Hydrology

Slug Tests and Baildown Tests

Slug tests

The aquifer tests that we have discussed so far involve pumping and have some practical problems.

- they are expensive, requiring monitoring wells and many person-hours of labor to conduct.

- because water has to be removed and disposed of during the test, they pose disposal problems if the aquifer being tested is contaminated.

- tests in low permeability strata, such as might be considered for waste containment or that might already be contaminated, are not practical because of the difficulty of pumping water from low permeability material.

An alternative to a pump test is a slug test (also called a baildown test). In this test the water level in a small diameter well is quickly raised or lowered. The rate at which the water in the well falls (as it drains back into the aquifer) or rises (as it drains from the aquifer into the well) is measured and these data are analyzed.

Water can be poured into the well or bailed out of the well to raise or lower the water level. However, perhaps the easiest way to raise the water level in the well is to displace some of the water in the well by lowering into it a solid piece of pipe called a slug (ahhh! So that’s where the name comes from!)

Slug tests can be used to estimate transmissivity of the aquifer in the immediate vicinity of the well. Storativity can also be estimated, although storativity estimates are often difficult to make with any degree of accuracy.

Slug test for a fully screened, confined aquifer - the Cooper-Bredehoeft-Papadopulos Method

In this slug test, water level is raised in a well, and the level of the water in the well is measured over time as the water drains back into the aquifer and the level falls.
A plot is made on semi-log graph paper, with the ratio of the measured head to the head after injection (H / H₀) plotted on the Y (linear) axis and time plotted on the X (logarithmic) axis.

The ratio of H/H₀ is equal to a defined function:

\[ \frac{H}{H_0} = F(\eta, \mu) \]

Where...

\[ \eta = \frac{Tt}{r_c^2} \]

and

\[ \mu = \frac{r_s^2 S}{r_c^2} \]

Values of F have been tabulated for different \( \mu \) (mu) and \( \eta \) (eta). To analyze the slug test data we need to match the data curve to one of a series of type curves.
Each type curve consists of $H/H_0$ values plotted against a range of $\eta$ values for a particular value of $\mu$.

In this case, we need to keep the Y axis of the two graphs the same, while sliding the overlay along until the data points are matched by one of the curves.

The matched curve gives us an approximate value for $\mu$, while reading the time value from the data graph that is equivalent to $\eta = 1$, gives us a $t_1$ value. We can solve the following equations for $T$ and $S$:

$$T = \frac{1.0 r_c^2}{t_1}$$

and

$$S = \frac{(r_c^2 \mu)}{r_s^2}$$

In our example on the overhead, the data were obtained on a pump test of a fully confined aquifer. The radius of the casing was 7.6 cm, the radius of the screen was 5.1 cm. The slug dropped (injected) into the well raised the water level 0.42 meter.

From the graph overlay, $t_1 = 12.5$ seconds and $\mu = \log -3 = 10^{-3}$.

$$T = (7.6)^2 / 12.5 = 4.6 \text{ cm}^2/\text{sec}$$

$$S = 10^{-3} \times (7.6)^2 / (5.1)^2 = 2.2 \times 10^{-3}$$

It must be noted that the $T$ value obtained is that of the aquifer in the immediate vicinity of the well.

Also, it is often the case that the $S$ value obtained is not very accurate due to the difficulty in exactly matching a particular type curve.

**Hvorslev Slug Test Method**

This is a method for analyzing slug test data from wells or auger holes that are not fully penetrating or fully screened.

For example, a piezometer well may be sunk to monitor the head and water quality of a specific level in an aquifer. This kind of monitoring well is easier and cheaper to install than a fully penetrating well.
This diagram shows the configuration for a piezometer sunk into a low permeability clay layer. The gravel pack is needed to keep the clay from entering the well.

If the length (L) of the piezometer intake is more than 8 times the radius (R) of the well screen (or gravel pack) then the following formula will apply for estimating hydraulic conductivity:

\[ K = \frac{r^2 \ln(L/R)}{2LT_0} \]

r is the radius of the well casing (the well radius above the screen).

\( T_0 \) is the time it takes for the water level to rise or fall to 37 percent of the initial change. This can be found easily by plotting the head ratio \( H/H_0 \) on a log Y axis against time on a linear X axis. The data points form a straight line, and the t value that corresponds to \( H/H_0 = .37 \) can be read from the graph.

There are other methods for analyzing slug test data. Usually these methods yield an estimated value for hydraulic conductivity or transmissivity, but not a value for storativity. However, in many cases the rate of movement of water through an aquifer or aquiclude is of primary interest, particularly where the movement of contaminants is being tracked.

**Long term monitoring of drawdown**
A final word about pumping tests. Long term monitoring of the drawdown of an aquifer during pumping can yield valuable information as to the nature of the aquifer.

If drawdown is plotted against time on a logarithmic scale, it should form a straight line showing with no leveling off (the cone of depression will expand indefinitely).

If the curve bends upward it means that some source of recharge has been encountered by the cone of depression, either vertical leakage across a confining layer of the aquifer or horizontal recharge from a recharge boundary.

If the curve bends downward, it means that the cone of depression has encountered some kind of barrier to groundwater flow, such as the margin of the aquifer layer.