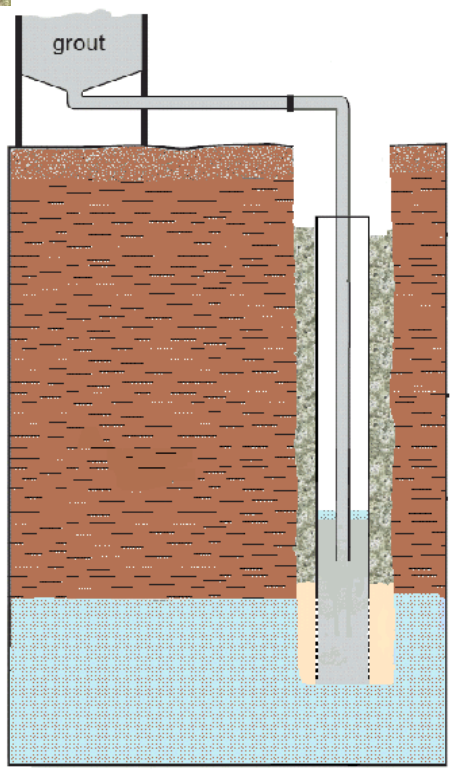
State of Ohio
Environmental Protection Agency

Division of Drinking and Ground Waters

Technical Guidance Manual for Ground Water Investigations

Chapter 9

Sealing Abandoned Monitoring Wells and Boreholes



February 2009

Governor : Ted Strickand
Director : Chris Korleski

TECHNICAL GUIDANCE MANUAL FOR GROUND WATER INVESTIGATIONS

CHAPTER 9

SEALING ABANDONED MONITORING WELLS AND BOREHOLES

October 2009
Revision 2

Ohio Environmental Protection Agency
Division of Drinking and Ground Waters
P.O. Box 1049 50 W. Town Street, Suite 700
Columbus, Ohio 43216-1049
Phone: 614-644-2752
http://www.epa.state.oh.us/ddagw/

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. DDAGW now maintains this guidance as a series of chapters rather than as an individual manual. These chapters can be obtained at http://www.epa.state.oh.us/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. In Ohio, the authority over pollution sources is shared among various Ohio EPA divisions, including the Emergency and Remedial Response (DERR), Hazardous Waste Management (DHWM), Solid and Infectious Waste (DSIWM), and Surface Water (DSW), as well as other state and local agencies. DDAGW provides technical support to these divisions.

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. Note that the term implies no enforcement authority. The Agency may not require an entity to follow methods recommended by this or any other guidance document. It may, however, require an entity to demonstrate that an alternate method produces data and information that meet the pertinent requirements. Ohio EPA recognizes that inflexibility in the language and/or interpretation of guidance can lead to the adoption of inappropriate measures, delay, and inefficiency. 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.

ACKNOWEDGMENTS

This guidance was developed by Ohio EPA's Division of Drinking and Ground Waters (DDAGW). The following are acknowledged.

Lisa Koenig, DDAGW-CO had primary responsibility for researching and writing this chapter in 1995 and completing this updated version.

Jeff Patzke, DDAGW-CO who served as editor and project coordinator the Technical Guidance Manual.

Jeff Martin, DDAGW-CO, **Rich Bendula**, DDAGW-SWDO, and **Ralph Baker**, DDAGW-NWDO, and **Eric Sainey**, DERR-CO provided technical input to the updated version.

The Ohio EPA would also like to thank the numerous people who provided input during the development of the 1995 document. The comments and recommendations from the DDAGW-District Offices, and other Ohio EPA Divisions, State and Federal Agencies, private consultants, and regulated community were greatly appreciated.

TECHNICAL CHANGES FROM FEBRUARY 2005

The Ohio EPA Technical Guidance Manual for Hydrogeologic Investigations and Ground Water Monitoring (TGM) was finalized in 1995. This document represents an update to Chapter 9 (Monitoring Well and Borehole Abandonment) of the 1995 TGM.

No major changes were made. Some clarification was added for when disinfection of a well/borehole is needed prior to sealing.

TABLE OF CONTENTS

CHAPTER 9
SEALING ABANDONED MONITORING WELLS AND BOREHOLES

Boreholes that are not completed as monitoring wells and monitoring wells that no longer are being sampled or used for ground water level measurements are considered abandoned and should be sealed properly. Proper sealing is necessary to: 1) prevent poor quality water from one saturated zone entering another, 2) prevent contamination of the ground water by surface contaminants, 3) restore an aquifer to as close to its original condition as possible, 4) eliminate physical hazards, and 5) 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 an abandoned well/borehole and documentation of sealing activities. The sealing material and method depends on: 1) the design and construction of the well/borehole, 2) hydrogeologic conditions, 3) the chemical environment, 4) safety hazards and 5) disposal of contaminated materials removed. In general, sealing should consist either of a method for well removal and simultaneous grouting of the borehole with bentonite, neat cement, or 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 "State of Ohio Technical Guidance For Sealing Unused Wells" (SCCGW, 1996).

SEALING MATERIALS

The chosen sealing material should:

- Not react with contaminants, ground water, or geologic materials.
- Have a hydraulic conductivity comparable 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.
- 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 comprised of concrete, neat cement, or sodium bentonite.

Most wells completed in unconsolidated formations or non-creviced rock may be satisfactorily sealed with neat cement or bentonite. 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 an abandoned well/borehole below the water table (Gordon and Koch, 1988). Above the water table, 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.

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 can not 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).

At no time should a borehole or well be backfilled with cuttings or with any materials of unknown integrity. However, in some geologic environments, such as 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).

PROCEDURES
PLANNING

Careful review should be conducted prior to sealing abandoning 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.
- 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). For additional information on downhole logs, see Chapter

Prior to the sealing of monitoring wells, it is recommended that a work plan detailing the procedures/methods be submitted to the appropriate regulatory authority.[1] The information should include:

- Reasons for sealing.
- Identification and location coordinates.
- Casing diameter and material.
- Screen material, length, and depth.
- Total depth.
- Geologic materials opposite well screen.
- Drilling log and construction diagrams.

---

[1]If a regulated entity is conducting a hydrogeologic investigation or a ground water monitoring program, a ~~well sealing~~ work plan should be submitted prior to initiating the program. In this situation, a separate workplan is not necessary.

- Type and concentrations of contaminants present[2], if any.
- Procedure for disposal of any contaminated media.
- Method for sealing.
- Type of sealing material.
- An estimation of the volume of sealing material needed.
- Measures to protect the health and safety of individuals.

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.

The following basic procedure is recommended for sealing monitoring wells and boreholes. Steps 1 and 2 are not necessary for sealing of exploratory boreholes. It should be understood that no single method and material are suitable for all situations. Site-specific characteristics may merit modifications or procedures not discussed below. Additional information can be found in the references listed.

1. 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. 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 5299-99 provided a discussion on various removal techniques. The borehole should be overdrilled using a bit with a diameter at least 1.5 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.

   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):

[2]If contamination was detected or suspected in the original well or boring, appropriate health and safety requirements should be followed.

a. The well can be filled with clean (ANS/NSF 61[3]) disinfected sand to one foot above the screen in the event that the screened area is adjacent to a highly permeable formation.

b. 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 will sink, whereas pellets will often float to the water table.)

c. The chips/pellets should be hydrated, if placed above the water table.

d. 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.

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.

3. Where evidence of microbiological growth is present, 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 needed, 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

[3] 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/business/water_distribution/standards.asp?program=WaterDistributionSys).

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", February 9, 2001, Document Number NSF/ANSI 60-2001 (NSF Web Site).

4. 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). 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.

5. 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).

6. 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 cement or concrete.

7. 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.)

Additionally, Ohio Revised Code 1521.05(B)(9) 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
(For Abandoned or Unused Wells)
OHIO DEPARTMENT OF NATURAL RESOURCES
Division of Water, Ground Water Resources Section
1939 Fountain Square Drive
Columbus, Ohio 43224-1360

LOCATION

County _____ Township _____ Section _____
Property Owner _____
Address of Property _____
Location: _____ miles _____ (n, e, s, w) of _____ (nearest intersection)
on the _____ (n, e, s, w) side of _____ (road name)

ORIGINAL WELL

ODNR Well Log Number _____ Copy attached? Yes or No (circle one)

MEASURED CONSTRUCTION DETAILS Date of measurements _____

Depth of Well _____ Static Water Level _____
Size of Casing _____ Length of casing _____
Well Condition _____

SEALING PROCEDURE

Method of Placement _____

			Sealing Material	Volume
Placement:	From _____	To _____	_____	_____
	From _____	To _____	_____	_____
	From _____	To _____	_____	_____

Was Casing Removed? Yes or No (circle one)
Condition of Casing _____
Perforations: From _____ To _____
From _____ To _____
Date Sealing Performed _____
Reason(s) for Sealing _____

CONTRACTOR

Name _____ ODH Registration # _____
Address _____
City/State/Zip _____ Signature _____

DNR 7810.93 **SUBMIT COMPLETED FORM TO ODNR-DIVISION OF WATER**

Figure 9.1 ODNR form for reporting well abandonment procedures.

(Contact ODNR, Division of Water for Form. 614-265-6739).

REFERENCES

Aller, L., T. W. Bennett, G. Hackett, R. J. Petty, J. H. Lehr, H. Sedoris, D.M. Nielsen, and J. E. Denne. 1991. Handbook of Suggested Practices for the Design and Installation of Ground Water Monitoring Wells. Environmental Monitoring Systems Laboratory, Office of Research and Development, U.S. Environmental Protection Agency. Las Vegas, Nevada. EPA/600/4-89/034. (In cooperation with the National Water Well Association).

American Society for Testing Materials. Method D5299-99(2005). Decommissioning of Ground Water Wells, Vadose Zone Monitoring Devices, Boreholes, and other Devices for Environmental Activities. American Society for Testing Material Standards. Philadelphia, Pennsylvania.

American Water Works Association. 1984. Appendix I: Abandonment of Test Holes, Partially Completed Wells, and Completed Wells. American Water Works Association Standard for Water Wells. American Water Works Association. Denver, Colorado. pp. 45-47.

Christman, M., C.H. Benson, T.B. Edil. 2002. Geophysical Study of Annular Well Seals. Ground Water Monitoring and Remediation. Volume 22, Number 3, pp. 104-12.

Edil, T.B., M.M.K. Chang, L.T. Lan, T.V. Riewe. 1992. Sealing Characteristics of Selected Grouts for Water Wells. Ground Water. Volume 30, Number 3, pp. 351-361.

Gordon, D. L. and D. Koch. 1988. Guidelines for Plugging Abandoned Water Wells. Iowa Department of Natural Resources, Geological Survey Bureau. Technical Information Series 15. Iowa City, Iowa.

Kraemer, C. A., J. A. Shultz, and J. W. Ashley. 1991. Monitoring Well Post-Installation Considerations. In: D. M. Nielsen (editor), Practical Handbook of Ground-Water Monitoring. Lewis Publishers, Inc. Chelsea, Michigan. pp. 333-363.

Renz, M. E. 1989. In-Situ Decommissioning of Ground Water Monitoring Wells.Water Well Journal. Vol. 43, No. 5, pp. 58-60.

Smith, A. Stuart. 1994 Well & Borehole Sealing: Importance, Materials, Methods and Recommendations for Decommissioning. Ground Water Publishing Co. Dublin, Ohio.

State Coordinating Committee on Ground Water. 1996. State of Ohio Technical Guidance for Sealing Unused Wells.