Stochastic evaluation of sewer inlet capacity on urban pluvial flooding

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Abstract
In this paper we present an innovative methodology to stochastically assess the impact of sewer inlet conditions on urban pluvial flooding. The results showed that sewer inlet capacity can have a large impact on the occurrence of urban pluvial flooding. The methodology is a useful tool for dealing with uncertainties in sewer inlet operational conditions and contribute to comprehensive assessment of urban pluvial risk assessment.

Keywords
Sewer inlets, clogging, urban pluvial flooding, flood hazard, stochastic risk analysis, GIS

INTRODUCTION
Urban drainage systems are essential to modern cities and make up a large proportion of the constructed urban infrastructure. These systems represent an invaluable asset that is expensive build, operate and maintain. The components of these systems, including sewer inlets, need to be in good operational conditions to ensure a good service (e.g., reduce flood probability and consequences).

This paper evaluates the impact of sewer inlet capacity on the occurrence and magnitude of urban pluvial flooding in an urban catchment in Coimbra, Portugal. A stochastic methodology is proposed to take into account variations in sewer inlet hydraulic capacity in urban pluvial flood hazard estimation. Based on the experience of the water utility responsible for the drainage system and previous studies, we consider a probabilistic distribution (the PERT distribution) to characterise the variability of sewer inlet capacity due to blockage. We compare the results obtained with the proposed stochastic methodology against those produced using a deterministic approach.

BACKGROUND
Several laboratory and numerical studies have been conducted in recent years which have defined the discharge capacity of different inlet structures (e.g. Brown et al., 2009, Russo and Gómez, 2011; Russo et al., 2013; Saul, 2012; Martins et al., 2014). While these studies provide valuable information to design inlets and improve their representation in urban drainage models, most of the mathematical representations presented are limited to optimal operational conditions (i.e. fully clean inlets).

The clogging condition of inlets structures has been addressed as a factor to reduce the inlet discharge capacity (Guo, 2009; ten Veldhuis, et al., 2011; Gómez et al, 2013; Russo et al., 2015). These studies highlighted for the importance of inlet clogging on the amount of surface runoff that can enter the sewer system. However, they did not consider clogging variability as suggested in the present study.

SEWER INLET HYDRAULIC CAPACITY VARIABILITY

The proposed methodology comprises three main steps: (i) identification of sewer inlets most prone to clogging based upon a spatial analysis of their proximity to trees and evaluation of their location in relation to terrain depressions; (ii) Monte Carlo simulation of the capacity of inlets prone to clogging and subsequent simulation of flooding for each scenario, and (iii) water depth and extent analysis and stochastic flood hazard map creation

The identification of the sewer inlets prone to flooding is conducted based on several geographic data sets (Digital Elevation Model, sewer network data, road network and orthophotos of the catchment); intersection and union spatial operations are carried out to select the inlets prone to clogging.

To study the effect of the hydraulic capacity of the sewer inlets on urban pluvial flooding, this parameter (i.e. inlet capacity) was allowed to vary stochastically between 0% and 100% of the maximum discharge capacity using the PERT probability distribution (Figure 1). In most of the cases, sewer inlets are assumed to be relatively clean; the inlets prone to clogging are considered to have 80% of their full hydraulic capacity most of the time, as the performance of annual cleaning process of the inlets is not 100% effective and the accumulation of debris can make the clogging process more acute - information provided by the water utility company and Gómez et al. (2013).

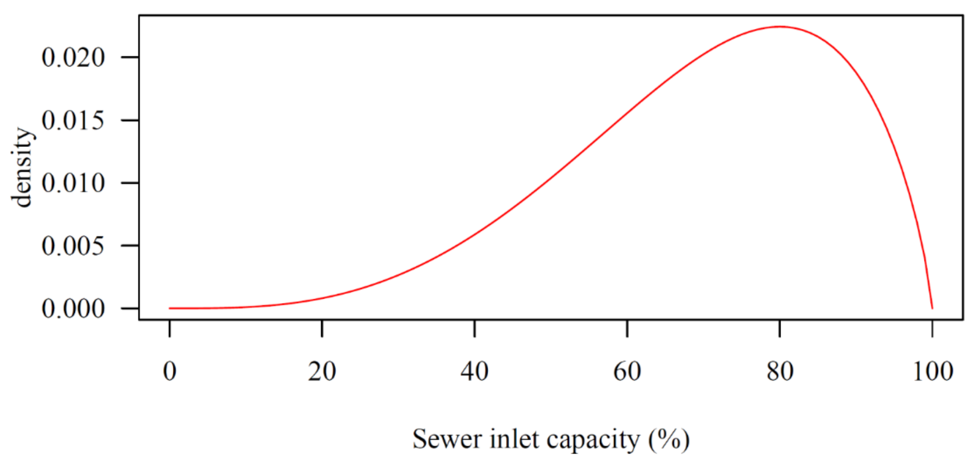

Figure 1. PERT distribution used in this study with parameters min: 0%; max: 100% and mode (most likely value): 80%

URBAN FLOOD MODELLING

For each hydraulic model used in the Monte Carlo simulation, the inlets identified as prone to clogging were assigned a hydraulic capacity factor, sampled from the PERT distribution. Hydraulic simulations for each of the resulting urban drainage models, i.e., for different sewer inlet hydraulic conditions, were conducted.

The case study selected to demonstrate the importance of the sewer inlet operational condition on urban flooding was the *Zona Central* catchment located in Coimbra, Portugal (Figure 1). The sewer system is nearly 35 km long, most of which is combined, draining an area of approximately 1.5 km^2

with 24% average slope. Some of the catchment areas have a significant number of deciduous trees. By the end of autumn, these trees lose their leaves, which may accumulate on top of the sewer inlets if they are not regularly cleaned, increasing thus the risk of flooding.

The 1D/2D urban drainage model used in this study was implemented on Infoworks ICM (Innovyze, 2013) and calibrated with data collected in the sewer system and flooding records. Photographs of flooding events recorded the floodplain limits. In addition, rainfall in the catchment has been continuously recorded with rain gauges.

RESULTS

The proposed methodology was demonstrated using as case study design storms as well as two real storm events observed in the city of Coimbra. The design storms were used to analyse the benefit of the proposed methodology and the observed rainfall events to validate and show a real application of it.

The results show that variations in sewer inlet hydraulic capacity can largely affect flooding occurrence and extent, and that considering such variations can lead to more accurate representation of urban pluvial flooding, as compared to traditional deterministic methods (Figure 2). The deterministic rainfall simulations of the observed rainfall event did not capture any flooding in any event. In contrast, the proposed stochastic methodology shows a small likelihood of flooding and in reality flooding did occur in one event.

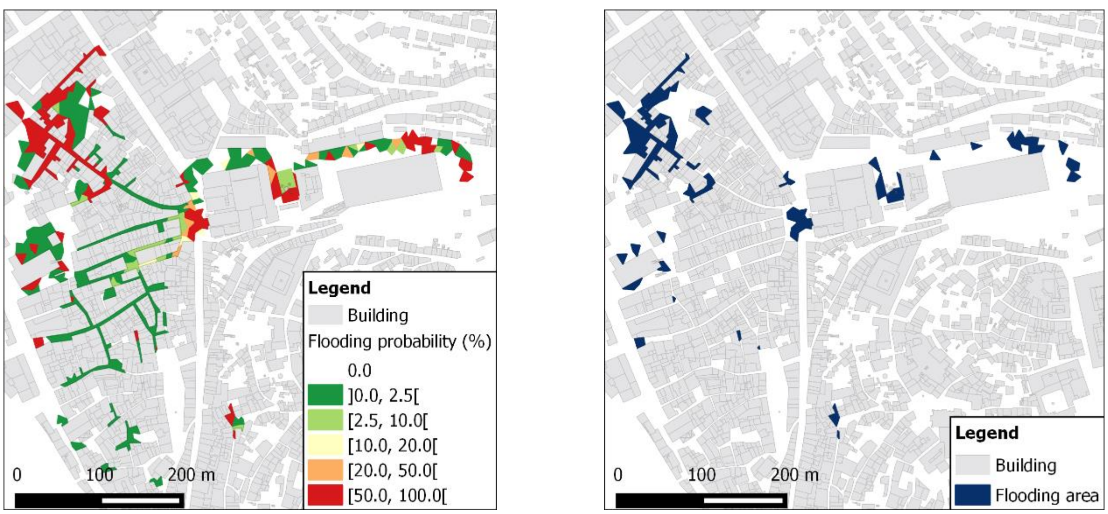

Figure 2. Left: Detail of the flood extent for a stochastic 20 years return period design storm simulation in the most critical area; Right: Detail of the flood extent for a stochastic 20 years return period design storm simulation in the most critical area.

CONCLUSIONS

We investigated the impact of sewer inlet capacity variability on the occurrence and magnitude of urban pluvial flooding. The methodology presented is innovative and introduces a new dynamic concept related with the maintenance status of the gullies that are of outmost importance for urban flood modelling, and allow the generation of stochastic flood maps taking into account inlet capacity variability. The new methodology capture flood vulnerabilities not captured by deterministic approaches, showing that sewer inlet capacity has a strong impact on urban pluvial flood modelling results.

ACKNOWLEDGEMENT

Rui Pina acknowledges the financial support from the Fundação para a Ciência e Tecnologia - Ministério para a Ciência, Tecnologia e Ensino Superior, Portugal [SFRH/BD/88532/2012]. Susana Ochoa-Rodriguez acknowledges the support of the Interreg IVB NWE RainGain project. Special thanks are due to AC, Águas de Coimbra for providing rainfall and sewer data of the pilot location and to Innovyze for providing research licences of InfoWorks ICM software.

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