Use of Isotope data to quantify the interaction between the river Rhine and the groundwater at Oberriet, CH

Christian Gmünder¹, Simon Nusch¹, Stephanie Zimmermann²

¹Simultec AG, Zürich
²BAFU, Abteilung Hydrologie, Sektion Hydrogeologische Grundlagen, Ittigen
The interaction between river and groundwater and the flow velocity towards drinking water wells must be known.

The BAFU performs oxygen isotope ($^{18}$O) measurements at the Balanggen well at Oberriet.

Can the $^{18}$O measurements be used to improve the results.

Numerical groundwater model of the Alpenrhein valley and simulations of the electric conductivity (EC) values at the wells.
Balanggen well
- 400 m from the River Rhine
- Groundwater flow is directed from the Rhine to the well
- A clear annual cycle of EC and $^{18}$O can be measured at the well and the river.

But
- Infiltration is strongly dependent on river discharge
- An undercurrent of the riverbed is suspected

→ Complex situation – can’t be treated by a simple time series analysis
Task Analysis

Needs
- Numerical model needed
- Model must be transient
→ Local model embedded in the existing regional model

Unknown Parameters
- Leakage through the riverbed
- Aquifer permeability
- Effective porosity
- EC: mineralisation speed

Discharge dependent Cauchy boundary

Model boundaries and boundary conditions
Candidate observations

**EC**
- Cheap measurements
- river and background GW concentration differ
- Adapts to background value
- Background values 600 µS/cm

**18O**
- Expensive measurements
- river and background GW concentration differ
- No change during gravel passage
- Background values -10.3 ‰ [4]

Electrical conductivity measurements

Oxygen isotope measurements
Methods

Boundary conditions
- All inflows to the model get a zero concentration
- Inflows from the river Rhine get a concentration calculated as the difference between background and measured concentration
- Mineralization of EC is considered by an exponential degradation of concentration

Transport model
- Dispersion considered
- Needs a fine element discretisation to avoid numerical dispersion

Mass balance along flow paths
- Flow paths in continuous velocity field \[^{1,3}\]
- Faster and more stable
- Statements about flow times possible

Transport model screenshot
Calibration by groundwater level measurements

- Aquifer permeability can be calibrated
- Level fluctuations are not sensitive to leakage values at project site
- Effective porosity can’t be calibrated (not fillable/drainable porosity)
Calibration by $^{18}$O signal

- Effective porosity can be calibrated by modelling the time lag between signal in the river and signal in the well.
- Leakage value can be calibrated by simulating the absolute values.
Results: Rhine Water Fraction

- Rhine River fraction depends strongly on Rhine discharge
- Fraction values between 0% and 50%
Results: Flow Times from Rhine to Well

- Flow times from Rhine to well depend on Rhine discharge
- Values along different flow paths vary between 70 and 360 days
Added value: EC mineralization speed

- Mineralization speed can be estimated by a sensitivity analysis
- Half time values are in the range of 100 to 200 days
Conclusions

- Knowledge on the interaction between river Rhine and groundwater was gained by building up a transient groundwater model.
- The use of oxygen isotopes helped us to calibrate the leakage value of the river.
- Measuring frequency should be higher than four times per year.
- As a byproduct, we were able to estimate the EC mineralization speed.

Questions?

2. EAWAG (2011). Untersuchung der Flusswasserinfiltration mittels Zeitreihenanalyse der NAQUA Daten Oberriet, Kappelen und Brugg, interner Abschlussbericht BAFU.