



# Standard Test Method for (Field Procedure) for Withdrawal and Injection Well Testing for Determining Hydraulic Properties of Aquifer Systems<sup>1</sup>

This standard is issued under the fixed designation D4050; 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 ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

## 1. Scope\*

1.1 This test method covers the field procedure for selecting well locations, controlling change (discharge or injection) rates, and measuring water levels used to analyze the hydraulic properties of an aquifer or aquifers and adjacent confining beds.

1.2 This test method is used in conjunction with an analytical procedure such as Test Methods D4105 or D4106 to evaluate the data and determine aquifer properties.

1.3 The appropriate field and analytical procedures are selected as described in Guide D4043.

1.4 Limitations—The limitations of this test method are primarily related to the correspondence between the field situation determined by this test method and the simplifying assumptions of the analytical Test Methods D4105 or D4106 and D4043.

1.5 The values stated in SI units are to be regarded as standard.

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

1.6.1 The procedures used to specify how data are collected/recorded or calculated, in this 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 this standard to consider significant digits used in analytical methods for engineering design.

1.7 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the*

<sup>1</sup> This test method 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, 2014. Published July 2014. Originally approved in 1991. Last previous edition approved in 2008 as D4050 – 96 (2008). DOI: 10.1520/D4050-14.

*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:<sup>2</sup>

D653 Terminology Relating to Soil, Rock, and Contained Fluids

D2488 Practice for Description and Identification of Soils (Visual-Manual Procedure)

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

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

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

D6026 Practice for Using Significant Digits in Geotechnical Data

## 3. Terminology

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

## 4. Summary of Test Method

4.1 This test method describes the field practices in conducting aquifer performance tests by either withdrawal or injection through a well point. These methods involve changing the control well water level by either the withdrawal of

<sup>2</sup> 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

water from or injection of water to an aquifer and measurement of the water-level response in the aquifer. The analysis of the data from this field practice is described in standards such as Test Methods **D4105** and **D4106**.

NOTE 1—The injection of water into an aquifer may be regulated or require regulatory approvals. Withdrawal of contaminated waters may require that the removed water be properly treated prior to discharge.

## 5. Significance and Use

5.1 Withdrawal or injection well test field procedures are used with appropriate analytical procedures in appropriate hydrogeological sites to determine transmissivity and storage coefficient of aquifers and hydraulic conductivity of confining beds.

5.2 Practice **D3740** provides evaluation factors for the activities in this test method.

NOTE 2—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.

5.3 This test method may be limited due to the correspondence between the field situation determined by this test method and the simplifying assumptions of the analytical Test Methods **D4106** or **D4106** and **D4043**.

## 6. Apparatus

6.1 Various types of equipment can be used to withdraw or inject water into the control well, measure withdrawal and injection rates, and measure water levels. The test procedure may be conducted with different types of equipment to achieve similar results. The objectives to be achieved by the use of the equipment are given in this section and in Sections **7** and **8**. The selection of equipment and measuring apparatus will be evaluated to ensure that sufficient accuracy and sensitivity will be provided for the later evaluation of data by **D4105** and **D4106**.

6.2 *Control Well*—Discharge or injection well test methods require that water be withdrawn from or injected into a single well. This well, known as the control well, must be drilled and completed such that it transmits water to or from the aquifer (usually the entire thickness of the aquifer) at rates such that a measurable water level change will occur at observation wells. The control well should be as efficient as possible, to reduce the head loss between the aquifer and the well. Well development should be as complete as possible to eliminate additional production of sand or silt and consequent changes in well efficiency and pumping water levels during the test. The cuttings from the control well should be described and recorded according to Practice **D2488**. The analytical method selected for analysis of the data may specify certain dimensions of the control well such as screen length and depth of screen placement. Specific requirements for control wells may be given in standards for specific analytical methods (see, for example, Test Methods **D4105** and **D4106**).

6.3 *Observation Wells or Piezometers*—Numbers of observation wells and their distance from the control well and their screened interval may be dependent upon the test method to be employed. Refer to the analytical test method to be used for specifications of observation wells (see, for example, Test Methods **D4105** and **D4106**).

6.4 *Control Well Pump*—A pump capable of withdrawal of a constant or predetermined variable rate of water from the control well. The pump and motor should be adequately sized for the designed pumping rate and lift. The pump or motor must be equipped with a control mechanism to adjust discharge rate. In the case of diesel-, gasoline-, or natural-gas-fueled engines, throttle settings should allow for small adjustments in pumping rates. Pumps equipped with electric motors are usually controlled by adjusting back pressure on the pump through a gate valve in the discharge line. Take care to select a discharge rate small enough such that the rate can be maintained throughout the test without fully opening the gate valve. If neither method of control is practical, split the discharge and route part of the discharge back to the well through a separate discharge line. If water is withdrawn, the discharge should be at a distance sufficiently away from the area to prevent recharging back into the aquifer being tested.

6.5 Many aquifer tests are made at “sites of opportunity,” that is, using existing production wells as the control well and using other existing wells for observation of water level. In such cases the locations and screened intervals of the wells should be compatible with the requirements of the method of test analysis.

6.6 *Water-Level Measurement Equipment*—Manual measurements can be made with a steel tape or electric tape, with a mechanical recorder linked to a float, or combination of pressure transducer and electronic data logger. The accuracy of the water level measurement should be adequate to satisfy the requirements of **D4105** and **D4106**. Generally a water level accuracy of 0.254 cm should be adequate.

6.6.1 *Mechanical Recorders*—Mechanical recorders employ a float in the well to produce a graphic record of water level changes. Early in the test, it may be difficult to distinguish small increments of time on the recorder chart, therefore the recorder should be supplemented with additional early time measurements or by marking the trace of an automatic water-level recorder chart and recording the time by the mark. Check the mechanical recorder periodically throughout the test using the steel tape.

6.6.2 *Pressure Transducers and Electronic Data Loggers*—A combination of a pressure transducer and electronic data logger can provide rapid measurements of water-level change, and can be programmed to sample at reduced frequency late in the test. Select the pressure transducer to measure pressure changes equivalent to the range of expected water level changes. Check the transducer in the field by raising and lowering the transducer a measured distance in the well. Also check the transducer readings periodically with a steel tape.

6.6.3 Equipment used for measuring flows and water levels should have calibration records, or be calibrated for the test.

6.7 *Sand Content Measurement Device*—Apparatus to measure the sand content in discharged water. Cone Types (for example, Imhoff) can be used for higher concentrations of sand in the discharge water and centrifugal sand separators (for example, Rossum) can be used for lower levels and are commercially available and commonly used.

6.8 *Barometric Pressure*—Barometric pressures should be determined and routinely logged, particularly if the test is of a long duration, such as over several days between the initial and final readings.

**7. Conditioning**

7.1 *Pre-Test Procedures:*

7.1.1 *Selecting Aquifer-Test Method*—Develop a conceptual model of the site hydrogeology and select the appropriate aquifer test method according to Guide D4043. Observe the requirements of the selected test method with regard to specifications for the control well and observations wells.

7.1.2 *Field Reconnaissance*—Make a field reconnaissance of the site before conducting the test to include as much detail as possible on depth, continuity, extent, and preliminary estimates of the hydrologic properties of the aquifers and confining beds. Note the location of existing wells and water-holding or conveying structures that might interfere with the test. The control should be equipped with a pipeline or conveyance structure adequate to transmit the water away from the test site, so that recharge is not induced near the site. Make arrangements to ensure that nearby wells are turned off well before the test, and automatic pump controls are disabled throughout the anticipated test period. Alternately, it may be necessary to pump some wells throughout the test. If so, they should be pumped at a constant rate, and not started and stopped for a duration equal to that of the test before nor should they be started and stopped during the test.

7.1.3 *Testing of Control Well*—Conduct a short term preliminary test of the control well to estimate hydraulic properties of the aquifer, estimate the duration of the test and establish a pumping rate for the field procedure.

7.1.4 *Testing Observation Wells*—Test the observation wells or piezometers prior to the aquifer test to ensure that they are hydraulically connected to the aquifer. Accomplish this by adding or withdrawing a known volume of water (slug) and measure the water-level response in the well. The resultant response should be rapid enough to ensure that the water level in the piezometer will reflect the water level in the aquifer during the test. Redevelop piezometers with unusually sluggish response. Information on performing a slug test can be found in D4044.

7.1.5 *Measuring Pre-Testing Water-Level Trends*—Measure and record water levels in all observation wells prior to start of pumping for a period long enough to establish the static pre-test water level trend. This period is at least equal to the length of the test. The trend in all observation wells should be similar. A well with an unusual trend may reflect effects of local disturbances in the hydrologic system, or may be inadequately developed.

7.1.6 *Selecting of Pumping Rate*—Select the pumping rate, on the basis of the preliminary test (see 7.1.3), at which the

well is to be pumped, such that, the rate can be sustained by the pump for the duration of the test. The rate should not be so large that the water level is drawn down below the perforations in the control well, causing cascading water and entrained air in the well. Under no circumstances should the rate be so large that the water level is drawn down to the water-entry section of the pump or tailpipe.

**8. Procedure**

8.1 *Withdrawing or Injecting Water from the Aquifer*—Regulate the rate at which water is withdrawn from, or injected into, the control well throughout the test. The short-term discharge should not vary more than 10 % about the mean discharge. For constant-discharge tests, long-term variation of discharge from the beginning to end of test generally should be less than 5 %.

NOTE 3—The addition of water to a well should be fully evaluated prior to the test. The water quality must be known, and may be subject to regulatory approval. The additional of water may change the chemistry of the well water for subsequent monitoring, and the rapid injection may damage the well pack and surrounding natural soils. The withdrawal of water from a well with contamination may be problematic by the generation of contaminated water that will have to be handled and disposed of in accordance with applicable regulations.

NOTE 4—The use of a sand content measurement device can be used when a well is pumped to assess the well condition, determining a pumping rate, and avoiding damage to the well.

8.2 Measure and record discharge frequently, for example every 5 min, and if necessary adjust discharge during the beginning of the test. When the discharge becomes more stable, reduce the frequency of adjustments and check discharge at least once every 2 h throughout the test. Variations in electric line load throughout the day will cause variations in discharge of pumps equipped with electric motors. Changes in air temperature and barometric pressure will likewise affect diesel motors. Late in a lengthy test, measure, record, and adjust discharge much more frequently than the water levels are measured.

8.3 *Measuring Water Level; Frequency of Measurement*—Measure and record water levels in each observation well at approximately logarithmic intervals of time. Measure at least ten data points throughout each logarithmic interval. A typical measurement schedule is listed in Table 1.

8.4 *Duration of Pumping Phase of Test*—Make preliminary analysis of the aquifer-test data during the test using the appropriate test method (such as Test Methods D4105 and D4106). Continue the test until the analysis shows adequate test duration.

8.5 *Measuring Recovery of Water Levels:*

**TABLE 1 Typical Measurement Frequency**

Frequency, One Measurement Every:	Elapsed Time, For the First:
30 s	3 min
1 min	3 to 15 min
5 min	15 to 60 min
10 min	60 to 120 min
20 min	2 to 3 h
1 h	3 to 15 h
5 h	15 to 60 h

8.5.1 If the recovery data are to be analyzed completely as a part of the test and used to determine long-term background water-level changes, the recovery of water levels following pumping phase should be measured and recorded for a period of time equal to the pumping time. Analyze the recovery data to determine the hydraulic parameters of the system. The frequency of measuring water levels should be similar to the frequency during the pumping phase (see [Table 1](#)).

8.5.2 If water level data during the early part of the recovery phase are to be used from the control well, the pump should be equipped with a foot valve to prevent the column pipe fluid from flowing back into the well when the pump is turned off.

#### 8.6 *Post-Testing Procedures:*

8.6.1 Tabulate water levels, including, pre-test water levels, for each well or piezometer, date, clock time, time since pumping started or stopped, and measurement point.

8.6.2 Tabulate measurements of the rate of discharge or injection at the control well, date, clock time, time since pumping started, and method of measurement.

8.6.3 Prepare a written description of each well, describing the measuring point, giving its altitude and the method of obtaining the altitude, and the distance of the measuring point above the mean land surface.

8.6.4 Make plots of water-level changes and discharge measurements as follows:

8.6.4.1 Plot water levels in the control well and each observation well against the logarithm of time since pumping began. Plot the rate of discharge,  $Q$ , of the control well on arithmetic paper.

8.6.4.2 Prepare a plot of the log of drawdown,  $s$ , versus the log of the ratio of time since pumping began,  $t$ , to the square of the distance from the control well to the observation well,  $r$ , that is  $\log_{10}s$  versus  $\log_{10}t/r^2$ , on a single graph and maintain the graph as the test progresses. Unexpected, rapid deviations of the data from the type curves may be caused by variations in discharge of the control well, or by other wells in the vicinity starting, stopping or changing discharge rates, or by other changes in field conditions. Such interfering effects may need to be measured, and adjustments made in the final data, or it may be necessary to abort the test.

8.6.4.3 *Plot Recovery of Water Levels*—Plot recovery data, consisting of plots of water level versus log of the ratio of time since pumping started ( $t$ ) to the time since pumping stopped ( $t'$ ). Prepare mass plots of log of recovery versus log of the quantity: ratio of time since pumping stopped ( $t'$ ) to the square of the distance from the control well to the observation well ( $r^2$ ), that is  $\log_{10}t$  versus  $\log_{10}t'/r^2$ .

### 9. Report: Test Data Sheet(s)/Form(s)

9.1 The methodology used to specify how data are recorded on the test data sheet(s)/form(s), as given below, is covered in 1.6.

9.2 Record as a minimum the following general information (data):

9.2.1 Field data including a description of the field site, plots of water level and discharge with time, and preliminary analysis of data.

9.2.2 The purpose of the test, dates and times water-level measurements were begun, dates and times discharge or injection was begun and ended, and the average rate of discharge or injection.

9.2.3 The “as built” description and diagrams of all control wells, observation wells, and piezometers.

9.2.4 A map of the site showing all well locations, the distances between wells, and location of all geologic boundaries or surface-water bodies which might affect the test.

9.2.4.1 The locations of wells and boundaries that would affect the aquifer tests need to be known with sufficient accuracy to provide a valid analysis. For most analyses, this means the locations must provide data points within plotting accuracy on the semilog or log-log graph paper used in the analysis. Radial distances from the control well to the observation wells usually need to be known within  $\pm 0.5\%$ . For prolonged, large-scale testing it may be sufficient to locate wells from maps or aerial photographs. However, for small-scale tests, the well locations should be surveyed. All faults, streams, and canals or other potential boundaries should be located. When test wells are deep relative to their spacing it may be necessary to conduct well-deviation surveys to determine the true horizontal distance between well screens in the aquifer.

9.2.5 Calibration or verification records for flowmeters, water level devices and systems.

9.3 Record as a minimum the following test specimen data:

9.3.1 Tabulated field data collected during the test.

9.3.2 Sand content in discharge water data, if used.

9.3.3 Barometric pressures logged during the monitoring and testing. Water levels on open wells should be corrected for barometric changes.

### 10. Precision and Bias

10.1 *Precision*—Test data on precision is not presented due to the nature of the ground water water tested by this test method. It is either not feasible or too costly at this time to have ten or more laboratories participated in a round-robin testing program. It is not practicable to specify the precision of this test method because the response of aquifer systems during aquifer tests is dependent upon ambient system stresses.

10.2 *Bias*—There is no accepted reference value for this test method, therefore bias cannot be determined.

### 11. Keywords

11.1 aquifer tests; aquifers; discharging wells; drawdown; ground water; hydraulic conductivity; injection wells; recovery; storage coefficient; transmissivity

**SUMMARY OF CHANGES**

In accordance with Committee D18 policy, this section identifies the location of changes to this standard since the last edition (1996 (Reapproved 2008)) that may impact the use of this standard. (Approved June 1, 2014)

- (1) Added additional ASTM References to D3640, D4044, and D6026.
- (2) Added caveat that SI units are standard.
- (3) Edited the title and text to clarify that using injection or withdrawal are the same method.
- (4) Removed definitions that are general and already in D653.
- (5) Added information to the Summary of Method and Significance and Use.
- (6) Removed references to withdrawn standards.
- (7) Added calibration of equipment to Apparatus and Report Section.
- (8) Added Sand content measure equipment to apparatus and in a note.
- (9) Added notes concerning the injection of fluids into an aquifer.
- (10) Edited the title of Section 9, added rounding and reporting of data in accordance with D6026.
- (11) Added summary of Changes.
- (12) Made editorial changes for clarity and consistency throughout.

*ASTM International takes no position respecting the validity of any patent rights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of the validity of any such patent rights, and the risk of infringement of such rights, are entirely their own responsibility.*

*This standard is subject to revision at any time by the responsible technical committee and must be reviewed every five years and if not revised, either reapproved or withdrawn. Your comments are invited either for revision of this standard or for additional standards and should be addressed to ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend. If you feel that your comments have not received a fair hearing you should make your views known to the ASTM Committee on Standards, at the address shown below.*

*This standard is copyrighted by ASTM International, 100 Barr Harbor Drive, PO Box C700, West Conshohocken, PA 19428-2959, United States. Individual reprints (single or multiple copies) of this standard may be obtained by contacting ASTM at the above address or at 610-832-9585 (phone), 610-832-9555 (fax), or service@astm.org (e-mail); or through the ASTM website (www.astm.org). Permission rights to photocopy the standard may also be secured from the Copyright Clearance Center, 222 Rosewood Drive, Danvers, MA 01923, Tel: (978) 646-2600; <http://www.copyright.com/>*