Assessment of long-term performance of Green infrastructure in urban catchments

Dr Sangaralingam Ahilan
Centre for Water Systems, University of Exeter
• Barriers to adoption of Blue-Green infrastructure

• Ouseburn catchment, Newcastle upon Tyne, UK

• East Lents floodplain restoration, Portland, USA
Grey to Green

• Grey infrastructure

Flood defence

• Green infrastructure

Flood risk management

www.urbanfloodresilience.ac.uk
Blue-Green Cities
Hydrologic and environmental attributes in Grey and Blue-Green Cities
Barriers to adaptation of Blue-Green infrastructure

- Physical science (preconceptions)
- Technical / technological

- Institutional
- Legal / regulatory
- Political
- Monetary
- Social – ‘hearts and minds’
Aim:
Investigate long-term flow and sediment dynamics of the green infrastructure.

Approach
The hydro-morphodynamic model developed by (Guan et al, 2014, 2015) is used.

1. full 2D shallow water equation, +
2. dispersion-advection equation, +
3. morphological evolution equation.
Ouseburn catchment

Land Cover

- Grassland
- Horticulture
- Suburban
- Urban

www.urbanfloodresilience.ac.uk
Stormwater pond
Event-based hydro-morphodynamic simulation
Event-based hydro-morphodynamic simulation

<table>
<thead>
<tr>
<th></th>
<th>5-year ‘without’ pond</th>
<th>5-year ‘with’ pond</th>
</tr>
</thead>
<tbody>
<tr>
<td>Input (SSL m³)</td>
<td>7.35</td>
<td></td>
</tr>
<tr>
<td>Deposited in the Pond (SSL m³)</td>
<td>4.58</td>
<td></td>
</tr>
<tr>
<td>% SSL deposit</td>
<td>62.03</td>
<td></td>
</tr>
</tbody>
</table>

www.urbanfloodresilience.ac.uk
<table>
<thead>
<tr>
<th></th>
<th>16.71</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Input (SSL m³)</strong></td>
<td></td>
</tr>
<tr>
<td>Deposited in the Pond (SSL m³)</td>
<td>7.29</td>
</tr>
<tr>
<td>% SSL deposit</td>
<td>43.63</td>
</tr>
</tbody>
</table>
100-year ‘without’ pond  100-year ‘with’ pond

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Input (SSL m$^3$)</td>
<td>28.41</td>
</tr>
<tr>
<td>Deposited in the Pond (SSL m$^3$)</td>
<td>7.50</td>
</tr>
<tr>
<td>% SSL deposit</td>
<td>26.40</td>
</tr>
</tbody>
</table>

www.urbanfloodresilience.ac.uk  Urban Flood Resilience @BlueGreenCities
Hydraulic evaluation
Pre-sedimentation
Cumulative sediment accumulation in the pond

Annual sedimentation and trap efficiency of the pond
<table>
<thead>
<tr>
<th></th>
<th>5-year</th>
<th>30-year</th>
<th>100-year</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Relative Attn (%)</td>
<td>HRT (hr)</td>
<td>Relative Attn (%)</td>
</tr>
<tr>
<td>Pre-sedimentation</td>
<td>85.45</td>
<td>0.59</td>
<td>45.75</td>
</tr>
<tr>
<td>Post-sedimentation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>After 5 years</td>
<td>84.68</td>
<td>0.58</td>
<td>45.28</td>
</tr>
<tr>
<td>After 10 years</td>
<td>81.41</td>
<td>0.58</td>
<td>42.26</td>
</tr>
<tr>
<td>After 20 years</td>
<td>75.15</td>
<td>0.51</td>
<td>36.64</td>
</tr>
<tr>
<td>After 30 years</td>
<td>77.47</td>
<td>0.54</td>
<td>38.11</td>
</tr>
</tbody>
</table>
The influence of floodplain restoration on flow and sediment dynamics in an urban river

S. Ahilan¹, M. Guan¹, A. Sleigh¹, N. Wright² and H. Chang³

¹ water@leeds, School of Civil Engineering, University of Leeds, Leeds, UK
² Faculty of Technology, De Montfort University, Leicester, UK
³ Department of Geography, Portland State University, Portland, OR, USA

Correspondence
Sangaralingam Ahilan, School of Civil Engineering, University of Leeds, Leeds, LS2 9JT, UK
Email: s.ahilan@leeds.ac.uk; sangar.ahilan@gmail.com
DOI: 10.1111/jfr3.12251

Key words
Floodplain; hydro-morphodynamic model; river restoration; sediment dynamics; urbanisation.

Abstract
A study of floodplain sedimentation on a recently restored floodplain is presented. This study uses a two-dimensional hydro-morphodynamic model for predicting flow and suspended-sediment dynamics in the downstream of Johnson Creek, the East Lents reach, where the bank of the river has been reconfigured to reconnect to a restored floodplain on a 0.26 km² (26-ha) site. The simulation scenarios include 10-, 50-, 100- and 500-year event-based deposition modelling of flood events and long-term modelling using the 64 historical flood events between 1941 and 2014. Simulation results showed that the restored floodplain significantly attenuates the upstream flood peak by up to 25% at the downstream. Results also indicated that approximately 20%-30% of sediment from the upstream is deposited on the East Lents floodplain. Furthermore, deposited sediment over the simulated period (1941–2014) is approximately 0.1% of the basin’s flood storage capacity; however, the reduction in the storage does not offset the overall flood resilience impact of the flood basin. The sediment conservation at the East Lents flood basin as predicted by the model reduces the annual sediment loading of the Johnson Creek by 1% at the confluence with Willamette River, providing both improved water quality and flood resilience further downstream.
Johnson Creek, Portland

Source: Chang et al. 2010 Annals of the Association of American Geographers
Why study about Johnson Creek

- Regular Flooding

- Water Quality Issues
  - High faecal coliform
  - Chronically low dissolved oxygen (DO)
  - High water temperatures in the summer
  - Low pH (elevated water acidity)

Creek has flooded 37 times since 1942
Johnson Creek management strategies

Grey Infrastructures
1) Widening
2) Deepening
3) Rock-lining the creek
4) Creating a trapezoidal channel
Green Infrastructures

1994, Pre Land Acquisition

2011, Post Phase I Restoration
Flood peak attenuation
Event-scale deposition in the floodplain

- Meanwhile, the overbank flow lead to amount of sediment deposition in the floodplain.
- Over 20% of total input sediment was deposited.
- A faster deposition rate during peak period.
Sediment deposition in East Lents floodplain during continuous flooding

Temporal change of cumulative deposition during the identified 64 flood events
Cumulative sediment deposition in East Lents floodplain during continuous flooding

![Graph showing cumulative volume and flow during flooding](image)
Effect of sediment deposition on downstream flood peak

It does increase downstream flood peak, but just slightly because of the small deposition volume in the floodplain.
Floodplain restoration:

- Working with river’s natural dynamics is essential for long term sustainability.
- Restored East Lents floodplain provides up to 30% flood peak reduction.
- Floodplain provides up to 20-30% sediment trapping.
- Sediments tend to concentrate during the moderate (5-25 year) flow events at lower elevations. Larger events re-suspended the previously deposited sediments.
- At the end of the 64 long-term simulation, 2000m$^3$ of sediment was deposited in the floodplain.
FOSTER FLOODPLAIN NATURAL AREA

More fish. Less flooding.

Thank You Portland!