Designation: D5912 – 20

Standard Practice for (Analytical Procedure) Determining Hydraulic Conductivity of an Unconfined Aquifer by Overdamped Well Response to Instantaneous Change in Head (Slug)[1]

This standard is issued under the fixed designation D5912; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This practice covers the determination of hydraulic conductivity from the measurement of inertial force free (overdamped) response of a well-aquifer system to a sudden change in water level in a well. Inertial force free response of the water level in a well to a sudden change in water level is characterized by recovery to initial water level in an approximate exponential manner with negligible inertial effects.

1.2 The analytical procedure in this practice is used in conjunction with the field procedure in Test Method D4044/D4044M for collection of test data.

1.3 *Limitations*—Slug tests are considered to provide an estimate of hydraulic conductivity. The determination of storage coefficient is not practicable with this practice. Because the volume of aquifer material tested is small, the values obtained are representative of materials very near the open portion of the control well.

NOTE 1—Slug tests are usually considered to provide estimates of the lower limit of the actual hydraulic conductivity of an aquifer because the test results are so heavily influenced by well efficiency and borehole skin effects near the open portion of the well. The portion of the aquifer that is tested by the slug test is limited to an area near the open portion of the well where the aquifer materials may have been altered during well installation, and therefore may significantly impact the test results. In some cases, the data may be misinterpreted and result in a higher estimate of hydraulic conductivity. This is due to the reliance on early time data that is reflective of the hydraulic conductivity of the filter pack surrounding the well. This effect was discussed by Bouwer (**1**).[2] In addition, because of the reliance on early time data, in aquifers with medium to high hydraulic conductivity, the early time portion of the curve that is useful for this data analyses is too short (for example, <10 s) for accurate measurement; therefore, the test results begin to greatly underestimate the true hydraulic conductivity.

1.4 *Units*—The values stated in SI units are to be regarded as the standard. No other units of measurement are included in this standard. Reporting of test results in units other than SI shall not be regarded as nonconformance with this standard.

1.5 All observed and calculated values shall conform to the guidelines for significant digits and rounding established in Practice D6026.

1.5.1 The procedures used to specify how data are collected/recorded and calculated in the standard are regarded as the industry standard. In addition, they are representative of the significant digits that generally should be retained. The procedures used do not consider material variation, purpose for obtaining the data, special purpose studies, or any considerations for the user's objectives; and it is common practice to increase or reduce significant digits of reported data to be commensurate with these considerations. It is beyond the scope of these test methods to consider significant digits used in analysis methods for engineering data.

1.6 This practice offers a set of instructions for performing one or more specific operations. This document cannot replace education or experience and should be used in conjunction with professional judgment. Not all aspects of the practice may be applicable in all circumstances. This ASTM standard is not intended to represent or replace the standard of care by which the adequacy of a given professional service must be judged, nor should this document be applied without the consideration of a project's many unique aspects. The word "Standard" in the title of this document means only that the document has been approved through he ASTM consensus process.

1.7 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.8 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

[1] This practice is under the jurisdiction of ASTM Committee D18 on Soil and Rock and is the direct responsibility of Subcommittee D18.21 on Groundwater and Vadose Zone Investigations.

Current edition approved June 1, 2020. Published June 2020. Originally approved in 1996. Last previous edition approved in 2004 as D5912–96(2004), which was withdrawn in 2013 and reinstated in June 2020. DOI: 10.1520/D5912-20.

[2] The boldface numbers in parentheses refer to a list of references at the end of this standard.

***A Summary of Changes section appears at the end of this standard**

2. Referenced Documents

2.1 *ASTM Standards:*[3]

D653 Terminology Relating to Soil, Rock, and Contained Fluids

D3740 Practice for Minimum Requirements for Agencies Engaged in Testing and/or Inspection of Soil and Rock as Used in Engineering Design and Construction

D4043 Guide for Selection of Aquifer Test Method in Determining Hydraulic Properties by Well Techniques

D4044/D4044M Test Method for (Field Procedure) for Instantaneous Change in Head (Slug) Tests for Determining Hydraulic Properties of Aquifers

D4104/D4104M Practice for (Analytical Procedures) Determining Transmissivity of Nonleaky Confined Aquifers by Overdamped Well Response to Instantaneous Change in Head (Slug Tests)

D5717 Guide for Design of Ground-Water Monitoring Systems in Karst and Fractured-Rock Aquifers (Withdrawn 2005)[4]

D6026 Practice for Using Significant Digits in Geotechnical Data

3. Terminology

3.1 *Definitions*—For definitions of common technical terms used in this standard, refer to Terminology D653.

3.2 *Symbols and Dimensions:*

3.2.1 *A [nd]*—coefficient that is a function of L/r_w and is determined graphically.

3.2.2 *B [nd]*—coefficient that is a function of L/r_w and is determined graphically.

3.2.3 *C [nd]*—coefficient that is a function of L/r_w and is determined graphically.

3.2.4 *D [L]*—aquifer thickness.

3.2.5 *H [L]*—distance between static water level and the base of open interval of the well.

3.2.6 *L [L]*—length of well open to aquifer.

3.2.7 *rc [L]*—inside diameter of the portion of the well casing in which the water level changes.

3.2.8 R_e *[L]*—effective radius, determined empirically based on the geometry of the well, over which *y* is dissipated.

3.2.9 r_w *[L]*—radial distance from well center to original to well casing.

3.2.10 t_f *[T]*—time at end point of straight-line portion of graph.

3.2.11 t_0 *[T]*—time at beginning of straight-line portion of graph.

3.2.12 y_f *[L]*—head difference at end point of straight-line portion of graph.

3.2.13 y_0 *[L]*—head difference at beginning of straight-line portion of graph.

3.2.14 *K [LT–1]*—hydraulic conductivity.

4. Summary of Practice

4.1 This practice describes the analytical procedure for analyzing data collected following an instantaneous change in head (slug) test in an overdamped well. The field procedures in conducting a slug test are given in Test Method D4044/D4044M. The analytical procedure consists of analyzing the recovery of water level in the well following the change in water level induced in the well.

4.2 *Solution*—The solution given by Bouwer and Rice (**1**) follows:

$$K = \frac{r_c^2 \ln(R_e/r_w)}{2L}\frac{1}{(t_f - t_0)}\ln\frac{y_0}{yf} \tag{1}$$

where:
if $D > H$

$$ln(R_e/r_w) = \left[\frac{1.1}{ln(H/r_w)} + \frac{A + B\,ln[(D-H)/r_w]}{L/R_w}\right]^{-1} \tag{2}$$

if $D = H$

$$lnR_e/r_w = \left[\frac{1.1}{ln(H/r_w)} + \frac{C}{L/r_w}\right]^{-1} \tag{3}$$

NOTE 2—Other analytical solutions are given by Hvorslev and Cooper et al; (**2**, **3**, **4**) however, they may differ in their assumptions and applicability.

NOTE 3—Bouwer (**1**) provided discussion of various applications and observations of the procedure described in this practice.

NOTE 4—Practice D4104/D4104M describes the analytical solution following Cooper et al (**3**).

NOTE 5—The use of the symbol K for the term hydraulic conductivity is the predominant usage in groundwater literature by hydrogeologists, whereas, the symbol k is commonly used for this term in soil and rock mechanics and soil science.

4.3 More recent work (Zlotnik et al. 2010 (**5**)) have revealed that the shape factors used for calculation of hydraulic conductivity (K) in the Bouwer and Rice model may result in the under estimation of K by as much as 25 % to 40 % depending on the well construction and aquifer characteristics. Please refer to the work of Zlotnik et al. (2010) (**5**) for a discussion of the development of general steady state shape factors for the condition of an overdamped, partially penetrating well.

4.4 Numerous commercial computer software programs are available to evaluate slug test data. Only those programs that provide analysis of the data based on graphical curve matching, rather than simply least-squares analysis, and allow for the generation of data plots should be used.

5. Significance and Use

5.1 *Assumptions of Solution:*

5.1.1 Drawdown (or mounding) of the water table around the well is negligible.

5.1.2 Flow above the water table can be ignored.

5.1.3 Head losses as the water enters or leaves the well are negligible.

5.1.4 The aquifer is homogeneous and isotropic.

NOTE 6—Slug and pumping tests implicitly assume a porous medium.

[3] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[4] The last approved version of this historical standard is referenced on www.astm.org.

Fractured rock and carbonate settings may not provide meaningful data and information.

5.2 *Implications of Assumptions:*

5.2.1 The mathematical equations applied ignore inertial effects and assume that the water level returns to the static level in an approximate exponential manner.

5.2.2 The geometric configuration of the well and aquifer are shown in Fig. 1, that is after Fig. 1 of Bouwer and Rice (**1**).

5.2.3 For filter-packed wells, Eq 1 applies to cases in which the filter pack remains saturated. If some of the filter pack is dewatered during testing, r_c^2 should be replaced by the following:

$$r_c\,(corrected) = \left[(1-n)r_a^{\,2} + n r_w^{\,2}\right]^{0.5} \tag{4}$$

where:

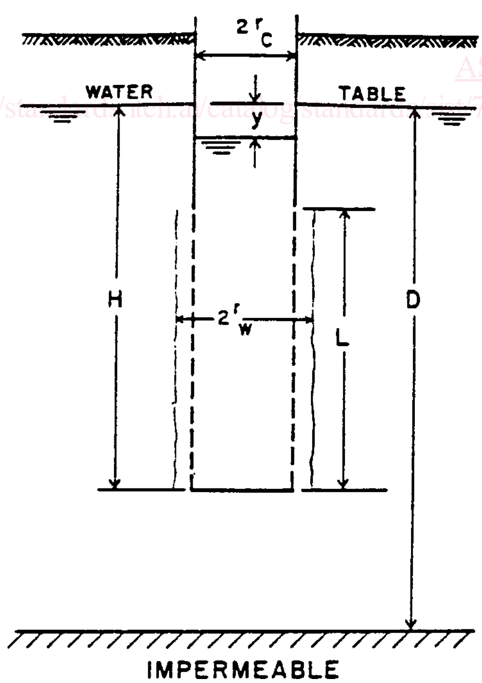
n = short-term specific yield of the filter pack,
r_a = uncorrected well casing radius,
r_w = borehole radius, and
y = difference in static water level and the level during the field test.

NOTE 7—Short term refers to the duration of the slug test.

NOTE 8—The function of wells in any unconfined setting in a fractured terrain might make the determination of k problematic because the wells might only intersect tributary or subsidiary channels or conduits. The problems determining the k of a channel or conduit notwithstanding, the partial penetration of tributary channels may make a determination of a meaningful number difficult. If plots of k in carbonates and other fractured settings are made and compared, they may show no indication that there are conduits or channels present, except when with the lowest probability one maybe intersected by a borehole and can be verified, such problems are described by Smart (1999) (**6**). Additional guidance can be found in Guide D5717.

NOTE 9—The comparison of data from various methods on variable head permeability tests has been documented. Variation in instrumentation, assumptions and calculational methods will lead to differing results (**7**). Users should be familiar with the assumptions, instrumentation and calculational aspects of the test when evaluating the results (**8**).

NOTE 10—The quality of the result produced by this standard is dependent on the competence of the personnel performing it, and the suitability of the equipment and facilities used. Agencies that meet the criteria of Practice D3740 are generally considered capable of competent and objective testing/sampling/inspection/etc. Users of this standard are cautioned that compliance with Practice D3740 does not in itself assure reliable results. Reliable results depend on many factors; Practice D3740 provides a means of evaluating some of those factors.



NOTE 1—See Fig. 1 of (**1**).

FIG. 1 Geometry and Symbols of a Partially Penetrating, Partially Perforated Well in Unconfined Aquifer with Gravel Pack or Developed Zone Around Perforated Section

6. Procedure

6.1 The overall procedure consists of conducting the slug test field procedure (see Test Method D4044/D4044M) and analysis of the field data that is addressed in this practice.

6.2 The water level data are corrected so that the difference between the original static water level and the water level during the test is known. This difference in water level at time "t" is denoted as "y_t".

6.3 The dimensionless coefficients of *A, B*, and *C* are determined graphically based on their relationship with L/r_w. An example of the curves relating *A, B*, and *C* to L/r_w is given in Fig. 2, that is after Fig. 3 of Bouwer and Rice.[2]

7. Calculation

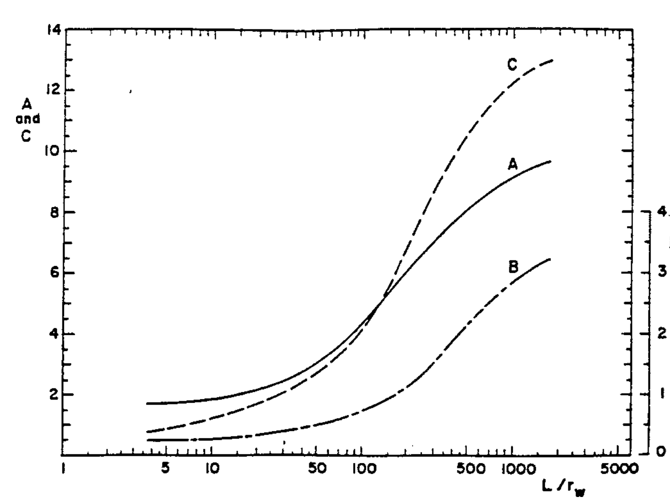
7.1 Determine $ln(R_e/r_w)$ using Eq 2 or Eq 3, as appropriate.

7.2 Plot at a semilogarithmic scale the relationship of "y" on the log scale versus elapsed time on the arithmetic scale.

7.3 Determine the straight-line portion of the graph.

7.4 Determine the end point values of the straight-line portion of the graph and substitute along with value for $ln(R_e/r_w)$ determined in 7.1, into Eq 1.

NOTE 11—An example of the plot of this test method is given in Fig. 3. The data used to prepare the plot is presented in Table 1. Table 1 also presents the well configuration data and the corresponding values of *A, B*, and *C*.



NOTE 1—See Fig. 3 of (**1**).

FIG. 2 Curves Relating Coefficients *A, B*, and *C* to L/r_w