Homework 5 - Spring 2008: Earth 441 – Aquifer Mechanics

Assigned: Feb 21, 2008; Qu. 1-3 Due: Feb 26, 2008, 5:00pm; Qu. 4 Due: Feb 27, 2008, Noon

Please make sure to show all your work, including any diagrams you used, and cite sources in order to get full credit. This may be submitted in paper or electronic format (Shasta@nmt.edu).

1. Computing drawdown caused by pumping in a confined aquifer (17 pts)

Background:
A fully penetrating well that is screened in an infinite, confined aquifer is to be pumped at a rate of 165,000 ft³/day for 30 days. The aquifer transmissivity is 5320 ft²/day, and the storativity is 0.0007.

Required:
a) Determine the drawdown at distances of 50, 150, 250, 500, 1000, 3000, 5000, and 10,000 ft from the pumping well and plot the results. Use the Theis equation. Remember that the well has been pumping for 30 days. Please provide a table of the drawdowns at the various distances.
b) Determine the distance at which u crosses the threshold value of 0.01 and plot it on the graph. Discuss what happens at this point and why it is important.

Source: Modified from Fetter, 2001, Problem 5.2

2. Steady-state flow in a confined aquifer and estimation of transmissivity (20 pts)

Background:
The multi-observation well data in the following table was obtained during a pump test. The data was taken after 810 minutes of pumping. The pumping rate was 8.6 x10⁻³ m³/sec.

<table>
<thead>
<tr>
<th>Piezometer (subscript indicates distance in meters from pumping well)</th>
<th>P₀.5</th>
<th>P₂₅</th>
<th>P₈₀</th>
<th>P₂₅₀</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drawdown (in meters)</td>
<td>4.472</td>
<td>2.123</td>
<td>1.432</td>
<td>0.500</td>
</tr>
</tbody>
</table>

** Note that drawdowns have been given instead of heads. **

Required:
This data set must be analyzed by hand or with Excel. Do not AQTESOLV or any other well analysis package to analyze the data.

a) Use the Thiem equation to calculate the transmissivity using every possible pair of piezometers (six combinations)—that is, use only the observation well pairs. Do not use the radius of influence concept. Find the arithmetic average of the six T values. Report answers in m²/day. (If you use a spreadsheet, please email this to me separately)
b) What is the likely reason that the transmissivity calculated in part (a) above, using just P₈₀ and P₂₅₀, is so much lower than the other values?
c) Find the average transmissivity (m²/day) using the multi-well Theim distance-drawdown graphical method (plotting drawdown versus log distance). Compare this value to the numerical average found in part (a) above.
3. **Boundary conditions** (14 pts)

Required: For the following situations, determine whether a Dirichlet, Neumann, or Cauchy boundary condition is evident.

(a) Surfaces marked by the label “water level” above and below the dam in Figure 1.
(b) The boundary between two media with different hydraulic conductivities through which ground water is flowing (for example, Figure 2).
(c) The water-table surface in Figure 3.

![Figure 1](image1.png)

Figure 1. Flow in an x-z plane through pervious rock beneath a dam (Figure 5.6 from Schwartz and Zhang, 2003). Flow lines are solid black lines, whereas equipotential lines are dashed lines.

![Figure 2](image2.png)

Figure 2. Diagrams illustrating how flow lines refract in moving across hydraulic conductivity boundaries in systems of aquifers and confining beds (Figure 5.10 from Schwartz and Zhang, 2003; Heath, 1983).
4. **Superposition** (40 pts)

Background:
A well (pumping well #1) is located in a horizontal, confined aquifer. The upper and lower confining formations have very low permeability and are not leaky. The well was completed such that it is fully penetrating and screened across the entire vertical thickness of the aquifer. An observation well is located in the same aquifer 110 m to the northeast (i.e., azimuth bearing of 45°), and it also is fully penetrating and screened across the entire vertical thickness of the aquifer. The thickness of the aquifer is 175 m, the aquifer storativity is \(4.69 \times 10^{-4}\), and the aquifer transmissivity is \(0.55 \text{ m}^2/\text{min}\). The well is pumped at a rate of \(3.579 \text{ m}^3/\text{min}\) for exactly 12 hours and another well begins pumping. The second well, pumping well #2, is located 220 m due east (i.e., azimuth bearing of 90°) of pumping well #1 and is pumped at a rate of \(3.750 \text{ m}^3/\text{min}\). Drawdown was measured at the observation well.

Required:

a) Plot drawdown versus time in the observation well for each pumping well independently, and for their superposition, giving the total drawdown. Your graph of the drawdowns for pumping wells #1 and #2 and their superposition should all be on the same graph. Use the following times after the start of pumping well #2: 17, 35, 65, 110, 310, 550, 1050 minutes. The axes of your graphs should have arithmetic (i.e., linear) scales. Time should be plotted on the x-axis. The range for time on the x-axis should correspond to the time that pumping well #2 is pumping.

b) What characteristic of the groundwater flow equation allows us to superimpose the solutions from two wells pumping in the same aquifer? What conditions could invalidate this approach? Why?