# ICUD-0448 *Real time flow control to utilise existing in-sewer storage*

L. Maluf[1], W. Shepherd[2], S. Ostojin[3], N. Simões[1], A. Sá Marques[1], S. Mounce[2], P. Skipworth[3], J.P. Leitão[4]

[1]MARE, Department of Civil Engineering, University of Coimbra, Coimbra, Portugal
[2] Pennine Water Group, Department of Civil and Structural Engineering, University of Sheffield, Sheffield, S1 3JD, UK.
[3] Environmental Monitoring Solution, Unit 7, President Buildings, Savile Street East, Sheffield, S4 7UQ, UK
[4] EAWAG Überlandstrasse 133 CH-8600 Dübendorf Switzerland

**Keywords:** Real time control; sewer flooding; fuzzy logic; flow control

**Summary**

Urban flooding events which are often caused by a lack of capacity of the urban collecting system, can be a risk to human life. The CENTAUR project is developing an innovative, cost effective, local and autonomous sewer flow control system to reduce urban flood risk. The CENTAUR system consists of a flow control device controlled by a Fuzzy Logic algorithm to allow upstream storage capacity to be used to reduce downstream flood risk. Results will be presented from a modelling study of this system, based on the sewer network in the city of Coimbra, Portugal. These results show the ability of the system to decrease water level in a critical location, without increasing flood risk upstream.

**Introduction**

Climate change and the reduction of permeable surfaces in urban areas will affect surface water runoff volumes and may increase the frequency and magnitude of urban floods (Piro, 2007 and Piro et al., 2010). A main cause of urban flooding is due to the drainage system overflowing during intense rainfall events. Excess water can be managed using storage tanks and retention basins, however this type of construction can be technically and economically costly. In contrast, it is possible to store the excess of water directly within the drainage system, avoiding larger investments (Schütze et al., 2004, Bach et al., 2014 and Beeneken et al., 2013).

The CENTAUR project aims to develop an innovative, cost effective, local, independent sewer flow control system, which creates in-line storage by utilising unused capacity in the existing drainage network. The proposed solution is the installation of an autonomous sewer flow control device (FCD) within a manhole at the downstream end of a length of the drainage network which has spare capacity. The FCD can dynamically control the flow and, therefore, influence water depths both up and downstream.

**Materials and Methods**

In order to test the CENTAUR concept, Coimbra, a medium size city in the centre of Portugal, has been selected for a pilot case study. Initially, a sewer flow survey has been carried out in order to build a SWMM hydrodynamic model of the sewer network. The calibrated hydraulic model was utilised as a tool, along with site visits, to select a manhole that would receive the FCD (Fig. 1 shows the chosen location of FCD for the pilot testing). Here the control point does not actually flood, this is because the pilot testing needs an objective which can be met several times in a testing period of around 6 months, as flood return periods are longer than six months it is likely that the FCD would not be activated at all during the pilot testing if its aim was to prevent flooding.

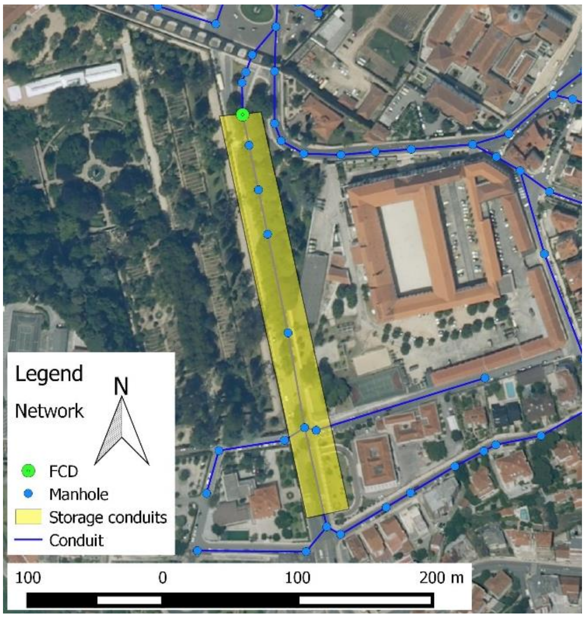


*Fig. 1. FCD and storage conduits.*

The FL algorithm has been developed in Matlab and was implemented using the MatSWMM toolbox (Riano-Briceno et al, 2016). This virtual testing was initially developed on a truncated sewer network model as described in Shepherd et al (2016) and is now applied to the Coimbra network. Fig. 2 is a schematic of the control algorithm. The input data is derived from level sensors in the network, this data is input to FL membership functions (MFs), which split the data into fuzzy categories, a general example is shown in Fig. 3. Each combination of MFs is assigned a rule which relates to a control action for the FCD.

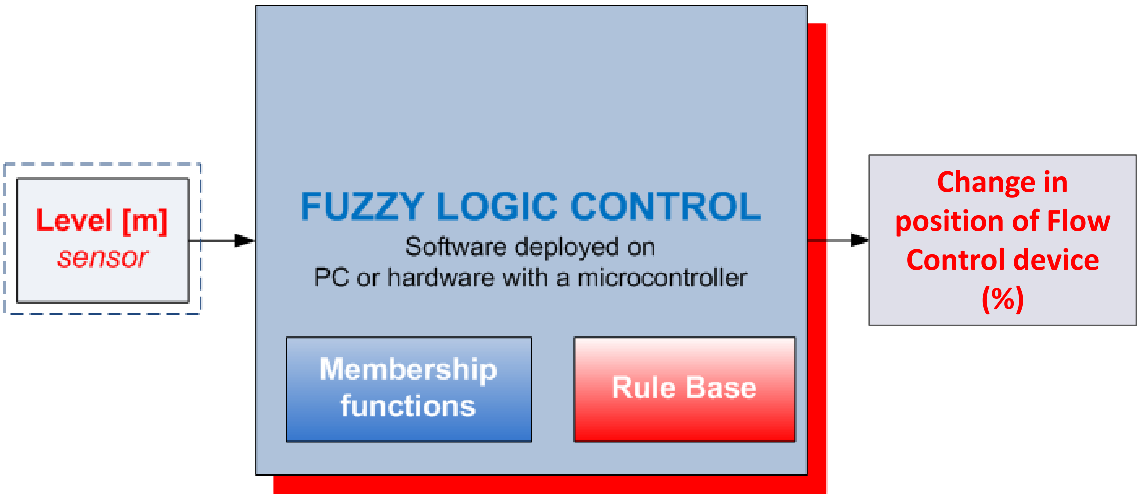


*Fig. 2. Schematic of the control algorithm*

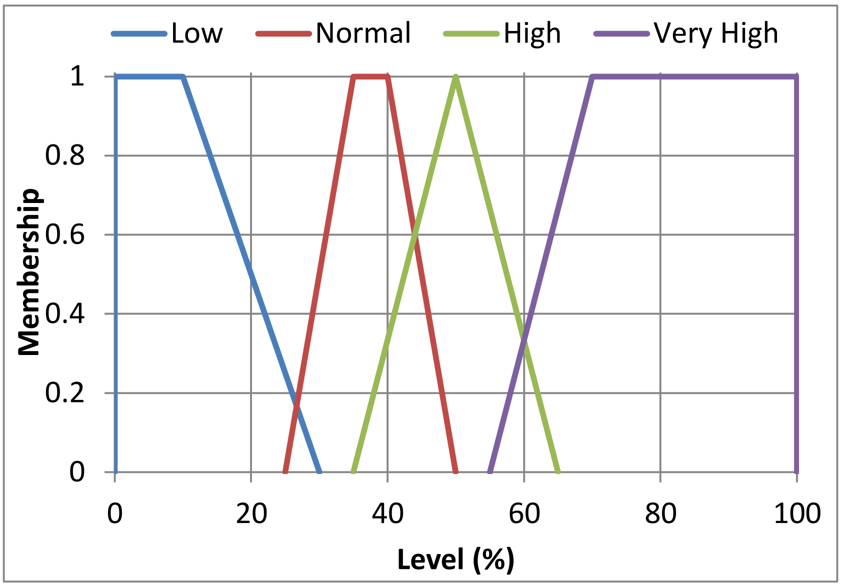


*Fig. 3. Example Fuzzy Logic membership function*

## Results and Discussions

The fuzzy logic control algorithm has been tuned for the Coimbra network using recorded rainfall events from 2016 as input to the virtual testing on the Coimbra SWMM model. Fig. 4 compares water depths in the sewer network for a 4 hour simulation using rainfall data from 8$^{th}$ May 2016. The baseline data is when the FCD is inactive and fully open. It can be seen that when the CENTAUR system is active, the FCD retains some volume, increasing the water level upstream of the FCD, but reduces the water depth at the control point (CP). The maximum impact that the FCD can have at the control point is limited as additional flows enter the sewer network between the FCD and the CP. After the event has passed, the FCD can be seen to gradually re-open, once open the storage volume is empty and ready for any subsequent rainfall to be controlled.

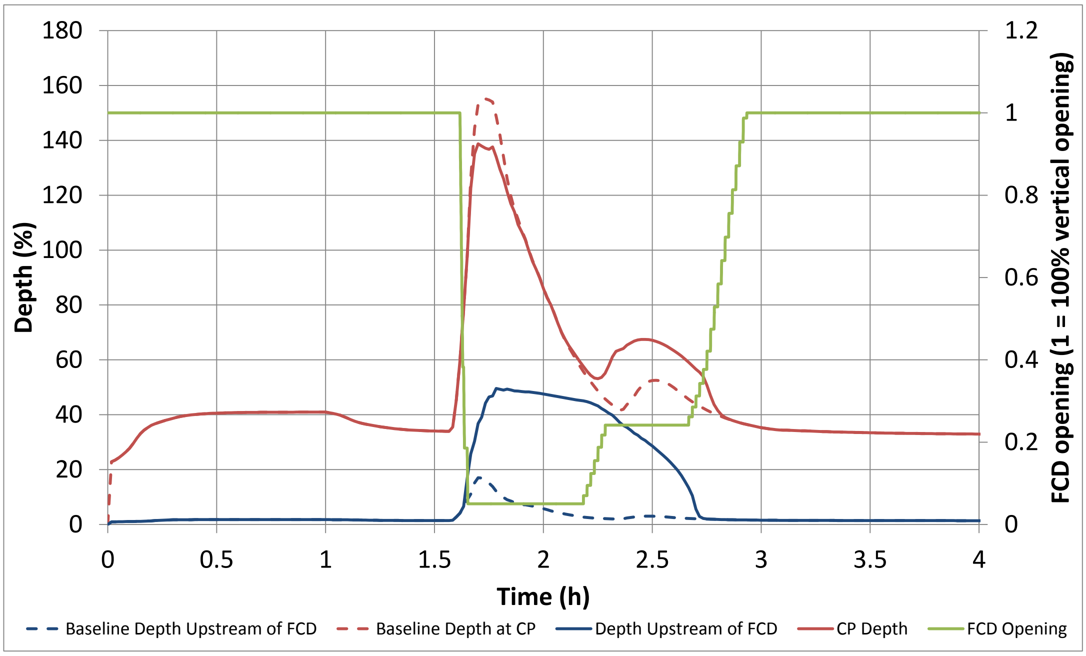


*Fig. 4. Modelled FCD operation results for 8$^{th}$ May 2016 event.*

## Conclusions

Initial results were verified with the hydraulic model and the developed algorithm demonstrated that the FCD can intelligently reduce the water level at the downstream control point. If more FCDs were installed, higher reduction should be obtained. The control algorithm will be tested in the field and the rules will be validated and optimised using evolutionary techniques during the tests.


## Acknowledgments

This project has received funding from the European Union's Horizon 2020 research and innovation program under grant agreement No. 641931. Special thanks are due to AC, Águas de Coimbra, E.M., Coimbra, Portugal for providing rainfall and sewer data of the pilot location.


## References


Bach P, Rauch W, Mikkelsen P, McCarthy D, Deletic A, A critical review of integrated urban water modelling—urban drainage and beyond, Environ. Model. Softw., 54 (2014), pp. 88–107.

Beeneken T, Erbe V, Messmer A, Reder C, Rohlfing R, Scheer M, Schuetze M, Schumacher B, Weilandt M, Weyand M, Real time control (rtc) of urban drainage systems-a discussion of the additional efforts compared to conventionally operated systems, Urban Water J., 10 (5) (2013), pp. 293–299

Piro P, 2007. Il bacino sperimentale urbano del canale liguori nella città di cosenza. Osservazioni sperimentali quali-quantitative nel periodo 1995-2003, ed. NUOVA BIOS, CS, Italy. ISBN 88-6093-019-7

Piro P, Carbone M, Garofalo G, Sansalone J, Size distribution of wet weather and dry weather particulate matter entrained in combined flows from an urbanizing sewershed, Water, Air Soil Pollut., 206 (14) (2010), pp. 83–94

Riano-Briceno G., Barreiro-Gomez J., Ramirez-Jaime A., Quijano N., Ocampo-Martinez C., MatSWMM - An open-source toolbox for designing real-time control of urban drainage systems, Environ. Model. Softw., vol. 83, pp. 143–154, 2016.

Schütze M, Campisano A, Colas H., Schilling W, Vanrolleghem P, Real time control of urban wastewater systems: Where do we stand today? J. Hydrol., 299 (3) (2004), pp. 335–348

Shepherd W, Ostojin S, Mounce S, Skipworth P, and Tait S, CENTAUR: Real time flow control system for flood risk reduction, Proceedings of CIWEM UDG conference, Blackpool, UK, 2016.