ALASKA DEPARTMENT OF ENVIRONMENTAL CONSERVATION

DIVISION OF SPILL PREVENTION AND RESPONSE
CONTAMINATED SITES PROGRAM

Monitoring Well Guidance

February 2009

Applicability

This document fulfills the regulatory requirements of 18 AAC 75 and 18 AAC 78 for monitoring well design, construction, installation, maintenance, and decommissioning. The Department of Environmental Conservation (DEC) recommends the use of this document in place of the April 1992 guidance titled *Recommended Practices for Monitoring Well Design, Installation and Decommissioning*, adopted by reference in 18 AAC 75 and 78.

The practices described in this document are not applicable to all situations; the department recognizes that regional, climatic, and geographic variables can influence monitoring well design and construction. While each monitoring well installation may differ, site-specific application should be technically sound.

Introduction

This document presents standards for the location, design, installation, decommissioning, and documentation of monitoring wells and well points associated with the investigation and cleanup of contaminated sites in Alaska. The goal is to obtain reliable and representative information regarding aquifer characteristics, groundwater flow directions, groundwater chemical and physical characteristics, and groundwater samples.

The focus of this document is permanent monitoring wells. Generally, the purpose of a permanent monitoring well is to establish long-term groundwater contaminant trends and to confirm that cleanup levels have been met in a known contaminated aquifer. Screening, site characterization, and short-term monitoring in shallow groundwater following soil excavation are scenarios that may be more applicable to temporary monitoring techniques. While this document does not describe specifications for temporary well placement, it is important to note that the general principals and precautions described herein are applicable to all situations. Contact DEC prior to installation if you believe a site-specific situation warrants the use of a temporary monitoring well.

Investigation of a contaminated site requires establishing clearly defined objectives before fieldwork commences. Identifying the type of contaminant and the manner of release to the environment is a primary step. Contaminant releases to land require an understanding of partitioning between the hazardous substance released, and soil, water, and air or soil gas. Water often acts as a carrier for contaminants as they move through the soil. If contaminant migration results in groundwater contamination, monitoring wells are required to assess groundwater quality. The installation, development, and decommissioning of monitoring wells must be done in accordance with this guidance document, or other methods approved by DEC (18 AAC 75.345(j)).

Before installing a monitoring well, DEC recommends developing a conceptual model of the site geology and hydrology. The purpose of a hydro geologic conceptual model is to estimate the distribution of the predominant geologic units and flow conditions at the site. The conceptual model may include estimates of the distribution of aquifer(s) and aquitards at or near the site, hydrologic boundaries, the water table surface, and other pertinent hydro geologic properties. The hydro geologic conceptual model should be updated with new data as it is obtained.

This guidance document includes the basic steps for recording a vertical soil profile, advancement of soil borings, design and installation of a monitoring well, well development, and well decommissioning. The references titled *Handbook of Suggested Practices for the Design and Installation of Ground-Water Monitoring Wells,* EPA/600/4-89/034 (hereafter referred to as EPA, 1991), and American Society for Testing and Materials (ASTM) D5092-04e1 *Standard Practice for Design and Installation of Ground Water Monitoring Wells* (2005) provide more comprehensive guidance.

Drilled Wells

Soil Boring Installation

Key Principals, Specifications, and Precautions

1. Select the proper drill rig.
2. Determine the proper inside diameter of the borehole (at least 4 inches larger than the riser and screen diameter).
3. Drill upgradient boreholes first.
4. Take appropriate precautions during drilling to avoid introducing contaminants into the borehole.
5. Proceed with soil recovery on a continuous basis from the surface to the proper depth.
6. Avoid using drilling mud, synthetic drilling fluids, or petroleum- or metal-based pipe joint compounds and other potential contaminants unless necessary.
7. If it is necessary to add water to the borehole during drilling, use only potable water and first identify the water source.
8. If it is necessary to add drilling mud to the borehole during drilling to stabilize the hole or control down-hole fluid losses, use only high yield sodium bentonite clay free of all organic polymer additives.
9. Properly decontaminate all equipment placed into the borehole by steam cleaning, high-pressure hot water, or similar methods before and after use at the site and between boreholes.
10. Manage cuttings, or water, removed from the borehole in accordance with 18 AAC 75 or 18 AAC 78.
11. Maintain a boring log.

Discussion

Soil borings assess the lithology of the subsurface and are often required during the installation of monitoring wells. Selection of the drill rig used to advance a soil boring (or install a groundwater monitoring well) must be appropriate to gather the project-specific data required. A common drill rig used for contaminated site investigation is the hollow-stem auger. The hollow-stem auger allows for continuous soil recovery and monitoring well installation. American Society for Testing and Materials (ASTM) standard D6151 (2003) provides detailed information on the use of hollow-stem augers for soil sampling. Direct push techniques are also popular in Alaska for advancing soil borings and installing monitoring wells. ASTM standards D6724 (2004) and D6725 (2002) provide detailed guidance on the installation of direct push monitoring wells. Air rotary drilling techniques may be useful when drilling through consolidated materials; ASTM standard D5782 (2000) provides a detailed discussion. Additionally, comprehensive evaluations of drilling methods are in Driscoll (1986) and EPA (1991).

Soil recovery should proceed on a continuous basis from the surface to generate an accurate record of the soil lithology, soil moisture content, and allow for soil sample collection. This record, termed a "boring log," is required for all soil borings. The boring log typically contains a description of the soil as classified under the Unified Soil Classification System or other universally accepted soil classification method.

ASTM standard D5434 (2003) provides detailed guidance on the type of information included in the boring log. An example log is in EPA (1991). If the soil boring is completed as a groundwater monitoring well, the well construction and completion information should be provided as a detailed "as-built" drawing. An example of an as-built drawing showing well construction and completion information is in EPA (1991).

When describing frozen soils, ASTM standard D4083 (2001) can be used as guidance. Rock core logs should describe the lithology, mineralogy, color, grain size, degree of cementation, degree of weathering, density and orientation of fractures, other primary and secondary features and physical characteristics of the rock, and the rock quality designation. Include a clearly labeled photographic record of all rock cores with the rock core logs.

For monitoring wells other than direct push, DEC recommends boreholes with a minimum inside diameter at least four inches larger than the outside diameter of the riser pipe and screen. This recommendation is to allow for proper installation of materials within the annular space and to ensure an adequate annular seal.

Monitoring Well Design and Installation

Key Principals, Specifications, and Precautions

1. Determine the purpose of the well.
2. Evaluate site-specific hydro geologic information from all available sources, including the physical and chemical properties of the groundwater and any contaminants known or suspected to be present in the groundwater.
3. Develop a conceptual hydrogeologic model of the site.
4. Determine screened interval.
5. Select the drill rig.
6. Determine the diameter of the well.
7. Drill upgradient wells first.
8. Take appropriate precautions during drilling to avoid introducing contaminants into the well. Prevent vertical movement of water or contaminants between water-bearing zones in either the boring or the well annulus.
9. Avoid using drilling mud, synthetic drilling fluids, or petroleum- or metal-based pipe joint compounds and other potential contaminants unless necessary.

10. If it is necessary to add water during drilling, use only potable water and first identify the water source.
11. If it is necessary to add drilling mud to stabilize the hole or control down-hole fluid losses, use only high yield sodium bentonite clay free of all organic polymer additives.
12. Properly decontaminate all equipment placed into the well by steam cleaning, high-pressure hot water, or similar methods between well installations.
13. Manage cuttings, or water, removed from the well in accordance with 18 AAC 75 or 18 AAC 78.
14. Minimize sediment and turbidity in water samples that may interfere with the results of water quality analyses.
15. Complete an "as built" drawing.
16. Survey wells vertically and horizontally.
17. Submit a record of the well design, installation, and the materials used to DEC.

Discussion

There are several purposes for groundwater monitoring, such as ambient monitoring, source monitoring, case preparation monitoring, and research monitoring (Barcelona et al., 1985). Wells installed for each of these purposes must satisfy different requirements, and may require different strategies for well design and installation. Prior to design and installation there should be a clear understanding of what the monitoring program is intended to accomplish. Is the monitoring well intended for site characterization or plume delineation, long-term monitoring, contaminant screening, final compliance with cleanup standards for site closure, product recovery or a remedial action, or some other purpose?

Selection of monitoring well type, materials, and drill rig is a site-specific determination. Site logistics and economics often influence choices. Locations without road access can be logistically challenging and incur increased project costs for site investigation. In all cases, clearly identify project objectives in a work plan developed in consultation with DEC.

Proper well spatial and vertical location is critical to ensure accurate monitoring of the groundwater flow regime. Monitoring wells are typically installed in the uppermost permeable water-bearing zone under or adjacent to a regulated facility or potential source of contamination. Consider natural, seasonal, and anthropogenic fluctuations in water table elevation in determining the well location. Natural fluctuations are typically due to infiltration of snowmelt or precipitation, proximity to rivers with seasonal high water levels, or tidal fluctuations. Anthropogenic fluctuations can result from pumping, wastewater disposal, or paving to decrease infiltration rates. Consider the behavior of a contaminant plume over distance to ensure that placement and construction of monitoring wells is appropriate (see Wiedemeier et al., 1999).

Well design and installation must be appropriate to ensure that groundwater samples and water level measurements characterize discrete stratigraphic intervals. Location of the screened interval relative to the water table elevation may influence sampling results. For example, a well screened at the water table, with some screen above the water table and some below the water table, will intercept floating petroleum product; a well with the top of the screened interval located below the water table will not intercept floating petroleum product under static conditions.

Well design and installation must prevent the introduction of surface contaminants into the groundwater and prevent leakage of groundwater or contaminants between stratigraphic intervals in the well bore or along the well annulus. If the well leaks, correct the leak or decommission the well. Do not install monitoring wells in locations where they are subject to periodic or seasonal inundation by floodwaters, unless the well has special watertight construction. Protect monitoring wells from loss of integrity by soil erosion, soil settlement, shrink-swell soil conditions, frost heaving of soils, damage by vehicles or heavy equipment, and other site-specific hazards. Completion of monitoring wells at- or below-grade is not recommended.

A monitoring well is generally composed of well casing, well screen, and filter pack (Figure 1). Construct monitoring wells with new materials that will not physically, chemically, or biologically affect the groundwater quality, or be deleteriously affected by the subsurface environment. Install the well casing into a borehole from the ground surface to the groundwater. The well screen is an intake where groundwater can flow into the well; the filter pack surrounds the well screen. Install the well in an open borehole created by advancing a soil boring, usually with a hollow-stem auger drill rig. Advance the soil boring until the soil core (s) demonstrates saturated soil conditions, indicating that the groundwater table has been encountered. After the water table has been identified in the soil boring, remove the drill rods from the open borehole and install the monitoring well.

Alternatively, install monitoring wells to depths below the water table, depending on the project objectives and site characteristics.

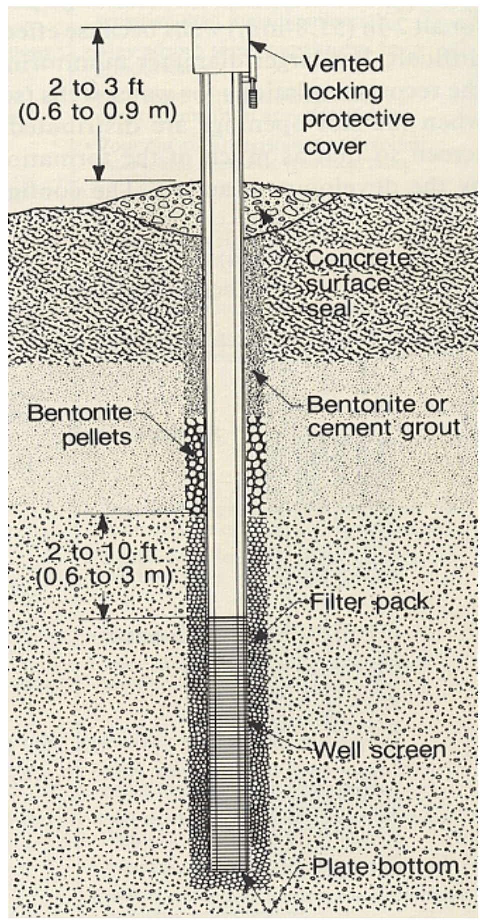


Figure 1. Typical Monitoring Well Installation. From Driscoll (1986).

Survey monitoring wells vertically and horizontally. Survey the top of the well casing and ground surface for use as a reference point to determine water-level elevations and sampling depths. At sites with long-term detection monitoring, survey the location of each well, the elevation of the land surface, and the top of each well casing. A registered professional surveyor or registered civil engineer engaged in the practice of surveying must conduct this work.

The location survey should achieve a horizontal accuracy of 0.2 foot, and the elevation surveys should achieve a vertical accuracy of 0.01 foot. Vertical elevation control should be the National Geodetic Vertical Datum 1929, and the horizontal control should be the North American Datum 1983. Sites undergoing contaminant assessment monitoring with a large number of monitoring wells should have the wells surveyed as described above. Re-survey monitoring wells every five years, or more frequently, if freeze-thaw processes compromise the well. On a site-specific basis, DEC will evaluate sites that do not require this level of detail.

For accurate water level measurements, permanently mark the monitoring well with a reference point on the actual monitoring well casing, not the outer surface casing. Permanently attach a facility or project-unique identification number on the inner and outer well casings.[1]

Submit documentation of the well design, well construction logs, and the materials used to DEC. This information is useful for determining if the monitoring well design, installation, or history may be affecting sampling results or the interpretation of site conditions.

Well Casing

Key Principals, Specifications, and Precautions

1. Determine the appropriate casing material for the application.
2. Determine the proper casing length and diameter.
3. Join casing sections properly.
4. Install to account for freeze-thaw processes.

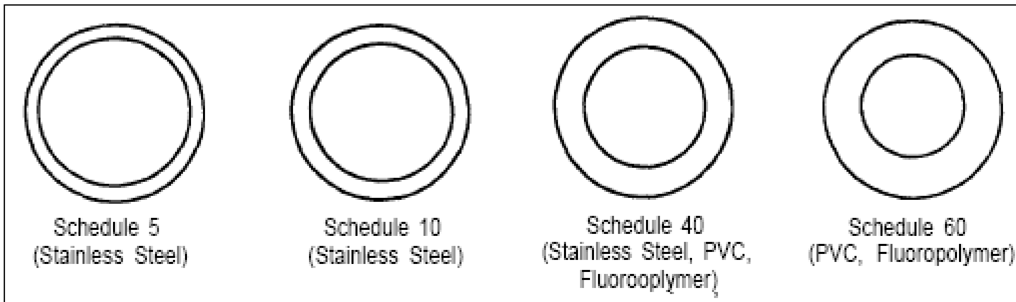
Well casing allows access to groundwater from the ground surface. The casing should be non-reactive with the subsurface environment and any contaminant the monitoring well may encounter. Casing length is determined based on the borehole depth and the data quality objectives on a site-specific basis. Join casing sections together with threads and couplings or solvent welds, rather than glues, in order to eliminate the introduction of contaminants when sampling. Threaded connections should have o-rings to complete the seal, and casings should be flush-fit on the inside. Casing diameter is also determined on a site-specific basis. The inside diameter of the well casing should be at least 1.9 inches,

[1] All well construction logs with soil boring information are required to be submitted to the Alaska Department of Natural Resources Division of Mining Land and Water in accordance with 11 AAC 93.140.

with the exception of piezometer installations. Monitoring wells in Alaska are commonly schedule 40 polyvinyl chloride (PVC), nominal 2-inch diameter casing. Deep wells or those that need larger-sized, dedicated pumps or tubing may require 4-, 6-, or 8-inch casing. However, DEC recommends the use of a smaller diameter, such as 2- or 4-inch, to minimize the amount of water generated during sampling events. See Figure 2 below for a table of the inner diameters of various well casing schedules.

There are many different casing materials used in design of a monitoring well; thermoplastic materials (such as PVC) and stainless steel are the most widely used. PVC is commonly used because of its high strength, low maintenance, and chemical resistance. EPA (1991) discusses special applications to monitoring wells for materials other than PVC. All monitoring well materials should conform to ASTM Standards.

Consider chemical resistance/interference during monitoring well design; many well materials may react with the groundwater, resulting in poor-quality or erroneous data. EPA (1991) and Driscoll (1986) offer in-depth discussion of the limitations of each material. In most cases in Alaska, PVC will provide a strong monitoring well with good chemical resistance (EPA, 1991, page 79).



Wall Thickness (Inches)	Sch 5	Sch 10	Sch 40	Sch 80	Outside Diameter (Standard)
Nominal 2	0.066	0.109	0.164	0.218	2.375
Nominal 3	0.063	0.120	0.216	0.300	3.500
Nominal 4	0.083	0.120	0.237	0.337	4,500
Nominal 5	0.109	0.134	0.258	0.375	5.563
Nominal 6	0.109	0.134	0.280	0.432	6.625
Inside Diameter	Sch 5	Sch 10	Sch 40	Sch 80	
Nominal 2	2.245	2.157	2.067	1.939	
Nominal 3	3.334	3.260	3.068	2.900	
Nominal 4	4.334	4.260	4.026	3.826	
Nominal 5	5.345	5.285	5.047	4.813	
Nominal 6	6.407	6.357	6.065	5.761	

Figure 2. Casing thickness and diameter for monitoring well materials. From EPA (1991).

When choosing monitoring well casing material, three parameters determine its strength: tensile, compressive, and collapse strength. Tensile and collapse strength are the main drivers for failure. The tensile strength of the casing joints is critical because the joint is typically the weakest point in a casing string. Tensile forces are generally greatest on a dry string of casing hung in the open boring hole during installation. See Figure 3 for illustration of these forces on the well casing.

The outside diameter and wall thickness determines the resistance of casing to collapse. Casing collapse strength is directly proportional to the cube of the wall thickness. Therefore, a small increase in wall thickness provides a substantial increase in collapse strength. Properly installed casing, supported by the filter pack and annular seal, seldom leads to collapse (National Water Well Association and Plastic Pipe Institute, 1981).

Freeze-thaw processes creating "frost heaving" can "jack" wells from the ground, due to freezing and upward expansion of the soil. Frost heaving will change the height of the well casing, and in some cases overcome the tensile strength of the casing joint and separate casing sections. Minimize damage by installing a surface outer casing to a depth of 5-10 feet below ground surface and a steeply inclined cement cap around the surface casing (Driscoll, 1986). When frost heaving occurs and pressure is exerted on the cement cap, the surface casing may rise without affecting the monitoring well casing (Driscoll, 1986). More information about frost heave and frost heave susceptible soils is available in ASTM standard D5918 (2001).

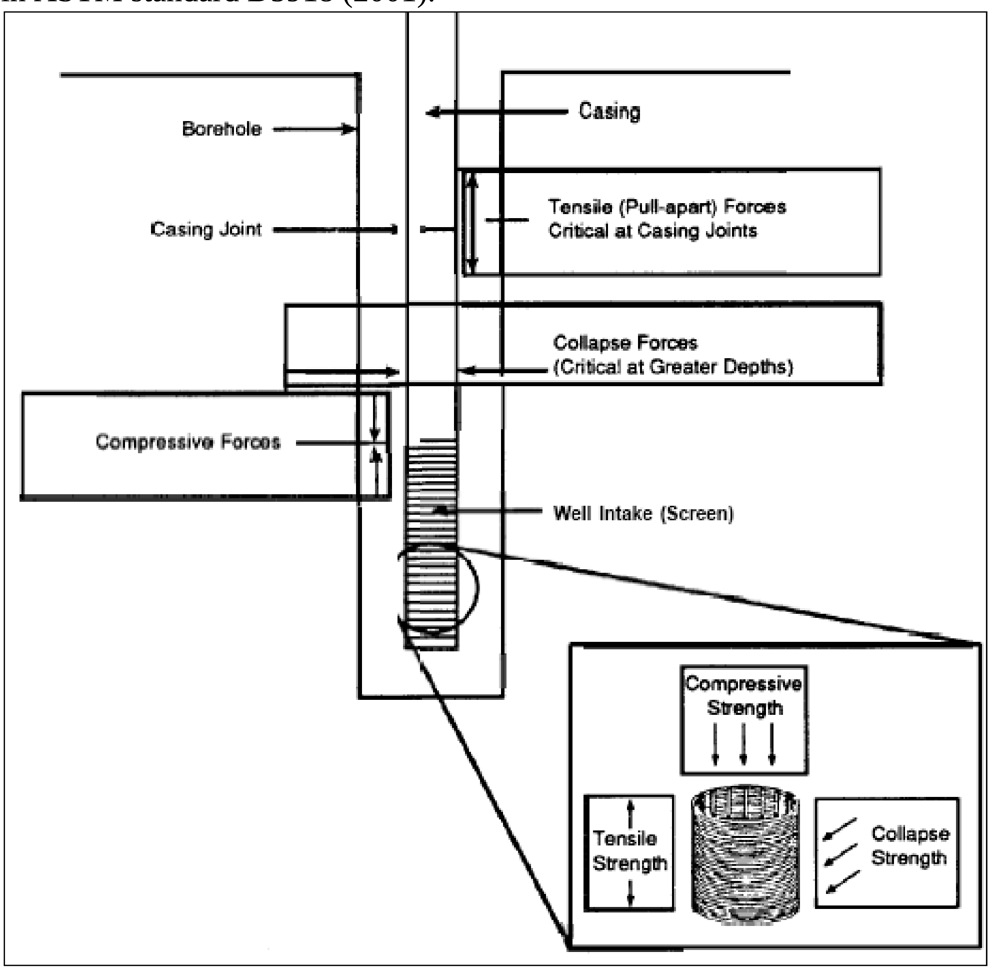


Figure 3. Forces acting on a monitoring well casing during installation. From EPA (1991).

Filter Pack

Key Principals, Specifications, and Precautions

1. Conduct a sieve analysis to determine grain size distribution.
2. Determine the appropriate filter pack application (natural or artificial).
3. Use clean, chemically inert, and well-rounded siliceous material.
4. Determine appropriate filter pack thickness (2-8 inches).
5. Extend filter pack at least two feet above well screen.

Discussion

Surrounding the monitoring well intake with materials that are coarser, of uniform grain size, and have a higher permeability than natural formation material allows groundwater to flow freely into the well from adjacent formation material while minimizing or eliminating the entrance of fine-grained materials. Typically, installing an artificial filter pack meets these objectives. Alternatively, develop a natural well where the formation consists of suitable material that does not require a filter pack. Deciding between these two options depends on the grain-size distribution of the natural formation materials in the monitored zone. Grain size distribution can be determined by conducting a sieve analysis of a sample collected from the intended screened interval. Naturally developed wells can be used when the maximum borehole diameter closely approximates the outside diameter of the well, and when the surrounding formation is coarse-grained and permeable (EPA, 1991). Size the filter pack for wells installed in unconsolidated material to retain most of the surrounding formation. However, most monitoring wells installed in Alaskan unconsolidated soils are artificially filter-packed, typically with a No.10-20 or 20-40 silica sand pack. Artificial filter pack is more appropriate to use under the following circumstances (EPA, 1991).

- Natural formation is uniformly fine grained
- Long screened interval required and/or the intake spans highly variable lithology
- Formation is a poorly cemented sandstone
- Formation consists fractured rock or karst
- Formation consists of shales or coals that will act as a constant supply of turbidity
- Borehole diameter is significantly greater than the screen

The filter pack should extend above the well screen to a length of 20% of the well screen length, but no less than 2 feet (ASTM D5092, 2005). The thickness of the filter pack should be at least 2 inches between the borehole and the well screen, and no greater than 8 inches (EPA, 1991).

The filter pack should consist of clean, chemically inert, and well-rounded siliceous material. Do not use crushed limestone or dolomite, material containing clay, or filter fabrics. The sand or gravel used for filter packs should be of uniform size, hard and durable, and should have an average specific gravity of 2.50 or greater. The sand and gravel should be well washed and free of clay, dust, and organic matter. Not more than five percent of the sand or gravel should be soluble in hydrochloric acid. Additional information regarding the filter pack is provided in EPA (1991), ASTM D5092 (2002), and Driscoll (1986).

Well Intake

Key Principals, Specifications, and Precautions

1. Determine the proper slot size (intake opening) based on the selected filter pack.
2. Ensure the screen retains at least 90% of the filter pack.
3. Use commercially manufactured well intakes only.
4. Account for resistance to corrosion and chemical degradation.
5. Determine the proper well screen length; minimize screen length to avoid dilution during sampling.
6. Install well clusters as individual wells in close proximity.

Discussion

The well intake is the aquifer access location. Except for wells in bedrock, install well screens in all monitoring wells.

Determine the slot size for the screened section based upon the filter pack selected for the monitoring well, as discussed above. Select the appropriate screen slot size by sieve analysis of the formation material in which the well screen will be positioned. The screen should be capable of retaining at least 90% of the filter pack. However, this step is laborious, and may be bypassed if the site is understood well enough from previous investigation. Typical installations in Alaska for unconsolidated soil use a 20-slot intake with a No.10-20 silica sand pack, or 10-slot intake with a No.20-40 silica sand pack. Commercially manufactured well intakes are required for use in monitoring wells because commercial manufacturers follow stricter quality control measures. All wells require machine slotted well screens. Do not use hand cut screens.

Screened interval location relative to the water table elevation can influence sample results. Increased open area in the monitoring well intake allows effective development and easy flow of water from the formation into the well. The type of well intake and slot size controls the amount of open area in a well intake (EPA, 1991). Consider water table variations, site stratigraphy, expected contaminant behavior, and groundwater flow when selecting the screen length and position in the borehole. When existing contamination is suspected or known, downhole geophysical techniques or groundwater sampling may be necessary to aid in selecting the location of the screened interval.

Determine the well screen length on a site-specific basis and project objectives. Minimize the length of well screens to avoid dilution during sampling. Well screens typically measure one (1) to 10 feet in length, and only rarely equal or exceed 20 feet in length (EPA, 1991). For conventional monitoring wells at petroleum-contaminated sites in Alaska, the well screen length is typically ten (10) feet long and placed with some well screen above the high water table. However, there are several instances where this convention is not appropriate (API, 2006). A short-screened interval will provide data from a specific discrete interval, whereas a long screen length accounts for water table fluctuations and the inherent variability between water levels during and after drilling. However, this application may result in composite groundwater samples, even in relatively homogeneous formations (Church and Granato, 1996; Britt, 2005).

Monitoring wells installed at multiple depths to determine the vertical hydraulic or contaminant concentration gradient, also known as piezometers, are typically screened less than five feet. Install piezometers as either nested or clustered. DEC does not recommend wells consisting of multiple aquifer completions in a single borehole. Well clusters should consist of individual wells in close proximity, screened at varying depths, each installed in its own borehole. For well clusters, drill the deepest well in the cluster first. Use borehole sampling information to determine what formation interval to screen, or where to place seals to prevent communication between the aquifers.

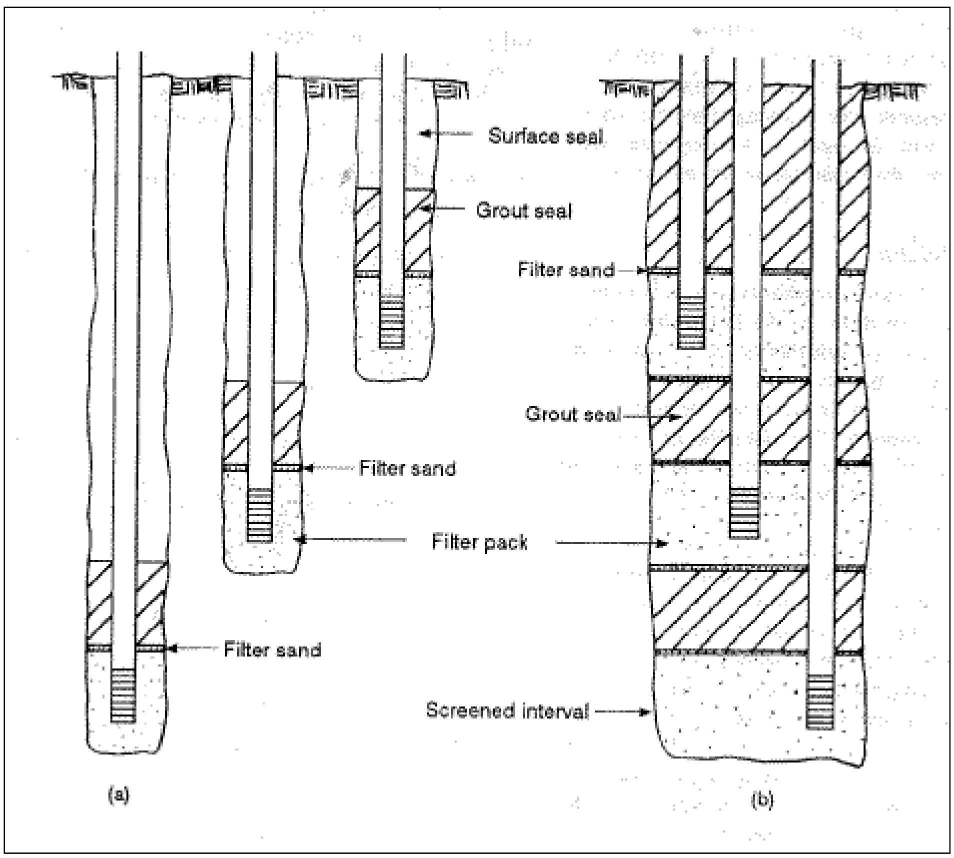


Figure 4. Piezometers installed as (a) clusters, or (b) nested. From EPA (1991).

Annular Space Seals

Key Principals, Specifications, and Precautions

1. Seal the well casing to the adjacent soil formation.
2. Seal with bentonite pellets, bentonite slurry, or similar material a minimum of two feet above the filter pack and two feet below the ground surface.
3. Install bentonite pellets in one-foot thick layers; hydrate before placing the next layer.
4. Seal the annular space with materials such as:
   - neat Cement Grout (not recommended for use with schedule 40 PVC well casing or where there may be shrinkage that may allow leakage along the casing);
   - sodium based bentonite slurry with a mud weight of at least 10.00 pounds per gallon;
   - sodium based bentonite granules;
   - sodium based bentonite pellets; or,
   - bentonite – cement grout.

Discussion

Install annular seals to restrict vertical movement of water or contaminants by sealing the well casing to the adjacent soil formation. There are typically two seals in a standard monitoring well, one above the filter pack and one at the ground surface.

Construct all permanent monitoring wells with filter packs with a seal at the top of the filter pack. Install this seal to confine the well screen to the sampling interval. Extend the seal a minimum of two feet upward from the top of the filter pack to prevent seal material from leaching into the filter pack. This annular seal should consist of bentonite pellets, bentonite slurry, or similar material.

To protect the screened interval from "cross contamination" from infiltration of runoff and potential contaminants at the ground surface, install an annular seal in the annulus at the ground surface. Extend this annular seal from the ground surface to 2 -3 feet below the ground surface. This annular seal should consist of bentonite pellets, bentonite slurry, or similar material.

For shallow wells, it is common to grout the annulus with bentonite from the annular seal above filter pack to the annular seal at the ground surface. For deeper wells, there is often inert material, typically sand, between these two seals.

When using bentonite pellets, install the filter pack seal in sequential, one-foot thick layers. Hydrate each one-foot layer by pouring an approximate equal volume of water down the borehole before placing the next layer of pellets. Continue this process until the required minimum two-foot seal thickness is installed. Use a tape measure, measuring rod, or similar device to ensure that the filter pack seal is installed over the proper depth interval.

EPA (1991) and ASTM 5092 (2005) discuss the properties of annular seals and grout as well as the uses. In some cases, annular seal materials are mixed with water to form a "slurry," which can be injected into the annular space to provide a high integrity seal. Nested or clustered wells require special care to seal off water bearing zones from cross contamination. Use bentonite grouts when freeze–thaw processes may affect the well.

Surface Monument Seal

Key Principals, Specifications, and Precautions

1. Protect permanent wells with a surface monument.

Discussion

Construct all permanent monitoring wells with a surface monument to protect the well casing from damage. Typically, use concrete to secure the monument and provide an additional surface seal. Install the concrete around the monument to slope away from the well casing so that it sheds water away from the well. On a site-specific basis, DEC may approve alternative well construction design; for example, where permafrost exists, frost jacking occurs, or in areas with shallow groundwater.

Construction Procedures

Key Principals, Specifications, and Precautions

1. Properly decontaminate well construction materials prior to installation.
2. Prevent contamination when joining casings and attaching the screen.
3. Pour the filter pack into the annulus to a minimum of two feet above the top of the screen and one foot beneath the well end cap.
4. Use bottom caps or end plugs.
5. Use permanent or temporary surface casing if contamination or sloughing is a potential issue.
6. Apply filter packs with a tremie pipe or similar method (unless using a pre-packed filter).
7. Reduce the required filter pack height to allow for annular space sealant.
8. Following installation, "sound" the filter pack for proper placement.

9. Place a finer-grained sand filter six inches to two feet thick at the top of the filter pack and below the annular seal to help prevent infiltration of bentonite into the filter pack.
10. Apply bentonite pellets or granules to seal the annular space by pouring freely or through a tremie pipe.
11. If the well is 40 feet or greater in depth, pump grouts or slurries to seal the annular space using a tremie pipe.
12. For wells less than 40 feet in depth, pour grouts or slurries freely with or without the use of a tremie pipe.
13. If more than 10 feet of standing water is present, use a tremie pipe to install neat cement and bentonite-cement grouts.
14. Submerge the end of the tremie pipe in the sealing material when installing a slurry or grout.
15. Allow 24 hours between annular space installation and installation of the protective cover pipe when using a slurry or grout.
16. Fill settling in the annular space seal before installing the protective cover.
17. Install a cement surface seal at the ground surface surrounding the outer surface.

Discussion

Design and install monitoring wells (Figure 5) under the direct supervision of a geologist, engineer, or other professional with direct experience in the design and installation of monitoring wells.

Properly decontaminate well casing and screen materials with detergent before use (EPA, 1991). Well construction begins with lowering a screened section connected to a section of casing into the open borehole. Care should be taken while joining the casings and attaching the screen to prevent contamination. Center the monitoring well and well screen in the borehole, then pour the filter pack into the annulus surrounding the well screen to a height of no less than two feet above the top of screen and one foot beneath the well end cap. Use centering guides to center the well screen in the borehole in deeper wells. Use bottom caps or end plugs on all monitoring wells.

Use permanent or temporary surface casing during well drilling and installation in all cases where: 1) contaminated groundwater could migrate in the borehole by gravity flow or under artesian pressure into other water-bearing zones, and 2) the formations penetrated have a tendency to slough or cave into the borehole and affect filter pack and annular seal placement or integrity.

Unless using wells with pre-packed filters, place the filter pack using a method that ensures positive placement opposite the well screen without bridging or size segregation of the filter pack material, such as by use of a tremie pipe or other similar method. If necessary, reduce the required filter pack height above the top of the well screen to six inches to allow for placement of the required volume of annular space sealant.

As the auger flights are retrieved, installers should continually measure the depth to the top of the sand pack to ensure it extends two feet above the screened intake. Following the filter pack installation, the top of the filter pack should be “sounded” to check for proper placement. Place a finer-grained sand filter six inches to two feet thick at the top of the filter pack and below the annular seal to help prevent infiltration of bentonite into the filter pack. Above the filter pack, install the annular seal to protect the well intake. Lastly, fill the annular space above the seal with grout or inert material, as discussed above.

When using bentonite pellets or granules to seal the annular space, they may either be poured freely down the borehole or added through a tremie pipe. Place the pellets to ensure bridges, gaps, or channels do not form. When using approved grouts or slurries to seal the annular space, pump the material down the borehole using a tremie pipe if the well is 40 feet or greater in depth. For wells less than 40 feet in depth, pour the material freely down the borehole with or without the use of a tremie pipe. If more than 10 feet of standing water is present, use a tremie pipe to install neat cement and bentonite-cement grouts.

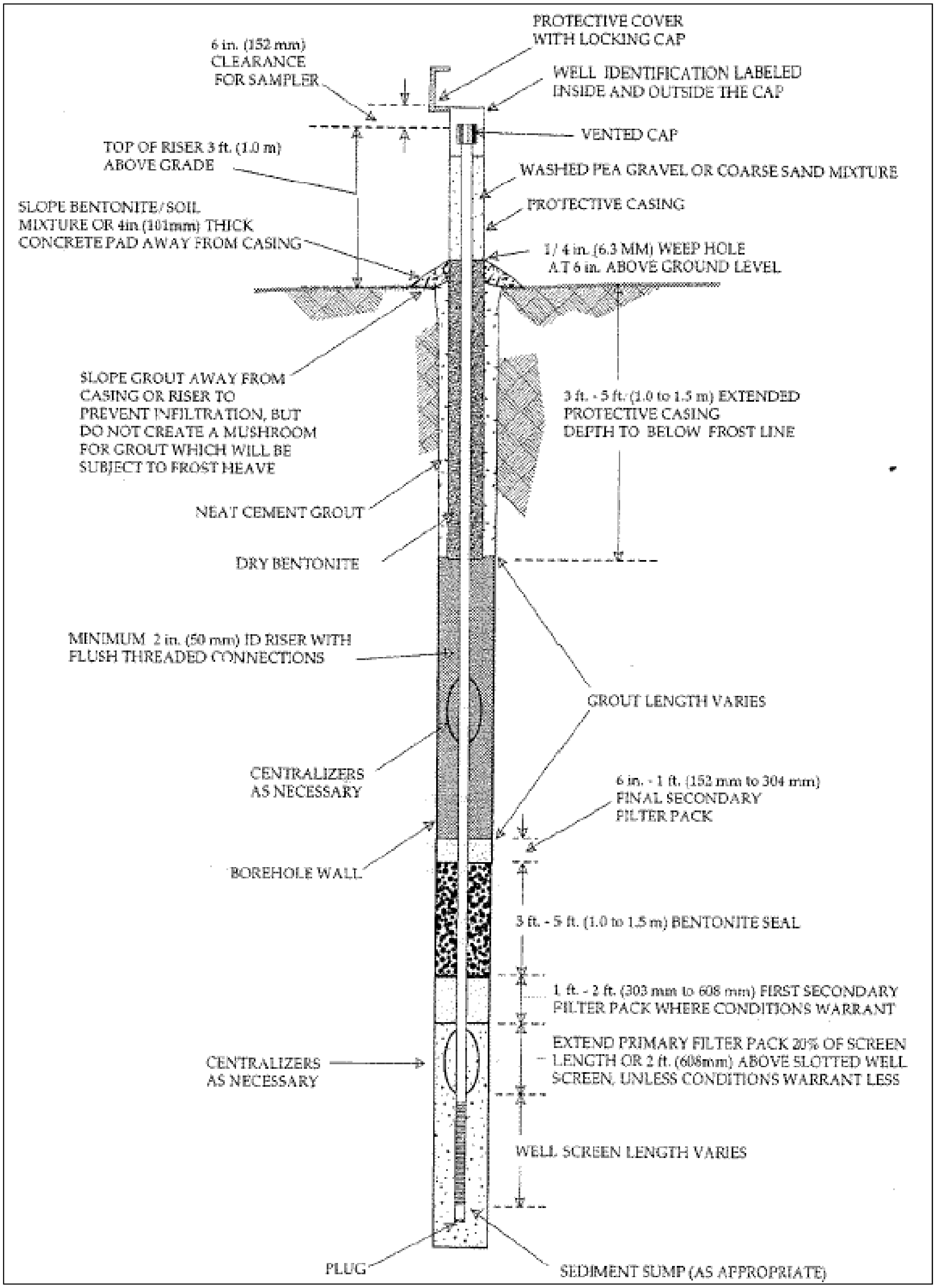


Figure 5. Example monitoring well construction design with filter pack. From ASTM 5092 (2005)[2].

[2] Extracted, with permission, from the D5092-04e1 Standard Practice for Design and Installation of Ground Water Monitoring Wells, copyright ASTM International, 100 Barr Harbor Drive, West Conshohocken, PA 19428. A copy of the complete standard is available ASTM (www.astm.org).

When using a tremie pipe to install a slurry or grout, the lower end of the pipe should remain submerged in the sealing material during the installation process. When using a slurry or grout, allow 24 hours between annular space seal installation and installation of the protective cover pipe or monument. Fill any settling in the annular space seal before installing the protective cover. Install a cement surface seal at the ground surface surrounding the outer surface casing. EPA (1991) describes surface completion is in detail.

Well Protection

Key Principals, Specifications, and Precautions

1. Install protective casings and locks for wells completed above ground.
2. For a well completed below the ground surface, install a lockable vault or equivalent.
3. Install protective guard posts.

Discussion

Monitoring wells can either be above ground or flush mounts. If the well casing is composed of metal and completed above the ground surface, attach a lockable cap to the top of the casing. If the well is not cased with metal and completed above the ground surface, install a metal protective casing around the well. Extend the protective casing at least six inches above the top of the well casing, and at least two feet into the ground. Attach a lockable cap to the top of the protective casing. For a well completed below the ground surface, install a lockable vault or equivalent around the well. Install a protective cover, level with the ground surface, with a waterproof seal to prevent the inflow of surface water. Design the cover to withstand the maximum expected loadings.

Install guard posts for monitoring wells completed above the ground to protect the wells from damage. Guard posts should consist of three metal posts at least three inches in diameter set in concrete. Install the posts in a triangular array around the casing, and at least two feet from it. Extend the posts at least three feet above and below the ground surface. Paint the above ground portion with a bright colored paint. Other surface protection methods may be used if they meet the intent of protecting the above ground portion of a monitoring well.

Restore damaged wells with well protection measures and casing as prescribed by this chapter. Decommission wells that are damaged beyond repair.

Direct Push Techniques

Key Principals, Specifications, and Precautions

1. Select the proper installation method, either exposed- or protected-screen, for the application.

Discussion

Direct push monitoring wells, sometimes known as microwells, have improved in technology over the last several years and have become increasingly common at contaminated site investigations. Significant cost savings can be achieved with direct push methods due to faster installation, replacement, and decommissioning. While the method of well installation and construction materials differs from traditional drilled wells, direct push wells are still subject to the considerations discussed in this guidance to yield representative groundwater samples.

Install direct push wells using steel drive rods advanced by hydraulic hammers or rams, directly emplacing the well screen and riser, or providing subsurface access for installation of well components similar to drilled wells. These differing installation methods are classified as either exposed-screen or protected-screen installations (see Figure 6). In an exposed-screen installation, the casing and screen surrounds the drive rods, or are used as the drive rod. During installation, the well screen is directly exposed to the formation, and installation is completed without a filter pack or annular seal. In the protected-screen installation, the casing and screen are inside the drive rod, or lowered as the drive rods are advanced. The filter pack and annular seal can be installed in the protected installation as discussed above. Alternatively, pre-packed well screens and expanding foam annular seals are commonly available for direct push wells.

Advantages of Direct Push

- Faster installation rate
- Small well diameters allows for rapid purge volume removal
- Sampling may occur immediately after installation
- Individual wells can be sequentially sampled at successive depths for a complete aquifer profile
- No soil cuttings
- More accessible in remote locations because the equipment is smaller and easier to transport
- Facilitates more complete site characterization.

Disadvantages of Direct Push

- Some installations have no filter pack, which can possibly lead to well silting
- Exposed-screen installations can "drag down" contamination
- Some conventional instruments, such as submersible pumps, may not fit in smaller diameter wells,
- Recharge rates may not be sufficient for some pump test volume requirements
- Depth for well installation is less than with a drill rig
- Cobbles in unconsolidated deposits can limit direct push rods

ASTM Standards D6001-05 (2005), D6724-04 (2004), 6725-01 (2002), ASTM D6282-98 (2005) provide detailed instructions on direct-push methods for drilling, and soil and ground-water sampling. A common problem experienced with this method in Alaska is difficult advancement of drive points and casing in some soil conditions, such as cobbles or glacial tills.

Comparison studies between direct push and hollow-stem auger drilled wells in a wide range of formations show little difference in performance. Studies conducted by BP Corporation North America Inc. and the UST Programs of the USEPA Regions 4 and 5 (2002) and Kram et al. (2001) were of short duration, but found that water-level elevations and contaminant concentrations were statistically comparable between the two well types. Bartlett et al. (2004) and BP and USEPA (2002) found that some types of direct push wells yielded slightly lower hydraulic conductivity values than drilled wells, but that proper well development and variables other than well construction were of greater significance. Direct push wells installed with proper filter packs and annular seals

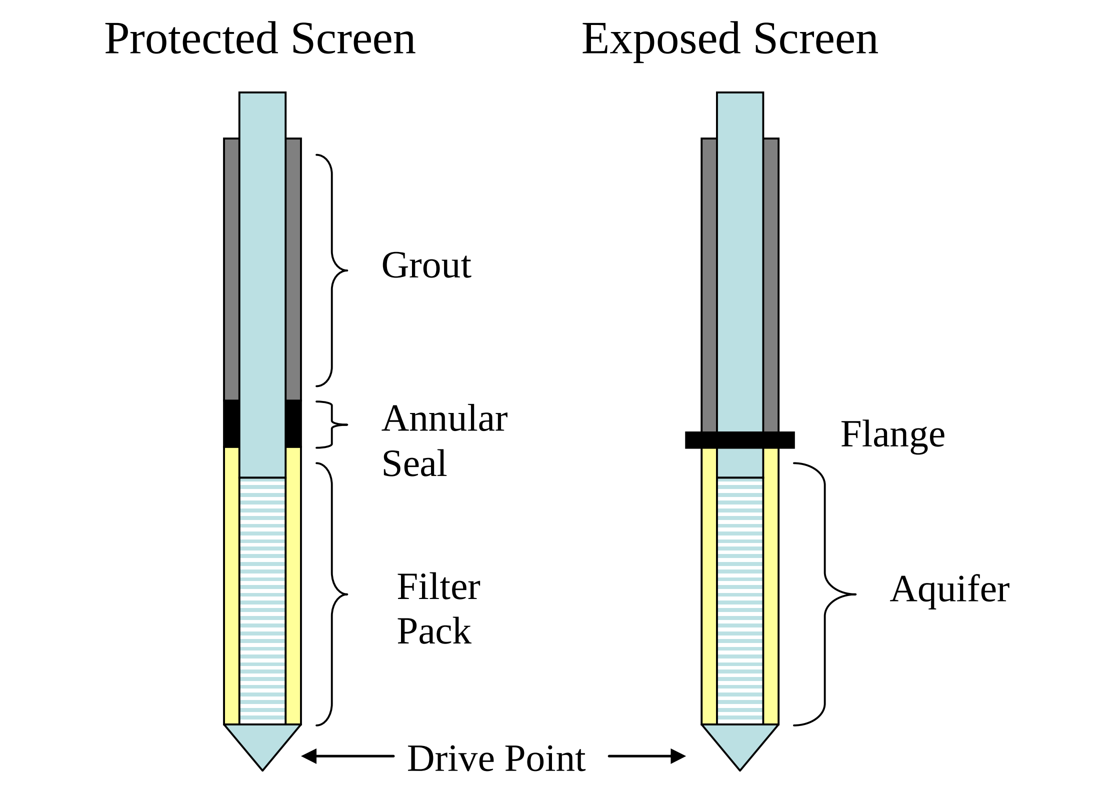


Figure 6: This diagram illustrates two different types of well installations, a "protected" screen direct push installation, and an "exposed" screen direct push installation (Naval Facilities Engineering Command, 2005).

may be approved by DEC for long-term monitoring. The lack of an annular seal in exposed-screen installations may result in the introduction of water or contaminants from the ground surface or across water bearing zones. These type of direct push well are therefore not approved for long-term monitoring, but may be appropriate for collecting grab samples during site characterization as long as the well is properly developed prior to sampling. It is important to note that the resultant data will be restricted in use.

Well Development and Maintenance

Key Principals, Specifications, and Precautions

1. Develop the well by surging, pumping, and bailing.
2. Monitor water quality parameters.
3. Do not develop the well for at least 48 hours following installation.

Discussion

The primary function of a monitoring well is to provide a representative sample of groundwater as it exists in the formation. The goal of well development is to repair the damage caused during drilling or direct-push emplacement to the area immediately adjacent to the well, ensuring proper hydraulic connection to the aquifer. Formation changes during drilling are variable, but are usually the compaction of unconsolidated particles surrounding the annulus. In fine-grained soils, this can result in a “mudwall” around the boring annulus, which can impede free flow of the formation water into the well. Development should agitate the adjacent formation and pull fines into the well, where they settle in between the filter pack and native soil boundary. Well installations in finer-grained deposits are more difficult as the filter pack will not completely stop fines from entering the well.

Common well development methods are a combination of surging, pumping, and bailing. Monitor water quality parameters such as turbidity, pH, dissolved oxygen, temperature, and specific conductance during well development. In relatively permeable formations, lower a bailer to the water column and surge by use of a surge block attached to the bailer to help breakdown any mudwall and prevent particle bridging. Pumping the unidirectional flow into the well can cause formation particles to “bridge” together and form blockages. Stopping and starting the pump can aid in a surge toward the formation, which can help break up bridged particles. It is more effective to alternate between using a surge block and bailing or pumping so that there is multidirectional flow on the filter pack around the well. Continue pumping, bailing, and surging until the turbidity caused from drilling and well installation decreases. Ideally, the formation water pulled from the well will now be clear. However, it is important not to overdevelop a well by overly aggressive surging. Occasionally, it may not be possible to clear the water from a well due to high concentrations of naturally occurring suspended solids in the aquifer.

Develop permanent groundwater monitoring wells that can be purged dry by first purging the well and then adding one well casing volume of potable water to the well. After adding the water, surge the well vigorously for approximately 10 minutes by using either a surge block or bailer. Add more water as necessary. After surging the well, purge it dry again to complete the development process. Add water only as a last resort. If the well will recover, continued development should occur only with formation water.

Alternative development procedures may be used if they will not affect the ability of the well to provide representative samples. Well development should not proceed until 48 hours after well installation to allow annular seal materials to set or cure. Although 48 hours is recommended for equilibration, DEC recognizes that remote site work may make this unpractical. Contact your DEC project manager for approval if sampling is to be conducted prior than 48 hours after installation.

DEC decisions are based on trends over time, not a single sampling event. More than one water sample is required to establish the water quality in any monitoring well, especially a newly installed well. The water quality in a newly installed monitoring well becomes more reliable over time, as the aquifer and the newly installed well reach a state of chemical equilibrium.

ASTM standard D5521 (1994) provides guidance on the development of monitoring wells, and standard D5978 (2000) provides guidance on maintaining and repairing a monitoring well. Additionally, EPA (1991) provides a detailed discussion on well development.

Monitoring Wells in Frozen Ground

Key Principals, Specifications, and Precautions

1. Minimize effects on the subsurface thermal regime.
2. Maintain wells to ensure sample collection at any time of year.
3. Ensure representative samples from the seasonal active layer.
4. Screen wells greater than the greatest expected thaw depth.
5. Consider impacts to volatile contaminants.
6. Be aware of flowing artesian conditions during installation.
7. Seal the thawed annulus between the pipe and the permafrost to prevent upward seepage.

Discussion

Design and construct monitoring wells to minimize effects on the subsurface thermal regime and to withstand freeze-thaw forces. Maintain monitoring wells that penetrate frozen ground so that representative groundwater samples can be collected during any time of the year. Design and construct monitoring wells installed into seasonally frozen ground (i.e. screened in the seasonal active layer) to obtain a representative groundwater sample during the period of thaw. Screen such wells deeper than the greatest expected depth of thaw to prevent them from going dry in the thawing season. Additionally, groundwater that rises in the casing up into the permafrost or frozen ground zone may freeze. Consider the impact on volatile constituents when using heat or compressed gas to prevent freezing.

Wells installed in a permafrost layer require special attention. Use caution when installing a well through permafrost that may be acting as a confining unit because flowing artesian conditions may occur. In addition, firmly seal the thawed annulus between the pipe and the permafrost to prevent seepage upward from the confined aquifer.

Monitoring Well Decommissioning

Key Principals, Specifications, and Precautions

1. Decommission wells that are out of use within 60 days
2. Remove the well casing/screen
3. Pipe sealing materials directly to the point of application
4. Ensure that sealing grouts are properly mixed and prepared in accordance with manufacturer recommendations prior to placement.
5. Grout/slurry sealant should be used rather than bentonite/sealant pellets in order to achieve a complete and competent seal.
6. Pellets can bridge during placement, resulting in voids and an incomplete seal.
7. If using cement grout, neat cement, or puddled clay as sealing materials below the static water level in the well, introduce from the bottom up.
8. When using a tremie tube to place grout, submerge the discharge end in the grout to avoid breaking the seal while filling the annular space.
9. For artesian wells, place a cement grout or concrete plug in the confining stratum overlying the artesian zone to prevent upward seepage from the artesian zone.
10. Fill the remainder of the well with cement grout or bentonite.
11. Record decommissioning procedures and report to DEC.

Discussion

The goal in decommissioning monitoring wells is to remove the well casing and screen in a manner that ensures that the abandoned borehole is sealed to a lesser permeability than the native soils surrounding the borehole. Casing removal is important because the outside of the casing can act as a conduit through horizontal formation changes even if the inside of the casing is grouted. The well casing and screen shall be removed when wells are decommissioned unless permafrost, remoteness of the well or other unique conditions make it impracticable. If the casing cannot be completely removed, unscrew the top section and grout from there. Otherwise, excavate the surface soil surrounding the well and cut the casing below the ground surface. DEC approval must be obtained for all monitoring well decommissioning methods.

Well decommissioning requires the prior approval of DEC. Decommission wells that are damaged beyond repair, abandoned, or not intended for future use. A well that is no longer maintained and secured is susceptible to damage that can prevent proper future decommissioning, and is a potential conduit for direct surface contamination to the aquifer. Unless DEC approves an alternative schedule, decommission wells within 60 days if they are abandoned or no longer used.

Most monitoring wells are constructed of PVC casing and screen with flush-threaded joints. Well casing and screen should typically never be removed unless sealing grout is concurrently placed in the vacated borehole during removal.

Decommissioning - Well Casing Removal: The decommissioning method is to remove the well casing ; however they should not be withdrawn without being first completely filled to near the ground surface, from the bottom up, with sealing grout. Removing the well casing and screen without the concurrent placement of grout sealant will lead to a collapsed and lost borehole that may never be properly sealed. The well casing and screen serve as the conduit allowing placement of a hose or other tremie tube to the bottom of the well for purposes of grout placement and screen using the following procedures:

- Puncture or separate the bottom well cap by driving a steel drill rod or steel pipe against/through the end cap. The well casing/screen/end cap assembly can be lifted from the borehole slightly prior to driving off the end cap, in order to raise the end cap above the underlying compacted soil and assist in breaking it off the end of the well casing/screen.

- After the end cap has been ruptured or separated, sealing grout is pumped/placed to the bottom of the well, using a hose or other tremie tube installed down the casing to the bottom of the well, until a column of grout fills the casing to the near ground surface.

- The well casing can now be withdrawn; however, the grout level within the casing will lower as the casing is withdrawn and grout will flow out the base of the well casing/screen to fill the borehole void space. Grout should be periodically added as the casing is removed to keep a column of grout near the ground surface. This will prevent the sloughing of the borehole, and fill any borehole void space, should the casing break while being pulled from the borehole.

Decommissioning – Well Casing Remaining In-Place: Permafrost or other unique circumstances may prevent the removal of the well casing and screen assembly at the time of decommissioning. If the original construction of the well is known to have included a competent annular grout seal surrounding the well casing, the screen/casing should be completely grouted in-place up to the casing cutoff point located near the ground surface.

Re-drilling the Well: Re-drilling of the well with hollow stem augers in order to seal the borehole by placing grout down the hollow augers during auger removal can be an effective fall-back option in circumstances where the well has been damaged, broken, filled, or plugged with soil or other extraneous media, preventing successful decommissioning using either of the prior two described methods. The concern with re-drilling a monitoring well borehole is there is no way to ensure that the augers will follow the original borehole to the completed well depth. For this reason, re-drilling should only be used when neither decommissioning method described above can be successfully employed. This fall-back option consists of re-drilling the borehole to the full depth of the well. PVC casing and well screen will be destroyed and broken into multiple pieces while re-drilling the borehole. After the auger string has been drilled to the total depth of the well, grout sealant is placed by hose or tremie tube to the bottom of the augers until a grout column is established within the augers to near the ground surface and the top of the drill string. Then the augers are methodically withdrawn while adding grout to maintain the grout column within the augers to near the ground surface until all of the augers have been removed.

EPA (1991) and ASTM standard D5299 (2005) discuss well decommissioning in more detail.

Sealing materials should be piped directly to the point of application by means of a dump bailer or tremie tube. If using cement grout, neat cement, or puddled clay as sealing materials below the static water level in the well, introduce from the bottom up using methods that avoid segregation or dilution of the material. When using a tremie tube to place grout, submerge the discharge end of the tube in the grout to avoid breaking the seal while filling the annular space. For artesian wells, place a cement grout or concrete plug in the confining stratum overlying the artesian zone to prevent upward seepage from the artesian zone. Fill the remainder of the well with cement grout or bentonite.

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Definitions

1) Active thaw layer - Surface layers of organic matter and mineral soil that thaw each year

2) Annular space seal - (a) For wells constructed with filter packs, the material above the top of the filter pack seal up to the surface concrete seal, and between the well casing and the adjacent formation. (b) For wells constructed in bedrock formations and without well screens, the material placed from the bottom of the enlarged drill hole up to the surface concrete seal, and between the well casing and the adjacent formation.

3) Aquifer - Geologic formation, group of formations, or part of a formation that is saturated, and is capable of providing a significant quantity of water

4) Aquitard - Lithologic unit that impedes groundwater movement and does not yield water freely to wells or springs but that may transmit appreciable water to or from adjacent aquifers.

5) Assessment monitoring - An investigative monitoring program that is initiated after the presence of a contaminant in groundwater has been detected to determine the concentration of constituents that have contaminated the groundwater and to quantify the rate and extent of migration of these constituents

6) ASTM - American Society for Testing and Materials

7) Bailer - Hollow tubular receptacle, fitted with a check valve at the bottom, used to facilitate withdrawal of fluid from a well or borehole

8) Bentonite cement grout - Mixture of five pounds of sodium based montmorillonite clay with 94 pounds of Portland cement and fix to six gallons of water

9) Bentonite slurry - Mixture of sodium based montmorillonite clay and water that has a minimum mud weight of 10 pounds per gallon

10) Borehole - Circular hole deeper than it is wide constructed in earth material for the purpose of either installing a well or obtaining geologic or groundwater related data

11) Borehole log - Record of geologic units penetrated, drilling progress, depth, water level, sample recovery, volumes and types of materials used, or other significant observations regarding the drilling of an exploratory borehole or well

12) Casing - 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, and/or to isolate the zones being monitored

13) Casing (Protective) - Section of large diameter pipe placed over the upper end of a smaller diameter monitoring well riser or casing to provide structural protection to the well and restrict access to the well.

14) Casing (Surface) - Pipe used to stabilize a borehole near the surface during and following the drilling of the borehole

15) Concrete grout - Slurry mixture of 94 pounds of cement, equal volumes of dry sand and gravel, and five to six gallons of water. The ratio of sand and gravel should not exceed three parts to one.

16) Detection monitoring – Program of monitoring for the express purpose of determining whether or not here has been a contaminant release to groundwater.

17) Drillhole – Equivalent to borehole

18) Filter pack - Clean silica sand or sand and gravel mixture of rounded grains with a selected grain size and graduation that is installed in the annular space between the borehole wall and the well screen, extending an appropriate distance above the screen for the purpose of retaining and stabilizing the particles from the adjacent strata

19) Flush-joint or flush-coupled - Casing or riser with ends threaded such that a consistent inside and outside diameter is maintained across the threaded joints or couplings

20) Grout – Low permeability material placed in the annulus between the well casing or riser pipe and the borehole wall (i.e., in a single cased monitoring well), or between the riser and casing i.e., in a multi-cased monitoring well), to maintain the alignment of the casing and riser and to prevent movement of groundwater or surface water within the annular space

21) Inside diameter - Distance, perpendicular to the long axis of the casing, between the inner walls of either a well casing, hollow stem auger, or tremie pipe

22) Neat cement grout - Slurry mixture of 94 pounds of Portland cement mixed with 5 to 6 gallons of water.

23) Piezometer - Well installed for the specific purpose of determining the elevation of the potentiometric surface

24) Purge - An action that removes water from a well, commonly accomplished using a pump or bailer

25) Riser pipe - Pipe extending from the well screen to or above the ground surface

26) Rotary drilling method - Drilling method whereby the drillhole is constructed to the depth of casing setting and the well casing is set to the bottom of the drillhole rather than driven

27) Sodium based bentonite - Clay consisting of at least 85 percent sodium montmorillonite

28) Static water level - The elevation of the top of a column of water in a monitoring well or piezometer that is not influenced by pumping or conditions related to well installation, hydrologic testing, or nearby pumpage

29) Surge - An action causing water to move rapidly in and out of the well screen thereby removing fine material from the surrounding aquifer

30) Top of bedrock - The top of firm rock, as indicated by at least 70 percent of the drill cuttings being either (1) angular rock fragments, as in the case of crystalline rock or (2) rock fragments composed of individual grains or rock particles that are cemented together to form an aggregate

31) Top of filter pack seal - Sealing material at least two feet in length placed in the annular space above the filter pack and below the annular space seal

32) Tremie pipe - Metal pipe or steel wire-braided, rubber-covered hose used to convey well construction materials down a drillhole

33) Unconsolidated material - Material found above firm bedrock, composed of single sediment particles, individual grains or rock fragments

34) Water table - The surface of unconfined groundwater where the pressure is equal to atmospheric pressure

35) Water table observation well - Any groundwater monitoring well installed for the specific purpose of determining either the elevation of the water table, or the physical, chemical, biological, or radiological properties of groundwater at the water table or both

36) Well depth - Distance from the land surface to the bottom of the well screen or drillhole

37) Well screen - Filtering device used to retain the primary or natural filter pack, usually a cylindrical pipe with openings of a uniform width, orientation, and spacing

38) Well volume - Volume of water standing in the well casing

39) Zone of saturation - A hydrologic zone in which all the interstices between particles of geologic material or all of the joints, fractures, or solution channels in a consolidated rock unit are filled with water at pressure greater than that of the atmosphere