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Water Supply Network District Metering

Theory and Case Study



International Centre
for Mechanical Sciences



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PREFACE

A water supply network is the key link in the water distribution chain, because it allows for the distribution of the resource for civil, industrial and agricultural uses.

Reported by many sources, both in Italy and other countries (UNESCO, 1993, United Nation, 2000, 2002a and 2002b; National Geographic Italia, 2002; World Water Council, 2003; Ministero dell'Ambiente e della Tutela del Territorio, 2004 and 2005), the waste of water resources in supply networks is considerable.

The deterioration of these systems is due to many causes related to aging technology (average life of European water networks exceeds 30 years) and to negligence and poor organization of the various authorities in charge of ordinary and extraordinary management.

These reasons add to the essential complexity of the urban water distribution systems arising from many technical and scientific problems.

Among technical problems, it is worth mentioning:

- *poor knowledge of the actual plans due to the unplanned growth of the water system along with the urban sprawl, of the 1970's and 1980's;*
- *lack of digitalized plans and TIS (Territorial Information Systems);*
- *scarce availability of up-to-date and reliable databases;*
- *aging of supply networks and hydraulic devices (pipelines, gates, adjustment valves, special works, flow meters, pressure transducers, etc.);*
- *considerable physical and administrative water leakages;*
- *difficulty in defining the two leakage rates ("revenue" and "non-revenue" water);*
- *technological and operational backwardness due to the absence of modern systems of remote-controlling, and to the lack of intervention plans for both ordinary and extraordinary maintenance;*
- *non-compliance, in many countries, with local management "best practice";*
- *complexity of the procedure to carry out hydraulic checks in very large water systems;*

- *poor hydraulic performances (inadequate pressure, reduced resources during drought, poor quality, etc.);*
- *faulty planning of many water systems currently in operation;*

Among the scientific problems, it is worth mentioning:

- *non linear behavior of equations modeling the water distribution systems;*
- *presence of a very high number of variables which makes the application of optimization techniques particularly complicated;*
- *difficulty in defining cost functions due to the lack of data relating to the management of water services;*
- *difficulty in defining optimal criteria for district metering pursuant to management “best practice”;*
- *low number of pilot sites;*
- *implementation of case studies on small water networks;*
- *lack of multi-scenario analyses relating to drought;*

Obviously, these issues, especially the technical ones, assume more or less importance depending on the international reality taken into account.

In many countries, as is the case in Italy, there is a clear need for modernization to reach standards of cost-effectiveness: by improving service, updating databases, billing consumptions regularly, creating multithematic TIS, using modern monitoring technologies and criteria and integrated systems to optimize the whole water system.

In order to do so, it is necessary to develop Decision Support Systems, DSS, (Loucks and da Costa, 1991; Loucks, 2000) which help managers by simplifying (thanks to remote controlling, optimization models and operational research) the complexity of water systems in term of hydraulics and customer satisfaction.

Indeed, besides achieving satisfactory hydraulic performance, a water supply company has to fulfill the needs that modern consumer societies demand, and rightly so, i.e., all those elements which make a company more competitive than another and which result from the maximum possible control of the whole system.

In this study two techniques are put forward to improve water supply system management: “Water District Metering (WDM)” and “Water Pressure Management (WPM)” with reference to leakage reduction.

Specifically, after a theoretical introduction of two techniques in Chapter 1 and Chapter 2, the study proposes the use of both techniques in tandem defining two tools for WDM design and WPM setting (Chapter 3). Water district metering and pressure management were already used in some other experiences, often using empirical approaches applied to small water networks.

In this study two original tools are proposed; they are based on heuristic and optimal criteria, arranged in design support methodologies to assist water network operators.

In Chapter 4 the two techniques are tested on a case study of the Monterusciello network in Pozzuoli (Italy) confirming the effectiveness of the approach presented.

The results illustrated in this monograph are part of a research work conducted by CIRIAM (Centro Interdipartimentale di Ricerca in Ingegneria Ambientale) of Seconda Università di Napoli (SUN).

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1. Water Leakage Management

The greatest problem for a water network - and surely the most important from an economic and social standpoint - is related to water leakages. In many areas of the world more than one third of the resource, which is first extracted, then treated to improve its organoleptic qualities to make it drinkable, and then conveyed to urban water networks, is lost before it reaches end users.

Leakages are a major technical and management problem also for industrialized countries. High leakage levels, sometimes even more than 50% [64] of the supplied volume, are nowadays not sustainable for a water utility, both from an environmental and economic point of view. Some countries have been tackling the leakage problem for many years, promoting basic research, special laws and the implementation of best practices [101]; many others, instead, addressed the problem with enormous delay [62].

The importance of the topic, internationally recognised also by organizations like UNESCO [91], has led many important associations [2, 49] to analyse its technical and scientific aspects in depth, and to promote the dissemination of technologies already available on the market or previously experimented by important water utilities.

Leakages, in a preliminary evaluation, can be divided into real (or physical) losses, that is water actually lost when delivering the service, and apparent (or unauthorized consumption) losses, i.e. water delivered to consumers but not billed [3]. The considerable presence of both kinds, for different reasons, undoubtedly represents a poor physical situation of the water system and the absence of reliable systems of metering and management of the service, with clear effects on the economic, political and social aspect and, in general, on conserving and managing water resources.

For many years a number of international technical and scientific organizations have been concerned with the issue of water leakages [1, 66]. The International Water Association (IWA), in 1996, promoted a specific Task Force to analyze and evaluate the methodologies for the international comparison of water leakages from water distribution systems with the following goals:

- standardization of the terminology for the calculation of water balance and actual and apparent losses;
- the review of possible performance measures for the international comparison of leakages.

The work of the Task Force is summarized in the document “Losses from Water Supply Systems: Standard Terminology and Recommended Performance Measures” [49, 29], which includes, in particular, a standardized methodological scheme to evaluate the water balance relating to water supply systems and represents a valuable reference in order to properly understand and standardize water flows.

This schematization is illustrated in several other documents and sector studies and can be considered as the methodological standard of reference in the international framework.

This IWA document also includes a methodological scheme to understand the water outflows from an adduction and/or distribution system, aimed at properly defining - within the framework of the difference input volumes less billed authorised volumes - the quantities actually lost in adduction and distribution networks, in utility storage tanks, connections and those attributable to unbilled and authorised consumptions, to unbilled and unauthorised consumptions, and inaccurate metering. This methodological scheme, shown in Table 1, can be considered as the international reference for studies and operational management in this field.

A	B	C	D	E
System Input Volume (m ³ /year)	Authorised Consumption (m ³ /year)	Billed Authorised Consumption (m ³ /year)	Billed Metered Consumption (including water exported)	Revenue water (m ³ /year)
			Billed Unmetered Consumption	
		Unbilled Authorised Consumption (m ³ /year)	Unbilled Metered Consumption	
			Unbilled Unmetered Consumption	
	Water Losses (m ³ /year)	Apparent Losses (m ³ /year)	Unauthorised Consumption	Non Revenue water (m ³ /year)
			Metering Inaccuracies	
		Real Losses (m ³ /year)	Leakage on Transmission and/or Distribution Mains	
			Leakage and Overflows at Utility's Storage Tanks	
			Leakage on Service Connections up to point of Customer metering	

Table 1. Elements of the water balance suggested by IWA