Standard Practice for Direct Push Installation of Prepacked Screen Monitoring Wells in Unconsolidated Aquifers[1]

This standard is issued under the fixed designation D 6725; 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 is based on recognized methods by which direct push monitoring wells may be designed and installed for the purpose of detecting the presence or absence of a contaminant, and collecting representative ground water quality data. The design standards and installation procedures herein are applicable to both detection and assessment monitoring programs for facilities.

1.2 The recommended monitoring well design, as presented in this practice, is based on the assumption that the objective of the program is to obtain representative ground water information and water quality samples from aquifers. Monitoring wells constructed following this practice should produce relatively turbidity-free samples for granular aquifer materials ranging from gravels to silty sand. Strata having grain sizes smaller than the recommended design for the smallest diameter filter pack materials should be monitored by alternative monitoring well designs which are not addressed in this practice.

1.3 Direct push procedures are not applicable for monitoring well installation under all geologic and soil conditions (for example, installation in bedrock). Other rotary drilling procedures are available for penetration of these consolidated materials for well construction purposes (Guide D 5092). Additionally, under some geologic conditions it may be appropriate to install monitoring wells without a filter pack (EPA 1991). Guide D 724 may be referred to for additional information on these and other methods for the direct push installation of ground water monitoring wells.

1.4 The values stated in inch-pound units are to be regarded as standard. The values in parentheses are for information only.

1.5 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

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 judgement. Not all aspects of this 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 consideration of the 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:*

D 1452 Practice for Soil Investigation and Sampling by Auger Borings[2]

D 1587 Practice for Thin-Walled Tube Sampling of Soils for Geotechnical Purposes[2]

D 2488 Practice for Description and Identification of Soils Visual-Manual Procedure[2]

D 3694 Practice for Preparation of Sample Containers and for Preservation of Organic Constituents[3]

D 4043 Guide for Selection of Aquifer-Test Method in Determining of Hydraulic Properties by Well Techniques[2]

D 4044 Test Method for (Field Procedure) for Instantaneous Change in Head (Slug Tests) for Determining Hydraulic Properties of Aquifers[2]

D 4104 Test Method for (Analytical Procedure) for Determining Transmissivity of Nonleakey confined aquifers by Over-damped Well Response to Instantaneous Change in Head (Slug Test)[2]

D 4448 Guide for Sampling Ground Water Monitoring Wells[4]

D 4700 Guide for Soil Sampling from the Vadose Zone[2]

D 5088 Practice for Decontamination of Field Equipment Used at Nonradioactive Waste Sites[2]

D 5092 Practice for Design and Installation of Ground Water Monitoring Wells in Aquifers[2]

D 5314 Guide for Soil Gas Monitoring in the Vadose Zone[2]

D 5521 Practice for Development of Ground-Water Monitoring Wells in Granular Aquifers[2]

D 5778 Test Method for Performing Electronic Friction Cone and Piezocone Penetration Testing of Soils[2]

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[1] This practice is under the jurisdiction of ASTM Committee D18 on Soil and Rock and is the direct responsibility of Subcommittee D18.21 on Ground Water.

Current edition approved Nov. 10, 2001. Published January 2002.

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

[3] *Annual Book of ASTM Standards*, Vol 11.07.

[4] *Annual Book of ASTM Standards*, Vol 11.04.

D 5781 Guide for Use of Dual-Wall Reverse-Circulation Drilling for Geoenvironmental Exploration and the Installation of Subsurface Water-Quality Monitoring Devices[5]

D 5782 Guide for Use of Direct Air-Rotary Drilling for Geoenvironmental Exploration and the Installation of Subsurface Water-Quality Monitoring Devices[5]

D 5783 Guide for Use of Direct Rotary Drilling with Water Based Drilling Fluid for Geoenvironmental Exploration and the Installation of Subsurface Water-Quality Monitoring Devices[5]

D 5784 Guide for Use of Hollow-Stem Augers for Geoenvironmental Exploration and the Installation of Subsurface Water-Quality Monitoring Devices[5]

D 5785 Test Method for (Analytical Procedure) for Determining Transmissivity of Confined Nonleakey Aquifers by Underdamped Well Response to Instantaneous Change in Head (Slug Test)[5]

D 5786 Practice for (Field Procedure) for Constant Drawdown Tests in Flowing Wells for Determining Hydraulic Properties of Aquifer Systems[5]

D 5787 Practice for Monitoring Well Protection[5]

D 5881 Test Method for (Analytical Procedure) Determining Transmissivity of Confined Nonleakey Aquifers by Critically Damped Well Response to Instantaneous Change in Head (Slug)[5]

D 5912 Test Method for (Analytical Procedure) Determining Hydraulic Conductivity of an Unconfined Aquifer by Overdamped Well Response to Instantaneous Change in Head (Slug)[5]

D 6001 Guide for Direct-Push Water Sampling for Geoenvironmental Investigations[5]

D 6282 Guide for Direct Push Soil Sampling for Environmental Site Characterizations[5]

D 6285 Guide for Locating Abandoned Wells[5]

D 6634 Guide for Selection of Purging and Sampling Equipment for Ground Water Monitoring Wells[5]

D 6724 Guide for Installation of Direct Push Monitoring Wells

3. Terminology

3.1 *Definitions*—Refer to ASTM D 653 for definitions of terminology.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *prepacked screen*—a manufactured well screen that is assembled with a slotted inner casing and an external filter media support. The external filter media support may be constructed of a stainless steel wire mesh screen or slotted PVC that retains filter media in place against the inner screen. The filter media is usually composed of graded silica sand.

3.2.2 *tremie pipe or tube*—a pipe or tube that is used to transport filter pack materials and/or annular sealant materials from the ground surface into the borehole annulus or between casings and casings or riser pipe of a monitoring well.

4. Summary of Practice

4.1 This practice provides information for installing a prepacked screen monitoring well using direct push techniques. When constructed following this Standard Practice the direct push installed monitoring wells can meet most state regulations and federal guidelines (EPA 1986, 1991, 1992) for well construction (Fig. 1) and protection of the aquifer and ground water resources.

4.2 Initially the outer casing (or probe rod) is advanced to depth using direct push methods. The monitoring well is constructed inside the casing with prepacked well screens and riser pipe. The casing is retracted to set the well at the desired depth in the formation. Bottom up tremie installation of the annular seal and grout is conducted through the outer casing as it is retracted. This grouting method is required to obtain the highest integrity well construction. Commonly available types of above ground or flush mount well protection are installed to physically protect the well and prevent tampering. The small diameter wells may be developed using bailers, peristalic pumps, bladder pumps or an inertial check valve system. The inertial check valve and tubing system is especially effective when used for development in medium to coarse-grained aquifers. This development method simultaneously surges and purges fines from the screen interval. Slug testing of the wells can be conducted to determine local aquifer properties and verify that development has been successful. Low flow and other sampling techniques may be used to obtain representative water quality samples. Clear and accurate documentation of the well construction is required.

5. Significance and Use

5.1 This practice is intended to provide the user with information on the appropriate methods and procedures for installing prepacked screen monitoring wells by direct push methods. The monitoring wells may be used to obtain representative water quality samples for aqueous phase contaminants or other analytes of interest, either organic or inorganic (Kram et al. 2000, McCall 2000, McCall et al. 1997). The monitoring wells may also be used to obtain information on the potentiometric surface of the local aquifer and properties of the formation such as hydraulic conductivity or transmissivity.

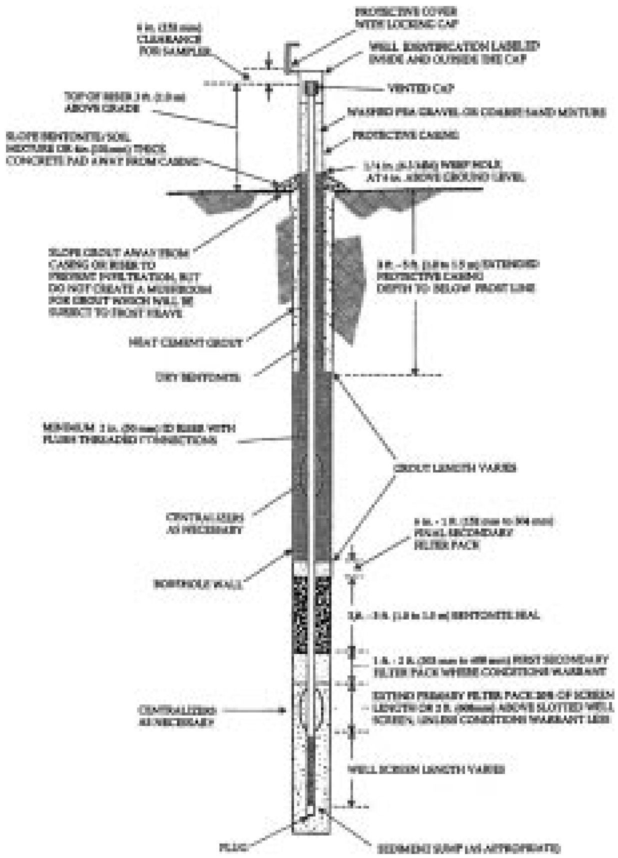
5.2 Use of direct push methods to install monitoring wells can significantly reduce the amount of potentially hazardous drill cuttings generated during well installation at contaminated sites. This may significantly reduce cost of an environmental site investigation and ground water monitoring program. Minimizing generation of hazardous waste also reduces the exposure hazards to site workers, local residents, and the environment.

5.3 Direct push methods for monitoring well installation are limited to use in unconsolidated formations such as alluvial/stream sediments, glacial deposits, and beach type sediments. Direct push methods are generally successful at penetrating clays, silts, sands and some gravel. Deposits such as soils with thick caliche layers, or glacial tills with large cobbles or boulders may be difficult or impossible to penetrate to the desired depth. Direct push methods are not designed for penetration of consolidated bedrock such as limestone, granite or gneiss.

6. Site Characterization and Well Placement

6.1 *Characterization*—Understanding the project goals as

[5] *Annual Book of ASTM Standards*, Vol 04.09.



NOTE 1—This well design is consistent with most state regulatory requirements promulgated prior to development of direct push techniques (after Practice D 5092)

FIG. 1 Specifications for Conventional Monitoring Wells Installed with Rotary Drilling Methods.

well as the subsurface geology, hydrogeology, and contaminant distribution at a site is necessary before installation of monitoring wells can be completed successfully. Steps in a site characterization program may include investigating site history, literature search, site reconnaissance, and field investigation and sampling efforts. The field investigation may include completion of borings to collect soil and ground water samples and to determine the ground water flow direction. Geophysical methods may also be applied to obtain an understanding of the subsurface geology. Several ASTM standards are available for use in conducting the site characterization and sampling efforts; these include Guide D 6001, Guide D 6282, Practice D 5088, Standard Test Method D 5778, Standard Test Method D 4044, Practice D 1452, Test Method D 1586, Practice D 1587, Practice D 2488, Practice D 3694, Guide D 4448, Guide D 4700, Method D 4750, and Guide D 5314. Other important sources of information include state and local agencies having responsibilities for ground water protection and regulation. A list of state geological surveys are included in Guide D 6285Depending on site conditions, when direct push methods are used for site characterization (for example, D 6001 and D 6282) it may be possible to complete the site characterization and monitoring well installation activities in one mobilization. Practice D 5092 provides further details on site characterization necessary for successful installation of monitoring wells and development of a site conceptual model.

6.2 *Well Placement*—The well location, depth and length of screen interval should be based on project requirements, information obtained during the site characterization activities and background research. In general at least one well is placed at a depth and location considered to represent undisturbed background water quality conditions. The length and depth of the screened interval for the background well(s) should reflect those of the wells installed hydraulically down gradient of the site. Information obtained during site characterization regarding local hydrogeology, water level(s), contaminant distribution, and ground water flow direction should be used to determine appropriate well placement. If multiple aquifers separated by aquitards are present beneath the site monitoring wells with screened intervals at multiple depths may be required at each location. The purpose for installation should be considered in selecting the locations of the monitoring wells. Purposes may include detection monitoring, long term monitoring, or data collection to determine the presence, extent, and concentrations of potential contaminants. Guidance on selection of well locations, screen lengths and intervals are found m several references, some of which are: EPA 1986, 1991, 1992, 1998, Nielsen 1991, Fetter 1994, and USGS 1997.

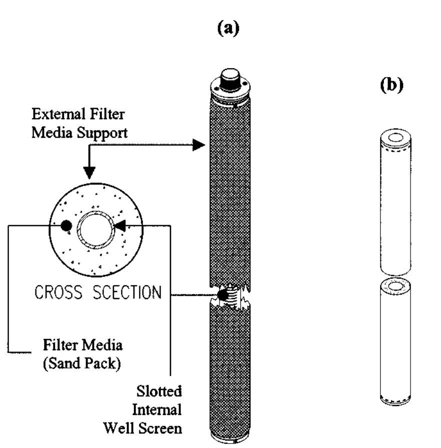
7. Monitoring Well Construction Materials

7.1 *General*—The materials that are used in the construction of a prepacked screen monitoring well should not measurably alter the chemistry of the ground water sample(s) to be collected when appropriate sample collection methods are used. Ideally, PVC should not be used when monitoring for neat organic solvents that are PVC solvents (Parker 1992). While conventional steel materials (for example, carbon steel or galvanized steel) are not suitable for use under most ground water monitoring conditions stainless steel has been found to perform well in most corrosive environments, particularly under oxidizing conditions (EPA 1991). In most cases Type 304 stainless steel will perform satisfactorily for many years (Driscoll 1986). Under highly corrosive and reducing conditions Type 316 stainless steel will perform better than Type 304 stainless steel (EPA 1991). The prepacked screens and well casing used in the well construction should be delivered from the manufacturer to the field site in a clean state sealed in protective wrapping. Any other equipment used in the well construction process (e.g. casing, measuring tapes, grout hoses, other down hole tools) that could impact the resultant water quality should be cleaned and decontaminated following appropriate methods (Practice D 5088) prior to use in the well installation. Additional guidance and information on well construction practices can be obtained from Practice D 5092, EPA 1986, 1991, 1992, Nielsen 1991, and USGS 1997. Always verify compliance with state and local regulations by contacting the appropriate agency or agencies.

7.2 *Water*—In general, little water is used in the construction of direct push installed prepacked screen wells other than in preparation of annular seal and grout mixtures. However, there are situations that may require addition of water to the well or borehole during installation. One of the most common situations that may require addition of water is under drilling conditions where formation blow-in may occur. Under these conditions (most often saturated sands) water must be added to the boring to prevent blow-in and assure that the well is properly installed at the desired depth. When water is used in the well installation and construction process (to prevent blow-in, or mix grout) water of known quality must be used to assure that the sample integrity will not be compromised. The volume of water added to each well must be documented.

7.3 *Prepacked Screen*—There are three primary components of the prepacked well screen (Fig. 2). These are the internal well screen, the external filter media support, and the contained filter media (sand pack). Some prepack screens are assembled with the internal PVC screen as an integral part of the assembly (Fig. 2a). Alternatively, some prepack screens are available as sleeves or jackets (Fig. 2b) that may be installed over factory available casing. The components used in construction of the prepacked well screen must not adversely affect the ground water quality so that representative samples may be acquired. Subsurface conditions, including but not limited to site geology, geohydrology, ground water chemistry, and the analytes to be monitored must be considered to assure that the prepacked well screens are compatible with the system to be monitored. A sump may be attached to the base of the screen to capture any fines entering the well. The bottom of the screen or sump must be sealed with a plug constructed of compatible material. The prepacked well screen must be of sufficient strength to withstand the forces and stress of installation and development without being damaged or otherwise compromised. Some of the prepacked well screens are packed with filter media by the manufacturer. Other prepacked screens are shipped without filter media and are packed in the field with acceptable filter media materials just prior to installation.

7.3.1 *Internal Well Screen*—The most common material used for construction of this component is polyvinyl chloride (PVC). Other materials (for example, stainless steel or fluoropolymers) may be used where and when appropriate. Routinely used internal well screen diameters include nominal 0.5-inch, 0.75-inch, and 1.0-in. PVC. For optimum performance of the well the screen slot size should be determined relative to the grain size analysis of the stratum to be monitored and the gradation of the filter pack material. For further details on the selection of screen slot size refer to Practice D 5092.



NOTE 1—The internal well screen is usually constructed of Schedule 40 or 80 PVC (a) with a factory cut 0.010 in. slots while some are available with 0.25 slots. The external filter media support is usually constructed with stainless steel wire cloth with pore size of approximately 0.011 in. and graded silica sand or equivalent material is used for the filter media. Some prepacked screens are available as sleeves or jackets (b) that slide over factory available slotted PVC.

FIG. 2 Typical Prepacked Well Screens.

The most widely available slot size is 0.010-in. in the prepacked well screens. The slot size used for the internal well screen should retain at least 90 % of the filter media.

7.3.2 *External Filter Media Support*—The purpose of the external filter media support is two fold. The primary purpose is to retain the filter media around the internal well screen as the screen is being placed in the boring. Additionally the external filter media support assures accurate and complete placement of the filter pack media in the desired screen interval. Emplacement of the filter media in this fashion eliminates problems with formation collapse against bare screen or bridging and creation of voids around the bare screen as when gravity installation of the filter media is conducted. One of the most common materials used for construction of this screen component is a stainless steel wire mesh. Slotted PVC, fluoropolymers or other compatible materials may be used for construction of this screen component when and where appropriate. The external diameter of the prepacked screen ranges from about 1.4- to 3.0-in., depending on the inner well screen diameter and the inside diameter of the probe rods used to advance the boring.

7.3.3 *Filter Media*—The filter media or gravel pack most commonly consists of uniformly graded siliceous particles washed and screened to have the appropriate particle size distribution. Refer to Practice D 5092 for details on the selection of appropriate grain size distribution for the filter media. One of the most widely used grain size distributions for prepacked screen well filter media is 20-40 grade silica sand.

7.3.4 *Sump*—The sump is usually constructed of a length of well casing material ranging from a few inches in length to several feet in length depending on the well design and formation characteristics. It is attached to the base of the well screen and is plugged at the bottom. The sump provides a space for fine sediments entering the well to settle without obstructing a portion of the screen interval and interfering with recharge or sampling activities. The sump also allows for the collection of dense nonaqueous phase fluids (DNAPLs) at locations where they are present.

7.4 *Casing or Riser*—The well casing should be made of clean, new materials that will not alter the quality of the water samples being collected. Most casing or riser is made of PVC but other materials (for example, stainless steel, fluoropolymers, etc.) may be appropriate in some situations. The inside diameter and wall thickness of the casing should match that of the internal well screen of the prepacked well. Threaded and flush jointed casing fitted with o-rings of appropriate material are generally recommended for the casing. Glued or solvent welded joints are not recommended as the glues and solvents generally contain hazardous chemicals that can cause contamination of the ground water to be sampled. The casing and casing joints must be of sufficient strength to withstand the forces of installation and development. Further information on the selection of appropriate casing materials can be found in Practice D 5092, EPA 1986, 1991 and 1992, Nielsen 1991, Ranney and Parker 1997, 1998a, 1998b, and USGS 1997.

7.5 *Grout Barrier*—The grout barrier serves to prevent the annular sealants from entering into the screen interval resulting in the alteration of the water chemistry, because common annular sealants and grouts (e.g. bentonite and Portland cement) can have a significant impact on the local ground water chemistry a grout barrier is emplaced immediately above the screened interval. The grout barrier may be constructed by gravity or tremie installation of fine sand or by installation of a mechanical or modular barrier.

7.5.1 *Gravity or Tremie Installation*—The grout barrier may be constructed with silica sand having the same or finer gradation than the materials used in the filter media. When the filter media is course-grained use of a finer grained grout barrier is recommended. The grout barrier usually extends one to two feet above the top of the screened interval. The granular material used for the grout barrier may be poured through the annular space in the well for installation (Fig. 9) or placed through a tremie tube if conditions permit.

NOTE 1—Slowly add the barrier material to prevent bridging and to allow time for the material to settle through the water column.

7.5.2 *Modular Barriers*—Some direct push well systems offer the option of installing a modular grout barrier (Fig. 10). This modular barrier is assembled with the screen and casing and lowered into the well annulus. When the outer casing is retracted this modular barrier expands and creates a seal above the prepacked screen. These modular barriers are constructed with polyurethane foam covered with a polyethylene sleeve. These modular barriers are not recommended for use below the water table because of potential for absorption and desorption of some contaminants.

7.6 *Annular Seal and Grout*—The annular seal and grout are prepared of materials that will eliminate or at least minimize the potential for surface or up-hole water (or fluids) from moving down the well annulus. This is important because these fluids could significantly alter the water quality or cause cross contamination in the zone being monitored.

7.6.1 *Annular Seal*—State regulations may recommend the use of sodium bentonite in construction of the annular seal immediately above the grout barrier. However, different sealants may be required when subsurface geology, chemistry of the ground water, or high concentrations of contaminants are present. When present in high concentrations, some organic

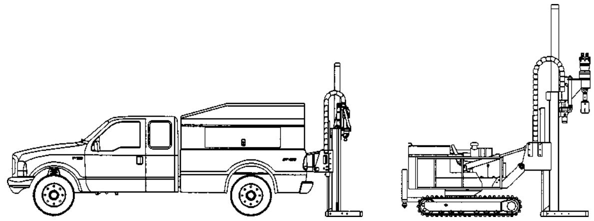


FIG. 3 Typical percussion type direct push units are often mounted in conventional pick-up trucks or more rugged track vehicles for access to difficult locations. Some percussion-type units, such as the track unit shown here, are fitted with optional auger heads.

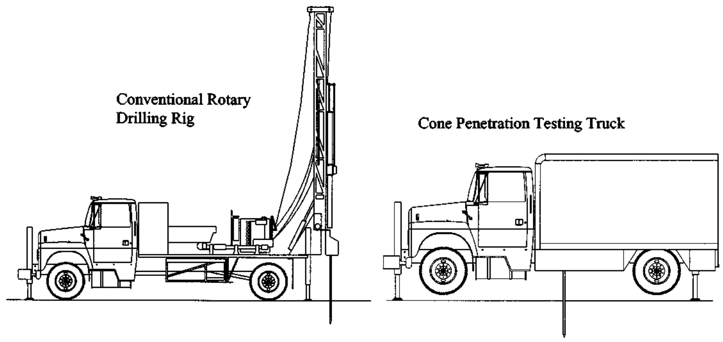
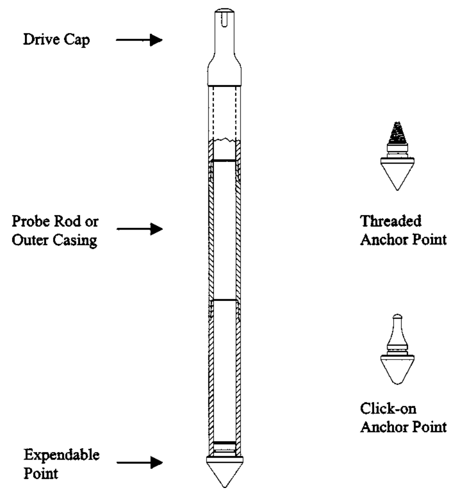


FIG. 4 Hydraulics and SPT hammers on rotary drilling rigs may be used to advance direct push tools under some conditions. CPT units may weigh from 15 to 30 tons. These vehicles have been used to install monitoring wells by direct push methods at many locations.



NOTE 1—Some prepack well systems are available with expendable anchor points with either a thread or click on mechanism to anchor the screens in position.

FIG. 5 Advanced Direct Push Casing (or probe rod) to Depth with an Expendable Point to Prepare for Installation of a Prepacked Screen Monitoring Well.

contaminants can cause desiccation and cracking of bentonite seals resulting in cross contamination of the well and potential migration of contaminants to a previously clean aquifer. Efforts should be taken in the site characterization program to determine if these conditions may exist at the site. Annular seals may be installed by gravity or tremie methods and modular seals are available for some prepacked well systems.

7.6.1.1 *Gravity and Tremie Installations*—Bentonite chips, granules, or pellets may be used to construct the annular seal when the field conditions and size of the well annulus permit. Gravity or tremie installation of these dry bentonite materials is most successful when the top of well screen is at or near the water table. Use of a small diameter tremie tube and grout pump with bentonite slurries may provide the most reliable method of placing the annular seal (Fig. 11). Bentonite slurries ranging from 20 to 30 % solids by weight may be required by state or local regulations. Check the state and local regulations to verily compliance. A side port tremie tube may be used to minimize the jetting of the slurry into the grout barrier.

7.6.1.2 *Modular Seals*—These seals are constructed with paper sleeves containing bentonite attached to a segment of blank casing. This modular seal (Fig. 10) is placed above the grout barrier (modular) and prepacked screens to provide an annular seal.

7.6.2 *Grout*—There are two primary types of grout slurry used in monitoring well construction. These are bentonite grouts and cement grouts. The grout slurries should be mixed until smooth to prevent clogging of the tremie tube. State and local regulations for grout compositions and density vary considerably and these regulations should be reviewed to assure compliance. Additional information on grouting requirements is provided in Practice D 5092 and EPA 1991.

7.6.2.1 *Bentonite Grout*—Some bentonite powders contain additives to accelerate the gelling of the slurry and increase viscosity. For the smaller diameter direct push installed monitoring wells where a small well annulus may require the use of small diameter tremie tubes these additives may cause clogging of the tremie tube. The use of bentonite powders (200 mesh) without additives is commonly used for grout when small diameter tremie tubes are required. In general bentonite slurry densities of 20 to 30 % solids by weight are required by regulation. A 20 % solids by weight bentonite slurry may be prepared by adding 2.1 pounds of bentonite powder to one gallon of clean water. Bentonite grouts are recommended for

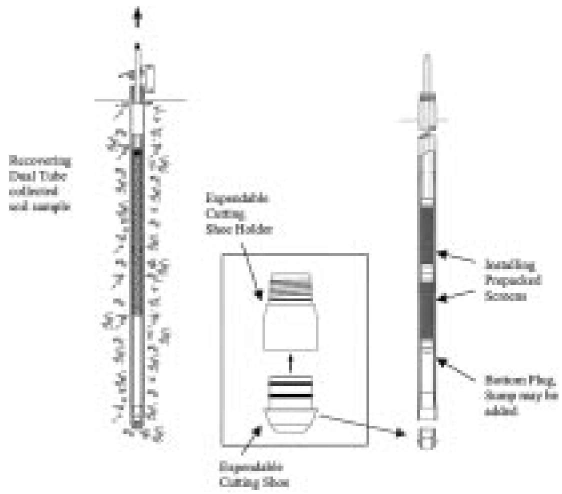
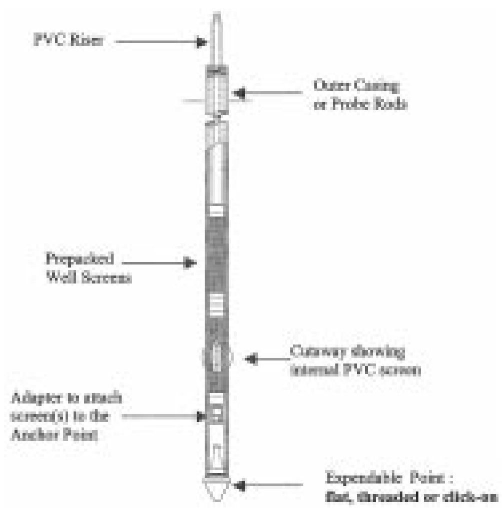


FIG. 6 When an expendable cutting shoe is used during dual tube soil sampling prepacked screens may be installed after sampling is completed. In saturated noncohesive formation (sands) it may be necessary to add water to the probe rods to prevent blow-in during sample collection activities.



NOTE 1—A simple plug may be added to the base of the well screens and a sump may be used. A special adapter may be used if the screens are attached to an expendable anchor point. Some threaded anchor points make it possible to thread the PVC screen directly to the point.

FIG. 7 Lowering Assembled Prepacked Screens Through the Casing as PVC Riser is Added to the Well Assembly.

use only in the saturated zone as dessication may occur in the unsaturated zone compromising the integrity of the seal. Additional information on grout mixtures is provided in Practice D 5092 and state regulations should be consulted.

7.6.2.2 *Cement Grout*—Cements containing additives to accelerate the setting process are not recommended for use in grouting. These additives may prematurely cause thickening of the slurry and result in clogging of the tremie tube used for bottom up installation. Additionally, these additives may leach from the grout and alter the local water chemistry. In most cases neat cement should be used for grouting. Cement grout is typically mixed by adding one 94-pound bag of Type I Portland cement to 6 to 7 gallons of clean water, check state and local regulations to verify compliance. When small diameter tremie tubes are required it is best to use fresh cement so that lumps of hardened cement will not clog the tremie tube. Additional information on grout mixtures is provided in Practice D 5092 and state regulations should be consulted.

7.7 *Well Protection*—There are two primary types of well protection commonly used for monitoring wells, these are above-ground and flush mount well protectors. The above ground protector is used in locations where vehicular traffic is not a concern. The above ground protection is also more widely approved because of its ability to eliminate or at least minimize the potential for surface runoff to enter the well head and thus contaminate the local aquifer. Flush mount well protection is used in areas where vehicular traffic is a concern. Most states require a regulatory variance for use of this well protection design because of the increase in potential for cross contamination of the local aquifer by infiltration from surface runoff waters or chemical spills. Check local and state regulations before using flush mount protection and obtain the necessary variance(s) where needed. Further specifications on well protection are available in Practice D 5787.

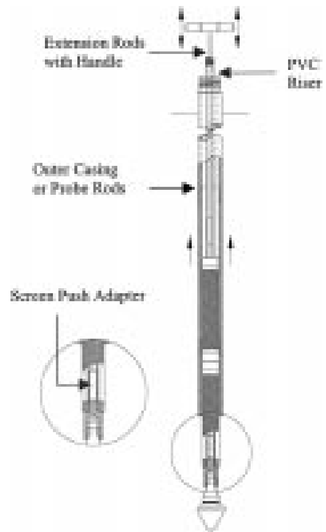


FIG. 8 Small diameter extension rods equipped with an adapter may be used to free the prepacked screens if they become lodged inside the casing. Care must be used to prevent damage to the well.

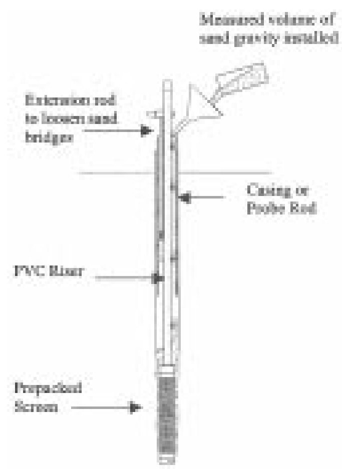


FIG. 9 One method to construct the grout barrier is by pouring medium to fine grained sand through the casing annulus. If any bridging occurs an extension rod or jetting with water may be used to re-open the well annulus.

8. Direct Push Methods

8.1 *General*—There are three basic methods for advancing direct push tools into the subsurface. Traditionally, cone penetration testing (CPT) equipment has used the static weight of the vehicle (15 to 30 tons), sometimes coupled with anchors, to advance tools down hole. Smaller and lighter weight direct push vehicles rely on percussion methods together with vehicle weight to advance tools. Another method for advancing tools or casing into the subsurface is sonic or resonance drilling. This method uses high frequency percussion combined with rotary action to advance tools and casing into the subsurface. A review of the local geologic conditions and any available records of previous sampling by direct push or rotary drilling methods should be conducted prior to mobilization to determine which direct push method should be applied for well installation at the site under consideration. If site specific conditions are not amenable to direct push methods other rotary drilling methods (D 5781, D 5782, D 5783, D 5784, D 5785, D 5786) may be reviewed for potential use.

8.1.1 *Percussion Methods*—Advancement of tools or casing into the subsurface with percussion methods can be completed with hydraulic, pneumatic and mechanically operated hammers. These hammers are used in conjunction with hydraulic slides and vehicle weight to advance tools. Typical DP units may be mounted in trucks or other vehicles (Fig. 3) to facilitate site access. The percussion procedures are some of the most widely used direct push methods. These methods are generally capable of penetrating clays, silts, sands, and some gravel as commonly encountered in alluvial and glacial deposits. Monitoring wells are routinely installed at depths of 20 feet to 50 feet with percussion methods, and may be installed at depths exceeding 100 feet in amenable geologic conditions. Densely packed glacial deposits, deposits with cobbles or boulders, or thick zones of caliche may make penetration with percussion methods difficult or impossible. Some percussion-type direct push units are also equipped with rotary drilling capabilities. These capabilities make it possible for direct push methods to be used where a significant gravel, cobble, or caliche layer may have previously limited their use.

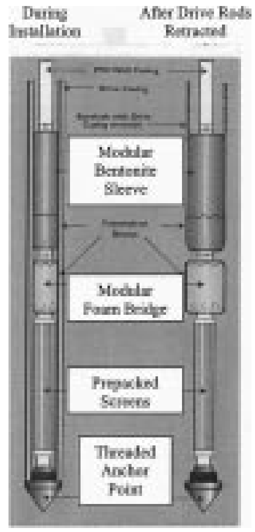


FIG. 10 Some direct push prepacked well systems use modular grout barriers and modular annular seals attached to the well casing. The modular foam barrier, used primarily above the water table, expands when the drive casing is retracted. The modular annular seal with polyethylene barrier is used below the water table. The bentonite in the modular seal is hydrated by the ground water and expands to seal the annulus prior to grouting.

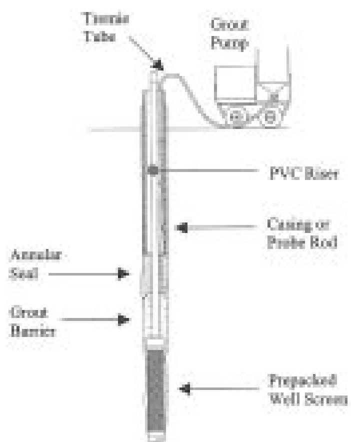


FIG. 11 Another option for installation of the annular well seal is with a side-port tremie tube and grout pump. This may be the most effective option when the screen is below the water table.

8.1.2 *Static Weight Methods*—Cone penetration (CPT) systems are the most commonly used static weight method for advancing tools and installing monitoring wells. Hydraulic rams are used to advance the tool string into the subsurface using the static force of the vehicle weight. Large CPT trucks (Fig. 4) may use anchors or add ballast to the vehicles (tanks of water, or lead blocks) to increase vehicle weight and depth of penetration. Capabilities and limitations of the static weight method are similar to those of the percussion methods.

8.1.3 *Sonic or Resonance Drilling Methods*—These are generally more powerful drilling methods that combine high frequency sonic or resonance with rotary action to advance tools into the subsurface. These methods can generally penetrate to greater depths than percussion or static methods and have been used to penetrate difficult formations such as cobble rich glacial till.

8.1.4 *Rotary Drilling*—Some conventional rotary drilling methods can be combined with direct push methods for sampling and well installation. Hollow stem augers (Fig. 4) are sometimes advanced to depth and then the hydraulic hammer generally used for standard penetration testing (Test Method D 1586) may be used to advance tools or casing ahead of the augers. Occasionally, the manual cathead-and-rope method is used to advance tools or casing ahead of the augers to facilitate sampling or well installation.

8.2 *Advantages and Limitations*—Direct push methods have some advantages and limitations when compared to rotary drilling methods. One of the primary advantages of direct push methods is that essentially no waste cuttings are generated as the tool string or casing is advanced into the subsurface. At locations where hazardous contaminants may be present this significantly minimizes the handling, drumming, storage, sampling, testing, transportation, and disposal of contaminated cuttings. Elimination of these waste handling and disposal activities will not only reduce cost but also reduce potential exposure hazards for site workers, local residents and the environment. Direct push methods are generally limited to unconsolidated formations composed of clays, silts, sands and some gravel. Conventional rotary drilling methods will be required for penetration of consolidated bedrock (for example, limestone, granite, gneiss) and some very dense unconsolidated formations or formations with an abundance of cobbles or boulders.

9. Monitoring Well Installation

9.1 *General*—Several of the procedures described below are similar to those used for installation of monitoring wells by rotary drilling techniques and Practice D 5092 may be referenced for additional information or guidance as needed. Manufacturer's standard operating procedures for installing direct push prepacked screen monitoring wells (Geoprobe Systems 1998, 1999, GeoInsight 2000) may also provide additional information on installation techniques. Installation of monitoring wells in an open/uncased borehole is not recommended for direct push or rotary drilling procedures. Installation of a monitoring well through an open borehole may result in slough of potentially contaminated material down the well bore either prior to or during the well installation procedure. This can lead to cross contamination and water quality samples that are biased and inaccurate and ultimately abandonment and replacement of the incorrectly installed well. While open hole installation of temporary piezomenters for water level monitoring in uncontaminated formations may be acceptable this is not an acceptable installation method for monitoring wells to be used for water quality sampling.

9.2 *Installation of Drive Casing*—The direct push method (percussion, static, sonic) which is selected based on site conditions is used to advance the drive casing to the desired depth. Use of O-rings or Teflon tape on casing joints is recommended to eliminate the potential for cross contamination as the tools are advanced to depth.

9.2.1 *Advance Casing*—Information from the site characterization is used to determine the appropriate depth and screen length for each well. The direct push unit is set up over the proposed well location and leveled. Depending on the specific well construction and casing advancement procedures to be used either an expendable point, anchor point, or expendable cutting shoe is installed on the lead casing section. If the casing is to be advanced without sampling either an expendable point or expendable anchor point (Fig. 5) is placed in the lead casing section. If continuous or targeted dual tube soil sampling (see Guide D 6282) is to be conducted as the casing is advanced an expendable cutting shoe (Fig. 6) can be installed on the lead casing section to permit well installation after sampling is completed. The appropriate drive cap (Fig. 5) is used to advance the tool string to depth. New sections of casing are added incrementally as needed to achieve the desired depth. To prevent the infiltration of potentially contaminated formation water as the casing is advanced o-rings or other acceptable materials (for example, Teflon tape) may be used to seal each casing joint. A water level indicator should be used to check the bore of the rods prior to installation of the prepacked screens to determine if water is present. If potentially contaminated water is present in the drive rods it should be evacuated before continuing with the well installation.

9.2.2 *Assembly and Installation of Screen and Riser*—The well screens to be installed may have been prepacked by the manufacturer prior to shipping, or may require addition of the filter media in the field before installation. Follow the manufacturer's specifications for adding the filter media to prepack the screens if required. If an expendable point or cutting shoe is used in the installation then the lower end of the screen or sump will require a bottom plug (Fig. 6). A threaded anchor point may be used and in this situation the base of the screen or sump is threaded directly onto this point to seal the bottom of the well (Fig. 7). If an expendable anchor point is to be used to anchor the well screen(s) in the formation an adapter (Fig. 7) may have to be installed in the base of the screen or sump. Then the screen section or sections are assembled and riser added as the screen(s) is (are) lowered through the casing (Fig. 7). Sufficient PVC riser is added to the assembly so that the final piece of riser extends above the drive casing. If an expendable anchor point is used the adapter on the base of the screen is attached to the anchor point. If a threaded anchor point is used, the screen attaches directly to the point by threading the base of the PVC onto the anchor point.

9.3 *Retraction of Drive Casing*—To deploy the assembled prepacked well screen and risers the direct push casing must be retracted. A rod retraction system that allows for access to the open ID of the casing is recommended. Such a system will enable the operator to confirm that the well screen(s) and riser stay at the required depth as the casing is retracted. The unit hydraulics are used with the retraction tools to retract the casing above the top of the screened interval. If the casing is advanced well below the static water level of the aquifer in a cohesionless formation it may be necessary to add water (of known quality) to the annulus of the rods prior to retracting the screen to prevent flow of formation materials between the screen and casing. If flow-in occurs the prepacked screen can become lodged inside the casing. If for any reason the prepacked screen becomes lodged inside the casing as it is retracted small diameter extension rods may be lowered into the open bore of the well (Fig. 8). The extension rods are used to gently push or tap on the base of the screen to dislodge it from the casing. Adding water to the casing can increase the hydraulic head inside the well relative to the formation helping to dislodge the screen from the casing.

NOTE 2—**Caution:** Excessive force used to dislodge the screen from the casing can result in damage and possible loss of the well.

9.4 *Emplacing Grout Barrier*—The grout barrier may be installed by gravity or tremie methods, or a modular system may be used. Alternatively, collapse of the natural formation may be used to create a natural barrier when the formation material is of appropriate grain size and cohesion.

9.4.1 *Gravity or Tremie Methods*—If project specifications require that an artificial grout barrier be installed above the prepacked screen(s) the rods should be retracted no more than two to four inches above the top of the prepacked screens. Then medium to fine grained sand can be slowly poured though the well annulus (Fig. 9) as the casing is retracted to build the grout bamer. If the top of the screen is several feet below the static water level the sand should be poured slowly to prevent bridging. Periodic monitoring of the annular depth should be conducted with a weighted tape to verify that bridging does not occur. If bridging does occur clean water can be pumped by a tremie tube to jet out the bridge. The grout barrier should generally be extended two feet above the top of the prepacked screen to assure that annular sealants do not penetrate into the screened interval. Local and state regulations vary on the thickness requirements for the grout barrier. Verify local regulations to maintain compliance.

9.4.2 *Modular Grout Barrier*—There are at least two types of barriers that fall in this category. The first is a seal comprised of a polyurethane foam and the second is a combination of a modular bentonite annular seal with a polyethylene sleeve barrier (Fig. 10). The foam seal may be threaded onto the casing string immediately above the prepacked screen (Fig. 10). Alternatively, the modular seal and polyethylene sleeve-barrier may be used alone (below water table) or in conjunction with the foam seal. Once the barrier is in place PVC riser is added to the assembly as it is lowered down the drive casing. Depending on the length of the modular grout barrier multiple units may be needed in sequence to meet state or local regulatory requirements for length of the barrier. Verify local regulations to maintain compliance.

9.4.3 *Natural Grout Barrier*—In poorly cohesive materials natural collapse of the formation may occur as the casing is retracted above the screen. Under these conditions it may be possible to use the natural formation collapse as the grout barrier. Samples of the formation should be examined to determine if the material would provide an effective barrier to the movement of annular sealants into the well screen interval. Coarse-grained sands or gravels may not sufficiently impede the migration of annular sealants and under these formation conditions an artificial or modular grout barrier should be emplaced. Review local and state regulations to verify that use of a natural grout barrier is acceptable. The natural grout barrier should be a minimum of two feet in length and monitoring with a weighted tape should be used to verify the amount of formation collapse.

9.5 *Annular Seal*:

9.5.1 *Gravity Installation*—If the top of the sand barrier is near or above the static water level it may be possible to pour in fine chips or pellets of bentonite to construct the annular seal. Use chips or pellets not more than one-fifth the width of the open annulus to minimize the potential for bridging and formation of voids in the seal. Incrementally retract the drive casing as bentonite is poured down the well annulus. Use of a weighted tape to verify the length of the seal is necessary. The weighted tape also may be used to detect any bridging of the bentonite material during installation. Bridges must be removed and length of the seal verified. Generally the length of the annular seal should be at least two feet. Verily state and local regulations on requirements for length of the annular seal to maintain compliance.

9.5.2 *Tremie Installation*—For the highest integrity annular seal, especially in deeper wells and where the static water level is several feet above the grout barrier, it will be necessary to use bottom-up tremie installation of the seal (Fig. 11). Because of the small well annulus on most direct push wells smaller diameter tremie tubes (0.25- to 0.5-in. inside diameter) will be required to pump bentonite slurries down hole. Because of the viscosity of the 20 to 30 % solids bentonite slurries used for annular seals a high pressure grout pump will be required to pump the slurry down hole through the small ID tremie tubes. Piston operated or other positive displacement pumps are often the best for pumping the viscous slurries through the small ID tremie tubes. To prevent intrusion of the slurry into the grout barrier and screen interval it is recommended that a side port tremie be used for installing the annular seal slurries. The annular seal should be emplaced slowly as the casing is retracted and should usually extend two feet above the top of the grout barrier. State or local regulations may vary as to the composition and thickness of the annular seal. Check applicable regulations to maintain compliance.

9.5.3 *Modular Installation*—When modular annular seals (bentonite sleeves) are used they arc assembled on the well casing above the prepacked well screen(s) (Fig. 10). Additional well casing is added to this assembly as it is lowered down the bore of the drive casing. The drive casing is then retracted just above the top of the modular seal. An adequate amount of water is added to the well bore to hydrate the bentonite. Sufficient time is allowed for hydration of the bentonite in the modular seal before grouting can commence Use of a weighted tape is necessary to verify the modular seal has hydrated and plugged the well bore. State or local regulations may vary as to the composition and length of the annular seal. Check applicable regulations to maintain compliance.

9.6 *Grouting*—The bottom-up tremie method of grout installation (Fig. 11) will provide the highest integrity annular seal for most field conditions. The appropriate grout slurry (see 7.6.2) should be emplaced slowly as the casing is retracted. For best results the grout is pumped into the well annulus until undiluted grout is observed flowing from the top of the casing. Then the casing is slowly retracted as additional grout is pumped into the annulus to replace the void created as casing is removed. Care should be taken to keep several feet of grout up inside the casing so that the potential for formation collapse against the casing or the presence of voids in the grout are eliminated, or at least minimized. Annular grout usually extends from the well seal to within two to four feet of ground surface. Review state and local regulations for the recommended grout mixture and depth to grout below ground surface. It is recommended that bentonite grout be used only in the saturated zone because of potential for dessication and loss of integrity in the unsaturated zone. Cement based grouts may provide a better seal in the unsaturated zone.

9.7 *Well Protection*—Above ground or flush mount well protection should be installed to protect the well from physical damage or tampering (Fig. 12). Concrete is used to set the well protection in place and usually extends below the frost line (where applicable) to prevent frost heave from damaging the well head. A concrete pad two- to three-feet in diameter and four-inches thick is usually constructed around the well head. The pad is sloped away from the well head to encourage storm water runoff. Check state and local regulations for detailed requirements for well protection and construction. For smaller diameter riser an outer protective casing may be needed to provide a locking well cap. Generally a 2-in. PVC casing can be installed over the well riser extending three to four feet below grade. Locking well caps are commercially available for

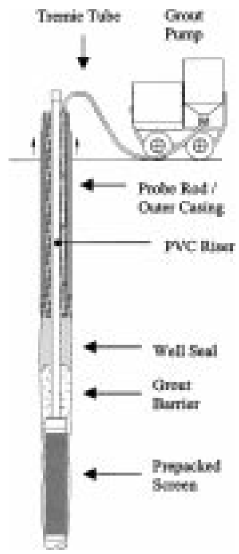


FIG. 12 The casing is filled with grout by a bottom up tremie tube before retraction of the casing continues.

2-in. diameter PVC pipe. An inner cap or plug is recommended for use on the small diameter casing to assure protection of water quality. When a flush mount protector is used in areas with vehicle traffic it should meet state and Dept. of Transportation requirements for weight loading rate. It may be necessary to install posts or traffic bumpers when above ground protectors are used in some locations. Further information on well protection may be found in Practice D 5092, D 5787, EPA 1986, 1991 and 1992.

10. Post Installation Activities

10.1 *Development*—Development is the process by which damage done to the formation during the drilling and well installation process is rectified and natural flow from the formation into the well screen is reestablished. Development is also used to lower turbidity of water withdrawn from the well for sampling and assure accurate hydraulic conductivity is measured during slug testing. There are several development methods available including mechanical surging, over pumping, airlifting, and well jetting. Details on each development method may be found in Practice D 5092, D 5521, EPA 1986, 1991, and Nielsen 1991. Information on different monitoring well purging devices is available in Guide D 6634. One common method for developing the small diameter prepacked screen monitoring wells is the use of an inertial check valve or foot valve and tubing to simultaneously surge and purge from

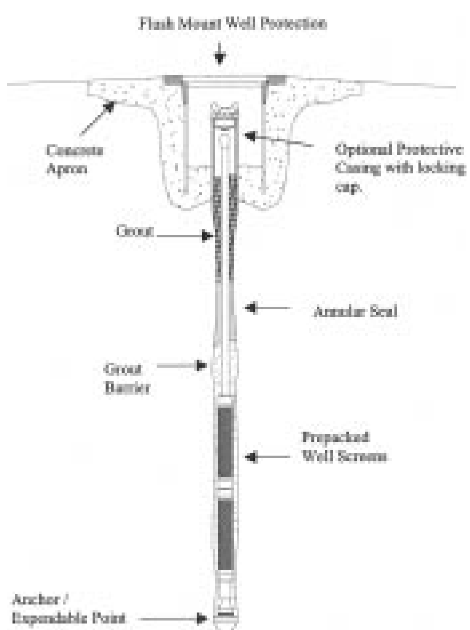


FIG. 13 A completed prepacked screen monitoring well installed by direct push methods showing flush mount well protection installed. Use of flush mount well protectors may require variance from local or state regulations. Above ground protectors may be used if desired.

the well screen (Fig. 14). Often the check valve and tubing are nearly the same diameter as the ID of the riser and so a surging action is effected as the tubing is briskly raised and lowered in the well bore. At the same time water is purged from the well removing the fines loosened by the surging action. This is usually an effective development technique for the small diameter wells. However, in formations with a high proportion of clays and silts development is problematic and may not improve the well yield or water quality. If development is attempted in these finer grained formations, care must be taken not to over surge the well and clog the screen with fines resulting in a significant loss of natural flow into the well and possibly damaging the well screen and filter media. Low flow pumping with a peristaltic pump or bladder pump may be an option if development of low yield/fine grained formations is attempted.

10.2 *Survey*—It is recommended that a survey be conducted to accurately determine the location and elevation of a reference point on the well. This information can be used to determine the elevation of static ground water level in the well. If multiple wells are installed the location and elevation data can be used to determine the ground water flow direction and possibly to construct a potentiometric surface map.

10.3 *Sampling*—Various methods for purging and sampling the small diameter prepacked screen wells are available (D 6634). These include bailers, inertial check valves, peristaltic pumps, and most recently small diameter bladder pumps. The analytes to be tested for and local field conditions should guide the procedure selected for sample collection. Additional information on sampling equipment, methods and procedures can be found in Guide D 4448, EPA 1986, 1991, 1992,1996, and Nielsen 1991. Low flow/minimal drawdown sampling methods (EPA 1996) may be particularly useful when sampling for volatiles or when low turbidity samples are needed. Information on decontamination of sampling equipment is provided in Practice D 5088 and Parker and Ranney 2000.

10.4 *Aquifer Testing*—Recent studies (Butler et al., in review) have found that small diameter direct push installed ground water sampling tools can be used for aquifer testing procedures. Tests in an alluvial aquifer have shown that the direct push installed tools can be used as observation wells during pumping tests. Side by side comparisons of the direct push installed devices and conventional designed monitoring wells indicate that the direct push tools provide the same results as conventional observation wells during pump tests. Field comparisons have also shown that direct push installed devices can be used to obtain accurate measurement of formation hydraulic conductivity from slug tests (Butler et al. 2001, McCall et al. 2001). Modifications of conventional slug testing methods for use in smaller diameter wells can be successfully applied (Butler et al. 2001). For the smaller diameter devices (< 1.0-in. ID) field studies have shown that the maximum hydraulic conductivity which can be measured accurately is 250ft/day (8.8×10^{-2}cm/sec). In aquifers where higher hydraulic conductivity exists larger diameter wells would be required to obtain accurate determinations from slug test methods (Butler et al. 2001). Further information on slug testing procedures can be found in Test Method D 4044, D 5881, D 5912, D 5785, D 4104, Guide D 4043, Butler 1997, Fetter 1994, Nielsen 1991. Information on pump test procedures may be found in Guide D 4043 that provides guidance on selection of appropriate test methods and procedures for pump testing and slug testing. Additional information on pump testing is providedin Nielsen 1991 and Fetter 1994.

11. Monitoring Well Installation Report

11.1 Documentation of the direct push installed prepacked screen monitoring well should be completed to provide clear and precise information on the well installation and construction procedures. An example well construction diagram (Fig. 15) provides guidance on the information that should be documented during well construction. Accurate documentation of the volumes of materials such as grout, bentonite, and sand used in the well construction should be maintained. Additional, and or different information may be required for documentation depending on the purpose and uses of the prepacked screen well installation.

12. Keywords

12.1 aquifer; direct push; ground water; monitoring well; prepacked screen; water quality

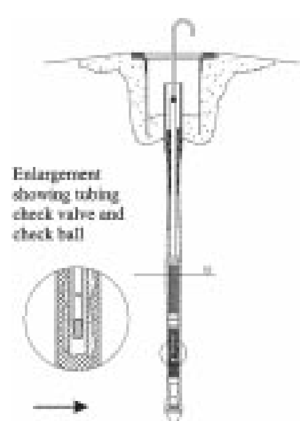


FIG. 14 One method of well development is by using a simple tubing check valve assembly. This assembly is oscillated up and down to simultaneously surge and purge the well. In finer grained formations the use of a peristaltic pump or bladder pump may be preferred to prevent clogging of the well screen.

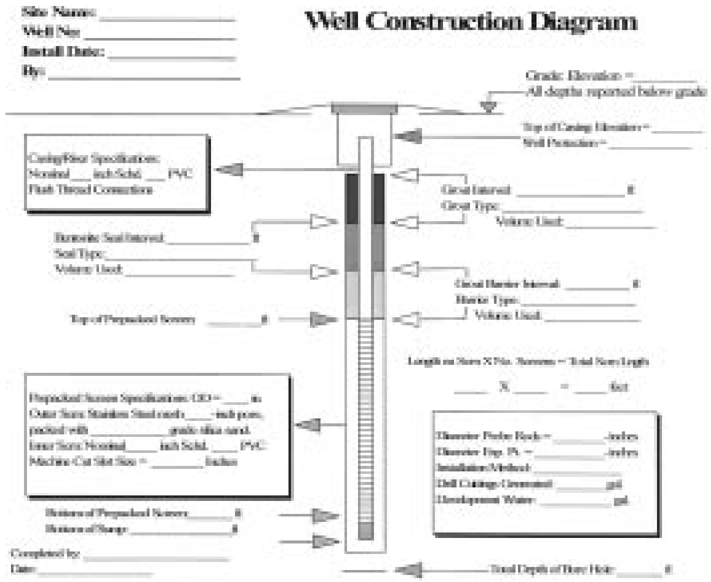


FIG. 15 Example well construction diagram for use in documenting well specifications. Additional information may be required.

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