**Groundwater - Homework 4**
Due November 8

## Question 1

(a) You are studying a confined aquifer and deem that pumping has caused the system to reach its steady state

Two observation wells are placed at a distance of 3.3 and 11 meters from a pumping well. The well is pumped at a flow rate of 1250 liters/minute. The depth to water is 22m and 15 m for the first and second well respectively.

What is the transmissivity of the aquifer? If the thickness of the aquifer is 10m, what is the hydraulic conductivity?

(b) You are studying an unconfined aquifer and deem that pumping has caused the system to reach its steady state

Two observation wells are placed at a distance of 2.2 and 7.9 meters from the pumping well. The well is pumped at a flow rate of 750 litres/minute The depth to water is 4m and 1 m for the first and second well respectively. What is the hydraulic conductivity of the aquifer, if the depth to the bottom of the aquifer is 10m?

(c) ***Conceptual***: Given what you know about transient pumping tests, how would you determine or make an executive decision that the system has reached steady state. Look carefully at the analytical solutions for transient pumping before writing an answer.

**Question 2**

Consider the data given below for a pumping test conducted at a field site. Drawdown is recorded at two wells. The flow rate is 20m^3/min and the wells are located at 2m (well 1) and 5 m (well 2) from the pumping well.

(i) Determine the Transmissivity and Storativity of the aquifer considering both data sets (for the sake of experience try using both a graphical, using the graph in the powerpoint notes and analytical approximation- also a good check for consistency).

(ii) Are the measurements at both wells consistent? If not, look at some of the assumptions associated with the interpretation method you chose to use and discuss which you may think are dubious.

| Time(min) | Drawdown 1(m) | Drawdown 2(m) |
|---|---|---|
| 0.01 | 0.00003449 | 0.00000000 |
| 0.02 | 0.00201575 | 0.00000000 |
| 0.03 | 0.02475452 | 0.00000000 |
| 0.05 | 0.12230100 | 0.00000073 |
| 0.09 | 0.35204287 | 0.00017920 |
| 0.16 | 0.73013674 | 0.00506511 |
| 0.29 | 1.23422890 | 0.04076822 |
| 0.50 | 1.82894647 | 0.15696208 |
| 0.88 | 2.48279807 | 0.38876343 |
| 1.54 | 3.17311686 | 0.73467203 |
| 2.69 | 3.88520458 | 1.17030853 |
| 4.71 | 4.61004669 | 1.66762408 |
| 8.25 | 5.34228203 | 2.20414039 |
| 14.44 | 6.07877675 | 2.76446701 |
| 25.27 | 6.81771682 | 3.33888363 |
| 44.22 | 7.55805797 | 3.92151439 |
| 77.38 | 8.29920096 | 4.50889296 |
| 135.41 | 9.04080254 | 5.09900236 |
| 236.97 | 9.78266630 | 5.69067808 |
| 414.69 | 10.52467993 | 6.28325077 |
| 725.71 | 11.26677920 | 6.87633662 |
| 1269.99 | 12.00892742 | 7.46971592 |
| 2222.48 | 12.75110362 | 8.06326297 |
| 3889.33 | 13.49329580 | 8.65690590 |
| 6806.33 | 14.23549711 | 9.25060362 |

**Question 3**

The following data was obtained from a slug test. As per the Geological Survey guidelines three were performed.

(i) Knowing nothing about the well casings and just looking at this data, which of the interpretation methods that you learned would you use and why? Now you are told that the case does not fully penetrate the aquifer. Would you still use the same method?

(ii) Apply your method of choice to infer the aquifer parameters knowing that the radius of the screen is 0.5 m, the radius of the casing is 0.6m and the length of well screen is 4m

| t(s) | H1(cm) | H2(cm) | H3(cm) |
|---|---|---|---|
| 0.10 | 79.88008996 | 79.86012243 | 79.90006247 |
| 0.25 | 79.70056180 | 79.65076451 | 79.75039022 |
| 0.50 | 79.40224439 | 79.30305359 | 79.50155925 |
| 0.75 | 79.10504357 | 78.95686058 | 79.25350466 |
| 1.00 | 78.80895517 | 78.61217885 | 79.00622404 |
| 2.00 | 77.63564268 | 77.24843330 | 78.02479296 |
| 3.00 | 76.47979855 | 75.90834568 | 77.05555342 |
| 4.00 | 75.34116269 | 74.59150559 | 76.09835396 |
| 5.00 | 74.21947891 | 73.29750973 | 75.15304503 |
| 6.00 | 73.11449482 | 72.02596181 | 74.21947891 |
| 7.00 | 72.02596181 | 70.77647240 | 73.29750973 |
| 8.00 | 70.95363494 | 69.54865883 | 72.38699344 |
| 9.00 | 69.89727294 | 68.34214509 | 71.48778777 |
| 10.00 | 68.85663811 | 67.15656166 | 70.59975221 |
| 20.00 | 59.26545765 | 56.37504718 | 62.30406265 |
| 30.00 | 51.01025213 | 47.32442915 | 54.98314230 |
| 40.00 | 43.90493089 | 39.72682430 | 48.52245278 |
| 50.00 | 37.78932422 | 33.34896157 | 42.82091428 |
| 100.00 | 17.85041281 | 13.90191548 | 22.92038375 |
| 200.00 | 3.98296547 | 2.41579067 | 6.56679989 |
| 300.00 | 0.88871972 | 0.41980147 | 1.88141967 |
| 400.00 | 0.19830017 | 0.07295056 | 0.53903576 |
| 500.00 | 0.04424675 | 0.01267691 | 0.15443633 |
| 1000.00 | 0.00002447 | 0.00000201 | 0.00029813 |

**Question 4**

A slug test was made with a piezometer that has a casing radius of 2.54 cm and a screen of radius 2.54 cm. A slug of 4000 $cm^3$ of water was injected, which raised the water level by 197.3 cm. The well completely penetrated a confined stratum that was 2.3 m thick. The decline in head with time is given the following chart below. Plot the data on a semilogarithmic paper and find the transmissivity and storativity using the Cooper-Bredehoeft-Papadopolous method. A copy of the CBP figure is available on the following page along with a table with values from the original paper on this work.

| Elapsed Time (s) | Head (cm) |
|---|---|
| 0 | 197.3 |
| 1 | 185.4 |
| 2 | 178.6 |
| 3 | 173.6 |
| 5 | 167.7 |
| 7 | 158.8 |
| 10 | 147.0 |
| 13 | 140.0 |
| 17 | 129.2 |
| 22 | 118.4 |
| 32 | 99.6 |
| 53 | 74.0 |
| 84 | 51.3 |
| 119 | 35.5 |
| 170 | 23.3 |
| 245 | 15.2 |
| 400 | 8.7 |
| 800 | 4.3 |

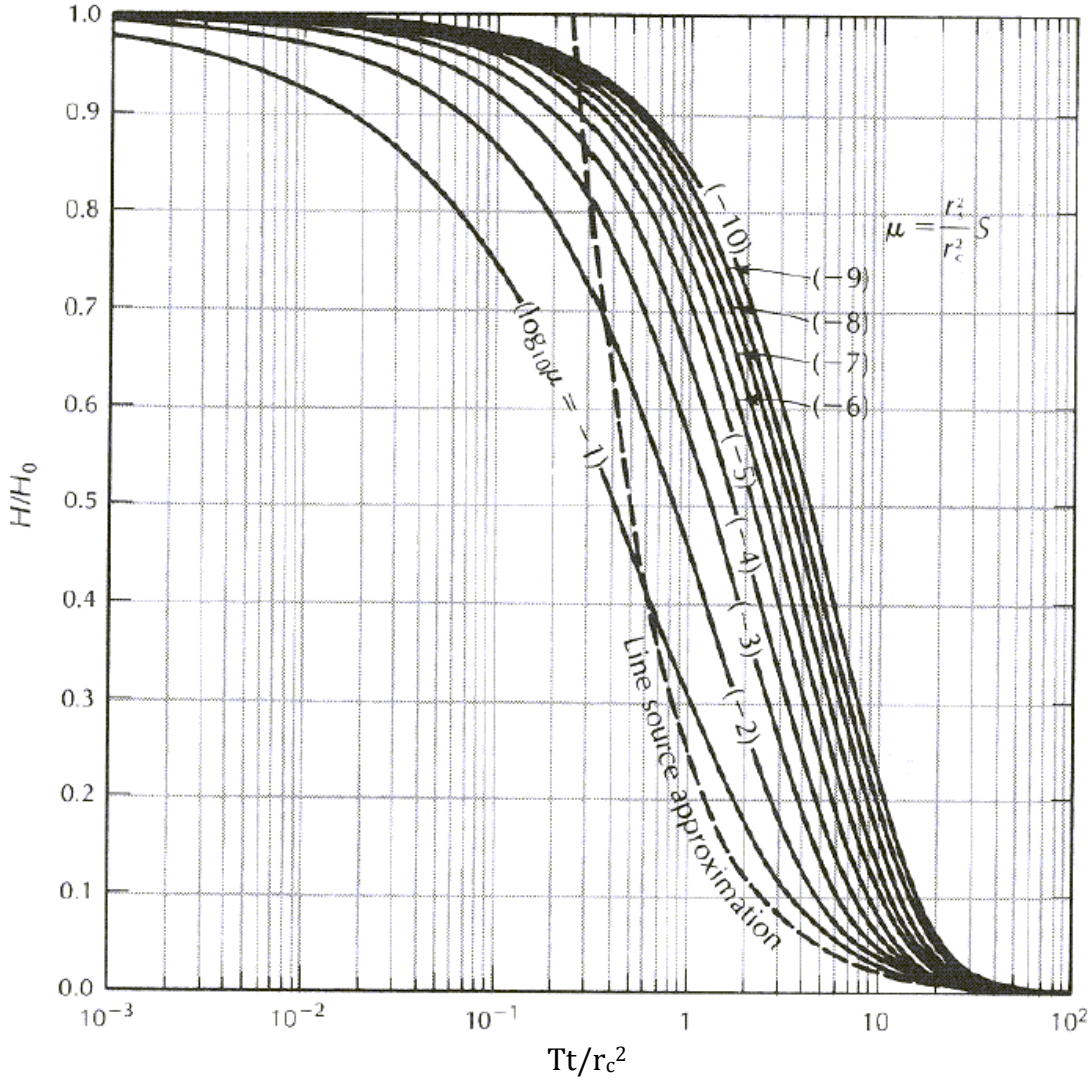
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
H/H0
10−3
10−2
10−1
1
10
10²
Tt/rc²
(−10)
(−9)
(−8)
(−7)
(−6)
(−5)
(−4)
(−3)
(−2)
(log10μ = −1)
Line source approximation

TABLE 1. Values of $H/H_0$ for a Well of Finite Diameter

| $Tt/r_c^2$ | $\alpha = 10^{-6}$ | $\alpha = 10^{-7}$ | $\alpha = 10^{-8}$ | $\alpha = 10^{-9}$ | $\alpha = 10^{-10}$ |
|---|---|---|---|---|---|
| 0.001 | 0.9994 | 0.9996 | 0.9996 | 0.9997 | 0.9997 |
| 0.002 | 0.9989 | 0.9992 | 0.9993 | 0.9994 | 0.9995 |
| 0.004 | 0.9980 | 0.9985 | 0.9987 | 0.9989 | 0.9991 |
| 0.006 | 0.9972 | 0.9978 | 0.9982 | 0.9984 | 0.9986 |
| 0.008 | 0.9964 | 0.9971 | 0.9976 | 0.9980 | 0.9982 |
| 0.01 | 0.9956 | 0.9965 | 0.9971 | 0.9975 | 0.9978 |
| 0.02 | 0.9919 | 0.9934 | 0.9944 | 0.9952 | 0.9958 |
| 0.04 | 0.9848 | 0.9875 | 0.9894 | 0.9908 | 0.9919 |
| 0.06 | 0.9782 | 0.9819 | 0.9846 | 0.9866 | 0.9881 |
| 0.08 | 0.9718 | 0.9765 | 0.9799 | 0.9824 | 0.9844 |
| 0.1 | 0.9655 | 0.9712 | 0.9753 | 0.9784 | 0.9807 |
| 0.2 | 0.9361 | 0.9459 | 0.9532 | 0.9587 | 0.9631 |
| 0.4 | 0.8828 | 0.8995 | 0.9122 | 0.9220 | 0.9298 |
| 0.6 | 0.8345 | 0.8569 | 0.8741 | 0.8875 | 0.8984 |
| 0.8 | 0.7901 | 0.8173 | 0.8383 | 0.8550 | 0.8686 |
| 1.0 | 0.7489 | 0.7801 | 0.8045 | 0.8240 | 0.8401 |
| 2.0 | 0.5800 | 0.6235 | 0.6591 | 0.6889 | 0.7139 |
| 3.0 | 0.4554 | 0.5033 | 0.5442 | 0.5792 | 0.6096 |
| 4.0 | 0.3613 | 0.4093 | 0.4517 | 0.4891 | 0.5222 |
| 5.0 | 0.2893 | 0.3351 | 0.3768 | 0.4146 | 0.4487 |
| 6.0 | 0.2337 | 0.2759 | 0.3157 | 0.3525 | 0.3865 |
| 7.0 | 0.1903 | 0.2285 | 0.2655 | 0.3007 | 0.3337 |
| 8.0 | 0.1562 | 0.1903 | 0.2243 | 0.2573 | 0.2888 |
| 9.0 | 0.1292 | 0.1594 | 0.1902 | 0.2208 | 0.2505 |
| 10.0 | 0.1078 | 0.1343 | 0.1620 | 0.1900 | 0.2178 |
| 20.0 | 0.02720 | 0.03343 | 0.04129 | 0.05071 | 0.06149 |
| 30.0 | 0.01286 | 0.01448 | 0.01667 | 0.01956 | 0.02320 |
| 40.0 | 0.008337 | 0.008898 | 0.009637 | 0.01062 | 0.01190 |
| 50.0 | 0.006209 | 0.006470 | 0.006789 | 0.007192 | 0.007709 |
| 60.0 | 0.004961 | 0.005111 | 0.005283 | 0.005487 | 0.005735 |
| 80.0 | 0.003547 | 0.003617 | 0.003691 | 0.003773 | 0.003863 |
| 100.0 | 0.002763 | 0.002803 | 0.002845 | 0.002890 | 0.002938 |
| 200.0 | 0.001313 | 0.001322 | 0.001330 | 0.001339 | 0.001348 |

Taken from
http://www.agu.org.proxy.library.nd.edu/pubs/crossref/1973/WR009i004p01087.shtml

(If you want to download this paper and you get an error you can get it by going through the library web page and searching for the journal Water Resources Research).

**Question 5**

Below we have data from another slug test (only a single one). The well is known to be fully penetrating. The screen and casing radius are both 2.54cm.

(i) Of the methods you know, which do you deem applicable and why?
(ii) Now calculate the aquifer transmissivity with this method. Assume a storage coefficient of 2 x 10^-5.

| Time(s) | h(cm) |
|---|---|
| 0.00 | 60.00000000 |
| 1.00 | 50.59032345 |
| 2.00 | 29.92571343 |
| 3.00 | 3.76429619 |
| 4.00 | -21.27701652 |
| 5.00 | -39.35525494 |
| 6.00 | -46.72534080 |
| 7.00 | -42.46552433 |
| 8.00 | -28.47856115 |
| 9.00 | -8.82403433 |
| 10.00 | 11.40866695 |
| 11.00 | 27.38454871 |
| 12.00 | 35.64824560 |
| 13.00 | 34.83608462 |
| 14.00 | 25.83814806 |
| 15.00 | 11.41424975 |
| 16.00 | -4.60326393 |
| 17.00 | -18.29936757 |
| 18.00 | -26.60968263 |
| 19.00 | -27.98063636 |
| 20.00 | -22.62114846 |
| 21.00 | -12.31765777 |
| 22.00 | 0.11014223 |
| 23.00 | 11.55636894 |
| 24.00 | 19.38634066 |
| 25.00 | 22.02416840 |
| 26.00 | 19.24447881 |
| 27.00 | 12.12194372 |
| 28.00 | 2.67687549 |
| 29.00 | -6.67583117 |
| 30.00 | -13.72881613 |

**Question 6 - Field Data**

Download the slug test data from the homework web page and estimate the hydraulic conductivity of the soils at the ND-LEEF site in St Patrick's Park