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Standard Guide for Direct-Push Groundwater Sampling for Environmental Site Characterization[1]

This standard is issued under the fixed designation D6001/D6001M; 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 guide covers a review of methods for sampling groundwater at discrete points or in increments by insertion of groundwater sampling devices using Direct Push Methods (D6286/D6286M, see 3.3.2). By directly pushing the sampler, the soil is displaced and helps to form an annular seal above the sampling zone. Direct-push water sampling can be one time, or multiple sampling events. Knowledge of site specific geology and hydrogeologic conditions is necessary to successfully obtain groundwater samples with these devices.

1.2 Direct-push methods of water sampling are used for groundwater quality and geohydrologic studies. Water quality and permeability may vary at different depths below the surface depending on geohydrologic conditions. Incremental sampling or sampling at discrete depths is used to determine the distribution of contaminants and to more completely characterize geohydrologic environments. These explorations are frequently advised in characterization of hazardous and toxic waste sites and for geohydrologic studies.

1.3 This guide covers several types of groundwater samplers; sealed screen samplers, profiling samplers, dual tube sampling systems, and simple exposed screen samplers. In general, sealed screen samplers driven to discrete depth provide the highest quality water samples. Profiling samplers using an exposed screen(s) which are purged between sampling events allow for more rapid sample collection at multiple depths. Simple exposed screen samplers driven to a test zone with no purging prior to sampling may result in more questionable water quality if exposed to upper contaminated zones, and in that case, would be considered screening devices.

1.4 Methods for obtaining groundwater samples for water quality analysis and detection of contaminants are presented. These methods include use of related standards such as; selection of purging and sampling devices (Guide D6452 and D6634/D6634M), sampling methods (Guide D4448 and D6771) and sampling preparation and handling (Guides D5903, D6089, D6517, D6564/D6564M, and D6911).

1.5 When appropriately installed and developed many of these devices may be used to perform pneumatic slug testing (Practice D7242/D7242M) to quantitatively evaluate formation hydraulic conductivity over discrete intervals of unconsolidated formations. These slug tests provide reliable determinations of hydraulic conductivity and can be performed after water quality sampling is completed.

1.6 Direct-push water sampling is limited to unconsolidated formations that can be penetrated with available equipment. In strong soils damage may result during insertion of the sampler from rod bending or assembly buckling. Penetration may be limited, or damage to samplers or rods can occur in certain ground conditions, some of which are discussed in 5.7. Drilling equipment such as sonic drilling (Practice D6914/D6914M) or rotary drilling (Guide D6286/D6286M) can be used to advance holes past formations difficult to penetrate using typical Direct Push equipment. Some soil formations do not yield water in a timely fashion for direct-push sampling. In the case of unyielding formations, direct-push soil sampling can be performed (Guide D6282/D6282M).

1.7 Direct push water sampling with one-time sealed screen samplers can also be performed using cone penetrometer equipment (Guide D6067/D6067M).

1.8 This guide does not address installation of permanent water sampling systems such as those presented in Practice D5092/D5092M. Direct-push monitoring wells for long term monitoring are addressed in Guide D6724/D6724M and Practice D6725/D6725M.

1.9 *Units*—The values stated in either SI units or inch-pound units [presented in brackets] 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 from the two systems may result in nonconformance with the standard. Reporting of test results in units other than SI shall not be regarded as nonconformance with this standard.

1.10 All observed and calculated values shall conform to the guidelines for significant digits and rounding established in Practice D6026, unless superseded by this standard.

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

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1.11 *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.*

1.12 *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.*

1.13 *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.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D653 Terminology Relating to Soil, Rock, and Contained Fluids

D1586/D1586M Test Method for Standard Penetration Test (SPT) and Split-Barrel Sampling of Soils

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

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

D4448 Guide for Sampling Ground-Water Monitoring Wells

D4750 Test Method for Determining Subsurface Liquid Levels in a Borehole or Monitoring Well (Observation Well) (Withdrawn 2010)[3]

D5088 Practice for Decontamination of Field Equipment Used at Waste Sites

D5092/D5092M Practice for Design and Installation of Groundwater Monitoring Wells

D5314 Guide for Soil Gas Monitoring in the Vadose Zone (Withdrawn 2015)[3]

D5434 Guide for Field Logging of Subsurface Explorations of Soil and Rock

D5521/D5521M Guide for Development of Groundwater Monitoring Wells in Granular Aquifers

D5778 Test Method for Electronic Friction Cone and Piezocone Penetration Testing of Soils

D5903 Guide for Planning and Preparing for a Groundwater Sampling Event

D6026 Practice for Using Significant Digits in Geotechnical Data

D6067/D6067M Practice for Using the Electronic Piezocone Penetrometer Tests for Environmental Site Characterization and Estimation of Hydraulic Conductivity

D6089 Guide for Documenting a Groundwater Sampling Event

D6187 Practice for Cone Penetrometer Technology Characterization of Petroleum Contaminated Sites with Nitrogen Laser-Induced Fluorescence (Withdrawn 2019)[3]

D6235 Practice for Expedited Site Characterization of Vadose Zone and Groundwater Contamination at Hazardous Waste Contaminated Sites

D6452 Guide for Purging Methods for Wells Used for Ground Water Quality Investigations

D6517 Guide for Field Preservation of Ground Water Samples

D6564/D6564M Guide for Field Filtration of Groundwater Samples

D6634/D6634M Guide for Selection of Purging and Sampling Devices for Groundwater Monitoring Wells

D6724/D6724M Guide for Installation of Direct Push Groundwater Monitoring Wells

D6725/D6725M Practice for Direct Push Installation of Prepacked Screen Monitoring Wells in Unconsolidated Aquifers

D6771 Practice for Low-Flow Purging and Sampling for Wells and Devices Used for Ground-Water Quality Investigations

D6911 Guide for Packaging and Shipping Environmental Samples for Laboratory Analysis

D7242/D7242M Practice for Field Pneumatic Slug (Instantaneous Change in Head) Tests to Determine Hydraulic Properties of Aquifers with Direct Push Groundwater Samplers

D7352 Practice for Volatile Contaminant Logging Using a Membrane Interface Probe (MIP) in Unconsolidated Formations with Direct Push Methods

D8037/D8037M Practice for Direct Push Hydraulic Logging for Profiling Variations of Permeability in Soils

2.2 *Drilling Methods:*[2]

D5781/D5781M Guide for Use of Dual-Wall Reverse-Circulation Drilling for Geoenvironmental Exploration and the Installation of Subsurface Water Quality Monitoring Devices

D5782 Guide for Use of Direct Air-Rotary Drilling for Geoenvironmental Exploration and the Installation of Subsurface Water-Quality Monitoring Devices

D5783 Guide for Use of Direct Rotary Drilling with Water-Based Drilling Fluid for Geoenvironmental Exploration and the Installation of Subsurface Water-Quality Monitoring Devices

D5784/D5784M Guide for Use of Hollow-Stem Augers for Geoenvironmental Exploration and the Installation of Subsurface Water Quality Monitoring Devices

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[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.

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

D5875/D5875M Guide for Use of Cable-Tool Drilling and Sampling Methods for Geoenvironmental Exploration and Installation of Subsurface Water Quality Monitoring Devices
D5876/D5876M Guide for Use of Direct Rotary Wireline Casing Advancement Drilling Methods for Geoenvironmental Exploration and Installation of Subsurface Water-Quality Monitoring Devices
D6286/D6286M Guide for Selection of Drilling and Direct Push Methods for Geotechnical and Environmental Subsurface Site Characterization
D6914/D6914M Practice for Sonic Drilling for Site Characterization and the Installation of Subsurface Monitoring Devices

2.3 *Soil Sampling:*[2]
D6282/D6282M Guide for Direct Push Soil Sampling for Environmental Site Characterizations

3. Terminology

3.1 *Definitions:*

3.1.1 For definitions of common technical terms in this standard, refer to Terminology D653.

3.2 *The definitions below are in Terminology D653, and as adopted from Practice D5092/D5092M on installation of monitoring wells.*

3.2.1 *bailer, n—in wells*, a hollow tubular receptacle used to facilitate removal of fluid from a well or borehole.

3.2.2 *borehole, n—in drilling*, an open or uncased subsurface hole, generally circular in plain view, created by drilling.

3.2.2.1 *Discussion*—Normally, a borehole is advanced using an auger, a drill, or casing with or without drilling fluid, but for this standard it is made using direct push methods (3.3.2).

3.2.3 *casing, n—in drilling*, pipe, finished in sections with either threaded connections or beveled edges to be field welded, which is installed temporarily or permanently to counteract caving, to advance the borehole, or to isolate the zone being monitored, or combination thereof.

3.2.4 *caving; sloughing, v—in drilling*, the inflow of unconsolidated material into a borehole that occurs when the borehole walls lose their cohesive strength.

3.2.5 *centralizer, n—in drilling*, a device that assists in the centering of a casing or riser within a borehole or another casing.

3.2.6 *PTFE tape, n—in drilling*, joint sealing tape composed of polytetrafluorethylene.

3.2.6.1 *Discussion*—For sampling of (PFAS, 3.3.11), PTFE tape may not be used in well assembly due to the potential for cross contamination.

3.2.7 *slot, n—in well screen opening*, slot openings have been designated by numbers which correspond to the width of the openings in thousandths of an inch.

3.2.7.1 *Discussion*—A No. 10 slot screen, for example, is an opening of 0.25 mm [0.010 in.].

3.2.8 *well screen, n—in wells*, a device used to retain the primary or natural filter pack; usually a cylindrical pipe with openings of uniform width, orientation, and spacing.

3.3 *Definitions of Terms Specific to This Standard:*

3.3.1 *assembly length, n*—length of sampler body and riser pipes.

3.3.2 *direct-push (DP) method, v*—a subsurface exploration method by which drive rod, casing tube, sampling, and logging devices are pushed, driven, or vibrated into soils or unconsolidated formations to be sampled or logged without rotary drilling and removal of cuttings.

3.3.2.1 *Discussion*—For the purposes of this guide, a subsurface exploration method that uses hand-held percussion driving devices, or hydraulic percussion, quasi static push, or vibratory drive systems that are mounted to a truck, van, all-terrain vehicle, trailer, skid, or drill rig.

3.3.3 *direct-push groundwater sampler, n*—a sampler specially designed for use with direct push methods to collect groundwater from relatively pervious soils (aquifers).

3.3.4 *exposed screen sampler, n—in drilling*, a sampler with an exposed screen driven to the sampling depth that may be exposed to cross contamination prior to the sampling.

3.3.5 *exposed screen length, n*—the length of a screen open or exposed to water bearing strata.

3.3.5.1 *Discussion*—In some DP groundwater sampling devices only a portion of the screen may be exposed to the formation to target a discrete zone for sampling.

3.3.6 *effective seal length, n*—the length of soil above the sampler screen that is in intimate contact with the riser pipe and prevents connection of the screen with groundwater from overlying zones.

3.3.7 *grab groundwater sampling, v—in groundwater*, the process of rapidly collecting a water sample with minimal purging or development using simple equipment like bailers or pumps at a specific time, location, and depth.

3.3.7.1 *Discussion*—Grab sampling is a rapid sampling event with little or no purging or development of the test zone, often using simple devices like a bailer or inertial pumps.

3.3.8 *incremental drilling and sampling, n—in drilling*, insertion method where rotary drilling and sampling events are alternated for incremental sampling. Incremental drilling is often needed to penetrate harder or deeper formations.

3.3.9 *groundwater profiling, v*—the method of advancing a groundwater sampling device incrementally and collecting discrete samples of groundwater at each depth interval.

3.3.10 *percussion driving, v*—insertion method where rapid hammer impacts are performed to insert the sampling device and the percussion is normally accompanied with application of static down force.

3.3.11 *PFAS, n*—polyfluorinated alkyl substances: includes PFOS (perfluorooctane sulfonate) and PFOA (perfluorooctanoate acid) that have very low detection levels, in parts per trillion for combined concentration in drinking water.

3.3.11.1 *Discussion*—PFAS includes hundreds of poly fluorinated compounds, many of which are components of aqueous fire-fighting foams (AFFF) previously used at military and commercial airports. PFAS compounds have been used in many industrial and commercial products. Polytetrafluoroethylene containing materials and products are excluded from use when PFAS sampling is conducted.

3.3.12 *push depth, n*—the depth below a ground surface datum that the end or tip of the direct-push water sampling device is inserted.

3.3.13 *sampler screen, n*—a well screen mesh or slot system designed to filter coarse particles from the sampling test zone or ports of the direct push groundwater sampler.

3.3.14 *sealed screen sampler, n*—a groundwater sampler where the sampler screen is sealed until the sampling depth is reached thus preventing exposure to groundwater from previous depths and accurate evaluation of water quality at the point of sampling.

3.3.15 *unconsolidated geologic materials, n—in groundwater, geology, or hydrogeology*, a loosely aggregated solid (particulate) material of geologic origin (soil, sediments, etc.).

3.3.15.1 *Discussion*—Groundwater hydrologists, and geologists, use the terms unconsolidated formations, deposits, sediments, units, materials, etc., to refer to the general term "soil" including other soils (alluvium, glacial till, etc.) as defined in D653. These terms are often found in groundwater standards applied to aquifers. Unconsolidated materials are non-lithified, typically lacking cementation of individual particles (clay, silt sand, gravel, etc.). The term "unconsolidated" should not be confused with geotechnical terms of the degree of soil consolidation (over, normally, under-consolidated) as defined in D653.

3.4 *Acronyms:*

3.4.1 *DP*—Direct Push methods (3.3.2).

4. Summary of Guide

4.1 Direct-push groundwater sampling may be performed using different procedures depending on the device design and purpose of the investigation. One single-tube procedure consists of pushing a sealed protected screen sampler to a known depth, opening the sampler screen over a specified interval, and sampling groundwater from the interval. The single tube sealed screen method will provide the highest integrity water quality samples. A sampler, often with constant outside diameter is inserted directly into the soil by percussion hammering and/or static push until sufficient riser pipe is seated into the soil to ensure a seal. Sealed screens can be exposed by retraction of riser pipes. While the riser is seated in the soil, water samples can be taken, and water injection or pressure measurements may be performed. Following adequate development many of these devices can be slug tested using pneumatic methods (Practice D7242/D7242M) to obtain data about formation hydraulic conductivity.

4.2 Profiling samplers allow the operator to collect samples of groundwater at multiple, increasing depths as the tool is incrementally advanced. These exposed screen samplers may be advanced as water is injected into the formation through the screen(s) or port(s). The injection pressure and flow rate of the water may be monitored to evaluate formation permeability as some devices are advanced. These devices are subject to cross contamination and "drag down" of contaminants as the exposed screens are advanced to increasing depths. Injection of clean water out of the screen(s) as the tools are advanced to increasing depths may help reduce the drag down effect.

4.3 Dual-tube groundwater systems provide for the insertion and removal of fresh screens at multiple depths as the outer casing is incrementally advanced to depth. The system can be used for one-time sampling events as a sealed screen sampler. However, a one-time sampling event when used for multiple vents and after soils sampling the water from previous sampling intervals left in the outer casing as the exposed screen tool string is advanced may lead to cross contamination. In saturated sands formation heave may be difficult to control in the dual tube sand formations systems without the addition of excessive amounts of water to control the hydraulic head. Dual-tube systems may be slug tested (Practice D7242/D7242M) to determine the hydraulic conductivity of the screened formation, following adequate development.

4.4 Development of the screened formation and sampling groundwater may be performed using a variety of tools and methods depending on the design of the sampling device (Guide D5521/D5521M). Development is most often performed with an inertial check valve in the small diameter piezometers having an open annulus to the surface. Occasionally, a mini-surge block or similar device may be used for development of these types of tools. Sampling of the open annulus tools may be performed with devices such as a mini-bailer, inertial pump, peristaltic pump or small diameter bladder pump (Guide D6634/D6634M). Review project data quality objectives to determine the appropriate sampling device and method. DP groundwater profiling devices often have tubing, integrated pumps and/or trunk lines in the annulus of the drive casing. This precludes performance of typical formation development procedures, other than pumping. The profiling devices are often purged and sampled with a peristaltic pump or integrated downhole pump. The integrated pumps may be of various design.

5. Significance and Use

5.1 Direct-push groundwater sampling and profiling are economical methods for obtaining discrete interval groundwater quality samples in many soils and unconsolidated formations without the expense of permanent monitoring well installation (**1-10**).[4] Many of these devices can be used to profile groundwater quality or contamination and/or hydraulic conductivity with depth by performing repetitive sampling and testing events. DP groundwater sampling is often used in expedited site characterization (Practice D6235) and as a means to accomplish high resolution site characterization (HRSC) (**11, 12**). The formation to be sampled should be sufficiently permeable to allow filling of the sampler in a relatively short time. The zone to be sampled and/or slug tested can be isolated by matching sampler screen length to obtain discrete samples of thin saturated, permeable layers. Use of

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

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these sampling and hydraulic testing techniques will result in more detailed characterization of sites containing multiple aquifers. The field conditions, sampler design and data quality objectives should be reviewed to determine if development (Guide D5521/D5521M) of the screened formation is appropriate. The samplers do not have a filter pack designed to retain fines like conventional wells, but only a slotted screen or wire-mesh covered ports. So, obtaining low turbidity samples may be difficult or even impossible in formations with a significant proportion of fine-grained materials. With most systems turbidity will always be high so consult Guide D6564/D6564M if field filtration of samples is required. Discrete water sampling, combined with knowledge of location and thickness of target aquifers, may better define conditions in thin multiple aquifers than monitoring wells with long screened intervals that can intersect and allow for intercommunication of multiple aquifers (**4**, **6**, **11-15**). DP sampling performed without knowledge of the location and thickness of target aquifers can result in sampling of the wrong aquifer or penetration through confining beds. Results from DP explorations can be used to develop conceptual site models, guide placement of permanent groundwater monitoring wells, and direct remediation efforts. These devices are often used under dynamic work plans (**11**, **16**) to complete site characterizations in a single mobilization. However, multiple sampling events can be performed to depict conditions over time or refine earlier work if needed.

5.2 *Targeting Aquifer Sample Test Zones for Accurate Sampling*—As with any investigation it is important to phase the investigation such that target intervals for groundwater sampling are accurately located. For sites that allow surface push of the sampling device, discrete water sampling is often performed in conjunction with the cone penetration test (Test Method D6067/D6067M) (**4-6**, **13**, **14**) or continuous soil sampling (Guide D6282/D6282M) which is often used for stratigraphic mapping of aquifers and to delineate high-permeability zones for sampling. Alternately, resistivity logging, or injection logging (Practice D8037/D8037M) may be used to assess formation permeability and lithology prior to the groundwater sampling or profiling activities to guide selection of sampling intervals (**10**, **15**, **17**). In such cases, DP water sampling is normally performed close to previous test holes. In complex depositional environments (**12**), thin aquifers may vary in continuity such that water sampling devices may not intersect the same layer at equivalent depths as companion HPT, cone penetrometer, or electrical resistivity profiling soundings.

5.2.1 When volatile organic contaminants (VOC) such as trichloroethylene (TCE) or benzene are present in the subsurface, logging with the membrane interface probe (MIP) (Practice D7352) may be performed prior to groundwater sampling. MIP logs identify where significant concentrations of many VOCs are present and may be used to guide selection of groundwater sampling locations, depths and intervals (**17**). When petroleum fuels are present in the subsurface laser induced fluorescence (LIF) (Practice D6187) or the Optical Imaging Profiler (OIP) (**18**) may be used to identify where significant petroleum contamination is present to assist in guiding selection of sample locations and depths.

5.3 Slug tests can be performed with several of the DP groundwater samplers (D7242/D7242M) to determine hydraulic conductivity over discrete intervals. Development of the screened interval should be conducted to assure that formation flow into and out of the device is representative of natural formation conditions. Development with a simple inertial pump to surge and purge the formation is often adequate. Other methods for development (D5521/D5521M) may be advised depending on field conditions and data quality objectives.

5.4 Water sampling chambers may be sealed to maintain in situ pressures and to allow for pressure measurements and permeability testing (Practice D7242/D7242M) (**6**, **13**, **19**). Sealing of samples under pressure may reduce the possible volatilization of some organic compounds. Field comparisons may be used to evaluate any systematic errors in sampling equipments and methods. Comparison studies may include the need for pressurizing samples, or the use of vacuum to extract fluids more rapidly from low hydraulic conductivity soils (8.2.3.1(*2*)).

5.5 DP groundwater profiling tools (**7**, **8**, **10**, **20**, **21**) allow the investigator to sample groundwater at multiple depths during incremental advancement of the device. Clean water is injected through the screen(s) or port(s) of these tools to keep the screens open and rinsed as advancement proceeds. Concerns for cross contamination and contaminant drag down must be considered. Some tools have an inline pressure transducer either above grade or down hole to monitor pressure required to inject water into the formation during advancement. The pressure injection log may be used to guide selection of permeable zones for sampling. When the injection flow rate is also measured, estimates of formation permeability may be calculated.

5.6 Degradation of water samples during handling and transport can be reduced if discrete water sampling events with sealed screen samplers are combined with real time field analysis of potential contaminants. In limited studies, researchers have found that the combination of discrete sealed screen sampling with onsite field analytical testing provide accurate data of aquifer water quality conditions at the time of testing (**4**, **6**). DP water sampling with exposed screen sampling devices, which may require development or purging, are considered as screening tools depending on precautions that are taken during testing.

5.7 In difficult driving conditions, penetrating to the desired depth to make sure of sealing of the sampler screen may not be possible. If the screen cannot be inserted into the formation with an adequate seal, the water-sampling event would require sealing in accordance with Practice D5092/D5092M to isolate the aquifer. Selection of the appropriate equipment and methods to reach required depth at the site of concern should be made in consultation with experienced operators or manufacturers. If there is no information as to the subsurface conditions, initial explorations consisting of penetration-resistance tests, such as Test Method D6067/D6067M, resistivity profiling, or DP logging with the injection logging system (Practice D8037/D8037M) to perform trials can be performed to select the appropriate testing system.

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5.7.1 Typical penetration depths for a specific equipment configuration depend on many variables. Some of the variables are the driving system, the diameter of the sampler and riser pipes, and the resistance of the materials.

5.7.2 Certain subsurface conditions may prevent sampler insertion. Penetration is not possible in hard rock and sometimes not possible in softer rocks such as claystones and shales. Coarse particles such as gravels, cobbles, and boulders may be difficult to penetrate or cause damage to the sampler or riser pipes. Cemented soil zones may be difficult to penetrate depending on the strength and thickness of the layers. If layers are present that prevent DP from the surface, then rotary or percussion drilling methods (Guide D6286/D6286M) can be employed to advance a boring through impeding layers to reach testing zones.

5.7.3 Driving systems are generally selected based on testing depths and the materials to be penetrated. For systems using primarily static reaction force to insert the sampler, depth will be limited by the reaction weight of the equipment or anchoring stability and penetration resistance of the material. The ability to pull back the rod string is also a consideration. Impact or percussion soil probing has an advantage of reducing the reaction weight required for penetration. Penetration capability in clays may be increased by reducing rod friction by enlarging tips or friction reducers. However, over reaming of the hole may increase the possibility of rod buckling and may allow for communication of differing groundwater tables. Hand-held equipment is generally used on very shallow explorations, typically less than 5 m [15 ft] depth, but depths on the order of 10 m [30 ft] have been reached in very soft lacustrine clays. Intermediate size driving systems, such as small truck-mounted hydraulic-powered push and impact drivers, typically work within depth ranges from 5 to 30 m [20 to 100 ft]. Larger DP machines may be capable of reaching 60 m [200 ft] depending on subsurface conditions. Heavy static-push cone penetrometer vehicles, such as 20 ton trucks, typically work within depth ranges from 15 to 45 m [50 to 150 ft], and also reach depth ranges on the order of 100 m [300 ft] in soft ground conditions. Guide D6286/D6286M shows depth ranges of other drilling equipment to attain greater depths.

NOTE 1—Users and manufacturers cannot agree on depth ranges for different soil types. Users should consult with experienced local producers and manufacturers to determine depth capability for their specific site conditions.

5.8 Combining multiple-sampling events in a single-sample chamber (profiling) without decontamination (Practice D5088) is generally discouraged. In this application, purging of the screen or sampling chamber should be performed to make sure of isolation of the sampling event. Purging should be performed by removing several volumes of fluid until new chemical properties have been stabilized or elements are flushed with fluid of known chemistry. Purging requirements may depend upon the materials used in the sampler and the sampler design (Guide D6634/D6634M). Rinsate samples may be collected and analyzed to assess concerns with carryover of contaminants from overlying zones that are heavily contaminated. Monitoring water quality parameters (pH, specific conductance, dissolved oxygen, oxidation-reduction potential, etc.) to stability is often used to document when representative water is being purged from a sampling interval (Practice D6771).

5.9 Bottom-up profiling by driving a DP groundwater sampler to the base of the formation and retracting incrementally, while the screen is exposed, for sampling at decreasing depths should be avoided as this may lead to cross contamination and inaccurate contaminant distribution information. Slug tests should not be performed by bottom-up profiling as there is poor or no control on the length of formation being tested under these conditions.

5.10 Screens designed and deployed in dual tube use are generally designed for use inside the dual tubing and overdriving the screen past the casing can damage the sampler screen and subsequent exposed screen samples would be subject to cross contamination. Use equipment according to manufactures instructions.

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. Practitioners 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.

Practice D3740 was developed for agencies engaged in the testing and/or inspection of soils and rock. As such, it is not totally applicable to agencies performing this field practice. However, users of this practice should recognize that the framework of Practice D3740 is appropriate for evaluating the quality of an agency performing this practice. Currently there is no known qualifying national authority that inspects agencies that perform this practice.

6. Apparatus

6.1 *General*—A direct-push sampling system consists of a tip; well screen; chambers, if present; and drive rods (casing and/or riser pipes) extending to the surface. DP water sampling equipment can be either with a sealed screen or exposed screen. There are also two types of drive systems, single tube and dual (double) tube (see 6.2.3).

6.2 *Sampler Types*—Samplers with protected or sealed screens depend on the seals to avoid exposure of the sampling chamber or screen to contaminated soil or water from other layers during advancement. Seals also should be maintained at each rod joint to prevent infiltration of water or fines from intervals above the desired sample interval where o-rings or plumbers' tape may be used. These devices can be considered as accurate point-source detectors. Single-tube sealed screen devices are normally recovered and decontaminated between sampling events. In dual-tube systems the screen may be installed after the outer casing is advanced to the desired sampling depth acting as a sealed screen sampler for one-time sampling events. If the dual tube is advanced in a soil sampling mode, and then a water sampler is taken, the sampler screen is exposed to water in the casing. Exposed-screen samplers driven from the surface are subject to contaminant drag down and may require additional purging and development. Exposed screen samplers in these modes are considered as screening devices for profiling relative degrees of contamination. Exposed Screen Profiling samplers used for groundwater profiling

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inject clean water during incremental advancement to minimize contaminant drag down and carryover and can provide accurate point source water quality sampling.

6.2.1 *Single-Tube Sealed-Screen Samplers*—An example is shown in Fig. 1(**22**). This simple arrangement allows for grab sampling through the riser pipe with minimal purging or development if there is no leakage at the screen seals and riser pipe joints. If desired, development of these devices may be conducted prior to sampling. Development of the screened intervals is required before slug testing is performed (D7242/D7242M). Fig. 2 shows a schematic of a DP water sampler with a sealed screen and with the ability to work in the grab sampling mode or by allowing water to enter a sample chamber in the sampler body (**5**). Most simple sample chambers allow for flow through the chamber. When a flow through chambered sampler is opened, it is possible that the groundwater from the test interval can fill into the rods above the chamber. In those cases, it may be advisable to add water of known chemistry into the rods prior to opening the screen. Some sealed-screen samplers have sample chambers designed to reduce volume and pressure changes in the sample to avoid possible loss of volatile compounds (**6**, **13**, **19**). The need for pressurization is dependent on the requirements of the exploration program and should be evaluated by comparison studies in the field with simpler systems allowing the sample to equalize at atmospheric pressure. There are different approaches to pressurizing the sample chamber including use of inert gas pressure or using sealed systems. An example of a sealed vial-septum system is discussed by Berzins (**6**). In the sealed vial system, a septum is punctured with a hypodermic needle connected to a sealed vial. With this approach, the vial will contain both a liquid and gas at aquifer pressure which could be problematic for volatile organic compounds.

6.2.2 *Profiling Sampler—Single Tube Exposed Screen*—Some exposed screen samplers have been developed for multiple sampling events (profiling) as an exposed screen or sample ports are advanced incrementally (Fig. 3 and Fig. 4) (**7**, **8**, **10**, **20**, **21**). These multiple event "groundwater profilers"

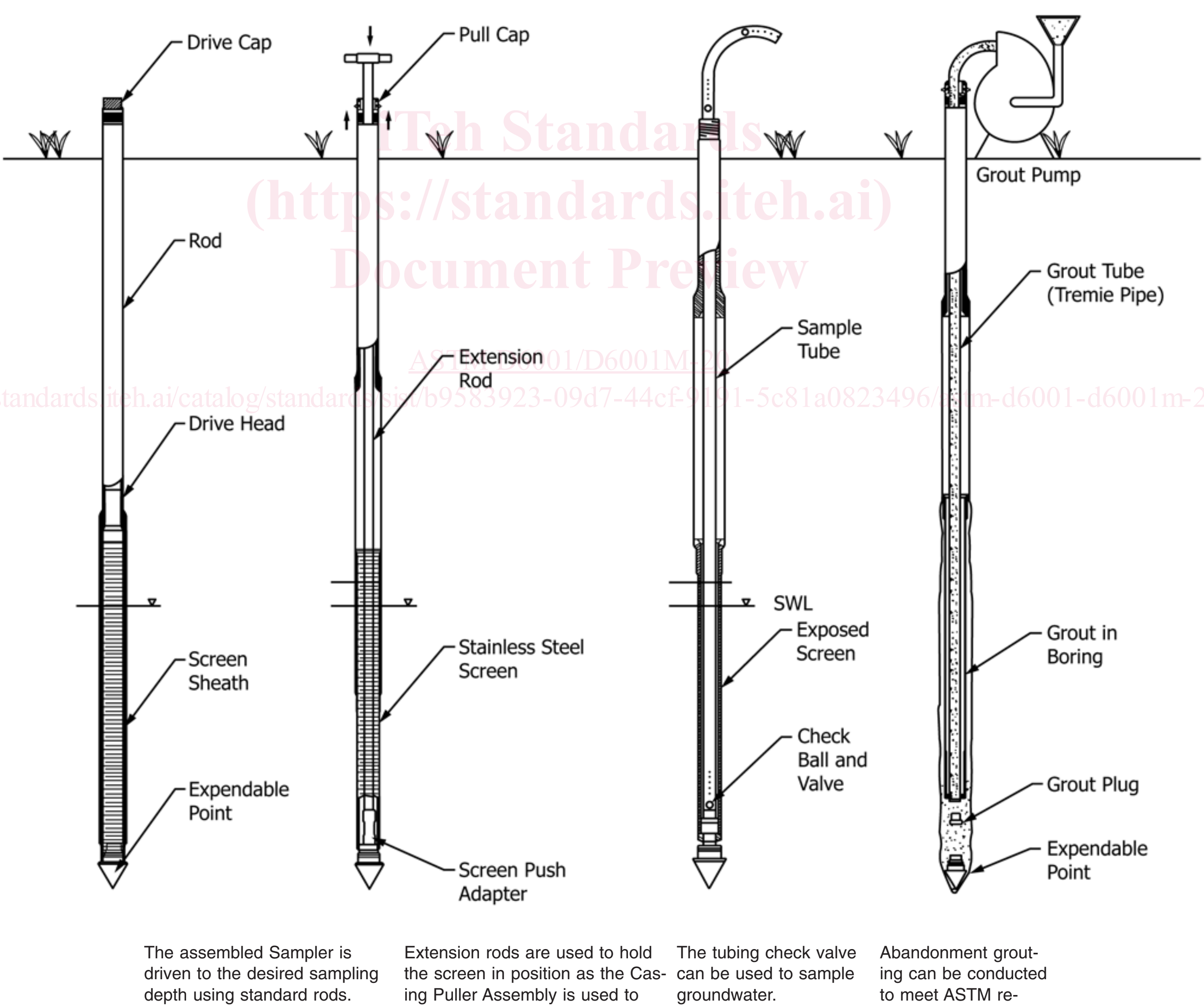
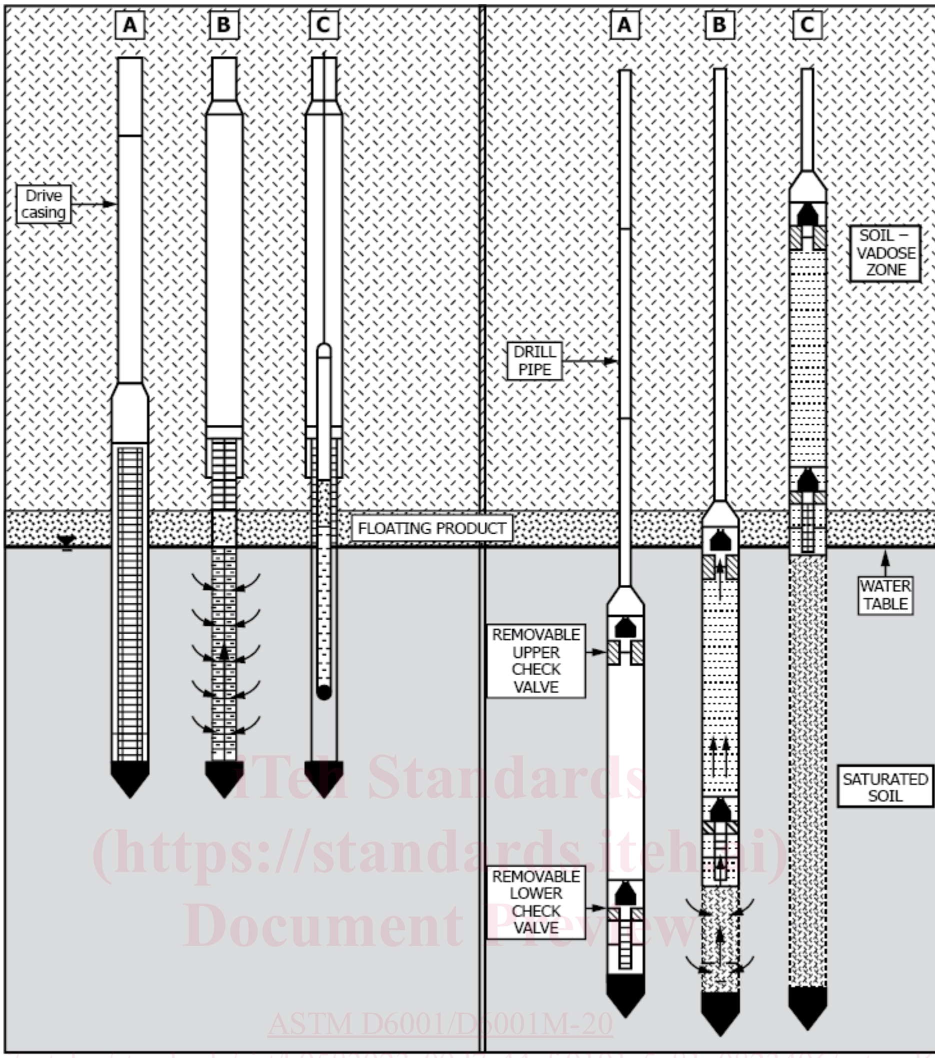


FIG. 1 Simple Sealed Screen Sampler (22)



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Legend: Grab Sampling

A Penetrometer closed while being driven into position.
B Tool opened and 5 foot screen telescopes into position for collection of hydrocarbon or water sample at the very top of the aquifer.
C Hydrocarbon sample being collected using bailer lowered through drive casing.

Legend: Water Sampling in Chamber

A Penetrometer closed while being driven into position.
B Cone separated and tool open to collect sample.
C Check valves closed as sample is retrieved within body of the tool.

FIG. 2 Sealed Screen Sampler Capable of Working in Grab or Chamber Sampling Modes (5)

inject clean water out of the ports during advancement to keep the ports from clogging. Injection flow is stopped during sampling events. Purging the pump and sampling line between sampling events minimizes the potential for contaminant carry over. Collection and analysis of rinseate samples may help document the presence of or lack of contaminant carry over as the devices are sampled at increasing depths. Some of these devices have in-line pressure sensors to measure the pressure required to inject water during advancement. Reviewing injection pressure logs during advancement can identify higher permeability (low pressure) zones for sampling and lower permeability (high pressure) zones that will not yield water for sampling. Some systems also monitor injection flow rate. The injection pressure and flow rate may be used to estimate formation permeability (Practice D8037/D8037M). Sampling can be conducted with various downhole pumps or with a peristaltic pump when the water level is sufficiently shallow.

6.2.3 *Dual-Tube Groundwater Samplers*—The Dual Tube system can be used in several modes. For the highest quality water sample with, minimal cross contamination potential, the sample can be taken as a single event using the sealed drive tip driven to the target sampling depth. The Dual Tube system can also be used for profiling but groundwater remaining in the

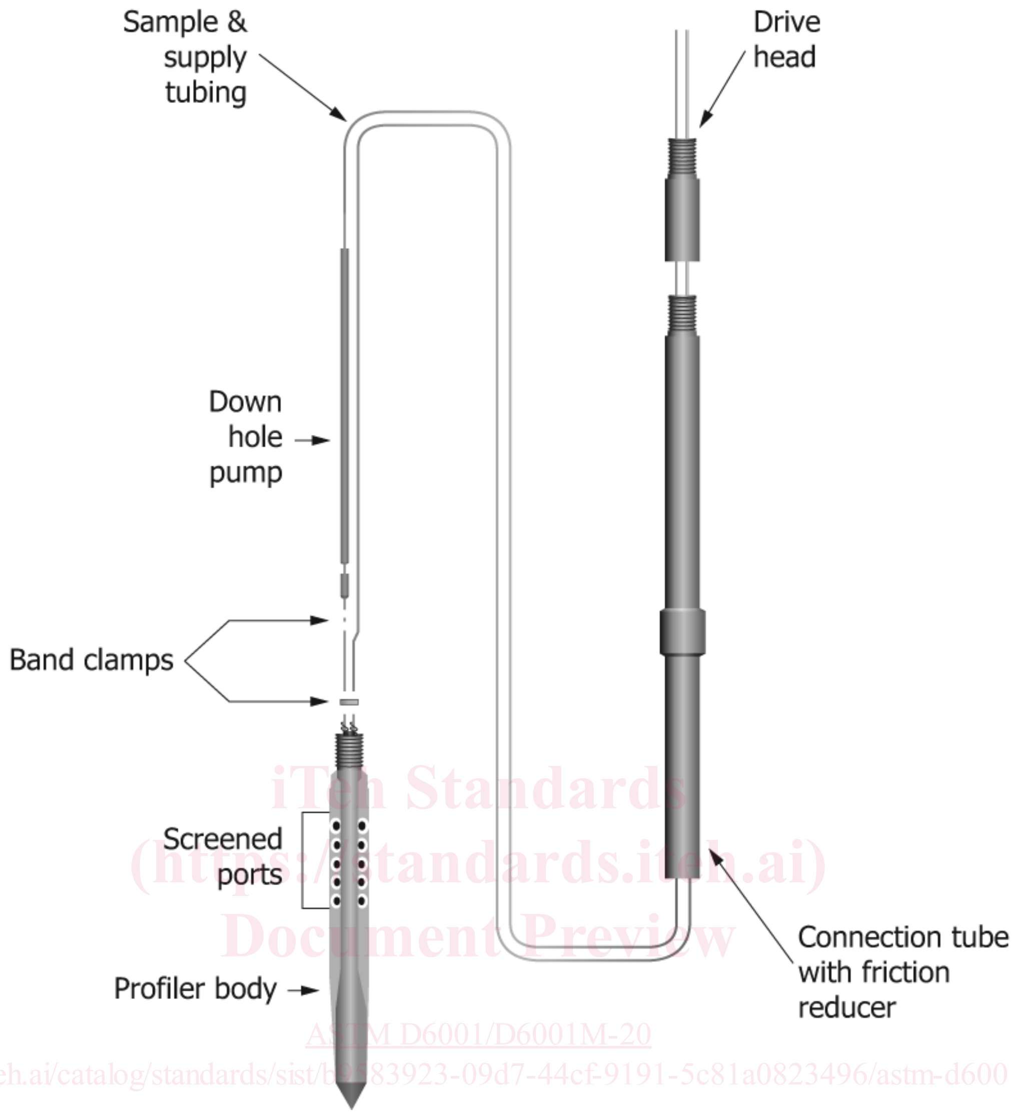

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FIG. 3 Single-Tube Groundwater Profiling Tools Typically Inject Clean Water through Screened Ports on the Device During Advancement to Prevent Clogging and Reduce the Potential for Contaminant Drag Down. Injection Flow is stopped during the purging-sampling process. Down hole pumps or peristaltic pumps may be used for sampling (20).

casing from previous events may require extensive purging prior to the sampling events.

6.2.3.1 *Sealed Sampling Single Event*—The installation of dual-tube devices is often done by advancing a sealed outer casing to the desired depth interval equipped with an expendable point (Fig. 5) **(23)**. When at the desired depth a screen with riser pipe is lowered to the base of the outer casing. The outer casing is then retracted to expose the screen to the formation for development, sampling, and slug testing if desired. The tool string is then removed and decontaminated for advancement at the next location or depth.

6.2.3.2 *Multiple Sampling Events*—Dual tube systems allow for continuous soil coring as the tool string is advanced. When at the desired depth(s) a screen may be installed after the soil core is removed (Fig. 6). Then the casing is retracted to deploy the screen. This sequence may be repeated to conduct groundwater profiling. Alternately, the outer casing may be advanced to the initial sampling depth with an inner drive rod holding a retrievable point in the shoe. Once at the desired depth, the inner drive rod and point are removed, and the screen and riser pipe are inserted down the outer casing. The outer casing is retracted to set the screen in the formation for development, sampling and slug testing, as desired. Once sampling and testing at the first interval is completed the screen and riser pipe are retrieved for decontamination. The inner drive rod and point are re-installed, and the dual tube system is advanced to the next depth interval. The process is repeated at multiple depths for groundwater profiling and multi-level slug testing. The problem with multiple sampling events can be residual groundwater in the dual tube casing from upper test zones. For water sampling this could cross contaminate deeper samples. Sample quality must be evaluated by the user. If cross contamination is suspected, then it may be required to go back and target intervals for discrete sealed screen samplers or just consider data as screening level for detection of hot spots. In unstable formations (heaving sands, etc.) it is necessary to add

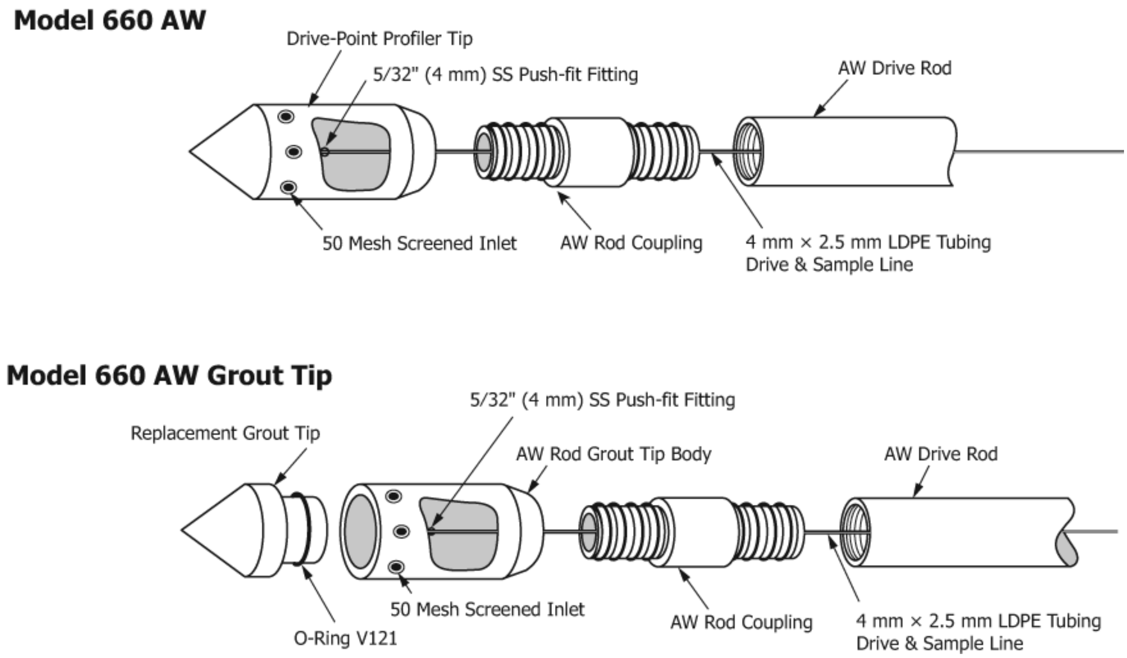

FIG. 4 Drive Point Profiler and Profiler Showing Expendable Grout Tip Option (Solinst, (21))

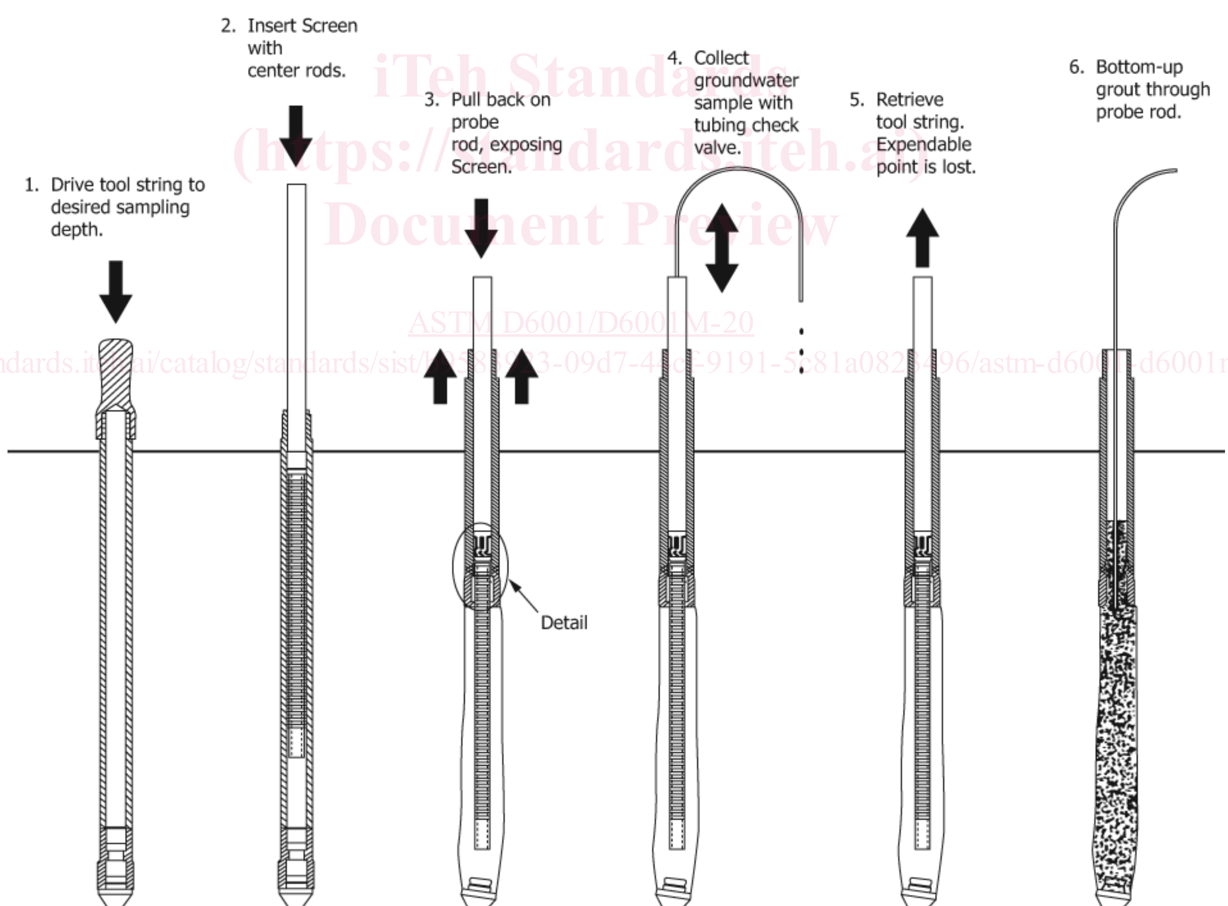

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FIG. 5 Dual Tube Groundwater Sampling Operation Modes—Operation as an Expendable Point Single Depth Sampler (23)

clean water to the outer casing as the inner rod and drive point or screen and riser pipe are removed to prevent formation heave into the outer casing. This may slow progress and additional purging may be advised to achieve stabilized water quality parameters before sampling is performed at each interval.

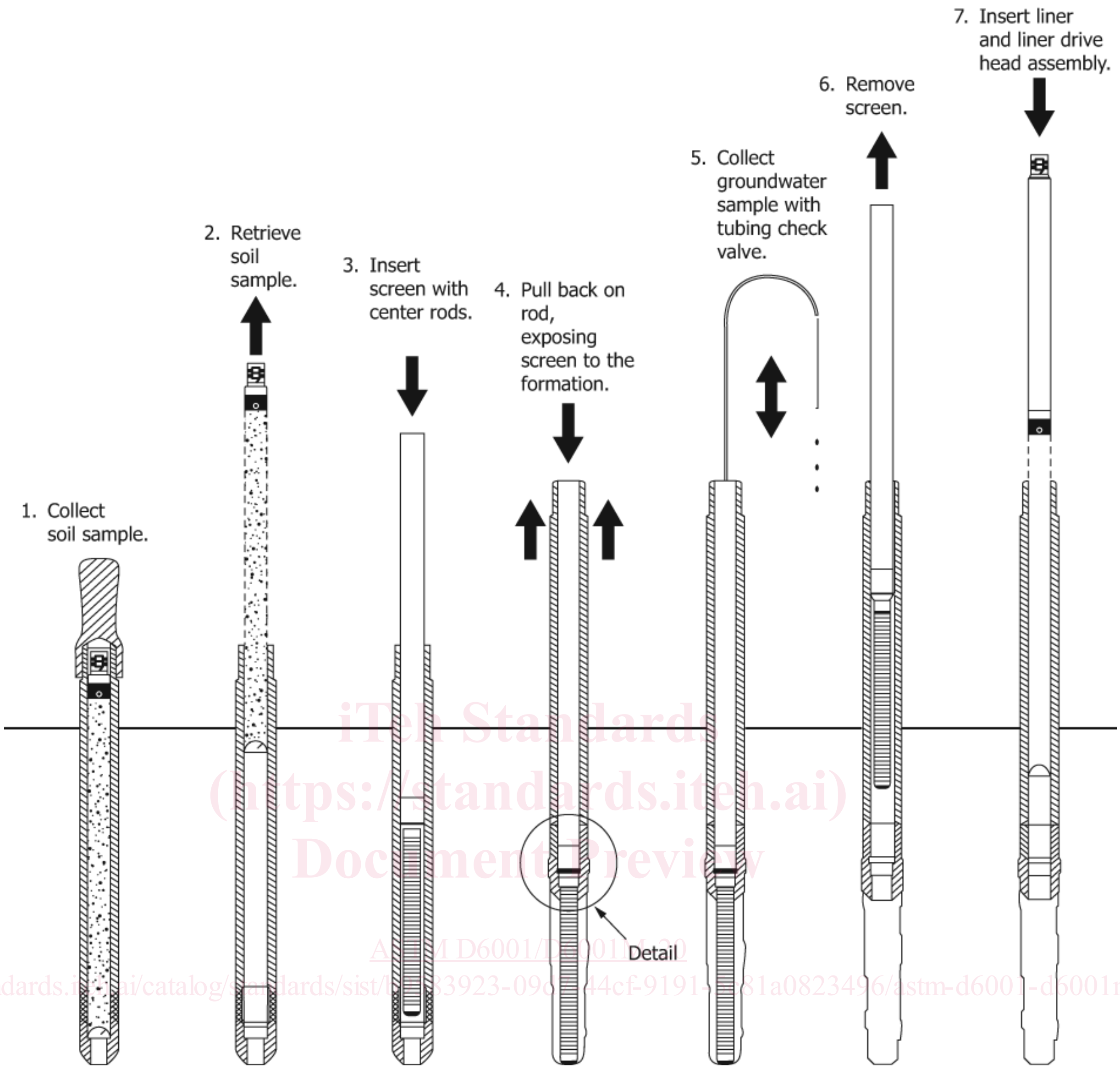

FIG. 6 Dual Tube Groundwater Sampling Operation Modes, Operating as a Dual Tube Combination Soil and Groundwater Sampler with Profiling Capabilities. A solid drive point may be substituted for the sample tube during advancement to close off the cutting shoe if no soil coring is needed (23)

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6.2.4 *Cone Penetrometer with Exposed Sampling Ports*—Another form of an exposed-screen sampler has been incorporated into cone penetrometer bodies **(24)**. The cone penetrometers have sample chambers with measurement devices such as temperature and conductivity. Some cone penetrometers have been equipped with pumps for drawing in water samples into sample chambers or to the surface. Samplers equipped with chambers and subjected to multiple sampling events may require purging between sampling events.

6.2.5 *Simple Exposed Screen Sampler*—A simple exposed screen sampler inserted through a drill or drive casing is shown on Fig. 7. In this case the drive rod is sealed at the drive point and allows the exposed screen sampler to be placed in the desired sampling interval. If exposed-screen well points are pushed through predrilled, cased holes, the screen and riser may fill with water present in the borehole and require purging before sampling.

6.2.5.1 *Temporary wells or T wells*—The practice of inserting exposed screen slotted PVC pipe in an open hole after drilling (Guide D6286/D6286M) or direct push testing is sometimes performed on worksites in dry holes and are left overnight for estimating groundwater levels and even chemical testing. In this case, the hole is open to the surface and unsealed to the surface for a long time period. Groundwater may come in from different zones intersected by the borehole. Water level may not be stabilized unless monitored and may not reflect the true groundwater level conditions. Groundwater chemistry may be adversely affected by exposure to air causing oxidation/reduction effects and loss of volatile compounds. Any results from these type of water samples may be representative, but should be considered questionable and used for screening purposes only. If chemical contamination is detected, reliable values of concentrations should be obtained by sealed screen samplers or properly installed and sampled wells (Practice