Experimental and Numerical Investigation of Flow Exchange in Urban Flood Flows

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INVESTIGATORS

Dr. James Shucksmith, The University of Sheffield
Prof. Adrian Saul, The University of Sheffield
Dr. Wernher Brevis, The University of Sheffield
Dr. Georges Kesserwani, The University of Sheffield
Prof. Slobodan Djordjevic, The University of Exeter
Dr. Jorge Leandro, The University of Bochum
Matteo Rubinato, The University of Sheffield

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GENERAL AIM

A three year EPSRC funded research project focused on urban flood modelling led by the University of Sheffield. The proposal will utilise a unique surface/subsurface scale model of an urban drainage facility at the University of Sheffield together with numerical and computational advances in the solution of the hydraulic and pollutant transport equations to make significant improvements in the capabilities of pluvial flooding models in terms of accuracy and capability.

This will be achieved by providing high quality datasets concerning above/below ground flow interaction and shallow urban flows, by which modelling approaches can be compared, calibrated and validated.
OBJECTIVES

The specific technical objectives are:

1. Develop a sophisticated measurement system to experimentally determine the hydraulic characteristics of the interaction of overland surface flow and flooding from the below ground sewer system at manholes in time varying pluvial flood conditions.

2. Complete a series of experimental studies of the interaction between the below and above ground systems for a range of pluvial flooding conditions.

3. Experimentally characterise the fate and transport of soluble material from sewers to surface flows via manholes and determine the transport and mixing characteristics in typical shallow flow flooding conditions.

4. Utilise the experimental findings to calibrate and validate current coupled Dual Drainage numerical models, test advanced numerical modelling approaches and develop an accurate, practical, experimentally verified numerical model for pluvial flooding and pollutant transport.

5. Create a unique data set that will be made available to other researchers and software developers.

Hydraulic models are increasingly being used to both plan significant asset investment and form the basis of flood awareness/warning schemes and hence the resulting improvements in modelling accuracy will see significant benefits in terms of more efficient drainage design/investment and increased resilience to flood events.

An improved understanding of the fate and transport of sewer derived contaminants in surface flood flows will lead to an improved understanding of the potential health impacts of pluvial flood events.
BENEFICIARIES

The proposal will significantly advance the academic field of urban flood modelling by providing unique datasets with which to calibrate and validate urban flood models. Specifically, the ability to independently control sewer and surface flows will allow detailed investigation of the performance of weir/orifice equations to simulate sewer/surface interactions in time-varying flooding conditions.

Taking high-resolution surface PIV measurements will improve the scientific understanding of the complex flow structure (velocity and turbulence fields) around manholes, and more generally around submerged discharges into shallow flows. The work will develop new understanding of the transport of pollutants in urban environments (urban drainage systems and shallow surface flows), quantify the impacts of shear and trapping zones and determine the applicability of established Fickian models in pluvial flooding events.

The study will benefit other researchers by providing a range of experimental datasets including detailed measurements of flow, pressure, depth, velocity, mixing and discharge coefficients, 2D velocity and turbulence fields in the sewer and free surface flow. Experiments will be conducted in both steady and time-varying conditions. The experimental facility is unique and hence these datasets will be of significant value to the international academic and modelling community working in a wide range of fields, including urban flooding, but also solute mixing and mass transport, hydrodynamics of shallow flows, water quality modelling, numerical modelling, stormwater management, and health impacts of flooding.

IMPACT SUMMARY

Pluvial flooding causes significant long-term damage to residual and commercial areas, economic disruption, danger to life and social upheaval. The development of tools and techniques to predict surface water flooding is one of the key recommendations of the 2008 Pitt Review. Together with the wider public who are at risk (it is estimated that 3.2 million residents in the UK will be ‘at risk’ of urban flooding by 2050), all stakeholders with a responsibility for managing urban flooding would benefit from a more accurate quantification of flood risk, including local authorities, the water industry, emergency responders, the insurance industry and the Environment Agency.

Hydraulic modellers and consultants involved in the work will also benefit by having access to experimental data. Developing and extending their products will enable them to become more competitive in the water modelling sector and further establish UK expertise in the sector.
The outcome of the project will be a significantly enhanced modelling capability for urban flood flows, with the development of new improved software. Specifically by making significant improvements to the capabilities of pluvial flooding models in terms of accuracy, speed and information provided.

As hydraulic models are increasingly being used to evaluate urban flood risk, the resulting improvements in modelling accuracy will see significant benefits in the targeting of asset investment (e.g. upgrading of wastewater networks or the implementation of SUDS), developing accurate flood risk mapping (leading to improved resilience of homes and higher awareness amongst residents), the development early warning systems, and the development of safe surface water management plans. In addition, it is increasing becoming recognised that it is infeasible to manage all storm water in below ground systems, partly due to the increased sewer flows forecast from climate change and changing urban hydrology.

Given the unfeasible cost expanding all sewer networks to cope with increased flow, planning effective and safe management of storm water on the surface is becoming increasingly important in future drainage design. The accurate prediction of surface water flow paths, depths and velocities as well as how contaminants such as faecal matter moves though the urban environment in exceedance flow is will be critical to safe urban drainage design. An accurate characterisation of the hydraulics and transport processes in pluvial flooding conditions would enable risk mapping based on a physically based model of pollutant transport. This would allow a hazard and vulnerability assessment health risk to individual areas or properties and prioritise health checks/screening in the event of flooding by identifying those areas/properties that are potentially exposed to the highest concentrations of contaminants.
PLUVIAL SCENARIOS
CONTACTS

Dr. James Shucksmith (Principal Investigator)
Mail j.shucksmith@sheffield.ac.uk
Telephone: +44 (0) 114 222 5706

Matteo Rubinato (Research Assistant)
Mail m.rubinato@sheffield.ac.uk
Telephone: 07794995864