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Modelling of Sanitary Sewer Systems integrating Rainfall-Derived Infiltration and Inflow

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Abstract: Municipal wastewater management difficulties may occur when excessive wet weather flow determine sanitary sewer overflows (SSOs) mainly caused by the contribution of rainfall-derived infiltration and inflow (RDII) into sanitary sewers. This excess of wet weather flow can lead to serious problems to public health and environment as well as to suboptimal operation of wastewater treatment plants. This paper presents the implementation of a methodology based on hydroinformatic tools to determine the contribution of RDII in complex municipal sewer systems in order to establish adequate urban wastewater management policies that will effectively mitigate SSOs. USEPA SWMM, and digital cadastral database with field verification were applied in a simulation study of a small scale sanitary sewer network whose results will be used in a larger scale to create a city-wide model for wastewater systems management.

Keywords: Digital cadastral database; modelling sanitary sewer systems; municipal wastewater management

Introduction

Wastewater utilities often have management difficulties when excessive wet weather flow leads to serious impacts in public health and environment as well as disturbing operational conditions in wastewater treatment plants (WWTP). This phenomenon, resulting from rainfall-derived infiltration and inflow (RDII), occurs mainly due to defects in pipes and manholes (infiltration) and to illicit connections from downspouts, foundation drains or cross-connections with storm sewers (inflow), contributing to sanitary sewer overflows (SSOs) (Muleta and Boulos, 2008). These difficulties related to SSOs negatively affect: (i) the capacity and operation of sanitary sewer collection; (ii) the performance and treatment efficiency of WWTP; (iii) the risk of a public health hazards and environmental contamination.

This well-known wastewater managerial problem is very difficult to locate and quantify in practice since the needed adequate measurement equipment often entails unsustainable costs for utilities. Wastewater flow mathematical modelling integrating a digital cadastral database using Geographic Information Systems (GIS) constitutes a sound methodology in predicting sanitary sewer systems performance which is a critical issue within SSOs reduction and remediation programs. The application of this methodology to a network of coordinated geo-referenced system for solving the sanitary sewer overflow problem is presented in this paper.

Materials and methods

Study area

Mathematical modelling integrating a digital cadastral database for determining the hydrodynamics behaviour of dry- and wet-weather flows in sanitary sewers was applied in a network of the small district of Espinho in the city of Braga (Portugal). This sanitary sewer system serves predominantly residential areas and an industrial zone and covers a total area of 4.6 Km^2 with a population equivalent of about 1560 inhabitants and 525 dwellings (Figure 1). It is a fully geo-referenced sewer system which includes a WWTP and a Sewage Pumping Station (SPS) operating as an inverted siphon. The gravity sewer system wastewater is composed of PVC, corrugated PP and ductile cast iron pipes with varied diameters of DN 200, 250 and 315 mm.

Model initialization

An exhaustive field work was developed in order to determine subcatchments parameters and characteristics in the GIS InterAqua in order to export the topological file into the SWMM model. The characteristics of each subcatchment (area, width, pervious and impervious areas) were determined using the municipal land-use planning and the quantification of the subcatchment parameters were consulted in Rossman (2015). Other components like rain gage, outfalls, orifices and SPS were introduced in the exported model using SWMM interface. Figure 2 depicts the conceptual layout of the Espinho sewer system obtained after exporting the cadastral information and the hydrological model exported to the SWMM environment.

Data collection

The two components of wastewater flow (dry- and wet-weather) were modelled for 2015 and 2016 under standard procedures (Walski *et al.*, 2007), using measurements of the daily sewage flow rates arriving the Espinho WWTP, and the daily precipitation data collected by the rain gage located in the Espinho area. Suspicious records (e.g., in weekends and holidays) and missing data affected by metering failure, system disruptions or other factors that could cause abnormal wastewater flows were reviewed and corrected by interpolation

SWMM model application, calibration and verification

Estimation of dry-weather flow considered an average daily flow rate for days when precipitation did not occur, for each month. To this average daily dry-weather flow rate a daily standard pattern for each day of the week was associated to simulate the variability in drinking water demands through a Time Pattern. As for the wet-weather flow estimation, for each month, a time series was inserted into the model with real precipitation data registered by the rain gage. In order to associate the infiltration process to the model, a unit hydrograph (RDII) common to all months was inserted at each node of the sanitary wastewater system, based on the R-T-K method.

For the dry-weather calibration process 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). As for the wet-weather calibration process 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 from model calibration and verification demonstrated that the adopted mathematical model successfully described the hydraulic behaviour of the two components of wastewater flow (Figure 3).

Conclusions

Utilities are often facing the very difficult management problem of SSOs due to excessive wet-weather flow resulting from RDII. Remediation programs always imply rehabilitation/replacement or additional construction of expensive sewer systems.

Application of sound hydroinformatics tools for RDII estimation as proposed in this research work will enable utilities upgrade wastewater management in supporting RDII reduction and remediation programs that will effectively mitigate SSOs.

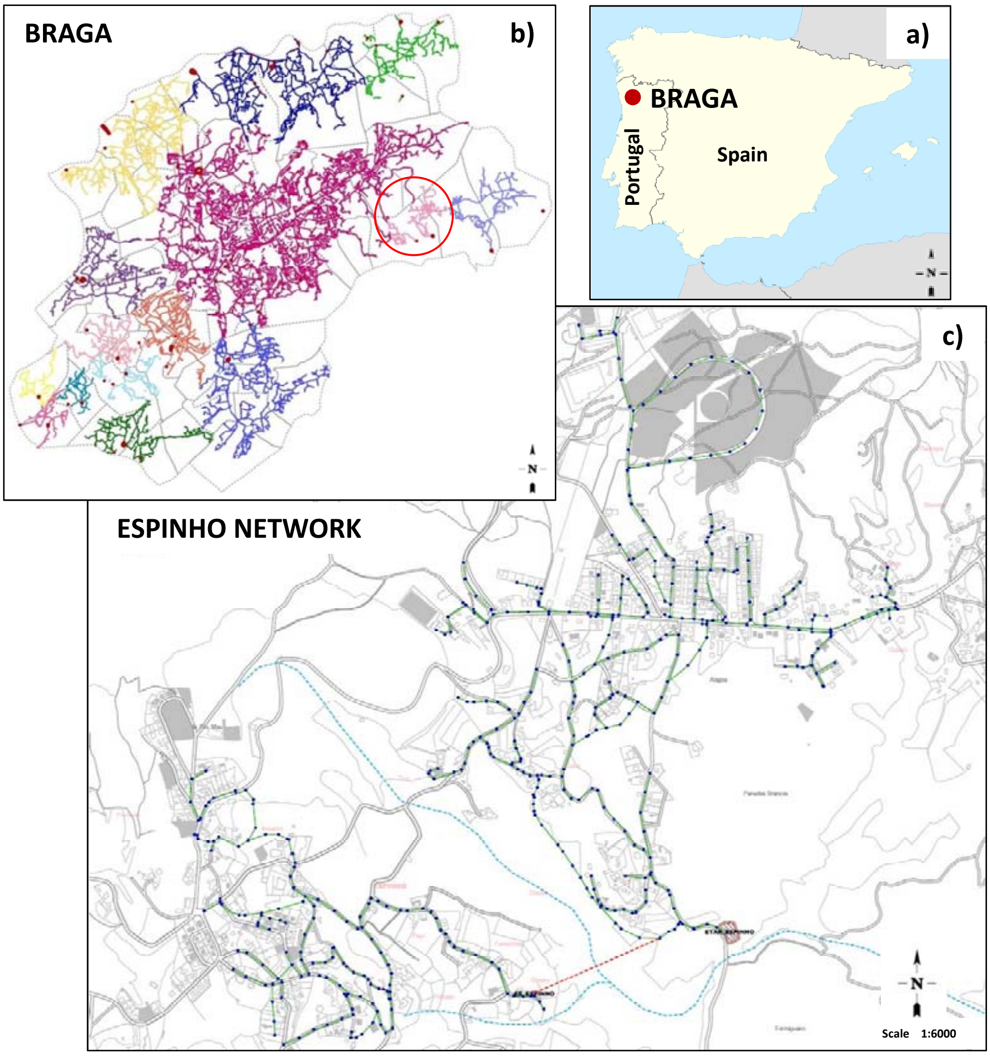

Figure 1 Braga wastewater system representation: a) Study site location; b) Network subsystems highlighting the Espinho subsystem; c) Espinho wastewater network subsystem.

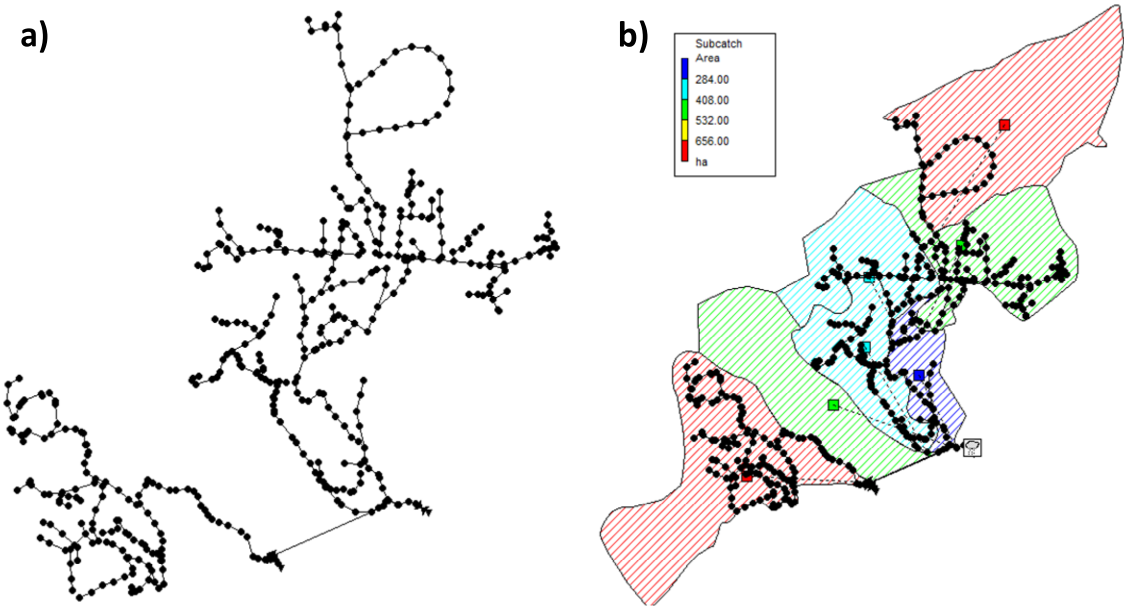

Figure 2 SWMM models' representation of Espinho wastewater subsystem: a) hydraulic model; b) hydrological model for 7 subcatchments.

a) Dry weather **b) Wet weather**

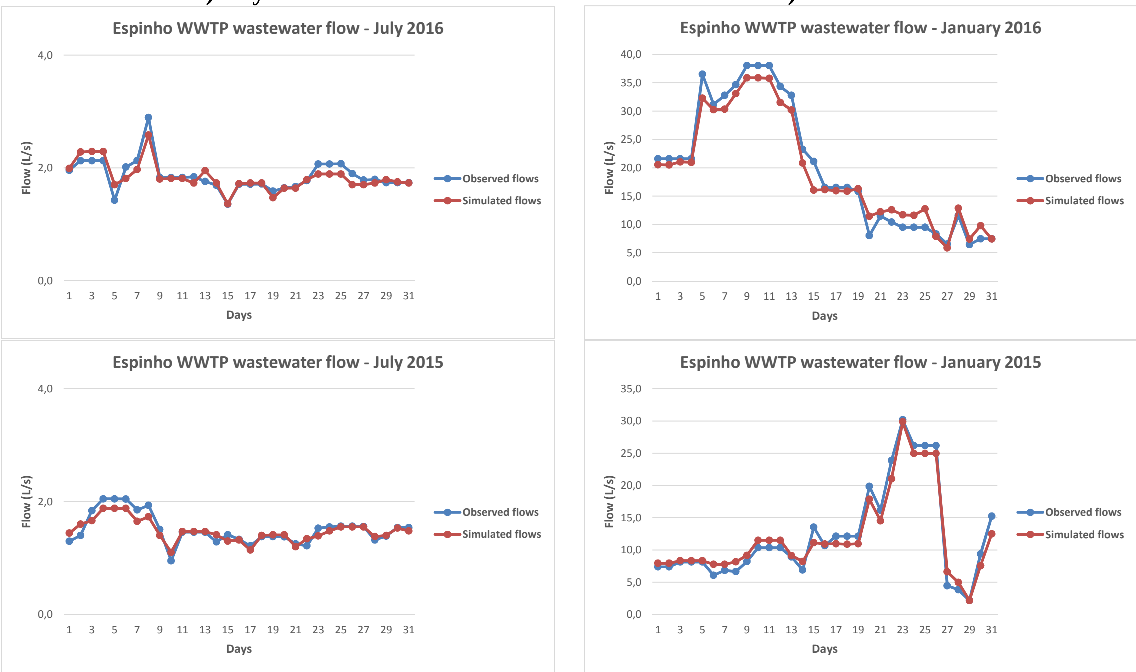

Figure 3 Modelling results: a) Espinho WWWT wastewater flow in dry weather conditions; b) Espinho WWWT wastewater in wet weather conditions.

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