WATER RESCUE

Water resources efficiency and conservative use in drinking water supply systems

Interreg
Greece-Bulgaria
WATER RESCUE
European Regional Development Fund
EUROPEAN UNION

WP	**4 Common Methodologies and Tools**
Deliverable *Tool*	**4.3.2 Water Use Efficiency joint methodology report** *Joint Deliverable*
Sub-Deliverables integrated	**D.4.1.2**
Project Beneficiary No	**PB3**
Beneficiary Institution	**University of Thessaly-Special Account Funds for Research-Department of Civil Engineering**

The Project is co-funded by the European Regional Development Fund (ERDF) and by national funds of the countries participating in the Cooperation Programme Interreg V-A "Greece-Bulgaria 2014-2020".

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Chapter 1. Introduction: The WATER RESCUE project in brief

1.1 The Project in brief

WATER RESCUE project's concept is based on the common cross-border (CB) water management problems in the two international river basin districts (RBDs) shared between Greece & Bulgaria (Struma-Strymonas; Maritsa-Evros). The common CB problems include water resources quality & quantity being at risk due to natural and human activities and climate change conditions. The consequence is that water bodies fail to meet the good ecological status (GES) (recorded in the river basin management plans-RBMP). In particular, drinking water faces significant risks due to the deteriorated water resources quality while at the same time significant water volume is lost in the water distribution networks (WDNs). The project aims at the sustainable and efficient management of drinking water supply by increasing drinking water use efficiency in WDNs and improving water quality in the whole water supply cycle (from the source and back to the environment). Good Ecological Status can be achieved by improving water quality and reducing water abstraction and can be maintained by taking climate change adaptation measures. The project focuses in drinking water supply management suffering from high Non-Revenue Water (NRW) levels and deteriorated water quality jeopardizing the drinking water consumers' safety and health and their quality of life. Urban water volumes end up to the sewerage networks while wastewater treatment plants are a pressure to water resources quality. Surface water bodies are both used for drinking water abstraction and are the final recipient of treated effluents. Thus, their ecological status is affected by both water quantities abstracted and water quality in the whole water supply cycle (from the resource to the water supply and the wastewater treatment plant and back to the environment).

1.2 Theme of the Project

WATER RESCUE project is expected to achieve Non-Revenue Water/water losses reduction by upgrading and adapting already developed methodologies, technologies and tools including Water Balance assessment and Performance Indicators, hydraulic simulation models, decision support systems and GIS tools. Additionally, WATER RESCUE is expected to achieve water quality improvement across the entire water supply chain (from the water intake point and the raw water treatment plant, back to the environment after the waste water treatment plant) through constant monitoring of water quality parameters in real time, water quality simulation models (including water age) and automatic chlorination systems on line and in line. Climate change impacts will be assessed to finally propose and adopt measures for climate change adaptation. WATER RESCUE has a clear innovative character since the methodologies and tools are integrated and do not tackle individual problems. It is the first time that integrated methodologies will be adapted to include the entire drinking water supply cycle. These methodologies/tools will serve as Early - Warning Systems both for water quantity and quality. WATER RESCUE results will improve drinking water management. At the same time as drinking water is involved, the consumers' safety and health are safeguarded and their quality of life is improved. Non-Revenue Water reduction will increase water resources efficiency, since less water will be abstracted from surface and groundwater bodies and reduce energy consumption as water and energy are interconnected in water supply systems (water-energy nexus). Drinking water quality will be improved through real time monitoring of water quality parameters across the entire water supply chain, from the water intake points, to the water treatment plant and the water distribution network, back to the environment through the wastewater treatment plant. Thus, drinking water quality will be safeguarded from its source up to the consumer's tap. As wastewater effluents return to water resources, their quality monitoring prevents water resources degradation due to this pressure. Water and energy resources efficiency will be promoted and the ability of the cross-border area to adapt to climate change conditions will be improved as all possible natural and man-made pressures will be evaluated, including climate change conditions. Water saving will be accomplished through water losses reduction and increase of the environmental awareness of the public. The quality of life is expected to be upgraded with special emphasis to the protection of the natural environment. Joint policy recommendation guidelines and papers will be developed. Good governance, transparency and participation of all stakeholders in the design, implementation and monitoring of these policies is expected. Know-how and technology transfer will take place not only among the beneficiaries but also in the stakeholders' network that will be developed.

1.3 Project Objectives

The project's main objective is the sustainable cross –border drinking water supply management aiming at water resources efficiency and conservative use through:

1. Adaptation of a joint methodological framework for water resources management (qualitatively and quantitatively) in relation to the climate change and the natural and human activities and reduction of the water resources vulnerability;

2. Increase water use efficiency through the reduction of Non-Revenue Water and water losses in the water supply networks by implementing measures tackling NRW causes;

3. Improve water quality and safety in the whole drinking water supply cycle, from the water resources to the water distribution network and back to the environment through the continuous monitoring of water quality parameters in real time and the in-line disinfection to reduce the risk of low chlorine residuals and excessive concentrations of THMs (toxic substances causing cancer);

4. Increase innovative technologies use through the integrated management of water resources including GIS-based applications; hydraulic simulation models & decision support systems;

5. Development of "green behavior", increase water saving & reduce water consumption through public awareness campaigns.

WP	Task	Leader	Duration	Nov 2017	Dec 2017	Jan 2018	Feb 2018	Mar 2018	Apr 2018	May 2018	June 2018	July 2018	Aug 2018	Sept 2018	Oct 2018	Nov 2018	Dec 2018	Jan 2019	Feb 2019	Mar 2019	Apr 2019	May 2019	June 2019	July 2019	Aug 2019	Sept 2019	Oct2 019	Nov2 019
WP1: Project Management & Coordination	1.1 Preparation activities	LB	10/11/2017-9/11/2019																									
	1.2 Project Management																											
	1.3 Self evaluation																											
	1.4 Steering committee meetings																											
	1.5 Audit Costs																											
WP2: Project Communication & Dissemination	2.1 Project Communication Plan	LB	10/11/2017-9/11/2019																									
	2.2 Project Website																											
	2.3 Publication & Dissemination Material																											
	2.4 Awareness events																											
	2.5 Final events Awareness Events																											
WP3: Current Status Analysis & Assessment	3.1 Climate change impacts asssessment	PB5	10/11/2017-9/11/2018																									
	3.2 Water Audit																											
	3.3 Water quality																											
WP4: Common Methodology & Tools	4.1 Cross border water resources vulnerability assessment	PB3	10/11/2017-9/5/2019																									
	4.2 Water use efficiency																											
	4.3 Water quality																											
WP5: Pilot Actions	5.1 Ex Ante evaluation	PB2	10/11/2017-9/11/2019																									
	5.2 Pilot actions implementation																											
	5.3 Workshops & transfer visits																											
	5.4 Ex Post evaluation																											
WP6: Policy Recommendation	6.1 Joint water efficiency policy recommendation	PB4	2/5/2019-9/11/2019																									
	6.2 Joint water quality policy recommendation																											

Figure 1. WATER RESCUE timetable

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1.4 The Project structure and timetable

The project consists of six work packages:

- WP1: Project Management and Coordination (duration: 24 months)
- WP2: Project Communication and Dissemination (duration: 24 months)
- WP3: Current Status Analysis & Assessment (duration: 12 months)
- WP4: Common Methodology and Tools (duration: 18 months)
- WP5: Pilot Actions (duration: 24 months)
- WP6: Policy Recommendation (duration: 6 months)

The total project duration is 24 months, from 10/11/2017 to 9/11/2019 (Figure 1).

1.5 Project Beneficiaries

Lead Beneficiary is the Municipal Water Supply and Sewerage Company of Komotini (Greece); Beneficiary 2 is the Municipal Water Supply and Sewerage Company of Thermi (Greece); Beneficiary 3 is the University of Thessaly-Special Account Funds for Research-Department of Civil Engineering (Greece); Beneficiary 4 is the Municipality of Kardzhali (Bulgaria); Beneficiary 5 is the Municipality of Gotse Delchev (Bulgaria); and Beneficiary 6 is the Municipal Water Supply and Sewerage Company of Thermaikos (Greece).

Table 1. WATER RESCUE beneficiaries

PB #	PB name	City	Country
PB1	Municipal Water Supply and Sewerage Company of Komotini	Komotini	Greece
PB2	Municipal Water Supply and Sewerage Company of Thermi	Thermi	Greece
PB3	University of Thessaly-Special Account Funds for Research-Department of Civil Engineering	Volos	Greece
PB4	Municipality of Kardzhali	Karddzhali	Bulgaria
PB5	Municipality of Gotse Delchev	Gotse Delchev	Bulgaria
PB6	Municipal Water Supply and Sewerage Company of Thermaikos	Neoi Epivates	Greece

1.6 The present deliverable

1.6.1 The subject of the present deliverable

The present deliverable refers to WP4.2. This deliverable presents a joint methodology on water use efficiency in water distribution networks. Specifically, it refers to the development/adaptation of a joint methodology and tools on water supply systems management and water use efficiency by reducing Non-Revenue Water (NRW) serving as an early warning system regarding NRW & water losses based on Decision Support Systems (DSS), the hydraulic simulation model and the GIS tools. Before presenting the methods and tools used to reduce NRW, water auditing is presented as the first step of an integrated methodology.

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Chapter 2. Water Supply Systems Performance Assessment Methodology

An integrated methodology used to reduce Non-Revenue Water consists of the following steps (Figure 2):

- First, the water audit should be done in order to identify the water volumes entering the system and the water volumes consumed and lost. This step will identify the NRW level of the system and it will also provide evidence of the water volumes being lost.
- To perform water auditing, the International IWA Water Balance and its modifications can be used, along with the use of specific Performance Indicators.
- The next step is the identification of NRW causes.
- Based on the causes of losing water volumes, a NRW reduction strategy can be formulated targeting the specific causes.
- Specific measures can be decided in order to tackle each of the NRW causes.

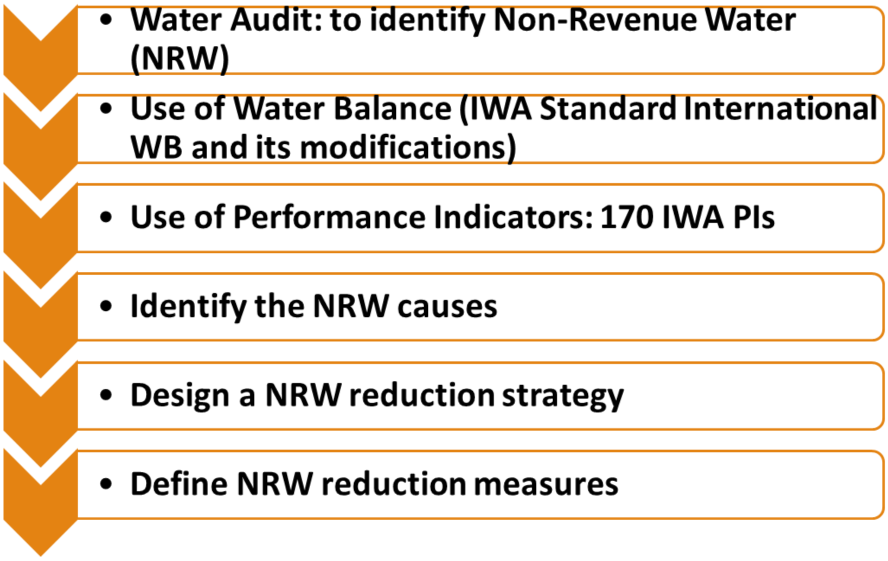

Figure 2. Integrated methodology towards NRW reduction steps

<table>
<tr><td rowspan="7">System Input Volume (A3)</td><td rowspan="4">Authorized Consumption (A14=A10+A13)</td><td rowspan="2">Billed Authorized Consumption (A10=A8+A9)</td><td>Billed Metered Consumption (A8)</td><td rowspan="2">Revenue Water (A20=A8+A9)</td></tr>
<tr><td>Billed Unmetered Consumption (A9)</td></tr>
<tr><td rowspan="2">Unbilled Authorized Consumption (A13=A11+A12)</td><td>Unbilled Metered Consumption (A11)</td><td rowspan="5">Non-Revenue Water (NRW) (A21=A3-A20)</td></tr>
<tr><td>Unbilled Unmetered Consumption (A12)</td></tr>
<tr><td rowspan="3">Water Losses (A15=A3-A14)</td><td rowspan="2">Apparent Losses (A18=A16+A17)</td><td>Unauthorized Consumption (A16)</td></tr>
<tr><td>Customer Meter Inaccuracies & Data Handling Errors (A17)</td></tr>
<tr><td colspan="2">Real Losses (A19=A15-A18)</td></tr>
</table>

Figure 3. The Standard International IWA Water Balance (Lambert et al., 1999)

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2.1 The Water Balance

The International Standard IWA Water Balance is a user-friendly water audit tool, widely used (Figure 3) (Lambert et al., 1999). It is firstly launched by Lambert et al. in 1999, trying to identify the water volumes not providing revenues to the water utility. The IWA WB can be used as a diagnostic approach, well acknowledged, which has been implemented in cases all around the world. It estimates NRW values and allocate the water volume which enters the water distribution network to its uses (several kinds of consumption or water losses).

The principal components definitions of the IWA WB are the following (Lambert et al., 1999; Farley and Trow, 2003) (Table 2):

Table 2: The WB variables, their symbols and meaning

Symbol	Variable	Meaning
A3	System Input Volume	the annual volume of water entering the system or part of the system
A14	Authorized Consumption	The annual water volume, metered and unmetered, used by registered customers who are authorized to use water
A21	Non-Revenue Water (NRW)	the difference between system input volume and billed authorized consumption
A13	Unbilled Authorized Consumption	The water volume legally consumed but not billed due to the policy of the water utility: metered and unmetered. It includes: fire-fighting, flushing of mains and sewers, cleaning of suppliers' storage tanks, water taken from hydrants, water used for cleaning streets, watering of municipal gardens, public fountains, frost protection, water, building, etc.
A18	Apparent Losses	The water volumes consumed but not registered due to metering errors or/and theft and illegal use.
A16	Unauthorized consumption	Water volume illegally used due to illegal connections, water theft, etc. It reasonable managed systems should not exceed 1% of the system input volume
A17	Customer metering errors	Include: (a) random errors due to accounting procedures such as misread meters, incorrect estimates for stopped meters, computer programming errors, etc. and (b) systematic errors due to under-registration or over-registration of customer meters.
A19	Real Losses	Annual water volumes lost through leaks, breaks or tanks' overflows. When leakage data are available, real losses can be estimated by performing the "bottom up" approach. Real losses consist of (Alegre et al., 2006): ✓ Real losses on raw water mains and at the treatment works; ✓ Leakage on transmission and/or distribution mains; ✓ Leakage and overflows at transmission and/or distribution storage tanks; and ✓ Leakage on service connections up to the measurement point.

Following the initial launch of the International Standard IWA Water Balance, McKenzie et al. (2007) and Kanakoudis and Tsitsifli (2010) proposed two amendments. The first one (by McKenzie et al. (2007)) introduces the water billed but not paid for element, which is a common issue in low income countries where the consumers cannot afford to pay their water bills. The second amendment (by Kanakoudis & Tsitsifli (2010)) introduced the concept of "Minimum Charge Difference" (MCD) which is actually water losses recovered by the water utilities and thus provide revenues (Figure 4). MCD is not actual water volumes consumed. MCD refers to the amount of money water utilities recover through their pricing policies and in particular through the fixed charge the water utilities charge to their consumers regardless their water consumption.

<table>
<tr><td rowspan="7">System Input Volume (A3)</td><td rowspan="4">Authorized Consumption (A14=A10+A13)</td><td rowspan="2">Billed Authorized Consumption (A10=A8+A9)</td><td>Billed Metered Consumption (A8)</td><td rowspan="2">Revenue Water (A20=A8+A9)</td><td>Revenue Water (water billed & paid for) (A24=A8+A9-A23)</td></tr>
<tr><td>Billed Un-Metered Consumption (A9)</td><td>Water billed but NOT PAID for (apparent NRW) A23</td></tr>
<tr><td rowspan="2">Unbilled Authorized Consumption (A13=A11+A12)</td><td>Unbilled Metered Consumption (A11)</td><td rowspan="5">Non-Revenue Water (NRW) (A21=A3-A20)</td><td rowspan="4">Accounted for Non-Revenue Water (A26=A3-A24-A23-A25)</td></tr>
<tr><td>Unbilled Un-Metered Consumption (A12)</td></tr>
<tr><td rowspan="3">Water Losses (A15=A3-A14)</td><td rowspan="2">Apparent Losses (A18=A16+A17)</td><td>Unauthorized Consumption (A16)</td></tr>
<tr><td>Customer Meter Inaccuracies & Data Handling Errors (A17)</td></tr>
<tr><td colspan="2">Real Losses (A19=A15-A18)</td><td>Water Losses generating revenues (MCD) A25</td></tr>
</table>

Figure 4. The 2nd modified Water Balance (Kanakoudis & Tsitsifli, 2010)

2.2 The concept of MCD

Usually water utilities charge the fixed charge to their consumers by following two pricing policies:

- the fixed charge is expressed in water volume: there is a minimum water volume charged (threshold), either consumed or not. When the actual water use is below that "threshold", a minimum use is being charged for, resulting in a difference between the actual metered consumption level and the billed one.

- the fixed charge is expressed in monetary units: there is a minimum charge. Water consumption charge is added to this fixed charge.

2.2.1 Calculating the MCD when the Fixed Charge is expressed in €

When the fixed charge is expressed in € (included in the water bill), the MCD expresses the equivalent water volume (in m^3), that if sold (on net water price, excluding the fixed cost) would have resulted in the same revenues (in €), minus the actual fixed cost (opportunity cost) (Kanakoudis and Tsitsifli, 2015). So, given a specific time period (T) of analysis, the Total Revenues (R) (in €) related to the water being sold (and related water services) within this time period (T) of analysis, are the sum of the revenues *(R_{fc})* related to the fixed cost and those *(R_{wuc})* related to the water being sold:

$$R = R_{fc} + R_{wuc} \tag{1}$$

The former (R_{fc}) can be expressed as the sum of the costs (R_{dc}) related to the water consumption and those (R_{ndc}) not related to that. R_{ndc} actually represents the opportunity cost the consumers have to pay:

$$R_{fc} = R_{dc} + R_{ndc} \tag{2}$$

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The total water volume Q_{wst} (in m^3) entering the system (System Input Volume – SIV) is the sum of the water volume sold (Q_{ws}) and the water volume (Q_{wns}) not sold for various reasons (e.g. leaks, breaks, water theft, zero charge etc.):

$$Q_{wst} = Q_{ws} + Q_{wns} \Leftrightarrow Q_{ws} = Q_{wst} - Q_{wns} \quad (3)$$

The water volume sold (Q_{ws}) is the sum of the water volume (Q_{wsp}) generating revenues to the utility, and the water volume (Q_{wsnp}) that although being sold does not generate revenues:

$$Q_{ws} = Q_{wsp} + Q_{wsnp} \quad (4)$$

Although the mean unit rate (A) of revenues (in €/m^3) is:

$$A = \frac{R}{Q_{wsp}} \quad (5)$$

the mean apparent/actual unit charge of water use A_{wuc} (in €/m^3) is smaller:

$$A_{wuc} = \frac{R_{wuc}}{Q_{wsp}} \quad (6)$$

If R_{ndc} expresses (in €) the actual fixed cost of the water services (opportunity cost), then the MCD (in m^3) is:

$$MCD = \frac{R_{fc} - R_{ndc}}{\frac{R_{wuc}}{Q_{wsp}}} \quad (7)$$

2.2.2 Calculating the MCD when the Fixed Charge is expressed in m^3

When the Fixed Charge is expressed in m^3, then to calculate the MCD (in m^3) is quite straight forward (Kanakoudis and Tsitsifli, 2015). The MCD represents the water volume that although included in the water bills as water consumption, is not actually being used. It is evident that from this volume, someone must exclude the water volume that if sold under the mean apparent/actual unit charge of water use A_{wuc} (€/m^3) it would generate revenues equal to the actual Fixed Cost (opportunity cost). Thus, the MCD equals to:

$$MCD = Q_{tot}^{bill} - Q_{tot}^{used} - Q_{opportunity\ cost} \quad (8)$$

Where: Q_{tot}^{billed} is the total billed water use (m^3); Q_{tot}^{used} is the total the water volume used; $Q_{opportunity\ cost}$ is the water use (m^3) representing the opportunity cost the consumer has to pay. The latter must be calculated based on the actual costs the water utility pays and are not related to the actual water use (m^3):

$$Q_{opportunity\ cost} = \frac{R_{ndc}}{A_{wuc}} \quad (9)$$

2.3 How to estimate the Water Balance

The steps for the new modified water balance development are (Figure 5):

Step 1	•Determination of the System Input Water Volume (A3)
Step 2	•Determination of the Billed Metered Use (A8) and Billed Unmetered Use (A9). Calculation of Billed Authorized Use (A10=A8+A9) and Revenue Water (A20=A8+A9).
Step 3	•Determination of Water Billed but not paid for (A23). Calculation of Water Billed and Paid For (A24=A20-A23).
Step 4	•Calculation of Non-Revenue Water (A21=A3-A23-A24)
Step 5	•Determination of Minimum Charge Difference (A25). Calculation of Accounted For Non-Revenue Water (Minimum Charge Difference has been deducted) (A26=A21-A25).
Step 6	•Determination of Unbilled Metered Consumption (A11) and Unbilled Unmetered Consumption (A12). Calculation of Unbilled Authorized Consumption (A13=A11+A12).
Step 7	•Calculation of Authorized Consumption (A14=A10+A13).
Step 8	•Calculation of Water Losses (A15=A3-A14).
Step 9	•Determination of Unauthorized Consumption (A16) and Customer meter Inaccuracies and data handling errors (A17). Calculation of the Apparent Losses (A18=A16+A17)
Step 10	•Calculation of Real Losses (A19=A15-A18)

Figure 5. The steps for the estimation of the new modified water balance (Kanakoudis and Tsitsifli, 2015)

1. Determination of the System Input Water Volume (A3)
2. Determination of the Billed Metered Use (A8) and Billed Unmetered Use (A9). Calculation of Billed Authorized Use (A10=A8+A9) and Revenue Water (A20=A8+A9).
3. Determination of Water Billed but not paid for (A23). Calculation of Water Billed and Paid For (A24=A20-A23).
4. Calculation of Non-Revenue Water (A21=A3-A23-A24)
5. Determination of Minimum Charge Difference (A25). Calculation of Accounted For Non-Revenue Water (Minimum Charge Difference has been deducted) (A26=A21-A25).
6. Determination of Unbilled Metered Consumption (A11) and Unbilled Unmetered Consumption (A12). Calculation of Unbilled Authorized Consumption (A13=A11+A12).
7. Calculation of Authorized Consumption (A14=A10+A13).
8. Calculation of Water Losses (A15=A3-A14).
9. Determination of Unauthorized Consumption (A16) and Customer meter Inaccuracies and data handling errors (A17). Calculation of the Apparent Losses (A18=A16+A17).
10. Calculation of Real Losses (A19=A15-A18).

The necessary variables for the estimation of the new modified water balance are given in Table 3.

Table 3: Necessary IWA variables for the new modified water balance estimation

IWA Variable		Meaning
A3	System input volume	The water volume input of the global system during the assessment period
A5	Exported raw water	Total volume of raw water transferred to other water undertaking or to another system from the same supply area during the assessment period
A8	Billed metered consumption	Total amount of billed metered authorised consumption (including exported water) during the assessment period
A9	Billed unmetered consumption	Total amount of billed unmetered authorised consumption (including exported water) during the assessment period
A11	Unbilled metered consumption	Total amount of unbilled metered authorised consumption (including exported water) during the assessment period
A12	Unbilled unmetered consumption	Total amount of unbilled unmetered authorised consumption (including exported water) during the assessment period
A16	Unauthorised cosnumption	Total amount of unauthorised water consumption during the assessment period, including water theft.
A17	Metering inaccuracies water losses	Total amount of water consumed during the assessment period, but unaccounted-for due to metering inaccuracies
A23	Non Recoverd Water	Water volume billed but never paid by the consumers
A25	MCD (Recovered Real Losses)	Difference between water volume billed to the customers and water volume registered by their water meters

To estimate the WB is a hard thing to do as many variables are not metered and also the water utilities do not keep data records. In order to estimate some of the usually not metered variables, there are some tips and tricks used based on the international literature and on the experience. Of course, each water supply network is different and its specific characteristics should be taken into consideration. Sometimes water managers have an idea of the values of some variables.

Tip 1: to estimate the billed metered consumption the period used in the calculation should be consistent with the auditing period

Tip 2: to estimate the billed unmetered consumption, the household customers or the points of consumption should be determined. Then, a pilot project during a small time period can be implemented. For commercial customers the pilot project should be more precise

Tip 3: unbilled unmetered consumption should not be overestimated. In Australia it is 0.5% of SIV, in the UK it is 1.25% of the SIV. IWA suggests that unbilled authorized consumption should not be less than 1% of SIV

Tip 4: Unauthorized consumption in the UK is 0.25% of SIV and in Australia 0.1% of SIV. In general, it should not exceed 1% of SIV.

Tip 5: Customer meter inaccuracies (household) in the UK are 3.3% of the household consumption and 4.7% of the non-household consumption. In Australia under-registration is 2% of the household consumption and 2% of the non-household consumption.

Tip 6: IWA considers that apparent losses can range from 0 to 10% of SIV for direct pressure systems but for systems with customer tanks they are more.

The international literature provides some limits for the unbilled authorized consumption, the apparent losses and the real losses (Table 4). If unbilled authorized consumption ranges between 1 -5 % the new tariffs should be introduced, while if they exceed 5% the overall billing policy should be reviewed. In cases where apparent losses ranging between 2 – 5%, unauthorized consumption, meter reading and accounting errors should be reduced. The metering accuracy / policy should be reviewed if apparent losses exceed 5%. When real losses range between 5-10%, visual leakages and overflows should be reduced. When real losses exceed 10%, active leakage control should be improved, effective maintenance and pressure management should be done.

Table 4. Critical limits for unbilled authorized consumption, apparent losses and real losses and suggested actions (Charalambous & Hamilton, 2012)

Unbilled Authorized Consumption	Up to 1%	Considered within acceptable limits
	1-5%	Introduce new tariffs
	5% and above	Review overall billing policy
Apparent Losses	Up to 2%	Considered within acceptable limits
	2-5%	Reduce unauthorized consumption, meter reading and accounting errors
	5% and above	Review metering accuracy / policy
Real Losses	Up to 5%	Considered acceptable, may be uneconomic to reduce
	5-10%	Reduce visual leakages and overflows at storages and fix visual network leaks
	10% and above	Improve active leakage control, effective maintenance, pressure management

2.4 Assessing real losses

Real losses can be assessed by:

- ✓ Component analysis where leakage is estimated using background leakage at joints and fittings, reported leaks and bursts and unreported leaks and bursts
- ✓ Analysis of night flows using the Minimum Night Flow analysis (MNF).

Minimum Night Flow analysis is based on the fact that water consumption reached its lowest levels in the night, somewhere between 2-5 o'clock in the morning. Monitoring the night flow and excluding the night consumption, the remaining flow is due to leakages (Figure 6).

The Minimum Night flow consists of the Minimum Night Consumption, which is metered or can be estimated, the burst leakage and the background leakage. The latter represents the leakage that cannot be found, and it is not economical to be repaired. The literature proposes that the minimum night consumption ranges between 1.8 to 3.0 L/h/household. The values of the night water consumption differ among different countries and consumers. It is known that in the UK, the night household consumption has been reported to be 1.7L/household/hr, while the non-household night consumption has been reported to 1 to 60L/consumer/hr (Fantozzi & Lambert, 2012). In Germany and Austria, the minimum night consumption ranges from 0.4 to 0.8 L/person/hr (Fantozzi & Lambert, 2012). The formula used to calculate the night household consumption is:

$$House\ hold\ Night\ Consumption = \text{no. of households} \times \text{typical night water use} \quad (1)$$

Table 5. Minimum Night Flow Analysis

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Minimum Night Flow (MNF)								
Night Consumption					Night Leakages			
Night Use			Night consumer leakage		Breaks		Background leakage	
Exceptional Night use	Household Night use	Non-household night use	Night leakage at the consumer's building	Night leakage outside the consumer's building	Unreported breaks	Reported breaks (not yet repaired)	In consumers' connections	In water pipes (transmission and distribution)

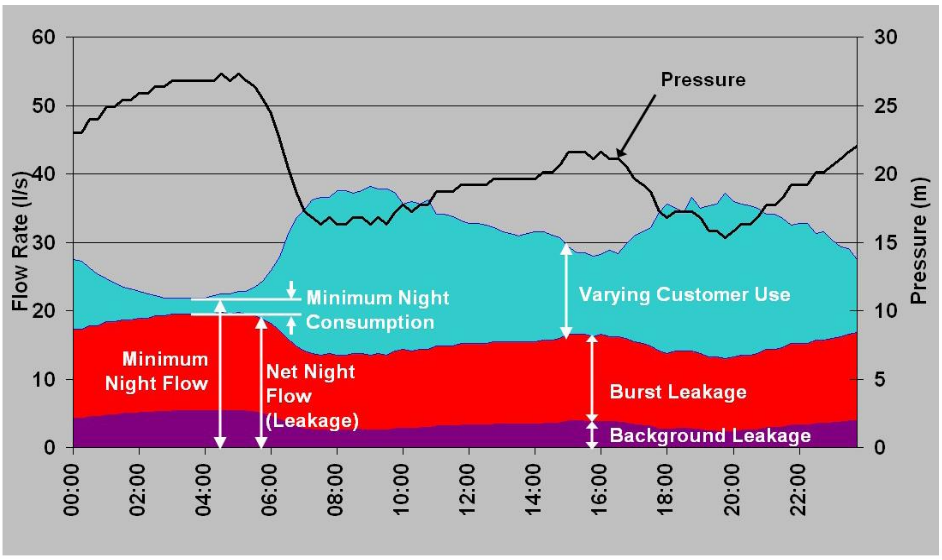

Figure 6. Water flow and pressure within 24 hours (Morrison et al., 2007)

To estimate the commercial consumption, equation (2) is used:

$$Commercial\ consumption = \text{no. of commercial consumers} \times \text{typical night use} \quad (2)$$

Where, typical night use for the commercial consumers is estimated from 8 to 10L/hr/consumer. However, in commercial consumers it is better that the water utility records their night water use as it might differ a lot.

The estimation of the special night consumption should be handled case by case. The night consumptions should be recorded separately.

Background leakages are very small leakages whose localization and repair are not economically beneficial. To calculate background leakage, equation (3) can be used:

$$\Delta B = 0{,}02 \times L + 1{,}25 \times N + 0{,}033 \times s \quad (3)$$

Where L is the mains length (m), N is the connections number and s is the connections' length (m). The background leakage is estimated in L/hr. Equation (3) is valid for a distribution network in good condition and night pressure of 50m. For different night pressure, equation (3) is transformed to equation (4):

$$\Delta B = [0{,}02 \times L + 1{,}25 \times N + 0{,}033 \times s] \times \left(\frac{P_{night}}{50}\right)^{1{,}5} \quad (4)$$

The burst leakage is the one that can be located and repaired, and it is calculated using equation (5):

$$Burst\ leakage = \text{Minimum night flow} - \text{minimum night use} - \text{background leakage} \quad (5)$$

To calculate the leakages for 24 hours, if the average zone pressure is different, the night – day factor (NDF) should be used. This factor is the ratio of the night leakage rate (m^3/hr) and the average leakage rate in 24 hours (m3/day). Thus, the average day value of leakages is calculated by multiplying the night leakage rate with the NDF. In distribution networks where water supply is done by gravity, the NDF is less than 24 hours. For networks using pressure reduction valves (PRVs) or with pumps, the NDF may exceed 24 hours.

Chapter 3. Performance Indicators (PIs)

3.1 Performance Indicators (PIs)

Performance indicators measure the provided services efficiency and effectiveness and are the result of several variables combination. IWA has recorded 170 performance indicators (Alegre et al, 2016). The performance indicators consist of general indicators providing an overview of the efficiency and effectiveness and detailed indicators dealing with specific aspects of the utility functionally. They are divided in 6 groups: water resources (WR); Personnel (Pe); Quality of Services (QS); Operational (Op); Physical (Ph); and Economic and Financial (Fi) (Table 6). 232 variables are used to calculate the 170 PIs (Alegre et al., 2016). The variables are divided in 8 groups (A to H).

Table 6. PIs groups (Alegre et al., 2016)

PIs	PIs no.	PIs	PIs no.	PIs	PIs no.
Water Resources	**4**	**Operational**	**44**	**Economic and financial**	**47**
Personnel	**26**	Inspection & maintenance of physical assets	6	Revenues	3
Total Personnel	2	Instrumentation calibration	5	Costs	3
Personnel per main function	7	Electrical & signal transmission equipment inspection	3	Composition of running costs per type of costs	5
Technical services personnel per activity	6	Vehicle availability	1	Composition of running costs per main function of the water utility	5
Personnel qualification	3	Mains, valves and service connection rehabilitation – pumps rehabilitation	7	Composition of running costs per technical function activity	6
Personnel training	3	Operational water losses	7	Composition of capital costs	2
Personnel health & safety	4	Failure	6	Investment	3
Overtime work	1	Water metering	4	Average water charges	2
Quality of service	**34**	Water quality monitoring	5	Efficiency	9
Service coverage	5	**Physical**	**15**	Leverage	2
Public taps and standpipes	4	Treatment	1	Liquidity	1
Pressure & continuity of supply	8	Storage	2	Profitability	4
Quality of supplied water	5	Pumping	4	Economic Water losses	2
Service connection and meter installation & repair	3	Transmission & distribution	2		
		Meters	4		
Customer complaints	9	Automation & Control	2		

3.2 The most important IWA PIs

3.2.1 Non-Revenue Water (NRW) Index

NRW as percentage of SIV (NRW% by volume) is considered as one of the IWA 'best practice' PIs (Alegre et al., 2016) well-known. International data show that NRW% by volume for a typical system ranges from 5% to over 50%. There are many reasons for this wide variation, not only management efficiency and infrastructure condition related reasons:

- Economic NRW management policies depend on water cost and availability;

- High consumption values decrease NRW percentages, while low consumption values increase NRW percentages;
- Intermittent supply reduces the time length the system is pressurized and leaking, but it is not a good practice as it reduces infrastructure life;
- Apparent losses are influenced by meters type and whether customers are supplied by direct pressure or using roof tanks;
- Average operating pressures vary from less than 20m to over 100m and average real losses vary approximately linearly with pressure for large systems with mixed pipe materials;
- Some systems include transmission mains and service reservoir real losses, while others do not;
- Real losses may include leakage on customers' private pipes, depending on ownership, maintenance responsibility for different sections of the service connection, and customer meter location.

Although "%NRW by volume" index represents the SIV part not generating revenues, it does not take into account the different valuations of NRW components, nor the system's operating costs.

A better expression for NRW is the "volume of NRW as % by cost", which calculates the cost of each of the three main NRW components (Unbilled Authorised Consumption, Apparent Losses and Real Losses) by attributing different monetary valuations (per m^3) to each of these components, dividing them by the system's operating cost (Figure 7).

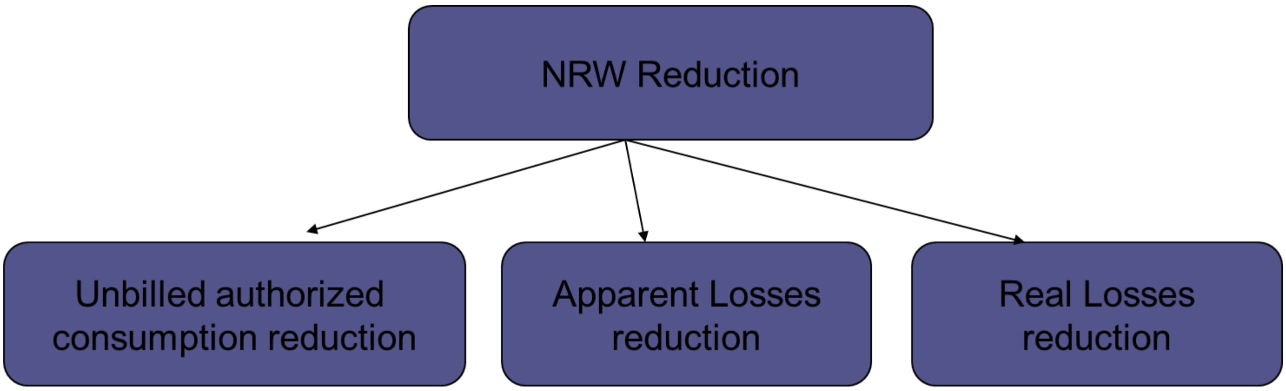

Figure 7. NRW and its components

3.2.2 Apparent Losses Index

IWA proposes two PIs for apparent Losses:

- Apparent Losses % (Op25)
- Apparent Losses per System Input Volume (Op26)

According to Alegre et al. (2016), indicators Op25 and Op26 shall be used in alternative: Op25 applies to distribution systems and Op26 to bulk supply systems.
For specific studies of apparent losses associated to customer meters, an indicator expressed as apparent losses per customer (m^3/customer) may be useful in alternative or in complement.

The Apparent Loss Team members have agreed that the % PI (both as a % of SIV and as a % of Water Supplied) is a poor indicator, containing few valuable information that can be acted upon (Liemberger et al., 2007). The main reason is the complexity of the Apparent Losers:

- The apparent losses include four components (Figure 8) (Farley & Trow, 2003);
- Systems with tanks on the roofs provide a completely different scenario from the systems not having tanks. When private roof tanks exist, under-registration is much higher (Lambert, 2002);

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- Apparent Losses volume may actually be negative when greater consumption is recorded in the case of single-jet and multi-jet meters.

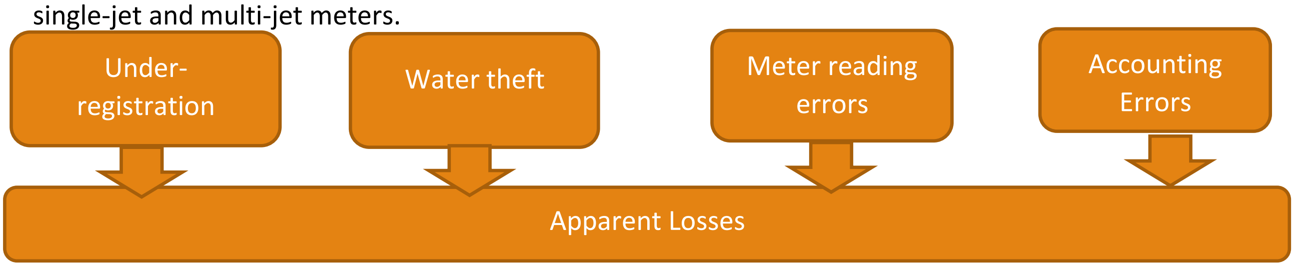

Figure 8: Apparent Losses components (Farley & Trow, 2003)

3.2.3 Real Losses Index

IWA proposes two real losses indices (Alegre et al., 2016):

- Real losses per connection (L/connection/day when system is pressurized) – Op27
- Real losses per mains length (L/Km/day when system is pressurized) – Op28

Indicators Op27 and Op28 shall be used in alternative. Op28 applies if service connections density <20/km of mains

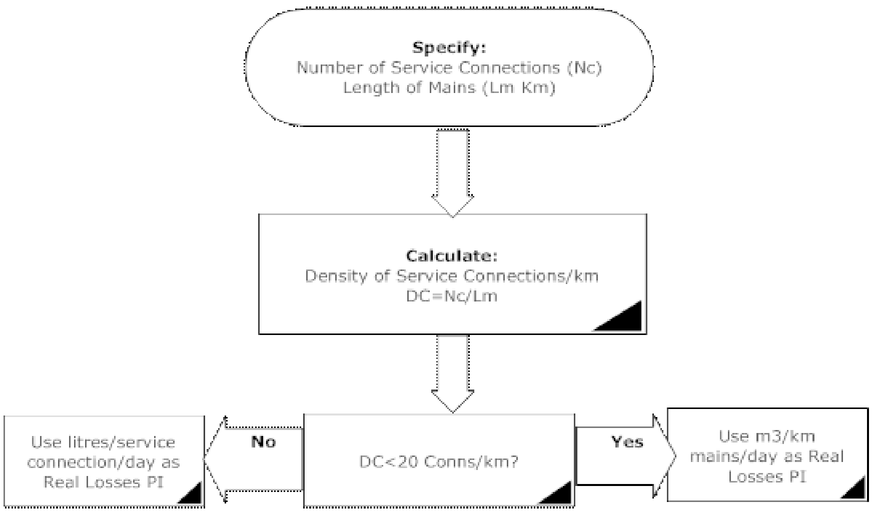

Figure 9: Process to determine the PI for Real Losses operational management (Alegre et al., 2016)

As most distribution systems have connections density greater than 20 per km of mains, 'per service connection' should logically become the predominant basic operational PI for the real losses in the future. In the case of systems subject to intermittent supply, the PI is expressed as 'litres/service connection/day when the system is pressurized' (Figure 8) (Farley and Trow, 2003).

3.2.4 Unavoidable Annual Real Losses - UARL

Real losses cannot be eliminated totally. The lowest technically achievable annual volume of real losses for well-managed systems is the UARL, represented by the smaller rectangle in Figure 10 (Farley & Trow, 2003). The large square area represents the Current Real Losses (CARL) in m^3/year for any system. The difference between the UARL and the CARL is the potentially recoverable real losses.
UARL is a useful concept as it can be used to predict, with reasonable reliability, the lowest technically achievable annual real losses for any combination of mains length, number of connections, customer meter location and average operating pressure – assuming that the system is in good condition with high standards for management of real losses (Farley & Trow, 2003).

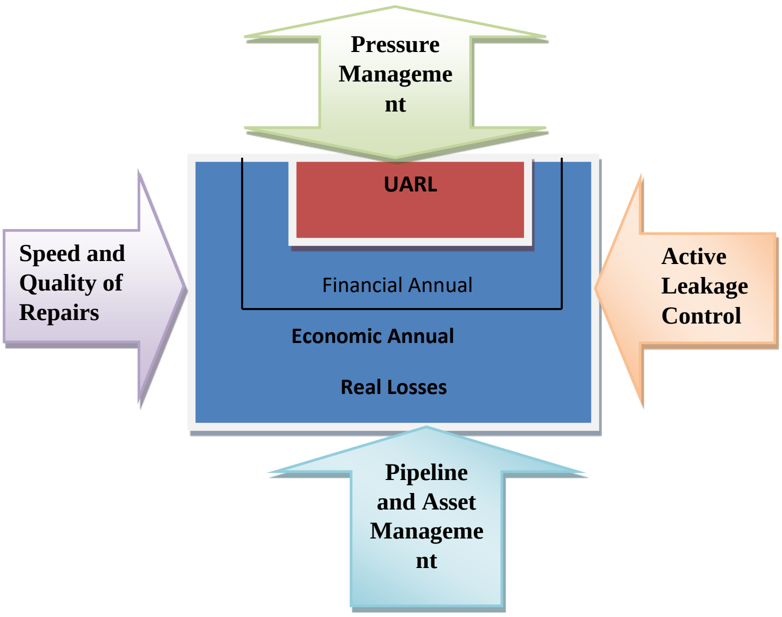

Figure 10: The four basic methods to managing real losses

The Water Losses Task Forces developed a system-specific equation for the lowest technically achievable real losses. Using appropriate parameter values for burst frequencies, maximum durations and pressure-related typical flow rates for well-managed systems with infrastructure maintained in good condition, the following components of UARL were obtained:

On mains	18 lt/km mains/day/metre of pressure
On service connections (up to property boundary)	0.8 lt/service connection/day/ metre of pressure
On service connections (property boundary to customer meter)	25 lt/km/day/metre of pressure

System-specific values of UARL can be assessed using an empirical formula developed by the IWA Water Losses Task Force (Lambert et al., 1999). In the most basic form, UARL in lt/day is:

$$UARL = (18 \times L_m + 0.80 \times N_c + 25 \times L_p) \times P \quad (6)$$

where L_m is mains length in Km, N_c is number of service connections, L_p is the total length in km of underground pipe (between the street limit and the customer's meter), and P is average operating pressure in meters. This basic equation can be manipulated into many other forms and units.

UARL in L/connection/day/m pressure is given by equation (7):

$$UARL = [\frac{18}{D_c} + 0{,}8 + 25 \times \left(\frac{L_p}{N_c}\right)] \quad (7)$$

UARL in L/km mains/day are given by equation (8):

$$UARL = [18 + 0{,}8 \times D_c + 25 \times \left(\frac{L_p}{L_m}\right)] \times P \quad (8)$$

UARL in L/km mains/day/m pressure are given by equation (9):

$$UARL = 18 + 0{,}8 \times D_c + 25 \times (\frac{L_p}{L_m}) \quad (9)$$

Where, Dc is the connections density and is given by equation (10):

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$$D_c = \frac{N_c}{L_m} \tag{10}$$

UARL varies with the density of connections (per km of mains), for systems with customer meters located close to the customer's property limits. If UARL is expressed in m^3/km of mains/day/meter of pressure, the UARL value rapidly rises as the density of connection increases. This means that when Real Losses are expressed as "per km of mains", it is only possible to compare performance for systems within specified narrow bands of connections density (Farley & Trow, 2003). For connection densities more than 20 per km of mains, UARL expressed in litres/service connection/day/meter of pressure, is found to be almost constant (Farley & Trow, 2003).

As the system ages, there is a tendency for a natural rate of rise of real losses through new leaks and bursts, some of which will not be reported to the utility. This tendency is controlled and managed by some combination of the four primary components of real losses management, namely:

- pipeline and assets management;
- pressure management (which may mean increases or decreases of pressure);
- speed and quality of repairs;
- active leakage control, to locate unreported leaks.

The number of new leaks arising each year is influenced primarily by long-term pipeline management. Pressure management can influence the frequency of new leaks, and the flow rates of all leaks and bursts. The average duration of the leaks is limited by the speed and quality of repairs, and the active leakage control strategy controls how long unreported leaks run for before they are located. The extent to which each of these four activities is carried out will determine whether the volume of annual real losses increases, decreases or remains constant.

3.2.5 Infrastructure Leakage Index (ILI)

The ratio of the CARL to UARL is the Infrastructure Leakage Index (ILI) – Op29. The ILI measures how effectively the infrastructure activities in figure 10- repairs, active leakage control and pipeline/assets management – are being managed at current operating pressure.

For each of the four activities, there is some economic level of investment and activity, which needs to be calculated or assessed, depending upon the marginal value, in local currency/m^3, placed on the real losses. Depending upon local circumstances and practice, the marginal value placed on real losses may be low – perhaps power and chemicals cost only – or high, and this profoundly influences the economic management policies for controlling real losses.

Values close to 1.0 represent near-perfect technical management of real losses from infrastructure, at actual operating pressures.

The World Bank classifies water distribution systems in 4 categories, depending on ILI or real losses values for a constant pressure value and on the system's origin, being in developed or developing country (Figure 11). Depending on the classified category, the World Bank is proposing measures for water losses reduction.

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

Figure 11: World Bank Physical Losses Assessment Matrix

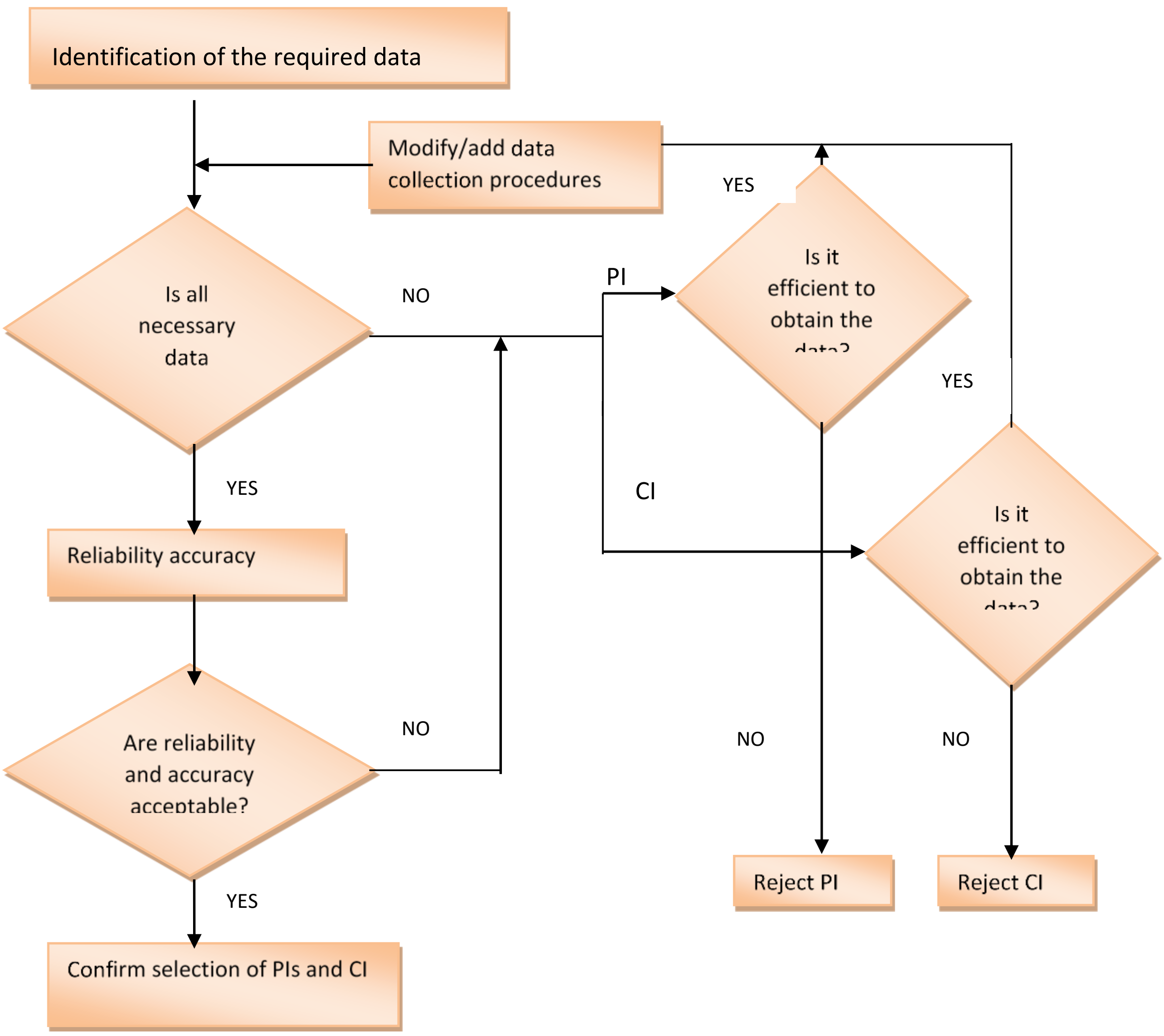

Figure 12: PIs selection process (Alegre et al., 2016)

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3.3 PIs selection process

The next step in the selection process of an appropriate PI system consists of adequately selecting and defining the PIs that will be used and the necessary context information (CI) that might be needed.

The selection phase is important for the following reasons:

- The total number of PIs may be a factor for the project success. Too many indicators and the costs and difficulties of implementing the system will increase significantly. On the other hand too few and the system will not provide a proper performance assessment.
- The indicators selected should provide balance in studying the utility’s different sectors. There is no meaning to choose a small number of indicators referring to the same field, while the objectives and strategies refer to a broader scope.
- The indicators nature may affect the interpretation of the results. For example, the water losses volume expressed as a percentage may be a misleading indicator in certain cases.
- The indicators should be consistent in their construction. A well-defined PI system will consist of indicators that have the same structure and level of detail in their definitions, assessment period and units. Also, the system should be structured in such a way that the common variables are shared by indicators and have unique definitions, assessment periods and units.

To select the appropriate performance indicators and context information from the IWA set, the following five steps are presented (Figure 12) (Alegre et al., 2016):

1. Pre-selection of the PIs considered being important for the assessment (and relevant to the selected objectives, strategies and critical success factors).
2. Selection of the actual PIs and CI to be used in the initial assessment.
3. Development of additional PIs and CI if necessary. Consistency check.
4. Pilot testing of the initially selected PIs.
5. Final selection of PIs considered being important and to be used in the assessment process.

The first step is to classify the PIs according to their significance for the evaluation process. This classification should be done based on the stakeholders’ opinions and needs. Three levels classification (high, medium, low) would be correct for this phase. This classification must be done, regardless of the information availability or quality. When the key indicators will be identified it may be necessary to modify data and processes. These improvements should be made taking into consideration the PIs importance being calculated from these data.

The PIs initial selection process should be done at a higher level (strategic team) after consultation with the team, which will interact with data suppliers. Additional consultations outside the company may be required for example where performance evaluation is extended for regulation or external reasons. External stakeholders are likely not to be taken into consideration regarding the internal evaluation.

If there is a significant indicator but there are no variables, the indicator should be included in the database and variables measurements must be done to obtain data for future evaluations.

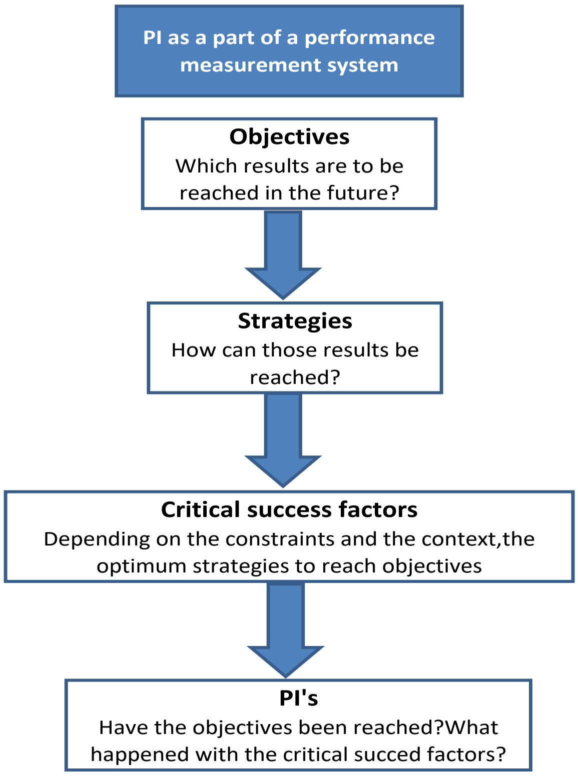

Figure 13: PIs as a part of a performance measurement system (Alegre et al., 2006)

3.4 Establishment of a Performance Indicators System

The implementation of any PI system has to be objective-oriented. Performance Indicators are the last step of a larger management strategy that should link the utility's objectives to strategies, define critical success factors and then bring performance indicators to evaluate the success of these strategies (Figure 13) (Alegre at al., 2016).

Assessment of the values of the system PIs should be done accordingly to objectives, strategies and critical factors already established. A PI cannot be assessed unless it is compared to a reference value. These reference values can be predefined objectives, part values of the same PI or external values of the PI (obtained from benchmarking projects or external references). The immediate consequence of assessing the results provided by the PI should be an improved decision-making process. In the first stage, PIs should provide information about the adequacy and success of the strategies defined as critical success factors in achieving the objectives. As a result, PIs results may be used to make immediate decisions or to define long term strategies. Figure 8 shows the phases of the PI system implementation process.

3.5 New Indicators

IWA has established 170 PIs (Table 6 & 7) which are divided in six (6) groups: water resources (WR); Personnel (Pe); Quality of Services (QS); Operational (Op); Physical (Ph); and Economic and Financial (Fi). New PIs have been developed during WATERLOSS project and they are presented in Table 8 (Kanakoudis et al., 2013). Table 9 includes the new variables that need to be measured for the calculation of the new PIs (Kanakoudis et al., 2013).

The new developed PIs are operational (24), quality of service (8), physical (4) and economic (5) indicators. It is obvious that the 170 IWA PIs do not cover all issues faced by a water utility. There are certain parameters that are not addressed by the existing IWA PIs referring to water losses. International literature clearly states that pipe breaks and leaks are affected by several parameters like pipe characteristics (pipe material; diameter; age; pipe operational state; etc.), operational and maintenance factors (operating pressure; last break event characteristics; maintenance characteristics; water quality; etc.), and environmental/ climate conditions (soil type; soil temperature; rainfall; traffic and loads; etc.). Therefore, such parameters as pipe material and pipe diameter are used to form new PIs derived from the existing ones. Also, apparent losses are affected by the existence and the volume of roof tanks.

Specifically, there are PIs investigating the impact of pipe material and/or diameter in the real losses values; investigating the impact of roof tanks and their volume in the apparent losses values; checking the water volume lost per water meter; investigating how much water is lost compared to the volume abstracted from the water resources; investigating NRW in relation to the number of connections or length of mains; and estimating the mains' failures per type of main, as studies showed that the pipe material affects mains' failures. Additional PIs covering issues, such as social, environmental, and health factors, energy use, and conservation, have also been included. Topics such as carbon footprint and energy losses are also being addressed. The MCD is used to form new PIs (Kanakoudis et al., 2013).

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Table 7: The 170 IWA Performance Indicators (Alegre et al., 2016)

A/A	GROUP	PERFORMANCE INDICATORS	MEANING	FORMULA	MEASURED IN
WR1	Water Resources	Inefficiency of use or water resources	(Real losses during the assessment period / system input volume during the assessment period) x 100	WR1=(A19/A3)*100	%
WR2		Water resources availability	(System input volume during the assessment period x 365 / assessment period / (annual yield capacity of own recourses + annual imported water allowance)) x 100	WR2=(A3*365/H1*(A1+A2))*100	%
WR3		Own water resources availability	(System input volume during the assessment period x 365 / assessment period/ annual yield capacity of own recourses) x 100	WR3=(A3*365/H1*A1)*100	%
WR4		Reused supplied water	Reused supplied water during the assessment period / system input volume during the assessment period x 100	WR4=(A22/A3)*100	%
Pe1	Total Personnel	Employees per connection	Number of full-time equivalent employees of the water undertaking / number of service connections x 1000	Pe1=(B1/C24)*1000	No./1000 connections
Pe2		Employees per water produced	(Number of full-time equivalent employees of the water undertaking / (water produced the assessment period x 365 / assessment period)) x 10^6	Pe2=[B1/(A6*365/H1)]*10^6	No./(10^6m3/year)
Pe3	Personnel per main function	General management personnel	Number of full-time equivalent employees dedicated to directorate, central administration, strategic planning, marketing and communications, other stakeholder relations, legal affairs, internal audits, environmental management, new business development and general co.	Pe3=(B2/B1)*100	%
Pe4		Human resources management personnel	(Number of full-time equivalent employees dedicated to personnel administration, education and training, occupational safety and health services and social activities / Number of full-time equivalent employees of the water undertaking) x 100	Pe4=(B3/B1)*100	%
Pe5		Financial and commercial personnel	(Number of full-time equivalent employees dedicated to economic and financial planning, economic administration, economic controlling and purchasing and material management / Number of full-time equivalent employees of the water undertaking) x 100	Pe5=(B4/B1)*100	%
Pe6		Customer service personnel	(Number of full-time equivalent employees dedicated to accounting and control and to customer relations and management activities / Number of full-time equivalent employees of the water undertaking) x 100	Pe6=(B5/B1)*100	%
Pe7		Technical services personnel	(Number of full-time equivalent employees dedicated to planning, construction, operations and maintenance activities / Number of full-time equivalent employees of the water undertaking) x 100	Pe7=(B6/B1)*100	%
Pe8		Planning and construction personnel	(Number of full-time equivalent employees of technical services working in planning & construction / Number of full-time equivalent employees of the water undertaking) x 100	Pe8=(B7/B1)*100	%
Pe9		Operations and maintenance personnel	(Number of full-time equivalent employees of technical services working in operations & maintenance / Number of full-time equivalent employees of the water undertaking) x 100	Pe9=(B8/B1)*100	%
Pe10	Technical services personnel per activity	Water resources and catchment management personnel	[Number of full-time equivalent employees working in the water resources and catchment management / (water produced during the assessment period x 365)/assessment period)]*10^6	Pe10=[B9/(A6*365/H1)]*10^6	No./(10^6m3/year)
Pe11		Abstraction and treatment personnel	[Number of full time equivalent employees working in planning, design, construction, operations and maintenance of the abstraction and treatment / (water produced during the assessment period x 365)/assessment period)]*10^6	Pe11=[B10/(A6*365/H1)]*10^6	No./(10^6m3/year)

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A/A	GROUP	PERFORMANCE INDICATORS	MEANING	FORMULA	MEASURED IN
Pe12		Transmission, storage and distribution personnel	[Number of full time equivalent employees working in planning, design, construction, operations and maintenance of the transmission, storage and distribution system / (water produced during the assessment period x 365)/assessment period)]*10^6	Pe12=(B11/C8)*100	No./100 km
Pe13		Water quality monitoring personnel	[Number of full-time equivalent employees working in water quality sampling and testing / (total number of tests carried out by the undertaking laboratories during the assessment period x 365 / assessment period)]*10000	Pe13=[B12/(D52*365/H1)]*10000	No./10000 tests/year
Pe14		Meter management personnel	Number of full-time equivalent employees working in meter management / (total number of system and customer meters) x 10000	Pe14=[B13/(C10+E6)]*1000	No./1000 meters
Pe15		Support services personnel	(Number of full-time equivalent employees working in support services / total number of full-time equivalent employees working in technical services) x 100	Pe15=(B14/B6)*100	%
Pe16	Personnel qualification	University degree personnel	(Number of full-time equivalent employees of the water undertaking with university degree / number of full-time equivalent employees of the water undertaking) x 100	Pe16=(B15/B1)*100	%
Pe17		Basic education personnel	(Number of full-time equivalent employees of the water undertaking with basic education / number of full-time equivalent employees of the water undertaking) x 100	Pe17=(B16/B1)*100	%
Pe18		Other qualification personnel	(Number of full-time equivalent employees of the water undertaking with basic education / number of full-time equivalent employees of the water undertaking) x 100	Pe18=(B17/B1)*100	%
Pe19	Personnel training	Total training	[(Number of training hours during the assessment period x 365)/assessment period]/number of full-time equivalent employees of the water undertaking	Pe19=[(B18*365)/H1]/B1	hours / employee / year
Pe20		Internal training	Number of internal training hours / number of full time equivalent of the water undertaking	Pe20=[(B19*365)/H1]/B1	hours / employee / year
Pe21		External training	[(Number of external training hours during the assessment period x 365)/assessment period]/number of full-time equivalent employees of the water undertaking	Pe21=[(B20*365)/H1]/B1	hours / employee / year
Pe22	Personnel health and safety	Working accidents	{[(Number of working accidents requiring medical care occuring with personnel during the assessment period x 365)/assessment period]/number of full-time equivalent employees of the water undertaking} x 100	Pe22={[(B21*365)/H1]/B1}*100	No./100 employees/year
Pe23		Absebteeism	[(Total number of days of absenteeism occuring during the assessment period x 365)/assessment period]/number of full-time equivalent employees of the water undertaking	Pe23=[(B22*365)/H1]/B1	days / employee / year
Pe24		Absedeeism due to working accidents or illness at work	[(Total number of days of absenteeism due to accindets or illness at work occuring during the assessment period x 365)/assessment period]/number of full-time equivalent employees of the water undertaking	Pe24=[(B23*365)/H1]/B1	days / employee / year
Pe25		Absedeeism due to other reasons	[(Total number of days of absenteeism occuring during the assessment period that were not due to working accidents or illness at work x 365)/assessment period]/number of full-time equivalent employees of the water undertaking	Pe25=[(B24*365)/H1]/B1	days / employee / year
Pe26	Overtime work	Overtime work	(Overtime work during the assessment period / normal work during the assessment period) x 100	Pe26=(B26/B25)*100	%
Ph1	Treatment	Treatment plant utilisation	(Maximum daily volume of water treated in treatment plants during the assessment period / maximum daily capacity of the existing treatment plants) x 100	Ph1=(A4/C3)*100	%

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A/A	GROUP	PERFORMANCE INDICATORS	MEANING	FORMULA	MEASURED IN
Ph2	Storage	Raw water storage capacity	(Net capacity of raw water reservoirs / system input volume during the assessment period) x assessment period	Ph2=(C1/A3)*H1	days
Ph3		Transmission and distribution storage capacity	(Total capacity of treated water reservoirs (private storage tanks excluded)/ system input volume during the assessment period) x assessment period	Ph3=(C2/A3)*H1	days
Ph4	Pumping	Pumping utilisation	[Sum, for all installed pumps, of the number of operation hours of the maximum energy consumption day during the assessment period multiplied by the nominal power of the pump / (maximum nominal power that can be used simultaneously in the system x 24)] x 100	Ph4=[D2/(C7*24)]*100	%
Ph5		Standardised energy consumption	Energy consumption for pumping during the assessment period / Sum of the volume elevated during the assessment period multiplied by the pump head / 100	Ph5=D1/D3	kWh/m3/100m
Ph6	Treatment	Reactive energy consumption	Reactive energy consumption for pumping during the assessment period / total energy consumption for the pumping during the assessment period multiplied by the pump head x 100	Ph6=(D4/D1)*100	%
Ph7		Energy recovery	(Energy recovered by the use of turbines of reverse pumps during the assessment period / total energy consumption for pumping during the assessment period) x 100	Ph7=(D5/D1)*100	%
Ph8	Transmission and distribution	Valve density	Number of isolating valves / total distribution mains length	Ph8=C22/C9	No./km
Ph9		Hydrant density	Number of hydrants / total distribution mains length	Ph9=C23/C9	No./km
Ph10	Meters	District meter density	(Number of district meters / number of service connections) x 100	Ph10=(C11/C24)*1000	No./1000 service connections
Ph11		Customer meter density	Number of direct customer meters / number of service connections	Ph11=E6/C24	No./service connections
Ph12		Metered customers	Number of direct and bulk customer meters / number of registered customers	Ph12=(E6+E9)/E10	No./ customer
Ph13		Metered residential customers	Number of residential-equivalent customer meters / number of residential registered customers	Ph13=E7/E11	No./ customer
Ph14	Automation and control	Automation degree	(Number of automated control units / number of control units) x 100	Ph14=(C16/C15)*100	%
Ph15		Remote control degree	(Number of remotely controlled units / number of control units) x 100	Ph15=(C17/C15)*100	%
Op1	Inspection and maintenance of physical assets	Pump inspection	[(Total nominal power of pumps and related ancillaries subjected to inspection during the assessment period x 365) / assessment period] / total nominal power of pumps	Op1=[(D6*365)/H1]/C6	/ year
Op2		Storage tank cleaning	[(Volume of storage tank cells cleaned during the assessment period x 365) / assessment period] / total volume of storage tank cells	Op2=[(D7*365)/H1]/C2	/ year
Op3		Network inspection	[(Length of transmission and distribution mains where at least valves and other fitting were inspected during the assessment period x 365) / assessment period) / total mains length] x 100	Op3=[(D8*365)/H1/C8]*100	% / year
Op4		Leakage control	[(Length of mains subject to active leakage control during the assessment period x 365) / assessment period) / total mains length] x 100	Op4=[(D9*365)/H1/C8]*100	% / year
Op5		Active leakage control repairs	[(Number of leaks detected and repaired due to active leakage control during the assessment period x 365) / assessment period) / total mains length] x 100	Op5=[(D10*365)/H1/C8]*100	No./100km/year

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A/A	GROUP	PERFORMANCE INDICATORS	MEANING	FORMULA	MEASURED IN
Op6		Hydrant inspection	[(Number of hydrants inspected during the assessment period x 365) / assessment period) / total number of hydrants] x 100	Op6=[(D11*365)/H1]/C23	/ year
Op7	Instrumentation calibration	System flow meters calibration	[(Number of system flowmeter calibrations carried out during the assessment period x 365) / assessment period)] / number of system flow meters installed in the system (permanently or temporarily)	Op7=[(D12*365)/H1]/C10	/ year
Op8		Meter replacement	[(Number of customer flow meters replaced during the assessment period x 365) / assessment period)] / number of customer meters	Op8=[(D45*365)/H1]/E6	/ year
Op9		Pressure meters calibration	[(Number of pressure meter calibrations carried out during the assessment period x 365) / assessment period)] / number of pressure meters installed in the system (permanently or temporarily)	Op9=[(D13*365)/H1]/C12	/ year
Op10		Water level meters calibration	[(Number of water level meter calibrations carried out during the assessment period x 365) / assessment period)] / number of water level meters installed in the system (permanently or temporarily)	Op10=[(D14*365)/H1/C8]*100	/ year
Op11		On-line water quality monitoring equipment calibration	[(Number of on-line water quality monitoring instrument calibrations carried out during the assessment period x 365) / assessment period)] / number of on-line water quality instrument installed in the system (permanently or temporarily)	Op11=[(D15*365)/H1]/C14	/ year
Op12	Electrical & signal transmission equipment inspection	Emergency power system inspection	[(Sum of the nominal power of the emergency power systems inspected during the assessment period x 365) / assessment period)] / total nominal power of the emergency power systems	Op12=[(D16*365)/H1]/C18	/ year
Op13		Signal transmission equipment inspection	[(Number of the signal transmission units inspected during the assessment period x 365) / assessment period)] / total number of signal transmission units	Op13=[(D17*365)/H1]/C19	/ year
Op14		Electrical switchgear equipment inspection	[(Number of electrical switchgear units inspected during the assessment period x 365) / assessment period)] / total number of electrical switchgear units	Op14=[(D18*365)/H1]/C20	/ year
Op15	Vehicle availability	Vehicle availability	Number of vehicles daily available, on a permanent basis, in average, for field works in operations and maintenance activities / (total mains length x 100)	Op15=(D19/C8)*100	No./100km
Op16	Mains, valves and service connection rehabilitation	Mains rehabilitation	[(Length of transmission and distribution mains rehabilitated during the assessment period x 365) / assessment period)] / total mains length] x 100	Op16=[(D20*365)/H1/C8]*100	% / year
Op17		Mains renovation	[(Length of transmission and distribution mains rehabilitated during the assessment period x 365) / assessment period)] / total mains length] x 100	Op17=[(D21*365)/H1/C8]*100	% / year
Op18		Mains replacement	[(Length of mains replaced during the assessment period x 365) / assessment period)] / total mains length] x 100	Op18=[(D22*365)/H1/C8]*100	% / year
Op19	Inspection & maintenance of physical assets	Replaced valves	[(Length of mains valves replaced during the assessment period x 365) / assessment period)] / total number of mains valves] x 100	Op19=[(D23*365)/H1/C21]*100	% / year
Op20		Service connection rehabilitation	[(Number of service connections replaced or renovated during the assessment period x 365) / assessment period)] / total number of service connections] x 100	Op20=[(D24*365)/H1/C24]*100	% / year
Op21	Pumps rehabilitation	Pump refurbishment	[(Total nominal power of pumps subject to overhaul during the assessment period x 365) / assessment period)] / total nominal power of pumps] x 100	Op21=[(D25*365)/H1/C6]*100	% / year
Op22		Pump replacement	[(Total nominal power of pumps replaced during the assessment period x 365) / assessment period)] / total nominal power of pumps] x 100	Op22=[(D26*365)/H1/C6]*100	% / year
Op23	Operational Water Losses	Water losses per connection	[(Water losses during the assessment period x 365) / assessment period]/number of service connections	Op23=[(A15*365)/H1]/C24	m3/ connection / year

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A/A	GROUP	PERFORMANCE INDICATORS	MEANING	FORMULA	MEASURED IN
Op24		Water losses per mains length	(Water losses during the assessment period / assessment period)/mains length	Op24=(A15/H1)/C8	m3/km/year
Op25		Apparent losses	[Apparent losses / (system input volume - exported water)] x 100	Op25=[A18/(A3-A5-A7)]*100	%
Op26		Apparent losses per system input volume	Apparent losses during the assessment period / system input volume - exported water x 100	Op26=A18/A3	%
Op27		Real losses per connection	(Real losses during the assessment period x 1000) / [(number of service connections x number of hours system is pressurised during the assessment period)/24]	Op27=(A19*1000)/[(C24*H2)/24]	lt/connection/day when system is pressurised
Op28		Real losses per mains length	(Real losses during the assessment period x 1000) / [(mains length x number of hours system is pressurised during the assessment period)/24]	Op28=(A19*1000)/[(C8*H2)/24]	lt/km/day when system is pressurised
Op29		Infrastructure Leakage Index (ILI)	Real losses (Op27) / technical achievable low-level real losses (when system is pressurised)	Op29=Op27/(18*C8+0,8+0,025*C 25)/ (D34/10)	
Op30	Failure	Pump failures	[(Sum, for all pumps, of the number of days during the assessment period when the pump is out of order x 365) / assessment period] / total number of pumps	Op30=[(D27*365)/H1]/C4	days / pump / year
Op31		Mains failures	[(Number of mains failures during the assessment period (including failures of valves and fittings) x 365) / assessment period] / total mains length] x 100	Op31=[(D28*365)/H1/C8]*100	No./km/year
Op32		Service connection failures	[(Number of service connection failures during the assessment period x 365) / assessment period] / number of service connections] x 1000	Op32=[(D29*365)/H1/C24]*1000	No./1000 connections / year
Op33		Hydrant failures	[(Number of hydrant failures during the assessment period x 365) / assessment period] / number of hydrants] x 1000	Op33=[(D30*365)/H1/C23]*1000	No./1000 hydrants/ year
Op34		Power failures	[(Sum, for all pumps, of the number of hours each pumping station is out of service due to power supply interruption during the assessment period x 365) / assessment period] / total number of pumping stations	Op34=[(D31*365)/H1]/C5	hours / pumping station / year
Op35		Water-point failures	Number of water-points failures during the reference period / total number of waterpoints	Op35=[(D32*365)/H1]/F6	No./water point/year
Op36	Water metering	Customer reading efficiency	[(Number of effective meter readings effective meter readings carried out during the assessment period x 365) / assessment period]/(number of residential customer meters x residential customer meter reading frequency + number of industrial customer meters x industrial customer meter reading frequency + number of bulk customer meters x bulk customer meter reading frequency)	Op36=[(D42*365)/H1]/(E7*D39+ E8*D40+E9*D41)	
Op37		Residential customer reading efficiency	[(Number of effective residential meter reading carried out during the assessment period x 365)/assessment period]/ (number of residential customer meters x residential customer meter reading frequency)	Op37=[(D43*365)/H1]/(E7*D39)	
Op38		Operational meters	(Number of direct customer meters installed that are not out-of-service at the reference time / number of direct meters) x 100	Op38=(D44/E6)*100	%
Op39		Unmetered water	(System input volume-metered consumption / system input volume during the assessment period) x 100	Op39=[(A3-A8-A11)/A3]*100	%
Op40	Water quality monitoring	Tests carried out	(Number of treated water carried out during the assessment period / number of reated water tests required by applicable standards or legislation during the assessment period) x 100	Op40=(D46/D57)*100	%

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A/A	GROUP	PERFORMANCE INDICATORS	MEANING	FORMULA	MEASURED IN
Op41		Aesthetic tests carried out	(Number of aesthetic tests of treated water carried out during the assessment period / number of aesthetic tests of treated water required by applicable standards or legislation during the assessment period) x 100	Op41=(D47/D58)*100	%
Op42		Microbiological tests carried out	(Number of microbiological tests of treated water carried out during the assessment period / number of microbiological tests of treated water required by applicable standards or legislation during the assessment period) x 100	Op42=(D48/D59)*100	%
Op43		Physical-chemical tests carried out	(Number of physical-chemical tests of treated water carried out during the assessment period / number of physical-chemical tests of treated water required by applicable standards or legislation during the assessment period) x 100	Op43=(D49/D60)*100	%
Op44		Radioactivity tests carried out	(Number of radioactivity tests of treated water carried out during the assessment period / number of radioactivity tests of treated water required by applicable standards or legislation during the assessment period) x 100	Op44=(D50/D61)*100	%
QS1	Service coverage	Households and businesses supply coverage	(Number of households and businesses connected to the public network / total number of households and businesses) x 100	QS1=(E1/E3)*100	%
QS2		Buildings supply coverage	(Number of buildings connected to the public network / total number of buildings and businesses) x 100	QS2=(E2/E4)*100	%
QS3		Population coverage	(Resident population served by the water undertaking / total resident population) x 100	QS3=(F1/E5)*100	%
QS4		Population coverage with service connections	(Resident population served by the water undertaking through service connections / total resident population) x 100	QS4=(F2/E5)*100	%
QS5		Population coverage with public taps or standpipes	(Resident population served by the water undertaking through public taps or standpipes / total resident population) x 100	QS5=(F3/E5)*100	%
QS6	Public taps and standpipes	Operational water points	(Number of water points that are not out-of-service / number of water points) x 100	QS6=(F7/F6)*100	%
QS7		Average distance from waterpoints to households	Sum, for all water points, of the distance between the water point and the far-most household served by it / total number of water points	QS7=F4/F6	m
QS8		Per capits water consumed in public taps and standpipes	(Sum, for all water points, of the water consumption at the water point during the assessment period x 1000 / resident population served by the water undertaking through public taps or standpipes) / assessment period	QS8=(F5*1000/F3)/H1	lt/person/day
QS9		Population per public tap or standpipe	Resident population served by the water undertaking through public taps or standpipes / number of public taps or standpipes	QS9=F3/F8	persons/tap
QS10	Pressure and continuity of supply	Pressure of supply adequacy	(Number of delivery points that receive and are likely to receive pressure equal to or above the guaranteed or declared target level at the peak demand hour (but not when demand is abnormal) / number of service connections) x 100	QS10=(D33/C24)*100	%
QS11		Bulk supply adequacy	(Number of delivery points that are supplied at any time according to the target flow, volume and/ or pressure/number of delivery points) x 100	QS11=(D33/E9)*100	%
QS12		Continuity of supply	[(Number of hours when the system is pressured during the assessment period/24)/assessment period)] x 100	QS12=[(H2/24)/H1]*100	%
QS13		Water interruptions	[Sum, for the assessment period, of the population subject to a water multiplied by the respective duration of the interruption in hours / (population served x 24 x assessment period)] x 100	QS13=[D35/(F1*24*H1)]*100	%

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A/A	GROUP	PERFORMANCE INDICATORS	MEANING	FORMULA	MEASURED IN
QS14		Interruptions per connection	{[(Total number of interruptions during the assessment period x 365)/assessment period]/number of service connections} x 1000	QS14={[(D36*365)/H1]/C24}*1000	No./1000 connections/year
QS15		Bulk supply interruptions	[(Total number of interruptions during the assessment period x 365)/assessment period]/number of delivery points	QS15=[(D36*365)/H1)/E9	No./delivery point/year
QS16		Population experiencing restrictions to water service	[Sum, for the assessment period, of the population affected by restrictions to water service multiplied by the respective duration of the restrictions to water service in hours / (population served x 24 x assessment period)] x 100	QS16=[D37/(F1*24*H1)]*100	%
QS17		Days with restrictions to water service	(Total number of days with restrictions to water service during the assessment period/assessment period) x 100	QS17=(D38/H1)*100	%
QS18	Quality of supplied water	Quality of supplied water	[(Total number of treated water tests complying with the applicable standards or legislation during the assessment period/total number of tests of treated water carried out during the assessment period] x 100	QS18=[(D62+D63+D64+D65)/D51]*100	%
QS19		Aesthetic tests compliance	(Number of aesthetic tests of treated water complying with the applicable standards or legislation during the assessment period/total number of aesthetic tests of treated water carried out during the assessment period) x 100	QS19=(D62/D53)*100	%
QS20		Microbiological tests compliance	(Number of microbiological tests of treated water complying with the applicable standards or legislation during the assessment period/total number of microbiological tests of treated water carried out during the assessment period) x 100	QS20=(D63/D54)*100	%
QS21		Physical-chemical tests compliance	(Number of physical-chemical tests of treated water complying with the applicable standards or legislation during the assessment period/total number of physical-chemical tests of treated water carried out during the assessment period) x 100	QS21=(D64/D55)*100	%
QS22		Radioactivity tests compliance	(Number of radioactivity tests of treated water complying with the applicable standards or legislation during the assessment period/total number of radioactivity tests of treated water carried out during the assessment period) x 100	QS22=(D65/D56)*100	%
QS23	Service connection and meter installation and repair	New connection efficiency	Total time spent for establishing new connections during the assessment period / number of new connections installed during the assessment period	QS23=F9/F10	days
QS24		Time to install a customer meter	Total time spent for customer meters during the assessment period / number of customer meters installed during the assessment period	QS24=F11/F12	days
QS25		Connection repair time	Total time spent for repairing service connections during the assessment period / total number of connections repaired during the assessment period	QS25=F13/F14	days
QS26	Customer complaints	Service complaints per connection	[(Number of complaints of quality of service during the assessment period x 365)/assessment period/number of service connections] x 1000	QS26=[(F15*365)/H1/C24]*1000	No.complaints/1000 connections/year
QS27		Service complaints per customer	[(Number of complaints of quality of service during the assessment period x 365) /assessment period] /number of bulk supply customers	QS27=[(F15*365)/H1]/E10	No.complaints/customer/year
QS28		Pressure complaints	(Number of pressure complaints during the assessment period / number of service complaints during the assessment period) x 100	QS28=(F16/F15)*100	%
QS29		Continuity complaints	(Number of continuity complaints during the assessment period / number of service complaints during the assessment period) x 100	QS29=(F17/F15)*100	%

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A/A	GROUP	PERFORMANCE INDICATORS	MEANING	FORMULA	MEASURED IN
QS30		Water quality complaints	(Number of water quality complaints during the assessment period / number of service complaints during the assessment period) x 100	QS30=(F18/F15)*100	%
QS31		Interruption complaints	(Number of complaints due to supply interruptions during the assessment period / number of service complaints during the assessment period) x 100	QS31=(F19/F15)*100	%
QS32		Billing complaints and queries	[(Number of billing complaints and queries during the assessment period x 365)/ assessment period] / number of registered customers	QS32=[(F20*365)/H1]/E10	No./customer/year
QS33		Other complaints and queries	[(Number of other complaints and queries during the assessment period x 365)/ assessment period] / number of registered customers	QS33=[(F21*365)/H1]/E10	No./customer/year
QS34		Response to written complaints	(Number of written responses within the target time during the assessment period /number of written complaints during the assessment period) x 100	QS34=(F22/F23)*100	%
Fi1	Revenues	Unit revenue	(Operating revenues - capitalised costs of self-constructed assets) / authorised consumption (including exported water), during the assessment period	Fi1=(G2-G35)/A14	EUR/m3
Fi2		Sales revenues	(Self revenues / total revenues) x 100, during the assessment period	Fi2=(G3/G1)*100	%
Fi3		Other revenues	(Other revenues nto coming from sales / total revenues) x 100, during the assessment period	Fi3=[(G1-G3)/G1]*100	%
Fi4	Costs	Unit total costs	(Running costs + capital costs) / autorised consumption (including exported water), during the assessment period	Fi4=G4/A14	EUR/m3
Fi5		Unit running costs	Running costs / authorised consumption (including exported water), during the assessment period	Fi5=G5/A14	EUR/m3
Fi6		Unit capital costs	Capital costs / authorised consumption (including exported water), during the assessment period	Fi6=G6/A14	EUR/m3
Fi7	Composition of running costs per type of costs	Internal manpower costs	(Internal manpower costs / running costs) x 100, during the assessment period	Fi7=(G8/G5)*100	%
Fi8		External services costs	(External services costs / running costs) x 100, during the assessment period	Fi8=(G9/G5)*100	%
Fi9		Imported (raw and treated) water costs	(Imported (raw and treated) water costs / running costs, during the assessment period) x 100	Fi9=(G10/G5)*100	%
Fi10		Electrical energy costs	(Electrical energy costs / running costs) x 100, during the assessment period	Fi10=(G11/G5)*100	%
Fi11		Other costs	[(Purchased merchandises + leasing and rentals + taxes, levies & fees + exceptional earning & losses + other operating costs) / running costs] x 100	Fi11=[(G12+G13+G14+G15+G16)/ G5]*100	%
Fi12	Composition of running costs per main function of the water undertaking	General management functions costs	(Running costs of general management functions / running costs) x 100, during the assessment period	Fi12=(G17/G5)*100	%
Fi13		Human resources management functions costs	(Running costs of resources management functions / running costs) x 100, during the assessment period	Fi13=(G18/G5)*100	%
Fi14		Financial and commercial functions costs	(Running costs of financial and commercial functions / running costs) x 100, during the assessment period	Fi14=(G19/G5)*100	%
Fi15		Customer service functions costs	(Running costs of customer service functions / running costs) x 100, during the assessment period	Fi15=(G20/G5)*100	%
Fi16		Technical services functions costs	(Running costs of customer service functions / running costs) x 100, during the assessment period	Fi16=(G21/G5)*100	%

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A/A	GROUP	PERFORMANCE INDICATORS	MEANING	FORMULA	MEASURED IN
Fi17	Composition of running costs per technical function activity	Water resources and catchment management costs	(Running costs of the water resources and catchment management / running costs) x 100, during the assessment period	Fi17=(G22/G5)*100	%
Fi18		Abstraction and treatment costs	(Running costs of the abstraction and treatment / running costs) x 100, during the assessment period	Fi18=(G23/G5)*100	%
Fi19		Transmission, storage and distribution costs	(Running costs of the transmission, storage and distribution / running costs) x 100, during the assessment period	Fi19=(G24/G5)*100	%
Fi20		Water quality monitoring costs	(Running costs of the water quality sampling and testing / running costs) x 100, during the assessment period	Fi20=(G25/G5)*100	%
Fi21		Meter management costs	(Running costs of the meter management / running costs) x 100, during the assessment period	Fi21=(G26/G5)*100	%
Fi22		Support services costs	(Running costs of the support services / running costs) x 100, during the assessment period	Fi22=(G27/G5)*100	%
Fi23	Composition of capital costs	Depreciation costs	(Depreciation costs / capital costs) x 100, during the assessment period	Fi23=(G28/G6)*100	%
Fi24		Net interest costs	(Interest expenses costs - interest income / capital costs) x 100, during the assessment period	Fi24=[(G29-G30)/G6]*100	%
Fi25	Investment	Unit investment	Cost of investments (expenditures for plant and equipment) / authorised consumption (including exported water), during the assessment period	Fi25=G32/A14	EUR/m3
Fi26		Investments for new assets and reinforcement of existing assets	(Cost of investments for new assets and reinforcement of existing assets / total cost of the investment) x 100, during the assessment period	Fi26=(G33/G32)*100	%
Fi27		Investments for asset replacement and renovation	(Cost of investments for the replacement and renovation ("like to like") of existing assets / total cost of the investment) x 100, during the assessment period	Fi27=(G34/G32)*100	%
Fi28	Average water charges	Average water charges for direct consumption	Water sales revenue from residential, industrial and other customers (exported water excluded, public water taxes excluded) / (total authorised - exported water), during the assessment period	Fi28=G36/(A14-A7)	EUR/m3
Fi29		Average water charges for exported water	Water sales revenue from exported water (excluding public water taxes)/ exported water, during the assessment period	Fi29=G37/(A5+A7)	EUR/m3
Fi30	Efficiency	Total cost coverage ratio	Total revenues / total costs, during the assessment period	Fi30=G1/G4	
Fi31		Operating cost coverage ratio	Total revenues / running costs, during the assessment period	Fi31=G1/G5	
Fi32		Delay in accounts receivable	(Accounts receivable from drinking water at the reference date / sales revenues during the assessment period) x assessment period	Fi32=(G38/G3)*H1	days equivalent
Fi33		Investment ratio	Investments subject to depreciation/ depreciation costs, during the assessment period	Fi33=G39/G28	
Fi34		Contribution of internal sources to investment	Investments financed by the cash flow / total investment, during the assessment period	Fi34=(G40/G32)*100	%
Fi35		Average age of tangible assets	(Depreciated historical value of tangible assets / historical value of tangible assets) x 100, during the year	Fi35=(G41/G42)*100	%
Fi36		Average depreciation ratio	(Depreciated costs/ historical value of tangible assets) x 100, during the year	Fi36=G28/G42	

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A/A	GROUP	PERFORMANCE INDICATORS	MEANING	FORMULA	MEASURED IN
Fi37		Late payments ratio	[1 - (annual debt from customers / amount billed during the year)], during the year	Fi37=1-(G43/G44)	
Fi38		Inventory value	Value of overall inventory at the end of the fiscal year / operating revenues during the year	Fi38=G51/G2	
Fi39	Leverage	Debt service coverage ratio	(Cash - flow / financial debt services) x 100, during the assessment period	Fi39=(G45/G46)*100	%
Fi40		Debt equity ratio	Total debt / shareholders' equity, at the end of the fiscal year	Fi40=G47/G48	
Fi41	Liquidity	Current ratio	Current assets / current liabilities, at the reference date	Fi41=G49/G53	
Fi42	Profitability	Return on net fixed assets	[Operating income / (historical value of tangible assets - depreciated historical value of tangible assets)] x 100, during the year	NetFi42=[G54/(G42-G41)]*100	%
Fi43		Return on equity	(Net income (net income after interest payment and taxes) / shareholders' equity) x 100, during the year	Fi43=(G56/G48)*100	%
Fi44		Return on capital employed	[(Operating income (EBIT) - related taxes) / total assets] x 100, during the year	Fi44=[(G54-G55)/G50]*100	%
Fi45		Asset turnover ratio	Sales revenues / total assets, during the year	Fi45=G3/G50	
Fi46	Economic water losses	Non-revenue water by volume	(Non-revenue water / system input volume, during the assessment period) x 100	Fi46=(A21/A3)*100	%
Fi47		Non-revenue water by cost	(Valuation of non-revenue water components / running costs, during the assessment period) x 100	Fi47={[(A13+A18)*G57+(A19*G58)]/G5}*100	%

Table 8. New proposed PIs (Kanakoudis et al.,2013)

NEW SUGGESTED PIS			FORMULA	UNITS
Ph16	Inhabitants per water meter	Number of inhabitants / number of water meters	E5/E6	Inh/wm
Ph17	Energy per volume	Energy used (KWh) / System Input Volume (m3)	D68 / A3	KWh/m^3
Ph18	Under 5 years old Domestic water meters rate	(domestic water meters aged less than 5 years old/ total water meters) *100	(C28/E6)*100	%
Ph19	5 to 10 years old Domestic water meters rate	(domestic water meters aged between 5 -10 years old/ total water meters) *100	(C29/E6)*100	%
Op45	Real Losses per pipe material	Real Losses / pipes length of the same material	A19 / C32(a-i)	m^3/km
Op46	Real Losses per pipe diameter	Real Losses / pipes length of the same diameter	A19 / C33(a-i)	m^3/km
Op47	Real Losses per pipe material & diameter	Real Losses / pipes length of same diameter & material	A19 / C34(a-i)	m^3/km
Op48	Real Losses per pipe age	Real Losses / pipe length with the same age	A19/C35(a-i)	m^3/km
Op49	Real Losses per roughness coefficient	Real Losses / roughness coefficient	A19/C36(a-i)	

NEW SUGGESTED PIS			FORMULA	UNITS
Op50	Real Losses - pressure	Real Losses / average operating pressure	A19/D34	m^3/m
Op51	Apparent Losses per roof tank	Apparent Losses / number of roof tanks	A18 / C26	m^3
Op52	Apparent Losses per roof tank volume	(Apparent Losses / roof tanks volume) *100	(A18/C30)*100	%
Op53	Apparent Losses per water meter	(Apparent Losses) / (number of water meters)	A18/E6	m^3/water meter
Op54	ALI	Apparent Losses / 5% of Water Sales	A18/(0,05*G3)	
Op55	Water Losses per water resources	(Water Losses/Water taken from the resources) *100	{A15/(ΣC27(a-i))}*100	%
Op56	Water Losses % water use (domestic, industrial, commercial)	(Water Losses / water use)*100	(A15/E14(a-i))*100	%
Op57	Water Losses per buildings height	Water Losses / average buildings height	A15 / C27	m^3/m
Op58	NRW per connection	(NRW*1000) / (number of service connections * assessment period)	(A21*1000)/C24/H1	lt/connection/day
Op59	NRW per mains length	NRW / mains length	A21/C8	m3/km mains/year
Op60	Mains failures per type of main	[(Number of failures of the same material of mains during the assessment period x 365) / assessment period] / mains length of the same material] x 100	[(D79(a-i)*365)/H1/C32(a-i)]	No./km/year
Op61	Leakage energy or Energy loss due to leakage (sum of the leaks-related energy loss and additional energy required to overcome leakage)	the sum of energy loss through leaked water and the additional energy required to overcome friction with the increased flow rate needed to overcome leakage (difference between the actual energy dissipated in friction losses and the value of friction losses in a leak-free network)	(D77+D73-D74)/D78	
Op62	Standards compliance	(energy delivered to users / minimum required useful energy) *100	(D75/D76)*100	%
Op63	Carbon Footprint per SIV	Carbon Footprint produced during WS process / SIV	D72 / A3	tns CO2/m3
Op64	Meter replacement	(flow meters replaced/ total number of flow meters) *100	(D69/C10)*100	%
Op65	Assessment of failures according to type of material and fittings in mains and service connections	failure rates (for each type of failure) in No of failures/total No of devices	D80(a-i) / Q26	
Op66	Elasticity of Losses related to operating pressure	Elasticity of real losses related to pressure differences	(ΔA19/A19)/(ΔD34/D34)	m3/m
Op67	Elasticity of failures occurrence rate related to the operating pressure	Elasticity of mains and service connections failures related to pressure differences	[Δ(D28+D29)/(D28+D29)]/ (ΔD34/D34)	failures/m
Op68	Number of days to respond to repair leakage events	Total No of days to respond to repair leakage events/total number of repairs occurred	D70 / D71	days/repairs
QS35	Residential Consumption size	(Residential Consumption / of total consumption) *100	(E12/A14)*100	%
QS36	Commercial Consumption size	(Commercial Consumption / of total consumption) *100	(E13/A14)*100	%
QS37	Low pressure-related complaints rate	(No of water low pressure-related complaints/total No of complaints) *100	(F27/F15)*100	%

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NEW SUGGESTED PIS			FORMULA	UNITS
QS38	Low pressure-related complaints per service	No of water pressure-related complaints/No of water meters	F16/E6	
QS39	Grade of consumer's satisfaction	(satisfied customers/total population served) *100	(F24/F1)*100	%
QS40	Tap water Grade of satisfaction	(satisfied customers drinking tap water/total population served) *100	(F25/F1)*100	%
QS41	Water taste Grade of satisfaction	(customers affected by the taste and chlorination of potable water/total population served) *100	(F26/F1)*100	%
QS42	Grade of employees' valuation of customer's satisfaction	Grade of employees' valuation of customer's satisfaction	(F28/B1)*100	%
Fi48	MCD per Real Losses	(MCD / Real Losses)*100	(A25/A19)*100	%
Fi49	MCD per connection	MCD / number of connections / assessment period (days)	A25/C24/H1	m^3 /connection/day
Fi50	Accounted for NRW per NRW	(Accounted for NRW / NRW)*100	(A26/A21)*100	%
Fi51	Energy costs per volume	Energy cost (€) / System Input Volume (m3)	G11 / A3	€/m^3
Fi52	willingness to pay index (consumer's sensitivity to issues of water shortage and drought)	cost to safeguard water supply/authorised consumption during the assessment period	G59/A14	EUR/m3

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Table 9: The 38 new variables needed to calculate the 41 new suggested PIs (Kanakoudis et al., 2013)

NEW VARIABLES		UNITS
A25	Minimum Charge Difference	m^3
A26	Accounted for NRW	m^3
A27(a-i)	Water volume abstract from the same water resource	m^3
C26	Roof tanks number	no.
C27	Average building height	m
C28	Domestic water meters aged less than 5 years	no.
C29	Domestic water meters aged between 5 -10 years old	no.
C30	Roof Tanks Volume	m^3
C31	total number of devices	no.
C32(a-i)	Pipes length of the same material	Km
C33(a-i)	Pipes length of the same diameter	Km
C34(a-i)	Pipes length of the same material and diameter	Km
C35(a-i)	Pipes length with the same age	Km
C36(a-i)	Roughness coefficient	
D66	Minimum operating network pressure	m
D67	Maximum operating network pressure	m
D68	Energy used	KWh
D69	Flow meters replaced	no.
D70	Time to respond to repair leakage events	hours
D71	total number of repairs occurred	no.
D72	Carbon Footprint produced during the WS process	tons of CO_2
D73	Actual energy dissipated in friction losses	KWh
D74	Value of friction losses in a leak-free network	KWh
D75	Energy delivered to users	KWh
D76	Minimum required useful energy	KWh
D77	Outgoing energy through leaks	KWh
D78	Input energy supplied by the reservoir	KWh
D79(a-i)	Number of failures of mains of the same material	no.
D80(a-i)	Number of same type of failure in mains and fittings	no.
E12	Residential consumption	m^3
E13	Commercial consumption	m^3
E14(a-i)	Water use (residential, commercial, industrial)	m^3
F24	Number of satisfied customers	no.
F25	Number of satisfied customers drinking tap water	no.
F26	Number of customers affected by the taste and chlorination of potable water	no.
F27	Number of water low pressure - related complaints	no.
F28	Number of employees considering that customers are satisfied	no.
G59	Cost to safeguard water supply	€

Chapter 4. Water Audit Tools

To assess water distribution networks' performance, the methodology of the Water Balance and the PIs are used. Many software programmes – water audit tools have been developed to assist the users. The first water audit software was a basic Microsoft Word file in which the user simply followed a given template in a standard manner to derive the Unavoidable Annual Real Losses (UARL) and calculate the Infrastructure Leakage Index (ILI). BENCHLEAK (a standardized software package) followed in 2000. The models available today range from excel spreadsheets to complete Windows based packages. Most of them tend to be quick and efficient to use.

A brief presentation of the water audit tools is given in this chapter.

4.1 Presentation of the water audit tools

4.1.1 BENCHLEAK & BENCHLOSS

The BENCHLEAK model, developed by the Water Research Commission, aimed to facilitate the evaluation of leakage levels and, in particular, of the Non-Revenue Water (NRW) in water delivery systems (McKenzie & Lambert, 2002). It can be used to estimate the WB and the PIs based on the IWA methodology (Tsitsifli & Kanakoudis, 2010). Its inputs are: mains length; number of service connections; operating pressure; population; system input volume; components of authorized consumption; and valuation of real and apparent losses. Its outputs are: UARL; Apparent Losses; CARL; and ILI. The model is simple, user-friendly, based on an excel spreadsheet and is free. Firstly, it was used in South Africa to compare local water utilities performance level to international ones (McKenzie et al., 2002). BENCHLOSS is an Australian model that followed with minor differences BENCHLEAK.

4.1.2 AQUALITE

Aqualite (2007 version) (McKenzie, 2007) was developed to replace BENCHLEAK and is free. It can be used to evaluate the IWA WB and assess the Real Losses and NRW levels of a system. Confidence limits are provided to assess the ranges of the variables. It calculates the UARL and the ILI levels. It is designed to assess the real losses level based on the traditional IWA top down water balance. Aqualite incorporates the following features (McKenzie, 2007): a) 7 different units of measure in different countries; b) defined confidence limits on all key variables; c) facility to differentiate between mains which have different pressure profiles; d) ability to specify system pressures in a tabular format in order to derive the average system pressure for the distribution mains; e) ability to differentiate between connections and customers in certain calculations; f) detailed reporting forms which can be user-defined to provide either a summary report or a full detailed report; g) it does not require any other software to run the model; and h) it can be customized quickly and easily to user's requirements including language and general labeling.

4.1.3 AQUALIBRE

The AQUALIBRE was developed by BWS (Bristol WaterS) to help water utilities form their system's WB according to the IWA methodology (Liemberger & McKenzie, 2003). It differentiates from the other tools, as it uses the "top-down" approach to estimate Real and Apparent Losses and a Burst and Background Estimate (BABE) "bottom up" approach for a second estimate of Real Losses. Its features are: a) it can be used in the Water Utility level; b) it assesses the WB for the whole water distribution network and also at zone level; c)Real Losses are assessed in a dual way: from the WB (top down approach) and from the BABE approach (bottom up); d) the user can select the units for input and output data; e) confidence limits can be used for the accuracy of the results; f) it is a Windows based application needing no other software to run the model; and g) it is not a free software.

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4.1.4 LEAKS Suite of Softwares

LEAKS (Leakage Evaluation and Assessment Know-How Software) is a comprehensive suite of customizable software that allow the user to quantify leakage and leakage management options in a pressurized water distribution system. It was created by A. Lambert (www.leakssuite.com). LEAKS includes 5 standard software tools, namely CheckCalcs, PIFastCalcs, PressCalcs, ALCCalcs and ELLCalcs.

The introductory software CheckCalcs is used to calculate the "best practice" PIs, identify the appropriate actions and asses the benefits from managing adverse effects of excess pressure. CheckCalcs' outputs are: IWA WB; benchmark with bands from A to D; categorise opportunity for pressure management. It is a free software.

PIFastCalcs' outputs are: IWA WB; PIs; use of confidence limits; RL; UARL; UBL; ILI; ILI band categorization. It is not free.

PressCalcs' outputs are: key pressure measurement points; presence of surges and/or excess pressures at critical point; Night-Day factor, relating leakage at night to 24-hour average leakage. It is not a free software.

ALCCalcs' outputs are: Economic frequency of ALC intervention; economic % of system surveyed each year; annual budget for economic ALC; economic level of unreported real losses; provides guidance, analysis and interpretation of night flow measurements. It is not a free software.

ELLCalcs' outputs are: Short Run ELL (SRELL) at current pressure; SRELL at any alternative new pressure; how pressure management influences frequency and flow rates of reported leaks, rate of rise of unreported leakage, economic intervention frequency of ALC and reduction in background leakage. It is not free.

PreMoCalcs analyses data from 24-hour test measurement in a zone of pressures and inflows at the inflow point and pressures at Average Zone Point and Critical point and it is not free.

All the above softwares are based on Excel workbook.

Except of the standard software tools there is professional software packages that can be customized to the needs of specific utilities. The LEAKS suite software is upgraded whenever any significant improvements in international "best practice" are identified (Tsitsifli & Kanakoudis, 2010).

4.1.5 "WB-EasyCalc"

WB-EasyCalc is a spreadsheet-based free software, developed by Liemberger and partners, supported by the World Bank Institute (WBI) (www.liemberger.cc). The model is used to estimate the WB of a network and some of its basic PIs (Tsitsifli & Kanakoudis, 2010). Its advantage is that it does not only ask for physical data, but also information on how accurate this data is. It can calculate the NRW volume and its various components, in addition to the accuracy of these volumes. For example, it may determine that NRW is 21% with 66% accuracy, meaning that the actual NRW level ranges from 7% to 35% (Farley et al., 2008).

Its inputs include: annual system input volume; billed metered consumption; billed unmetered consumption; bulk water supply (export); unbilled metered consumption; unbilled unmetered consumption; no. of illegal connections; meter tampering, bypasses etc. at registered users; persons per house; daily Water Consumption; meter under registration; estimated % of under reading; length of distribution and transmission mains; no. of service connections; average length of service connection pipe; daily average pressure per area; supply time per area for intermittent supply; average tariff; variable production and distribution cost; and annual operating cost. The software's outputs are: WB estimation; value of Unbilled Metered Consumption; value of Unbilled Unmetered Consumption; value of Apparent Losses; value of Real Losses; NRW value; average supply time; average pressure; CARL; UARL; ILI; real losses (lt/conn/day); real losses (lt/conn/day/m press); real losses (m^3/km mains/hr); apparent losses as % of authorised consumption; NRW as % SIV; NRW value as % of annual operating cost; performance group categorisation according to World Bank System.

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4.1.6 “Sigma Lite 2.0”

Sigma Lite is a benchmarking and PI software for drinking and wastewater utilities, developed by ITA (Instituto Technologico del Agua-Valencia Polytechnic University) (www.ita.upv.es). It is a freeware package, based on a proposed by IWA set of PIs. It guides the user through the process of selecting and implementing a system of indicators for the utility. Sigma Lite was officially released in July 2000, as part of the IWAP Manual of Best Practice and PIs for Water Supply Services (Alegre et al., 2006). It offers the user additional predefined sets to select from and allows creating new indicators from scratch. It is the most integrated software for the calculation of all 170 IWA PIs. Its outputs are the IWA PIs while its inputs depend on the PIs pre-selected. It features (Alegre, 2002): a) a stand-alone PI evaluation system, independent of the database systems; b) the complete set of the IWA PIs; c) a user-friendly graphic interface, with intuitive management of the indicators and variables involved; d) easy operation (the PIs calculation is intuitive and fast. Chances of calculating errors are greatly reduced); and e) compatibility with MS-Excel for further interpretation and processing of the results.

4.1.7 American Water Works Association Water Audit tool (AWWA WLCC)

AWWA developed a free software tool (AWWA WLCC) for the estimation of the WB and the PIs based on the AWWA approved standard water audit methodology (Sturm & Thornton, 2007). It is actually an Excel workbook with data entries (inputs) and calculated outputs (Tsitsifli & Kanakoudis, 2010). For each input data value there is a grading system from 1 to 10 to specify its confidence. Finally, a water audit data validity level/score is provided to guide the user to set a target ILI and interpret the results of the audit.

The software’s inputs are: water volume from own sources; water imported; water exported; billed metered consumption; billed unmetered consumption; unbilled metered consumption; unbilled unmetered consumption; systematic data handling errors; mains’ length; no. of service connections; average length of customer service line; average operating pressure; total annual operational costs; customer retail unit cost; variable production cost. Its outputs include: the Water Balance and grading of the audit score.

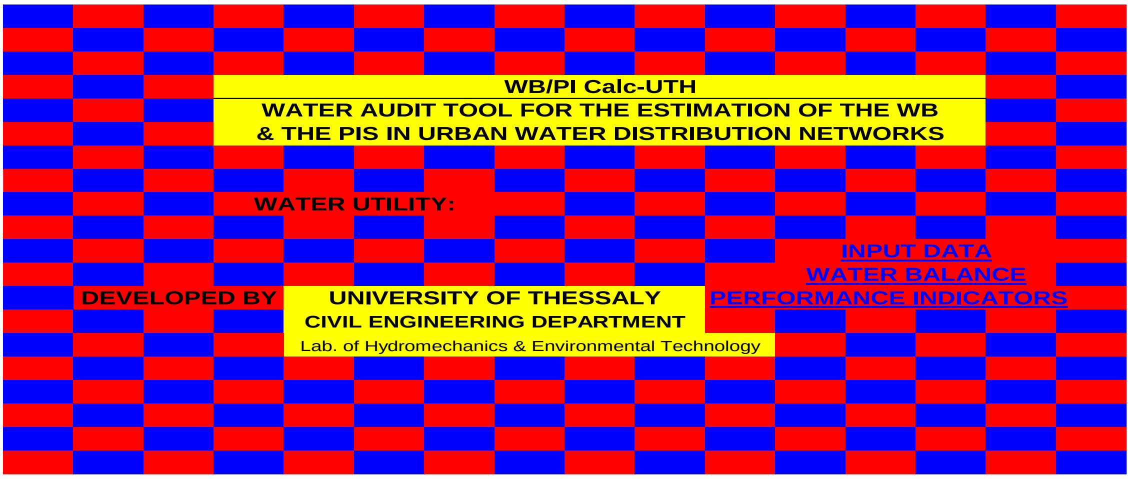

Figure 14: WB/PI Calc-UTH interface

4.1.8 WB/PI Calc-UTH

Tsitsifli & Kanakoudis (2010) developed a user-friendly tool (WB/PI Calc-UTH) to estimate the WB and the PIs according to the IWA methodology (Figure 14). They took into account their proposal for a modified WB to be used in the Mediterranean. Therefore, the Minimum Charge Difference should be considered in the WB and in the related PIs. No other existing software tool considers this modification and can be used in Greece. The inclusion of the Minimum Charge Difference in the WB is important because it shows the amount of water being lost (as part of Real Losses) and providing revenues to the utility. Otherwise the indicators related to the

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NRW and other PIs would be wrong. Therefore, the utility would have a wrong perception of the performance level of its network. WB/PI Calc-UTH is an Excel workbook where several variables need to be entered as data, while its outputs are the WB and some of the most crucial PIs (Table 10) (Tsitsifli & Kanakoudis, 2010). It calculates all 170 IWA PIs and it is flexible to calculate any new PI.

Table 10: WB/PI Calc-UTH inputs and outputs

WB/PI Calc-UTH Inputs	WB/PI Calc-UTH Outputs
System Input Volume	Water Losses per connection
Billed Metered Consumption	Water Losses per mains length per day
Billed Unmetered Consumption	Real Losses per connection
Bulk Water Supply (Export)	Real Losses per mains length
Unbilled Metered Consumption	Apparent Losses per connection
Unbilled Unmetered Consumption	Apparent Losses (lt/connection/day)
Unbilled Authorised Consumption	Apparent Losses as % of Authorised Consumption
No. of illegal connections / theft	Non-Revenue Water by Volume
Meter errors / Under registration	Non-Revenue Water (lt/connection/day)
Minimum Charge Difference	Non-Revenue Water (m3/mains km/year)
No. of service connections	UARL
Days of water supply	ILI
Service pipe length	
Operating pressure	
Mains length	
Water price (tariff's level and structure)	

4.2 Water audit software tools benchmarking

The water audit software tools presented above use different input data and provide different outputs. Every software tool has been developed to satisfy different needs. All of them are based on the IWA methodology for the WB and the PIs estimation. Table 11 (Tsitsifli & Kanakoudis, 2010) presents the comparison analysis of these water audit software tools.

Table 11: Water audit software tools benchmarking

Water audit tool / Features		BENCHLEAK	AQUALITE	AQUALIBRE	LEAKS Suite	WB-EasyCalc	SigmaLite2	AWWA Water Audit	WB/PI Calc-UTH
Based on		Excel	-	-	Excel	Excel	-	Excel	Excel
Free		√	√		Only CheckCalcs	√	√	√	√
Confidence limits			√	√	PIFastCalcs (not free)	√	√	Own grading system	Available soon
Different units			√	√					
Outputs	WB	√	√	√	√	√	√	√	√
	PIs	some	some	some	some	some	170 IWA	some	170 IWA
	ILI	√	√	√	√	√	√	√	√
	Modified WB								√
	New PIs								√

Chapter 5. How to reduce Non-Revenue Water (NRW)

NRW consists of the following three major components:

(1) Unbilled metered and un-metered consumption;

(2) Apparent losses: water theft; meter inaccuracies; metering inaccuracies;

(3) Real losses: leakage in mains; leakage in service connections; tank overflows; breaks

To confront NRW, each NRW component and sub-component has to be confronted.

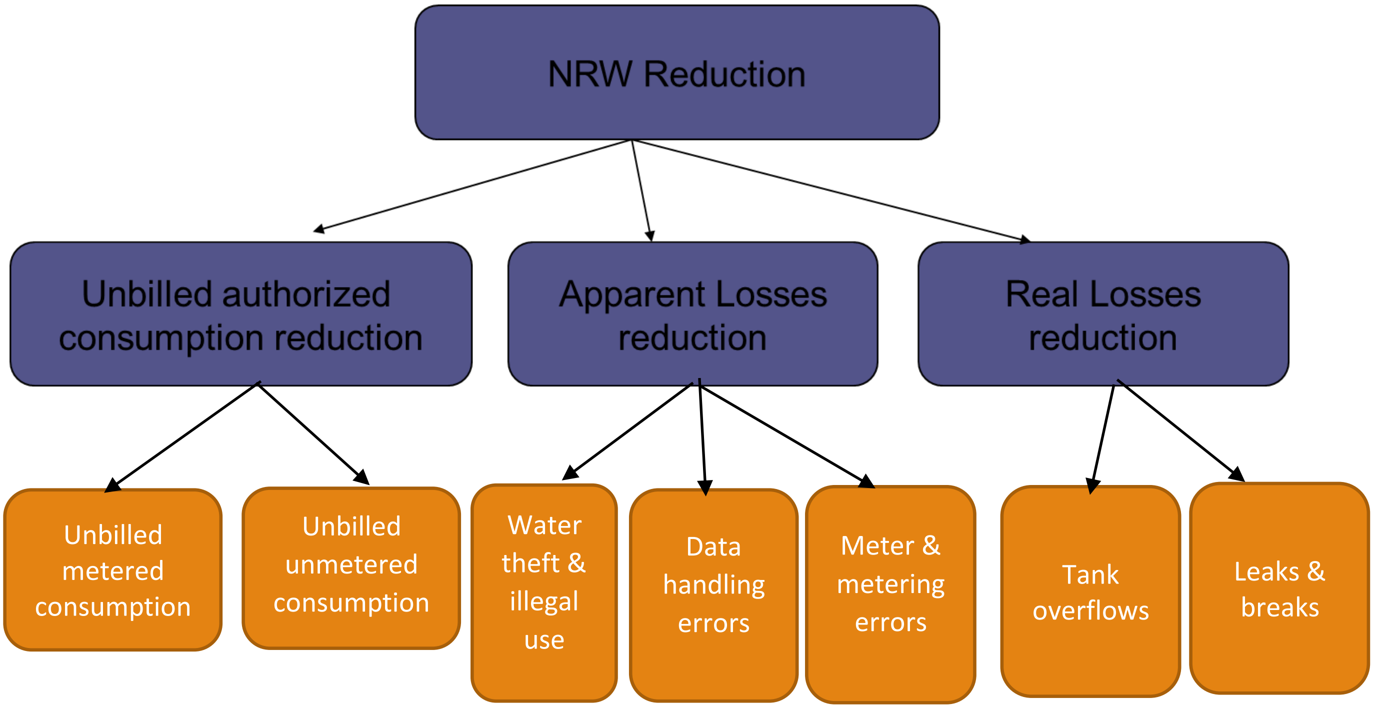

Figure 15. Confronting NRW components

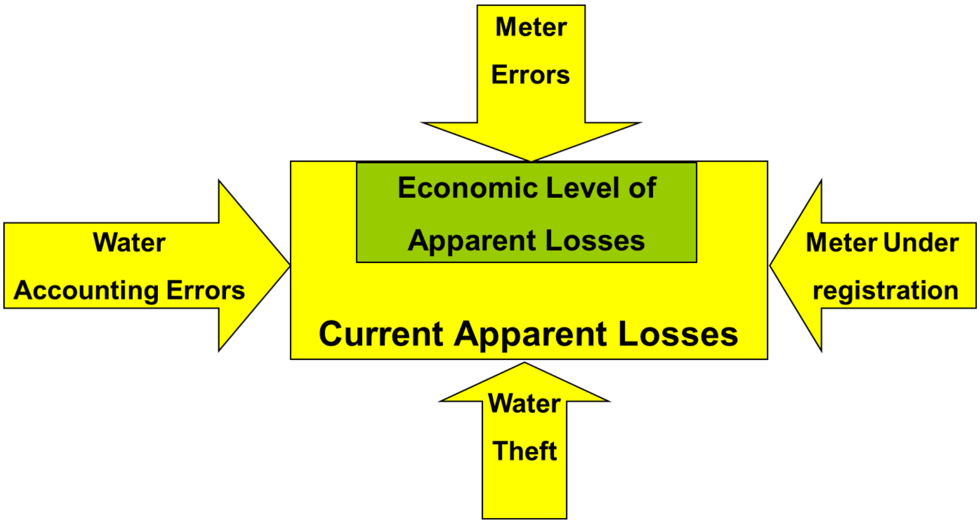

Figure 16. Apparent losses reduction pillars

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5.1 How to reduce unbilled authorized (metered & un-metered) consumption

Unbilled consumption (either metered or un-metered) consists of authorized consumption not billed due to the policy of the water utility. Such consumption includes firefighting and training, flushing of mains and sewers, cleaning of suppliers' storage tanks, filling of water tankers, water taken from hydrants, street cleaning, watering of municipal gardens, public fountains, frost protection, building water, etc. These water volumes can be either metered or unmetered. Unbilled authorized consumption normally should not exceed 1% of the SIV (Kanakoudis & Muhammetoglu, 2015).

5.2 How to reduce apparent losses

Apparent losses consist of four major components (Figure 16):

- water theft: Water theft describes water losses due to the illegal consumption of water. Such consumption includes misuse of fire hydrants and fire service connections and illegal connections.
- water accounting errors: Water accounting errors and meter reading errors refer to errors in the billing and in the meter reading procedure respectively.
- meter reading errors: Customer metering errors include random errors during the accounting procedure (differences between dates of source meter readings and customer meter readings, misread meters, incorrect estimates from stopped meters, adjustments to original meter readings, improper calculations, computer programming errors).
- meter under-registration: meter under-registration is a phenomenon where water is flowing through a meter but the meter either fails to register it or else not register the whole amount that passed through it. Systematic under-registration of customer meters depends on factors such as the type and class of meter, the method of installation, the water quality, the continuity of supply, the average working life of meters and the presence (or absence) of storage tanks on customers' properties. Usually, a very small part of the apparent losses is due to in-house leakage, a water volume not metered due to low flow. The factors responsible for this leakage are the dripping tap, flushes and roof tanks.

5.2.1 Reducing meter under-registration

The under-registration occurring in consumer water meters is the major cause of the apparent losses. It is known that, like all devices, water meters lose their precision over time. Under-registration, however, occurs from the beginning of the meter's life when the flow passing through the meter is below the lower limit of the recording, which varies according to the type and class of the meter. Thus, the water company suffers a significant loss of revenue, which usually results in the imposition of unfair and unequal pricing policies.

An Integrated Water Meter Management is required to counter under-registration. This includes:

• appropriate meter selection;

• Sampling and quality control of new meters;

• adequate dimensioning;

• Proper installation;

• optimal selection of cash samples;

• Optimum control and replacement time.

The first step in implementing an integrated meter management is to collect data for meters and create files. This can be accomplished by investigating historical meter supply and installation details, pricing records,

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customer complaints history, and results from their accuracy checks. More information on specific meters can be collected by trained staff who will visit consumer meters on the spot. The data required to be collected for the audit are:

• the serial number, the manufacturer and the model;

• Length, nominal diameter and flow rate;

• the reason why the audit is carried out;

• the identity of the customer, the city and the date of installation of the meter;

• the characterization of consumption (domestic, industrial, etc.) and infrastructure (direct connection, storage tanks, etc.);

• how they were installed in the field and their location during the audit;

• Photos during the test.

To overcome meter under-registration a device such as the unmeasured-flow reducer (UFR) can be used (Figure 17;18). This device works on differential pressures between the upstream and the downstream. The UFR comes into action only during low flows and is fully open under higher flows. The UFR can be installed upstream of customer meters. However, tests so far show that it is far less effective in eliminating the effect of the float valve. Also, in many cases there is no space to add such a device. Additional disadvantages are cost and the caused head losses. Therefore, replacing the existing inaccurate old meter with an accurate new one could be a preferable option.

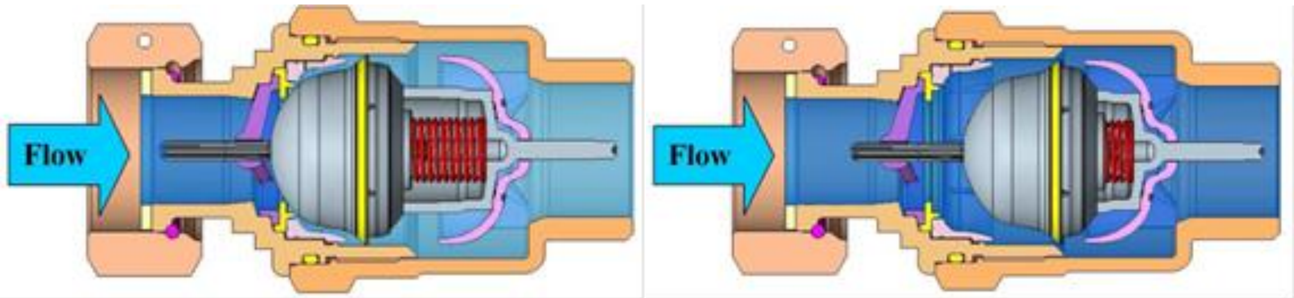

Figure 17. Unmeasured-flow reducer operation (Yaniv, 2009)

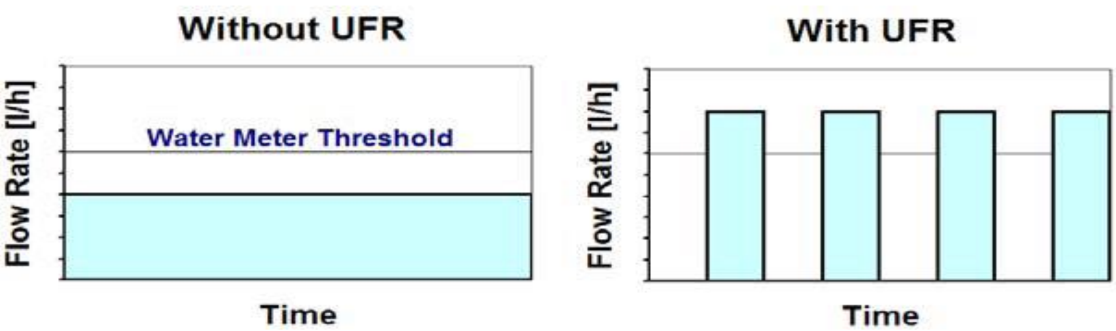

Figure 18. UFR principle of operation (Yaniv, 2009; Davidesko, 2007)

Meter under-registration can be confronted tackling its causes: installation layout of meter; wear of meter; effect of the plumbing system on the meter's performance; class and type of meter; meter sizing; spinning or jetting. The physical installation of the meter can impact on its performance. Also, the meter accuracy can be dependent on the stability and uniformity of the flow pattern on the approach to the meter. Meter age and water quality can affect the meter performance. The overall meter accuracy is a factor of the consumption profile of a premise and subsequently a factor of the actual distribution of flows against the accuracy curve of the meter. Innovative solutions to water metering include technological advancements that need to be combined with economic criteria related to new technologies.

The decision to replace the water meters is a result of econometric models. It is generally accepted and research proved that the optimum lifetime of a water meter is 10 years and their economic life from 5-10 years (Lambert & McKenzie, 2002). Of course, the age of the meter is not always related to the time the meter is used (age), but with the aging factor of the meter, also influenced by other factors (e.g. water quality). The use of economic models (such as the one presented below) in order to determine the optimum time for meter replacement is necessary.

The factors taken into account in calculating the optimum time for the replacement of water meters are (Arregui et al., 2010):

- The initial cost of purchasing and installing the meter, as well as the administrative costs associated with replacing them. It is taken into account that the value at the end of the life of the water meters is zero. Usually, the high initial cost entails an increase in the optimal renewal period.
- The cost of water not recorded represents a real cost to the water company. These costs must be taken into account for the entire lifetime of the meter.
- The standard error curve of the meter. This curve differs according to the operating principles and design features of the meters.
- User consumption profile.
- The weighted error. The error of the meter is related to the flow rate. If small amounts of water are consumed at a specific rate of supply, then their effect is lower than if larger volumes are consumed at the same rate of supply. For this reason we use the weighted error resulting from the study of the error at different delivery rates.
- The structure of the water bill. To convert the unrecorded water volume into a loss of revenue, the appropriate selling price of water must be taken into account. The loss of revenue caused by cash inaccuracies will be the cost of the last cubic meter consumed but not invoiced.
- Prepayment Rate. To calculate the cost of unrecorded water volume, the present value of future economic losses should be calculated. The known formula of the nominal discount rate r is used to calculate the present value. The actual discount rate r 'is calculated from equation (11), where s is inflation.

$$r' = \frac{(1+r)}{(1+s)} - 1 \tag{11}$$

In conclusion, if the volume of water consumed at low water supplies is high and the water company provides water with a high price, then the need for more accurate water meters is increased, with particular sensitivity to low supplies, but they also have a higher purchase price. In addition, the planned replacement period for these meters will be relatively small. On the other hand, when the water sales price is low and the leakages occurring in the consumer networks are limited, the meters to be used are not required to have increased sensitivity and measurement accuracy at very low supplies and therefore their purchase price will not be high.

A simple method of assessing the return on investment is that of Net Present Value. This method was used by Arregui et al. (2006a; b) for the calculation of the optimum time for the replacement of the water meters. The best solution is the one with the lowest cost or the highest gain (equations (12) and (13)). The Net Present Value method is applied by calculating either the total cost of the meter for the water company throughout its lifetime or its total profit.

$$Cost = C_{purchase} + C_{installation} + C_{administration} + \sum_{i=1}^{n} V * \varepsilon_i \frac{C_w}{(1+r')^{(i=1)}} \quad (12)$$

$$Profit = -C_{purchase} - C_{installation.} - C_{administration} + \sum_{i=1}^{n} V * (1-\varepsilon_i) \frac{C_w}{(1+r')^{(i=1)}} \quad (13)$$

Where: C_purchase the purchase cost, C_ (install) the installation cost, C_ (administration) the administrative costs, C_w the selling price of the water, Vi the average volume consumed by a user in year i is the weighted measurement error meter in year i, r 'the actual discount rate and n, the number of years of the replacement period. The choice of the most appropriate meter is simplified if for any reason the instrument renewal period is fixed and fixed. The model to be selected is what maximizes the value of the profit equation and minimizes the value of the cost equation.

In the absence of a fixed predetermined renewal period, the optimal life of the meter is the one that maximizes the benefits of the company. Because the maturity of the meter to be compared is different, the appropriate method is not the Net Present Value (NPV) but the NPVCn. This approach calculates the net present value of the cost for continuous substitutions that will be made at fixed intervals. Equation (14) calculates the Net Present Value of the Replacement Chain (Arregui et al., 2010):

$$NPVC_n = [C_{purchase} + C_{installation} + C_{administration} + \sum_{i=1}^{n} V_i \cdot \varepsilon_i \frac{C_w}{(1+r')^{(i-1)}}] \cdot \frac{(1+r')^n}{(1+r')^n - 1} \quad (14)$$

Where n, the optimum replacement period.

In order to determine the optimal lifetime of a given meter, the NVPCn should be calculated for each alternative. The value of n giving the lowest value of NVPCn will be the optimal alternative that creates the smallest cost for the water company. This model does not include data manipulation errors, water theft, and spoofing of cash.

5.2.2 Reducing meter reading and data accounting errors

There are many chances of introducing errors when reading consumer meters and processing the measurements. The meters are usually read either manually or through remote or automated Metering Reading (AMR). Manually reading readings by meter readers visiting consumer homes and collecting their meter readings is the traditional approach used by the majority of water companies. It is necessary to read the meter in an efficient way. This can be achieved by continuous monitoring and control of the people reading the meters, as well as local verifications. In order to tackle corruption problems, the staff reading the meters is replaced at regular intervals. Before final pricing, consumption levels must be verified in the pricing system.

AMR and AMI (Advanced Metering Infrastructure) methods are increasingly being applied, providing water companies with the opportunity to minimize the apparent losses due to meter read errors. Automated Meters Reading, or AMR, is the technology of automatically collecting consumption data, as well as other information from water meters or energy metering devices (gas, electricity) and transferring these data to a central basis for pricing, troubleshooting, and analyzing the recorded data.

For the implementation of this technology, it is required:

• A meter that has the appropriate infrastructure for AMR integration.

• A pulse or pulse generator that produces the digital signal that ultimately determines the measured value. These devices are usually energy autonomous.

• For the communication of the meters with the rest of the system a data acquisition system is used.

AMRs have benefits but drawbacks as well. AMR and AMI (Advanced Metering Infrastructure) methods are increasingly being applied, providing water companies with the opportunity to minimize the apparent losses due to meter reading errors. Three are the main types of data acquisition and processing systems:

1. Get walk-by system. Data is downloaded via a portable handset at a specific range from the point of installation of the meter (usually 10-200m).

2. Drive-by system. The data are downloaded by a portable device installed on a vehicle moving at low speed and within a certain range from the point of installation of the meter.

3. Receiving data over a fixed network. Data is downloaded through a fixed infrastructure consisting of signal repeaters and collectors.

In all three cases, the transfer of data is done over radio frequencies or through a mobile network, while the first two categories can be done by physically connecting the device to the computer.

5.2.3 Reducing data handling errors

Water companies trying to address the problem of data errors need to implement an efficient system for transferring data after reading the meter and as the pricing system. Such systems exist in AMRs. Of course, it is necessary to check before processing the data. Common errors in the pricing system may be incorrect conversion to electronic instruments or incomplete database etc. Water companies should regularly update their databases and perform sample checks to avoid errors.

5.2.4 Reducing unauthorized consumption

Water theft is both an economic and social problem and is a common practice in some parts of the world (McKenzie et al., 2007). Addressing it requires not only technical solutions but above all a social approach aimed at changing consumers' attitudes and imposing severe penalties (Mutikanga, 2012).

The water company must take action to counteract unauthorized consumption. Initially, the water utility has to investigate how easily one can get unauthorized water from the fire hydrants. Billing data should be checked to determine if there are active consumers with the same readings in their meters and therefore zero consumption in consecutive pricing cycles. On-site research will demonstrate whether unauthorized consumption is involved. On-the-spot checks still have to be made to consumers who have interrupted their connection to see if an illegal reconnection has occurred. Water meters must be secured by malicious actions by using devices that lock them.

The water company must review its regulations on the theft of water in the long run. The review takes time, as upcoming changes may be "politically sensitive". In order for the water company to make it easier for consumers facing financial problems, it can introduce a 'social tariff' at a reduced cost to socially sensitive groups. In many countries, rewarding complaints of illicit use is used as a theft remedy (Mutikanga, 2012).

Illegal use of water within the boundaries of consumer ownership is not as easily detectable as in the case of fire hydrants. However, new technologies such as Advanced Metering Infrastructure (AMI) provide tools for detecting signs of illegal water use. Any attempt to alter the meter's record is illegal. Some customers also attempt to interfere with AMR readings, which is more easily detected, as most such systems have the ability to detect interferences in their operation and send notice to the company when that happens.

5.2.5 Actions to reduce Apparent Losses

Apparent losses can be reduced by tackling its components. Some indicative measures (and their axes and actions) are given below:

Axis 1: Meter under registration

Action: Implement a pilot project to define the water meters under registration levels

Measure: replace stopped water meters

Measure: install UFR to catch low flow rates

Action: Monitor water consumption pattern and explore meters presenting sudden changes

Measure: impose high fines when water theft is found

Action: define water meters optimum replacement time

Measure: replace water meters aged over the optimum replacement age

Action: Deal with the roof tanks problem

Measure: abolition of roof tanks where possible

Measure: install UFR

Axis 2: Meter Errors

Action: Implement a pilot project to define water errors levels

Measure: training program to people recording water meters

Measure: provide them with technological tools (e.g. tablets, etc.)

Measure: install AMR

Axis 3: Water Theft

Action: Implement pilot projects to see where water theft takes place

Measure: Impose high fines to avert people of stealing water

Measure: information programs to the consumers

Axis 4: Water accounting errors

Action: define water accounting errors levels

Measure: training programs to the employees handling water accounting

Measure: Install AMR system (cost benefit analysis)

5.3 How to reduce Real losses

Real losses in a water supply network are water losses due to leaks and breaks in transmission, distribution, and connection pipelines, as well as overflows in water storage tanks. The consequences of real losses are related to the environment, the economy and public health. Leaky pipelines can pose a threat to public health because there is a risk of contamination of water by incoming solids and other pathogens (microorganisms) in the event of pressure drops (Karim, Abbaszadegan & LeChevallier, 2003). Environmental impacts include water losses, a scarce resource, depletion of energy sources, and an increase in the carbon footprint of the water company (Cabrera et al., 2010; Colombo & Karney, 2005; Mutikanga, 2012). The economic consequences are related to economic losses, since leaking water has been burdened with the cost of the raw water (e.g. energy

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costs for its extraction), its processing and transport to the consumer. At the same time, social costs include the cost of interruption of water supply to the consumer, any damage to property (e.g. underground, road breaks) and road traffic disruption due to pipe breaks and their repairs. Leakages also trigger early investment to develop / find new sources to cover residual demand (Jowitt & Xu, 1990; Mutikanga, 2012). Reducing real losses will delay the system-wide extensions (if not downgraded) that cost a lot and will result in the smaller annual operating costs of the respective water company. To confront real losses four ways have been identified (Figure 19).

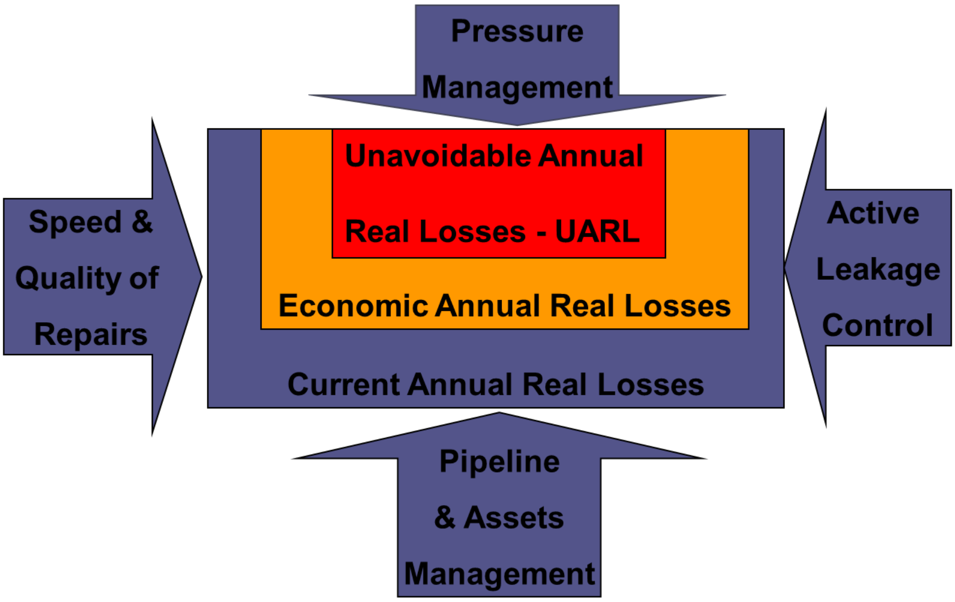

Figure 19. Real losses reduction pillars (Farley and Trow, 2003)

5.3.1 Pillar 1: Active leakage control

Water system managers apply two leakage control classes to identify leakages (Farley & Trow, 2003):

1. Active leakage control, through which the water company uses equipment and other resources to actively control leaks that were not detectable; and

2. Passive leakage control, where leakage is only perceived when visually detected or reduces pressure to a consumer.

In the case of passive leakage control, the total number of leaks in the network will continue to increase. Therefore, active leakage control is proposed, with the following advantages (Thornton et al., 2008):

• Reduction of production costs, since through the reduction of leakages, the incoming water in the network is reduced and consequently all the associated costs (e.g. water treatment costs, pumping costs, etc.) are also reduced;

• reducing the water entering the sewer system and adding unnecessary load to the wastwater treatment process;

• reducing the capital required to find new water supply resources to meet growing needs;

• avoid disastrous pipeline failures, since after leakage there is an increasing accumulation of leakages spatially and temporally;

• reducing the responsibility of the business;

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• increases the level of reliability and service delivery; and

• has a positive influence on the perception of consumers about the services offered by the water company.

The first application of active leakage control is expected to have significant results, as there are leaks that can be easily and quickly identified. However, since the most obvious leaks and breaks of pipelines with small investments are identified, greater effort and investment is needed to identify and repair leaks that are not easily identifiable. Active leakage control is one of the most practicable techniques for reducing leaks and, in general, water losses in networks worldwide. The methodology consists in identifying, through appropriate devices, the sound generated by the flow of water at the leakage point. With acoustic electronic devices, the other environmental sounds are blocked at the same time to detect the area of leakage by scanning the network (Figure 20).

Figure 20. Acoustic devices (a) (https://upload.wikimedia.org/wikipedia/commons/6/67/Geofonelight.jpg - By Dieter Altenburger (RCA HYDROTECH [1]) [Public domain], via Wikimedia Commons).

Active leakage control refers to monitoring flows within zones or district meter areas (DMAs) to locate unreported leaks. Flow metering and leak localizing, locating and pinpointing are the main activities for active leakage control. The latter includes the following steps: use flow meter data to identify where unreported leaks occur; narrow down the area of leakage; and pinpoint the exact position of the leak.

Except of the traditional methods to detect the leaks, other methods include: (i) acoustic correlation where cross correlation method is used to define the average interrelation between the signals at two (or more) points, identifying the difference in time taken for the leak noise to arrive at each sensor; (ii) the Sahara method (Bond & Marshallsay, 2007), where the Sahara leak location system is able to detect and pinpoint the location of very small leaks in mains of all materials (Figure 16b); (iii) aerial surveys – thermal imaging: a technique that does not rely on the acoustic detection of a leak, but is based on the detection of soil temperature anomalies produced by the presence of a leak; (iv) helium tracing: the distributed water is mixed with the helium gas and when the water escapes through a leak, the helium gas raises to the surface. The location of the leak is identified by surveying the area using a helium gas detector.

5.3.2 Pillar 2: Speed and quality of repairs

The next pillar for dealing with real losses is the speed and quality of repairs. The speed of repairs is related to reducing the leakage duration.

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The total time of a leak consists of: leakage awareness, location time, and repair time. Pipe breaks are easily identified and repaired due to the high rate of water loss, while the leakage awareness time is large, resulting in the overall volume of water lost being ultimately greater than that of the fractures. For example, a break that is apparent and its total duration is 1.2 days, while the rate of water loss is $72m^3$ / day, resulting in a total water loss of $86.4m^3$. A leakage of $32m^3$ / day in a connecting pipeline located and its total duration is 14 days, results in total water losses of $448m^3$. On the other hand, a leak at the same rate of $32m^3$ / day, not reported where only awareness time is equal to 164 days, results in water losses of more than 5,248 m^3.

There are some leaks detected and reported, and some not. This has an impact on the total leakage flow time, and especially on the awareness time that accounts for most of the total time. Leakages that have been identified and reported have small awareness time, since they can be perceived on the road or on the surface of the ground or can cause a drop in supply pressure that makes them detectable. Conversely, leaks that cannot be noticeable, can flow for long periods of time until they get bigger to get to the surface or get noticed. There are two actions that help reduce the awareness time of leaks that have not been reported: active leakage control and network separation into DMAs.

Active leakage control at regular intervals (at least once a year) contributes to reducing the awareness of unreported leaks. Greater frequency of active leakage control will further reduce awareness time. Of course, the frequency of active leakage control involves a cost of equipment and materials, as well as personnel costs. The cost-benefit analysis that will take these costs into account as well as the benefit of saved water will give the answer to the frequency of active leakage control.

Dividing the network into district metered areas (DMAs) contributes to the detection of unreported leaks, since with continuous monitoring of the flow rate, the minimum night flow is analyzed. The size of DMA plays a role in finding new leaks, since the smaller the DMA, the smaller leaks can be found. The combination of active leakage control and network separation into DMAs is a more efficient approach to active leakage control itself.

The quality of repairs plays an important role in the overall leakage management effort. The quality of materials and work is the two main factors influencing leakage management. If the quality of the repairs is insufficient, there is a significant likelihood of leaks occurring again in the same places but also in worse cases, creating new leaks.

5.3.3 Pillar 3: pipeline and assets management

Underground pipelines are one of the largest investments for a water company, and maintenance and replacement costs are often prohibitive, not only due to pipelines themselves but also to excavation and rehabilitation in dense urban areas. In many water companies, maintenance is often overlooked and intervention is required only when an emergency situation arises. However, each water loss management program must include special maintenance programs. Pipelines' maintenance can be done in a variety of ways, with different frequencies depending on the nature of the problem, the treatment the operator has and the severity of the situation. However, some of the programs most frequently encountered are corrosion control and pipeline coating or replacement. Many pipes suffer from high breaking frequencies from the start of their operation, especially if the quality of the material and the proper installation process are ignored. Any water company that thinks of replacing pipes, must first realize the cause of the pipeline failure and ensure that the new pipeline will not fail at the same frequency as the old pipeline.

In most water companies the decision to replace pipelines is related to the high cost of maintenance of pipelines due to their age. Water companies are urged to maintain customer service levels by performing repair work. However, only the age of pipelines is not a reliable indicator for replacing a pipeline. The frequency of pipe breaks depends on their material, their diameter, the condition of the soil, the quality of the pipes and other external factors. If, for example, a pipeline network is averaged over 50 years, the goal is to prevent further aging, thus replacing about 2% of the network each year. The decision to prioritize the pipelines to be replaced depends on a number of factors (e.g. leakage, public nuisance, cost, etc.) and one is the leakage level (Farley & Trow, 2003).

The dilemma "replace or repair" needs to be answered based on technical-economic criteria (Kanakoudis & Muhammetoglu, 2015). There are models already developed estimating the pipes optimum replacement time t_r (Kanakoudis & Tolikas, 2001). These models determine the pipes break rates, calculate all kinds of cost including the technical, social and environmental costs, determine the losses cost based on the alternative water resource and demand breaks incidents' data. A cost/benefit analysis needs to be done to determine the economic optimum solution:

$$t_r^* = t_0 + \frac{1}{A} \times \ln\left[\frac{UC_{Rm} \times \ln(1+R)}{UC_{Rr} \times N(t_0)}\right] \quad (15)$$

where t_0 is the time when the pipe was installed; A the growth rate coefficient; UC_{Rm} the replacement unit cost; R is the mean annual rate of inflation; UC_{Rr} is the repair unit cost; and $N(t_0)$ the number of breaks per km of the pipe in year t. Some pipes rehabilitation techniques include: (i) nonstructural ones: these techniques are used when the pipe is structurally sound but needs to be isolated from the water carried and consist in spraying a layer of epoxy, cement or polymer on the pipe to create a barrier between the pipe and the water; (ii) semi-structural ones: are used for partially deteriorated pipes what could be economically viable to rehabilitate. They consist in die-drawing, U lining, etc.; and (c) fully structural techniques used when the pipe needs to be replaced.

Pipeline replacement techniques include the complete replacement of both pipelines and consumer connections with the installation of new pipelines in place of the old ones, and there are also techniques that do not require excavation work. In the case of replacing the old pipeline with a new one, cost-related issues are often not practical, especially in densely populated cities. A pipeline replacement program would save large volumes of water, eliminating noisy leaks. It also reduces the incidence of new fractures and consequently reduces maintenance costs and leak detection programs (Thornton et al., 2008). There are also techniques for pipes' restoration, such as pipe lining.

5.3.4 Pillar 4: pressure management

The rate of water loss in water distribution systems is a function of the pressure supplied either by pump or gravity. The pressure-leakage relationship is well-known and proven. Since the rate of leakage is a function of pressure, it is evident that the higher the pressure the higher the leakage:

$$L_1 = L_0\left(\frac{P_1}{P_0}\right)^N \quad (16)$$

Where L_0 is the initial water loss, L_1 is the water loss after pressure reduction, P_0 is the initial operating pressure, P_1 is the final operating pressure and N is an indicator taking the values 0.5 for rigid pipes and 1.5 for flexible pipes, depending on the pipes' material.

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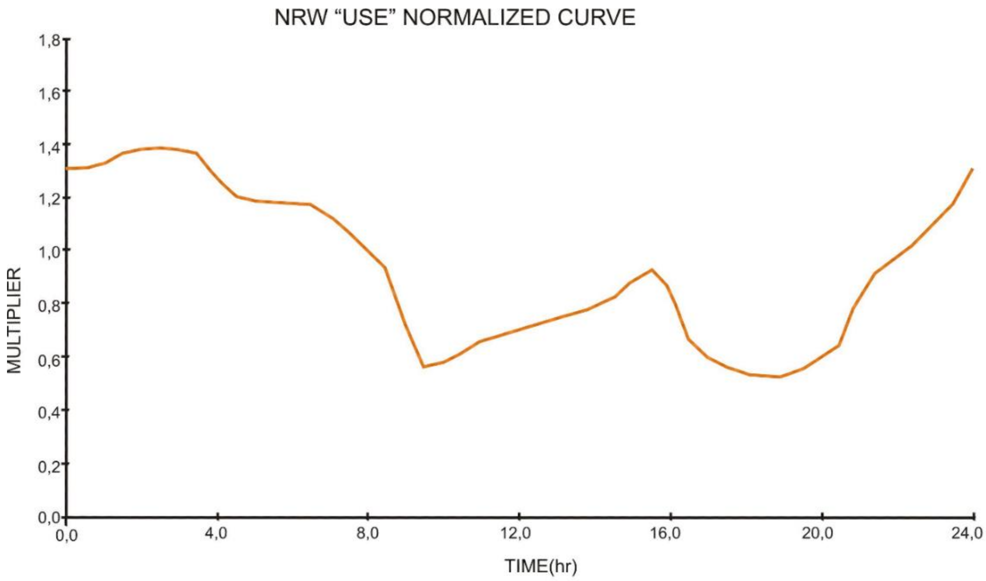

Figure 21. Typical NRW variation in 24 hours (Kanakoudis & Gonelas, 2015)

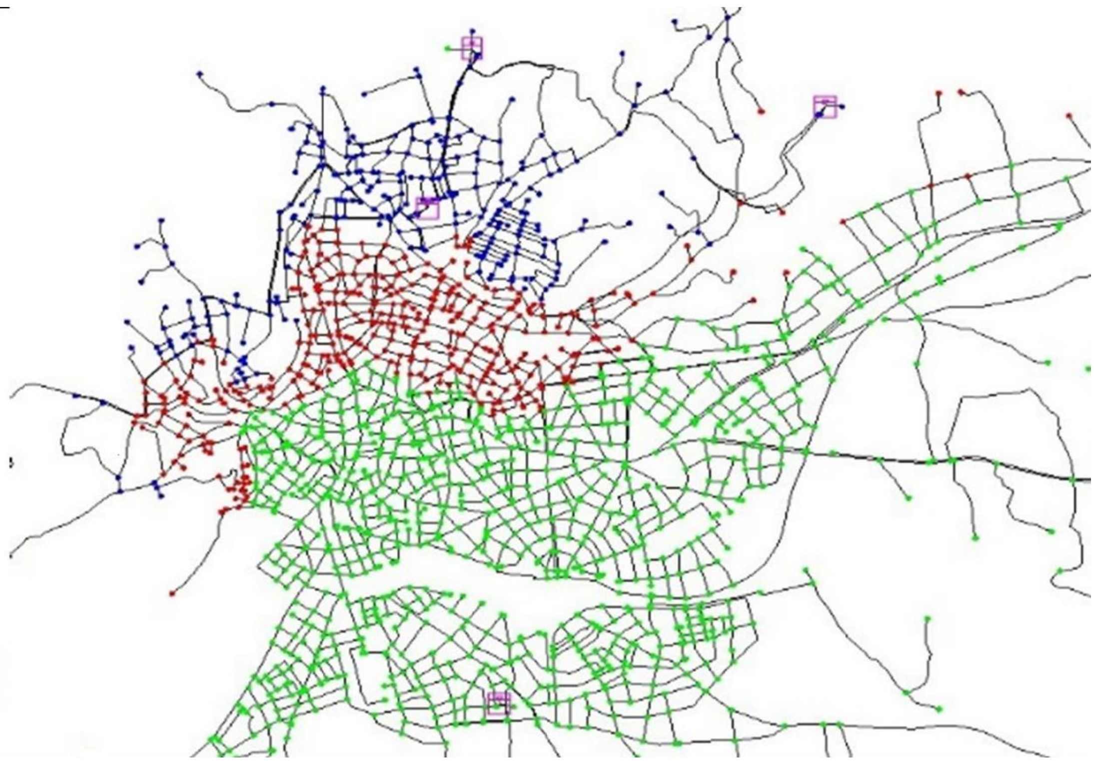

Figure 22. A network in pressure zones (with different color) (Kanakoudis & Gonelas, 2014)

The rate of breakage is also a function of the pressure, since the growth rate of breaks is linearly proportional to pressure (Farley & Trow, 2003). Real losses and consequently NRW levels fluctuate during the day due to the variation in pressure (Figure 21). Pressure management is one of the most basic and most effective methods of managing real losses in water supply networks, as it brings other impacts (Farley & Trow, 2003):

• As leakage rate is a function of pressure, pressure drop and consequently a reduction in leakage rate will have an impact on the level of detection and leakage required,

• the rate of supply from all leaks (breaks and background leaks) will also be reduced, while reducing overall leakage,

• the data used to calculate the loss targets and the financial level of the leaks should be revised when the pressure management technique is applied,

• Reducing the pressure will make it more difficult to find existing leaks because they will create less noise or will not be visible on the surface. Therefore, the pressure reduction must be combined with leak detection and repair work.

Zoning is one of the basic forms of pressure management and is very effective. The sub-zones are either physically or valve-separated and usually large enough and with many feed points. Thus, they do not usually have hydraulic problems due to valve closure (Figure 22).

Pressure reducing valves (PRVs) are equipment used to reduce or maintain pressure at the same level, installed at strategic points (Figure 23). PRVs are usually sited within a DMA, next to the flow meter.

Pressure reduction is achieved by using Pressure Reduction Valves (PRVs) (Figure 23). In practice, three are the types of PRVs used:

• Fixed outlet, where the pressure is initially defined at the outlet of the valve,

• time-modulated variable, where the pressure at the output is set by the manager and decreases at certain times of the day; and

• flow-modulated variable, where the output pressure decreases according to the demand for water received by the network.

Time-modulated PRVs include equipment with an internal timer. The method is very effective for areas with stable demand profiles and loss rates and is usually used when costs are a problem, but sophisticated pressure management is required.

Figure 23. PRV installed in a water distribution network (Kanakoudis & Tsitsifli, 2015)

Pressure management can be obtained by dividing the open network into smaller, more manageable areas, the DMAs.

The benefits of pressure management include (Lambert & Fantozzi, 2010):

• water losses: reduced leakage and breakage and reduced leakage rate,

• Consumer service: Improved service reliability due to fewer disruptions to water supply,

• inhibition of deterioration of the network condition: extended useful life of the equipment,

• operating and maintenance costs: reduced pumping energy, reduced repairs and active leakage control,

• social costs: reduced incidence of breakage of traffic and traffic disruption,

• capital costs: postponing the renewal of equipment and network extensions,

• demand management: less consumption than pressure-dependent water uses.

5.3.5 DMAs formation

Separating the network into District Water Metering Areas (DMAs) can be an integral part of the leakage control strategy for many water companies (Figure 24). DMAs have the advantage of combining two of the four pillars for dealing with real losses. On the one hand, they help to reduce leakage awareness by detecting new leakages through Minimum Night Flow analysis (MNF) and, on the other hand, improve efforts to actively control leakage, prioritizing area audits where the analysis MNF has shown that leakage levels are high. By dividing the distribution system into smaller, simpler management and monitoring areas, leakage levels can be quantified for each sub-band and the actions to control them are directed to those DMAs that display the highest leakage rates. Also, this approach has the advantage that, when losses are reduced to the optimum economic level, with the implementation of strategies and measures presented below, it is possible to closely monitor the next increase in leakage in the sub-zone.

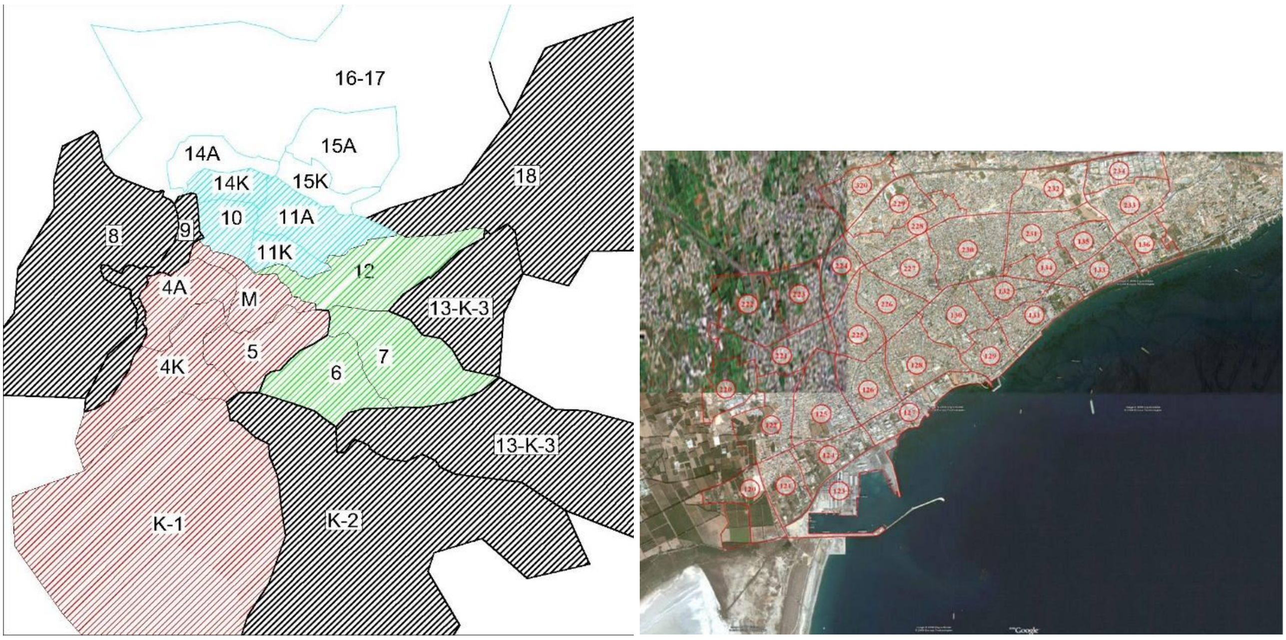

Figure 24. DMAs in a water distribution network. (a) source: Kanakoudis & Tsitsifli, 2015

DMAs enable network operators to manage the water distribution system more effectively in terms of pressure management. Pressure fluctuates within the 24- h day. The DMAs benefits include the NRW reduction, improved asset condition by maintaining asset life through pressure management and improved

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customer service by safeguarding water quality and enabling continuous water supply. The final result is that both leaks and breaks are greatly reduced.

5.3.6 Actions to reduce real losses

An action plan consisting of axes, actions and measures for real losses reduction is presented below:

Axis 1: Pressure Management

Action: Investigate the formation of pressure zones

Measure: pressure zones formation

Measure: install PRVs (pressure reduction valves)

Action: Investigate the formation of DMAs

Measure: DMAs formation

Measure: install PRVs

Action: Monitor pressure in the head of the zones

Measure: install PRVs

Axis 2: Active Leakage Control

Action: Investigate areas with high leakage rates and locate leakage problems

Measure: install permanent acoustic loggers

Measure: create teams detecting leaks with vehicles fully equipped

Measure: staff training in detecting and localizing leaks

Action: Leaks localizing, locating and pinpointing

Measure: noise loggers, leak noise correlators, ground microphones, sounding sticks procurement

Measure: leaks locating software procurement

Axis 3: Pipeline and assets management

Action: Investigate and record pipes age

Measure: record and validate pipes network in SCADA

Measure: record pipes material, diameters and age

Action: Determine the pipes optimum replacement time

Measure: Calculate the pipes optimum replacement time using the right formulas

Measure: pipes replacement

Action: Determine the spatial and time frequency of pipe failure incidents

Measure: Use the right models and record the pipes failures, their causes and the measures taken

Measure: Pipes replacement

Measure: pipes rehabilitation

Action: Implement proactive and preventive maintenance

Measure: Implement maintenance programs

Axis 4: Speed and quality of repairs

Action: Determine the time to repair a failure incident

Measure: training employees

Measure: Use fully equipped teams

Measure: Use emergency units

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Chapter 5. Lead Beneficiary input

The leak beneficiary, DEYA Komotinis, has reported its experience in reducing NRW. In general the utility has been implemented basic measures and this is why its NRW is quite high.

DEYA of Komotini supplies with water the whole municipality of Komotini, having 66,379 inhabitants. The internal water distribution network consists of transmission and distribution pipes as follows:

- Transmission pipes with diameter 280-400mm
- Distribution pipes with diameter 110-280mm
- Water connection pipes with diameter 90mm

Most of the pipes are made of polyethylene (PE) and PVC.

DEYA Komotinis has used various technologies in the past to reduce Non-Revenue Water (NRW).

Some of them are:

- Establishment of SCADA system and development of s stations network measuring water flow and pressure. The object of the project is the implementation of a modern telemetry / telecontrol system of parameters related to the operation of the water supply network in the city of Komotini. Specifically, the project involved the supply and installation of flow monitoring and pressure monitoring equipment to 10 leakage control stations in the internal water supply network of Komotini, as well as the supply of an additional 12 portable electromechanical meters. The stations were interconnected in the existing SCADA system of the service as well as in the Geographical Information System developed.
- Development of a Geographical Information System (GIS) system where:
  - The water distribution network has been spatially mapped
  - A database has been developed
  - Cartographic services and web application have been implemented. An inventory of the water network and related infrastructure, in the development of a spatially activated database, in the development and provision of cartographic services as well as in the creation of a web application for operational monitoring of networks and telemetry data. The data set is also interconnected with one hydraulic model to assess network operating parameters and to identify problems to reduce leakage.

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Chapter 6. Conclusions

The present deliverable presents a joint methodology on water use efficiency. Specifically, the deliverable includes the methodology that a water utility can follow in order to assess its performance in terms of NRW and water losses, then identify the causes of NRW and finally design a strategy including specific measures to reduce NRW.

The methodology includes the following steps:

- First, the water audit should be done in order to identify the water volumes entering the system and the water volumes consumed and lost. This step will identify the NRW level of the system and it will also provide evidence of the water volumes being lost.
- To perform water auditing, the International IWA Water Balance and its modifications can be used, along with the use of specific Performance Indicators.
- The next step is the identification of NRW causes.
- Based on the causes of losing water volumes, a NRW reduction strategy can be formulated targeting the specific causes.
- Specific measures can be decided in order to tackle each of the NRW causes.

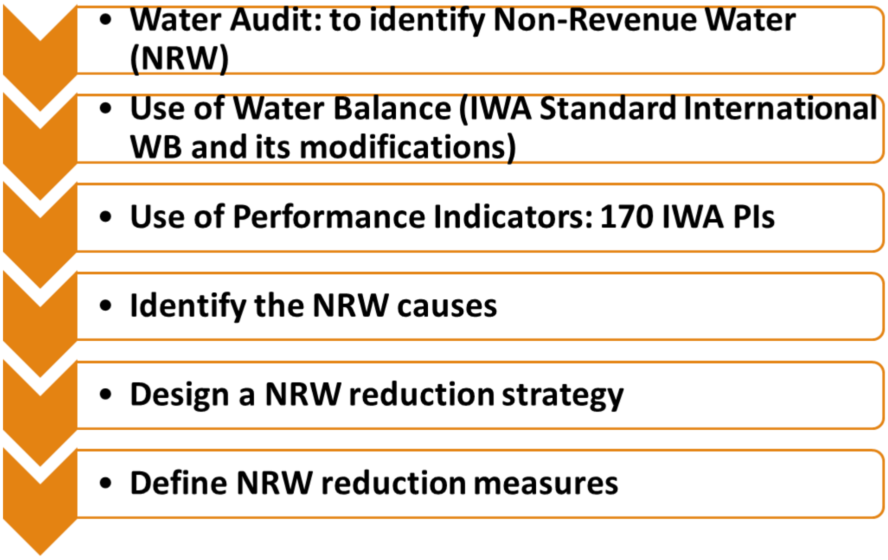

Figure 25. Integrated methodology towards water use efficiency

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Appendix A: IWA parameters

Table A1: The 232 IWA variables used to calculate the 170 PIs

A/A	VARIABLE	MEANING	MEASURED IN
A1	Annual yield capacity of own resources	Maximum annual volume of water that can potentially be abstracted from own resources, based on the availability of water resources and on any legal or contractual constraints	m3/year
A2	Annual imported water allowance	Maximum alloawance of raw and treated water importation	m3/year
A3	System input volume	The water volume input of the global system during the assessment period	m3
A4	Maximum water treated daily	Maximun daily volume of water treated in treated plans during the assessment period	m3/day
A5	Exporter raw water	Total volume of raw water transferred to other water undertaking or to another system from the same supply area during the assessment period	m3
A6	Water produced	Total volume of water treated for input to water transmission lines or derectly to the distribution system during the assessment period	m3
A7	Exported treated water	Total volume of treated water exported to other water undertaking or to another system from the same supply area during the assessment period	m3
A8	Billed metered consumption	Total amount of billed metered authorised consumption (including exported water) during the assessment period	m3
A9	Billed unmetered consumption	Total amount of billed unmetered authorised consumption (including exported water) during the assessment period	m3
A10	Billed authorised consumption	Total amount of billed authorised consumption (including exported water) during the assessment period	m3
A11	Unbilled metered consumption	Total amount of unbilled metered authorised consumption (including exported water) during the assessment period	m3
A12	Unbilled unmetered consumption	Total amount of unbilled unmetered authorised consumption (including exported water) during the assessment period	m3
A13	Unbilled authorised consumption	Total amount of unbilled authorised consumption (including exported water) during the assessment period	m3
A14	Authorised consumption	Total volume of metered and/or non-metered water that, during the assessment period, is taken by registered customers, by the water supplier itself, or by others who are implicitly authorised to do by the water supplier, for residential, commercial, industrial or public purposes. It includes water exported.	m3
A15	Water losses	Difference between system input volume and authorised consumption	m3
A16	Unauthorised cosnumption	Total amount of unauthorised water consumption during the assessment period, including water theft.	m3
A17	Metering inaccuracies water losses	Total amount of water consumed during the assessment period, but unccounted-for due to metering inaccuranies	m3
A18	Apparent losses	Total amount of water unaccounted-for due to unauthorised consumption and metering inaccurancies, durind the assessment period	m3
A19	Real losses	Total amount of physical water losses from the pressurised system during the assessment period, up to the point of costomer metering	m3
A20	Revenue water	Total amount of billed authorised consumption (including exported water) during the assessment period.	m3
A21	Non-revenue water	Difference between the system input volume and the billed authorised consumption (including exported water) during the assessment period.	m3
A22	Reused supplied water	Total volume of wastewater directly reused as water source during the assessment period, after adequate treatment, generally as a complement of conventional water sources.	m3
A23	Non Recoverd Water	Water volume billed but never paid by the consumers	m3
A24	Free Basic Recover Revenue	Difference between Revenue Water and Non Recovered Water	m3
A25	Minimum Charge Difference - MCD (Recovered Real Losses)	Difference between water volume billed to the customers and water volume registered by their water meters	m3
A26	Accounted Non Revenue Water	Difference between NRW and MCD	m3
B1	Total personnel	Total number of full time equivalent employees of the water undertaking as the reference date.	No.
B2	General management personnel	Total number of full time equivalent employees dedicated to directorate, central administration, environmental management, new business development and general computing support at the reference date.	No.
B3	Human resources management personnel	Total number of full time equivalent employees of the water undertaking dedicated to personnel administration, education and trainig, occupational safety, and health services and social activities, at the reference date.	No.

A/A	VARIABLE	MEANING	MEASURED IN
B4	Financial and commercial personnel	Total number of full time equivalent employees of the water undertaking dedicated to economic and financial planning, economic administration, economic controlling and purchasing and material management activities, at the reference date.	No.
B5	Customer service personnel	Total number of full time equivalent employees dedicated to accounting and control and to customer relations and management activities, at the reference date.	No.
B6	Technical services personnel	Total number of full time equivalent employees dedicated to planning, construction, operations and maintenance activities, at the reference date.	No.
B7	Planning and construction personnel	Total number of full time equivalent employees of technical services working in planning & construction of water supply systems, at the reference date.	No.
B8	Operations and maintenance personnel	Total number of full time equivalent employees of technical services working in operations & maintenance of water supply systems, at the reference date.	No.
B9	Water resources and catchment management personnel	Total number of full time equivalent employees working in the water resources and catchment management, at the reference date.	No.
B10	Abstraction and treatment personnel	Total number of full time equivalent employees working in the planning, design, construction, operations and maintenance of the water abstraction and treatment, at the reference date.	No.
B11	Transmission, storage and distribution personnel	Total number of full time equivalent employees working in the planning, design, construction, operations and maintenance of the transmission, storage and distribution system, at the reference date.	No.
B12	Water quality monitoring personnel	Total number of full time equivalent employees working in water quality sampling and testing, at the reference date.	No.
B13	Meter management personnel	Total number of full time equivalent employees working in the installation, maintenance and replacement of the water meters, at the reference date.	No.
B14	Support services personnel	Total number of full time equivalent employees working in thecentral stock repository, central workshops and the vehicle fleet, at the reference date.	No.
B15	University degree personnel	Number of full time equivalent employees of the water undertaking with university degree, at the reference date.	No.
B16	Basic education personnel	Total number of full time equivalent employees working of the water undertaking without a university degree but with at least a basic education, at the reference date.	No.
B17	Other qualification personnel	Total number of full time equivalent employees without basic education, at the reference date.	No.
B18	Total training time	Total number of training hours during the assessment period.	hours
B19	Internal training time	Total number of internal training hours during the assessment period.	hours
B20	External training time	Total number of external training hours during the assessment period.	hours
B21	Working accidents	Total number of working accidents requiring care occurring with personnel during the assessment period	No.
B22	Absebteeism	Total number of days of absenteeism occuring during the assessment period	days
B23	Absenteeism due to accidents or illness at work	Total number of days of absenteeism due to accidents or illnes at work occuring during the assessment period	days
B24	Absedeeism due to other reasons	Total number of days of absenteeism occuring during the assessment period that were not due to working accidents or illness at work.	days
B25	Working time	Total number of normal working hours of all the undertaking employees during the assessment period (employees hours gross - absence for holidays)	hours
B26	Overtime work	Total number of overtime working hours of the undertaking employees during the assessment period.	hours
C1	Raw water storage capacity	Total net volume of raw water reservoirs included in the system, at the reference date.	m3
C2	Treated water storage capacity	Total volume of transmission and distribution service reservoirs, at the reference date.	m3
C3	Daily treatment capacity	Maximum daily global capacity of the existing treatment plants, at the reference date.	m3/day
C4	Pumps	Total number of pumps of the system, at the reference date.	No.
C5	Pumping stations	Total number of pumping stations of the system (customer pumping systems excluded), at the reference date.	No.
C6	Pumping stations capacity	Total nominal power of the system pumps (customer pumping systems excluded), at the reference date.	kW
C7	Maximum operating pumping capacity	Maximum nominal pumping power that can be used simultaneously in the system.	kW

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A/A	VARIABLE	MEANING	MEASURED IN
C8	Mains length	Total transmission and distribution mains length (*service connections* not included), at the reference date.	km
C9	Distribution meins length	Total distribution mains legth (transmission lines and *service connections* not included), at the reference date.	km
C10	System flow meters	Total number of flow meters available for permanentor temporary installation in the trasmission and distribution system, such as meters for system control, district metering and accounting of imported and exported water (direct customer meters, E6, shall not be included).	No.
C11	District meters	Total number of water metering points permanently or systematically equipped for district metering, at the reference date.	No.
C12	Pressure meters	Total number of pressure meters available for permanet or temporary pressure monitoring, at the reference date.	No.
C13	Water level meters	Total number of water level meters available for permanent or temporary water level monitoring, at the reference date.	No.
C14	On-line water quality monitoring instruments	Total number of instruments available for permanent or temporary on-line water quality monitoring, at the reference date.	No.
C15	Control units	Total number of control units, defined as functionally independent sets of control devices of the system (e.g. control valves or pump switches) used in water wells, surface water catchments, pumping stations, energy recovery stations, treatment plants, storage tanks and raw water, transmission and distribution networks (at the reference date).	No.
C16	Automated control units	Total number of automated control units of the system, defined as functionally independent sets of control devices of the system (e.g. control valves or pump switches) that are locally controlled by a programmable logical controller, used in water wells, surface water catchments, pumping stations, energy recovery stations, treatment plants, storage tanks and raw water, transmission and distribution networks (at the reference date).	No.
C17	Remotely controlled units	Total number of control units of the system remotely controled from a central control system, usually via information cabling or radio connections, used in water wells, surface water catchments, pumping stations, energy recovery stations, treatment plants, storage tanks and raw water, transmission and distribution networks (at the reference date).	No.
C18	Emergency power systems	Total nominal power of the emergency power systems, at the reference date.	kW
C19	Signal transmission equipment	Total nominal of signal transmission units, at the reference date.	No.
C20	Electrical switchgear	Total number of the electrical switchgear equipments, at the reference date.	No.
C21	Mains valves	Total number of all kinds of valves installed in transmission and distribution system mains (valves installed in the service connections shall not be accounted for), at the reference date.	No.
C22	Isolating valves	Total number of isolating valves of all types installed in transmission and distribution system mains (valves installed in the service connections shall not be accounted for), at the reference date.	No.
C23	Hydrants	Total number of hydrants of all types installed in the distribution network, at the reference date.	No.
C24	Service connections	Total number of *service connections*, at the reference date.	No.
C25	Average service connection length	Average length (metres) from the property boundary (delivery point) to the *measurement point*, at the reference date.	m
D1	Pumping energy consumption	Total energy consumption for water pumping (customer pumping systems excluded) during the assessment period.	kWh
D2	Maximum daily pumping energy consumption	Sum, for all installed pumps, of the number of operation hours of the maximum energy consumption day during the assessment period multiplied by the nominal power of the pump, resulting in the maximum daily pumping energy consumption of the system.	
D3	Standardisation factor	Sum of D3(i) for all pumps of the system, D3(i) being: D3(i)=V(i)xh(i)/100, where V is the total volume (m3) pumped I during the assessment period and h(i) is the pump head (m).	m3*100m
D4	Reactive energy consumption	Total reactive energy consumption for pumping in the system during the assessment period.	kVar
D5	Energy recovery	Total energy recovered by the use of turbines or reverse pumps in the system during the assessment period.	Wh
D6	Pumping inspection	Sum of the nominal power of all pumps and related ancillaries in the system subjected to inspection during the assessment period	kW
D7	Storage tank cleaning	Total volume of water storage tanks cells cleaned during the assessment period.	m3
D8	Network inspection	Length of transmission and distribution mains where at least valves and other fittings were inspected during the assessment period	km
D9	Leakage control	Length of mains subject to *active leakage contro*l during the assessment period.	km

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A/A	VARIABLE	MEANING	MEASURED IN
D10	Leaks repaired due to active leakage control	Number of leaks detected and *repaired* due to *active leakage control* during the assessment period.	No.
D11	Hydrant inspection	Total number of hydrants *inspected* during the assessment period.	No.
D12	System flow meter calibrations	Number of system flowmeter *calibrations* carried out during the assessment period.	No.
D13	Pressure meter calibrations	Number of pressure meter *calibrations* carried out during the assessment period.	No.
D14	Water level meter calibrations	Number of water level meter *calibrations* carried out during the assessment period.	No.
D15	On-line water quality monitoring equipment calibrations	Number of *calibrations* carried out during the assessment period on on-line water quality monitoring instruments installed in the system (permanently or temporarily)	No.
D16	Emergency power systems inspection	Sum of the nominal power of the system emergency power equipment inspected during the assessment period.	kW
D17	Signal transmission equipment inspection	Number of signal transmission units in the system *inspected* during the assessment period	No.
D18	Electrical switchgear inspection	Number of electrical switchgear units in the system *inspected* during the assessment period	No.
D19	Permanent vehicles	Number of permanent vehicles daily available, in average, for field works in operations and maintenance activities, at the reference date.	No.
D20	Mains rehabilitation	Length of transmission and distribution mains rehabilitated the assessment period	km
D21	Mains renovation	Length of mains renovated during the assessment period by epoxy resine, cement mortar or other materials	km
D22	Mains replacement	Mains length replaced during the assessment period.	km
D23	Replaced valves	Number of mains valves replaced during the assessment period.	No.
D24	Service connection rehabilitation	Number of *service connections* replaced or renovated during the assessment period.	No.
D25	Pumps overhaul	Total nominal power of pumps subject, during the assessment perid, to refurbishment of relevant elements, necessary to bring unit back to original performance.	kW
D26	Pumpsreplacement	Total nominal power of pumps replaced during the assessment period.	kW
D27	Pump failures	Sum, for all pumps, of the number of days during the assessment period when the pump is out of order.	days
D28	Mains failures	Number of *mains failures* the assessment period, including failures of valves and fittings.	No.
D29	Service connection failures	Number of *service connection* failures the assessment period.	No.
D30	Hydrant failures	Number of hydrant failures during the assessment period.	No.
D31	Power failures	Sum, for all water pumping stations, of the number of hours during the assessment peiod each pumping station is out of service due to power supply interruptions.	hours
D32	Water-point failures	Number of water-points failures during the reference period.	No.
D33	Delivery points with adequate pressure	Number of *delivery points* that receive and are likely to receive pressure equal to or above the guaranteed or declared terget level at the peak demand hour (but not when demand is *abnornal*), at the reference date.	No.
D34	Average operating pressure	Average operating pressure at the delivery points when system is pressurised, at the reference date.	kPa
D35	Water interruptions	Sum, for all water interruptions, of the population subject to a water interruption multiplied by the duration of the interruption in hours), during the assessment period.	persons*hours
D36	Service interruptions	Total number of water interruptions, during the assessment period.	No.
D37	Water use restrictions	Sum, for all the *restrictions to water service* occurred during the assessment period, of the population affected by each restriction to water service multiplied by the reprective duration in hours.	persons*hours
D38	Days with restrictions to water service	Total number of days with *restrictions to water service* during the assessment period.	days

A/A	VARIABLE	MEANING	MEASURED IN
D39	Residential customer meter reading frequency	Frequency of residential customer meter readings, pre-defined by the water undertaking for the assessment period.	No./meter/year
D40	Industrial customer meter reading frequency	Frequency of industrial customer meter readings, pre-defined by the water undertaking for the assessment period.	No./meter/year
D41	Bulk customer meter reading frequency	Frequency of bulk customer meter readings, pre-defined by the water undertaking for the assessment period.	No./meter/year
D42	Customer meter readings	Total number of *effective meter readings* carried out during the assessment period for all types of metered customers.	No.
D43	Residential customer meter readings	Total number of *effective meter readings* carried out during the assessment period for all types of residential customers.	No.
D44	Opeational meters	Number of direct customer meters that are not out-of-service at the reference time.	No.
D45	Meter replacement	Number of customer meters replaced in the system during the reference period.	No.
D46	Required treated water quality tests carried out	Number of *treated water* tests carried out during the assessment period that are required by applicable standards or legislation.	No.
D47	Required aesthetic tests carried out	Number of *aesthetic tests of treated water* tests carried out during the assessment period that are required by applicable standards or legislation.	No.
D48	Required microbiological tests carried out	Number of *microbiological tests of treated water* tests carried out during the assessment period that are required by applicable standards or legislation.	No.
D49	Required physical-chemical tests carried out	Number of *physical-chemical tests of treated water* tests carried out during the assessment period that are required by applicable standards or legislation.	No.
D50	Required radioactivity tests carried out	Number of *radioactivity tests of treated water* tests carried out during the assessment period that are required by applicable standards or legislation.	No.
D51	Treated water quality tests carried out	Number of *treated water tests* carried out during the assessment period.	No.
D52	Water quality tests carried out	Total number of *tests* carried out by the water undertaking laboratories during the assessment period.	No.
D53	Aesthetic tests carried out	Number of *aesthetic tests of treated water* carried out during the assessment period.	No.
D54	Microbiological tests carried out	Number of *microbiological tests of treated water* carried out during the assessment period.	No.
D55	Physical-chemical tests carried out	Number of *physical-chemical tests of treated water* carried out during the assessment period.	No.
D56	Radioactivity tests carried out	Number of *radioactivity tests of treated water* tests carried out during the assessment period.	No.
D57	Water quality tests required	Number of *treated water tests* required by applicable standards or legislation during the assessment period.	No.
D58	Aesthetic tests required	Number of *aesthetic tests of treated water* required by applicable standards or legislation during the assessment period.	No.
D59	Microbiological tests required	Number of *microbiological tests of treated water* required by applicable standards or legislation during the assessment period.	No.
D60	Physical-chemical tests required	Number of *physical-chemical tests of treated water* required by applicable standards or legislation during the assessment period.	No.
D61	Radioactivity tests required	Number of *radioavtivity tests of treated water* required by applicable standards or legislation during the assessment period.	No.
D62	Compliance of aesthetic tests	Number of *aesthetic tests of treated water* carried out during the assessment period,which comply with the applicable standards or legislation.	No.
D63	Compliance of microbiological tests	Number of microbiological *of treated water* carried out during the assessment period,which comply with the applicable standards or legislation.	No.
D64	Compliance of physical-chemical tests	Number of *physical-chemical of treated water* carried out during the assessment period,which comply with the applicable standards or legislation.	No.
D65	Compliance of radioactivity tests	Number of *radioactivity of treated water* carried out during the assessment period,which comply with the applicable standards or legislation.	No.
E1	Households and businesses supplied	Total number of households and business connected to the water supply system at the reference time.	No.
E2	Building supplies	Total number of buildings connected to the water supply system at the reference time.	No.

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A/A	VARIABLE	MEANING	MEASURED IN
E3	Households and businesses	Total number of households and business of the area of influence of the water undertaking regarding water supply, at the reference time.	No.
E4	Buildings	Total number of buildings of the area of influence of the water undertaking regarding water supply, at the reference time.	No.
E5	Resident population	Total population who lives on a permanent basis in the area served by the water undertaking, at the reference date.	persons
E6	Direct customer meters	Total number of direct customer water meters at the reference date.	No.
E7	Residential customer meters	Total number of residential customer water meters at the reference date.	No.
E8	Industrial customer meters	Total number of industrial customer water meters at the reference date.	No.
E9	Bulk customer meters	Total number of bulk customer water meters at the reference date.	No.
E10	Registered customers	Total number of registered water supply customers at the reference date.	Customers
E11	Residential registered customers	Total number of residential registered water supply customers at the reference date.	Customers
F1	Population supplied	Resident population served by the water undertaking at the reference date.	Persons
F2	Population supplied with service pipes	Resident population served by the water undertaking through *service connections* at the reference date.	Persons
F3	Population served by public taps or standpipes	Resident population served by the water undertaking by public taps or standpipes at the reference date.	persons
F4	Distance from water points to households	Sum, for all water points, of the distance between the water point and the far-most household served by it, at the reference date.	m
F5	Public taps and standpipes consumption	Sum, for all public taps and standpipes,of the respective water consumption during the assessment period.	m3
F6	Water points	Total number of water-points at the reference date.	No.
F7	Operational water-points	Total number of water-points that are not out of service at the reference date.	No.
F8	Public taps and standpipes	Total number of public taps and standpipes,at the assessment period.	No.
F9	New connections establishment time	Sum, for all new connections established during the reference period, of the total time spent from the customer request until the availability of the water service.	Days
F10	New connections established	Total number of new connections established during the reference period.	No.
F11	Customer meter installation time	Sum, for all new customer meters installed during the assessment period, of the total time spent from the customer request until the availability of the service.	Days
F12	New customer meters installed	Total number of new water customer meters installed during the assessment period.	No.
F13	Connections repair time	Sum, for all *service connections* repaired during the assessment period, of the total time spent from the time failures are reported until the service is resumed.	Days
F14	Connections repaired	*Total number of water connections* repaired during the assessment period.	No.
F15	Service complaints	Number of direct, telephone, and written complaints of quality of service during the assessment period.	No.
F16	Pressure complaints	Number of pressure complaints during the assessment period.	No.
F17	Continuity complaints	Number of continuity complaints regarding the water supply service during the assessment period.	No.
F18	Water quality complaints	Number of water quality complaints during the assessment period.	No.
F19	Complaints on interruptions	Number of complaints due to water supply interruptions during the assessment period.	No.
F20	Billing complaints and queries	Number of direct, telephone, and written billings complaints and queries regarding the water supply service, during the assessment period.	No.
F21	Other complaints and queries	Number of other complaints and queries regarding the water supply service, during the assessment period.	No.
F22	Written responses	Number of written responses to written queries and complaints within the target time regarding the water supply service, during the assessment period.	No.
F23	Written complaints	Number of written complaints regarding the water supply service, during the assessment period.	No.
G1	Total revenues	Total operating revenues minus capitalised costs of self-constructed assets, regarding the water supply service, during the assessment period.	EUR

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A/A	VARIABLE	MEANING	MEASURED IN
G2	Operating revenues	Total operating revenues during the assessment period, including sales revenues (G3), work in progress, capitalised costs of self-constructed assets (G35) and other operating revenues, regarding the water supply service.	EUR
G3	Sales revenues	Operating revenues from sales during the assessment, regarding the water supply service.	EUR
G4	Total costs	Total costs during the assessment period, including capital and running costs, regarding the water supply service.	EUR
G5	Running costs	Total operations and maintenance net costs and internal manpower net costs (i.e. not including the capitalised costs of self costructed assets) during the assessment period, regarding the water supply service.	EUR
G6	Capital costs	Total net interest and depreciation (based on book values) during the assessment period, regarding the water supply service.	EUR
G7	Operational costs	Operational costs during the assessment period regarding the water supply service, including the net value (obtained by negative apportionment of related capitalised costs of self-constructed assets) of imported (raw and treated) water, energy, external services, leasing and rentals, chemicals, other consumables and materials for maintenance and repair, taxes, levies & fees and ecxeptional earning &losses, and other operating costs. Manpower shall not be included.	EUR
G8	Internal manpower costs	Internal manpower costs during the assessment period regarding the water supply service, referred to the net value (obtained by negative apportionment of related capitalised costs of self-constructed assets) of the personnel which salary is paid directly by the water undertaking.	EUR
G9	External services costs	The net value (obtained by negative apportionment of related capitalised costs of self-costructed assets) of total costs of external services (i.e. outsourcing), external manpower costs included, regarding the water supply service, during the assessment period.	EUR
G10	Imported (raw and treated) water costs	Total cost of the water imported (raw and treated) during the assessment period.	EUR
G11	Electrical energy costs	Total costs of electrical energy (including energy of pumping and for other water supply undertaking activities such as workshops, office buildings energy consumption, laboratories, etc), within the period of assessment, regarding the water supply service.	EUR
G12	Purchased merchandises	The net value (obtained by negative apportionment of related capitalized costs of self-constructed assets) of all materials, chemicals and other consumables not including in external services costs, regarding the water supply service, during the assessment period.	EUR
G13	Leasing and rentals	The net value (obtained by negative apportionment of related capitalized costs of self-constructed assets) of total cost of leasing and rentals, regarding the water supply service, during the assessment period.	EUR
G14	Taxes, levies and fees	All levies and licences strictly connected with the water supply system's operation to be paid to a govemmental or municipal authority (including direct taxes on EBT), during the assessment period.	EUR
G15	Exceptional earnings and losses	Exceptional income or expenditures related to sales/writing-off of fixed assets, regarding the water supply service, during the assessment period.	EUR
G16	Other operating costs	The net value (obtained by negative apportionment of related capitalized costs of self-costructed assets) of other operating costs, not included in chemicals, other consumables and materials for maintance and repair, leasing and rentals, taxes, levies and fees and exceptional earnings & losses, regarding the water supply service, during the assessment period.	EUR
G17	General management running costs	Part of the running cost related to the net value (obtained by negative apportionment of related capitalised costs of self-constructed assets) of costs of directorate, central administration, strategic planning, marketing and comunications, other stakeholder relations, legal affairs, internal audits, environmental management, new biseness development and general computing support activities, regarding the water supply service, during the assessment period.	EUR
G18	Human resources management running costs	Part of the running cost related to the net value (obtained by negative apportionment of related capitalised costs of self-constructed assets) of costs of personnel administration, education and training, occupational safety, health services activities and social activities, regarding the water supply service, during the assessment period.	EUR
G19	Financial and commercial running costs	Part of the running cost related to the net value (obtained by negative apportionment of related capitalised costs of self-constructed assets) of costs of economic and financial planning, economic administration, economic controlling and purchasing and material management activities, regarding the water supply service, during the assessment period.	EUR
G20	Customer service running costs	Part of the running cost related to the net value (obtained by negative apportionment of related capitalised costs of self-constructed assets) of costs of meter reading, accounting and control, customer relations and management activities, regarding the water supply service, during the assessment period.	EUR

A/A	VARIABLE	MEANING	MEASURED IN
G21	Planning, design, construction, operational & maintenance running costs	Part of the running cost related to the net value (obtained by negative apportionment of related capitalised costs of self-constructed assets) of the water supply technical planning, design, construction, operations and maintenance (including asset repair), during the assessment period.	EUR
G22	Water resources and catchment management running costs	Part of the running cost related to the net value (obtained by negative apportionment of related capitalised costs of self-constructed assets) of the water recources and catchment management, during the assessment period.	EUR
G23	Abstraction and treatment running costs	Part of the running cost related to the net value (obtained by negative apportionment of related capitalised costs of self-constructed assets) of the abstraction and treatment, during the assessment period.	EUR
G24	Transmission, storage and distribution running costs	Part of the running cost related to the net value (obtained by negative apportionment of related capitalised costs of self-constructed assets) of the transmission, storage and distribution, during the assessment period.	EUR
G25	Water quality sampling and testing running costs	Part of the running cost related to the net value (obtained by negative apportionment of related capitalized costs of self-constructed assets) of the water quality sampling and testing, during the assessment period.	EUR
G26	Meter management running costs	Part of the running cost related to the net value (obtained by negative apportionment of related capitalized costs of self-constructed assets) of the water meter management, during the assessment period.	EUR
G27	Support services running costs	Part of the running cost related to the net value (obtained by negative apportionment of related capitalized costs of self-constructed assets) of the support services, regarding the water supply service, during the assessment period.	EUR
G28	Depreciation costs	Depreciation costs (on book values), regarding the water supply service, during the assessment period.	EUR
G29	Interest expenses costs	Interest expenses costs, regarding the water supply service, during the assessment period.	EUR
G30	Interest income	Total interest income, regarding the water supply service, during the assessment period.	EUR
G31	Net interest	Interest expenses costs, regarding the water supply service, during the assessment period.	EUR
G32	Investment in tangible assets	Total cost of the investments in tangible (expenditures for plant and equipment), including capitalized cost of self-costructed tangible assets (the part of the G35 related to tangible assets), regarding the water supply service, during the assessment period.	EUR
G33	Investments for new assets and reinforcement of existing assets	Total cost of the investments in tangible assets that constitute a new development for the service (new assets and reinforcement of existing assets), including capitalised cost of self-costructed tangible assets (part of the G35 related to tangible assets newly constructed or reinforced), regarding the water supply service, during the assessment period.	EUR
G34	Investments for asset replacement and renovation	Total cost of the investments related to the replacement and renovation of existing water supply assets ("like for like", i.e., maintaining the approximately the same functionality of existing infrastructure), including capitalised cost of self-construction (part of G35 related to the replacement or renovaation of tangible assets), during the assessment period.	EUR
G35	Capitalised cost of self-constructed assets	Total capitalised cost of self-constructed assets during the assessment period, regarding the water supply service.	EUR
G36	Water sales revenue for direct consumption	Water sales revenue for direct water consumption during the assessment period.	EUR
G37	Water sales revenue fro exported water	Water sales revenue for exported water.	EUR
G38	Accounts receivable	Accounts receivable from drinking water, at the reference date.	EUR
G39	Investments subject to depreciation	Investments for assets subject to depreciation according to the accounting principles generally accepted, regarding the water supply service, during the assessment period.	EUR
G40	Investments financed by the cash flow	Investments financed by the cash flow (assessed as the sum of net income, depreciation and working capital variation), regarding the water supply service, during the assessment period.	EUR
G41	Depreciated historical value of tangible assets	Sum, for all the tangible assets, of the depreciation value applied, since the date of purchase, regarding the water supply service.	EUR

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A/A	VARIABLE	MEANING	MEASURED IN
G42	Historical value of tangible assets	Refers to the gross book value of total expenditures at the reference date in infrastructure and non-infrastructure tangible assets, regarding the water supply service.	EUR
G43	Annual debt from customers	Annual debt from customers, regarding the water supply service.	EUR
G44	Annual amount billed per year	Annual amount billed during the year, regarding the water supply service.	EUR
G45	Cash flow	Total available is the sum of net income, depreciation and the net value of decrease or increase in working capital, regarding the water supply service during the assessment period.	EUR
G46	Financial debt service	The financial debt service contains the expenditures for interest (G29), the cost of loans, and the principal (=capital) repayment debt instruments, regarding the water supply service, during the assessment period.	EUR
G47	Total debt	Sum of long term liabilities (bonds and long term financial debts) and current liabilities, at the end of the fiscal year, regarding the water supply service.	EUR
G48	Shareholders' equity	Surplus of the asset over the liabilities, at the end of the fiscal year, regarding the water supply service	EUR
G49	Current assets	Current assets include cash at bank and in hand, accounts receivable from drinking water, other accounts receivable, inventories and prepaid expenses, at the reference date, regarding the water supply service.	EUR
G50	Total assets	Sum of the intangible assets (including goodwill and net value of licences and rights), tangible assets (including net value of water undertaking plants and net value of other assets), financial assets (including net value of financial investments) and current assets (G49), regarding the water supply service, at the end of the fiscal year.	EUR
G51	Inventories	Accounted value of materials to be used in the production, process that are in stock in the undertaking at the reference date, regarding the water supply service	EUR
G52	Long term liabilities	Sum of bonds and long term financial debts at the reference date, regarding the water supply service.	EUR
G53	Current liabilities	Current liabilities include accounts payable, current portion of long term debt and miscellaneous current liabilities, at the reference date, regarding the water supply service.	EUR
G54	Operating income	Earning before interest and taxes (EBIT), regarding the water supply service, during the year.	EUR
G55	Operating income related taxes	Subset of the total taxes specifically related to the operating income (EBIT), regarding the water supply service, during the year.	EUR
G56	Net income	Net income after interest payment and taxes, regarding the water supply service, at the end of the fiscal year.	EUR
G57	Average water charges for direct consumption	Ratio between the water sales revenue for direct consumption and billed water.	EUR/m3
G58	Attributed unit cost for real losses	Highest of the variable component of improved water charge or *long run marginal cost (LRMC)* for own sources.	EUR/m3
H1	Assessment period	Period of time adopted for the assessment of the data and the PI.	Days
H2	Time system is pressurized	Amount of time the year the system in pressurized.	Hours

WATER RESCUE

Water resources efficiency and conservative use in drinking water supply systems

WP	**4 Common Methodology & Tools**
Deliverable *Tool*	**4.1.2 Water use efficiency joint methodology report** *Questionnaire*
Project Beneficiary No	**LB/PB1**
Beneficiary Institution	**Municipal Water Supply and Sewerage Company of Komotini**

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Name of the organization/institution: Municipal Water Supply and Sewerage Company of Komotini
Beneficiary number: PB1

1 Introduction

DEYA of Komotini supplies with water the whole municipality of Komotini, having 66,379 inhabitants. The internal water distribution network consists of transmission and distribution pipes as follows:

- Transmission pipes with diameter 280-400mm
- Distribution pipes with diameter 110-280mm
- Water connection pipes with diameter 90mm

Most of the pipes are made of polyethylene (PE) and PVC.

2 Technologies and techniques used to reduce NRW

DEYA Komotinis has used various technologies in the past to reduce Non-Revenue Water (NRW).

Some of them are:

- Establishment of SCADA system and development of s stations network measuring water flow and pressure. The object of the project is the implementation of a modern telemetry / telecontrol system of parameters related to the operation of the water supply network in the city of Komotini. Specifically, the project involved the supply and installation of flow monitoring and pressure monitoring equipment to 10 leakage control stations in the internal water supply network of Komotini, as well as the supply of an additional 12 portable electromechanical meters. The stations were interconnected in the existing SCADA system of the service as well as in the Geographical Information System developed.
- Development of a Geographical Information System (GIS) system where:
  - The water distribution network has been spatially mapped
  - A database has been developed
  - Cartographic services and web application has been implemented. An inventory of the water network and related infrastructure, in the development of a spatially activated database, in the development and provision of cartographic services as well as in the creation of a web application for operational monitoring of networks and telemetry data. The data set is also interconnected with one hydraulic model to assess network operating parameters and to identify problems to reduce leakage.