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Occurrence of transients in water distribution networks

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Abstract

The common existence of pressure transients in operational water distribution systems (WDS) requires their characterisation and assessment of their impact. This paper performs such characterisation by evidencing the occurrence and the differences in pressure transient behaviour in complex WDS. Ten samples of continuously recorded high resolution pressures from diverse networks and sources were analysed. The presented pressure traces show regular and occasional pressure transient waves in various complex networks. Histogram analysis of the rate of change of head provides some insight into transient behaviour in these sites. Although there was no distinct correlation between network characteristics (ie. length, diameter, age) and transient behaviour, network complexity was observed to change the transient characteristics. Transient characteristics were observed to be strongly influenced by likely sources, in particular commercial customers. The data highlights the need to understand, quantify and characterise transients and hence link to possible impacts, such as structural or water quality failures.

Keywords: water distribution system; transients; characterisation

1. Introduction

Water distribution systems (WDS) are complex networks whose main function is to maintain a reliable safe supply of water. Current regulation of WDS in the UK requires monitoring of pressure in networks, usually undertaken at 15 minutes intervals. This resolution is not fast enough to capture changes in pressure due to the water hammer (pressure transient) effect; therefore the current knowledge of the existence of these fast events in operational networks is largely unknown.

Some studies highlighted the fact that the presence of pressure transient waves are actually seen in operational and complex WDS [1–3], therefore these systems should no longer be considered as static or pseudo-static. This paper adds further evidence to support this statement and presents one possible way to analyse such changes. It provides information about the pressure transient occurrences, nature and the importance of the possible sources of transients in operational WDS.

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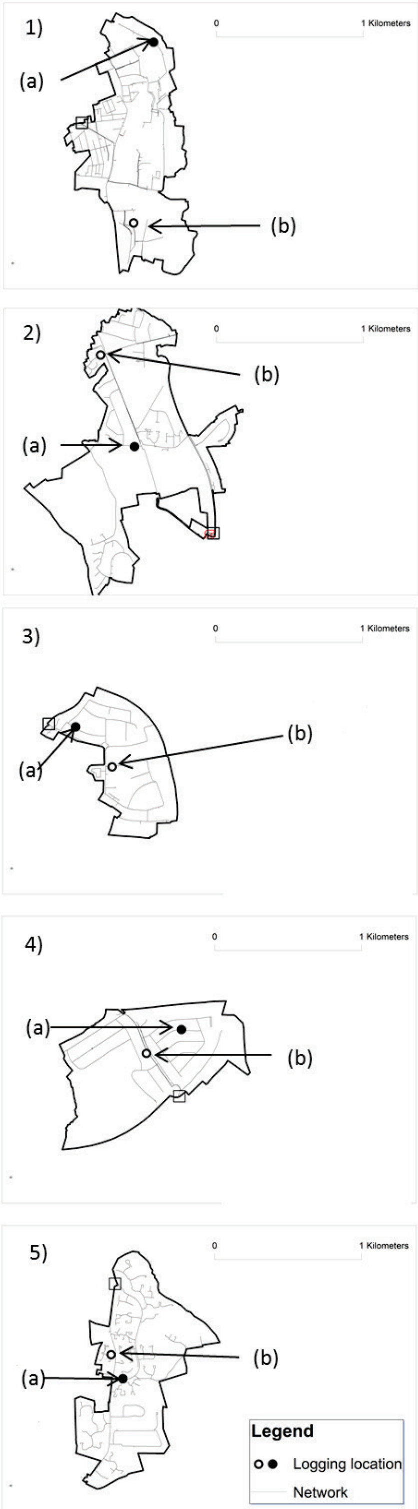

Figure 1. Network configuration for monitored sites, site boundaries in bold. (1) Site 1, (2) Site 2, (3) Site 3, (4) Site 4, (5) Site 5. Two monitored points per each site are marked as a) and b). Rectangles mark the inlets to the DMAs.

2. Background

The importance of understanding transient behaviour is due to the damage that transients may be causing to our vital WDS. There are two possible categories of damage from pressure transient events. The first has been largely documented in the literature as a catastrophic failure due to high magnitude force caused by fast pressure transient waves. These events were usually seen in large pumping mains and caused damage to the water network or equipment [4, 5]. In these scenarios the casual link between the failure and the transient is easy to determine. The second is the fatigue-like failures due to prolonged impact of smaller magnitude transients over a long time. This cause of fatigue has been recognized [6] but it has not been possible to fully explore. This is primarily due to the large time scales involved, failures may require many thousands of transients, and lack of long term high quality transient data. There is also a potential for transients contributing to water quality failures [7–9].

Real WDS systems tend to be large, complex and exhibit a large amount of uncertainty. Therefore current understanding of pressure transient behaviour is limited to simple networks. It is known that pressure transient magnitudes vary with factors such as a path, a length of the conveyance pipeline, diameter, thickness and type of a pipe (viscoelastic effect) [10, 11]. There is also a perception that network complexity should dissipate transients, while some modelling work [12, 13] suggests the opposite. Due to the lack of available high resolution transient data it is, to date, difficoult to categorically confirm or refute the results of the modelling studies and generalize to more networks.

There are a number of studies that consider the potential sources of transients. A comprehensive list of such can be found in the literature [14, 15]. Transient waves can be caused by any operation (planned, routine or accidental) which rapidly changes steady-state conditions of fluid flow in a pipe. It is known that a rapid closure of a valve and malfunction of other network instrumentation can cause pressure transients, therefore a number of occasions and possible sources of transient exists in operational WDS. Pump operating (switching on and off) is one of the commonly recognised and the most frequently analysed transient source [16–18]. Industrial activity can also produce large numbers of transients due to water being drawn at a fast rate from the network. The relative importance of such impacts and their likeness to occur in live WDS, have not been sufficiently documented and characterised yet.

The aim of this study was to explore the occurrence of pressure transients in several operational WDS and any site specific characteristic that may correlate with network properties and possible dissipation effects. This paper will also explore methods to better present and quantify the transient response of a WDS.

3. Method

In the UK the WDS are subdivided into District Metered Areas (DMAs). The WDS investigated in this paper include five typical UK DMAs. Sites were chosen to represent the complexity of the water network with looped and branched connections included, see Figure 1. Two of these sites were gravity fed (Figure 1 Site 1 and 5) and the remaining three were supplied by a pumping station (Figure 1 Site 2, 3 and 4). Only one site was directly supplied by a pump (Site 2, Figure 1). Site 3 was supplied by a pump, which was about 5.72 km away from this site. This connection, however, was not direct and proceeded by series interconnected DMAs. The situation was the same in Site 4 with the pump in the distance about 5.66 km from the site.