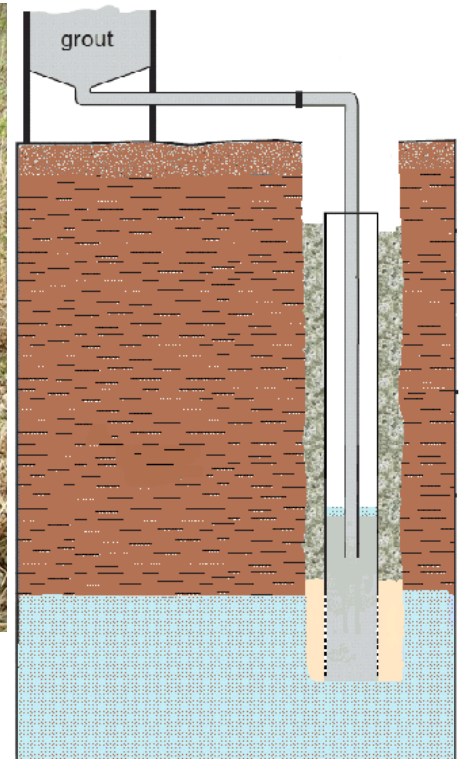




Technical Guidance Manual for Hydrogeologic Investigations and Ground Water Monitoring

Chapter 9

Sealing Boreholes and Decommissioned Monitoring Wells



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**TECHNICAL GUIDANCE MANUAL FOR HYDROGEOLOGIC
INVESTIGATIONS AND GROUND WATER MONITORING**

CHAPTER 9

**Sealing Boreholes and Decommissioned
Monitoring Wells**

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PREFACE

The subject of this document is techniques to characterize hydrogeology beneath a site. It is part of a series of chapters incorporated in Ohio EPA's *Technical Guidance Manual for Hydrogeologic Investigations and Ground Water Monitoring* (TGM), which was originally published in 1995. Ohio EPA now maintains this guidance as a series of chapters rather than as an individual manual. These chapters can be obtained at epa.ohio.gov/ddagw/tgmweb.aspx.

The TGM identifies technical considerations for performing hydrogeologic investigations and ground water monitoring at potential or known ground water pollution sources. The purpose of the guidance is to enhance consistency within the Agency and inform the regulated community of the Agency's technical recommendations and the basis for them.

Ohio EPA utilizes guidance to aid regulators and the regulated community in meeting laws, rules, regulations and policy. Guidance outlines recommended practices and explains their rationale. The methods and practices described in this guidance are not intended to be the only methods and practices available to an entity for complying with a specific rule. Unless following the guidance is specifically required within a rule, the agency cannot require an entity to follow methods recommended by the guidance. The procedures used to meet requirements usually should be tailored to the specific needs and circumstances of the individual site, project, and applicable regulatory program, and should not comprise a rigid step-by-step approach that is utilized in all situations.

CHANGES FROM THE APRIL 2015 TGM

Ohio EPA's *Technical Guidance Manual for Hydrogeologic Investigations and Ground Water Monitoring* (TGM) was first finalized in 1995. Chapter 9 (Monitoring Well and Borehole Abandonment) was subsequently updated in February of 2009.

One major change has been made since February, 2009. Per the Ohio EPA DERR-SIFU FSOP 1.9, Boring and Monitoring Well Decommissioning, finalized in September, 2015, drill cuttings may be used to fill in the borehole under very specific circumstances (Section 1.4).

This is the third revision to the chapter.

Section numbers were added to make the document easier to read. Wording has been changed from "abandoning" to "decommissioning".

References were updated, in particular, the references to Ohio Water Resources Council's (OWRC) *Regulations and Technical Guidance for Sealing Unused Water Wells and Boreholes*, finalized March 2015.

CHAPTER 9

SEALING BOREHOLES AND DECOMMISSIONED MONITORING WELLS

Exploratory boreholes that are not completed as monitoring wells and decommissioned monitoring wells that no longer are needed for sampling or potentiometric monitoring should be sealed properly. Proper sealing is necessary to:

- prevent poor quality water from one saturated zone entering another;
- prevent contamination of the ground water by surface contaminants;
- restore an aquifer to as close to its original condition as possible;
- eliminate physical hazards; and
- reduce potential for future liability.

A suitable program should be designed and implemented to meet these objectives. This guidance document provides recommendations on sealing materials, procedures to appropriately seal a borehole or decommissioned monitoring well and documentation of sealing activities. The sealing material and method depends on:

- the design and construction of the well/borehole,
- hydrogeologic conditions,
- the chemical environment,
- safety hazards and
- disposal of contaminated materials removed.

In general, sealing should consist either of a method for well removal and simultaneous grouting of the borehole with sodium bentonite, neat cement, a bentonite/cement mixture, or a method for grouting in-place that ensures complete sealing. Additional guidance on sealing of all types of wells can be found in the [Regulations and Technical Guidance for Sealing Unused Water Wells and Boreholes](#) (OWRC, 2015).

1.0 SEALING MATERIALS

1.1 QUALIFICATIONS FOR SEALING MATERIALS

The chosen sealing material should:

- Not react with contaminants, ground water, or geologic materials;
- Have a hydraulic conductivity equivalent to or lower than the in-situ material;
- Form a tight bond with the borehole wall and well casing;
- Be resistant to cracking and/or shrinking;

- Be of sufficient structural strength to withstand subsurface pressures; and
- Be capable of being placed at the appropriate depth.

Chapter 7 (Monitoring Well Design and Installation) should be consulted for details on different types of sealants and their application. No single material exhibits all of the desirable characteristics. Therefore, every situation should be evaluated carefully to determine the appropriate choice. Generally, materials used are sodium bentonite, neat cement or a bentonite/cement mixture. Concrete, asphalt or soil may be used to complete the sealed boring or well near within two to three feet of the ground surface depending of site conditions.

1.2 TYPES OF SEALING MATERIALS

1.2.1 Neat Cement or Sodium Bentonite

Most wells completed in unconsolidated formations or non-creviced rock may be satisfactorily sealed with neat cement or sodium bentonite. "Neat cement" is comprised of Portland cement and fresh water with no aggregate added. Wells that penetrate limestone or other creviced or channeled rock formations should be filled with concrete grout or neat cement to ensure seal permanence. The use of fine-grained materials to seal creviced rock may not be desirable because the materials might be displaced by flow of water through crevices (American Water Works Association, 1984). Neat cement or sodium bentonite should be used for sealing a borehole or decommissioned monitoring well below the water table (Gordon and Koch, 1988). Above the water table, sodium bentonite should be utilized. Sodium bentonite chips or pellets placed above the water table require addition of water during sealing. Neat cement may shrink if placed above the water table.

1.3 BENTONITE-CEMENT MIXTURE

A common sealing practice is to use a bentonite-cement mixture. Some have recommended a two to six weight percent of bentonite mixed with neat cement to reduce shrinkage. However, this may actually increase shrinking as it ties up water that would be incorporated in the cement. In addition, bentonite cannot compensate for shrinkage, as much of the sodium associated with bentonite mixed into a cement slurry is replaced by calcium due to ion exchange. Calcium bentonite has little or no expansive capacity (Smith, 1994). Therefore, cement-bentonite sealants should be used with care (Christman et al., 2002; Edil et al., 1992).

1.4 USE OF CUTTINGS/OTHER MATERIALS

In general, use of cuttings is not recommended. However, soil borings that are 6 feet deep or less and do not intersect the water table may be backfilled with the soil cuttings, topsoil, or other clean fill materials (e.g., sand or gravel) rather than bentonite provided that:

- The Ohio EPA client division representative approves of using a clean soil or fill material;

- The soil boring does not encounter any hazardous waste, solid waste, or construction and demolition debris (C&DD) materials
- The soil cuttings or other materials used for backfill are not known to contain contaminants exceeding any federal or state regulatory concentration levels
- The soil cuttings or other materials used for backfill do not contain any solid waste or C&DD (DERR-SIFU's FSOP for Boring and Monitoring Well Decommissioning, 2015)

In coarse gravel, where excessive loss of sealing materials may occur, or when grout may affect the water quality of nearby monitoring wells, clean sand or gravel or crushed rock in conjunction with regular materials can be used (Gordon and Koch, 1988; Kraemer et al., 1991).

2.0 PROCEDURES

Ohio EPA recommends the following procedure for sealing exploratory boreholes and decommissioned monitoring wells. The first two steps (2.1.1 and 2.1.2) are not necessary for sealing of exploratory boreholes. Ohio EPA understands that no single sealing method and material are suitable for all situations. Site-specific characteristics may merit modifications of the procedures discussed below or alternative procedures. All procedures and materials used must effectively seal the borehole or monitoring well and be protective of human health and the environment. Additional information is available in the reference section.

2.1 PLANNING

2.1.1 Historical and Current Conditions Review

Careful review should be conducted prior to sealing monitoring wells. This may include:

- Review of records pertaining to well construction and repair or modifications;
- Review of analytical chemical data for soil and ground water;
- Review of the hydrogeologic/geologic characteristics in the vicinity of the well; and
- Current conditions of the well, such as, total depth, amount of siltation, etc.

If a well is to be left in place, borehole geophysical techniques may be helpful in determining its integrity. This may include caliper logs to measure inside diameter; television logs to identify casing breaks, screen size, etc.; gamma logs to verify geologic information; cement bond logs to determine if the casing is firmly attached to the grout; flow logs to determine if vertical flow occurs within the casing; and hydraulic integrity tests to determine if the casing is intact (ASTM, D5299-99(2012)e1). For additional information on downhole logs, see Chapter 16, Application of Geophysical Methods for Site Characterization.

2.1.2 Detailed Workplan

Prior to the sealing of monitoring wells, Ohio EPA recommends that a work plan detailing the procedures/methods be submitted to the appropriate regulatory authority. The work plan should include:

- 1. The reasons for decommissioning and sealing the monitoring well**
- 2. Monitoring well information:**
 - a. Identification/designation and location coordinates (latitude/longitude or state plane)
 - b. The following well construction information, preferably on a well construction diagram with a drilling log documenting hydrogeologic conditions:
 - i. Surface seal and surface casing types
 - ii. Borehole diameter
 - iii. Total depth
 - iv. Casing type, diameter and length
 - v. Grout type(s) and depth
 - vi. Screen type, diameter and length
 - vii. Filter pack type and depth
 - viii. Geologic characteristics of the saturated zone or aquifer
 - c. Type and concentrations of remaining contaminants (if any)
- 3. Sealing procedures** (for each monitoring well to be sealed)
 - a. Final static water level and total depth measurements
 - b. Method(s) used to seal the monitoring well
 - c. Type(s) of materials used to seal the monitoring well, including an estimated volume of the sealing materials used
 - d. Field notes/report documenting the sealing procedures, including documentation of any problems encountered and steps taken to resolve them
- 4. Measures to protect health and safety during sealing** (or a separate health and safety plan that includes monitoring well sealing)

2.2 FIELD PROCEDURE

Monitoring wells have often been sealed by pulling the surface casing where possible, followed by pouring cement or bentonite into the hole. This procedure is inappropriate, especially if the construction of the well is unknown or the well intake spans more than one saturated zone. Incomplete seals may form due to bridging. Additionally, the procedure has little effect on the filter pack, which may allow communication between saturated zones.

2.2.1 Inspection and Preparation

Inspect the well and remove any obstacles (i.e., pumps, pressure lines, other debris, etc.) that may interfere with the placement and performance of the sealing material. If necessary, a camera survey can help to identify the depth and construction of the well if this information is not known. The outer protective casing should be removed.

2.2.2 Casing Removal

When the annular seal is inadequate, the filter pack connects two or more water bearing zones, water is flowing from around the outside of the casing, or when construction details are not known, the casing, screen, annular seal and filter pack should be removed. The casing and well screen can be removed by pulling or bumping the casing, overdrilling around the casing using a hollow stem auger, or drilling out the well using a solid stem auger or rotary bit (see Table 9.1). The method used should depend on the type, length, and diameter of the casing, conditions of the annular seal, and site geology. Aller et al. (1991) and ASTM D5299-99(2012)e1 provide a discussion on various removal techniques. Ohio EPA recommends the borehole be overdrilled using a bit with a diameter at least 1.25 times greater than the original diameter of the borehole. Drilling should be slightly deeper than the original depth to assure complete removal. To achieve an effective seal, the borehole should be cleared of any excess mud filtercake.

Table 9.1 Techniques for casing removal.

TECHNIQUE	METHOD
Pulling or bumping	Use a rig to pull out the well casing. This may be appropriate only for steel casing since plastic/Teflon casing may break.
Overdrilling	Drill around the well using the well casing as a guide, then pull out the casing. This method is limited by well diameter due to the high torque required to turn large diameter augers.
Drilling through well	Use a solid stem or rotary bit to drill the casing out. This can be done only with plastic/Teflon well material. It can be difficult to retrieve the cutting.

2.2.3 Sealing in Place

In some instances, such as when safety problems occur or when dealing with large diameter wells, casing removal can be difficult. If circumstances prevent complete removal of casing and screen, then the following procedure can be used (based on Renz, 1989):

- The well can be filled with clean (ANS/NSF 61¹) filter sand to one foot above the screen in the event that the screened area is adjacent to a highly permeable formation.
- One foot of bentonite chips/pellets can be placed above the screen in a manner that prevents bridging (i.e., through a tremie pipe or by tamping after installation). (Note: chips are recommended below the water table because they quickly sink; processed pellets are lighter and tend to float and fall slowly through the water column.)
- The chips/pellets should be hydrated, if placed above the water table.
- To allow the sealant to permeate and be effective, the casing should be perforated to one foot above the bentonite seal either by splitting it vertically (synthetic casing) or by making horizontal cuts every two feet with a retractable blade (steel casing).

Since the primary purpose of sealing is to eliminate vertical fluid movement, it is recommended that the casing and screen be removed and the boring be overdrilled to remove the annular seal and filter pack. However, monitoring wells can be sealed in-place when the construction details are known, the annular seal is intact, and the filter pack does not cross more than one ground water zone.

2.2.4 Disinfecting Wells/Boreholes

Where evidence of microbiological growth is a concern, a monitoring well may need to be disinfected. However, before disinfecting, an evaluation as to whether this would affect water quality monitoring results in the proximity should be made.

When such a concern is present, wells should be disinfected by slowly wetting the circumference of the well/borehole with the disinfection solution by using a tremie pipe starting from the bottom of the well and working upwards to assure that all sides are wetted by the solution. The solution should be well mixed within the well/borehole and purged before sealing with grout. Contact of disinfectant with bentonite should be avoided. The bentonite grout will not seal properly if it comes into contact with the disinfection solution. The disinfectant should:

- Have a concentration in the water column of approximately fifty milligrams per liter (mg/L) total chlorine, but no more than 100 mg/L.
- Have standard ANSI/NSF 60 certification. Standard ANSI/NSF 60 refers to "Standard ANSI/NSF 60, Drinking Water Treatment Chemicals - Health Effects", October 6, 2015, Document Number NSF/ANSI 60-2015 ([NSF Web Site](http://www.nsf.org/services/by-industry/water-wastewater/municipal-water-treatment/nsf-ansi-standard-61)).

¹ NSF/ANSI Standard 61: Drinking Water System Components -- Health Effects are both American National Standards, which means that the NSF Standards and the processes used to develop them conform to ANSI's requirements for voluntary consensus standards (<http://www.nsf.org/services/by-industry/water-wastewater/municipal-water-treatment/nsf-ansi-standard-61>).

2.2.5 Grouting the Borehole

The borehole should be pressure grouted using a tremie pipe as the drilling stem is removed. The sealant should be applied in one continuous procedure to prevent segregation, dilution, and bridging (Aller et al., 1991). The pipe should be in constant contact with the sealant to prevent air pockets from forming. The borehole should be sealed from the bottom up to the frost line (approximately two to three feet from the surface). The overflowing grout should be regularly evaluated as it reaches the surface. When the observed material is similar to that being pumped in, this stage of the sealing is considered complete. Wells sealed in-situ should be sealed from the bottom up to approximately three feet from the surface.

- Small diameter wells or boreholes (<2 inches) may present special challenges. A small diameter (3/4 inch) grout pipe can be used; however, high pumping pressures or less viscous materials may be necessary (ASTM D5299-99(2012)e1). Grouting machines are available for use with small diameter wells. A grouting machine reduces problems of bridging and incomplete seals associated with adding materials from the ground surface.
- When sealing wells that have two or more saturated zones or in flowing wells, it may be necessary to use a packer assembly. An inflatable packer can be placed at the top of the producing water zone to stop or restrict flow. The borehole can be sealed by pressure grouting from the bottom of the hole to the top of the packer. The packer can then be deflated and the grouting process continued.
- If dry sealant is introduced by gravity pouring, care must be taken that bridging does not occur. This can be accomplished by slowly adding the grout and stopping periodically (e.g., every five feet) to measure, tamp the grout and add water to hydrate. The amount of added water should be in accordance with manufacturer specifications. Coarse grade or bentonite pellets should be poured over a wire mesh to remove fines.

2.2.6 Completion of Borehole

The grout plug should be inspected 24 hours after installation to check for settling; grout should be added if needed. If the well is sealed in-place, the casing should be cut off approximately three feet below ground level and a PVC or stainless steel cap should be emplaced. The boring should be grouted to within two to three feet from the surface with appropriate material. Monitoring wells sealed in-place should be marked with a piece of metal to allow for location by a metal detector or magnetometer (Aller et al., 1991).

2.2.7 Final Surface Seal

The remaining area above the plug should be completed in a manner that is compatible with the site. For example, its top can be covered with one to two feet of soil if vegetative growth is desired. If the area is to be surfaced, then the final seal can be completed with asphalt or concrete.

2.3 DOCUMENTATION

2.3.1 Report Submittal to Ohio EPA

Proper sealing of monitoring wells/boreholes should be documented and reported to the Ohio EPA division regulating the site. The information should include, at a minimum:

- Identification (e.g., registration number, location, owner, and any other features).
- Well construction details.
- Date, time, person responsible, and contractor/consultant performing the work.
- Authority under which sealing was performed.
- Procedures and materials used (including predicted volume of grout, volume of grout used, and an explanation if any discrepancy exists between these values).
- Method/procedures for disposal of any contaminated materials. (Disposal of any contaminated material must be in accordance with any federal, state, or local regulations.)

2.3.2 Report Submittal to Ohio Department of Natural Resources (ODNR)

The Ohio Revised Code 1521.05(C) requires that a well sealing report be filed with the Ohio Department of Natural Resources (ODNR). Figure 9.1 is an example of the form. It can be obtained from ODNR, Division of Water (614-265-6739).

WATER WELL SEALING REPORT e-FORM
OHIO DEPARTMENT OF NATURAL RESOURCES
Division of Soil and Water Resources
2045 Morse Road, Bldg B
Columbus, OH 43229-6693
Voice: (614) 265-6740 Fax: (614) 265-6767

Sealing Report No.
0

LOCATION

County GEAUGA Township PARKMAN Section No. _____ Lot No. _____

Owner E. J. FUDD

Address of Well Location 1234 NOTKNOWN RD.

City ANYTOWN Zip Code 00000-1230

Well Location Description (120 Characters) 1/2 mile south of Maindrag on west side of Notknown.

Location of Well in either:
 { State Plane N S X _____ +/- _____ ft. Y _____ +/- _____ ft. }
 OR
 { Latitude/Longitude Latitude 41.41234 Longitude -81.01234 }

Elevation of Well 1022.00 +/- _____ ft. Datum Plane: NAD27 NAD83

Source of Coordinates: GPS Survey Other _____

Source of Elevation: GPS Survey Other _____

WELL IDENTIFICATION ODNR Well Log Number 123456 Project Well ID _____

MEASURED CONSTRUCTION DETAILS

Date of measurements 08/06/2012

Depth of Well 106 ft. Static Water Level 83 ft.

Borehole Depth 106 ft. Borehole Diameter _____ in.

Casing Diameter 5.63 in. Casing Length 27 ft. Casing Type steel

SEALING PROCEDURE

Placement:	Sealing Material	Volume/Weight Used <small>Units Required</small>	Placement Method
From <u>0</u> ft. To <u>106</u> ft.	<u>Bentonite/polymer slurry</u>	<u>115 gals/250 Lbs</u>	<u>Pumped w/tremie pipe</u>
From _____ ft. To _____ ft.	_____	_____	_____
From _____ ft. To _____ ft.	_____	_____	_____
From _____ ft. To _____ ft.	_____	_____	_____

Condition of Casing good Was Casing Removed? Yes or No (check one)

If casing **Not Removed**, was it Perforated? Yes or No (check one) Perforations: From _____ ft. To _____ ft.

Date Sealing Performed 08/08/2012

Comments/Reason for Sealing VERY HIGH IRON LEVELS WHICH KEEPS SEALING OFF THE WATER

CONTRACTOR

Name ACME DRILLING COMPANY ODH Registration # 9876

Address 1234 MAIN ST.

City/State/Zip SOCKERDOWNE, OH 56789

e-Signature W. E. COYOTE Filed electronically on 08/06/2012
I hereby certify the information given is accurate and correct to the best of my knowledge.

Completion of this form is required by section 1521.05, Ohio Revised Code - file within 30 days after completion of sealing. Distribute additional copies to: Customer, Driller and Local Health Department.

Figure 9.1 Example of an official Ohio water well sealing report form
(Contact ODNR, Division of Water for Form. 614-265-6739).

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