Assessing borehole geophysical data by simulating borehole flow in fractured bedrock aquifers

Andrew S. Reeve and Joseph Sawdey

University of Maine, Dept. of Earth Sciences
asreeve@maine.edu
What is a fractured bedrock aquifer?

Aquifer
Subsurface unit that yields a significant amount of water to a well.

Fractures
Breaks in rock that groundwater flows through.
Assess fractured bedrock aquifer with:

- rock core
- surface geophysics
- borehole geophysics
Assess fractured bedrock aquifer with:

- rock core
- surface geophysics
- borehole geophysics
Simulating borehole flow
Heat-Pulse Flow Meter

Model Flow Data:

- **Results:**
  - Transmissivity
  - Far-field Head

- **Purpose:**
  - Water Supply
  - Contaminant Transport

Andrew S. Reeve and Joseph Sawdey

Simulating borehole flow
Borehole Data (Jonesboro, Maine)

Caliper Log

H.P. Flow Meter

Andrew S. Reeve and Joseph Sawdey

Simulating borehole flow
Presented in Paillet (1998)
- Maximize value of data
- Quantify hydraulic parameters for discrete zones
- Model not widely available
- Trail and error methodology

Based on superposed sequence of slug tests
- Integral equation for recovery
- Cooper, Bredehoeft, Papadopulos (1967)

\[
\frac{8\alpha}{\pi^2} \int_0^\infty \frac{e^{-\frac{\beta u^2}{\alpha}}}{u(2\alpha J_1(u))^2 + (\beta J_0(u))^2} \, du
\]

\[
\beta = \frac{T \cdot t}{r_c^2} \quad \alpha = \frac{r_c^2 \cdot S}{r_c^2}
\]
Borehole Flow Model

Andrew S. Reeve and Joseph Sawdey
Simulating borehole flow
Borehole Flow Model

Simulating borehole flow

Andrew S. Reeve and Joseph Sawdey
Simulating borehole flow

1. Assign Hydraulic Data to Borehole
2. Numerically Integrate (scipy.integrate.quadpack.quad)
3. Interpolate Recovery vs. Time (scipy.interpolate.UnivariateSpline)
4. Loop over time
   - Loop over fractures
     - Sum fracture responses to slugs using Interpolation
     - Update well water level
   - Return flow in well between fractures
5. Compare with measured Data (scipy.optimize.leastsq)

Andrew S. Reeve and Joseph Sawdey
Validation

Q(Analytic)=0.5000 gpm
Q(Dt=0.5)=0.4999 gpm
Q(Dt=2.0)=0.4999 gpm

Andrew S. Reeve and Joseph Sawdey
Simulating borehole flow
Borehole Flow Model Fit

**Caliper Log**

\[ T = 2.42 \times 10^{-4} \text{ m}^2 \cdot \text{sec}^{-1} \]

Head Diff. = 0.096 m

**H.P. Flow Meter**

\[ T = 2.13 \times 10^{-3} \text{ m}^2 \cdot \text{sec}^{-1} \]

Head Diff. = -0.038 m

\[ T = 2.41 \times 10^{-3} \text{ m}^2 \cdot \text{sec}^{-1} \]

Head Diff. = -0.047 m

Andrew S. Reeve and Joseph Sawdey

Simulating borehole flow