Water exchanges in the hyporheic zone investigated by bank–side extraction well field tests

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Objectives

Hyporheic zone $\Rightarrow$ Water exchanges $\Rightarrow$ Biochemical processes

Flows in 4D $\Rightarrow$ complex
Objectives

Research aim

- Influence of **hydraulic conditions** on mixing and processes
- **Controlled flow regime** proposed for a better understanding
Experimental design

**Method** ⇒ Local field test approach

**Bank-side long-term extraction test**
⇒ Reduce hydraulic gradient between groundwater and river
⇒ Increase surface water diffusion within hyporheic zone?
Experimental design

Mini-drivepoint piezometers combined to multilevel samplers (20)

Heads and quality monitoring in the riverbed

Automatic pressure monitoring devices (8)

Box placed at the bottom of river

Piezometer in riverbed

River
Experimental site

Test site

- Urbanised reach of the River Tame, Birmingham (UK)
- Alluvial-drift deposits overlying ~100m of Permo-Triassic sandstone
Experimental site

- River ⇒ 10 m wide, ~50 cm deep, discharge ~2 m³/s
- Well ⇒ 16 m deep, 5 m from river

<table>
<thead>
<tr>
<th>Geological log</th>
<th>Depth (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Top soil</td>
<td>0</td>
</tr>
<tr>
<td>Made ground</td>
<td>-5</td>
</tr>
<tr>
<td>Alluvial deposits</td>
<td>-5</td>
</tr>
<tr>
<td>Sand and gravel</td>
<td>-10</td>
</tr>
<tr>
<td>Weathered sandstone</td>
<td>-15</td>
</tr>
<tr>
<td>Sandstone</td>
<td></td>
</tr>
</tbody>
</table>

River: 10 m wide, ~50 cm deep, discharge ~2 m³/s
Well: 16 m deep, 5 m from river
First results

Hydraulic data

- Positive gradients: vertical flows towards the river
- Spatial heterogeneity in hydraulic data
First results

Hyporheic zone follows aquifer
Hyporheic zone follows river
Effect of other pumping

Heads/River

- borehole
- river
- logger 7
- logger 8
First results

Variable mixing

- Groundwater–surface water mixing to 15–20cm below the riverbed
- Changes across the time
First results

E-W trend in the vicinity of the borehole: higher conductivities on the east side (squares), close to the river values

Lithology variations?
Preliminary flow simulations

- Calibrate the aquifer properties based on head monitoring
- Find an optimal extraction rate for long-term test

3 principal geological layers with different K values

- Riverbed (5 m/d)
- Alluvium (5 m/d)
- Made ground (1 m/d)
- Sandstone (2 m/d)

Reference hypothesis
- Test 1: base case properties
- Test 2: Kriverbed = 20 m/d
- Test 3: Ksandstone = 1 m/d

Sensitivity tests

- Gradient
- Depth (m)

- 50 m³/d at 0.5 m
- 150 m³/d at 1.0 m

- Low K ⇒ Increased effect of pumping
- At 150 m³/d, vertical exchanges might be inversed: negative gradient in test 3

Additionally, there is a graph showing the sensitivity tests with gradient and depth, indicating the rates at which different geological layers react to pumping.
Conclusion and perspectives

Conclusion

- Highlight of spatial heterogeneities in hydraulic and chemical data
- Mixing depth around 15–20 cm, in summer
- Optimum discharge rate below 150 m³/d

Future work

- Extraction tests planned in the next few weeks
- Follow denitrification activity
- 3D modelling
Chemical data

- **Chloride**: mg/l
- **Sulphate**: mg/l
- **Dissolved oxygen**: ppm
- **Nitrate**: mg/l

- **Groundwater-surface water mixing to 15–20 cm below the riverbed**
- **Complex temporal behaviors, possible reactions**
River conductivity

- Soils washing
- Dilution effect

Height (cm)
04/12/07 24/12/07 13/01/08 02/02/08

Cond (mS/cm)