction to be tracked. This software (renamed ANPER) has since been used by several other Italian Utilities.



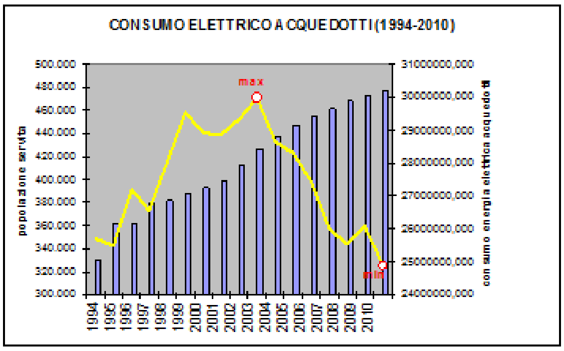
Comparison of 'top-down' and 'bottom-up' calculations of real losses for a DMA with confidence limits

The Italian Decreto 99 of 8th June 1997 required Italian Utilities to calculate Water Losses (real and apparent), and Real Losses (leakage), as %s of Distribution Input, and per km of mains, and also to measure pressure. More recently, use of IWA Water Balance and more appropriate performance indicators for Real Losses (ILI and litres per connection per day) was tested in Reggio Emilia and adopted by the regulator for that region. Many Italian Utilities have now calculated ILI, and the new Italian regulator has, in 2014, required all Italian Utilities to carry out and submit calculations of ILI, for review. The adoption of these performance indicators recommended by the IWA WLSG has allowed the results of Reggio Emilia to be rationally compared with those of other companies in Europe and internationally.

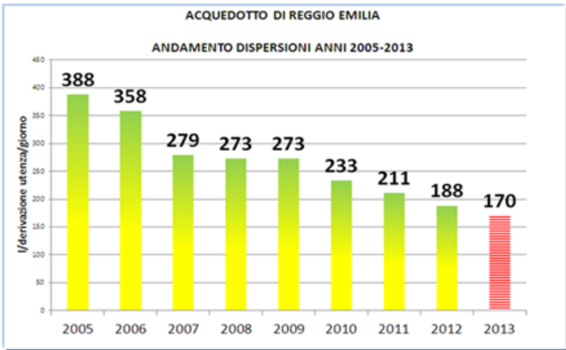
12.5 Details proven leakage reduction measure(s)

Water loss management is one of the primary goals of water supply management in Reggio Emilia. Benefits related to WLM are both environmental and economic. Also thanks to improved efficiency in WLM, Iren Reggio Emilia has been able to prevent early events of droughts without interruptions in service and with significant energy and cost savings.

The acceptance of the holistic IWA '4 components' approach and concepts from 2003 onwards provided a much clearer focus on performance measurement, influence of leak run times, targeting of economic ALC interventions, comparisons of 'top-down' and 'bottom-up' leakage estimates on a zonal basis, and opportunities for addition of pressure management into numerous existing zones, initially to reduce leak flow rates. ENIA has clearly recognized the need to separately record and analyse bursts and leakage on mains, and bursts and leakage on services. So in combination with the above activities, selective rehabilitation of service connections has also been applied where needed and convenient, in order to reduce bursts frequency and increase system reliability (see charts below).

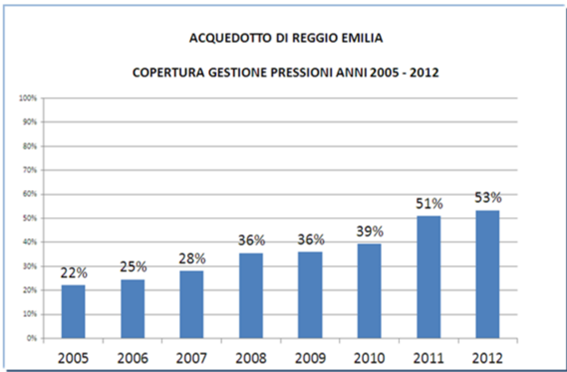


Energy consumption reduced by 20% since 2003

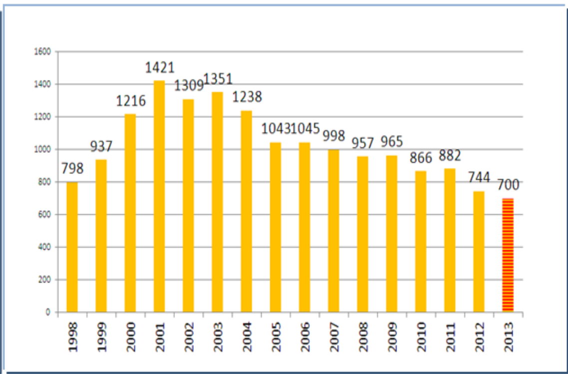


Reggio Emilia City: leakage reduction in litres/conn/day

In 2005, the WLTF pressure management group demonstrated (internationally) how reduction of excess pressure also reduced burst frequency, and this can be clearly seen in the chart below.



% of system subject to pressure management



Mains and services annual bursts reduced by 48% since 2003 (Reggio Emilia city only)

Importance: It is reasonable to say, with hindsight, that if one were starting again, with the concepts and knowledge now available using the IWA WLSG holistic approach, pressure management based on prioritized predictions of burst reduction would have been introduced earlier in the sequence of activities in Iren, at the same time as (or even prior to) the creation of DMAs. This is because it is now clearly seen as being fundamental not only to 'traditional' reduction of leak flow rates, but also to reduction of bursts, extension of asset life and several other Utility activities and customer service standards.

Approach: After quantifying leakage volume per day or year using a standard water balance or night flows, calculation of ILI provides a technical assessment of current leakage as a multiple of unavoidable annual real losses (UARL) based on the key parameters (mains length, number and length of service connections, average pressure) for each individual system. ILI can then be used to broadly identify general priorities for action, using International Leakage Performance Categories A to D.

One of the two traditional performance indicators based on infrastructure (litres/service connection/day, or m3/km mains/day, depending on connection density and country tradition) should then be used for tracking progress of leakage management within individual systems and sub-systems – but not for comparisons between different systems.

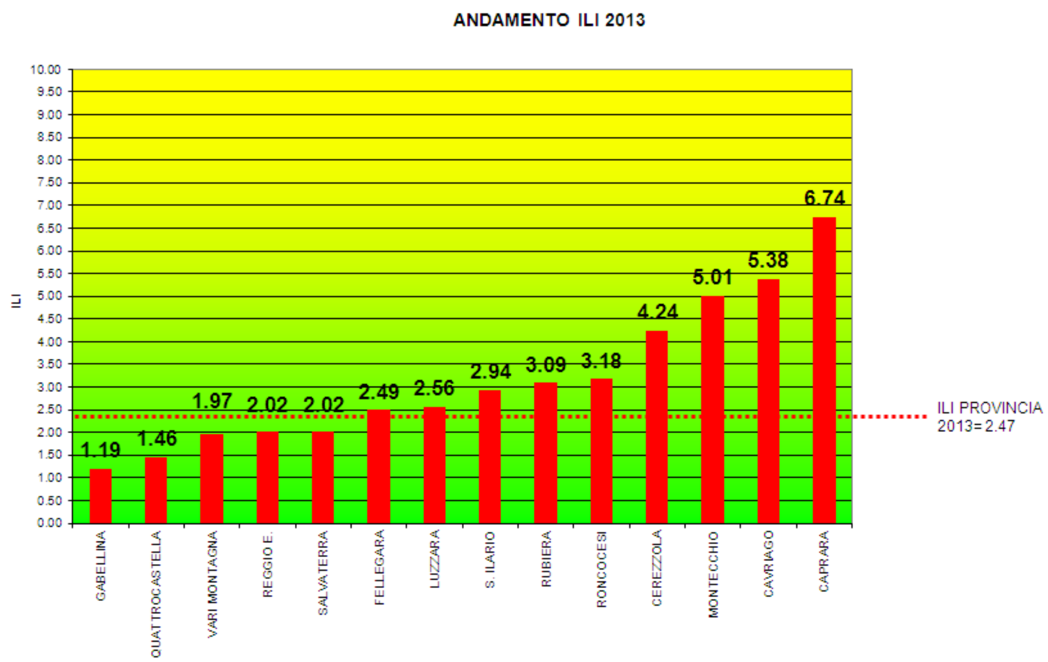
Other supplementary context parameters for deciding on priorities within the holistic IWA approach are listed in Section 6.4.1, Table 6.

Implementation Guidance: The IWA holistic approach identifies measurement of pressure and management of excess pressure (if necessary) as a fundamental first step in reducing leakage. Speed and quality of leak repairs – large and small - is also an obvious requirement.

Economic frequency of active leakage control varies widely from one sub-system to another, depending on individual rate of rise of unreported leakage. This means that each system and sub-system needs to be individually assessed for the most appropriate sequence and balance of actions – there is no universally applicable 'best' sequence to follow. Even in a single Utility such as Iren Emilia, where all Zones are subject to similar broad policies, the priorities for each Zone and the results achieved can be different.

The chart below shows ILIs varying from 1,19 to 6,74 for 14 Iren Reggio Emilia systems in 2013. Montecchio, which in 2013 had an ILI equal to 5, in 2010 was characterised by low pressure but also by presence of pressure transients which was responsible for high bursts frequency and therefore high level of real losses (ILI in 2010 was equal to 10). Only after the system was verified for presence of pressure transients using high frequency sampling data loggers, and the source of transients eliminated, was it possible to progressively reduce the bursts frequency and real losses volume, and therefore reduce ILI down to the current value of 5, which will be further improved in the future by optimising active leakage control intervention.

In this (as in many other cases) simply repairing bursts faster and doing more frequent ALC, rather than first identifying and dealing with the pressure management problems, would not have been an effective strategy.



ILI data set for Iren Reggio Emilia water systems in 2013

Basic 'BABE' leakage component (Bursts and Background Estimates) and FAVAD pressure:leak flow rate models, have been available for analytical purposes for almost 20 years, and pressure:bursts predictions can now be made with some confidence, enabling benefit:cost and payback periods to be assessed.

These modelling approaches are complementary to, but different from, network analysis models. The need for guesswork is now much reduced, for those Utilities that wish to use the tools now available.

12.6 Evaluation of further options for pressure management

Pressure management is considered to be by far the most effective activity to control real losses. It includes the reduction of excess pressures, by the installation of pressure reducing valves or variable frequency drives at pumping stations, and the detection and elimination of pressure transient phenomena (water hammer). The analysis of the water network by means of calibrated mathematical models permits redesign and progressive optimization of areas of pressure management, coupled with increasingly reliable predictions (using WLSG practical approaches) of the reductions in bursts on mains, and on services, which can be achieved in different Zones.

Calm management of the network progressively and permanently divided into districts and pressure management zones allows continuous monitoring of the level of losses, to immediately identify new bursts and to oversee the smooth operation of all equipment controlling pressure. For technical reasons it is not necessary, economic or possible to apply these techniques everywhere. However, by 2016 the target is to apply pressure management to 56% of the network. The technologies chosen are targeted to the needs of each specific area. They can be very simple, such as fixed reduction PRV or adjustable day/night PRV; or more sophisticated modulation according to flow or according to predefined pressure values at the critical point. Similar regulation modalities are being adopted in pumping stations when these are directly feeding the water systems.

12.7 Results and recommendations

The aggregate Water Balance for the Iren Emilia 14 Systems follows in Section 12.9 at the end of this Case Study.

The results shown in Section 12.5 of this Case Study are objectively measurable: a 20% (6 million KWH) reduction in electricity consumption since 2005; in Reggio Emilia City, a 33% reduction (343 fewer) bursts, and leakage reduced from 388 to 170 litres/connection/day. Maintenance costs and complaints are also declining due to a progressive decrease in breaks on the networks and the connections. Average ILI is down to 2,5, and Iren Emilia contributed ILIs for 14 systems to the latest European data set of 71 ILIs from 12 countries.

Whilst water loss management is often pictured as the implementation of technological solutions to a hidden problem, this is really only part of the real solution, which is all about managing Utility people to perform. It is about empowering them with the responsibility, training, practical tools and proven techniques, motivating them to perform, and inspiring them to believe that they can make a difference.

Iren Emilia personnel actively participated in the first training activities organised by the Italian branch of the IWA Water Losses Task Force in 2003, and have continually improved since then. It is reasonable to say, with hindsight, that if Iren was starting again, with the knowledge now available, pressure management based on prioritized predictions of burst reduction would have been introduced earlier in the sequence of activities, at the same time as (or even prior to) the creation of DMAs, as it is fundamental not only to leakage management, but also for infrastructure asset management and many other Utility activities.

12.8 References

Fantozzi M., F. Calza and A. Kingdon (June 2010): *Introducing Advanced Pressure Management at ENIA utility (Italy): experience and results achieved*. IWA Water Loss 2010 Congress, San Paolo, Brazil.

Calza F. and M. Fantozzi, M. (May 2010): *Pressure Management: the experience of ENIA Reggio Emilia*. Water Efficiency Conference, Accadueo Fair, Ferrara, Italy.

Fantozzi M., A. Lambert and F. Calza (April 2009): *Experience and results achieved in introducing District Metered Areas (DMA) and Pressure Management Areas (PMA) at ENIA utility (Italy)*. IWA Water Loss 2010 Congress, Cape Town, South Africa.

Lambert, A., B. Charalambous, M. Fantozzi, J. Kovač, A. Rizzo, S. Galea St John (March 2014): *14 Years' Experience of using IWA Best Practice Water Balance and Water Loss Performance Indicators in Europe.*

12.9 Water Balance Iren Emilia (year 2013)

DATA COLLECTION WORKSHEET FOR CASE STUDIES, BEST PRACTICE ON LEAKAGE REDUCTION				Version 2e	23-09-2014	by ILMSS Ltd
THIS WORKSHEET IS USED TO CALCULATE NON-REVENUE WATER AND ASSESS COMPONENTS NON-REVENUE WATER						
Colour coding:	Data entry	Essential data entry	Default Values	Calculated Values	Data from another Worksheet	
SIMPLIFIED IWA WATER BALANCE CALCULATIONS		Iren Emilia	14 former ENIA systems		# Conns =	94.410
Period of Water Balance	from 01-01-2013	to 31-12-2013	365 days	Mm³	1000 m³/day	lit/conn/day
Enter data for your system in yellow cells. Check the default %s in the purple cells, and change them if you have better information which will improve the reliability of the calculation. Add comments in the Comments Box below.	POTABLE WATER VOLUME INPUT FROM UTILITY TREATMENT WORKS			44,488	121,9	1291
	Potable Water Imported to this system			0,000	0,0	0
	SYSTEM INPUT VOLUME (Potable Water)			44,488	121,9	1291
	Potable Water Exported from this system			0,000	0,0	0
	Potable WATER SUPPLIED TO THIS SYSTEM			44,488	121,9	1291
	Billed Metered Consumption			32,907	90,2	955
	Billed Unmetered Consumption			0,451	1,2	13
	NON-REVENUE WATER NRW			11,130	30,5	323
	Unbilled Authorised Consumption	0,47%	of Billed Metered Consumption	0,155	0,4	4
	WATER LOSSES			10,975	30,1	318
	Unauthorised Consumption	0,68%	of Billed Metered Consumption	0,224	0,6	6
	Customer Metering Inaccuracies	6,95%	of Billed Metered Consumption	2,287	6,3	66
	APPARENT LOSSES			2,511	6,9	73
	CURRENT ANNUAL REAL LOSSES CARL			8,465	23,2	246
Information entered by	M Fantozzi and F Calza	07.07.2014	Contact	marco.fantozzi@email.it		

Comments: The customer meter park (Turbine meters Class B) is old and the water is hard, and many customer meters were not correctly installed horizontally. A sample of meters were tested in the lab proving the deterioration of performance over time. The estimate of under-registration of 6.95% is based on these tests. A meter replacement plan is being implemented.

Guideline maximum default %s for assessed components of Non-Revenue Water are shown below:				
If higher figures are claimed they should have been validated by Utility Specific data				
	Unbilled Authorised Consumption	0,50%	of Billed Metered Consumption	excluding Water Exported
	Unauthorised Consumption	0,20%	of Billed Metered Consumption	
Customer Metering Inaccuracies	Direct pressure systems	2,00%	of Billed Metered Consumption	
	Roof storage tanks	5,00%	of Billed Metered Consumption	
	Customer Metering Inaccuracies are positive for under-recording, negative for over-recording.			

		Potable Water Exported WE 0,00 Mm3			**Iren Emilia** / **14 former ENIA systems** / **01-01-2013** to **31-12-2013**
Potable Water Produced from Utility Treatment Works 44,49 Mm3	**System Input Volume SIV (Potable Water)** 44,49 Mm3	**Potable Water Supplied WS** 44,49 Mm3	**Billed Authorised Consumption (excluding Water Exported)** Metered 32,91 Mm3; Unmetered 0,45 Mm3		
Potable Water Imported to this System 0,00 Mm3			**Non -Revenue Water NRW** 11,13 Mm3	**Unbilled Authorised Consumption UAC** 0,15 Mm3	
				Water Losses WL 10,98 Mm3	**Apparent Losses AL** 2,51 Mm3
					Real Losses RL 8,46 Mm3

Infrastructure Parameter			**Performance Indicators for Leakage**					
Distribution mains length	4438,8	km	1907	m³/km/year	5,2	m³/km/day	0,22	m³/km/hour
Trunk and Distribution mains length	4941,0	km	1713	m³/km/year	4,7	m³/km/day	0,20	m³/km/hour
Service Connections (to 1st meter)	94410	Number	89,7	m³/conn/yr	246	l/conn/day	'per hour' is influenced by Night-Day Factor NDF	
Density of Connections	19,1	No/km	↑ Use PIs above this row to track leakage in individual systems ↑ / ↓ Use PIs below this row to compare leakage between systems ↓					
Length of underground Service	25,3	m/conn	Current Annual Real Losses CARL				8,46	Mm³/year
Connections, Main to first meter	2388,6	km	Unavoidable Annual Real Losses UARL				3,43	Mm³/year
Average Operating Pressure	43,7	metres	Infrastructure Leakage Index ILI =				2,47	
Annual Repair Frequencies — Mains (UARL)	13,0	/100 km	15,9	per 100 km		which is	1,2	x UARL frequency @ 50m
Annual Repair Frequencies — Connections (UARL)	5,8	/k conns	20,2	per 1000 conns		which is	3,5	
Comments:			↓ PIs based on %s are for comparison only, not recommended ↓					
			Leakage as % of System Input Volume SIV				19,0%	
			Leakage as % of Water Supplied, excluding exports				19,0%	

13 Maltese Case Study: Malta WSC

Contribution of Stephen Galea St John, Stefan Riolo, Manuel Sapiano and Michael Schembri.

13.1 Details Malta Water Services Corporation (Malta WSC)

The Water Services Corporation is the national water operator for all three Maltese islands – Malta, Gozo and Comino. Wholly government owned, it is responsible for both water and waste water operations. The problem of leakage has been holistically tackled since the intermittent supply problems of the mid-nineties. Almost all customers use indirect plumbing systems with large roof storage tanks, which create major meter under-registration quantified by detailed studies as being around 20% or more.

Figure 23 – Properties with roof storage tanks on Malta.

Meter under-registration and other significant problems in the previous billing system are being addressed by replacing older meters and an Automated Meter Reading (AMR) system, currently 80% completed. In recent years, annual volumes of real losses assessed by 'bottom-up' calculations from Night Flows and Night-Day Factors have been more reliable than 'Top-Down' Water Balances. Some 300 PMZs and DMAs are continuously monitored, with active leakage control interventions when target leakage levels, using the Snapshot ILI concept, are exceeded.

Malta is a popular tourist destination with large numbers of summer and winter visitors. Figure 24 below Table 44 shows the seasonal variation in Water Supplied. Figure 25 shows how leakage reduction of 7 Mm^3/year since 2001 has allowed Water Supplied (mostly seawater through Reverse Osmosis (RO) plants, the rest being groundwater) to be reduced from 36 Mm^3 to 31 Mm^3. Treated water in Malta is an expensive and energy intensive resource, and leakage reduction has allowed two RO plants to be dispensed with since the year 2000.

Country	Basin / Sub-basin	Water service provider	Other key stakeholders
Malta	Malta	Water Services Corporation (WSC)	Malta Resources Authority; Malta Environment & Planning Authority; Sustainable Energy & Water Conservation Unit

Table 44 – Geographical context of Malta WSC.

Characteristic	Value
Population	421.364
Number of billed properties (residential and non-residential)	256.000
Number of service connections (main to first meter)	140.000
Average length of underground service connections	7 m
Length of trunk mains	350 km
Length of distribution mains	1.950 km
Average operating pressure	35 m
% of time system is pressurised	100 % of year
% of total mains length subject to active pressure management	70 %
Annual volume of potable water supplied (excluding exports)	30.484.000 m^3/year
Average time from location of mains leaks to shutoff or repair	0,5 days
Average time from location of service leaks to shutoff or repair	2,5 days
Leaks on mains (number per 100 km/year)	24 No/year
Leaks on service connections (number per 1000 connections/year)	53 No/year
% of system having active leakage control interventions each year	100 %
Number of water treatment plants (Reverse Osmosis)	3
Number of pumping stations	13
Number of distribution reservoirs	24
Total number of staff	890
Staff directly involved in water operations	150
Average consumer price	€ 2,42/m^3
Highest unit cost of water	€ 0,94/m^3

Table 45 – Details water production system and distribution network Malta WSC.

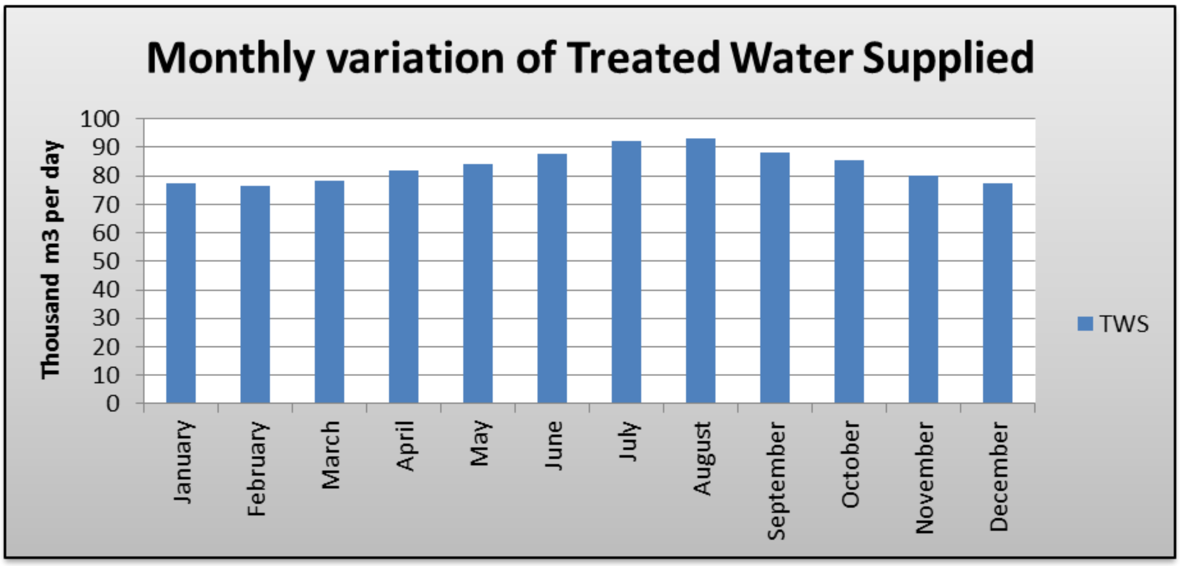


Figure 24 – Seasonal variation in Water Supplied by Malta WSC.

The graph above (Figure 24) shows the typical monthly variation on potable water supplied in thousands m^3/day for the year 2013. Consumption is the lowest in December to March, before increasing from April onwards before peaking in July and August.

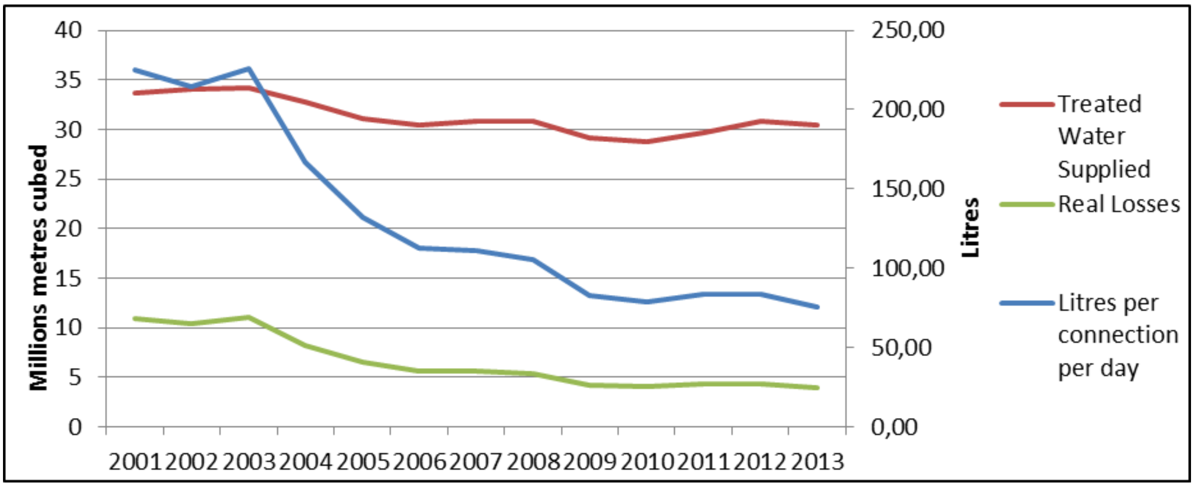


Figure 25 – Leakage Reduction has allowed Water Supplied to be reduced.

13.2 Details context Malta WSC

The Maltese Islands are densely populated but poorly endowed with freshwater resources. The main natural freshwater resources sustaining the islands' water demand are the sea-level aquifer systems; sustainable abstraction from which can however only meet around half of the islands' water demand. In order to address this imbalance between water demand and supply, Malta has been on the forefront of the development of alternative water resources. In fact, since the 1980s, drinking-water supply has been heavily dependent on saltwater desalination; thus ensuring the reliable supply of good quality drinking water. Today, significant investments are being made to develop the necessary infrastructure to enable the effective re-use of treated sewage effluents for secondary purposes, thus introducing a new source of water in the islands' water balance.

One must also note that the prevailing water scarcity conditions have resulted in the development of an underlying awareness on the need for water conservation. In fact, at around 100 l/cap/day the demand for water by the Maltese domestic sector is one of the lowest in Europe. The islands' water policy framework also adopts various tools to enhance the efficient use of water. Such tools include direct measures such as the active network leakage management and repair programme undertaken by the national utility as well as indirect measures such as the adoption of a rising-block tariff mechanism which presents increasing prices for higher water consumption.

Relevant factor	Yes	No
Abundant water resources at a basin level?		√
Limited measures required to improve water status to achieve WFD objectives?		√
River Basin Management Plan (RBMP) completed?	√	
Active quantity management incorporated in the RBMP?	√	
RBMP harmonised with other key socio-economic and land use planning documents prior to adaptation and incl. financing plans?	√	
Abundant water resources for water service provider all year every year?	√	
Water resources of good chemical quality (low or no treatment)?	√	
Water resources located at topographical levels above the level of the customer base (low or no energy costs)?		√
Are the economics of density reasonable (> 20 connections per km)?	√	
Cost effective investment and operating conditions?	√	
Distribution network designed for ease of operation and maintenance without maximum pressure stresses?	√	

Relevant factor	Yes	No
Pressure Management implemented throughout the system?	√	
District Metering implemented throughout the system?	√	
Good quality of the network installation (materials selection and workmanship at the time of installation)?	√	
Water pricing limitations?	√	
Conflicting socio-economic needs and/or historical legacy?	√	
Public affordability constrains?	√	
Ability- / willingness-to-pay constraints?	√	
Benefitting from EU Funds to finance significant water supply (and urban wastewater) treatment investments?	√	
Specific Regulator (Utility subject to regulation)?	√	

Table 46 – Specific context within Malta WSC is operating.

13.3 Overview leakage measures and indicators implemented at WSC

Night Flow measurements are used in Malta WSC for targeting leakage in DMAs and for assessment of annual leakage volumes, for the reasons described in Section 13.5. Because groundwater resources are insufficient, and seawater distillation through Reverse Osmosis is used continuously, the marginal cost of potable water is high, around €0,94/m^3. This means that intensive activity in pressure management, sectorisation, active leakage control and speed and quality of repair are economically justified, to reduce leakage as far as practical prior to infrastructure replacement.

Implemented measure on leakage assessment and reduction	Yes	No
Reliable Bulk Supply Metering	√	
Reliable District Metering	√	
Reliable Customer Metering		√
Good System Design and Installation	√	
Effective Management of Excess Pressure and Pressure Transients	√	
Speed and quality of repairs	√	
Active Leakage Control at an economic frequency	√	
Sectorisation and/or District Metering Area formation	√	
Asset Renewal: service connections	√	
Asset Renewal: mains	√	
Annual Volume of Real Losses (Level of Leakage, CARL)	**Value**	
For 2013	3.959.953 m^3/year	
Indicators used at Malta WSC	**Value**	
ILI based on weighted average of Snapshot ILI (used by regulators)	2,1	
Litres per connection per day	77,5	
Average system pressure	35m	

Table 47 – Implemented leakage reduction measure(s) at Malta WSC.

13.4 Details strategy and proven leakage reduction measure(s)

In the mid-1990s, the Malta WSC realised the extent of high leakage in its intermittent supply network, and set up a specialised Water Audit Section to study how to curb the ever-growing national demand and manage its water losses. Until that time, the Corporation's basic simple strategy of leak detection exercises over the whole distribution system several times per year was ineffective, as tests were not concentrated on weak and problematic locations.

Malta WSC now achieves continuous supply in a re-arranged, highly sectored pressure managed system where relatively poor quality infrastructure (as evidenced by high break frequencies, particularly on services) is combatted by intensive active leakage control in small DMAs with rapid repairs of leaks. Further improvements require significant infrastructure replacement.

Importance: The Water Audit Section success has been built on the solid foundation of a highly motivated in-house team – leakage engineers, technicians and detectors – who have provided experience, continuity and ingenuity in developing and implementing the evolving leakage management strategy based on IWA WLSG practical approaches, often using locally developed low cost methods and equipment.

Approach: The "Five-Force Leak Control Methodology" is based on IWA practical approach to managing leakage. Five components act in unison to decrease the value of Real Losses as close as possible to that of the unavoidable leakage amount. The components that contribute to the control of leakage, in approximate sequence of implementation, are:

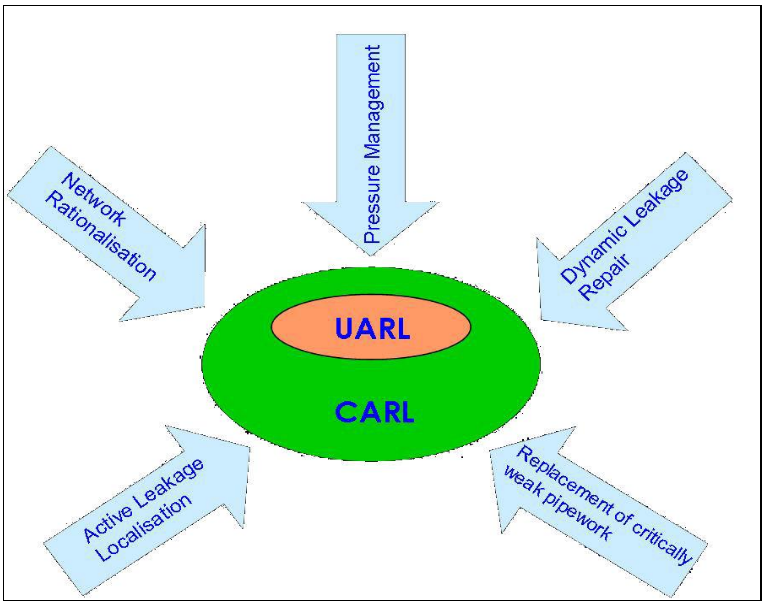


Figure 26 – Malta WSC "Five-Force Leak Control methodology".

Network rationalisation

To quantify leakage, the network was split into 300 defined, hydraulically-encapsulated zones or sectors (DMAs or PMAs) each with a single metered input. The Malta distribution network had developed in a very haphazard way, with little regard to this principle, so a lot of rationalisation and infrastructure works were needed.

Pressure Management

Excess pressures and pressure fluctuations are extremely detrimental to pipes, especially old brittle cast iron mains. Pressure management has reduced leak flow rates and burst frequencies in Malta, mainly through using:

- Fixed outlet PRVs, mostly on gravity-fed systems, some with night time-modulation.
- Variable frequency drives on pumps for pump-fed systems, which maintain a fixed head irrespective of changes in system demand.

80% of DMAs have some form of pressure control from 214 PRVs and 28 VFDs.

Active Leakage Localisation

The performance of the network is continuously monitored via night flows from zone meters. ALC to pinpoint hidden leaks, is only conducted in zones where targeted Snapshot ILI is exceeded; it incorporates several techniques: zone drying out, zone segmentation, pressure/flow data logging and acoustic leak detection.

Locally-created equipment for live monitoring of flows via a GSM modem overcomes disadvantages of traditional step-test techniques, and is one of the most frequently-used tools in the Malta WSC leak control arsenal.

Dynamic Leakage Repair

The longer a leak is left unrepaired, the more water is lost. This component implies speed and quality of repairing leakages. On average, the Malta WSC repairs main bursts in 0,5 days and service connections in 2,5 days.

Replacement of Critically Weak Pipe-work

Even at managed low pressure, the only feasible option for old, structurally weak cast iron and galvanised iron pipes is replacement. The WSC ongoing asset replacement programme renews around 40km (1,8%) of mains and 10km (7,1%) of service connections each year.

Results: The implementation of an effective holistic approach started reaping immediate dividends. Figure 27 shows how, by a combination of targeted actions, potable water production was gradually reduced from 50 to 30 Mm^3 per year between 1995 and 2013.

Figure 27 – Malta WSC Potable Water Production 1995-2013.

Leakage has to be tracked using meaningful performance indicators. Based on sector night flows, leakage was a staggeringly high 3.900 m^3/hour in 1995. In 2001, Malta WSC was the first European country to follow IWA guidance and switch from using %s by volume and m^3/km mains/day, to litres/connection/day and ILI.

Since then, WSC leakage has been reduced from 225 to 70 litres/connection/day, and ILI from 10 to 2,1. The four leakage management regions of the WSC (Gozo, and Malta North, South and Central) currently have ILIs of 1,7, 2,0, 2,2 and 2,3.

Implementation Guidelines: The "Five-Force Leak Control Methodology" was initially implemented on the Island of Gozo, which has very similar characteristics to Malta but is smaller and less densely populated. Gozo also has the topographical advantage that zones were easier to segregate. Following the rapid success of the methodology in Gozo, the management of the network on Malta was divided into three empowered regions (North, Central and South), each tasked with the target to lower leakage using the same approach used in Gozo.

The regions were headed by an engineer and they worked as a team together, whilst at the same time engaging in healthy competition for best outcomes. It was this cooperation that led to the creation of the concept of Snapshot ILI, a tool based on the traditional ILI methodology, yet enabling the quick compilation of results on a weekly basis, using night flows. This ensured that targets were assiduously and continuously monitored.

13.5 Details monitoring methods and leakage indicators

This Section explains the reasoning behind using Night Flows, rather than Water Balance, to assess annual leakage volumes in Malta. To use the top-down Water Balance approach, it is necessary that:

- Billed Metered Consumption volume is reliably known (within +/- 2% or better).
- Assessed components of Unbilled Authorised Consumption and Apparent Losses are only small %s of Billed Metered Consumption.

The Table below shows a Water Balance for a direct pressure system with guideline upper limits (Appendix B.1) for Unbilled Authorised Consumption and Apparent Losses; resulting Confidence Limits for Annual Real Losses Volume are +/- 15%.

Anytown Water Balance Direct Pressure system	Subsidiary calculations		Volume Mm3	Confidence limits +/-%	Confidence limits +/-Mm3
Potable Water Supplied			100.0	2.0%	2.00
Billed Metered Consumption (BMC)			80.0	2.0%	1.60
Non-Revenue Water (NRW)			20.0	12.8%	2.56
Unbilled Authorised Consumption UAC)	0.50%	of BMC	0.40	20.0%	0.08
Unauthorised Consumption (UC)	0.20%	of BMC	0.16	20.0%	0.03
Customer metering inaccuracies (CMI)	3.00%	of BMC	2.40	20.0%	0.48
Real Losses			17.2	15.2%	2.61

The problem in WSC with Billed Metered Consumption is that until recently the Corporation was using an old legacy Billing Application that could not cater for today's customer base. Reports from this application were not timely enough and often riddled with errors. The WSC has since updated its Billing software but it is still in the data-cleansing phase, so errors influencing Apparent Losses are still being ironed out.

The major reason why Apparent Losses are so difficult to quantify, however, is customer meter under-registration. The indirect plumbing systems with large water storage tanks on the roofs mean that even the most accurate commercially-available meters will struggle to register all flow that passes through them, and the performance of mechanical rotary piston meters gradually deteriorates. Although the Corporation has a continuous meter changing programme to combat this, the criterion to change meters to date has been the age of the meter, i.e. how long it has been installed.

In-depth studies have demonstrated that other factors, such as total volume registered, customer consumption profile, water pressure, etc. all have an effect on a meter's performance degradation. Other similar studies have shown that the under-registration of some of the meter park can vary from 20% to even 80% and over.

The Table below replicates the same Water Balance as the previous Table for a system with roof tanks, confidence limits for billed Metered Consumption of +/-10%, and average customer meter under-registration of 20%. The resulting Confidence Limits for Annual Real Losses Volume are +/- 45%, three times as large as for the direct supply system.

This is why, historically, Malta WSC has used Night Flows (bottom-up approach) to compute its leakage volumes in preference to the Top-Down Water Balance approach.

Anytown Water Balance with roof storage tanks	Subsidiary calculations		Volume	Confidence limits	
			Mm3	+/-%	+/-Mm3
Potable Water Supplied			100.0	2.0%	2.00
Billed Metered Consumption (BMC)			68.7	10.0%	6.87
Non-Revenue Water (NRW)			31.3	22.9%	7.16
Unbilled Authorised Consumption UAC)	0.50%	of BMC	0.34	20.0%	0.07
Unauthorised Consumption (UC)	0.20%	of BMC	0.14	20.0%	0.03
Customer metering inaccuracies (CMI)	20.0%	of BMC	13.74	20.0%	2.75
Real Losses			17.2	44.5%	7.67

This shows how using the top-down approach to assessing leakage is not sufficient to return a credible value in this situation. However, the WSC is well organised to compute leakage using the bottom-up approach with Snapshot ILI.

The whole of the Maltese Islands has been sectored into around 300 hydraulic zones (District Metered Areas). The Minimum Night Flows for each of these zones – all permanently metered and logged – is recorded and leakage is computed weekly from these values. The leakage for each zone is compiled by subtracting the legitimate night consumption for all the premises within the zone from the minimum night flow for that zone for that particular week. The result is multiplied by the Night-Day Factor to compensate for the fluctuations in the zone pressures between the day and the night. The sum of the leakage for all zones in the Maltese Islands is the weekly snapshot ILI computation and the average for this value over all the weeks of the year is the annual ILI. Leakage on the primary network is monitored by reconciling trunk main meters and the related zone meters.

The Snapshot ILI formula is based on the classical ILI formula but considers just the weekly leakage snapshot. Thus the formula becomes:

$$\frac{\text{Weekly Snapshot Real Losses}}{\text{Unavoidable Real Losses}} \quad \text{or} \quad \frac{(MNF - LNC \times N_a) \times NDF}{(18 \times L_m + 0{,}8 \times N_c) \times P}$$

where
- MNF = Minimum Night Flow during a particular week
- LNC = Legitimate Night Consumption
- N_a = Number of active accounts (properties with water supply)
- NDF = Night-Day Factor
- L_m = Length of mains
- N_c = Number of service connections, main to property line
- P = Average zone pressure

The values for the number of properties, number of connections and length of mains are accurately obtained from the WSC's GIS. To determine values for the average zone pressure and the legitimate night consumption, a number of empirical tests were conducted. These values were recently validated via two models, using Digital Terrain Maps/GIS tools for the pressure and AMM readings for the night consumption.

In a similar fashion, the Night-Day Factor was also determined via empirical tests. The Malta WSC is currently using a specialised software application to validate Night-Day Factors and determine confidence limits for the real losses values compiled.

The AMM project will enable the Malta WSC to test methods of reconciling 'bottom-up' and 'top-down' methods of quantifying leakage, by comparing each zone meter with the summation of all the revenue meters in that Zone. Whilst such a reconciliation will include both Real and Apparent losses, the comparison between the two methods should enable the Malta WSC to arrive at more reliable assessments of apparent losses, something that so far has not been very accurate or timely. This will be done on a zone-by-zone level, until eventually the entire network is mapped out.

A Water Balance in simplified IWA Water Balance format is enclosed in Section 13.9 at the end of this Case Study.

13.6 Evaluation of further options for pressure management

As 70% of the system is currently subject to pressure management, and the average system pressure has been reduced to 35 metres, the options for further pressure management are limited. However, the Malta WSC clearly understands the mantra that with pressure management 'every metre counts'[6].

Despite the relatively low average pressures, the burst frequencies for service connections (53 per 1.000 service connections/year) are particularly high by international standards, running at almost 18 times the frequency of 3 per 1.000 service connections per year used in the UARL formula. The burst frequencies for mains (24 per 100 km of mains/year) are approximately twice the frequency of 13 per 100 km per year used in the UARL formula.

13.7 Results and recommendations

The following recommendations are all planned for execution/completion over the coming months:

- Continue the exercise to boost confidence limits, with regards to the Night-Day Factor used in the bottom-up method to calculate leakage.
- Conclude the AMM project to assist in reconciling the bottom-up and top-down methods to calculate leakage, again to improve confidence limits.

Whilst the WSC will continue its efforts to manage leakage, even more focus will be placed on controlling apparent losses. In this area, the local situation dictates that major gains are possible through the management of meter under-registration. These include:

- An ongoing revenue meter replacement programme.
- Optimising the revenue meters replacement time using data from AMM and dedicated analytical tools.

13.8 References

AZP&NDFCalcsProfessional Software. ILMSS Ltd.

Galea St John, S., (2012): *Water Loss Control in Malta*.

Cini, S., (2006): *Infrastructure Leakage Index.*

[6] Trow, S., S. Tooms and A. Smith (2014): Pressure management of water distribution systems – Every Metre Counts. Water IDEAS 2014 conference, Bologna, Italy.

13.9 Water Balance Malta WSC (year 2013)

DATA COLLECTION WORKSHEET FOR CASE STUDIES, BEST PRACTICE ON LEAKAGE REDUCTION			Version 2x	23-07-2014	by ILMSS Ltd
THIS WORKSHEET IS USED TO CALCULATE NON-REVENUE WATER AND ASSESS COMPONENTS NON-REVENUE WATER					
Colour coding:	Data entry	Essential data entry	Default Values	Calculated Values	Data from another Worksheet

SIMPLIFIED IWA WATER BALANCE CALCULATIONS			Malta	Whole System		# Conns =	140.214	
Period of Water Balance	from	01-01-2013	to	31-12-2013	365 days	Mm³	1000 m³/day	lit/conn/day
Enter data for your system in yellow cells. Check the default %s in the purple cells, and change them if you have better information which will improve the reliability of the calculation. Add comments in the Comments Box below.	POTABLE WATER VOLUME INPUT FROM UTILITY TREATMENT WORKS					30,492	83,5	596
	Potable Water Imported to this system					0,000	0,0	0
	SYSTEM INPUT VOLUME (Potable Water)					30,492	83,5	596
	Potable Water Exported from this system					0,000	0,0	0
	Potable WATER SUPPLIED TO THIS SYSTEM					30,492	83,5	596
	Billed Metered Consumption					17,380	47,6	340
	Billed Unmetered Consumption					0,000	0,0	0
	NON-REVENUE WATER NRW					13,112	35,9	256
	CURRENT ANNUAL REAL LOSSES CARL (derived from minimum night flows)					3,960	10,8	77
	Unbilled Authorised Consumption		52,7%	of Billed Metered Consumption		9,152	25,1	179
	Unauthorised Consumption			of Billed Metered Consumption				
	Customer Metering Inaccuracies			of Billed Metered Consumption				
Information entered by		Stephen Galea St John		25-08-2014	Contact	anyone@anywhere.com		

Comments: Due to problems with under-registration of customer meters because of roof storage tanks, and the change-over from the existing unreliable billing system to smart metering (which commenced during 2013), the Billed Metered Consumption and the estimated volumes derived from it (Unbilled Authorised Consumption, Unauthorised Consumption, Customer Metering Inaccuracies) do not produce a reliable Water Balance. Accordingly, the Real Losses calculated from minimum night flows have been used to estimate the other unmetered components of NRW.

Guideline maximum default %s for assessed components of Non-Revenue Water are shown below:				
If higher figures are claimed they should have been validated by Utility Specific data				
	Unbilled Authorised Consumption	0,50%	of Billed Metered Consumption	excluding Water Exported
	Unauthorised Consumption	0,20%	of Billed Metered Consumption	
Customer Metering Inaccuracies	Direct pressure systems	2,00%	of Billed Metered Consumption	
	Roof storage tanks	5,00%	of Billed Metered Consumption	
	Customer Metering Inaccuracies are positive for under-recording, negative for over-recording.			

Infrastructure Parameter				**Performance Indicators for Leakage**					
Distribution mains length		1845,0	km	2146	m³/km/year	5,9	m³/km/day	0,25	m³/km/hour
Trunk and Distribution mains length		2313,0	km	1712	m³/km/year	4,7	m³/km/day	0,20	m³/km/hour
Service Connections (to 1st meter)		140214	Number	28,2	m³/conn/yr	77	l/conn/day	'per hour' is influenced by Night-Day Factor NDF	
Density of Connections		60,6	No/km	↑ Use PIs above this row to track leakage in individual systems ↑ ↓ Use PIs below this row to compare leakage between systems ↓					
Length of underground Service Connections, Main to first meter		7,0	m/conn	Current Annual Real Losses CARL				3,96	Mm³/year
		981,5	km	Unavoidable Annual Real Losses UARL				2,10	Mm³/year
Average Operating Pressure		35,0	metres	Infrastructure Leakage Index ILI =				1,88	
Annual Repair Frequencies	Mains (UARL)	13,0	/100 km	26,1	per 100 km		which is	2,0	x UARL frequency @ 50m
	Connections (UARL)	3,4	/k conns	93,8	per 1000 conns		which is	27,6	

Comments: The annual UARL formula uses total service pipe length main to meter, this is 7 m. not 4 m, as assumed in previous UARL calculations based on meters at the property line. This adjustment increases UARL by 7% and decreases the ILI by 7%.	↓ PIs based on %s are for comparison only, not recommended ↓	
	Leakage as % of System Input Volume SIV	13,0%
	Leakage as % of Water Supplied, excluding exports	13,0%

14 Portuguese Case Study: Lisbon

Contribution of Andrew Donnelly, EPAL (July 3, 2014).

14.1 Details EPAL and Lisbon

The largest and oldest water utility in Portugal, EPAL – Empresa Portuguesa das Águas Livres, SA is a limited liability company, with 100% public capital, owned by the Águas de Portugal group. EPAL undertakes the extraction, treatment and distribution of potable water, encompassing both bulk supplies to around three million people in 34 municipalities and direct supply to more than half a million people in the city of Lisbon.

This case study relates to the Lisbon distribution network, which receives treated water via EPAL's bulk supply network from the principal water source at Castelo de Bode, some 120 kilometres north of the city. The distribution network encompasses around 1.450 kilometres of mains, divided into five pressure zones and supplying in excess of 340.000 clients.

Country	Basin / Sub-basin	Water service provider	Other key stakeholders
Portugal	Tagus	EPAL, SA	Águas de Portugal

Table 48 – Geographical context of EPAL.

Characteristic	Value
Population	564.000
Number of billed properties (residential and non-residential)	343.975
Number of service connections (main to first meter)	87.815
Length of trunk mains	134 km
Length of distribution mains	1.314 km
Average operating pressure	51,2 m
% of time system is pressurised	100 %
% of total mains length subject to active pressure management	10 %
Annual volume of System Input Volume (SIV)	102.746.718 m^3
Average time from location of mains leaks to shutoff or repair	1 day
Average time from location of service leaks to shutoff or repair	1 day
Leaks on mains (number per 100 km/year)	38,2
Leaks on service connections (number per 1000 connections/year)	8,4
% of system having active leakage control interventions each year	32%
Number of water treatment plants	2
Number of pumping stations	9
Number of distribution reservoirs	11
Total number of staff	694
Staff directly involved in water operations	393
Average consumer price	€ 0,87/m^3
Highest unit cost production and distribution	€ 0,05/m^3
Energy usage	115,8 million kWh/year

Table 49 – Details water production system and distribution network EPAL.

The graph below shows the potable water supplied in 1.000 m^3/d for EPAL for the year 2013. It shows typical annual variations in the consumption pattern, varying between around 250.000 and 350.000 m^3/d, noting the unusual drop in late July and August during the otherwise higher summer consumption, when a high percentage of the population leave the city for holidays.

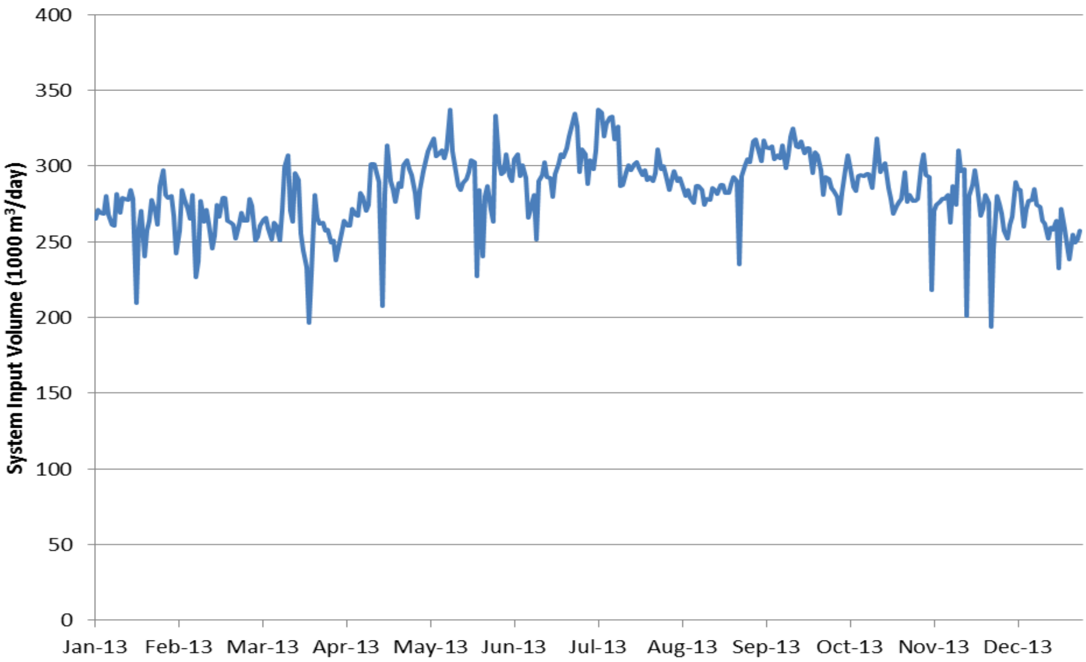


Figure 28 – System Input Volume by EPAL for the year 2013 in 1.000 m^3/day.

14.2 Details context EPAL and Lisbon

Water extracted and treated by EPAL is sourced entirely from the River Tagus basin, located in central Portugal and neighbouring Spain. Around 75% of the water source is obtained from the Castelo de Bode dam on the River Zêzere, a tributary of the River Tagus, from where a further 20% is extracted directly. The balance is obtained from groundwater sources in the lower Tagus valley, north of Lisbon. The Tagus basin was considered to be not water scarce in the EU report 'Resource & Economic Efficiency in Water Distribution Networks in the EU' (2013), although reference was made to the need for more knowledge of groundwater bodies, storage and sustainable yields in order to achieve the optimal water balance within the River Basin Management Plan.

Relevant factor	Yes	No
Abundant water resources at a basin level?	√	
Limited measures required to improve water status to achieve WFD objectives?	√	
River Basin Management Plan (RBMP) completed?	√	
Active quantity management incorporated in the RBMP?	√	
RBMP harmonised with other key socio-economic and land use planning documents prior to adaptation and incl. financing plans?		√
Abundant water resources for water service provider all year every year?	√	
Water resources of good chemical quality (low or no treatment)?	√	
Water resources located at topographical levels above the level of the customer base (low or no energy costs)?		√
Are the economics of density reasonable (> 20 connections per km)?	√	
Cost effective investment and operating conditions?	√	
Distribution network designed for ease of operation and maintenance without maximum pressure stresses?	√	
Pressure Management implemented throughout the system?	√	
District Metering implemented throughout the system?	√	
Good quality of the network installation (materials selection and workmanship at the time of installation)?	√	

Relevant factor	Yes	No
Water pricing limitations?	√	
Conflicting socio-economic needs and/or historical legacy?		√
Public affordability constraints?	√	
Ability- / willingness-to-pay constraints?	√	
Benefitting from EU Funds to finance significant water supply (and urban wastewater) treatment investments?	√	

Table 50 – Specific context within EPAL is operating.

The entire Lisbon distribution network is divided into five pressure zones, reflecting the topography of the city and requirement for each zone to be pumped separately. Whilst this pressure management is universal, pressure control and reduction measures (PRVs) are applied to only around 10% of the network. Tariff setting control by the sector regulator and socio-economic pressure due to the on-going financial issues in the country may be considered as constraint factors.

14.3 Overview leakage measures and indicators implemented at EPAL

The basis of leakage reduction measures implemented within the Lisbon distribution network is the segmentation of the system into permanently monitored DMAs, in order to assess and quantify potential water losses per sub-zone. This approach benefits considerably from the existence of a reliable and accurate GIS system and universal client metering, whilst DMA interventions are focused not only on real losses through leakage, but also apparent losses such as illegal or unmetered connections and stopped meters. Company policy is to repair every leak identified through active leakage control activities, with a significant majority of repairs undertaken within 24 hours.

Implemented measure on leakage assessment and reduction	Yes	No
Reliable Bulk Supply Metering	√	
Reliable Customer Metering	√	
Good System Design and Installation	√	
Effective Management of Excess Pressure and Pressure Transients	√	
Speed and quality of repairs	√	
Active Leakage Control at an economic frequency	√	
Sectorisation and/or District Metering Area formation	√	
Asset Renewal: service connections	√	
Asset Renewal: mains	√	
Annual Volume of Real Losses (Level of Leakage, CARL)	**Value**	
CARL	4.796.000 m^3/year	
Leakage Indicators used at EPAL S.A.	**Value**	
% of SIV	7,9%	
Real Losses per service connection per day	178 l/con/day	

Table 51 – Implemented leakage measures and indicators at EPAL in Lisbon.

14.4 Details strategy, monitoring methods and leakage indicators

The core strategy for reducing water losses within the Lisbon distribution system focuses on continuous monitoring of the network, segmented into District Metered Areas (DMAs), encompassed within what has been defined as the Water Optimization for Network Efficiency (WONE) methodology and software application. DMAs were designed relative to the network configuration, client distribution and flow capacity of each sub-zone with a series of baseline characteristics applied, where possible. As a result, DMAs mostly encompass between 1.500 and 3.000 clients, five to ten kilometres of mains with net daily consumption limited to not more than 1.200 m^3/day.

DMA implementation was undertaken over a four year period, with around 35 DMAs created annually, starting with naturally formed zones, often with single feed mains, followed by more complex areas where the closure of boundary valves required more in-depth planning and risk assessment. This process of network segmentation required installation of 180 monitoring points, featuring battery-powered electromagnetic flow meters, pressure tappings and associated telemetry data loggers, along with several interventions to install additional boundary valves, connection mains and discharge valves for flushing operations. DMA monitoring and boundaries are also subject to continuous improvement, based on operational experience and network optimization.

DMA Implementation Projects were produced for each zone, with analysis of proposed boundaries, installations, existing network performance, client data and GIS plan preparation. The planning process included review of DMA designs using EPANET for flow and pressure analysis whilst linking of GIS and customer billing systems was essential for providing accurate customer consumption data. Prior to implementation, each DMA project proposal was submitted to Network Operations, Maintenance and Commercial departments. Once approved, DMA lock-in was undertaken with real-time monitoring at critical points, with integrity of each verified through a pressure zero test, leading on to post-implementation analysis and subsequent active leakage control interventions. Combined with the fully DMA segmented network, new operational, infrastructure and equipment maintenance procedures were created with special emphasis on co-ordination of reported leak repairs to the maintenance area of the company.

DMA monitoring involves pressure and flow being registered at fifteen minute intervals at each monitoring point, with data available daily via a passive telemetry system or on-demand in case of pressure anomalies. DMA telemetry functions independently of the existing SCADA network management system, but is supported by the client telemetry network. The installation of more than 1.500 telemetry systems to high demand users, critical clients such as hospitals or any point with significant nocturnal consumption, such as garden watering and sprinkler systems, which influence DMA nightline evaluations has also been undertaken, using the same 15 minute flow and pressure registration. In terms of water loss control, the objective was to improve DMA analysis through assessing the impact of individual clients and to characterise losses between EPAL and customer networks, given that both incur losses. Data from all telemetry systems and SCADA is integrated with the software application specifically developed by the company to manage all data relevant to network performance monitoring and dedicated to leakage control.

The principal objective of the WONE application is to integrate all monitoring data from different sources into a single interface and calculate practical KPIs to support water loss control. Note that the KPIs used are entirely focused on assessing network performance in terms of water losses as a practical tool for system managers and are not directed towards overall company indicators, such as the water balance or inter-company comparisons. Obviously, data generated by the monitoring systems is considered in calculations of overall company indicators, such as Non-Revenue Water per service connection and characterisation into real and apparent losses.

The WONE application is hosted via secure server Internet, allowing global access for authorised users and produces statistical analysis of both net and total DMA daily total and nightline, pressure variations and alarms. A range of KPIs with practical applications are included, such as the percentage relationship between the daily minimum hour to average hour ratio using a minimum hour running mean calculation based on net values (the balance of DMA input/output meters and any high demand users with telemetry), total and nightline volumes per 1.000 clients or kilometre of network, in order to allow performance ranking, comparison and attribute intervention priorities between DMAs.

The most noteworthy KPI produced, is the estimate of recoverable losses per DMA and target minimum flow nightline. This is determined by deducting two variables from the net minimum nightline for each DMA; these being an allowance for inevitable real losses which cannot be expected to be located using leak detection techniques for which the Unavoidable Background Real Losses (UBRL) formula is used, taking into account a series of DMA variables such as network length, number and length of service connections and average pressure. The second variable is an estimate of authorised nocturnal client usage, with values of 1 litre/client/hour used for domestic clients and 4,8 litres/client/hour for non-domestic clients, values adopted to local characteristics based on EPAL's knowledge of its customer consumption profiles from UKWIR report 12/WM/08/48 *Assessment of Low Flow Components of Night Use and the Water Balance*.

By using the WONE application, leakage teams are directed to specific zones with information on their expected leak reduction targets and potential. Experience within EPAL has confirmed that this information is indispensable for field teams and decisions relating to planning and implementation of leak detection interventions or network diagnostics, whilst DMA monitoring data is also considered in the multi-criteria matrix for identifying priority network rehabilitation areas. In addition, daily consultation of application data by all operational units, emphasizes that the system and indeed entire DMA project, is a network management and diagnostic tool as opposed to one focused solely on water losses control. This reinforces the vision that any leakage reduction project is inherently connected with efficient network management and must not be considered as a stand-alone water loss reduction plan.

14.5 Details proven leakage reduction measure(s)

All activities relating to water loss control are the responsibility of the Network Monitoring Unit, part of EPAL's Asset Management Division, but with a high degree of co-ordination with the Maintenance Division for leak repairs, Operations Division for overall system management and Commercial Division for client metering, telemetry and client-side leakage.

EPAL defined the issue of reducing elevated water losses within the city of Lisbon distribution network as a strategic goal, with the WONE project given significant support by the management board and creation of a dedicated team with the necessary resources to not only control and reduce water to economic levels, but importantly, to create capacity to sustainably manage the issue in the future. The project has also been the catalyst behind much of the structural reorganisation of the company, aimed at increasing efficiency and reducing costs.

Based on detailed DMA and client data available to calculate the practical KPIs available in the WONE software application, as outlined in Section A.14.4, the selection and ranking of DMAs in undertaken on a daily basis, with those with the highest estimated recoverable water losses or percentage ratio between the minimum nightline and average daily flow rate being chosen for leak detection interventions or investigations into excessively high night or daily consumption.

Field teams are issued with pre-intervention DMA Project reports, which include all relevant information required for the intervention, such as the DMA plan, boundary valves, metering, key clients and estimated recoverable losses. Such information assists the field team in deciding the strategy to be applied in each intervention.

Leak detection teams are formed of two trained staff as street working in a busy city environment is deemed as high risk, especially when one technician may be using acoustic equipment with headphones on public roads. Teams have a range of equipment available, namely ground microphones, geophones, listening sticks, acoustic noise loggers, leak noise correlators and gas injection, with selection of which system to be used, dependent on the leak detection location and general environment, pipe size and material, expected leak size and access to the mains or accessories.

Each project starts with a boundary valve integrity validation, with new DMAs subject to a subsequent Lift & Shift operation using acoustic noise loggers, deployed across the entire DMA for periods of 48 to 72 hours. With larger DMAs or those which have been subject to previous leakage sweeps or urgent interventions, temporary modifications of DMA boundaries are also applied to accelerate the process, with considerable flexibility and reduced risk achieved by making use of the high inter-connectivity of DMAs in Lisbon distribution network and confidence in boundary valve integrity. By transferring subzones between DMAs and noting the variations in consumption profiles, this allows evaluation of network performance quickly and with little or no impact on service quality. Step-testing, which by necessity has to be undertaken during night time, is avoided where possible.

Most leaks are located using stop tap sounding with listening sticks or correlation along mains sections, with leak positions pinpointed using a ground microphone and geophones. Experienced technicians are fundamental to this process and significantly less usage of acoustic noise loggers has been a trend over recent years. In very specific situations, principally customer-side leakage detection, EPAL uses a gas tracer method, introducing an inert gas inside the mains with the gas being detected at the surface in areas where there are leaks.

In all cases, leaks are reported to the maintenance section to undertake repairs or the customer assistance unit where leaks are located on the customer side of the meter or property boundary. Post-repair verification of repair locations is undertaken to identify further leaks which may have been hidden in the initial sweep where large leaks were found and repaired. The location of all leaks reported and repaired by the maintenance division are recorded in the GIS system for future reference and to contribute to analysis of potential network renewal requirements.

As regards investigations into excessively high night or daily total consumption, significant focus has been made on identifying authorised, un-metered consumption locations, principally those of the local council and borough authority green space watering and irrigation systems. Meter installation at these locations has been fundamental to reduce the volume of estimated water usage, whilst a significant number of locations have been equipped with telemetry where consumption was identified during the night. Such consumption profiles can have a significant impact on DMA performance assessment using through nightline analysis, hence the requirement to quantify and subtract this authorised usage from net nightline calculations on a 15 minute basis.

A post-intervention DMA Analysis Project completes the process, to register all activities and repairs undertaken for future reference, quantify the impact on NRW reduction as well as incidents of illegal usage, customer side losses, metering failures and errors within the GIS system.

As a result, productivity of leak detection teams has risen significantly, given the increased targeting of active leakage detection in under-performing DMAs, despite the ever reducing volume of recoverable losses. The number of field technicians has been reduced by half, with more potential macro-leak localisation undertaken by office-based project engineers using data provided in the WONE application. In the seven years since the Network Monitoring Unit was created, around 40 DMA analysis projects have been completed per year, with an annual average in excess of 200 m^3/h of recovered water losses. More than 70% of the estimated recoverable losses have indeed actually been identified and resolved over this period with the leak detection teams having a 93% success rate (ratio of successful repairs to reported leaks). The software application has been licensed for use by several other Portuguese water utilities and EPAL is providing consultancy services as regards water loss control, both nationally and internationally, using the in-house capacity developed over recent years.

The existence and importance of a dedicated team for water loss control cannot be under-estimated, along with the sustainability gained through having a stable, trained team which has accumulated considerable experience, detailed knowledge and understanding of the company's distribution network. Water loss control activities must maintain strong and coherent links with the other operational areas of any company, but they should be separated from commercial, maintenance and network control areas. These latter areas work to differing regimes, priorities and timescales to those more appropriate to leakage detection assessment, which require medium to long term tendency analysis with less immediacy as opposed to constant on-line requirements. A water loss control team may be seen as fulfilling an internal consultants role within the company, supporting the operational areas who have responsibility for managing the network, whilst also providing valuable data for the planning, engineering and construction areas, especially as regards network renewal projects as well as company management.

Capacity building also needs to focus on decision supports systems and data management, which regularly and reliably collate essential data into workable formats with suitable, practical indicators calculated in order to support not only water loss control activities, but also provide highly valuable data for all operational areas of the company. In the future, developments are awaited as regards improved techniques for pin-pointing leaks on plastic pipes, which form an increasing percentage of mains in most companies and which present an ever greater challenge to leak detection teams given their specific acoustic characteristics, whilst the application of new communication methods for data collection, such as wireless, GPRS and FTP transfer must be developed to drive the tendency towards smart networks.

14.6 Evaluation of further options for pressure management

As noted, the Lisbon distribution system is a fully pumped network, divided into five pressure zones, at approximately 30 metre incremental height intervals, each with separate pumping elevation to maintain a 30 m c.a. minimum service pressure requirement. Given the undulating topography of the city, this results in most DMAs having critical supply points which negate the possibility of installing pressure reducing valves (PRVs) to control pressure across the entire DMA. Whilst a relatively small number of PRVs have been installed, given their widely acknowledged benefits in terms of reducing water losses, burst frequency and increasing infrastructure lifecycle, these are restricted to DMAs where the critical supply point has sufficient margin to allow pressure reduction or small sub-zones of DMAs where a clear excess of pressure exists.

Given the excellent overall performance level of the network in terms of water losses, the costs and difficulties of installing and maintaining additional PRVs to sub-divided existing DMAs has been determined as not financially viable under present conditions. However, the issue is subject to regular review and should conditions change, such as an increase in treated water costs or increased burst frequency which impacts on service quality, then policy may be reconsidered.

14.7 Results and recommendations

Through this process of network segmentation and increased monitoring and analysis, a far greater understanding of performance and systems dynamics has been obtained, which combined with Active Leakage Control interventions has seen NRW in 2013 reduced to less than one-third of the base-line 2005 level. All of the indicators used chart the successful reduction of annual water losses from around 27 million m^3 or 24% of System Input Volume (SIV) in 2005 to 8,1 million m^3 and less than 8% of SIV in 2013, with real losses per service connection from almost 500 litres/day/connection to 178 litres/day/connection. EPAL's NRW performance is now comparable with best practice levels obtained by the most efficient European companies and comfortably within both the Economic Level of Leakage, as well as more stringent Sustainable Economic Level of Leakage criteria.

The project has also provoked a cultural change at different levels and areas within the company as both technical and commercial areas have adopted to the DMA concept as a management and assessment tool, as well as a permanent distribution network surveillance tool for operational activities.

Key recommendations are to build capacity within the company, both in terms of physical infrastructure and equipment, but more important, as regards sufficiently trained staff in a dedicated team focused on water loss control, thus allowing the acquired empirical knowledge of the company's network to be maintained within the organisation. Success has been achieved by creating a dedicated water loss control team, supported directly by the management board, with resources and responsibility over the fundamental issues required to build a sustainable monitoring and control system. These key factors being DMA planning, implementation and subsequent management, maintenance of DMA meters, telemetry and boundary valves, leak detection activities and development of the data management software with KPIs directed strictly towards the daily assessment of water losses. Whilst the concept of network segmentation into DMAs is well-known, the challenge of sustainably managing such systems over the long-term with constant vigilance is seen as a key facet, along with a correlation between the size of DMAs implemented and potential achievable water loss reduction.

14.8 References

Lambert, A., O. Timothy, G. Brown, M. Takizawa and D. Weimer (1999): *A Review of Performance Indicators for Real Losses from Water Supply Systems*. IWA/AQUA.

UKWIR (2012): *Assessment of Low Flow Components of Night Use and the Water Balance*. UKWIR report 12/WM/08/48.

15 Scottish Case Study: Scottish Water

Contribution of Stuart Trow and Bill Brydon.

15.1 Details Scottish Water

Scottish Water (SW) is the statutory water and wastewater services provider for the whole of Scotland, covering an area over 79.000 square kilometres (a third of the area of Great Britain). SW is a public sector company formed under the Water Industry (Scotland) Act 2002. It is answerable to the people of Scotland and the Scottish Parliament and is funded through customer charges and borrowing from Scottish Government. Scottish Water's head office is in Dunfermline, with principal offices in Glasgow, Aberdeen, Dundee, Edinburgh and Inverness.

SW provides 2,39 million households (4,91 million population) with drinking water and provides 2,3 million households (4,73 million population) with wastewater services. SW also provides wholesale water and wastewater services to non-household properties; in Scotland there is wholesale / retail business separation for non-household users. Overall, Scottish Water produces around 1,8 billion litres of clean, safe and high quality drinking water per day and removes nearly 1 billion litres of waste water per day – which is taken away and treated to stringent levels of compliance before returning it safely to the environment.

Given the demographic characteristics of Scotland, water supply requires a large number of small water and waste water treatment works to deliver this vital public service, operating over 48.000 kilometres of distribution mains, 50.000 kilometres of sewer pipes, 1.837 waste water treatment works (including 1.206 septic tanks) and 241 water treatment works, pumping stations, sludge treatment centres, reservoirs etc., while conducting around 1.000 laboratory analyses every day on regulatory samples taken at treatment works, service reservoirs and customer taps.

Country	Basin / Sub-basin	Water service provider	Other key stakeholders
Scotland	Scotland and part of Solway/ Tweed	Scottish Water	WICS, SEPA, DWQR, Customer Forum, Scottish Government, Customers (Household and Non-household, Licensed Providers, Wholesale / Retail Business in Scotland)

Table 52 – Geographical context of Scottish Water (SW).

Characteristic	Value
Population	5.116.705
Number of billed properties (residential and non-residential)	2.535.994
Number of service connections (main to first meter)	2.305.449
Average length of underground service connections	Approx. 7 m
Length of trunk mains	4.071 km
Length of distribution mains	48.283 km
Average operating pressure	44,84 m AZP 46,42 m AZNP
% of time system is pressurised	100 % of year
% of total mains length subject to active pressure management PM	56 % of connections Circa 50% of length of mains subject to active PM. Further PM is via service reservoirs / break pressure tanks
Annual volume of potable water supplied (no imports / exports)	665,7 Mm^3/year

Characteristic	Value
Average time from location of mains leaks to shutoff or repair	1,8 days
Average time from location of service leaks to shutoff or repair	3,7 days
Leaks on mains (number per 100 km/year)	24,5 /100 km/year (Total 10.768 No/year)
Leaks on service connections (number per 1000 connections/year)	3,19/1000 conns/year (Total 8.312 No/year)
% of system having active leakage control interventions each year	approx. 40%
Number of water treatment plants	241
Number of pumping stations	755
Number of distribution reservoirs	1.077
Total number of staff	3.456
Staff directly involved in water operations	809
Unit value of leakage	€0.59/m^3

Table 53 – Details water production system and distribution network of SW.

The graph below shows the distribution input (DI) in Ml/d for Scottish Water for the year 2013-2014. It shows the high peak in DI in the summer of 2013 caused mainly by increased customer demand, but also by an increase in leakage. The weather was exceptionally hot and dry for Scotland.

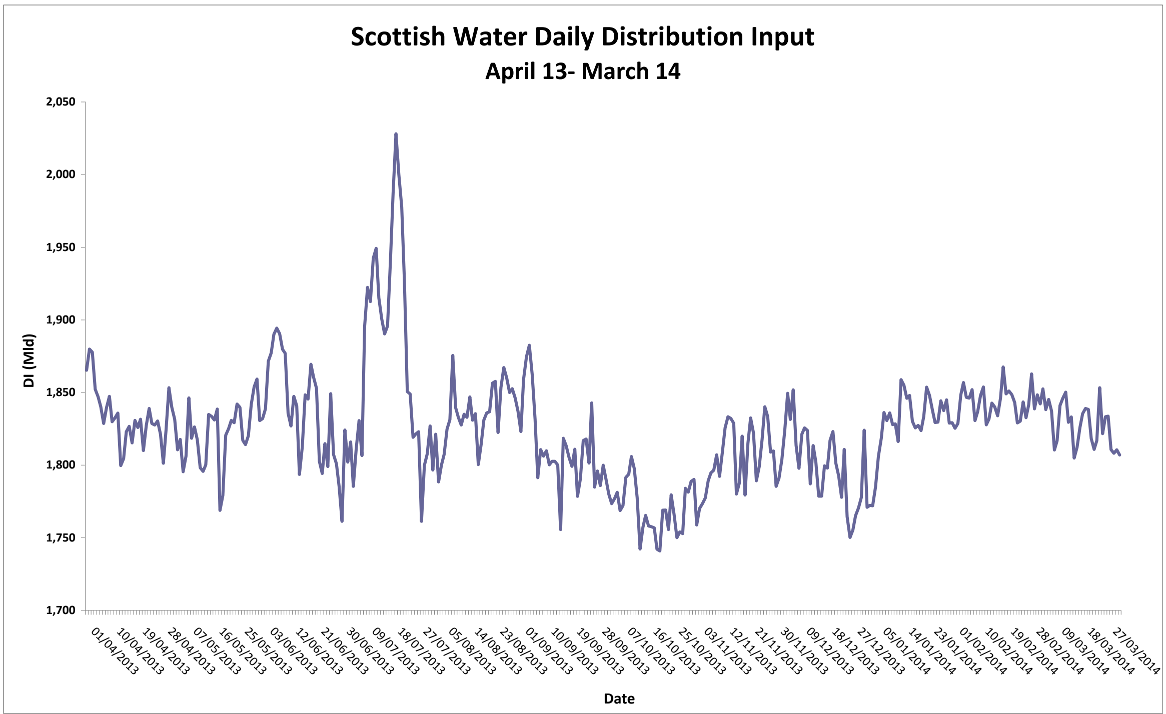


Figure 29 – Distribution input for the year 2013-2014 in Ml/d.

15.2 Details context Scottish Water

Scottish Water has 452 individual raw water sources feeding into 196 discrete Water Resource Zones. There are two river basin areas that SW water resources relate to, these being Scotland and Solway/Tweed. The latter is a cross border River Basin shared with the north of England. Programmes of measure have been developed to try and meet a target of all water bodies meeting Good Ecological Status or Potential by 2027. Scottish Water's investment programme contributes to this programme of measures through delivering improvements to water bodies where deemed required, after the conclusion of studies carried out in collaboration with the Environmental Regulator for Scotland, SEPA.

Relevant factor	Yes	No
Abundant water resources at a basin level?	Yes	
Limited measures required to improve water status to achieve WFD objectives?		No – other non-SW actions needed too
River Basin Management Plan (RBMP) completed?	Yes (1st RBMP)	2nd RBMP being produced
Active quantity management incorporated in the RBMP?	No	
RBMP harmonised with other key socio-economic and land use planning documents prior to adaptation and incl. financing plans?		
Abundant water resources for water service provider all year every year?	Generally and Yes if include drought measures as SW would take action	
Water resources of good chemical quality (low or no treatment)?		No
Water resources located at topographical levels above the level of the customer base (low or no energy costs)?	Not exclusively but many are	
Are the economics of density reasonable (> 20 connections per km)?	Yes – in large Central Belt WRZs circa 25 WRZs = circa 80% of DI	No – in large number of very small rural WRZs circa 170 WRZs = circa 20% DI
Cost effective investment and operating conditions?	Yes	
Distribution network designed for ease of operation and maintenance without maximum pressure stresses?	Yes	
Pressure Management implemented throughout the system?	Yes	
District Metering implemented throughout the system?	Yes (96% coverage and 90% operability at all times)	
Good quality of the network installation (materials selection and workmanship at the time of installation)?	Yes	
Water pricing limitations?	Regulated price controls	
Conflicting socio-economic needs and/or historical legacy?		
Public affordability constrains?	In some socio-economic groups	
Ability- / willingness-to-pay constraints?	In some socio-economic groups	
Benefitting from EU Funds to finance significant water supply (and urban wastewater) treatment investments?		No
Annual Volume of Real Losses (Level of Leakage, CARL)		**Value**
The MLE adjusted total leakage value		575 Ml/d

Table 54 – Specific context within Scottish Water is operating.

Total leakage is calculated using an MLE (Maximum Likelihood Estimation) technique based on the top down water balance, and a bottom up analysis of night flow data from DMAs.

Scottish Water is regulated by an economic regulator the Water Industry Commission for Scotland (WICS). As such leakage management in Scotland is driven by providing the least whole-life cost solution i.e. ELL / SELL, considering long-run drivers such as supply demand balance, off-setting supply-side investment (LR-ELL), security of supply etc. Recent engagement with customers in Scotland has determined that customers do not want SW to over-invest in reducing leakage beyond the SELL, but do want to be assured SW is effective and efficient in leakage management activities.

SW works collaboratively with all stakeholders in Scotland and has lead on the thinking around PESTLE (Political, Economic, Social, Technical, Legal and Environmental) influences and the True Value of Water (SW has presented some of its work at both annual and international leakage conferences).

This influences heavily SW's leakage management targeting, where an ELL / SELL / LR-ELL is assessed for each of the 196 WRZs and action plans developed to efficiently deliver the ELL. The leakage management interventions will be informed by the ELL model and will include ALC, pressure management, asset renewal etc. where appropriate. The level of intervention will be governed by the volume of detectable leakage and the cost / value of that leakage vs the cost of leakage management intervention i.e. the ELL.

However SW does review all leakage metrics e.g. l/property/day, m^3/km/day (these are also reviewed as cost metrics £/property/day, £/km/day), % DI, ILI, etc. so that SW can consider performance metrics as appropriate to the stakeholder interest. All metrics could be equally appropriate / inappropriate dependent upon the stakeholder and their understanding of the metric and its limitations e.g. ILI has no economic element, % DI is influenced by the level / balance of legitimate consumption, high / low PCC etc.

SW also looks at more granular Leakage PIs regarding leakage management performance to assess likely productivity / efficiency, including:

- Primary Leakage PIs:
    - Total leak detection man hours.
    - Total pressure management man hours split by activity.
    - Number of detection sweeps completed (by type).
    - Number of leaks detected by type.
    - Number of leak repairs completed (by type).
    - Number / % dry holes.
    - Leak repair times; by standard leak types (breakdown of total repair time required: reported, scheduled, hydraulic fix, etc.).
    - MNF (DMA) volume reductions (in month & annual averages).
    - AZNP values for DMAs/PMAs.
    - AZP values for DMAs/PMAs.
    - NRR estimates; monthly and year average (pragmatic/practical process for ongoing estimation of NRR).
    - Leakage savings per repair (l/s).

- Secondary Leakage PIs:
    - Leaks located by Company (by type split).
    - Percentage of properties covered by PMAs (by WOA/WRZ).
    - Number / type of leaks detected per hour.
    - Leaks repaired by Company (by type split Monthly).
    - Number / type of leakage repairs per FTE (full time equivalent).
    - Average FTE count for leak detection (in month, annual average, etc.).

- Average number of detection surveys per FTE.
- Average number of detection surveys by DMA stock.
- Number of connections (properties) surveyed per FTE.
- Length of mains surveyed per FTE.
- Cost per leak found by contactor per region.
- Hours per leak found by find technique per region.
- Cost per l/s saved by contractor per region.
- DMA/WOA with highest percentage of repairs with no visible savings.

15.3 Strategy adopted, and methods and PIs developed at Scottish Water

During 2006, regulatory leakage targets were introduced in Scotland for the first time. Prior to 2006, only ad-hoc leakage management had been practiced as and when required e.g. Dundee Drought Order 2003.

In October 2006, Scottish Water began to implement best / good practice leakage management following the appointment of its first Leakage Planning Manager. Since that time it has carried out a significant leakage investment programme, estimated the Sustainable Economic Level of Leakage (SELL) for Scotland, established a dedicated Leakage Delivery team in Water Operations with regional target leakage reductions towards SELL and become an active / leading voice in UK / international leakage forums e.g. WaterUK, UKWIR R&D, IWA, national and international conferences, etc.

SW has made significant investment in establishing 96% DMA coverage of all connections, and continuing investment to maintain high levels of operability (circa 90% at all times). SW also established a pressure management programme which continues to date, building on the 56% coverage of all connections in Scotland and reducing AZP / AZNP year on year. The wider benefits of pressure management (PM) are now recognised and form part of the cost / benefit analysis for continued PM in Scotland.

As household customers are not metered in Scotland, SW has established a Best-practice, Small Area Household PCC (per capita consumption) / PHC (per household consumption) Monitor (UKWIR Recommendations), which has circa 7.000 households which form a representative ample of the mix of households in Scotland (ACORN Socio Economic Classification). This has now been running for over 5 years for all circa 110 PCC Monitor areas.

SW has established dedicated Leakage Strategy / Planning and Leakage Delivery teams in-house and employs additional external resources when appropriate. SW's leakage management activities include ALC, Pressure Management, and Asset renewal (AR) as appropriate to delivering effective and efficient leakage management. SW has undertaken a number of projects in recent years to determine the cost-benefit and economic extent of these activities.

Since 2008, SW has outperformed the annual leakage targets agreed with the Water Industry Commission for Scotland (WICS), a significant achievement considering the severity of the 2009-2010 and 2010-2011 winters (see Figure 30). SW was challenged with being at ELL by 2013-2014 and being at least 50% of the way towards SELL by 2009-2010. The 2009-2010 target was outperformed, putting SW in a good position to achieve SELL by 2013-2014, which was achieved one year ahead of Regulatory expectation, with record reported annual leakage reductions achieved throughout the period (1.104 Ml/d in 2006 to 575 Ml/d in 2013).

SW Leakage Profile AR06 – AR14

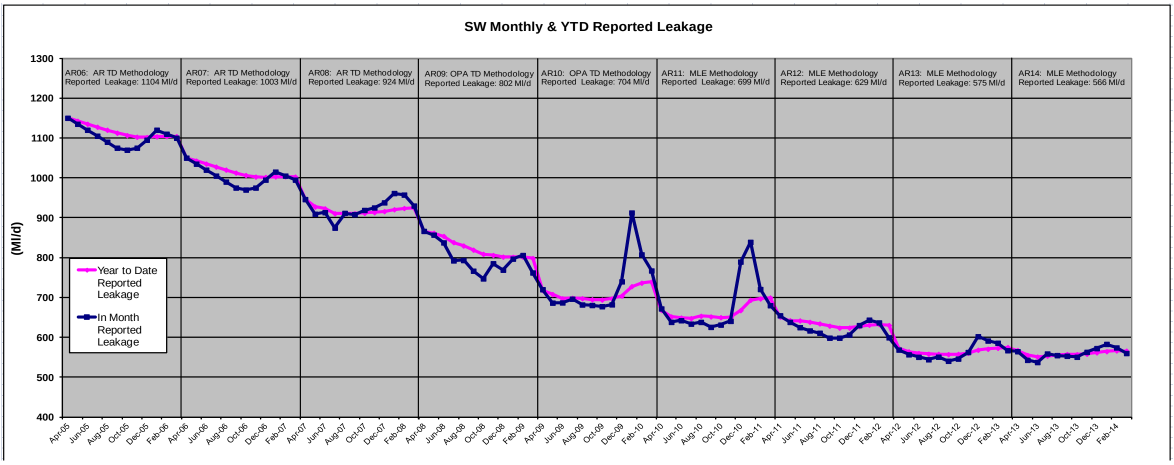


Figure 30 – Scottish Water Leakage Profile for the year 2006-2014 in Ml/d.

During this period, SW has developed a pro-active, collaborative working relationship with the WICS (and also with the Scottish Environmental Protection Agency, SEPA) and is now working towards being the leading UK leakage management practitioner for the benefit of Scotland and SW's customers. For the 2015-2025 business planning period, SW is working with the aforementioned stakeholders and the Leakage Reviewer (S. Trow working with Strategic Management Consultants (SMC); leakage advisory role with dual duty of care to SW and WICS) to determine how best leakage can be managed going forward. This involves ongoing, collaborative studies across the range of leakage management activities which place SW in the leading position in the UK in terms of its understanding of the economics of leakage management.

15.4 Evaluation of further options for pressure management

Implementing the findings of recent pressure management studies e.g. UKWIR studies, and the findings from in-house studies and data, information and experience from SW's extensive pressure management programme, SW continues to implement further pressure management schemes.

The aim is to continue to reduce AZNP / AZP as appropriate to each zone to reduce leakage, reduce bursts, reduce wider customer service issues / contacts and to extend asset life. The data to support such aspects of pressure management is increasingly available and informative as SW's pressure management programme has developed in recent years. An in-house study has identified the opportunity for further economic pressure management in Scotland, targeting reducing AZNP to circa 40 metres.

Additional investment in pressure management is also planned for the 2015-2021 period, to offset the need for significant water mains renewal; pressure management to reduce burst frequency.

15.5 Variation in ELL between Water Resource Zones

There is considerable variation in Long Run ELL (LR-ELL) between the numerous supply zones operated by Scottish Water. The top-12 zones account for some 80% of the total LR-ELL for the whole company. The graph below compares the zones in terms of litres/property/day and m^3/km of mains/day against the average for those companies in England and Wales with "upland" topography.

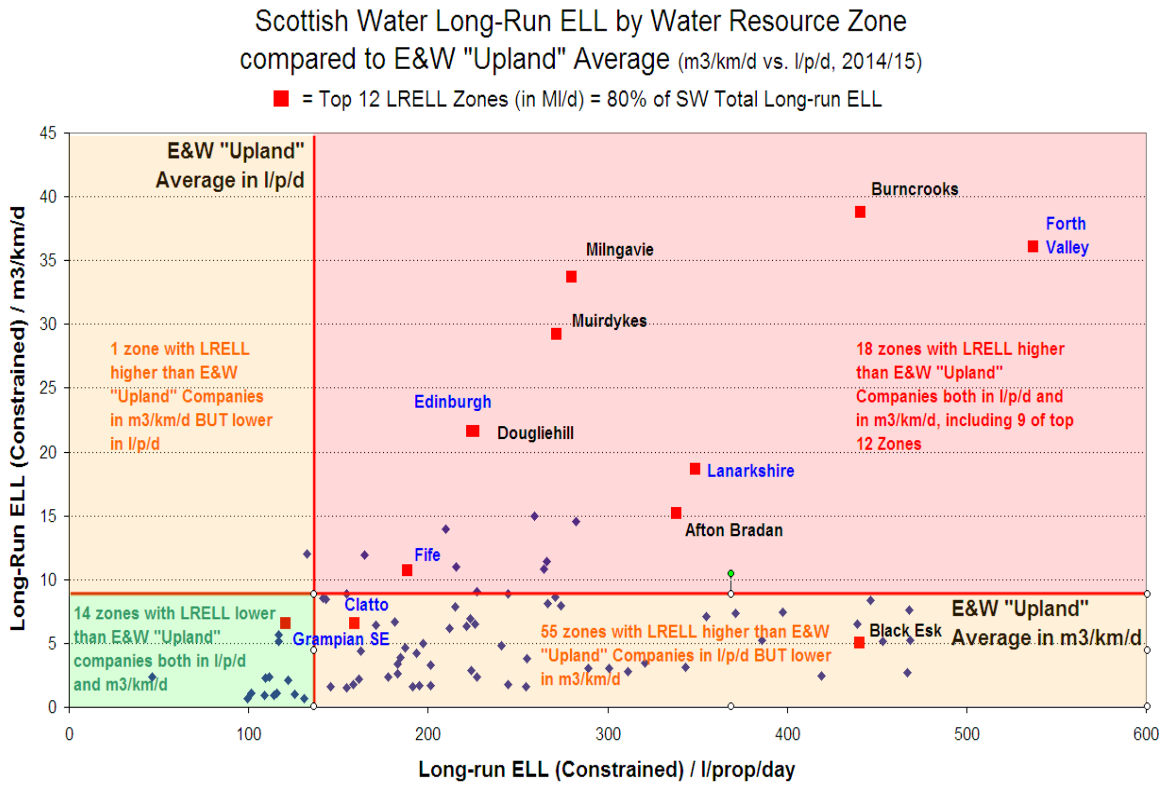


Figure 31 – Scottish Water LR-ELL by WRZ compared to E&W "Upland" Average.

Figure 31 shows the variation of long run economic level of leakage (LR-ELL) for the Scottish Water WRZs compared to a sample of systems from England and Wales from companies with "upland" topography. The graph shows each zone in terms of litres per property per day (l/prop/day) and m^3/km of mains/day to take out the difference in property density between urban and rural zones. The considerable variation between the zones shows the difficulty of estimating a target for leakage based on simple measures without a thorough analysis of all relevant technical, economic, and environmental factors.

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16 Serbian & Croatian Case Study: Mentoring

Contribution of Jurica Kovač.

16.1 Overview leakage situation context in the region

The Western Balkan region (Slovenia, Croatia, Bosnia and Herzegovina, Monte Negro, Serbia, Macedonia and Kosovo) has around 500 water distribution systems serving some 20 million people. All utilities are public and under the control of national regulators. Individual distribution systems of separate municipalities and towns are relatively small, other than the capital cities. For example, Croatia has some 150 utilities supplying water to 4,3 million people, 20% of whom live in the capital city of Zagreb, and similar situations occur in the other countries.

The economic downturn in the 1990s due to numerous reasons (political, social and economic) had a negative impact on water infrastructure condition and leakage due to war damages, lack of preventive maintenance, limited or zero investments in rehabilitation, low revenue due to low water tariff, slow economic recovery, etc. Water resources availability and capacity are generally adequate, so leakage is not usually considered an issue of high importance by managements and workforce with little experience of modern water loss management.

Table 55 broadly summarises the current overall situation in the Region.

Implemented measure on leakage assessment and reduction	Yes	No
Reliable Bulk Supply Metering	✓	
Reliable Customer Metering	✓	
Good System Design and Installation	✓	
Effective Management of Excess Pressure and Pressure Transients		✓
Speed and quality of repairs		✓
Active Leakage Control at an economic frequency		✓
Sectorisation and/or District Metering Area formation		✓
Asset Renewal: service connections		✓
Asset Renewal: mains		✓
Leakage Indicators used when mentoring	**Value**	
Litres/connection per day, to track progress in individual systems	71 to 1.387	
Unavoidable Annual Real Losses UARL, litres/conn/day/day	20 to 189	
ILI , for technical performance grading and comparisons	0,9 to 19,4	
Average pressure (metres)	17 to 65	
Price of water, produced or purchased (Euro/m3)	0,03 to 0,70	

Table 55 – Implemented leakage reduction measure(s) in 34 water Utilities.

16.2 Details proven mentoring approach in leakage reduction

A mentoring approach was developed to bridge the gap due to lack of national/regional education practice. The latest interesting development (2013) is a dedicated German/Croatian Training and Competence Centre for water utilities with various courses, including Water Loss topics based on IWA best practice methodology.

References

Kovač, J. and B. Charalambous (April 2012): *Coaching: an emerging need in Water Loss Management*. IWA Publishing Water 21 magazine.

Kovač, J. (September 2012): *Changes in Water Loss Management in Western Balkan Region*, IWA YWP Conference, St. Petersburg, Russia.

Summary of activities and results

Mentoring activities have been implemented over the last 15 years with various results depending on duration and specific circumstances. The collected data in this Case Study, based on conducted analyses of 34 water utilities in the West Balkan region, are presented in the following Table 56.

Number of utilities with ILI in the range:	<2	2 to <4	4 to <8	8 or more
High income countries (Croatia, Slovenia)	4	5	8	6
Low-middle income countries (Serbia, Bosnia H.)	0	0	4	7

Table 56 – Collected data of 34 water Utilities.

The main topics of interest in the mentoring approach for utilities regarding water loss management were: skills in use of leak detection equipment, free software for PIs calculation in local language, pressure management, DMAs, accurate and frequent flow and pressure measurements, understanding of networks and apparent losses.

It is important to emphasise the benefits of pressure reduction and control. The best ranking utilities with lowest leakage are using pressure management to a large extent. In contrast, all utilities with high leakage are without pressure management (or developed in very limited scope). Mentoring practice showed that fast, reliable and long term solutions in water leakage reduction are possible only if we take into consideration reduction of pressure (and reduction in pressure transients).

Temporary DMAs are also worth mentioning. In most cases implementation of zones into the system, with high costs for building measuring chambers, creates funding problems. As leakage control is more efficient with zones, a less costly but beneficial approach involves occasional but regular measurements of flow and pressure in individual zones, with leak detection based on rate of rise approach. Also monitoring leakage and bursts data in zones allows better understanding of burst frequencies.

Importance of mentoring to create conditions for change

Advanced water loss management activities require technical understanding and a wide perspective. Current key players in the water sector (water utilities, regulators, private companies, education institutions) lack these requirements for various reasons; different agendas, capacities, motivation, time availability, funding, competition, etc. This fragmentation of capacities produces random circumstances regarding efficient water loss control and savings. In most cases we are faced with one of two problems; funding is not available, or excessive costs with limited results.

In light of rising capacities of employees (competencies, skills, responsibilities) and through this change leading toward water loss reduction and increased system efficiency, mentoring of water utilities has proved a positive option in the West Balkan region. In situations with limited funding and a complex environment (political, social, economic, natural, etc.) people in water utilities are the key factor for success.

Figure 32 – Empowering people in water utilities via training and education.

Mentors who have expertise in water loss management and also other fields of activities (management, pedagogy, human behaviour, etc.) have a unique position to set things in motion by cooperating with all key market players with appropriate approaches and few limitations.

The two most important aspects of mentoring are sharing knowledge, and assisting in development and implementation of specific standardised water policies that produces clear industry targets, reduction of water losses and economic efficiency in water distribution systems.

Figure 33 – Promotion of knowledge and solutions – in the field and at the office.

Approach used in mentoring and promoting advanced water loss management

Creating change in approach and understanding about water leakage and losses requires a wide scope of activities; a selection is presented in the following list:

- Knowledge sharing and promotion (presentations, workshops, conferences, magazine articles) based on IWA methodology and in local language.
- Training and coaching (water utilities) with understanding of human behaviour.
- Projects implementation, testing and results evaluation (assistance to assure successful outcomes, building experience and confidence among utility staff).
- Staff motivation (in context of limited salaries, benefits) and seeking approval and recognition from managers and utility board members.
- Promotion of good examples and people responsible from water utilities (case studies papers, participation on conferences, experts community recognition).
- Influencing and assisting regulators (legislation, performance indicators, norms, standards, procedures).
- Cooperating with educational institutions - universities (promoting market importance, challenges, and opportunities for new generations).
- Developing an expert community (events, competition, awards, cooperation, innovation) as foundation for continuous and prosperous future.

Figure 34 is an example of how mentoring approach works in a water utility.

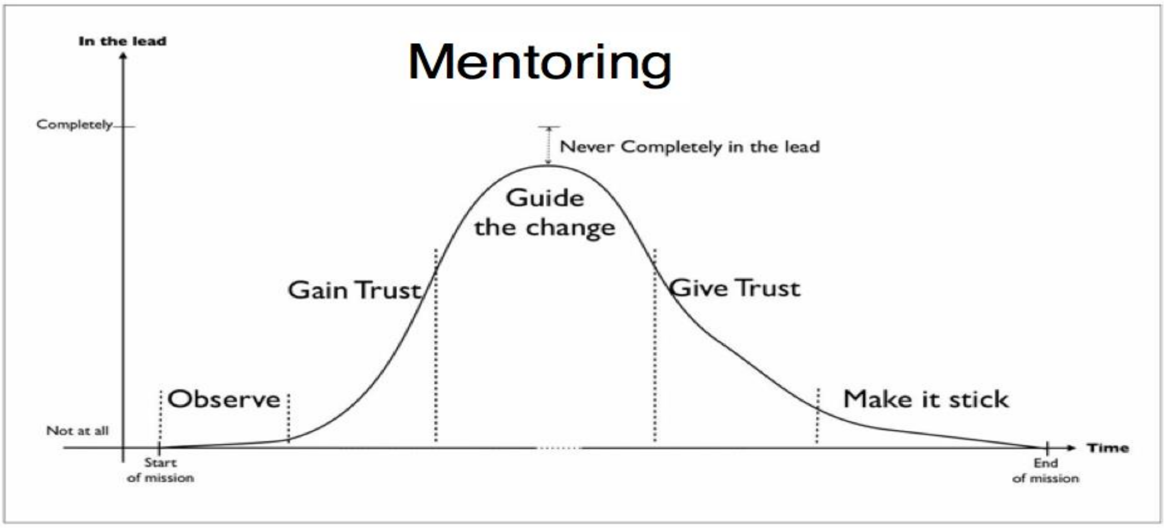

Figure 34 – Example of how mentoring approach works in a water Utility.

Results (or proof) mentoring works – examples

Table 57 shows progress in leakage reduction in five small water utilities. Using the recommended PIs for tracking progress (per connection or per km), leakage has been reduced by between 8% and 25%, after 1 to 3 years of mentoring.

	Start of mentoring				Results			
		NRW	CARL			NRW	CARL	
	Year	Mm^3	Mm^3	l/conn/d	Year	Mm^3	Mm^3	l/conn/d
Utility 1	2010	1,7	1,5	446	2012	1,8	1,5	390
Utility 2	2010	2,1	2,0	338	2013	2,1	1,9	312
Utility 3	2011	1,7	1,6	966	2013	1,4	1,3	726
Utility 4	2012	4,1	3,6	5,1*	2013	3,5	3,1	4,3*
Utility 5	2012	60,8	51,4	1.499	2013	57,0	48,1	1.387
* CARL indicator in m^3/km/day (connection density below 20/km)								

Table 57 – Progress in leakage reduction in five small Utilities after 1 to 3 years of mentoring.

Implementation guidance in building change influenced by mentoring

1st step: Promotion of knowledge and solutions.
2nd step: Empowering people in water utilities via training and education.
3rd step: Educating managers in water utilities.
4th step: Developing strategies and plans for water leakage control and reduction.
5th step: Educating utility board members and regulators.
6th step: Educating private sector (designers, service and equipment providers).
7th step: Establishing business community based on knowledge exchange.
8th step: Monitoring progress and sharing experience.

Comparison of Flow Pattern Distribution method

Contribution of Adriana Hulsmann in cooperation with Peter van Thienen and Ilse Pieterse-Quirijns (KWR Watercycle Research Institute).

Summary Network Flow Performance

With the Network Flow Performance tool the user can generate a clear and distinctive visualisation of complex and difficult to read flow-volume-time series, e.g. for a particular District Metered Area (DMA) or a supply area. This display provides support in the interpretation of the changes present in the time series in terms of known processes and influences (weather, holidays, etc.) and indications of unknown processes (new leakages, wrong valve positions, customer behaviour). Where there are indications of new leakages and/or wrong valve positions, then further inspections can be carried out. The tool therefore constitutes an important source of information to effectively reduce leakage losses, gain insight into customer behaviour and control the distribution process.

Importance

The analysis of flow volume data using the Comparison of Flow Pattern Distributions (CFPD) method provides insight into customer behaviour, leakages and non-registered network parameters, contributing to effective operational management and leakage reduction. When there are indications of new leakages and/or wrong valve positions, then further inspections – in the field for instance – can be carried out. The tool therefore constitutes an important source of information to effectively reduce leakage losses, gain insight into customer behaviour and control the distribution process. The benefits of the Network Flow Performance Tool compared to (some) of the other tools are:

- It is completely data-driven, thus needs no models with assumptions, etc.
- It requires only net inflow data; such data are almost always available and frequently standardly registered, so that no additional investment in registration is needed.
- It uses data measurements taken throughout the day (in contrast to Minimum Night Flow analysis).
- Limited time resolution (one measurement per hour) is not an obstacle.
- The method is very robust with respect to data gaps.

Approach

The analysis of flow volume data using the CFPD method provides insight which directly contributes to effective operational management and leakage reduction. The CFPD method is quick and simple. It uses measurement data exclusively and is therefore independent of assumptions or uncertainties, which are typical of many models. Water companies can use flow data, which they already collect as part of normal operations, to gain better understanding on how water is used and what causes of changes in demand are.

Figure 35 on the next page shows the CFPD analysis procedure and interpretation:

1. Flow time series.
2. CFPD analysis.
3. Identification of consistent changes.
4. Identification of inconsistent changes.
5. Interpretation of these in terms of known and unknown mechanisms.
6. Discarding changes by known mechanisms results in a reduced list of unknown events with a limited set of possible interpretations.
7. Any data quality issues which are found may initiate improvement measures.

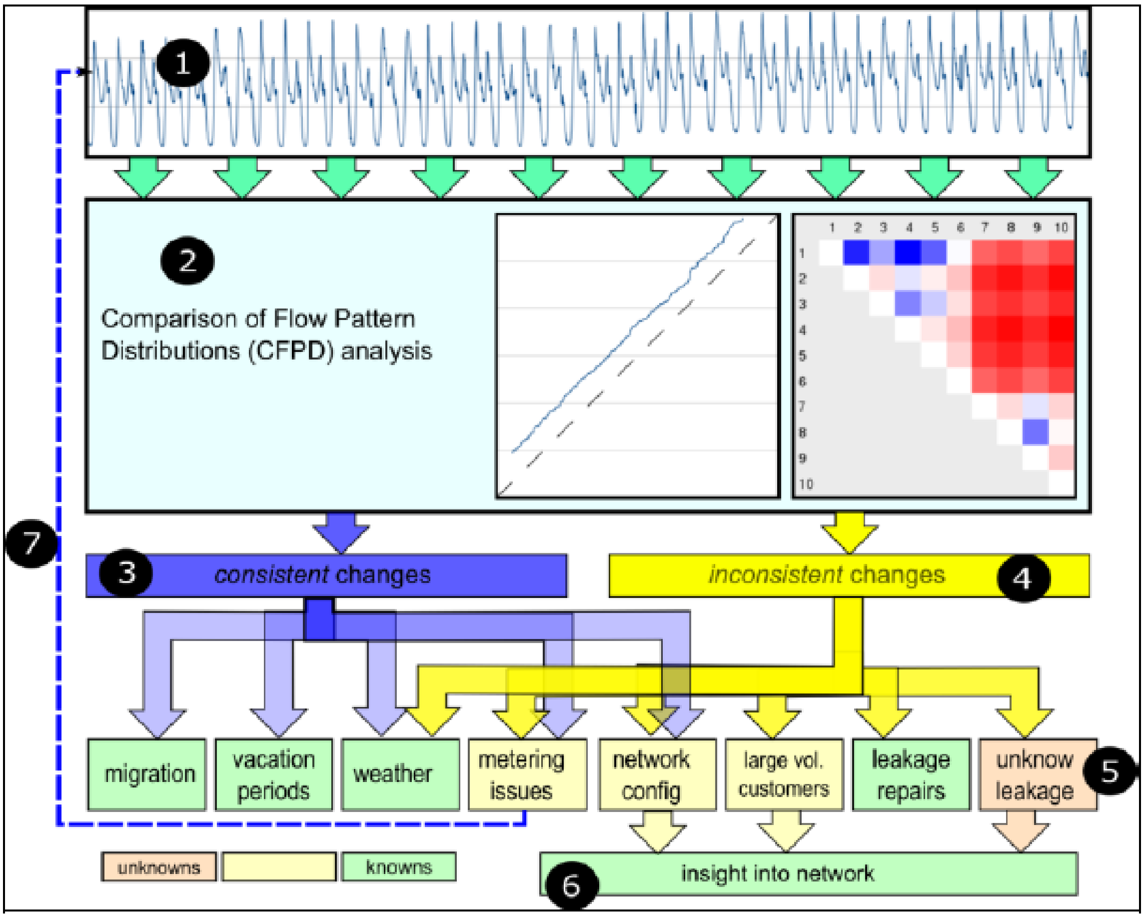

Figure 35 – CFPD analysis procedure and interpretation (KWR).

Results

Based on the supply patters for different periods the CFPD can characterise and quantify the demand changes and the changes in water losses due to leakage in a specific area. The method was developed in 2011 for the Dutch water companies and has up to now already been applied successfully at five of them: Dunea, Evides, PWN, Waternet and WMD. The method demonstrated e.g. how the presence of tourists on the island of Texel (PWN) influences demand patterns and detected among other things, an open connection to another, neighbouring supply area. At Evides an open connection between the Delft and Westland supply area was rapidly detected. Situations that can easily remain unnoticed and that disturb the water balanced are easily and rapidly detected using this new method. International tests and validations are at present ongoing (in Paris, France) or are being prepared.

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Advanced Network Modelling

Contribution of Adriana Hulsmann in cooperation with Peter van Thienen and Ilse Pieterse-Quirijns (KWR Watercycle Research Institute).

Summary

SIMDEUM® (SIMulation of water Demand and End-Use Model) is the water demand end-use model developed at KWR to predict water demand patterns with a small time scale (1 second) and a small spatial scale (residence level). The end-use model is based on independent statistical information and not on flow measurements. The input parameters are available before any information on annual or daily use is available: the parameter are not fitted on flow measurements. Therefore, the model is transferable to diverse residential areas in different countries. The model can be applied in the design stage (pre-build), in scenario studies, in water quality distribution network models and to determine leakage losses. The SIMDEUM® model has been applied in the Netherlands and abroad e.g. Hamburg, Germany.

Importance

SIMDEUM® is a new, proven tool that can be helpful in different ways. Firstly, it allows the drinking water installation for a new home, apartment building, hotel or office to be designed more efficiently and sustainably. Secondly, it supports the application and development of water quality models in the drinking water distribution network, to help to keep the water quality at a constant level. The reliable predictions made by SIMDEUM® of water demand in a residential or non-residential building give the designer the opportunity to make a sustainable, hygienic and energy-efficient drinking water installation, without compromising water quality or comfort.

SIMDEUM® can be used to predict water demand for various different types of buildings. This information can also be used to determine leakage losses. This becomes apparent when water consumption during the night period is much higher than predicted by SIMDEUM®.

A detailed understanding of the hydraulics in the drinking water distribution network cannot be gained solely on the basis of measurements. The variations in water demand over time and space are too great to make it possible to carry out sufficient measurements. Instead, what is needed is a reliable water demand model with a small temporal and spatial scale. SIMDEUM® is such a model. It makes a much better estimate of actual hydraulic circumstances possible. By incorporating a good understanding of the specific hydraulics, SIMDEUM® permits a better interpretation of water quality measurements in the distribution network, and better predictions of the water quality in the drinking water distribution network. An improved hydraulics model based on SIMDEUM® demand patterns supports the application and development of water quality models in the drinking water distribution network.

Approach

Our water use is predictable. Most people will use the toilet after they wake up; most take a bath or shower in the morning, or before they go to bed. When do they brush their teeth? Usually, after breakfast and before going to bed. How about doing the dishes? We tend to do them after dinner, or let the dishwasher run at night. SIMDEUM® combines the predictability of human behaviour with statistics on water use and the technical specifications of water-using appliances. It therefore makes extensive flow measurements at each tap unnecessary. SIMDEUM® simulates water demand over the course of the day on a per-second basis, and is based on information of water use at the fixture level.

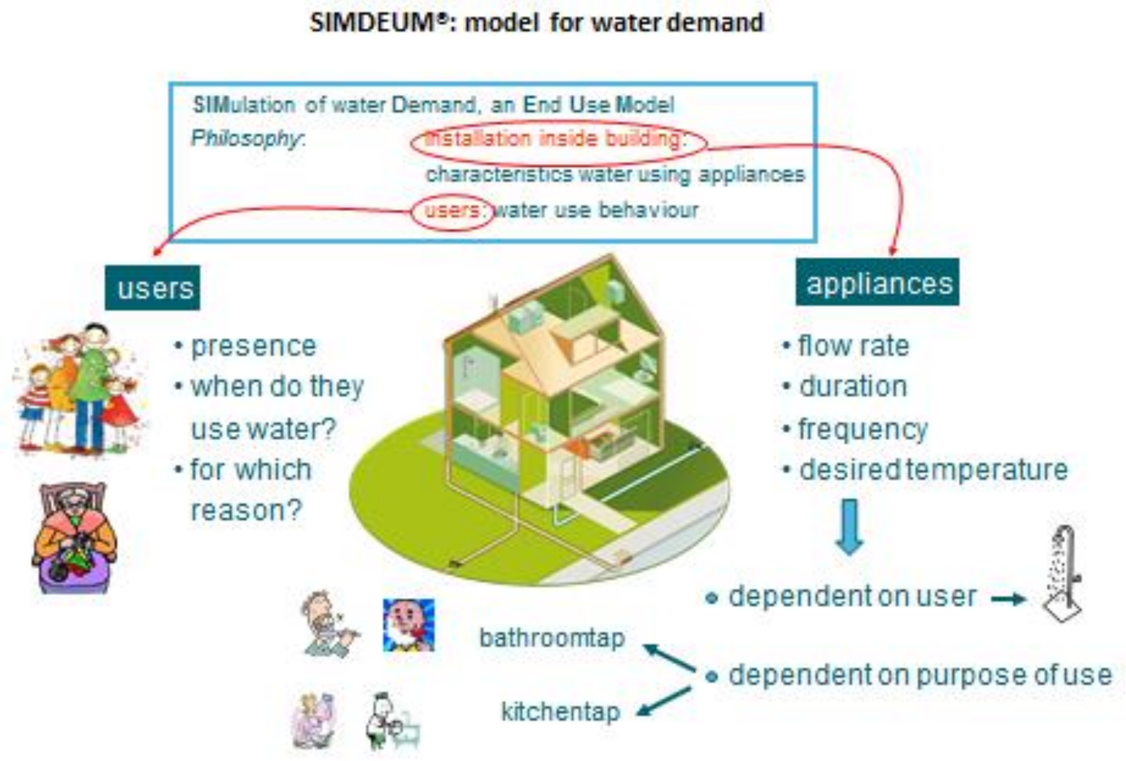

Figure 36 – SIMDEUM® SIMulation of water Demand and End-Use Model (KWR).

Census data such as the number of people per household and their ages; the frequency of use; duration and flow per water-use event; occurrence over the day for different end uses such as flushing the toilet, doing the laundry, washing hands etc. With this approach, residential water demand patterns can be simulated.

Results (or proof)

The Netherlands' Uneto-VNI has used SIMDEUM® to develop standard design parameters for water installations in new buildings. Drinking water company Oasen in the Netherlands has used SIMDEUM® to study the effect of using a separate hot tap water distribution network. Wageningen University & Research centre (the Netherlands) is employing SIMDEUM® to study the possibility of using alternatives to drinking water, such as grey water and rain water, for toilet flushing.

Implementation

Working together with a consultant, users will be able to identify the appropriate SIMDEUM® input parameters for their particular purposes. These might include specific behavioural components relevant to a certain country or region, or to a specific type of building. In addition, users will be identifying relevant design parameters; for example the maximum instantaneous flow, for sizing pipes, or the maximum hot water use over 10 minutes and 2 hours, for sizing the hot water tank. KWR will run the simulations with SIMDEUM® and extract the design parameters. On this basis the user will be in a position to produce a more sustainable design of the drinking water installation for a particular building in a specific country or region.

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