Improving Urban Flood Modelling towards Water-Wise Cities and Smart Water Systems

Dr Rubinato Matteo
m.rubinato@sheffield.ac.uk
Room D105
Civil and Structural Engineering Department
University of Sheffield

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Water systems that...

• Deliver drinking water;

• Ensure that wastewater is collected, treated properly and efficiently;

• Ensure that rainwater and stormwater is drained safely out of the city;

WE NEED TO PLAN THEM...

• IN THE CONTEXT OF THE WHOLE CITY

• IN THE WAY WE DESIGN OUR NEIGHBOURHOODS

• HOW WE INTEGRATE THEM ALL AT THE BASIN SCALE

looking at what’s happening upstream and downstream the city
Towards Water-Wise Cities

Cities are rapidly expanding and water resources are under increasing pressure.

We need to find ways to do more with less, while ensuring that cities are resilient to floods, droughts and the challenges of growing water scarcity. Transitioning cities to address these challenges has never been more urgent.
## The 17 IWA PRINCIPLES FOR WATER-WISE CITIES

<table>
<thead>
<tr>
<th>Principle</th>
<th>Description</th>
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<tbody>
<tr>
<td>Replenish Waterbodies and their ecosystem</td>
<td>Enable regenerative water services in urban spaces to reduce flood risks</td>
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<tr>
<td>Reduce the amount of water and energy used</td>
<td>Design urban spaces to reduce flood risks</td>
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<td>Use a systematic approach integrated with other services</td>
<td>Enhance liveability with visible water</td>
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<td>Increase the modularity of systems and ensure multiple options</td>
<td>Plan to secure water resources and mitigate drought</td>
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<td>Modify and adapt urban materials to minimise environmental impact</td>
<td>Protect the quality of water resources</td>
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<td>Empowered citizens</td>
<td>Prepare for extreme events</td>
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<td>Leaders that engage and engender trust</td>
<td>Regenerative Water Services</td>
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<td>Professionals aware of water co-benefits</td>
<td>Water Sensitive Urban Design</td>
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<td>Transdisciplinary planning teams</td>
<td>Basin Connected Cities</td>
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<tr>
<td>Policy makers enabling water wise action</td>
<td>Water-Wise Communities</td>
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URBAN FLOODING

Worldwide problem

Expected to increase in the future due to...

- Climate change (short duration heavy rainfall events will become more frequent)
- Increase of urbanisation
- Conditions of existing sewer systems
Objectives of flood modelling?

- Sewer system re-design / optimisation
- Major system design
- Damage assessment
- Flood risk attribution
- Hazard maps
- Real-time management
- Support to rescue services
- Uncertainty analysis
- Pollution, health problems
- Climate change impacts
- Effects of urban growth

All these objectives require the estimation of flow exchange between sewer and floodplain (especially associated with flooding events)

Surface water flooding is recognised as the hardest type of flooding to predict and defend against (Pitt Review)
Urban Flood Models

Pipe Network – 1D St. Venant Equations
Pipe Network – 2D St. Venant Equations

Inputs/Parameters
Rainfall runoff, pipe network, digital elevation model, roughness and energy loss parameters......
Verification

• How do we know models are telling the truth?
  – Comparison with Sewer Flow Data
  – Measured surface extents?
  – Photos?
Aim

• Develop a laboratory facility to provide good quality verification data for urban flood models
  – Evaluate some current assumptions within models
  – Provide better data to enhance future model development and testing

• Laboratory approach can provide high resolution data in controlled conditions, at the cost of scale + boundary effects
Experimental facility
Sub-surface/surface interactions

Inflow into unsurcharged sewer

\[ Q_e = \frac{2}{3} C_w \pi D_M (2g)^{1/2} (h_s)^{3/2} \]

Inflow into surcharged sewer

\[ Q_e = C_w \pi D_M (2g)^{1/2} (h_s) (h_s + z_{crest} - h_p)^{1/2} \]

Outflow over wet floodplain

\[ Q_e = C_o A_M (2g)^{1/2} \left( h_p - (h_s + z_{crest}) \right)^{3/2} \]

Outflow over dry floodplain \((h_s=0)\)

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Scenario 1

Surface \(Q_2\) -> Inflow \(Q_e\) -> Outflow \(Q_3\) -> Sewer \(Q_4\) -> Manhole

Scenario 2

Surface \(Q_2\) -> Inflow \(Q_e\) -> Outflow \(Q_3\) -> Sewer \(Q_4\) -> Manhole

Scenario 3

Surface \(Q_2\) -> Inflow \(Q_e\) -> Outflow \(Q_3\) -> Sewer \(Q_4\) -> Manhole

Scenario 4

Surface \(Q_2\) -> Inflow \(Q_e\) -> Outflow \(Q_3\) -> Sewer \(Q_4\) -> Manhole

✓ ✓ ✓ ✓
Sub-surface/surface interactions
Validation of shock capturing models...

Quantification of energy losses and validation of SIPSON

Numerical Streamlines (m/s)

Applicability of linking equations

Validation of numerical models to replicate velocity fields around the manhole

Validation of numerical models vs flow exchange
Outputs

• Validation of the applicability of weir and orifice equations
• Linking equations are sensitive to calculations of relative head within pipe and surface systems.
• In unsteady surcharging conditions, significant head losses are encountered over and above those in steady state flow
• In non-surcharging conditions, energy loss coefficients are unaffected by the presence of a manhole lid
• In surcharging conditions, the coefficients (and hence energy losses) are lower when the lid is removed
• Energy loss coefficient associated with the overflow is not dependent on the blockage in the pipe or the flow conditions on the surface.
• This behaviour is a consequence of the increasing proportion of flow which is transferred to the surface encountering higher turbulent losses as the flow moves from the sewer into the surface
Where to find them...


Health Risks of Urban Floods

- Urban floods (especially those in areas with combined sewers) contain high levels of pathogens and other harmful bacteria.
- Direct and indirect contamination risk, risk to vulnerable sites.
- Is it possible to develop modelling capability to include this?
International Conference on Urban Drainage 2017, Prague

- Presentation at ICUD 2017 from Head of Innovation at DHI
- Contaminant transport model added to flood model
- Calibration/Verification data?
The illuminated facility
Configurations tested (downstream view)
PRELIMINARY RESULTS:
- small inconsistencies around the reflection points to be improved;
- the parking slots on their own don't seem to have much effect, it's only when they are coupled with the obstacles, or the manhole is close to the edge of the roadway that the impact becomes important.
FUTURE STEPS

SHORT TERM:

• Calibrate the ADE model developed and investigate the spread of pollutants in floodwater in urban areas
• Assess the ability of a typical 2D model tailored to solve the depth-averaged Shallow Water Equations (SWE) on a non-uniform 2D mesh to represent the surface flow pattern during urban floods by comparing numerical simulations and laboratory experiments

LONG TERM:

• Increase awareness of the health impacts of urban flooding
• Develop health impact models
• Continue to support numerical modellers and improve the accuracy of flood modelling
Thanks a lot for your attention

Dr Rubinato Matteo
m.rubinato@sheffield.ac.uk
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Website: http://www.sheffield.ac.uk/floodinteract

All datasets collected are available in OPEN ACCESS