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# WATER HAMMER MONITORING IN REAL WATER DISTRIBUTION SYSTEMS

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ABSTRACT

The present research work is developed under the framework of TRANSMITWATER (TRANSient Management & mITigation solution for WATER utilities), which is an on-going three-year project carried out by the consortium CETAQUA, Aigües de Barcelona and AQUATEC. The project consists of the development of a Decision Support System (DSS) to reduce pipe failures caused by transient pressures occurred in daily water network operation by water utilities. This DSS encompasses a number of tools for analyzing transient's impact and mitigation approaches, namely a pipe failure tool, an assets life expectancy tool, and an investment planning tool, including a methodology for locating transient pressure sources. The scope of the present work focuses on the later, benefiting on the one side from a monitoring campaign to capture and characterize transient events, and on the other side on hydraulic modelling tools for their description and explanation.

**Keywords:** Transient flows, water distribution systems, water hammer, decision support system, monitoring campaign.

## 1. Problem statement and research objectives

Water supply systems operation and management become a rising challenge with the growth of urban areas, the aging of the water assets, climate change and water scarcity related issues, making reduction of water losses a mandatory effort for water utilities. Pipe failures are often attributed to factors associated with pipe conditions and external factors (loadings, roots, vandalism, etc.). In addition to these, intensive pipe cyclic pressure variations under steady and unsteady state hydraulic conditions contribute to structural degradation of pipelines, accelerating wear and tear and subsequent fatigue crack growth. In scientific literature there is extensive research on the short-term impact of extreme pressure transients (i.e. water hammer), however the medium- and long-term impacts, involving fatigue-related cracks and system deterioration, have been traditionally overlooked. This research aims at covering this gap by means of understanding the main causes of transient flows in water distribution systems and developing a tool for detecting, locating and characterizing the transient sources on the basis of a methodology that combines a transient pressure monitoring and a physics-based detection algorithm.

## 2. Monitoring campaign

With the goal to gather representative data for TRANSMITWATER project, two consecutive monitoring campaigns were conducted between the periods November 2024 to January 2025 for the first and March 2025 to June 2025 for the second in the network operated by Aigües de Barcelona. The first case-study (Fig. 1-left) named Transport_1 corresponds to a Pressure Management Zone (PMZ). This system consists of a total pipe length of 51.5 km, with pipe diameters ranging from 50 to 900 mm. The system includes 6 pump stations, 5 distribution tanks and the pressure is regulated by means of 5 pressure regulating valves. The second case study (Fig. 1-right), Distribution_1, is a district metered area (DMA) consisting of a total pipe length of 25.1 km predominantly composed of metallic pipes (81%) , with lesser lengths of plastic and alternative materials of HDPE, and with diameters ranging from 32 to 400 mm. The monitoring campaign is based on a cloud of 21 pressure sensors distributed in selected sites first in Transport_1 and then in Distribution_1. The acquisition system used is InflowSense$^{TM}$ from Inflomatix, which can cope with a maximum pressure of 20 bar at 0.1% accuracy and a maximum data sampling rate of 128 Hz.

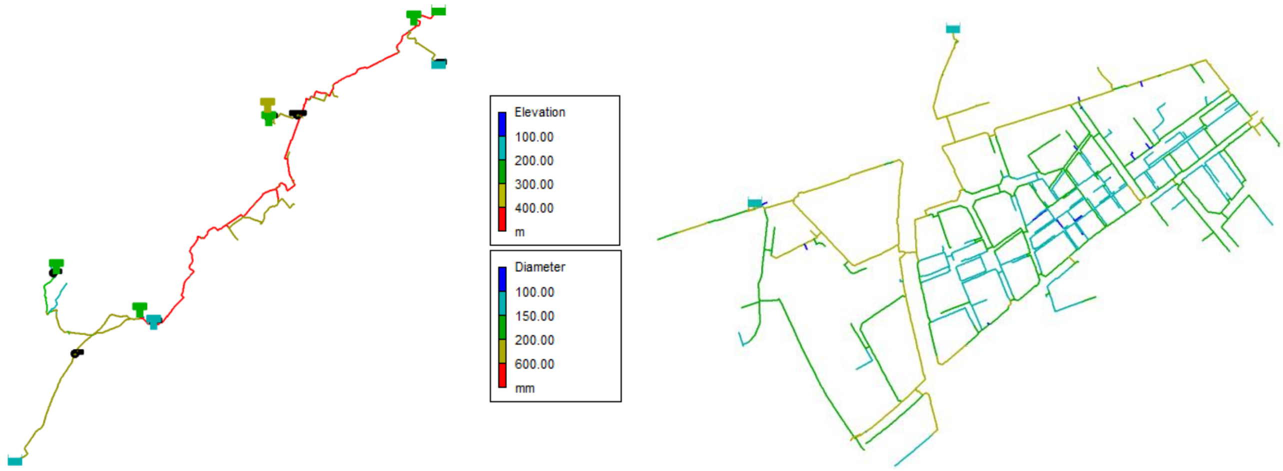


**Fig. 1.** Schematic of Transport_1 case-study (left) and Distribution_1 case study (right).

## 3. Data analysis

### 3.1. *Transport_1 case-study, PS_1 pumping station*

A first analysis of the data acquired at Transport_1 PMZ enabled the identification of transient sources related with regular pump operations, flow regulating and pressure reducing valves. On this basis, a more detailed analysis involving the hydraulic modelling of the largest pump station, i.e. PS_1, was carried out by means of Allievi software (Abreu et al., 2012). As a result of a tradeoff between computational power and domain discretization, Transport_1 network was trimmed and PS_1 hydraulic system was built in Allievi, including detailed pipe layout, pump units, flow regulating valves and hydropneumatic vessels. Figure 2 depicts a schematic of PS_1 system including pressure plots at the sampling points for the event on focus.

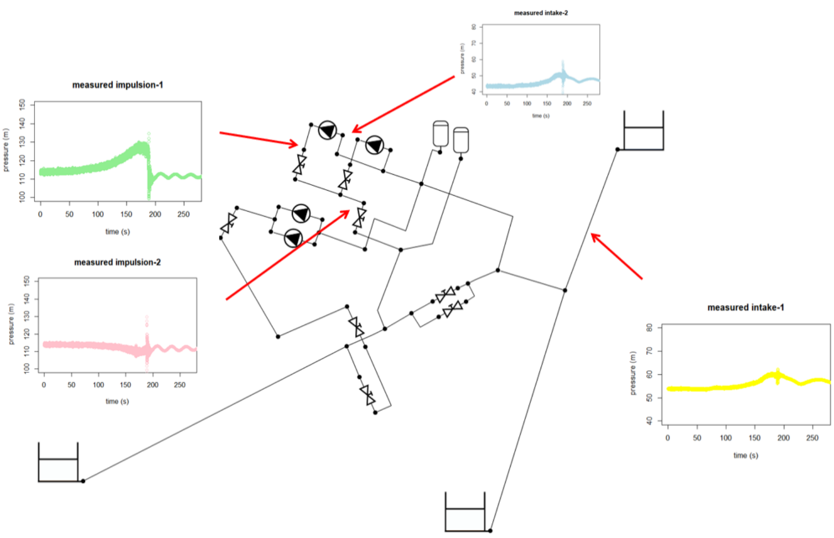


**Fig. 2.** Schematic of PS_1 pumping station and measurements of a transient event for a pump shut-down operation on the 15-01-2025

A manual calibration was carried out in the Allievi hydraulic model taking as reference the measurements shown in Fig.2 and adjusting system and operation parameters such as initial pressure conditions at system boundaries, pipe friction coefficients, initial inflation pressures in hydropneumatic vessels and valve maneuvers. Figure 3 shows the numerical output after this calibration for the four pressure measurements upstream and downstream the pump unit. Notice the good match with regard to the initial conditions at the four sampled points, while during and after the pump operation only the points at the impulsion side show a good agreement. The reason of this mismatch at the intake side has to do with the fact that the Transport_1 network was especially trimmed at the upstream side of PS_1 pump station, and only the main transport pipelines were partially represented in Allievi. Nonetheless, the model showed good performance with respect to the description of the pump station system behavior, and enabled a further testing considering mitigation measures under different operation scenarios.

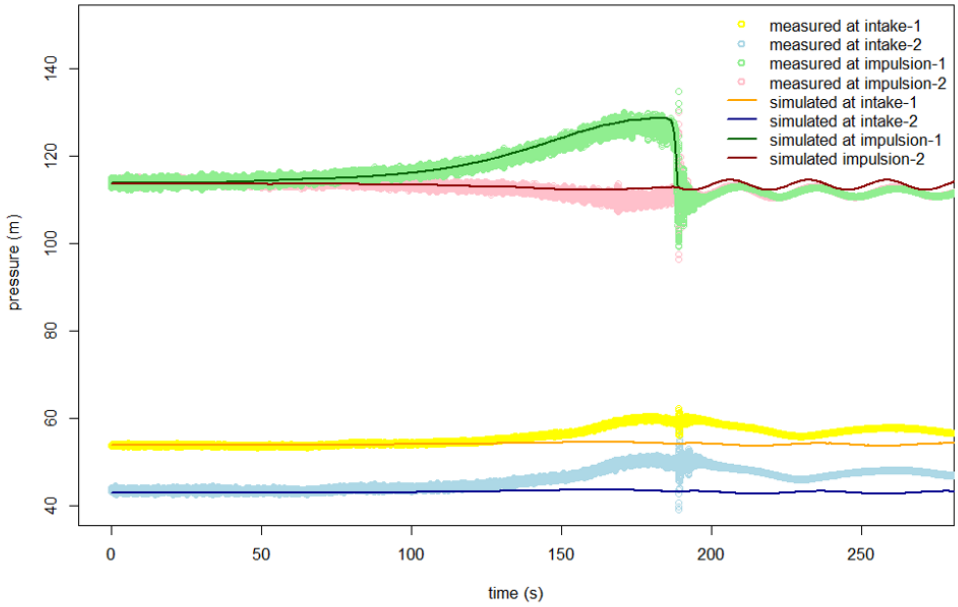


**Fig. 3.** PS_1 model output after calibration at the sampling points.

### 3.2. *Distribution_1 DMA*

The monitoring campaign at *Distribution_1* DMA enabled the identification of a number of transient sources in a rather complex looped network. Flow regulating and pressure reducing valve maneuvers as well as large consumers were determined as main causes of transient events in the network. Two different transient events, both captured on the 9-4-2025 are depicted in Fig. 4: one related with a sudden demand variation from a large consumer (left); and another one related with a pressure reducing valve maneuver (right). Notice that a sharp and rapidly attenuating transient wave is generated by the large consumer, while a smoother pressure variation is associated with the valve maneuver. Even though the slow maneuver has a quasi-steady system response, the associated pressure variation affects throughout the DMA.

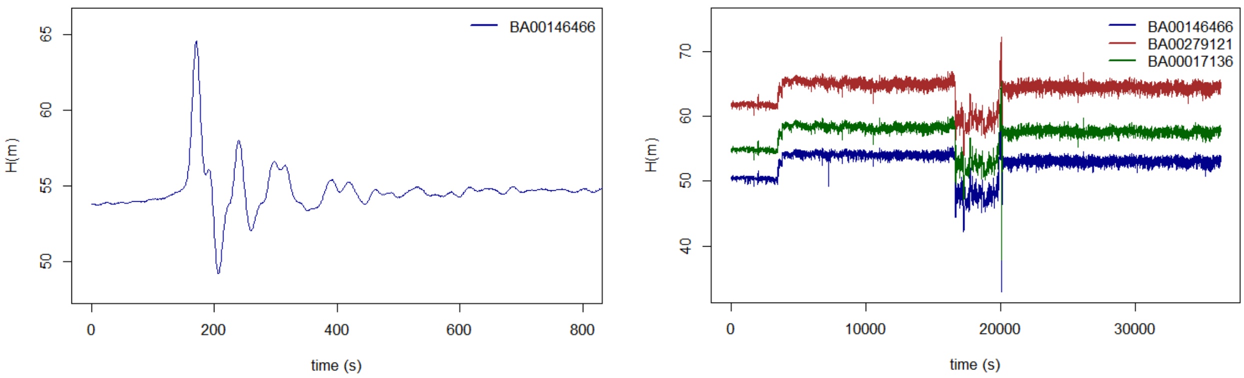


**Fig. 4.** Observed transient events for a large consumer demand variation (left) and a flow regulating valve maneuver (right)

For a more in-depth analysis of the observed transient events, an hydraulic model by means of TSNet library for Python (Xing and Sela, 2020) is planned to be built with the intention to firstly understand, and numerically describe, the generation and propagation of the identified transient events throughout Distribution_1 network, and secondly to evaluate mitigation strategies for the main characteristic transient events.

## 4. Conclusions

The two monitoring campaigns carried out in two different sites of a network operated by Aigües de Barcelona, by means of an exhaustive cloud of high frequency sensors, enabled the gathering of relevant data and an in-depth description of transient events related with pump operations, valve maneuvers and demand variations. Hydraulic models using free and open-source software have been used to extend the observations and provide a more complete picture of the transient waves propagation. Even though the calibrated Allievi model presented a good description of the system behavior, numerical challenges were pointed out with regard to domain discretization and model accuracy. As a next step a TSNet model is planned to be built for Distribution_1 case-study, which will be used to assess the observed transient events and evaluate mitigation measures.

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