CGN 6933 Groundwater Engineering

Homework #10 | Fall 2019

Due Tues., Dec. 3, 2019 | Prof. J. A. Cunningham

**This assignment will be collected and graded.**
**Complete this assignment in a team of 2 or 3 students.**

(1) A fully-penetrating extraction well is installed in a confined aquifer, and a monitoring well is installed at a distance 95 m from the extraction well. At time $t = 0$, the extraction well begins pumping water from the aquifer at a rate $Q = 1.6$ m$^3$/min $= 2300$ m$^3$/day, and the drawdown at the extraction well is monitored for 4 hours. Given the drawdown data shown in the table below, use the Theis "curve-matching" method to estimate the storativity and transmissivity of the aquifer.

Table 1: Drawdown at monitoring well vs. time

| time (min) | drawdown (m) |
|---|---|
| 0 | 0.0 |
| 1 | 0.15 |
| 2 | 0.22 |
| 4 | 0.30 |
| 8 | 0.39 |
| 15 | 0.46 |
| 30 | 0.55 |
| 60 | 0.63 |
| 120 | 0.72 |
| 240 | 0.81 |

(2) Consider the same conditions as in Problem 2, but estimate the transmissivity and storativity using the Jacob method instead of the Theis method. Compare your results from the two methods. How closely do they agree? What level of precision or uncertainty do you think is reasonable when employing these methods? How many significant digits do you feel confident reporting from these methods? Do you trust your estimates to within a few percent? to within 20%? within 50%? a factor of 2?

(3) Farmer Jones uses a well to get his drinking water. His well is dug into a confined aquifer. He is worried because the nearby city is planning to install a new municipal well into the aquifer to provide water for the city. Farmer Jones worries that the aquifer will get drawn down too far, and then he will have to dig a deeper well. The city's plan is to install the city well 670 m east of Farmer Jones's well, and to extract water at a rate of 1100 $m^3$/day. Farmer Jones calls the United States Geological Survey to find out the transmissivity and storativity of the aquifer. Then he uses the Theis equation to estimate the drawdown that he expects to observe in his well. (Farmer Jones is a pretty educated guy.) Here are Farmer Jones's predictions:

Table 2: Predicted Drawdown at Jones well vs. time

| time (days) | drawdown (m) |
|---|---|
| 1 | 2.0 |
| 10 | 3.0 |
| 100 | 4.0 |

(a) What are the transmissivity and storativity of the aquifer?

(b) It might be that Farmer Jones is worrying more than he needs to. He forgot that, 330 m to the west of his well, there is a river that is hydraulically connected to the aquifer. Given this information, what drawdown should Farmer Jones expect to see in his well at the times listed above (1 day, 10 days, and 100 days)? Hint: use the method of images.

(c) What will be the drawdown in Farmer Jones's well once the system reaches steady state?

(d) Using the condition for validity of the Cooper-Jacob approximation, estimate about how long it will take to reach steady state at Farmer Jones's well. Does your calculation agree with your results from part (b)?

(e) How much should he worry about the city's plan to install the new well?

(4) Suppose a river flows along the line $x = 0$. A well has just been installed at $(x = -200, y = 0)$ m. The aquifer is confined. The hydraulic head at the river is $h_0 = 26$ m. The aquifer is homogeneous with hydraulic conductivity $K = 1 \times 10^{-3}$ cm/s, thickness $b = 15$ m, and storativity $S = 0.0008$. At time $t = 0$, the pump is turned on in the well, and begins extracting water at a rate $Q = 100$ m$^3$/day.

(a) Plot the drawdown vs. time for the extraction well and for an observation well. The radius of the extraction well casing is $r_w = 0.15$ m. The location of the monitoring well is $(x = -100, y = 0)$ m. Put both drawdown curves on the same plot. Label the curves clearly.

(b) According to your plots, at what time is steady-state reached for the extraction well? for the monitoring well? Hint: you might want to make your time axis a logarithmic scale to get a better estimate of when steady-state is reached.

(c) At what time would you expect the Cooper-Jacob late-time approximation to be valid for this problem?

(d) Compare the times that you found in parts (b) and (c). Is steady-state reached before or after you expected the late-time approximation to be valid? Does this make sense? Discuss briefly.

(e) Remember that the Theis solution is not valid for unconfined aquifers. Verify that the aquifer remains confined, i.e., that the extraction well is not drawn down below a head equal to $b$.