University of Anbar
Department of Applied Geology
Ramadi-Iraq
Mahmood H. D. Al-Kubaisi

Lecture (9)

Piezometers

A piezometer (Figure --) is an open-ended pipe, placed in a borehole that has been drilled to the desired depth in the ground. When the depth to water is to be measured manually, the diameter of the piezometers need not be larger than 5 cm. If automatic water-level recorders or electronic water pressure transducers are used, larger diameter piezometers will be needed.

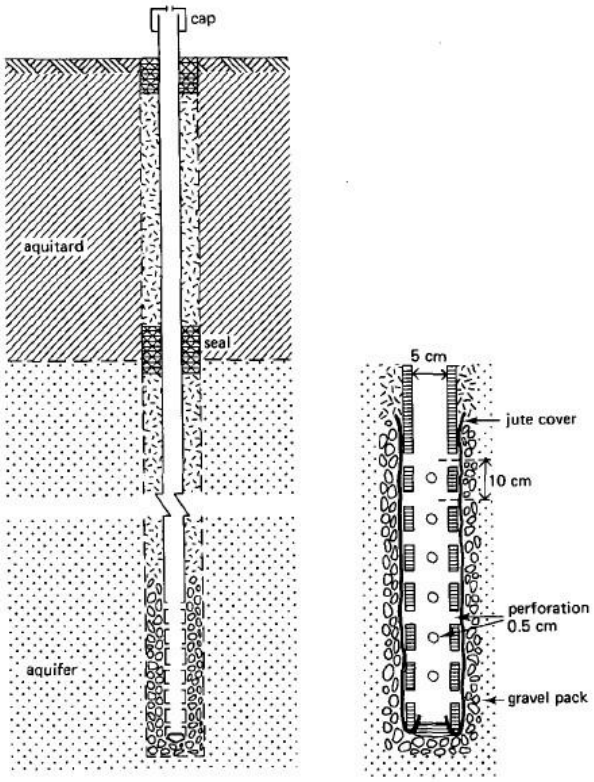

Figure --: A piezometer

After the well has been completed and its information analyzed, one has to decide how many piezometers to place, at what depths, and at what distances from the well.

- *The number of piezometers*

The question of how many piezometers to place depends on the amount of information needed, and especially on its required degree of accuracy, but also the funds available for the test. Three, at least, are recommended.

- *Their distance from the well*

Piezometers should be placed not too near the well, but not too far from it either. the distances at which piezometers should be placed depends on the type of aquifer, its transmissivity, the duration of pumping, the discharge rate, the length of the well screen, and whether the aquifer is stratified or fractured.

The type of aquifer: When a confined aquifer is pumped, the drawdown will be measurable at great distances from the well. In unconfined aquifers, the drawdown will only be measurable fairly close to the well. A leaky aquifer occupies an intermediate position.

Transmissivity: When the transmissivity of the aquifer is high, the cone of depression induced by pumping will be wide and flat (Figure --A). When the transmissivity is low, the cone will be steep and narrow (Figure --B). In the first case, piezometers can be placed farther from the well than they can in the second.

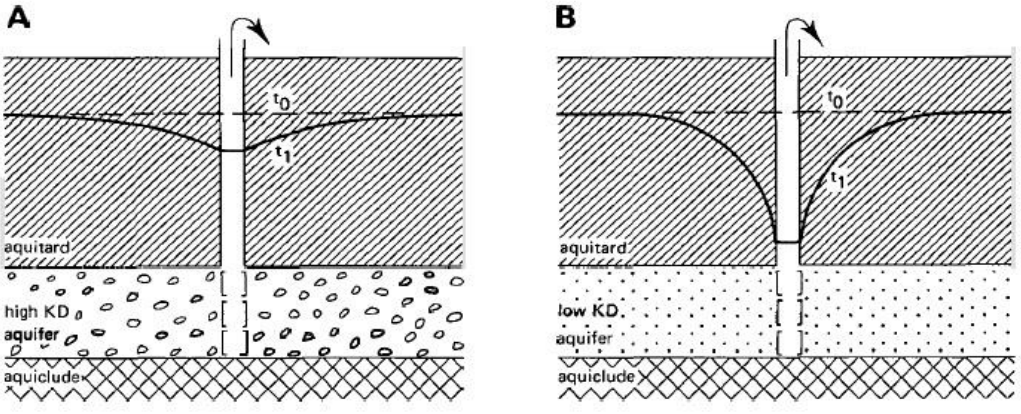

Figure Cone of depression at a given time t in:
A) an aquifer of high transmissivity
B) an aquifer of low transmissivity

The duration of the test: For tests of long duration, piezometers can be placed at greater distances from the well than for tests of short duration.

The discharge rate: If the discharge rate is high, the cone of depression will be wider and deeper than if the discharge rate is low. With a high discharge rate, therefore, the piezometers can be placed at greater distances from the well.

- *Depth of the piezometers:*

The depth of the piezometers is at least as important as their distance from the well. In an isotropic and homogeneous aquifer, the piezometers should be placed at a depth that coincides with that of half the length of the well screen. For example, if the well is fully penetrating and its screen is between 10 and 20 m below the ground surface, the piezometers should be placed at a depth of about 15 m. For heterogeneous aquifers made up of sandy deposits intercalated with aquitards, it is recommended that a cluster of piezometers be placed, i.e. one piezometer in each sandy layer (see Figure --).

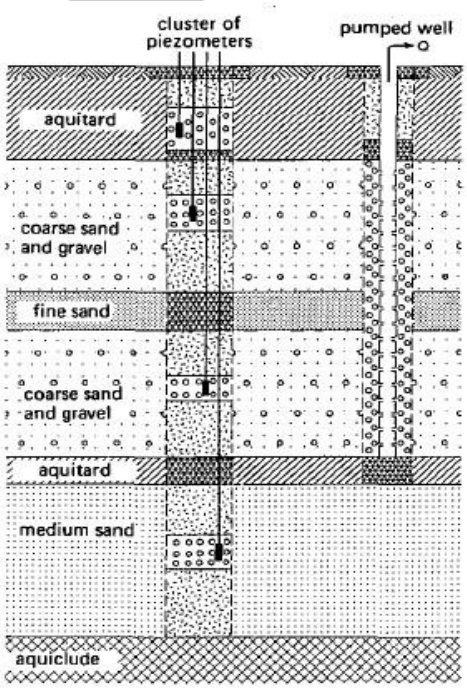

Figure --: Cluster of piezometers in a heterogeneous aquifer intercalated with aquitards.

The measurements to be taken

The measurements to be taken during a pumping test are of two kinds:

- Measurements of the water levels in the well and the piezometers;

- Measurements of the discharge rate of the well.

The water levels in the well and the piezometers must be measured many times during a test, and with as much accuracy as possible. Because water levels are dropping fast during the first one or two hours of the test, the readings in this period should be made at brief intervals.

After the pump has been shut down, the water levels in the well and the piezometers will start to rise - rapidly in the first hour, but more slowly afterward. These rises can be measured in what is known as a recovery test. If the discharge rate of the well was not constant throughout the pumping test, recovery-test data are more reliable than the drawdown data because the water table recovers at a constant rate.

Duration of the pumping test

The question of how many hours to pump the well in a pumping test is difficult to answer because the period of pumping depends on the type of aquifer and the degree of accuracy desired in establishing its hydraulic characteristics. Economizing on the period of pumping is not recommended because the cost of running the pump a few extra hours is low compared with the total costs of the test.

A steady-state is reached in leaky aquifers after 15 to 20 hours of pumping; in a confined aquifer, it is good practice to pump for 24 hours; in an unconfined aquifer, because the cone of depression expands slowly, a longer period is required, say 3 days.

Interpretation of the data

System identification includes the construction of diagnostic plots and specialized plots. Diagnostic plots are log-log plots of the drawdown versus the time since pumping started. Specialized plots are semi-log plots of drawdown versus time or drawdown versus distance to the well.

* Aquifers fall into two broad categories: unconsolidated aquifers and consolidated fractured aquifers. Within both categories, the aquifers may be confined, unconfined, or leaky. We shall first consider all three types of the unconsolidated aquifer, and then the consolidated aquifer, but only the confined type.

Figure 1 shows the log-log and semi-log plots of the theoretical time-drawdown relationships for confined, unconfined, and leaky unconsolidated aquifers.

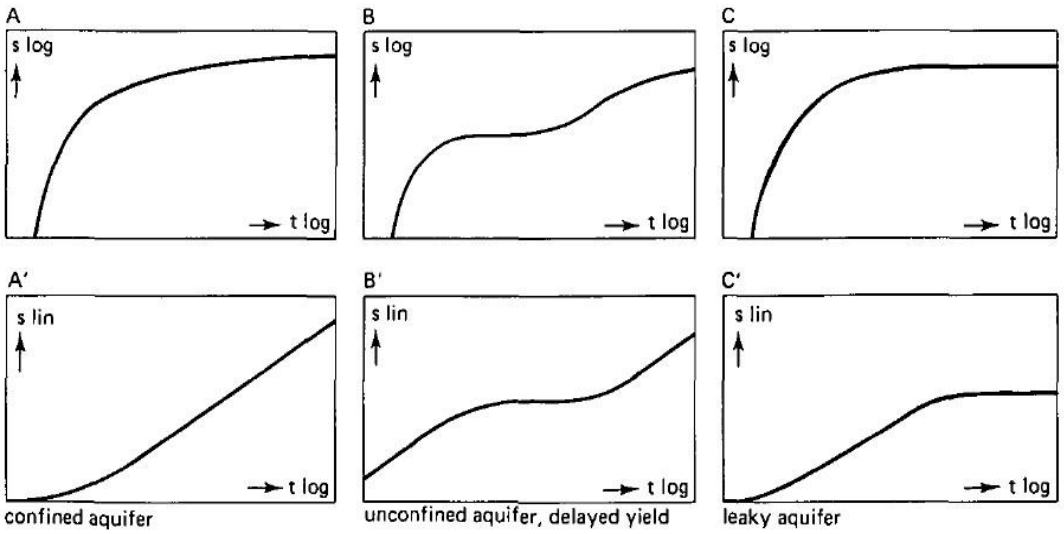

Fig.1: Log-log and semi-log plots of the theoretical time-drawdown relationships of unconsolidated aquifers: Parts A and A' Confined aquifer. Parts B and B' Unconfined aquifer. Parts C and C' Leaky aquifer.

We shall now consider the category of confined, consolidated fractured aquifers, shown in Figure 2. The shapes of the curves in Parts A and A' of Figure 2 resemble those of Parts B and B' of Figure 1, which refer to an unconfined, unconsolidated aquifer with delayed yield.

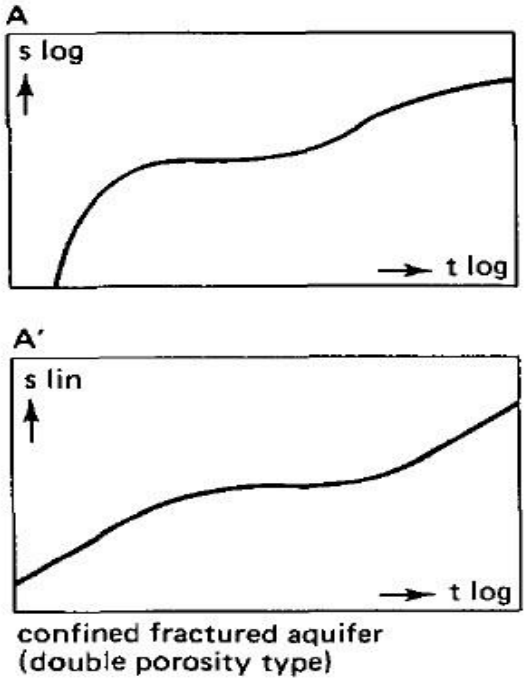

Fig. 2: Log-log and semi-log plots of the theoretical time-drawdown relationships of consolidated, pumped well in a single plane, fractured aquifers: Parts A and A': Confined fractured aquifer, double porosity type.

Reporting for Pumping tests

When the evaluation of the test data has been completed, a report should be written about the results, and it includes the following items:

1- A map, showing the location of the test site, the well, and the piezometers.

2- A lithological cross-section of the test site.

3- Tables of the field measurements made of the well discharge and the water levels in the well and the piezometers.

4- Hydrographs, illustrating the corrections applied to the observed data, if applicable.

5- Time-drawdown curves and distance-drawdown curves.

6- The considerations that led to the selection of the theoretical model used for the analysis.

7- The calculations in an abbreviated form, including the values obtained for the aquifer characteristics and a discussion of their accuracy.

8- Recommendations for further investigations, if applicable;

9- A summary of the main results.

References:

- **Groundwater hydrology third edition**, Todd, D. K. 2005.
- **Analysis and Evaluation of Pumping Test Data**, Kruseman, G. P., and de Ridder, N. A. 1994.
- **Hydrogeology Principles and Practice**, Second Edition, Kevin M. Hiscock and Victor F. Bense.
- **Watershed management**, Prof. T I Eldho, Department of Civil Engineering, IIT Bombay.
- **Manual on artificial recharge of groundwater**, Central Ground Water Board 2007.
- Getting Up to Speed, for "**Ground Water Contamination**" is adapted from US EPA Seminar Publication.
- **Lectures** by Professor Bayan Muhie Hussien. 2011.