A case study project in Wallonia

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Introduction

• Building of a new Knowledge and Resource Centre in Liège, targeting energy independence.

• First open-loop well-doublet ATES system in Wallonia.

• Injection, storage and recovery in the Meuse alluvial aquifer.

• Main goals:
  - Create a predictive 3D hydrogeological model.
  - Check the ATES system technical feasibility and initial implementation, based on building thermal needs.
Location
Study area
Field work

- Head and Temperature monitoring (O1 to O5).
- Pumping tests (21 to 63 m³/h) in W1 & W2.
- Na-naphtionate tracer test: 50 L (20 g/L) injection at O1, monitoring at W2.
- Heat tracer test: background T = 14 °C, 28 m³ injected at T = 48 °C (ΔT = 34 K).
- 4D time-lapse Electrical resistivity tomography (ERT) monitoring of the heat tracer test. But didn’t succeed.
Field work

A. Heat tracer test

- Temperature peak
- First arrival
- Injection stop

B. Dye tracer test (Na-naphtionate)

- Dye tracer peak
- First arrival
Numerical model

- Modeling code: FEFLOW®.
- Groundwater flow / heat transport.
- Transient simulations, fully saturated conditions.
- Groundwater flow: automatic calibration against hydraulic head, with pilot points (PEST; Doherty, 2015, 2016).

\[
\begin{align*}
\lambda &= 2.7 \text{ W/mK} \\
\rho_c &= 3.27 \text{ MJ/m}^3\text{K} \\
n_{	ext{eff}} &= 0.16 \\
K &= 8 \times 10^{-3} \text{ m/s}
\end{align*}
\]
Groundwater flow calibration

- Calibration under steady state conditions:
  - No active pumping well.
  - Low residuals calculated.
  - But, very low local hydraulic gradient.
- Validation under transient conditions:
  - 50 m³/h at W2.
  - Drawdown at piezometers: ok.

<table>
<thead>
<tr>
<th></th>
<th>Observed head (m)</th>
<th>Simulated head (m)</th>
<th>Residual (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>O1</td>
<td>59.21</td>
<td>59.21</td>
<td>0.00</td>
</tr>
<tr>
<td>O2</td>
<td>59.21</td>
<td>59.22</td>
<td>0.01</td>
</tr>
<tr>
<td>O3</td>
<td>59.19</td>
<td>59.18</td>
<td>-0.01</td>
</tr>
<tr>
<td>O4</td>
<td>59.18</td>
<td>59.16</td>
<td>-0.02</td>
</tr>
<tr>
<td>O5</td>
<td>59.24</td>
<td>59.23</td>
<td>-0.01</td>
</tr>
</tbody>
</table>
Predictive simulation

- Groundwater flow / heat transport.
- 10-year simulation, based on building energy needs estimated data.
- Injection and recovery, up to 24 m³/h.
- Max. authorized operational $\Delta T = 5$ K
- COP = 4.5 / EER = 7.0

<table>
<thead>
<tr>
<th></th>
<th>Heating season</th>
<th>Cooling season</th>
</tr>
</thead>
<tbody>
<tr>
<td>Duration [d]</td>
<td>105</td>
<td>260</td>
</tr>
<tr>
<td>Max. Q [m³/h]</td>
<td>7.2</td>
<td>25.1</td>
</tr>
<tr>
<td>Stored volume [m³]</td>
<td>5 100</td>
<td>50 000</td>
</tr>
</tbody>
</table>

$\Delta = 44 900$ m³
Simulated hydraulic head

- Meuse water level: seasonally dependent, controlled flow through locks located upstream.
- Major influence on groundwater head in the aquifer.
Simulated groundwater temperature

- Short-circuit during the cooling season.
- Meuse temperature: no impact on ATES system operational temperature.
- Thermal plume intercepted at O3 and O4 after a couple of cycles.
Temperature distribution in the aquifer

ATES cycle no. 1

ATES cycle no. 5

ATES cycle no. 10

End of cooling season

End of heating season

Absolute temperature [°C]

Hydraulic head [m]

100 m
Conclusion

Highly productive aquifer suitable for ATES application

**but** the imbalance between stored warm and cold water has to be monitored in the future.

**Is the thermal plume an issue?**
- Heat island effect linked to the thermal insulation of the building.
  → Cooling efficiency likely affected by the T° rise.
  → Increase inter-well distance to avoid short-circuiting.
- Simulation performed with ATES running in continuous mode.
  → Office building, working days.
- Overdesign: 100% efficient system simulated.
- Pooling/sharing the excess stored heat for old buildings in the district.

**Is the model reliable?**
- Calibrated model, but data scarcity.
- Uncertainty analysis needed.
- Long-term simulations to be run (25-30 years).
Thank you for your attention

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