



Designation: D6028/D6028M – 20

Standard Practice for (Analytical Procedure) Determining Hydraulic Properties of a Confined Aquifer Taking into Consideration Storage of Water in Leaky Confining Beds by Modified Hantush Method¹

This standard is issued under the fixed designation D6028/D6028M; 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 an analytical procedure for determining the transmissivity and storage coefficient of a confined aquifer taking into consideration the change in storage of water in overlying or underlying confining beds, or both. This practice is used to analyze water-level or head data collected from one or more observation wells or piezometers during the pumping of water from a control well at a constant rate. With appropriate changes in sign, this practice also can be used to analyze the effects of injecting water into a control well at a constant rate.

1.2 This analytical procedure is used in conjunction with Test Method **D4050**.

1.3 *Limitations*—The valid use of the modified Hantush method (**1**)² is limited to the determination of hydraulic properties for aquifers in hydrogeologic settings with reasonable correspondence to the assumptions of the Hantush-Jacob method (Practice **D6029/D6029M**) with the exception that in this case the gain or loss of water in storage in the confining beds is taken into consideration (see **5.1**). All possible combinations of impermeable beds and source beds (for example, beds in which the head remains uniform) are considered on the distal side of the leaky beds that confine the aquifer of interest (see **Fig. 1**).

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

1.4.1 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.

1.5 The values stated in SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values for the two systems may result in nonconformance with the standard. Reporting of results in units other than SI shall not be regarded as nonconformance with this standard.

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 the 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 Committee **D18** on Soil and Rock and is the direct responsibility of Subcommittee **D18.21** on Groundwater and Vadose Zone Investigations.

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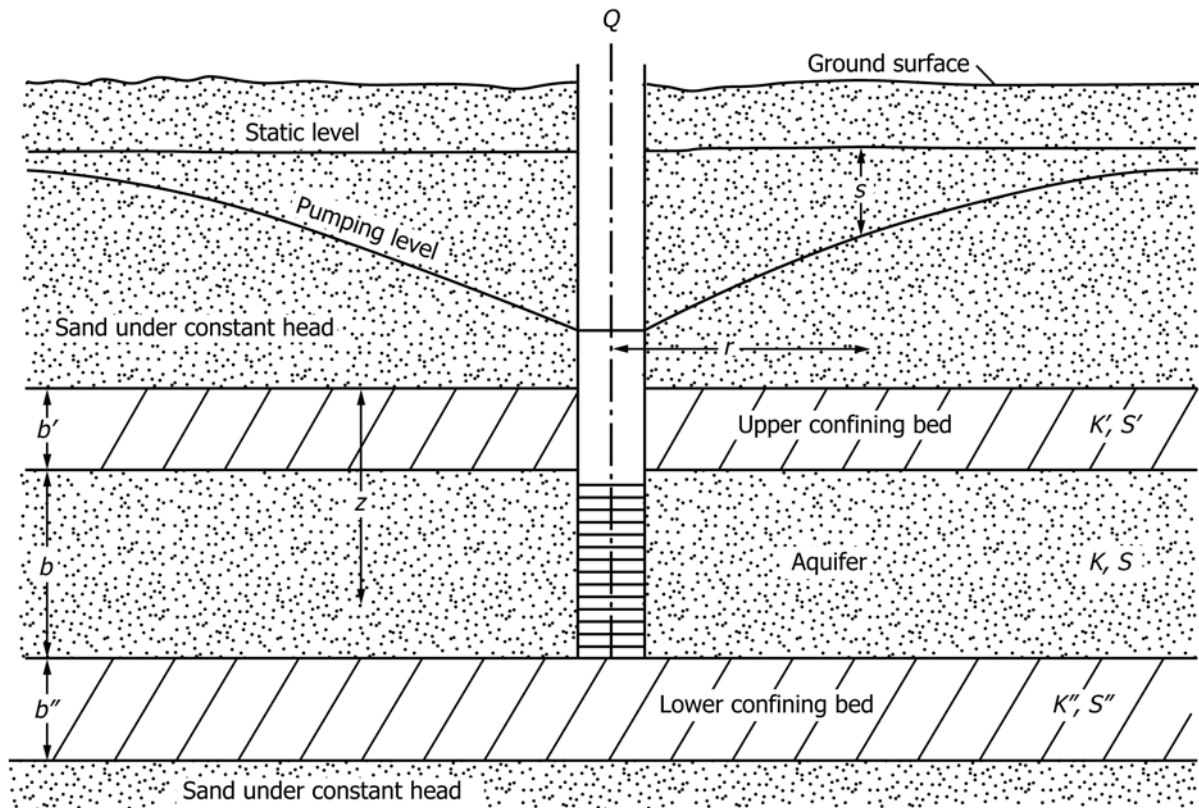
² The boldface numbers in parentheses refer to a list of references at the end of this practice.

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

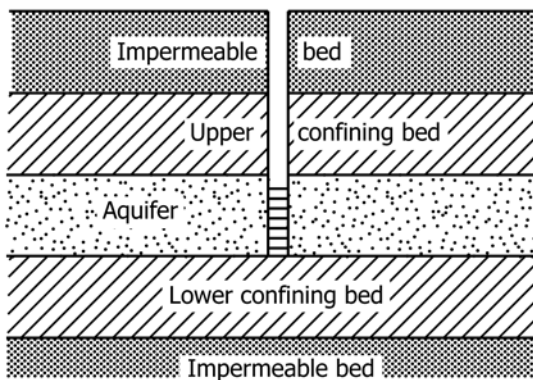


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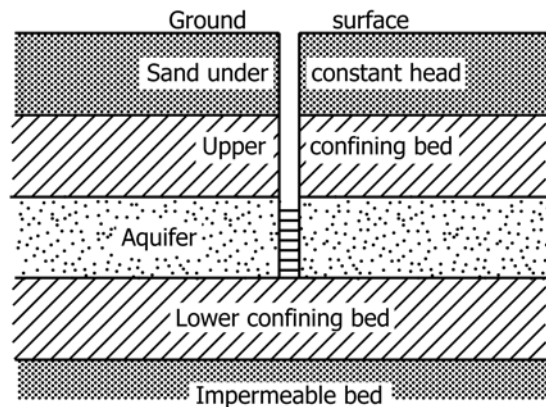
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CASE 1



CASE 2



CASE 3

FIG. 1 Cross Sections Through Discharging Wells in Leaky Aquifers with Storage of Water in the Confining Beds, Illustrating Three Different Cases of Boundary Conditions (from Reed (2))



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
- D4050** Test Method for (Field Procedure) for Withdrawal and Injection Well Testing for Determining Hydraulic Properties of Aquifer Systems
- D4106** Practice for (Analytical Procedure) for Determining Transmissivity and Storage Coefficient of Nonleaky Confined Aquifers by the Theis Nonequilibrium Method
- D6026** Practice for Using Significant Digits in Geotechnical Data
- D6029/D6029M** Practice for (Analytical Procedures) Determining Hydraulic Properties of a Confined Aquifer and a Leaky Confining Bed with Negligible Storage by the Hantush-Jacob Method

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 $H(u, \beta)$ —well function for leaky systems where water storage in confining beds is important [nd].

3.2.2 K —hydraulic conductivity of the aquifer [LT^{-1}].

3.2.2.1 *Discussion*—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.

3.2.3 K' , K'' —vertical hydraulic conductivities of the confining beds through which leakage can occur [LT^{-1}].

3.2.4 Q —discharge [L^3T^{-1}].

3.2.5 $S = bS_s$ —storage coefficient of the aquifer [nd].

3.2.6 $S' = b'S'_s$ —storage coefficients of the confining beds [nd].

$$S'' = b''S''_s$$

3.2.7 S_s —specific storage of the aquifer [L^{-1}].

3.2.8 S'_s , S''_s —specific storages of the confining beds. [L^{-1}]

3.2.9 T —transmissivity [L^2T^{-1}].

3.2.10 $u = \frac{r^2 S}{4Tt}$ [nd].

3.2.11 $W(u, r/B)$ —well function for leaky aquifer systems with negligible storage changes in confining beds [nd].

3.2.12 $W(u)$ —well function for nonleaky aquifer systems [nd].

3.2.13 b —thickness of aquifer [L].

3.2.14 b' , b'' —thicknesses of the confining beds through which leakage can occur [L].

3.2.15 r —radial distance from control well [L].

3.2.16 s —drawdown [L].

3.2.17 $B = \sqrt{\frac{Tb'}{K'}} [L]$.

3.2.18 t —time since pumping or injection began [T].

3.2.19 $\beta = \frac{r}{4b} \left(\sqrt{\frac{K'S'}{b'KS_s}} + \sqrt{\frac{K''S''}{b''KS_s}} \right) [nd]$.

4. Summary of Practice

4.1 This practice involves pumping a control well that is fully screened through the confined aquifer and measuring the water-level response in one or more observation wells or piezometers. The well is pumped at a constant rate. The water-level response in the aquifer is a function of the transmissivity and storage coefficient of the aquifer and the leakance coefficients and storage coefficients of the confining beds. Alternatively, the practice can be performed by injecting water at a constant rate into the control well. Analysis of buildup of water level in response to injection is similar to analysis of drawdown of water level in response to withdrawal in a confined aquifer. The water-level response data are analyzed using a set of type curves.

4.2 *Solution*—Hantush (**1**) gave solutions applicable to each of Cases 1, 2, and 3 shown in **Fig. 1** for “relatively small” values of time and for “relatively large” values of time. The solution applicable for each case for relatively small values of time can be written as follows

$$s = \frac{Q}{4\pi T} H(u, \beta) \quad (1)$$

where:

$$u = \frac{r^2 S}{4Tt} \quad (2)$$

and

$$\beta = \frac{r}{4b} \left(\frac{K'S'}{b'KS_s} + \frac{K''S''}{b''KS_s} \right) \quad (3)$$

$$H(u, \beta) = \int_u^\infty \frac{e^{-y}}{y} \operatorname{erfc} \frac{\beta \sqrt{y}}{\sqrt{y(y-u)}} dy \quad (4)$$

$$\operatorname{erfc}(x) = \frac{2}{\sqrt{\pi}} \int_x^\infty e^{-y^2} dy \quad (5)$$

where y is the variable of integration.

4.2.1 The “relatively small” times when **Eq 1** is applicable are when:

$$t < \frac{b'S'}{10K'} \text{ and } t < \frac{b''S''}{10K''} \quad (6)$$

Equation 1 is applicable at early times for each of the cases shown in **Fig. 1** even though the conditions on the distal sides of the confining beds are quite different because for early times the solution in the aquifer is essentially independent of conditions on the distal side of the confining beds. The effects of those distant boundary conditions are negligible for

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.