

Technical Note

Pneumatic Slug Testing Using the Level TROLL® 700

October 2011

Introduction

Hydraulic Conductivity

Estimating hydraulic conductivity (K) in groundwater is necessary in hydrologic investigations. Accurate hydraulic conductivity values are fundamental for complete site characterization, for planning and designing further test programs, and can be especially important for remediation applications.

Benefits of Slug Testing

Slug testing is one of the most common methods for field determination of hydraulic conductivity. Its conventionality is due to a number of advantages over other methods. Slug testing:

- Uses minimal equipment that is inexpensive to buy or rent, lowering total costs
- Can be performed by a single individual, who can perform multiple tests in a short period of time
- Involves a simple procedure and the equipment is easy to operate
- Does not produce wastewater or disposal problems
- Can be performed where pumping is prohibited
- Is appropriate in "tight" aquifers where pumping would cause the well to go dry
- Is useful in low conductivity environments where it may not be practical to perform a constant-rate pumping test
- Can be implemented in a series of wells so that horizontal and vertical variations in the transmissive and storage properties of a formation can be determined
- Determines hydraulic conductivity for each well tested. The spatial variability of this parameter across the site is useful for numerical modeling and designing subsequent multi-well aquifer pumping tests. *This is especially useful for remediation.*

Slug Test Variations

Conventional Slug Tests

A conventional slug test artificially raises or lowers the water level in a well bore from its normal static water level (SWL) by injecting or removing a known volume. The recovery of the water level to its original state is measured.

Tests employing a sudden rise in water level by injecting a volume are referred to as falling-head, slug, slug-in, and injection tests. Tests employing a sudden drop in water level by removing a volume are referred to as rising-head, bail-down, bailer, slug-out, and withdrawal tests. Both types can be referred to as response tests. The accuracy of the collected data is highly dependent upon the slug in/out event being nearly instantaneous. Refer to Figure 1 for a diagram of a slug-in test.

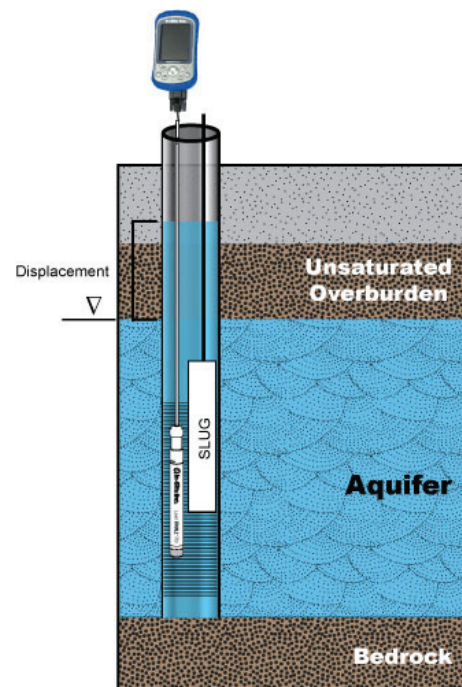


Figure 1. Example of a conventional slug-in test

Problems arise in traditional slug tests due to the physical insertion or removal of a slug. The initial slugging event can cause significant “noise” in early data because of the wave caused by the slug. The amount of displacement can be small, and even this small displacement may require a bulky slug. Slugs may be difficult to maneuver in well casings, can disturb the pressure instrument, and can create false data. Physical slugs can cause cross-contamination of wells, or regulations may prohibit injection slugs. Finally, manual insertion or removal of a slug can be extremely difficult to perform in a nearly instantaneous manner.

Pneumatic Slug Tests

Pneumatic slug testing is an apt solution to these problems. Pneumatic slug tests use pressurized air or nitrogen as the slugging agent. The well is sealed, and the water column is pressurized. As the pressure increases, the water level drops and water is forced out of the column and into the aquifer. The level drops until the pressure of the water head is equal to the increased air pressure in the well. Once equilibrium is attained, the pressure is instantaneously released and the water level begins to return to the SWL. Figure 2 depicts the water level changes of a pneumatic slug test.

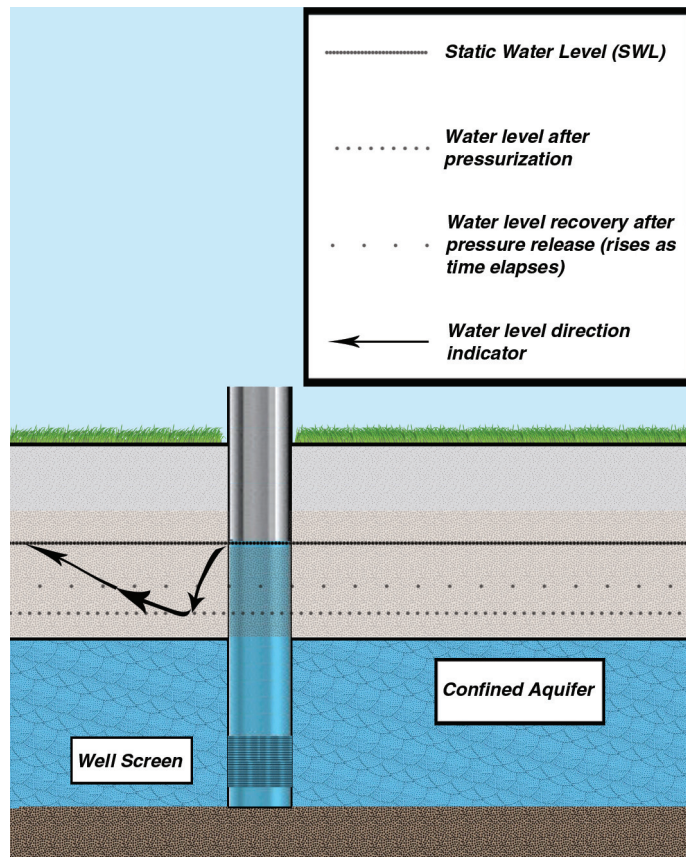


Figure 2. Water level changes during a pneumatic slug test

Benefits of Pneumatic Slug Testing

Pneumatic slug testing does not add noise to the data or disturb equipment in the well. The amount of displacement can be altered *in situ*. A pneumatic slug test eliminates cross-contamination of wells, reduces equipment contact with water that may be hazardous, and allows testing where a traditional slug test may be prohibited. While initial equilibration can take time in a pneumatic test, the slugging event is nearly instantaneous.

Completing a Pneumatic Slug Test

Well-head Assembly

In order to conduct a pneumatic slug test, a special well-head apparatus must be procured. Refer to Figure 3 for a diagram of a pneumatic slug test well-head assembly.

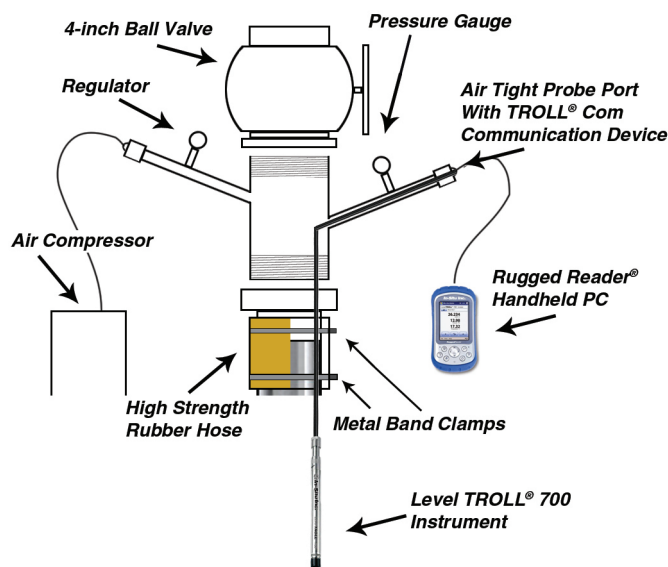


Figure 3. Example well-head assembly schematic

Crucial design elements include:

- A quick-release ball valve at the top of the unit that is of equal or larger diameter to the well head
- A ball valve orientation that, upon opening the valve, allows air to flow straight through the entire unit without encountering corners
- A probe insertion port that does not interfere with air flow and tightly seals around the instrument cable
- A pressure gauge and regulator that monitor and maintain constant air pressure in the column
- A base that can accommodate 2-inch or 4-inch wells, and can be easily installed and sealed
- An air compressor

Conducting a Pneumatic Slug Test

Two measurements must be made prior to conducting a pneumatic slug test. First is the depth of the SWL. You can determine the depth to the SWL by using an In-Situ® Rugged Water Level Tape. The second measurement is the depth from the SWL to the top of the well screen. You should consult the driller's log to determine the depth to the top of the screen.

IMPORTANT: The amount of pressure applied to the water column must not depress the SWL to the top of the screen. If the water level falls below the screen, gas can inadvertently be injected into the formation and cause the hydraulic conductivity value to be much lower than the actual value (Levy et al. 1993). If the SWL is too close to the well screen, a pneumatic slug test may not be practical.

When you have determined the distances and the maximum amount of pressure that can be applied, you can install the well-head assembly.

apart on a logarithmically decaying schedule until they become linear. In a slug test, the initial slug event causes a rapid change in water level, but as the level equilibrates the change becomes less substantial. You can use Win-Situ® 5 or Win-Situ Mobile Software to set the level reference to zero to accurately measure the change from the initial condition.

Program the data log to start prior to column pressurization in order to capture the original SWL and determine the elapsed time to column pressurization.

With the Level TROLL 700 log running, you can begin pressurizing the well. A pressure equivalent of two to eight feet (0.6 to 2.4 m) of water is recommended, but do not exceed the previously determined maximum to the well screen. Allow the pressure in the well to stabilize as determined by the pressure gauge on the well-head assembly. Once equilibrium is reached, the test may commence. You will need to restart the log in order to resume taking readings at the highest

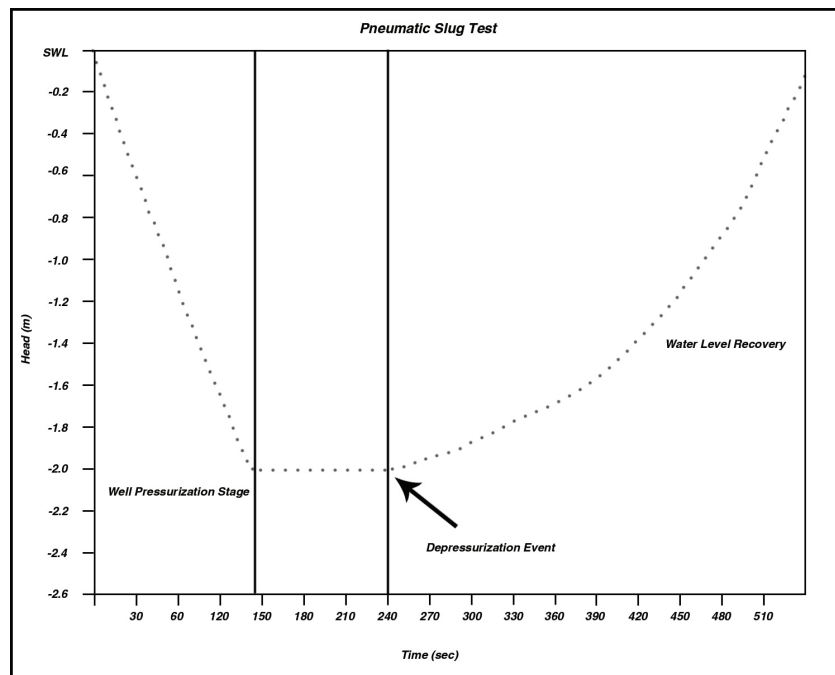


Figure 4. Example data plot of water level recovery

Once the assembly is installed, you will need to program the monitoring instrument. In-Situ® Inc. recommends the Level TROLL® 700 Instrument, which offers a true logarithmic sampling mode for precise water level measurements. True logarithmic sampling is ideal for pneumatic slug testing. True logarithmic sampling measurements are logged quickly at the beginning of the test, and are gradually taken further

sampling rate. Then release the ball valve and monitor the rise in water level. Once the level has reached the previously determined SWL, the test is complete. The Level TROLL 700 logs test data from which you can create a recovery curve graph. The data can be analyzed to calculate the hydraulic conductivity of the aquifer in that location. See Figure 4 for a sample recovery graph (**NOTE:** Graph is for illustration purposes only).

Conclusion

A pneumatic slug test may be the best way to determine hydraulic conductivity. In-Situ® Inc. can provide all of the monitoring equipment necessary for a pneumatic slug test, either as rental equipment or for purchase. The Level TROLL® 700 and Win-Situ® 5 or Win-Situ® Mobile Software provide industry-leading data logging and data management capabilities, and the Rugged Reader® Handheld PC allows for increased mobility in the field.

References

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- Zemansky, G.M, McElwee, C.D. 2005. High-resolution slug testing. *Ground Water.* 43: 222-230. DOI: 10.1111/j.1745-6584.2005.0008.x



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