Desalination and Water Treatment
www.deswater.com
2 (2009) 24–29
1944-3994/1944-3986

Minimization of losses in water supply systems: strategy definition in a Portuguese case study

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Received 30 July 2007; Accepted 14 September 2007

ABSTRACT

The water sector in Portugal incorporates two general types of utility services: those focused on bulk water supply and those responsible for the water distribution. To achieve the economic, operational and environmental sustainability, it is essential to act on the efficiency of both types of systems. One of the major challenges is to promote the necessary cooperation between those utility services, especially on water losses control. Specific mechanisms to promote the gradual reduction of losses in distribution systems are needed to improve operational levels of service. In the paper, a methodology and the practical application to a pilot case of AdAve is presented, including results obtained, emphasising constrains and difficulties encountered. This approach, innovative in Portugal, of collaboration between different stakeholders, is believed to allow sound improvements in performance and efficiency of water supply systems as a whole, and will contribute to a comprehensive view of the water losses current situation.

Keywords: Water losses; Leakage management; Real losses minimization; Performance

1. Introduction

The water sector in Portugal incorporates two general types of utility services: those focused on bulk water supply integrating the components of water abstraction, treatment, transport and storage; and those responsible for the water distribution. The former are mainly managed by multi-municipal and municipal concessions while the latter are mostly managed by local administration bodies.

To achieve the economic, operational and environmental sustainability of water supply systems it is essential to act on the efficiency of both types of systems. One of the major challenges is to promote the necessary cooperation between those utility services, especially on water losses control.

Available data regarding losses in water systems in Portugal reveal the relevance of investing in losses control in water supply systems. In fact, general national values for inefficiency of use of water resources are estimated in circa 40% [1], but uncertainty associated with this figure is high.

Multi-municipal concessions are subject to national regulation of the service, being obliged to report specific performance indicators (PI), and thus more accurate values are available in these cases. The published national average values (2004) for these concessions, for the two PI that are used for losses estimation, non-revenue water (%) and inefficiency of use of water resources (%), are 5%

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Presented at IWA Efficient 2007, May 20–23, 2007, Jeju, Korea.

(values up to 27%) and 4% (values up to 15%), respectively [2].

A large amount of water losses are associated with distribution systems, most of them managed by municipal services. Contributing factors for this situation include aged and degraded networks, and insufficient resources allocated to technical management tasks, resulting in deficient maintenance and rehabilitation. Economic and financial sustainability is penalised by the low tariffs which are insufficient to ensure costs recovery. Very few water distribution utilities are regulated (31 out of 276), representing 3,5 million inhabitants or circa 30% of the total population served. According to IRAR [2], for the regulated utilities, average national values (2004) are 26% (values up to 41%) and 19% (values up to 41%), respectively, for non-revenue water (%) and inefficiency of use of water resources (%). Thus, mechanisms to promote the gradual reduction of losses in distribution systems are needed to increase economic and environmental efficiency as well as to improve operational levels of service.

Within this scope Águas de Portugal (AdP), a publicly-owned company that presently covers about 70% of Portuguese territory and about 75% of the Portuguese population (in total about 7 million inhabitants), aims at developing partnerships with utilities managing distribution systems to implement strategies for overall reduction of water losses.

In order to establish a conceptual framework to be applied in all systems managed by the AdP group, a methodology was developed and implemented together with one of the subsidiary companies, the Águas do Ave (AdAve), in close collaboration with utilities responsible for the distribution systems.

In the present paper, emphasis is given to the macro analysis and to main constraints and difficulties in the application of the methodology.

2. Methodology

While the overall goal is the gradual reduction of water losses in the municipal systems to a sustainable level of leakage, the main objective of the conceptual framework proposed is to develop a plan for each Municipality incorporating appropriate measures adapted to the specific situation, in terms of local problems, constraints, and organisational and physical characteristics. Additionally, these plans should include implementation schedule, costs associated to each measure, resources allocation and recommendation on organizational issues.

Given the constraints in resources and limited information, the approach selected consists of a two-level analysis: a macro-analysis of the overall water supply systems and a micro-analysis, more detailed, to be carried out at selected district metering areas (DMA). The micro-analysis is essential to identify the contributing causes and its relevance per system, to allow quantification of the problem and select appropriate methods of rehabilitation.

The selected approach follows the directions given by the IWA Water Losses Task Force [3] and the technical guidance given at Alegre et al. [4]. Thus, the methodology, which aims at developing of a plan for each municipality, includes the following phases:

1. Characterization of present situation (reference). This phase includes:

- Gathering available system information, carrying out consistency analysis of data and identification of gaps, and establishment of a program for missing data collection;
- Characterization of water consumption (demand by different users) in each municipality for 3 years of data;
- Compilation of operation and maintenance information including functional problems identification (e. g. failures, complains);
- Preliminary water balance for each subsystem, using available data, and identification of additional data collection needs. Preliminary assessment of levels of losses for each subsystem;
- Diagnosis of the systems, relating the estimated values of losses with main contributing causes for losses (e.g. system physical characteristics, operation and maintenance practices).

2. Definition of specific objectives and goals

- Set-up of system's mathematical models for support in the definition of specific objectives and goals including the simulation of different scenarios to identify major factors influencing water losses and effect of control measures, using EPANET.
- Identification of system's control points and definition of DMA.
- Establishment of a monitoring program at selected DMA's per municipality, including the required field work. Minimum monitoring period is three months, to be adjusted depending on local situation. The DMA's are intended to be representative of the wider municipal system characteristics. Measurement locations include DMA inputs.
- Carrying out detailed water balance for each DMA.
- Calculation of performance indicators and critical analysis considering the knowledge obtained in the previous tasks.
- Definition of the specific objectives, for each municipality, on the short and medium term, taking into account intervention priorities derived from the diagnostics phase.

3. Establishment of a program of measures and activities:

- Selection of a set of tailored measures (structural, operational and social) for each municipality. Different scenarios should be considered in the program to incorporate the potential levels of implementation that might be achieved depending on the particular conditions of each municipality. For each scenario, required resources and expected benefits are estimated.
- Set-up of a program for each municipality and system establishing the priority measures, detailing schedule, associated resources and estimated costs of implementation.

4. Mechanisms and recommendations for implementation. This phase includes:

- Establishment of the plan for each municipality, based on the program of measures developed for each subsystem. Selection of the appropriate mechanisms for implementation of the plan. Different scenarios are to be considered.
- Identification of the necessary means for plan implementation, both in terms of technical team and required resources.
- Recommendations on the required training for personnel involved in plan implementation.
- Set-up of an auditing of performance program for the evaluation of the plan throughout implementation and procedures for control and adjustment.

3. Application to the Aguas Do Ave service area

3.1. General system characteristics

The AdAve bulk water supply system presently provides service to three municipalities, in total 90,126 inhabitants. The region is mostly rural with industrial clusters and some small urban areas, thus having a large proportion of dispersed agglomerations and, consequently, a large number of water abstraction locations. Urban areas networks are relatively old and maintenance rates relatively low.

In recent years, considerable investments have been made in order to reduce the number of abstractions, to better control potable water quality, resulting in the expansion of the bulk water supply systems managed by AdAve. The main characteristics for the connected municipal systems are presented in Table 1.

For the micro-analysis, six DMA were selected (two DMA, one DMA and three DMA, respectively for the municipalities A, B and C). To illustrate the application of the methodology, the case of A municipality is presented.

3.2. Municipality A case study

Within the 56 municipality A water supply subsystems, there are presently 104 abstraction works and 68 storage tanks. However, only one abstraction is used to serve 60% of the population served, and is the sole non-groundwater source. All the remaining are either springs or wells. During winter some abstractions are not used. The majority of the systems are supplied from storage tanks, upstream of which are water mains, which are part of the bulk water supply system.

- In terms of network characteristics, most of it was built or renovated after 1990, and the predominant material is HDPE.
- Despite significant topographic variations, pres-sure monitoring or management is not implemented. Furthermore, no losses control actions are currently done apart from local repairs of bursts identified visually by the water company personnel or by means of complaints.
- Rehabilitation works (renovation) are currently carried out with criteria not related with losses control but with changes in hydraulic conditions (increase in pipe pressure class) or changes in the system's layout.
- Bulk water metering is usually associated with disinfection facilities and not for water balance purposes. Billed metering is generalised for all types of customers. Public and other municipal water uses are usually not metered (e.g. public drinking fountains, municipal services, cemeteries, churches, water tanks, football fields, schools and gardens).

As mentioned above, two DMA were identified at municipality A, for which characteristics are summarised in Table 2. The application of the methodology was carried out in similar way in the three municipalities.

Table 1
Characteristics of studied municipalities (current situation)

Municipality	Total population (inhabitants)	Bulk water system capacity (%)	Connected population (%)	Geographic area (km^2)	Number of systems	Municipal network extension (km)
A	52,630	97	68	219.1	56	396
B	22,772	97	36	132.5	9	46
C	14,724	95	89	218.5	21	220

Table 2
Characteristics of municipality A DMA (2005)

DMA	Rural 1	Town centre 1
Number of customer meter	232	Not available
Population (inhabitants)	988	671
Network length (km)	21	1.5
Pipe materials	HDPE	HDPE
Average pressure (m)	59	Not available
Diameter (mm/length)	50/1.5	63/0.6
	63/16.0	75/0.05
	75/3.0	90/0.9
Total number of connections	232	Not available
Number of flow meters	2	1
Storage tanks	2	1

4. Results and discussion

The initial phase of the implementation revealed important gaps on available information, this having considerable impact on the results of this application. Main difficulties include:

- network mapping and systems data base is generally incomplete, inaccurate and not available in an appropriate format for the present purpose (e.g. nonexistent customer connections data base, pipe and valves characteristics such as age, location or condition not organised or incomplete);
- for historic reasons and availability of water sources, water consumption data are not recorded per system but per borough;
- systematic recording of operation and maintenance information is virtually nonexistent;
- mechanisms for construction quality control and supervision are insufficient;
- limited information exists on bulk water flows since meters are totalisers and thus records are not continuous;
- bulk water metering, often nonexistent, is usually associated with disinfection facilities and not for water balance purposes;
- public and other municipal water uses are usually not metered (e.g. public drinking fountains, municipal services, cemeteries, churches, water tanks, football fields, schools and gardens).

Therefore, these aspects are to be considered as key actions in the plans for all municipalities.

Preliminary values for the municipality A, expressed as non-revenue water, are given in Fig. 1 for a 3-year period. In this case, values of non-revenue water are high but appear to be stable within the studied period. However, uncertainties associated with the values used in the balance are significant.

Analysing globally for the municipality A, preliminary values of performance indicators for 49 subsystems show major variations. In Figs. 2–4, results are presented for IWA performance indicators Fi 46, Op23 and Op24, respectively [5].

Care in interpreting these results is essential given the difficulties described above that have direct influence on the application of the water balance. Values below 10% or above 80% are unlikely to be real. This provides a first picture of the system and allowed to identify major areas of improvement.

Given the high values obtained for some subsystems for Fi46, in a first phase a relatively high threshold value (50%) was selected as boundary between first priority subsystems. Thus, these have higher priority in the analysis, both for improving the water balance data input and for priority measures for losses control. Subsequently, as second priority are those subsystems showing Fi46 values between 20% and 50%. This lower threshold has been defined by the Portuguese regulator (IRAR) as target for water distribution systems.

In Fig. 3 values for Op23 are still sorted by the ranking given by the values of Fi46. Subsystems included are those having a connection density lower or equal to 20 connections per km. Subsystem 26 shows a higher value of Op23, for similar average value of Fi46, probably because is a town center subsystem while the remaining are smaller agglomerations, typically with lower connection densities.

Dispersion in the values presented for priority systems in Fig. 4 is caused by multiple factors, depending on the subsystem. For instance, while subsystem 43 has shown significant improvement during the three years analyzed, subsystem 47 performance has been worsen, largely due to doubling of system input volume in the period not followed by metered volume.

Since most subsystems are relatively small, customers having high consumption have a high impact on the water balance and on systems performance, especially if not metered. For example, large industries or construction works, if not continuously operating, can result in large variations in the values of the performance indicators.

Although performance indicators are useful to show trends, actual problems must be analysed in detail for sound conclusions and appropriate selection of actions conducting to the establishment of plans for minimisation of water losses. Performance indicators are also extremely useful for monitoring the implementation of measures for minimization of losses.

Furthermore, serious limitations on available data (e.g., lack of measurements, measurement errors, and undefined subsystems boundaries) invalidate, in some cases, the application of the methodology and, in others, might result in wrong conclusions. Thus, improvement of

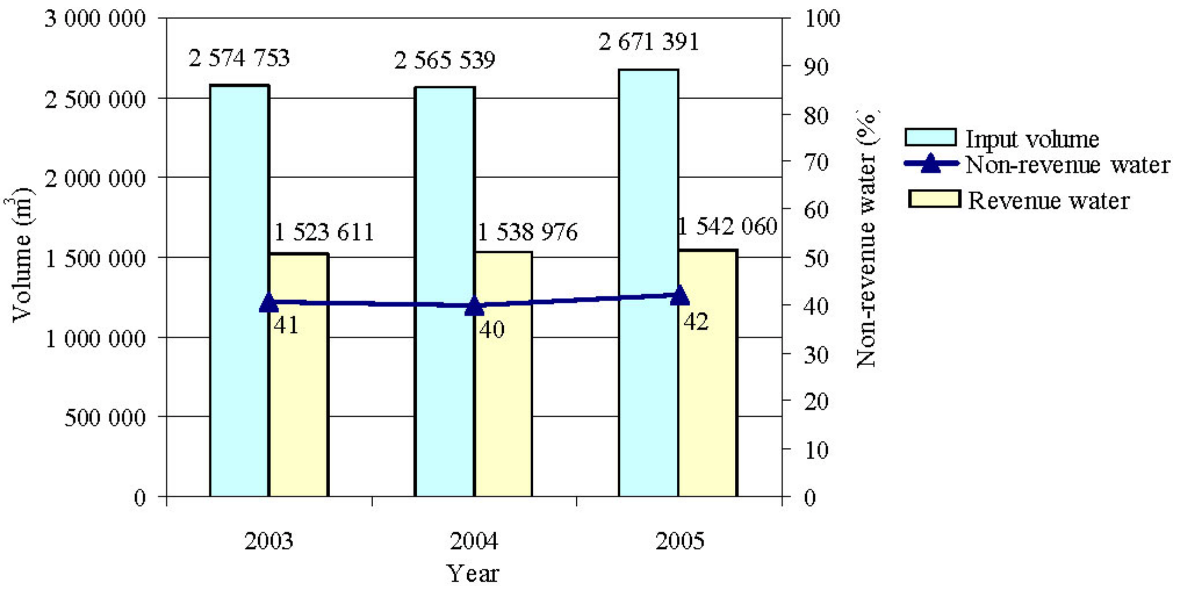

Fig. 1. Preliminary values of global water balance for municipality A.

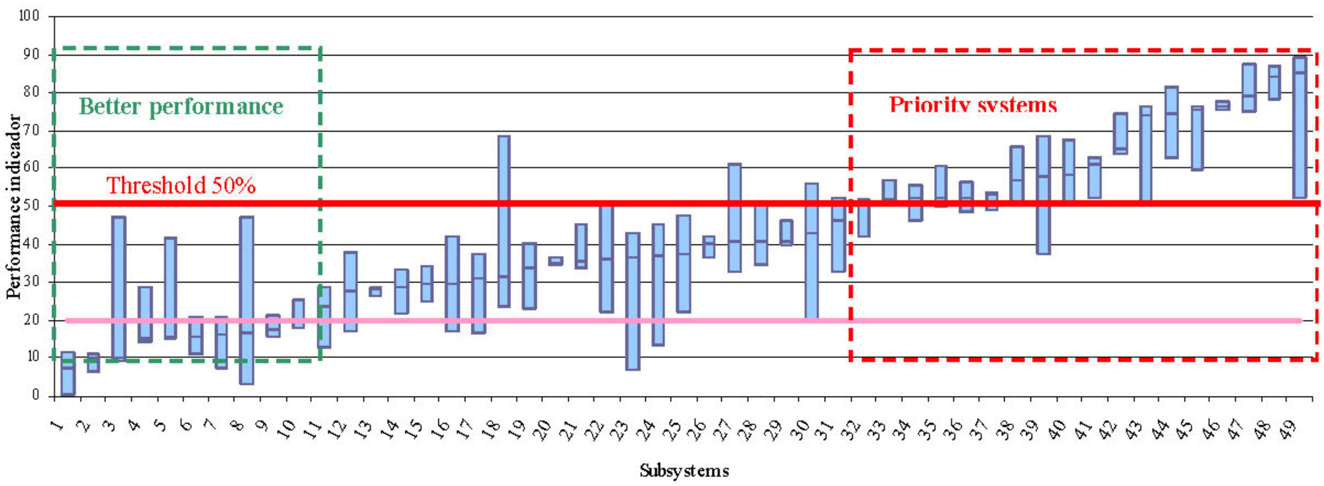

Fig. 2. Values of non-revenue water by volume (Fi 46), for municipality A (%)

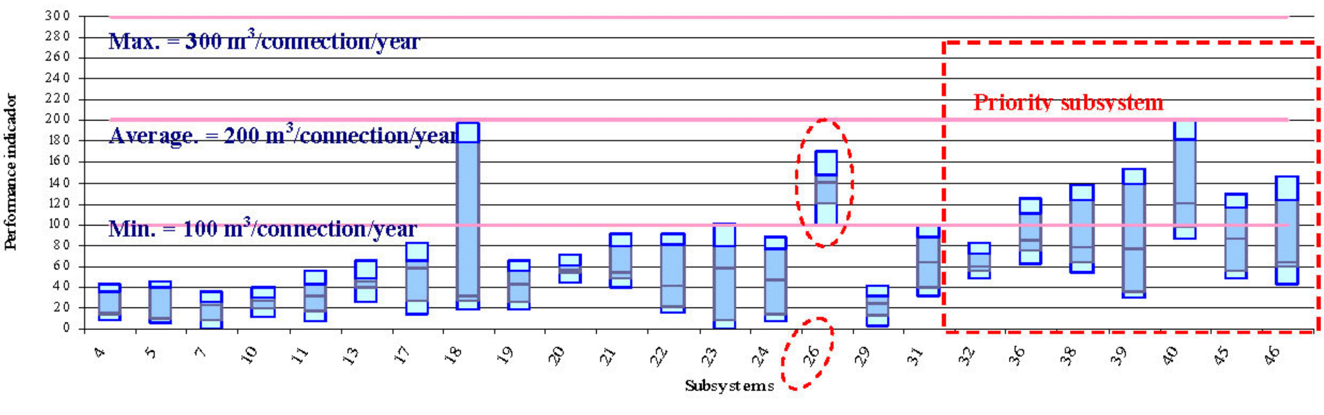

Fig. 3. Values of water losses per connection (Op23), for municipality A (m^3/connection/year).

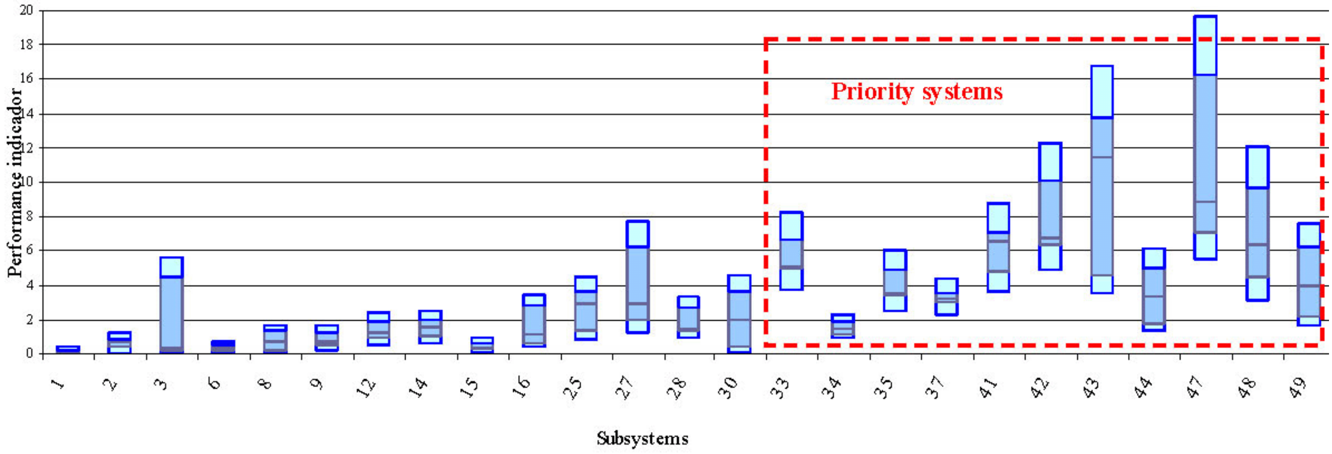

Fig. 4. Values water losses per mains length (Op24) for municipality A (m^3/km/d).

basic information for the application of the methodology has the higher priority within the tasks to be considered in the plans.

5. Conclusions

A major difficulty in the implementation of the methodology results from the ongoing construction of bulk water supply network in order to reduce the extremely high and dispersed number of abstractions. Although the methodology is established, changes in the network will result in alterations in systems boundaries and even in hydraulic conditions. This implies additional efforts in the implementation of the procedures in the medium and long term.

The practical application is essential for refining the methodology before generalised application to other subsidiary companies. This approach, innovative in Portugal, of collaboration between different stakeholders, is believed to allow for sound improvements in the performance and efficiency of water supply systems as a whole, and will contribute to a better knowledge of current situation in the distribution systems.

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