International Conference on Hydroinformatics

8-1-2014

Flood Risk Management In Small Urban River Using A Sustainable Urban Drainage System: Wortley Beck, Leeds, Uk

Sangaralingam Ahilan

Nigel G. Wright

Andrew Sleigh

Sean Too

Vassilis Glenis

See next page for additional authors

Authors
Sangaralingam Ahilan, Nigel G. Wright, Andrew Sleigh, Sean Too, Vassilis Glenis, Chris Kilsby, and Vedrana Kutija

11th International Conference on Hydroinformatics
HIC 2014, New York City, USA

FLOOD RISK MANAGEMENT OF A SMALL URBAN RIVER USING A SUSTAINABLE URBAN DRAINAGE SYSTEM: WORTLEY BECK, LEEDS, UK

AHILAN, SANGARALINGAM (1); WRIGHT, NIGEL (1); SLEIGH, ANDREW (1); TOO, SEAN (1); GLENIS, VASSILIS (2); KILSBY, CHRIS (2); KUTIJA, VEDRANA (2)
(1): School of Civil Engineering, University of Leeds, United Kingdom
(2): School of Civil Engineering and Geosciences, University of Newcastle, United Kingdom

ABSTRACT

This paper explores potential flood resilience approaches for the highly urbanised Wortley Beck river basin, south west of the City of Leeds, UK. Integrated 1D and 2D hydrodynamic modelling, using the ISIS and TUFLOW has been utilised to explore potential impact of SuDS on the flood hazard for three (1:15, 1:50 and 1:100) flood events. A direct rainfall runoff modelling approach has been employed to implicitly incorporate SuDS features within the case study region. Results indicate that SuDS reduce the flood hazard in downstream for all three (1:15, 1:50 and 1:100) flood events, with the effect more pronounced for the lowest rainfall (1:15) event.

INTRODUCTION

Recent flood episodes present a significant and growing challenge to the United Kingdom and the wider world. In the UK 80% of people currently live in urban areas (World Bank, 2011) and the estimated cost of urban flood damage is £270 million a year for England and Wales (POSTnote, 2007). Climate change and urbanisation coupled with an ageing drainage infrastructure are expected to increase flood risk in UK cities (Pitt, 2008). The consequences of flooding are far reaching – it afflicts communities, business and health. It also leads to the failure of critical infrastructure networks such as water, power and transport, further restricting access to basic services when they are needed most.

Thus, it is essential to adopt holistic flood risk management measures that are not solely reliant on conventional structural flood defences through strong governance and investment to minimise the risk of urban flooding. The UK government set out the process and timescale for improving critical infrastructure with the aim of making it as resilient as possible so as to minimise the flood risk and its consequences through the Flood and Water Management Act 2010. Nevertheless, upgrading the nation's drainage systems to cope with the most extreme storm conditions would be too expensive to build and operate. As a potential solution Sustainable Urban Drainage Systems (SuDS) are being adopted as a promising hope for urban water management in the UK. Recent studies suggest that the role of plants within structures such as green roofs, swales and pond systems have multiple benefits including flood alleviation, treatment of diffuse pollution, health and wellbeing and improved biodiversity (Ashley et al., 2013; Mentens et al., 2005; POSTnote, 2013). The UK environmental regulatory agencies promote the implementation of SuDS in cities through water sensitive urban design legislations.

Leeds is one of the most flood vulnerable cities in the UK with over 4,500 properties currently vulnerable to flooding and approximately £450 million of direct damage that would be caused by a major flood from the River Aire (Leeds City Council, 2013). This study focuses on a sub-catchment of the River Aire, Wortley Beck, south west of the City of Leeds, UK. Lower Wortley has experienced regular flooding over the last few years from a range of sources, including Wortley Beck River and surface water (and groundwater) flooding. The major 2002, 2005 and 2007 flood incidents substantially affected properties both upstream and downstream of Farnley Lake as well as the important transport link of Wortley Ring Road (A6110) (see Figure 1). This frequency of flooding has very serious implications on the society, the environment and economic activities of the city. The purpose of this research is to explore potential integrated sustainable urban flood resilience measures that may be used to reduce the flood risk in the Wortley Beck catchment.

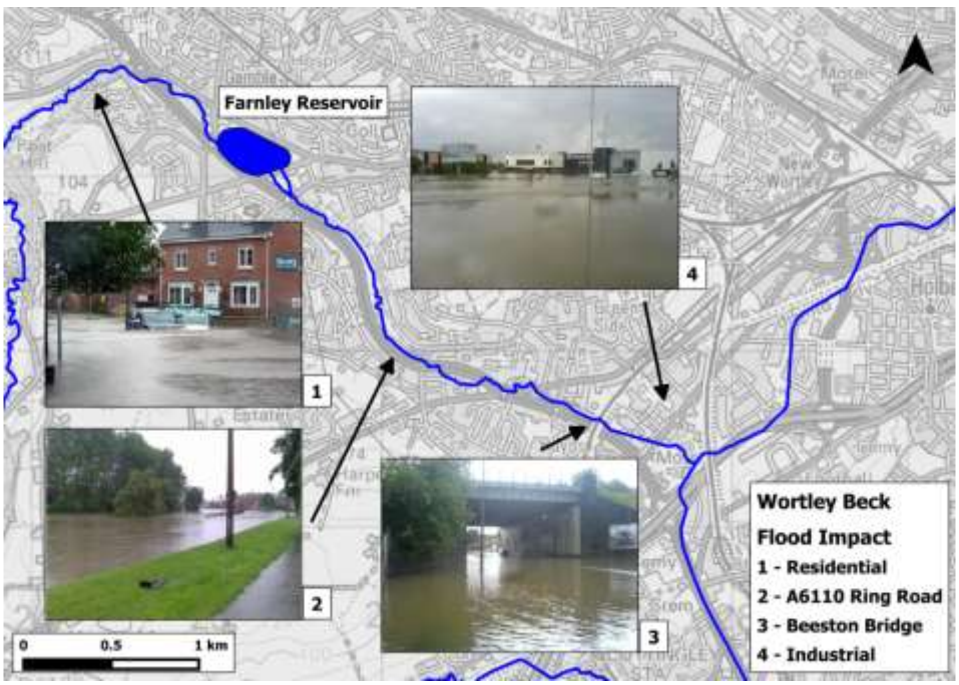


Figure 1 Wortley Beck Catchment 2007 Flooding

The initial stage of the study involves the systematic incorporation of Wortley Beck catchment landscape features on a QGIS platform to identify the river networks, floodplains, the extent of urban, forest and farmland areas, geology, etc. in the study region. This process will also enable the exploration of potential sustainable flood resilience measures: green spaces, green roofs, water retention ponds and swales, at appropriate locations and connect them with existing green corridors to maximise their productivity. The next stage involves developing a detailed 2D urban flood inundation model for the Wortley Beck catchment using the TUFLOW hydrodynamic model that is capable of modelling the effects of permeable/impermeable ground surfaces and landscape features. This integrated modelling study enables the systematic exploration of a range of sustainable flood resilient strategies for the Wortley Beck catchment.

MATERIALS AND METHODS

The Wortley Beck catchment is located in the south west of Leeds with a contributing area of 30 km² (Figure 2). It comprises of Pudsey, Tyersal, Tong and Farnley Beck in the upstream and Farnley Wood and Millshaw Beck in the downstream of the catchment. The catchment is densely covered by both industry and housing properties that significantly alter the hydrological cycle by reducing infiltration and increase urban runoff reaching drains and river systems which lead to a combination of pluvial and fluvial flooding. The length of the Wortley Beck river is 7.55 km and it passes through culverts, bridges and flows along narrow meandering urban channels and confluences with a culvert (near the M621 motorway) which then takes the flow to the River Aire in Leeds city centre. The M621 and A6110 are the two important transport links which intersect the Wortley Beck catchment. The M621 connects Leeds to the south and west of the country.

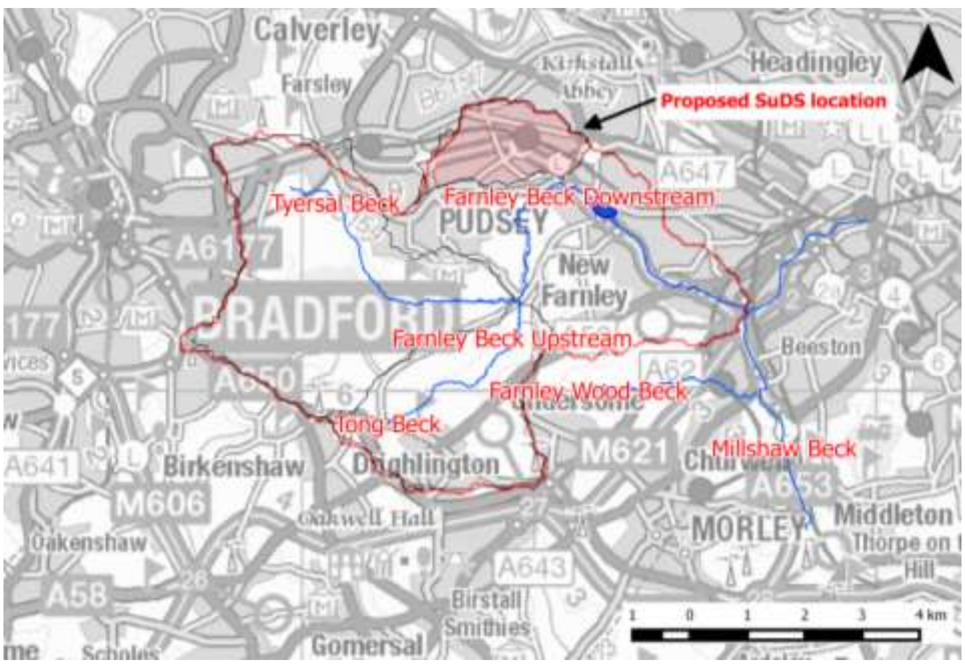


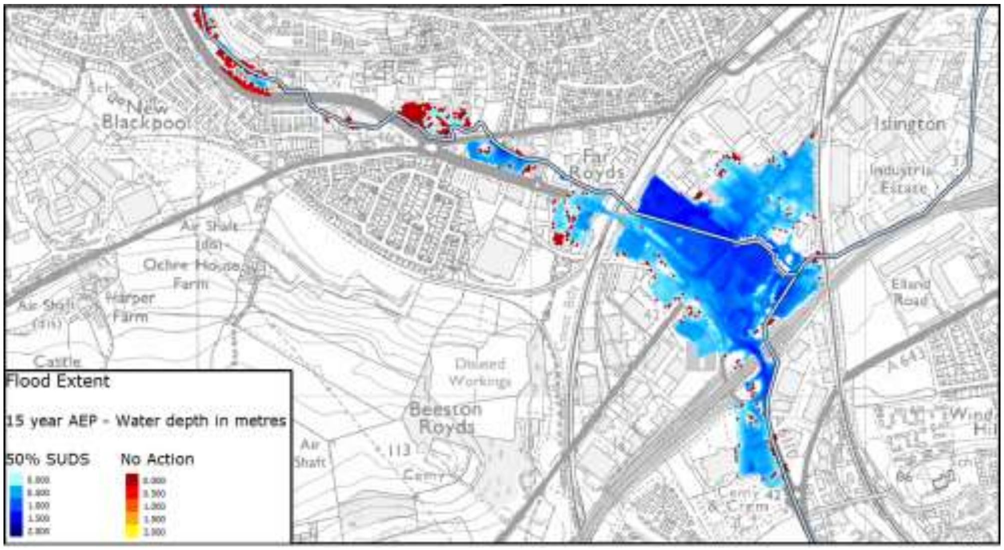
Figure 2 Wortley Beck Catchment

This study encompass coupled ISIS 1D and TUFLOW 2D hydrodynamic models. The ISIS 1D model is used to model the Wortley Beck catchment's river network with hydraulic structures including bridges, culverts, weirs etc. The TUFLOW model simulates the overland flow pattern of the catchment. A 2m resolution DEM and Ordnance Survey (OS) master map data sets were collated from the UK Environment Agency and used in the TUFLOW model. The OS master map data enable the sub categorisation of the catchment land use into a variety patterns, for example buildings, roads, green areas etc. This process also enables the building of different storage components for the permeable and impermeable areas. An area of the Wortley Beck catchment (2 km^2) was selected as shown in Figure 2 as a test case with it being a potential region to assess SuDS in a heavily urbanised area. The SuDS manual (CIRIA C697,

2007) is used to identify the potential SuDS features at appropriate locations based on the land use, topography and property ownership type within the identified sub catchment. The conditions where SuDS are recommended to perform well in storm water attenuation were selected with the total required surface area calculated. An event-based ISIS hydrological module based on the Revitalised Flood Hydrograph (ReFH) method is used to develop 1:15, 1:50 and 1:100 return periods gross and net storm profiles for the study region. The first stage of the rainfall runoff modelling involves in application of net rainfall that accounts for infiltration, evaporation, pooling losses in to the existing permeable area and gross rainfall into the impermeable area of the catchment for three storm events; this provides base line hydrographs at the catchment outlet. These hydrographs are then routed through the linked ISIS –TUFLOW model to develop an inundation polygon along the reach. The second stage of the analysis involves repeating the first stage rainfall runoff modelling with identified potential green features such as green roofs, permeable car parks, ponds etc, which will enable the production of resultant hydrographs at the outlet of the study catchment. Scenarios for various uptakes and attenuations of rainfall were modelled to give a range of the performances for the selected SuDS features. This revised hydrograph is then routed through the ISIS –TUFLOW model and compare against the base line inundation map and thus enable the assessment of the influence of SuDS on flood propagation.

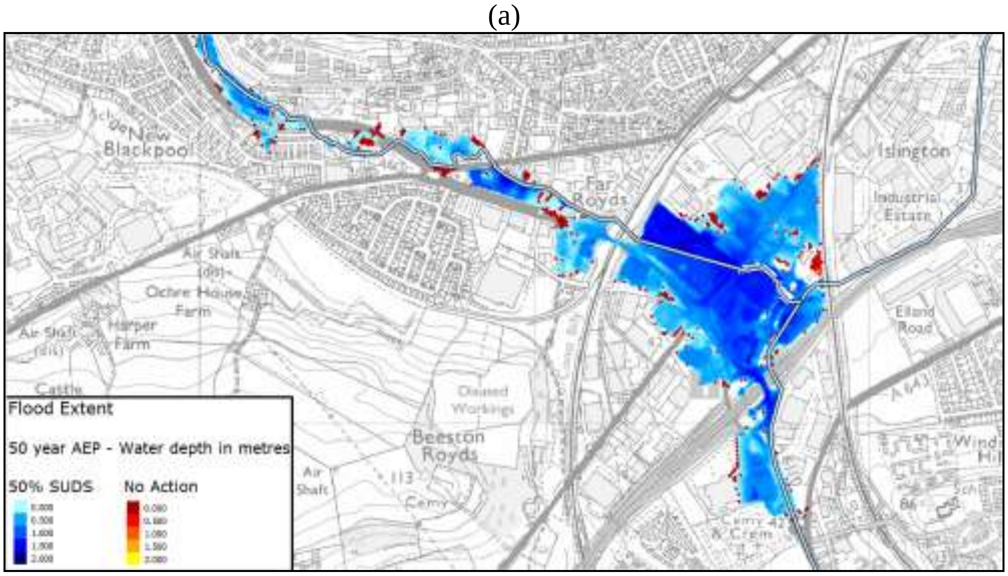
RESULTS AND DISCUSSION

The simulation results are shown in Figure 3 for 1:15; 1:50 and 1:100 year return period flood events for the current situation and a 50% permeable area. In developed cities, roofs take up a major portion of the impermeable urban surface area; in the region of 40 – 50%, any measures that reduces the rate and volume of roof runoff has the potential to contribute significantly to improved storm water management (Ellis et al., 2012). As shown in Figure 3, implemented SuDS reduce the flood hazard downstream for all three flood extents and has most significant impact with the lowest return period (1:15 year)flood events. This observation is consistent with previous studies: Ellis and Viavattene (2013) reported that SuDS exhibit significant reductions in total discharge volumes for storms up to 1:30 year return periods with only very limited volumetric reductions for storm events exceeding this return period. In this study proposed SuDS location covers less than 10% the size of the Wortley Beck catchment, the simulation results indicated that SuDS can reduce flood hazard in the downstream. To develop holistic flood risk management plans for the Wortley Beck Catchment further research need to be undertaken to understand the catchment response to multiple SuDS arrangements and its effects on the flood extents with detailed planning.



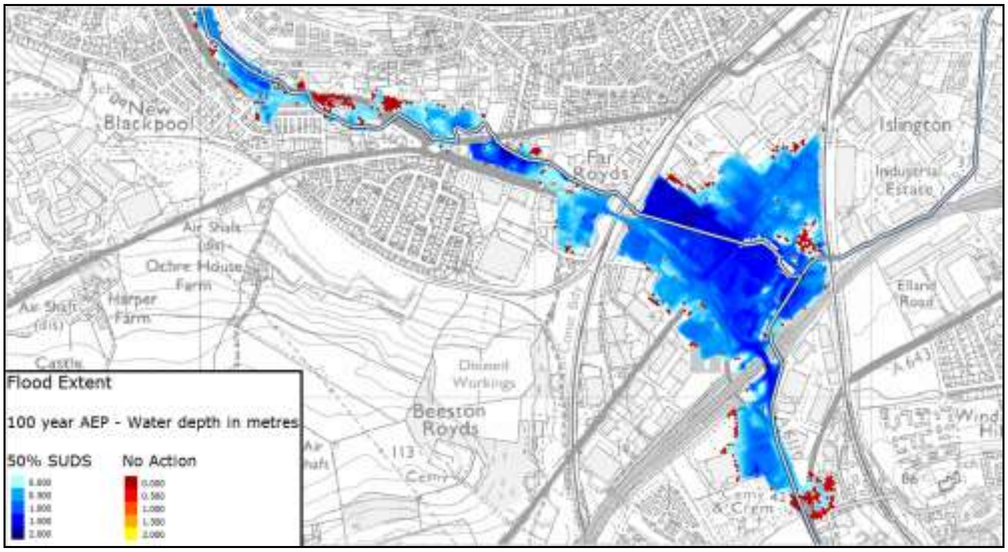
Flood Extent
15 year AEP - Water depth in metres
50% SUDS
No Action
New Blackpool
Far Royds
Islington
Industrial Estate
Elland Road
Beeston Royds
Disused Workings
Air Shaft
Ochre House Farm
Harper Farm

(a)



Flood Extent
50 year AEP - Water depth in metres
50% SUDS
No Action
New Blackpool
Far Royds
Islington
Industrial Estate
Elland Road
Beeston Royds
Disused Workings
Air Shaft
Ochre House Farm
Harper Farm

(b)



(c)

Figure 3 Flood Extent Maps for 1:15 (a), 1:50 (b), 1:100 (c) year return period

CONCLUSIONS

Integrated 1D and 2D hydrodynamic modelling, using the ISIS and TUFLOW software, has been utilised for simulating storm water runoff in Wortley Beck catchment. A direct rainfall runoff modelling in TUFLOW allowed implicit incorporation of SuDS features into the identified case study catchment. Results indicate that SuDS can reduce the flood hazard in the downstream area for all three (1:15, 1:50 and 1:100) flood events, with a more pronounced effect for the lowest (1:15) event. However this reduction in flood extent is based on SuDS in a relatively small sub catchment (2 km^2). In order to achieve efficient flood risk management it is essential develop appropriate SuDS measures throughout the catchment with good, well considered, planning.

ACKNOWLEDGEMENTS

This research was performed as part of an interdisciplinary project programme undertaken by the Blue-Green Cities Research Consortium (www.bluegreencities.ac.uk). The Consortium is funded by the UK Engineering and Physical Sciences Research Council (EPSRC) under grant EP/K013661/1, with additional contributions from the Environment Agency, Rivers Agency (Northern Ireland) and the National Science Foundation.

REFERENCES

[1] *Ashley R., Lundy L., Ward, S., Shaffer P., Walker L., Morgan C., Saul A., Wong T. and Moore S., "Water-sensitive urban design: opportunities for the UK", Proceedings of the Institution of Civil Engineers, Municipal Engineer, Vol. 166, ME2, (2013), pp 65-76.*

[2] *Ellis J.B., Revitt, D.M. and Lundy L., "An impact assessment methodology for urban surface runoff quality following best practice treatment", Science of the Total Environment, 416, (2012), pp 172-179.*

[3] *Ellis J.B. and Viavattene, C. "Sustainable Urban Drainage System Modeling for Managing Urban Surface Water Flood Risk", Clean – Soil, Air, Water, Vol. 42(2), (2014), pp 153-159.*

[4] *Leeds City Council. "Flood Alleviation Scheme", (2013). Avilable at http://www.leeds.gov.uk/residents/Pages/FloodAlleviationScheme.aspx [Accessed April 18th 2014]*

[5] *Mentens J., Raes D. and Hermy M., "Green roofs as a tool for solving the rainwater runoff problem in the urbanised 21st century?" Landscape and Urban Planning, Vol. 77, (2006), pp 217-226.*

[6] *Parliamentary Office of Science and Technology (2007) Urban Flooding. POSTnote. No 289, July (2007) pp 1-4. Available at www.parliament.co.uk/post [Accessed Nov 5th 2013].*

[7] *Parliamentary Office of Science and Technology (2013) Urban Green Infrastructure. POSTnote. No 448, Nov (2013) pp1-4. Available at www.parliament.co.uk/post [Accessed Nov 5th 2013].*

[8] *Pitt, M., "Learning lessons from the 2007 floods", The Cabinet Office, London (2008).*

[9] *The SuDS manual (2007) CIRIA C697*

[10] *World Bank, 2011, Urban population as percentage of total population 2011, World Development Indices.*

[11] *Wang T., "Water Sensitive Urban Design – the Journey Thus Far", Environment Design Guide 2007, Vol. 11, pp 1-10.*