Designation: ~~D4043 – 96 (Reapproved 2010)ε1~~ D4043 – 17

Standard Guide for Selection of Aquifer Test Method in Determining Hydraulic Properties by Well Techniques[1]

This standard is issued under the fixed designation D4043; 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.

~~ε1 NOTE—The units statement in 1.2 was revised editorially in September 2010.~~

1. ~~Scope~~ Scope*

1.1 This guide covers an integral part of a series of standards that are being prepared on the in situ determination of hydraulic properties of aquifer systems by single- or multiple-well tests. This guide provides guidance for development of a conceptual model of a field site and selection of an analytical test method for determination of hydraulic properties. This guide does not establish a fixed procedure for determination of hydrologic properties.

1.2 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.3 *Limitations*—Well techniques have limitations in the determination of hydraulic properties of groundwater flow systems. These limitations are related primarily to the simplifying assumptions that are implicit in each test method. The response of an aquifer system to stress is not unique; therefore, the system must be known sufficiently to select the proper analytical method.

1.4 *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.*

1.5 *This guide offers an organized collection of information or a series of options and does not recommend a specific course of action. This document cannot replace education or experience and should be used in conjunction with professional judgment. Not all aspects of this guide 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 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 the ASTM consensus process.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D653 Terminology Relating to Soil, Rock, and Contained Fluids

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

~~D4050 Test Method for (Field Procedure) for Withdrawal and Injection Well Testing for Determining Hydraulic Properties of Aquifer Systems~~

D4104 Test Method (Analytical Procedure) for Determining Transmissivity of Nonleaky Confined Aquifers by Overdamped Well Response to Instantaneous Change in Head (Slug Tests)

D4105 Test Method for (Analytical Procedure) for Determining Transmissivity and Storage Coefficient of Nonleaky Confined Aquifers by the Modified Theis Nonequilibrium Method

D4106 Test Method for (Analytical Procedure) for Determining Transmissivity and Storage Coefficient of Nonleaky Confined Aquifers by the Theis Nonequilibrium Method

D4630 Test Method for Determining Transmissivity and Storage Coefficient of Low-Permeability Rocks by In Situ Measurements Using the Constant Head Injection Test

[1] This guide 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 ~~Aug. 1, 2010~~Jan. 1, 2017. Published ~~September 2010~~January 2017. Originally approved in 1991. Last previous edition approved in ~~2004~~2010 as ~~D4043–96(2004).~~D4043–96(2010)ε1. DOI: ~~10.1520/D4043-96(2010)E01.~~10.1520/D4043-17.

[2] 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.

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

~~D4631 Test Method for Determining Transmissivity and Storativity of Low Permeability Rocks by In Situ Measurements Using Pressure Pulse Technique (Withdrawn 2017)~~[3]
D5269 Test Method for Determining Transmissivity of Nonleaky Confined Aquifers by the Theis Recovery Method
D5270 Test Method for Determining Transmissivity and Storage Coefficient of Bounded, Nonleaky, Confined Aquifers
D5472 Test Method for Determining Specific Capacity and Estimating Transmissivity at the Control Well
D5473 Test Method for (Analytical Procedure for) Analyzing the Effects of Partial Penetration of Control Well and Determining the Horizontal and Vertical Hydraulic Conductivity in a Nonleaky Confined Aquifer
D5716 Test Method for Measuring the Rate of Well Discharge by Circular Orifice Weir
D5785 Test Method for (Analytical Procedure) for Determining Transmissivity of Confined Nonleaky Aquifers by Underdamped Well Response to Instantaneous Change in Head (Slug Test)
D5786 Practice for (Field Procedure) for Constant Drawdown Tests in Flowing Wells for Determining Hydraulic Properties of Aquifer Systems
D5850 Test Method for (Analytical Procedure) Determining Transmissivity, Storage Coefficient, and Anisotropy Ratio from a Network of Partially Penetrating Wells
D5881 Test Method for (Analytical Procedure) Determining Transmissivity of Confined Nonleaky Aquifers by Critically Damped Well Response to Instantaneous Change in Head (Slug)
D5912 Test Method for (Analytical Procedure) Determining Hydraulic Conductivity of an Unconfined Aquifer by Overdamped Well Response to Instantaneous Change in Head (Slug) (Withdrawn 2013)[3]
D5920 Test Method (Analytical Procedure) for Tests of Anisotropic Unconfined Aquifers by Neuman Method

3. Terminology

~~3.1 *Definitions:*~~

~~3.1.1 *aquifer, confined*—an aquifer bounded above and below by confining beds and in which the static head is above the top of the aquifer.~~

~~3.1.2 *aquifer, unconfined*—an aquifer that has a water table.~~

~~3.1.3 *barometric efficiency*—the ratio of the change in depth to water in a well to the change in barometric pressure, expressed in length of water.~~

~~3.1.4 *conceptual model*—a simplified representation of the hydrogeologic setting and the response of the flow system to stress.~~

~~3.1.5 *confining bed*—a hydrogeologic unit of less permeable material bounding one or more aquifers.~~

~~3.1.6 *control well*—well by which the aquifer is stressed, for example, by pumping, injection, or change of head.~~

~~3.1.7 *hydraulic conductivity (field aquifer tests)*—the volume of water at the existing kinematic viscosity that will move in a unit time under unit hydraulic gradient through a unit area measured at right angles to the direction of flow.~~

~~3.1.8 *observation well*—a well open to all or part of an aquifer.~~

~~3.1.9 *piezometer*—a device used to measure static head at a point in the subsurface.~~

~~3.1.10 *specific capacity*—the rate of discharge from a well divided by the drawdown of the water level within the well at a specific time since pumping started.~~

~~3.1.11 *specific storage*—the volume of water released from or taken into storage per unit volume of the porous medium per unit change in head.~~

~~3.1.12 *specific yield*—the ratio of the volume of water that the saturated rock or soil will yield by gravity to the volume of the rock or soil. In the field, specific yield is generally determined by tests of unconfined aquifers and represents the change that occurs in the volume of water in storage per unit area of unconfined aquifer as the result of a unit change in head. Such a change in storage is produced by the draining or filling of pore space and is, therefore, mainly dependent on particle size, rate of change of the water table, and time of drainage.~~

~~3.1.13 *storage coefficient*—the volume of water an aquifer releases from or takes into storage per unit surface area of the aquifer per unit change in head. For a confined aquifer, the storage coefficient is equal to the product of specific storage and aquifer thickness. For an unconfined aquifer, the storage coefficient is approximately equal to the specific yield.~~

~~3.1.14 *transmissivity*—the volume of water at the existing kinematic viscosity that will move in a unit time under a unit hydraulic gradient through a unit width of the aquifer.~~

3.1 *Definitions*—For definitions of ~~other~~common terms used in this ~~guide,~~ test method, see Terminology D653.

4. Significance and Use

4.1 An aquifer test method is a controlled field experiment made to determine the approximate hydraulic properties of water-bearing material. The hydraulic properties that can be determined are specific to the test method. The hydraulic properties

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

that can be determined are also dependent upon the instrumentation of the field test, the knowledge of the aquifer system at the field site, and conformance of the hydrogeologic conditions at the field site to the assumptions of the test method. Hydraulic conductivity and storage coefficient of the aquifer are the basic properties determined by most test methods. Test methods can be designed also to determine vertical and horizontal anisotropy, aquifer discontinuities, vertical hydraulic conductivity of confining beds, well efficiency, turbulent flow, and specific storage and vertical permeability of confining beds.

5. Procedure

5.1 The procedure for selection of an aquifer test method or methods is primarily based on selection of a test method that is compatible with the hydrogeology of the proposed test site. Secondarily, the test method is selected on the basis of the testing conditions specified by the test method, such as the method of stressing or causing water-level changes in the aquifer and the requirements of a test method for observations of water level response in the aquifer. The decision tree in Table 1 is designed to assist, first, in selecting test methods applicable to specific hydrogeologic site characteristics. Secondly, the decision tree will assist in selecting a test method on the basis of the nature of the stress on the aquifer imposed by the control well. The decision tree references the sections in this guide where the test methods are cited.

5.2 *Pretest-Selection Procedures*—Aquifer test methods are highly specific to the assumptions of the analytical solution of the test method. Reliability of determination of hydraulic properties depends upon conformance of the hydrologic site characteristics to the assumptions of the test method. A prerequisite for selecting an aquifer test method is knowledge of the hydrogeology of the test site. A conceptual understanding of the hydrogeology of the aquifer system at the prospective test site should be gained in as much detail as ~~possible~~practicable from existing literature and data, and a site reconnaissance. In developing a site characterization, incorporate geologic mapping, driller's logs, geophysical logs, records of existing wells, water-level and water-quality data, and results of geophysical surveys. Include information on the thickness, lithology, stratification, depth, attitude, continuity, and extent of the aquifer and confining beds.

5.3 *Select Applicable Aquifer Test Methods*—Select a test method based on conformation of the site hydrogeology to assumptions of the test model and the parameters to be determined. A summary of principal aquifer test methods and their applicability to hydrogeologic site conditions is given in the following paragraphs. The decision tree for aquifer test selection, Table 1, provides a graphic display of the hydrogeologic site conditions for each test method and references to the section where each test method is cited.

5.3.1 *Extensive, Isotropic, Homogeneous, Confined, Nonleaky Aquifer:*

5.3.1.1 *Constant Discharge*—Test method in which the discharge or injection rate in the control well is constant are given by the nonequilibrium method of Theis (**1**)[4] for the drawdown and recovery phases. The Theis test method is the most widely referenced and applied aquifer test method and is the basis for the solution to other more complicated boundary condition problems. The Theis test method for the pumping or injection phase is given in Test Method D4106. Cooper and Jacob (**2**) and Jacob (**3**) recognized that for large values of time and small values of distance from the control well, the Theis solution yields a straight line on semilogarithmic plots of various combinations of drawdown and distance from the control well. The solution of the Theis equation can therefore be simplified by the use of semilogarithmic plots. The modified Theis nonequilibrium test method is given in Test Method D4105. A test method for estimating transmissivity from specific capacity by the Theis method is given in Test Method D5472. Test Method D5716 provides a means of means of measuring discharge from high capacity wells. Test Method D5269 provides a method of determining transmissivity in a non-leaky aquifer.

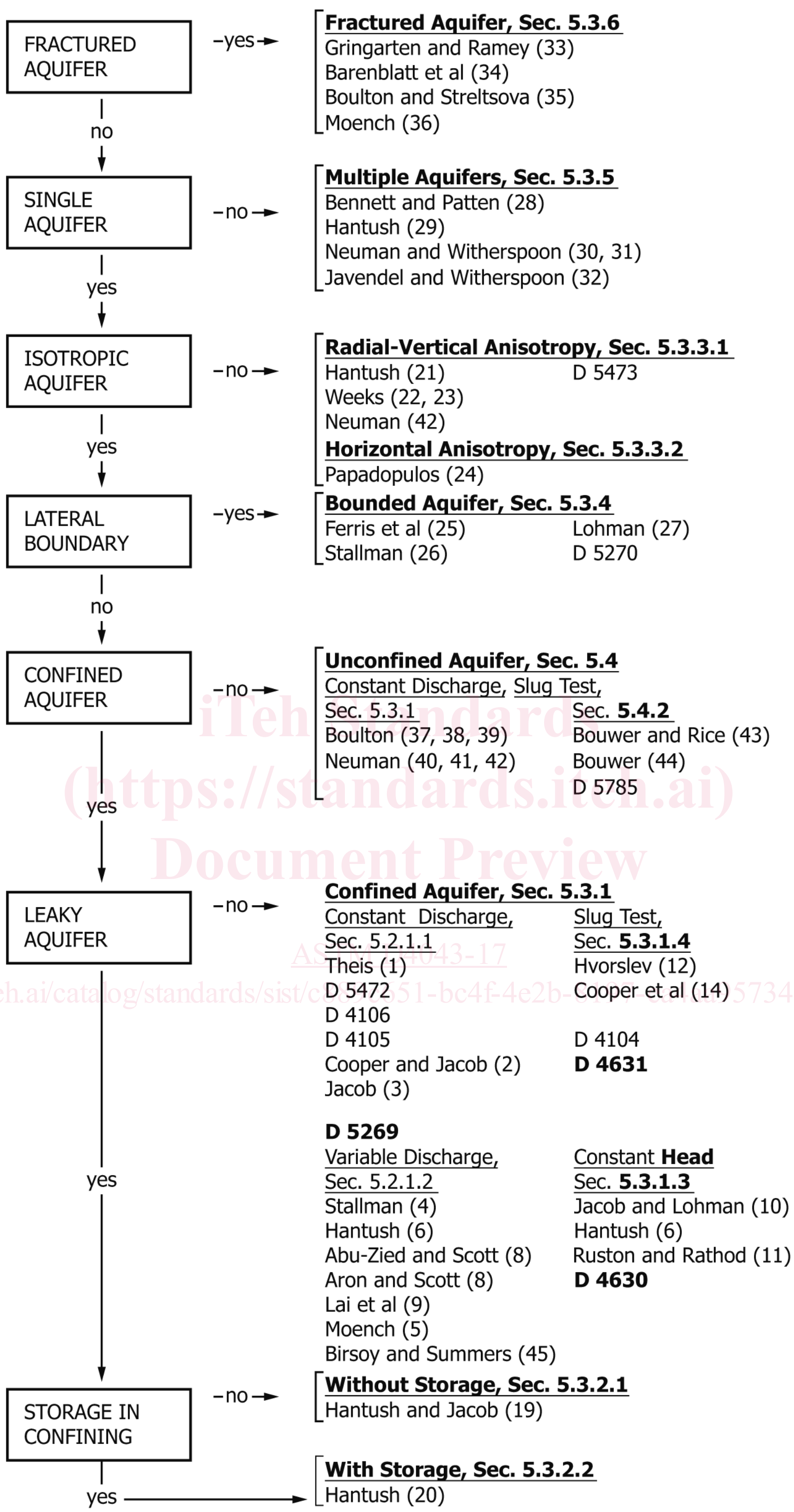
5.3.1.2 *Variable Discharge*—Test methods for a variably discharging control well have been presented by Stallman (**4**) and Moench (**5**) and Birsoy and Summers (**6**). These test methods simulate pumpage as a sequence of constant-rate stepped changes in discharge. The test methods utilize the principle of superposition in constructing type curves by summing the effects of successive changes in discharge. The type curves may be derived for control wells discharging from extensive, leaky, and nonleaky confined aquifers or ~~any situation~~ situations where the response to a unit stress is known. Hantush (**7**) developed drawdown functions for three types of decreases in control-well discharge. Abu-Zied and Scott (**8**) presented a general solution for drawdown in an extensive confined aquifer in which the discharge of the control well decreases at an exponential rate. Aron and Scott (**9**) proposed an approximate test method of determining transmissivity and storage from an aquifer test in which discharge decreases with time during the early part of the test. Lai et al (**10**) presented test methods for determining the drawdown in an aquifer taking into account storage in the control well and having an exponentially and linearly decreasing discharge.

5.3.1.3 *Constant Drawdown*—Test methods have been presented to determine hydraulic-head distribution around a discharging well in a confined aquifer with near constant drawdown. Such conditions are most commonly achieved by shutting in a flowing well long enough for the head to fully recover, then opening the well. The solutions of Jacob and Lohman (**11**) and Hantush (**7**) apply to aerially extensive, nonleaky aquifers. Rushton and Rathod (**12**) used a numerical model to analyze aquifer-test data. Reed (**13**) presents a computer program that includes some of the above procedures and also includes discharge as a fifth-degree polynomial of time. Practice D5786 provides information on performing constant drawdown tests in flowing wells.

5.3.1.4 *Slug Test Methods*—Test methods for estimating transmissivity by injecting a given quantity or *slug* of water into a well were introduced by Hvorslev (**14**) and Ferris and Knowles (**15**). Solutions to overdamped well response to slug tests have also been

[4] The boldface numbers in parentheses refer to the list of references at the end of this guide.

TABLE 1 Decision Tree for Selection of Aquifer Test Method



presented by Cooper et al (**16**). The solution presented by Cooper et al (**16**) is given in Test Method D4104. Solutions for slug tests in wells that exhibit oscillatory water-level fluctuations caused by a sudden injection or removal of a volume of water have been presented by Krauss (**17**), van der Kamp (**18**), and Shinohara and Ramey (**19**). The van der Kamp (**18**) solution is given in Test