Modelling Of Sanitary Sewer Systems Integrating Rainfall-Derived Infiltration and Inflow

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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) [1]. 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.

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 the small scale sanitary sewer network of Espinho (Braga, Portugal) whose results will be used in a larger scale to create a city-wide model for wastewater systems management.

METHODS

Mathematical modelling integrating a digital cadastral database for determining the hydrodynamics behaviour of dry- and wet-weather flows in sanitary sewers was applied in the Espinho network for 2015 and 2016 under standard procedures [2].

ESPINHO SANITARY SEWER SYSTEM

STUDY SITE

- Residential areas and a small industrial zone (~1560 inhabitants | total area: 4.6 Km^2)
- Fully geo-referenced in GIS InterAqua **(Figure 1)**
- Includes a WWTP and a Sewage Pumping Station (SPS) operating as an inverted siphon

MODEL INITIALIZATION

GIS → EXPORT → **SWMM**

GIS:
- Pipes
- Manholes
- Subcatchments
  - Using field work, subcatchments parameters [3] and characteristics (municipal land-use planning)

SWMM:
- Rain gage
- Outfalls (WWTP)
- Orifices
- SPS

(Figure 2)

DATA COLLECTION and MODEL APPLICATION, CALIBRATION AND VALIDATION

Dry-weather flow

- Daily sewage flow rates (WWTP)
  - Missing data corrected by interpolation
- Average daily flow rate for each month
  - Daily standard time pattern for each day of the week

Calibration → Validation **(Figure 3)**

July 2016 | July 2015

Lowest sum of precipitation intensity

Wet-weather flow

- Daily precipitation data (Rain gage)
  - Missing data corrected by interpolation
  - Time series for each month
- Unit hydrograph (RDII) for all months
  - Based on the R-T-K method

Calibration → Validation **(Figure 4)**

Jan 2016 | Jan 2015

Different intensities and highest sum of precipitation intensity

RESULTS

Model construction

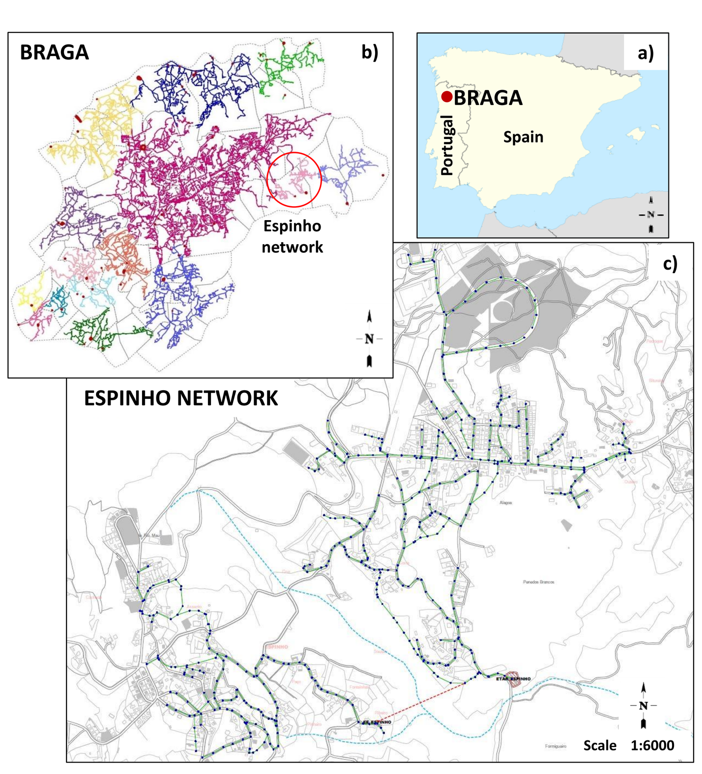


Figure 1 – Braga wastewater system representation: a) Study site location; b) Network subsystems highlighting the Espinho subsystem; c) Espinho wastewater network subsystem

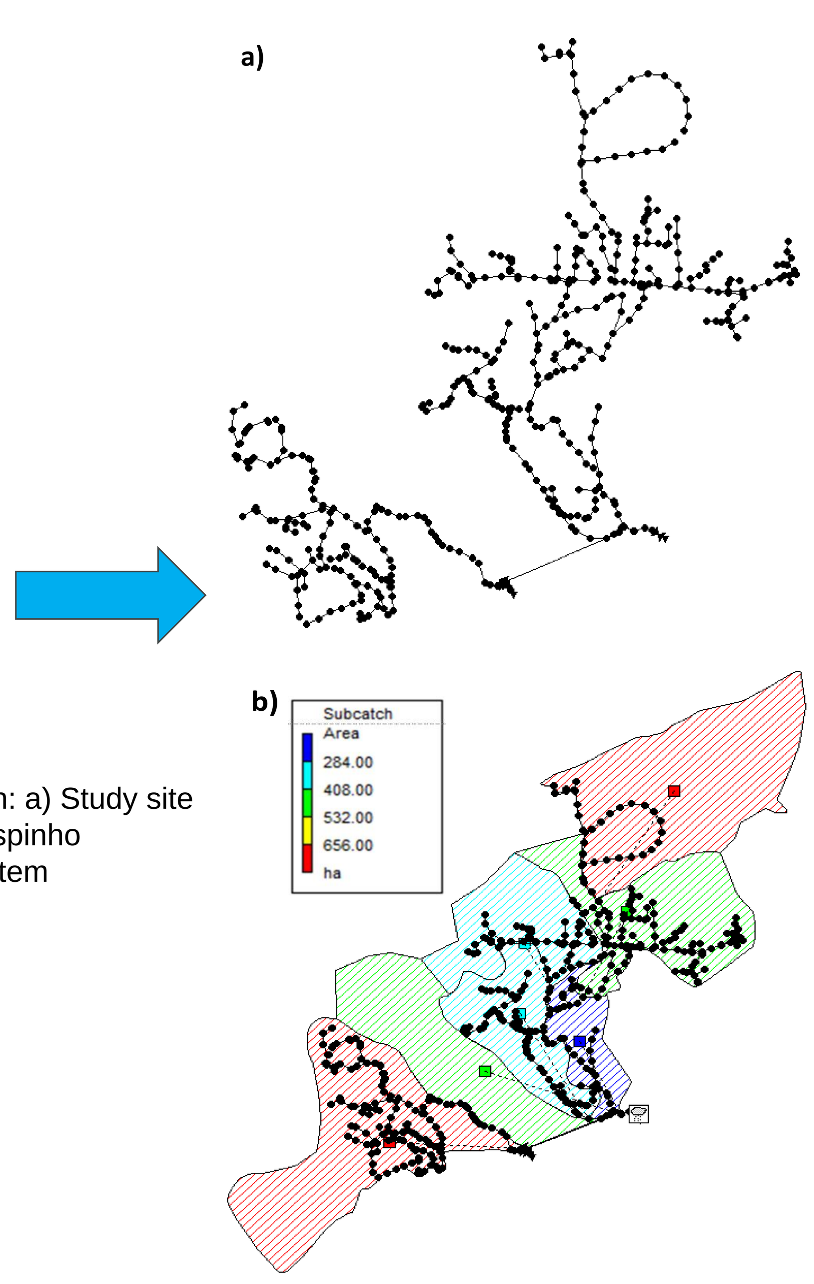
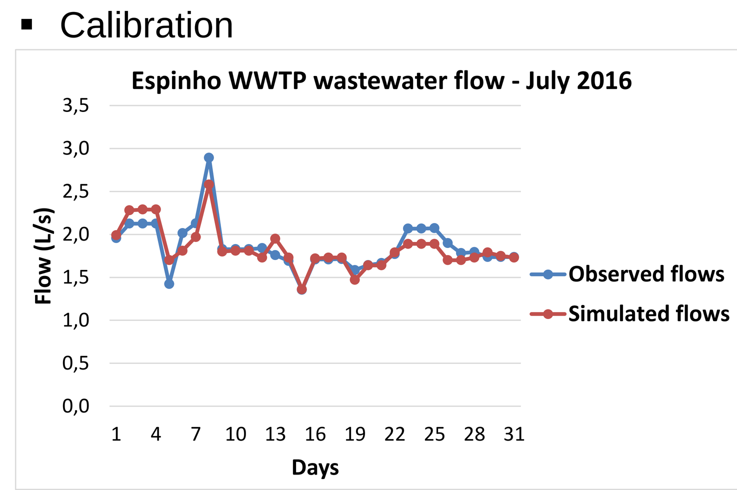


Figure 2 – SWMM models' representation of Espinho wastewater subsystem: a) hydraulic model; b) hydrological model for 7 subcatchments

DISCUSSION

Dry-weather flow

- Calibration



- Validation

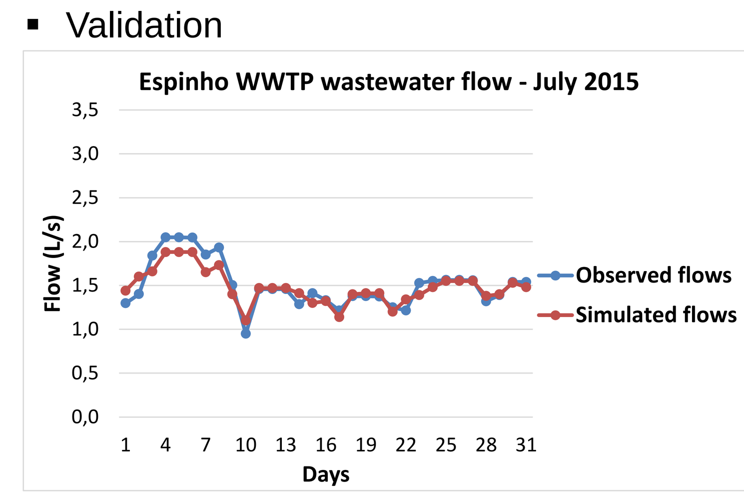
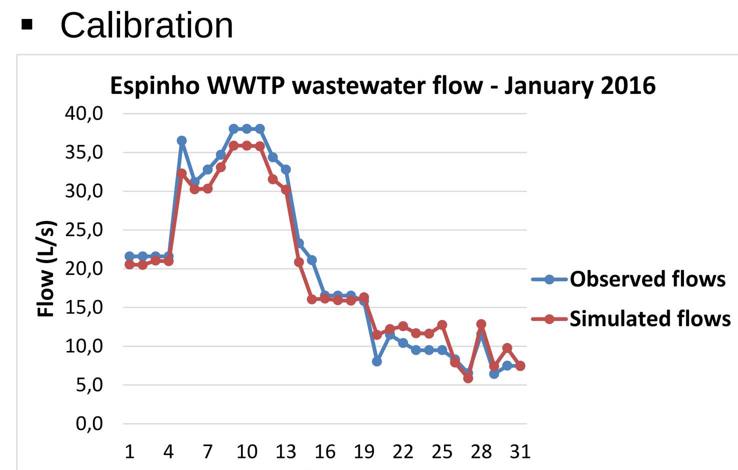


Figure 3 – Modelling results for Espinho WWTP wastewater flow in dry-weather conditions

Wet-weather flow

- Calibration



- Validation

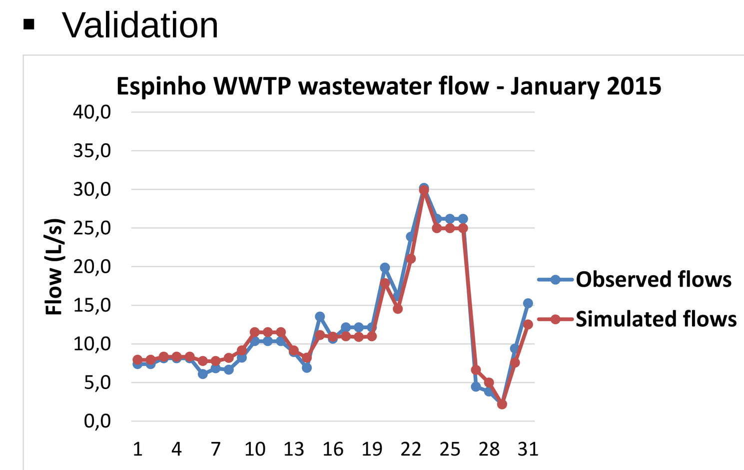


Figure 4 – Modelling results for Espinho WWTP wastewater in wet-weather conditions

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 at 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 behaviour of a sanitary sewer systems in an urban area using computational instruments for dynamic flow modelling using the US EPA SWMM model that allowed the importation of existing GIS registration information.

Through the calibration and validation processes, it was observed that the adopted mathematical model successfully described the hydraulic behaviour of the wastewater flow. It is also worth noting that the 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.

Mathematical modelling demonstrated to be an adequate tool with high potentiality for SSO management.

References: [1] Muleta, M. K.; Boulos, P. F. 2008 Analysis and calibration of RDII and design of sewer collection systems. Report of the World Environmental and Water Resources Congress 2008: Ahupua'A, Honolulu, Hawaii, 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 Institute Press, Exton, Pennsylvania, USA.

[3] 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.

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