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AMERICAN SOCIETY FOR TESTING AND MATERIALS
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Standard Test Method 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 D 5912; 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.

ϵ^1 NOTE—Note 5 was added editorially in December 1996.

1. Scope

1.1 This test method 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 test method is used in conjunction with the field procedure in Test Method D 4044 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 possible with this test method. 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 effect 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.[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 The values stated in SI units are to be regarded as the standard.

1.5 *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 and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

D 653 Terminology Relating to Soil, Rock, and Contained Fluids[3]

D 4043 Guide for Selection of Aquifer-Test Methods in Determining Hydraulic Properties by Well Techniques[3]

D 4044 Test Method (Field Procedure) for Instantaneous Change in Head (Slug Test) for Determining Hydraulic Properties of Aquifers[3]

D 4104 Test Method (Analytical Procedure) for Determining Transmissivity of Nonleaky Confined Aquifers by Overdamped Well Response to Instantaneous Change in Head (Slug Test)[3]

3. Terminology

3.1 *Definitions*—For definitions of terms used in this test method, see Terminology D 653.

3.2 *Symbols: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 undisturbed aquifer.

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[1] This test method is under the jurisdiction of ASTM Committee D-18 on Soil and Rock and is the direct responsibility of Subcommittee D18.21 on Ground Water and Vadose Zone Investigations.

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[2] Bouwer, H., and Rice, R. C., "A Slug Test for Determining Hydraulic Conductivity of Unconfined Aquifers with Completely or Partially Penetrating Wells," *Water Resources Research*, Vol 12, No. 3, 1976, pp. 423–428.

[3] *Annual Book of ASTM Standards*, Vol 04.08.

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.

4. Summary of Test Method

4.1 This test method 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 D 4044. 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[2] follows:

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

where:
if $D > H$

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

if $D = H$

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

NOTE 2—Other analytical solutions are given by Hvorslev[4] and Cooper et al;[5,6] however, they may differ in their assumptions and applicability.

NOTE 3—Bouwer[2] provided discussion of various applications and observations of the procedure described in this test method.

NOTE 4—Test Method D 4104 describes the analytical solution following Cooper et al.[5]

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

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.

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.[2]

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:

$$r_c\,(corrected) = [(1 - n)r_a^{\,2} + nr_w^{\,2}]^{0.5} \quad (4)$$

where:
n = short-term specific yield of the filter pack,
r_a = uncorrected well casing radius, and
r_w = borehole radius.

NOTE 6—Short term refers to the duration of the slug test.

6. Procedure

6.1 The overall procedure consists of conducting the slug test field procedure (see Test Method D 4044) and analysis of the field data that is addressed in this test method.

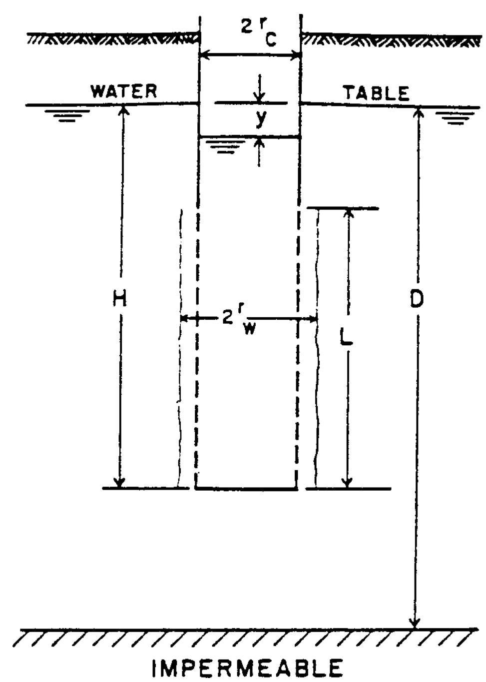
6.2 The water level data are corrected so that the difference between the original static water level and the water level during the test is known. This difference in water level at time "t" is denoted as "y_t".

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.



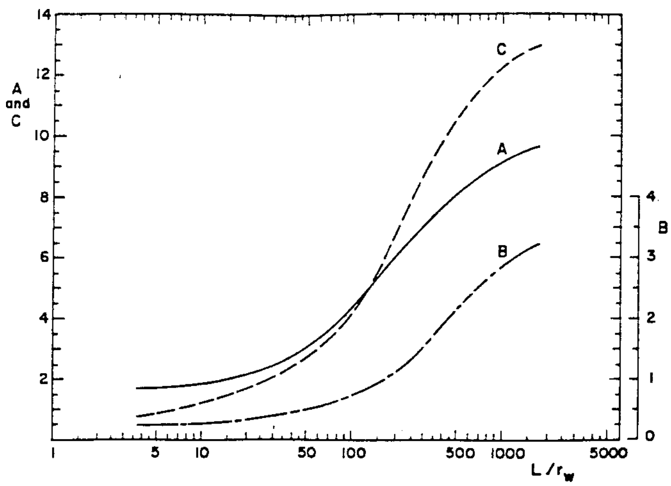
NOTE 1—See Fig. 1 of Footnote 2.

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

[4] Hvorslev, M. J., "Time Lag and Soil Permeability in Ground-Water Observations," Waterways Experiment Station, Corps of Engineers, *U.S. Army, Bulletin No. 36*, 1951.

[5] Cooper, H. H., Jr., Bredehoeft, J. D., and Papadopulos, I. S., "Response of a Finite-Diameter Well to an Instantaneous Change in Water," *Water Resources Research*, Vol 3, No. 1, 1967, pp. 263–269.

[6] Bouwer, H., "The Bouwer-Rice Slug Test—An Update," *Ground Water*, Vol 27, No. 3, 1989, pp. 304–309.



NOTE 1—See Fig. 3 of Footnote 2.

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

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 7—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*.

8. Report

8.1 Prepare a report including the information described in this section. The final report of the analytical procedure will include information from the report on the test method selection (see Guide D 4043) and the field testing procedure (see Test Method D 4044).

8.1.1 *Introduction*—The introductory section is intended to present the scope and purpose of the slug test method for determining hydraulic conductivity. Summarize the field hydrogeologic conditions and field equipment and instrumentation including the construction of the control well, and the method of measurement and of effecting a change in head. Discuss the rationale for selecting the method used (see Guide D 4043).

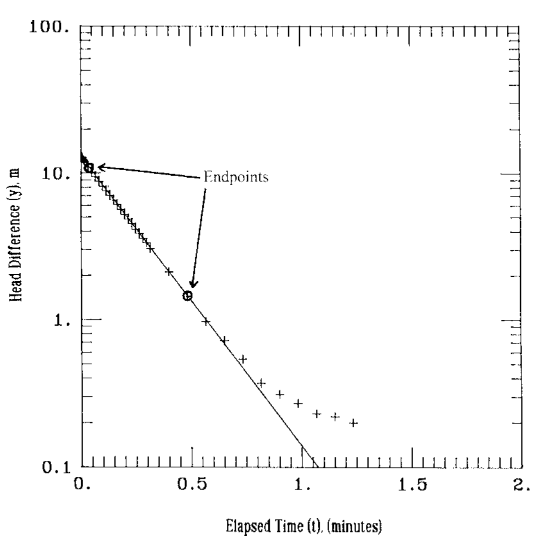


FIG. 3 Sample Plot of Slug Test Data

TABLE 1 Sample Slug Test Data[A,B]

NOTE 1—*A* and *B* are not used since *D* = *H*.
NOTE 2—Endpoint values are highlighted.

Elapsed Time, min	Head Difference, m
0.0034	12.86
0.0067	12.71
0.0100	12.40
0.0134	12.13
0.0167	11.96
0.0334	10.94
0.0500	10.15
0.0667	9.45
0.0834	8.80
0.1000	8.16
0.1167	7.05
0.1334	6.54
0.1500	6.10
0.1667	5.64
0.1834	5.21
0.2000	4.85
0.2167	4.51
0.2334	4.14
0.2500	3.88
0.2667	3.59
0.2834	3.35
0.3000	3.06
0.3167	2.12
0.4001	1.45
0.4834	0.97
0.5667	0.72
0.6501	0.54
0.7334	0.37
0.8167	0.31
0.9001	0.27
1.0667	0.23
1.1501	0.22
1.2334	0.20

[A] Well configuration data, m: *Rc* = 0.0833, *Rw* = 0.1615, *D* = 41.5, *L* = 8, and *H* = 41.5.
[B] Coefficients (dimensionless): *A* = n/a, *B* = n/a, and *C* = 2.624.

8.1.2 *Hydrogeologic Setting*—Review information available on the hydrogeology of the site; interpret and describe the hydrogeology of the site as it pertains to the method selected for selected for conducting and analyzing an aquifer test. Compare hydrogeologic characteristics of the site as it conforms and differs from the assumptions made in the solution to the aquifer test method.

8.1.3 *Equipment*—Report the field installation and equipment for the aquifer test. Include in the report, well construction information, diameter, depth, and open interval to the aquifer, and location of control well. Include a list of measuring devices used during the test; the manufacturer's name, model number, and basic specifications for each major item; and the name and date of the last calibration, if applicable.

8.1.4 *Test Procedures*—Report the steps taken in conducting the pretest and test phases. Include the frequency of head measurements made in the control well and other environmental data recorded before and during the test procedure.

8.1.5 *Presentation and Interpretation of Test Results*:

8.1.5.1 *Data*—Present tables of data collected during the test.

8.1.5.2 *Data Plots*—Present data plots used in analysis of the data.

8.1.5.3 Show calculation of hydraulic conductivity.

8.1.5.4 Evaluate the overall quality of the test on the basis of the adequacy of instrumentation and observations of stress and response and the conformance of the hydrogeologic conditions and the performance of the test to the assumptions (see 5.1).

9. Precision and Bias

9.1 It is not practical to specify the precision of this test method because the response of aquifer systems during aquifer tests is dependent on ambient stresses. No statement can be made about the bias because no true reference values exist.

10. Keywords

10.1 aquifers; aquifer tests; control wells; ground water; hydraulic conductivity; slug test