Integrating hydraulic modelling and GIS for wastewater systems management. A case study

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INTRODUCTION

The increasing costs related to operation and maintenance of urban wastewater systems has led to a special attention of utilities in promoting studies to address the key problem of water infiltration, inflow and improper connections entering the separate drainage networks. This is a common and hard to predict operational situation that needs to be identified and minimized as it negatively affects the managerial conditions of the network and the downstream wastewater treatment plant (WWTP) efficiency.

Management difficulties in separate drainage networks seldom occur when unexpected groundwater inflow, stormwater infiltration, and flows from improper connections enter into the dedicated sanitary sewer systems. Although the consequences that improper flows may have on wastewater systems are known, the problem is difficult to locate and quantify.

The use of modelling tools is of special relevance to the planning, management and rehabilitation of these types of systems, which can be very useful for: (i) evaluating the capacity of existing systems in real time; (ii) testing alternative solutions to solve problems detected; or testing different procedures to operate the systems in extreme events scenarios.

The implementation of mathematical models for determining the hydrodynamics behaviour of dry-weather and wet-weather flows in sewers was applied in a small urban wastewater network of the city of Braga in Portugal (Figure 1). The free user program US EPA SWMM [1] was applied with the integration of GIS InterAqua information related to the wastewater collection system.

METHODS

The Espinho SWMM model construction for dry- and wet- weather wastewater flow adopted the standard procedures [2] and was developed for every month through a 2015-2016 period. To start, a field work was developed in order to determine subcatchments parameters and characteristics, and network components in the GIS InterAqua to automatically export the topological file into the SWMM model. Figure 2 presents the hydraulic and the hydrological model exported to the SWMM environment generated from the topological file.

As input data it was considered for each month:

- An average daily wastewater flow rate arriving the Espinho WWTP for days when precipitation did not occur (dry-weather flow estimation);
- A time series of the daily precipitation data collected by a raingage in the Espinho area (wet-weather flow estimation);
- A daily standard pattern for each day of the week to simulate the variability in drinking water demands and in rain distribution for flow rate calculations through a Time Pattern;
- A unit hydrograph (RDII) common to all months inserted at each node of the sanitary wastewater system, based on the R-T-K method for the infiltration process.

Calibration and validation for dry-weather (Figure 3):

- It was selected the month in which the lowest sum of the precipitation intensity was verified (July 2016), and the verification was performed for the equivalent month for a different year (July 2015).

Calibration and validation for wet-weather (Figure 4):

- It was selected the month in which there were precipitation events with different intensities and the highest sum of precipitation intensity (January 2016), and the verification was also performed for the equivalent month for a different year (January 2015).

RESULTS

Model construction

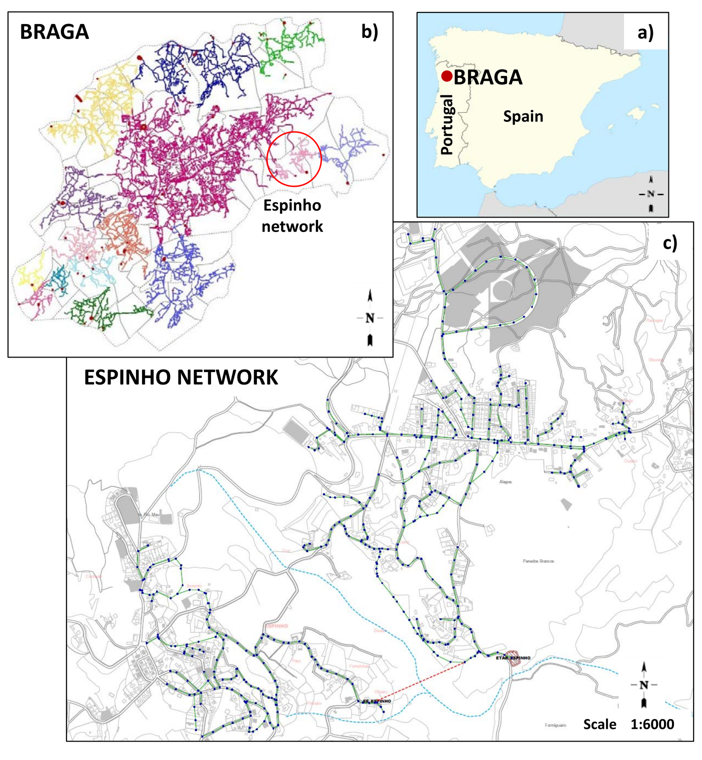

Figure 1 – Braga wastewater system representation: a) Study area location; b) Braga network subsystems highlighting the Espinho subsystem; c) Espinho wastewater network subsystem

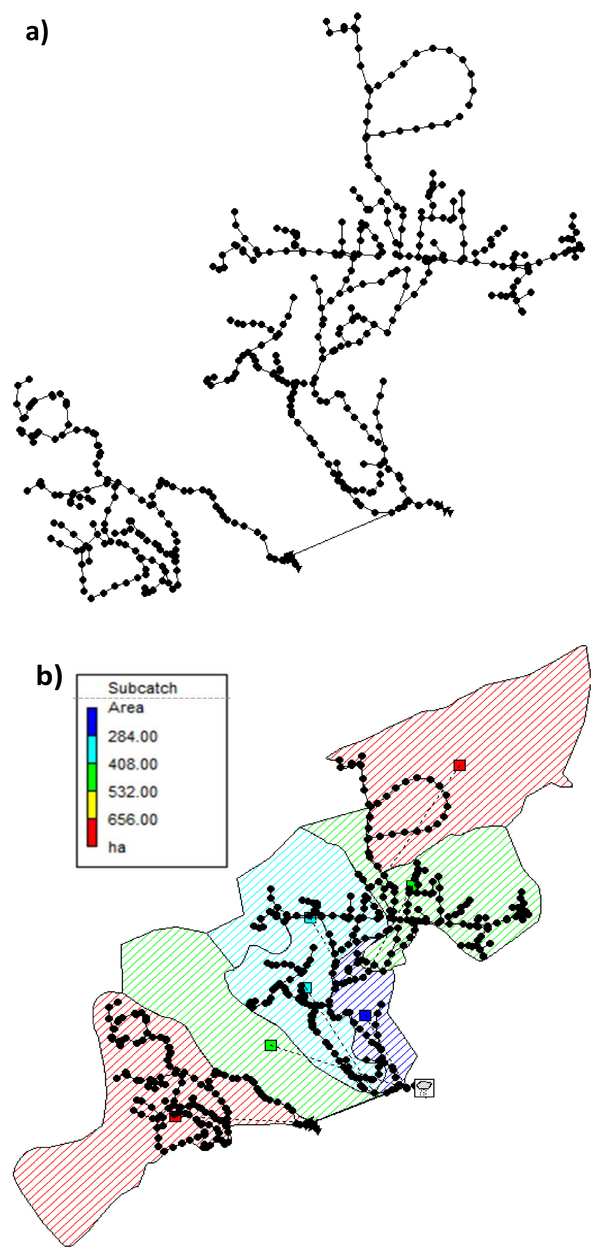

Figure 2 – SWMM models representation of Espinho wastewater subsystem: a) hydraulic model; b) hydrological model for 7 subcatchments.

DISCUSSION

Dry-weather flow

- Calibration
- Validation

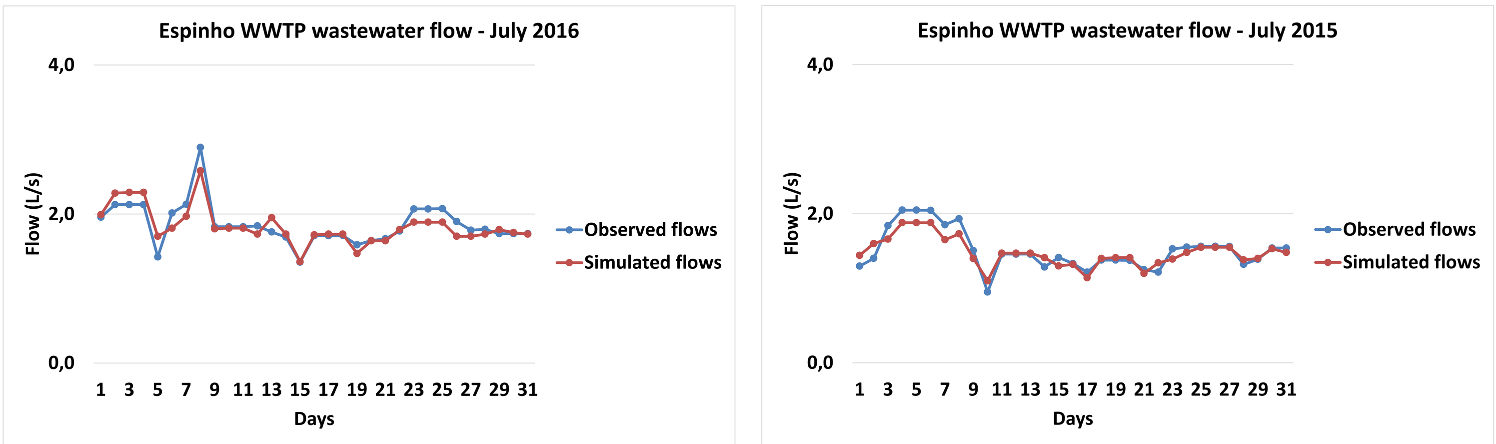

Figure 3 – Modelling results for Espinho WWWT wastewater flow in dry weather conditions

Wet-weather flow

- Calibration
- Validation

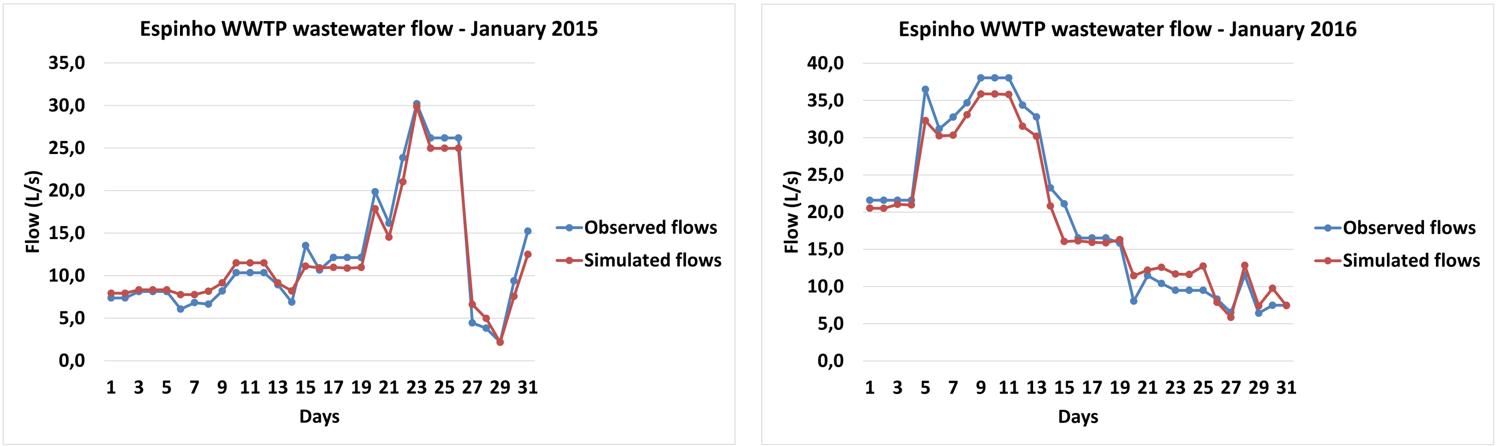

Figure 4 – Modelling results for Espinho WWWT wastewater in wet weather conditions

Although in global terms the model had good results with errors within the recommended limits, it was found that they were more consistent and accurate for dry weather flow rates than for wet weather flow rates. This fact can be justified by uncertainty associated to input data, namely:

- Use of average values of daily flows arriving to the WWTP;
- Inaccuracy of some flow values recorded at the WWTP, with emphasis on weekend values;
- Consideration of a uniform precipitation in the subcatchment area.

CONCLUSIONS

The main objective of this study was to analyse the hydraulic behavior of a drainage system in an urban area using computational instruments for dynamic flow modeling using the US EPA SWMM model that allowed the importation of existing GIS registration information.

Through the calibration and verification processes, it was observed that the adopted mathematical model successfully described the hydraulic behaviour of the wastewater drainage system. It is also worth noting that the use of dynamic modeling of urban drainage systems allows the support of management entities in the decision-making, operation and management of the system, as well as in project validation, where solutions can be found potentially more economical.

Thus, with this work, the potentialities that the mathematical models have for the management entity were demonstrated.

References: [1] Rossman, L. A. 2015 *Storm Water Management Model, Version 5.1: User's manual.* Water Supply and Water Resources Division, National Risk Management Research Laboratory, United States Environmental Protection Agency, Cincinnati, Ohio, USA.

[2] Walski, T.M., Barnard, T.E., Harold, E., Merritt, L.B., Walker, N., Whitman, B.E. 2007 *Wastewater Collection System Modeling and Design*, Bentley Systems, Exton, PA 19341, USA.

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