WATER DISTRIBUTION NEWORKS MANAGEMENT AND OPTIMISATION

Pedro GALVÃO[1], Adélio SILVA[2], Paulo LEITÃO[3], Pedro PINA[4] and Nivaldo RODRIGUES[5]

ABSTRACT

An efficient information management system and the ability to anticipate problems, or to plan operations in a proper way, are critical aspects to the water utilities due to the need to increase systems exploitation efficiency and the safety, to comply with more demanding environmental regulations and to improve the information to the consumer and the general public.

AQUASAFE platform's objectives are inline with these challenges by potentiating the use of information in real-time and its integration with forecast and diagnostic tools. The demonstration of some of the implemented capabilities is made for two situations: the first one regards the Itaquera subsystem, responsibility of the SABESP Eastern Water Operation Division, and the primary objective was to demonstrate the applicability of AQUASAFE in a complex system, integrating an existing hydraulic model with *scada* information, analysing water quality and pumping operation scenarios; the second one regards a idealized system comprising 3 pumping stations and their respective linked tanks, forced by real boundary conditions (consumptions, pumping and network characteristics) that could incorporate the characteristic variability of a high delivery supply system.

This document reports some of the results obtained from the acquired experience in this particular implementation of AQUASAFE platform.

Keywords: supply, water, models, consumption, energy management

1 Environmental Engineer, Hidromod, Lda. pedro.galvao@hidromod.com
2 Civil Engineer, Hidromod, Lda. adelio@hidromod.com
3 Civil Engineer, Hidromod, Lda. paulo.chambel@hidromod.com
4 Environmental Engineer, Bentley Systems. pedro.pina@bentley.com
5 Civil Engineer, Sabesp, nivaldorodrigues@sabesp.com.br

1   INTRODUCTION

AQUASAFE platform's objective is to potentiate the use of information in real-time and its integration with forecast and diagnostic tools. Functioning as an integrating element of models, external data sources, data from *scada* systems and sample collecting, AQUASAFE provides:

- Modelling results availability in real time, through the integration of *scada* systems or other external data source with models, without human intervention;

- Anticipation of trouble situations through the creation of personalised alarms to combine information from several data sources (real or modelled);

- Automatic launch of simulation scenario processes, to assess management options in real time;

- Leakages detection support;

- Generation of automated modelling results reports and/or measures, based on user pre-defined templates;

- Practical use of modelling results in the operation room, benefitting from the know-how of previously existing operators.

Apart from this, AQUASAFE offers tailor-made solutions, being compatible with (or easily adaptable to) the use of several models (water distribution and waste networks, *run-off*, meteorology, waves, etc.) and databases. It includes OPC protocol-based routines to "speak" directly with *scada* systems, as well as the possibility to customise interfaces according to the profiles of different users.
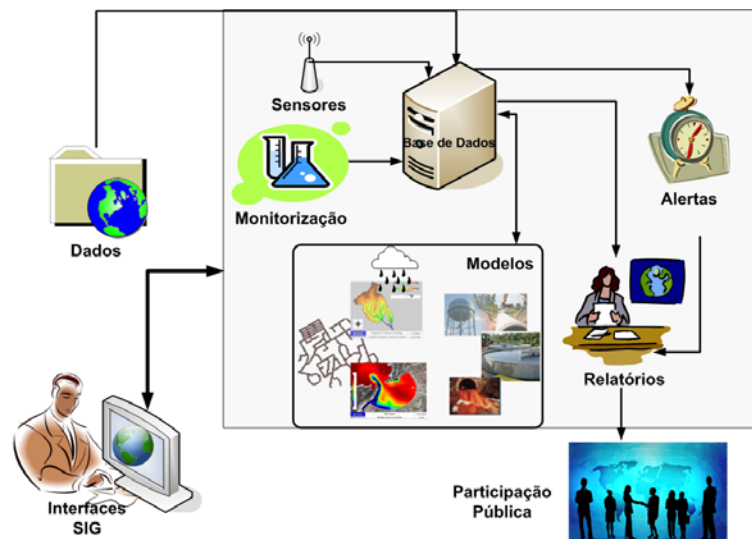

Figure 1 – General architecture.

2   REAL-TIME PROCESSING

Presently, the availability of large quantities of data, acquired in real-time by telemetry systems, is quite common. In order to transform this data into useful information, it is necessary to manage it, organise it and report it. AQUASAFE platform is specially indicated for these tasks, due to its capability to integrate and process data and models results for different types of problems: water losses and quality, energy, etc. For example, it is possible to establish integrated flow calculations or statistical pressure variation analysis over pre-established periods and to search, automatically and continuously, time discrepancies that may indicate anomalous situations like leaks or unplanned operations.

It is also possible to integrate all information gathered within water quality monitoring campaigns and report it based on parameters or system geometry, or to seek relations with other system variables (e.g. pressure, flow, speed). The platform allows the creation of screens with real-time data (dashboard type) to synthesise obtained information from intelligent network sensors or resulting from the integration of this type of data with mathematical modelling results.

Modelling tools may provide a relevant contribution to the system's assessment phase, but their full potential is put to the test when using the monitoring component. A fully functional calibrated model is the equivalent of having virtual sensors at any point of the network, able to analyse not only what happens, but also to forecast events to come.
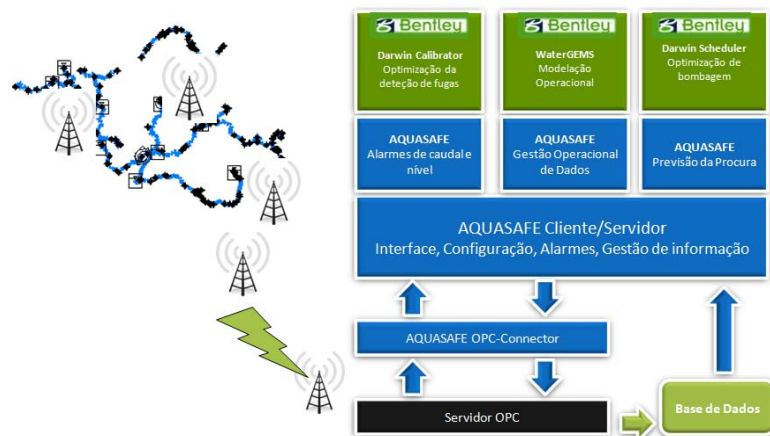

Figure 2 – Example of AQUASAFE integration between network model results and telemetry data

The availability of a management structure controlling all the necessary information flow, in order to obtain an adequate response in the context of typical water distribution problems, such as pressure, leaks, energy or water quality, constitutes a significant added value.

On the other hand, taking into consideration that different operators exhibit different technological levels, technical capabilities and specific problems, a structure such as this can only be successful and useful when it is able to provide tailor-made solutions to allow the use of the client's already existing infrastructures (databases, sensors, numerical model structure, etc.), as well as personalised interfaces according to the profiles of different users. This is one of the characteristics of the AQUASAFE system.

3   SYSTEM APPLICATIONS

AQUASAFE has multiple applications (in all types of systems that need to manage data to produce information), having been used to support management and operation of water distribution and wastewater networks, to deploy an early warning system to critical conditions in the water intake of the Sines thermoelectric plant and to integrate meteorological and oceanographic data and forecast models to support port operations.

Apart from these applications, the team which is responsible for the development of the AQUASAFE platform already had a significant experience in this area of expertise, proved by the system developed for CLABSA (Barcelona wastewater utility), to integrate results from the wastewater network model (based on MOUSE model), the telemetry network (real-time measurement of network flow), precipitation data and coastal models (currents, waves and effluent dispersion), to produce water quality forecasts regarding the Barcelona beaches. The system works in real-time, producing forecasts every 20 minutes, with the ability to issue automatic alerts in risky situations, following operation-defined rules (*Figure 3*).

This system is working for three years in Barcelona, having been implemented also in other locations such as Biarritz, showing great robustness. Although this application must not be mistaken with AQUASAFE, since it was developed to meet specific requirements and accordingly to client defined specifications, the acquired know-how and the perception of the problems associated with this type of systems exploitation have helped to sediment the requisites which have been the basis for AQUASAFE development.
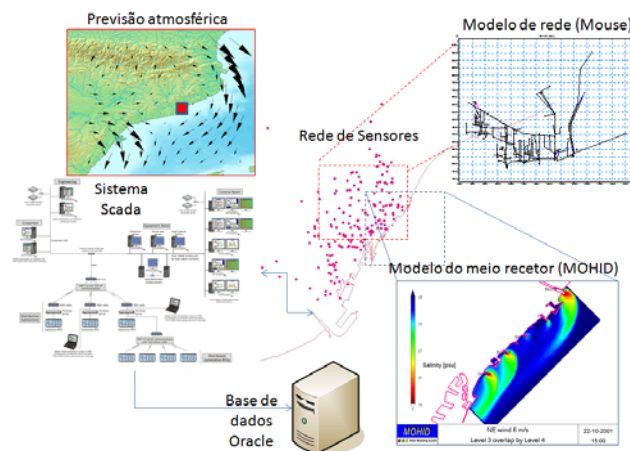

Figure 3 – General scheme of the COWAMA system implemented in Barcelona

3.1   The *Itaquera* system

The *Itaquera* system is included in the *São Paulo* Eastern Water Operation Division (SABESP), having been selected for a pilot implementation because it is one of the most advanced water distribution systems of *São Paulo*, in terms of modelling and measurement equipments. This network comprises nearly 500 Km of pipes, with diameters ranging from 50mm to 120mm. The network is divided into 4 measurement and control zones (DMZ) which cover around 150 Km each (the objective is to expand it to 15 zones in the near future). For each of these zones there is real-time information (*see*

Figure 4). The implementation objectives of AQUASAFE platform were centred in the support of the operational management of the network and energy analysis.
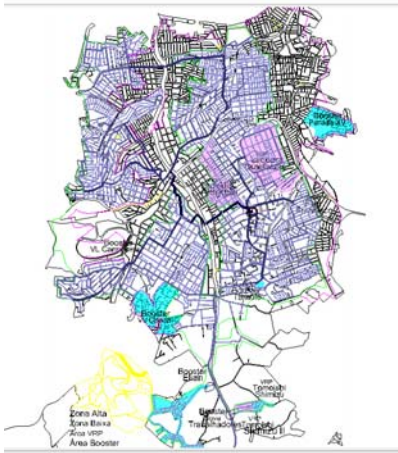

Figure 4 – General scheme of the *Itaquera* network

One of the system's great relevance aspect is the verification of the correct pumps functioning. In this case, data acquired by the flow sensors placed at the exit of the pumping stations is compared in real-time with the theoretical pump curves, allowing the timely detection of eventual efficiency losses in the system or expected deviations (*see Figure 5*). This is an analysis of great utility to management entities, because the verified real efficiency may often lead to conclusions that justify an equipment substitution.
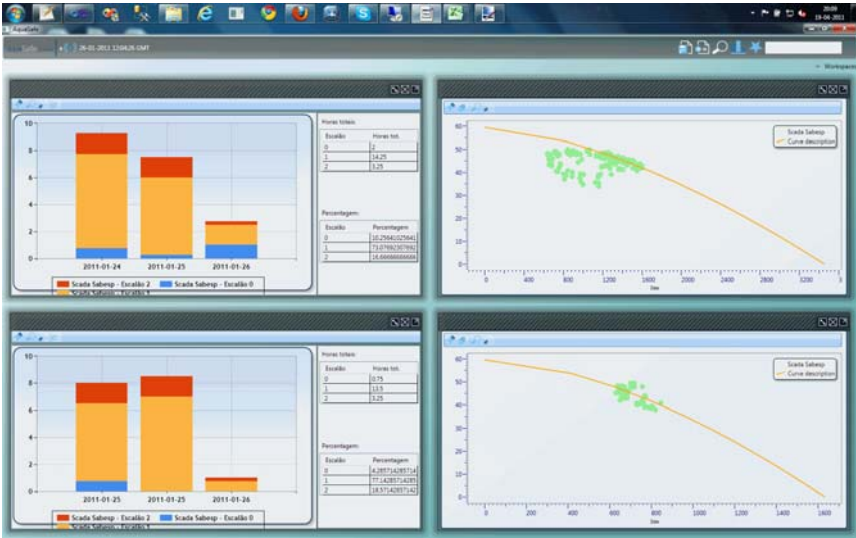

Figure 5 – Assessment of pumping efficiency. System application to Itaquera network (SABESP).

Based on the existing system, some emergency water quality simulations were also performed, like the interruption of disinfection stations due to power failure. By comparing simulated and measured data one can create alerts to identify the system's critical zones.
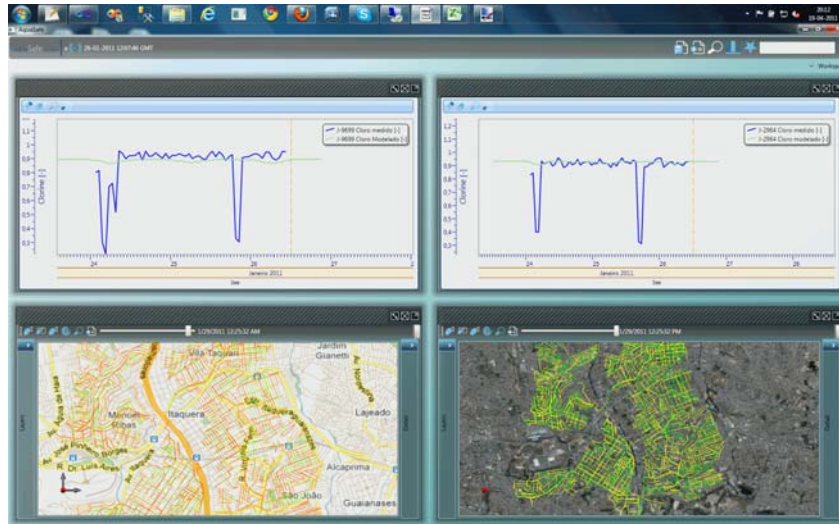
Figure 6 – Simulation of water quality problem caused by power failure in the disinfection zones. Graphics show the comparison between measured (blue) and simulated (green) data; maps show critical zones (integrated and time variable values) with concentrations below 0.2 mg/l.

3.2 Energetic efficiency analysis

Aiming to increase the energetic efficiency of systems, an application was developed within AQUASAFE tool, to optimise pumping cycles as a function of a detailed consumption pattern and pump functioning efficiency analysis, with the purpose of minimising energy consumption or costs. This application uses the potentialities of the Darwin Scheduler tool, integrated in the hydraulic model Bentley WaterGems. By this way it is possible to convert this sort of applications to a real-time tool that feeds on data from *scada* systems, producing optimisation scenarios to be transmitted to the operation centre.

With this perspective, an information flow and analysis scheme was implemented with detailed analysis of consumption patterns in reservoirs (in terms of daily, weekly and seasonal variation). This analysis is based on data acquired by sensors placed on the network, on the comparison between pump theoretical curves and their real functioning and on the simulation of alternative operation scenarios that may allow energy cost reduction, while maintaining the system's performance level to consumers (*see Figure 8*).

Based on this analysis and the restriction of the minimum admissible levels for reservoirs, it was possible to perform alternative scenarios simulations for pump functioning, to ensure an optimised distribution of the pumping periods, profiting from the cheapest fare periods. The result of this is presented in *Figure 9*, showing that the reprogramming of pumping periods in itself makes it possible to reduce pumping during periods of more expensive fares and increase it in cheaper ones.
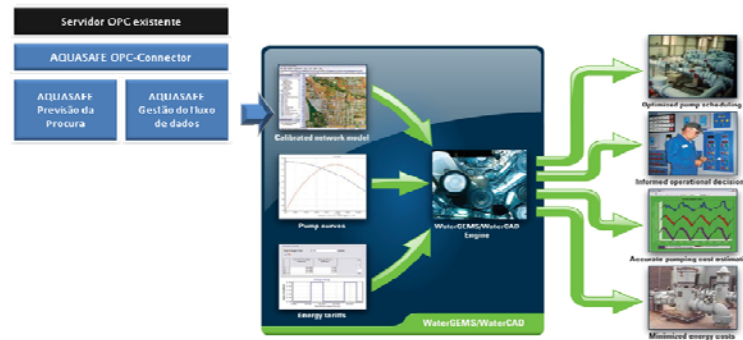
Figure 7 – General integration scheme between measurements and models, to optimise the exploration regime

Figure 8 – Alternative scenario analysis by reprogramming pumping periods. At the top, the left image shows the present regime and the right image shows an alternative. Below, one may see pump functioning periods and reservoir levels.

The energy and cost saving of the pumping optimisation module helps to find the best strategy to optimise the programming of pumping stations, based on cost or energy minimisation. This process makes it possible:

- To identify old pumps that have become inefficient due to the evolution of the system's characteristics;
- To find pump combinations that do not work well together;
- To compare constant and variable velocity pumps;
- To calculate energy cost for different functioning rules, to find the best strategy;
- To optimise pumping schedules automatically;
- To perform functioning analysis as a function of energy price variation throughout the day;
- To perform pumping analysis as a function of storage capability and system characteristics.

Based on this approach, it is possible to test optimisation scenarios in real-time, as well as to assess their impact, taking existing records into consideration. This way, solutions may be tested, verifying their impact and advantages in case they had been implemented in the analysed period, thus contributing to the decision making process.

3.3 Consumption pattern analysis

Scada signals may be analysed by means of a time series analysis tool, developed specifically for AQUASAFE platform. This tool allows the spectral analysis of the measured signal, identifying the most important time scales (*see Figure 6*). The analysis result is a 2D matrix in which one dimension is time and the other the percentile. It is possible to represent measured signals taking as a reference the time series that show the different percentiles that can be associated to the measured data series.
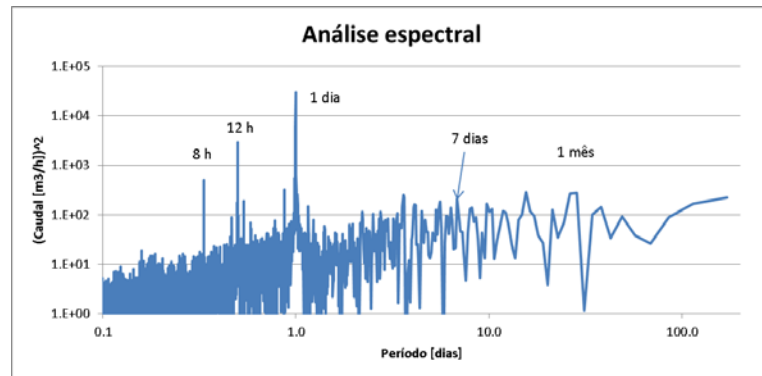

Figure 9 - Spectral analysis of a consumption curve in a specific point at *Itaquera* (São Paulo - Brazil). The analysed series displays an hour frequency, ranging from April 2010 to April 2011.

This tool also allows detailed frequency analysis that may be used to define alerts limits or simply to establish security bands, in order to determine whether measured values are normal or not. Sensor data is incorporated in the analysis as it is acquired. The frequency analysis may be performed for the whole time series, a time window centred on the analysed period, or a time window of a past period. For each time window, one may perform analysis of all data, by time of day (the latter being the most correct option, in case there is a clear daily pattern) or by week (to use when there is a clear weekly pattern).

The spectral analysis of the measured consumptions in a network point at *Itaquera* (*São Paulo –* Brazil) presented in Figure 9 shows there is a clear daily pattern in the time series. This result also reveals that, for the considered period, there is not a clear weekly pattern (*see Figure 10*).
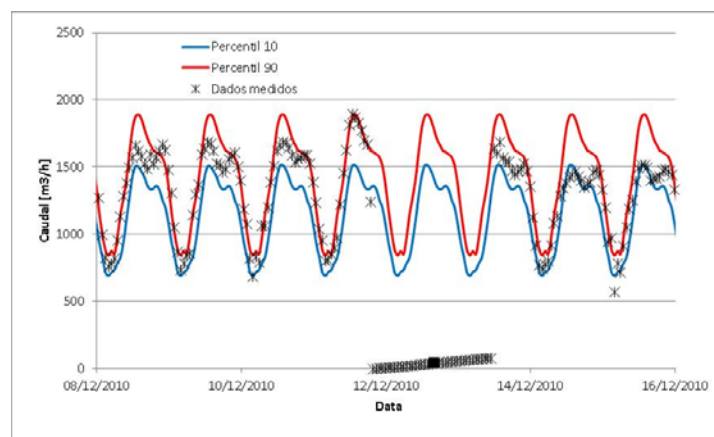

Figure 10 – Consumptions in a system point at *Itaquera* (*São Paulo –* Brazil) from December 8th to December 16th 2010 (dots in black). The continuous lines represent the result of the daily frequency analysis. The blue line represents percentile 10 and the red line represents percentile 90.

4   CONCLUSION

AQUASAFE incorporates useful capabilities to help water utilities to take more advantage of the acquired data and add value to it by means of advanced analysis systems and of its use to produce forecasts based on simulation models. By this way it is possible to provide system operatives and managers not only personalised reports on the network's maintenance needs, but also a perspective of potential problems that may arise, if current conditions persist. In these situations, it is possible to assess alternative intervention possibilities, by performing scenario analysis.

In this paper a description of some of AQUASAFE's capabilities is described by means of its use to support specific client requisites: early detection of pumping systems malfunctioning and optimization of pumping routines to save energy. In order to provide support to these requests specific data analysis routines were developed and the use of optimization modelling systems based on the use of Bentley's Darwin Scheduler was demonstrated.

5   ACKNOWLEDGEMENTS