

Constant-Drawdown Aquifer Tests: An Alternative to Traditional Constant-Rate Tests

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Introduction

When designing a traditional constant-rate pumping test, the hydrogeologist is faced with selecting an appropriate pumping rate. It is hoped that the selected pumping rate induces an adequate level of stress on the aquifer without 1) overpumping the well and having to prematurely end the test, or 2) having to reduce the flow rate, which seriously compromises the quality of the test. In selecting a pumping rate the hydrogeologist can either make a best guess of the proper flow rate based on “blown yield” or other pumping information such as that obtained during well development, or he can conduct a Step-drawdown test. A Step-Drawdown test is basically a pretest, requiring nearly the same level of effort and equipment as a full pumping test. In addition, the aquifer should be allowed to fully recover before the long-term test is initiated. Step-Drawdown tests are therefore costly in term of time and money.

Even if a proper Step-Drawdown test is conducted, however, it can still be difficult, in practice, to select the optimum pumping rate for some wells, particularly those with limited available drawdown and/ or relatively low yields. The Hydrogeologist’s best guess, even after a Step Drawdown test, often results in a pumping rate which is either too high or too low. If too high a flow rate is selected, excessive drawdown is created, often to the pump intake (effectively ending the test prematurely). Wells completed in fractured bedrock often seem to offer plenty of available drawdown, but may only have one or two significant water-bearing zones. When testing such wells it is often desirable to achieve the maximum amount of drawdown while avoiding dewatering of the uppermost water-bearing zone. Such dewatering is generally undesirable as it induces no additional yield from that zone or fracture, and if continued over time can result in the formation of inorganic precipitates or other fouling at the fracture intersection with the borehole, resulting in reductions in the well yield. Conversely, selection of a pumping rate that is too low can result in inadequate aquifer stress, compromising the validity of test data for calculating aquifer characteristics, as well as reducing the confidence in projections of the reliable long-term yield of a well. A constant-drawdown test procedure avoids these problems and makes a Step-Drawdown test optional.

Despite the benefits of constant-drawdown test, it is apparent from conversations with fellow hydrogeologists and a cursory review of the literature that this test method is not widely utilized. Some authors, however, have discussed this test method. Jones et. Al. (1992) and Jones (1993) discuss the practicality of constant-drawdown tests on wells completed in low-conductivity glacial till deposits. Mishra and Guyonnet (1992) mention the operational benefit of constant-drawdown tests in situations where the total available drawdown is limited by well construction and aquifer characteristics, and they present a

method of analyzing observation-well response to constant head testing. Bennett and Patten (1963) and Hantush (1964) describe constant-head pumping tests and derive solutions for analysis of these tests.

Constant-Drawdown Test Procedures

When conducting a constant-drawdown test, the operator holds the pumping water level constant at a preselected depth while precisely measuring flow rate changes and plotting these versus time. Therefore, the primary concern in the design of a constant-drawdown test is the exact drawdown level. For water-supply wells in bedrock aquifers, ENSAT generally selects a constant-drawdown level at a depth slightly above the first major water-bearing zone, thereby avoiding dewatering of these zones during the pumping test. In unconsolidated or overburden aquifers, the constant-drawdown level is usually based on the stratigraphy of the aquifer/s, or the need to precisely control the magnitude of drawdown, for example, to minimize “smearing” of free-floating petroleum product in the drawdown zone created by pumping.

At the beginning of a constant-drawdown, the water level should be lowered to the selected constant-drawdown level as quickly as possible. Drawdown is then maintained, as precisely as possible, at that depth for the duration of the test.

Data collection and analysis are slightly different for constant-drawdown tests than for traditional constant-rate tests. When using a constant-drawdown test procedure one measures flow rates during the test and plots specific drawdown (the constant-drawdown level divided by the flow rate) versus time. Constant-drawdown data plotted in this manner allows boundary conditions to be identified. Jacob and Lohman (1952) seem to have been the earliest researchers to evaluate the mathematics of constant-drawdown data analysis, and their paper presents a variation of the now commonly used simplified graphical method using semi-log plots of pumping test data. Kruseman and deRidder (1991) summarize analytical solutions presented by several researchers who also utilized variations on the straight-line technique for analysis of constant-drawdown test data to determine aquifer characteristics. Jones et. Al. (1992) present a method of analyzing constant-drawdown test data using the Theis solution by dividing the test into discrete step-change time intervals and selecting an average flow rate for each time interval. Observation-well data can also be analyzed to obtain both transmissivity and storativity values (Mishra and Goyonnet, 1992). Lastly, constant-drawdown tests produce well-yield data that can be projected over reasonable time intervals to estimate available quantities of water.

Equipment or Constant-Drawdown Tests

Constant-Drawdown tests are most easily conducted using some specialized equipment. It is critical to maintain the drawdown during the test at a constant, pre-selected depth. This could be done using a valve on the discharge piping. Controlling the drawdown level via a valve, however, is usually a poor way to maintain the drawdown for several reasons. First, it is labor intensive and tedious to have to frequently adjust a valve during

tests. Secondly, and perhaps most importantly, the necessary valve adjustments are usually very fine once the constant-drawdown level has been achieved: adjustments at this time; therefore, often cause the drawdown level and flow rate to vary more widely than desired, creating excessive “noise” in the test data.

Jones et al. (1992) used a peristaltic pump, with the end of the tubing placed at the desired drawdown depth, to conduct their tests. This is an easy, practical approach, but is limited to shallow water-table situations and very low-yield aquifers. Higher yields could be obtained using other suction-lift devices, but, again, maximum drawdowns would be somewhat limited. Other types of pumps, such as pneumatic pumps, could also be utilized, but electric submersible pumps seem best suited to this application because they pump continuously, thereby allowing flow rates (the critical data in a constant-drawdown test) to be closely monitored.

ENSAT uses non-electronic, mechanically-operated, water-level control device, originally designed to protect submersible pumps in water-supply wells from cavitation, to maintain the desired constant-drawdown level during tests. This device, which has proven effective under a variety of drawdown and well-yield conditions, controls the discharging piping above the pump, and it mechanically senses the water level in the well. As the water level in the well begins to drop below the center of the device, it efficiently and continuously recirculates a portion of the pumped water back into the well, as necessary, to precisely maintain the drawdown level throughout the test.

In addition to precisely controlling the drawdown level, it is necessary to measure flow rates accurately during the course of a constant-drawdown test. Because of the importance of accurately monitoring flows, ENSAT typically uses two flow meters during tests, including a totalizing, dial-type, and an automatic instantaneous-measurement type meter. The totalizing meter allows flows to be calculated by precisely timing several “sweeps” of the meter and dividing the gallons pumped by the time interval. ENSAT also uses a flow meter that interfaces with an electronic data logger; this meter measures flow instantaneously. Use of the electronic flow meter, in conjunction with a device for automatic drawdown level control, allows semi-automated test to be performed, significantly reducing labor costs associated with long-duration aquifer tests.

Summary

Constant-drawdown aquifer tests differ from traditional constant-rate tests in that the drawdown level in the pumping well is held constant while decreases in flow rate are measured and plotted versus time. The test data can be analyzed in a similar manner using several different solutions. Constant-drawdown tests are most easily conducted using equipment that can automatically control the drawdown level. Use of a flow meter that interfaces with a data logger, in conjunction with a device that automatically controls the drawdown level, can allow a semi-automated test to be performed, greatly reducing test costs. Constant-drawdown test produce the maximum amount of pumped water over a given time frame at a chosen drawdown, and do so in a controlled manner while

avoiding problems associated with under pumping or over pumping test wells. Most importantly, using a constant-drawdown test procedure ensures that a test will successfully continue to completion, and that optimum aquifer stress and yield are achieved in an efficient manner.

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References

Bennett, G.D. and E.P. Patten, Jr. 1963. Constant-head pumping test of multiaquifer well to determine characteristics of individual aquifers. U.S. Geological Survey Water-Supply Paper 1536-G, pp. 181-203.

Hantush, M.S. 1964. Hydraulics of wells, in *Advances in hydroscience* (V.T. Chow, ed.), v.1. Academic Press, New York, pp. 281-432

Jacob, C.E. and Lohman, S.W. 1952. Nonsteady flow to a well of constant drawdown in an extensive aquifer. *Trans. AGU*, v. 33. pp. 559-569.

Jones, L., T. Lemar, and C-T Tsai, 1992. Results of two pumping tests in Wisconsin age weathered till in Iowa. *Ground Water*. V. 30 no. 4. pp. 529-538.

Jones, L. 1993. A comparison of pumping and slug tests for estimating the hydraulic conductivity of unweathered Wisconsin age till in Iowa. *Ground Water*. V. 31 no. 6, pp. 896-904.