CHAPTER 7: WELL ABANDONMENT PROCEDURES

7.1 INTRODUCTION

Unsealed or improperly sealed wells may threaten public health and safety, and the quality of the groundwater resources. Therefore, the proper abandonment (decommissioning) of a well is a critical final step in its service life.

Act 610, the Water Well Drillers License Act, includes a provision for abandonment of wells. This legislation makes it the responsibility of a well owner to properly seal an abandoned well according to the rules and regulations of the department. In the absence of more stringent regulatory standards, the procedures outlined in this section represent minimum guidelines for proper abandonment of wells and borings. These procedures may be applicable for, but not limited to, public and domestic water supply wells, monitoring wells, borings or drive points drilled to collect subsurface information, test borings for groundwater exploration, and dry wells (drains or borings to the subsurface).

Proper well abandonment accomplishes the following: 1) eliminates the physical hazard of the well (the hole in the ground), 2) eliminates a pathway for migration of contamination, and 3) prevents hydrologic changes in the aquifer system, such as the changes in hydraulic head and the mixing of water between aquifers. The proper decommissioning method will depend on both the reason for abandonment and the condition and construction details of the boring or well.

7.2 WELL CHARACTERIZATION

Effective abandonment depends on knowledge of the well construction, geology, and the hydrogeology. The importance of a full characterization increases as the complexity of the well construction, site geology, and the risk of aquifer contamination increases. Construction information for wells drilled since 1966 may be available from the Bureau of Topographic and Geologic Survey's (BTGS) Water Well Inventory System database. Additional well construction data and information describing the hydrologic characteristics of geologic formations may be available from reports published by BTGS and the United States Geological Survey (USGS). Site or program records also may exist. The well should be positively identified before initiating the abandonment. Field information should be compared with any existing information.

Water levels and well depths can be measured with a well sounder or weighted tape measure. In critical situations, well construction details and hydrogeology can be determined with borehole geophysics or a downhole camera. For example, a caliper log, which is used to determine the borehole diameter, can be very helpful in locating cavernous areas in open hole wells.

7.3 WELL PREPARATION

If possible, the borehole must be cleared of obstructions prior to abandonment. Obstructions such as pumps, pipes, wiring, and air lines must be pulled. Well preparation also may involve fishing obstacles out of the borehole. An attempt should be made to pull the casing when it will not jeopardize the integrity of the borehole. Before the casing is pulled, the well should be grouted to near the bottom of the casing. This will at least provide some seal if the well collapses after the casing is pulled.

The presence of nested or telescoped casing strings complicates well abandonment. Inner strings should be removed when possible, but only when removal will not jeopardize the abandonment of the well. If inner strings cannot be removed and sealing of the annular space is required, then the inner string should be vertically split (plastic cased wells) or cut (metal-cased wells) at intervals necessary to insure complete filling of the annular space.

Damaged, poorly constructed or dilapidated wells may need to be redrilled in order to apply proper abandonment techniques. Also, in situations where intermixing of aquifers is likely, the borehole may need to be redrilled.

7.4 MATERIALS AND METHODS

7.4.1 Aggregate

Materials that eliminate the physical hazard and open space of the borehole, but do not prevent the flow of water through the well bore, are categorized as aggregate. Aggregates consist of sand, crushed stone or similar material that is used to fill the well. Aggregates should be uncontaminated and of consistent size to minimize bridging during placement.

Aggregate is usually not placed in wells smaller than two inches in diameter. Nominal size of the aggregate should be no more than 1/4 of the minimum well diameter through which it must pass during placement. Because aggregate is usually poured from the top of the well, care must be taken to prevent bridging by slowly pouring the aggregate and monitoring the progress with frequent depth measurements.

Aggregates may be used in the following circumstances: 1) there is no need to penetrate or seal fractures, joints or other openings in the interval to be filled, 2) a watertight seal is not required in the interval to be filled, 3) the hole is caving, 4) the interval does not penetrate a perched or confined aquifer, and 5) the interval does not penetrate more than one aquifer. If aggregate is used, a casing seal should be installed (see Section 7.5.1). The use of aggregate and a casing seal must be consistent with the future land use.

7.4.2 Sealants

Sealants are used in well abandonment to provide a watertight barrier to the migration of water in the well bore, in the annular spaces or in fractures and openings adjacent to the well bore. Sealants usually consist of portland cement based grouts, "bentonite" clay, or combinations of these substances. Additives are frequently used to enhance or delay specific properties such as viscosity, setting time, shrinkage, or strength.

Sealing mixtures should be formulated to minimize shrinkage and ensure compatibility with the chemistry of the groundwater in the well.

A grout pump and tremie pipe are preferred for delivering grout to the bottom of the well. This method insures the positive displacement of the water in the well, and will minimize dilution or separation of the grout.

If aggregate is to be placed above sealant, a sufficient amount of curing time should pass before placing the aggregate above the seal. Curing time for grout using Type 1 cement is typically 24 - 48 hours, and 12 hours for Type III cement.

General types of sealants are defined as follows:

Neat cement grout: Neat cement grout is generally formulated using a ratio of one 94 lb. bag of portland cement to no more than 6 gallons of water. This grout is superior for sealing small openings, for penetrating any annular space outside of the casings, and for filling voids in the surrounding rocks. When applied under pressure, neat cement grout is strongly favored for sealing artesian wells or those penetrating more than one aquifer. Neat cement grout is generally preferred to concrete grout because it avoids the problem of separation of the aggregate and the cement. Neat cement grout can be susceptible to shrinkage and the heat of hydration can possibly damage some plastic casing materials.

Concrete grout: Concrete grout consists of a ratio of not more than six gallons of water, one 94-lb. bag of Portland cement, and an equal volume of sand. This grout is generally used for filling the upper part of the well above the water bearing zone, for plugging short sections of casings, or for filling large-diameter wells.

Concrete grout, which makes a stronger seal than neat cement, may not significantly penetrate seams, crevices or interstices. Grout pumps can handle sand without being immediately damaged. Aggregate particles bigger than this may damage the pump. If not properly emplaced, the aggregate is apt to separate from the cement. Concrete grout should generally not be placed below the water level in a well, unless a tremie pipe and a grout pump are used.

Grout additives: Some bentonite (2 to 8 percent) can be added to neat cement or concrete grout to decrease the amount of shrinkage. Other additives can be used to alter the curing time or the permeability of the grout. For example, calcium chloride can be used as a curing accelerator.

High-solids sodium bentonite: This type of grout is composed of 15-20 percent solids content by weight of sodium bentonite when mixed with water. To determine the percentage content, the weight of bentonite is divided by the weight of the water plus the weight of the bentonite. For example, if 75 lbs. of powdered bentonite and 250 pounds of granular bentonite were mixed in 150 gallons of water (at 8.34 lbs. per gallon), the percentage of high-solids bentonite is approximately 20 percent (325/(1251+325)). High-solids bentonite must be pumped before its viscosity is lowered. Pumping pressures higher than those used for cement grouts are usually

necessary. Hydration of the bentonite must be delayed until it has been placed down the well. This can be done by 1) using additives with the dry bentonite or in the water, 2) mixing calcium bentonite (it expands less) with sodium bentonite, or 3) using granular bentonite, which has less surface area.

In addition, positive displacement pumps such as piston, gear, and moyno (progressive cavity) pumps must be used because pumps that shear the grout (such as centrifugal pumps) will accelerate the congealing of the bentonite. A paddle mixer is typically used to mix the grout. A high-solids bentonite grout is not made from bentonite that is labeled as drilling fluid or gel.

Chip Bentonite: Chip (coarse grade) or pelletized bentonite can form adequate seals. This type of bentonite is poured directly down the borehole. The size of the bentonite chips also should be no more than 1/4 of the minimum well diameter through which it must pass during placement. Because of the potential for bridging, this material may not be suitable for deep wells or borings where positive displacement is necessary to seal the well.

When coarse bentonite is placed above the water level, water must be added frequently to hydrate the bentonite. Care must be taken with chip or pelletized bentonite to not overload the interval to be sealed. Rapidly swelling bentonite could result in incomplete hydration and a heterogeneous seal containing lumps of dry bentonite. The level of the bentonite should be checked often to make sure that bridging of the chips does not occur.

7.4.3 Bridge Seals

A bridge seal can be used to isolate cavernous sections of a well, to isolate two producing zones in the well, or to provide the structural integrity necessary to support overlying materials (and thus protect underlying aggregate or sealants from excessive compressive forces). Bridge seals are usually constructed by installing an expandable plug made of wood, neoprene, or a pneumatic or other mechanical packer. Additional aggregate can be placed above the bridge.

7.5 RECOMMENDATIONS

The complexity of the abandonment procedure depends primarily on the hydrogeology, geology, well construction, and the groundwater quality. Four principal complicating factors have been identified; they include 1) artesian conditions, 2) multiple aquifers, 3) cavernous rocks, and 4) the threat or presence of contamination. The recommended procedures for abandoning wells will be more rigorous with the presence of one or more complicating factors. The procedures may vary from a simple casing seal above aggregate to entirely grouting a well using a tremie pipe after existing casing has been ripped or perforated. Figure 10 summarizes the general approach to well abandonment.

7.5.1 Casing Seal

The transition from well casing to open borehole is the most suspect zone for migration of water. In order to minimize the movement of water (contaminated or otherwise) from the overlying less consolidated materials to the lower waterbearing units, this zone must be sealed. Generally this can be accomplished by filling at least the upper 10 feet of open borehole and the lower five feet of casing with sealant. The length of open borehole sealed should be increased if extenuating circumstances exist. Such circumstances would include a history of bacterial contamination, saprolitic bedrock, or possibly deep fracture zones. Waterbearing zones reported in the upper 20 feet or so of open borehole are indications of fractures and would warrant additional sealant. Casing that is deteriorated should be sealed along its entire length. If the casing is to be pulled the sealant used should remain fluid for a period of time adequate for removal of the casing.

If the casing is to remain, then whenever feasible, it should be cut off below land surface. After the casing seal discussed above achieves adequate strength, the open casing should at a minimum, be filled with aggregate. It is strongly suggested that a sealant be used in the upper 2 to 5 feet of casing.

7.5.2 Wells in Unconfined or Semi-Confined Conditions

These are the most common type of wells in Pennsylvania. The geology may consist of either unconsolidated or consolidated materials. When applicable, unconfined wells in non-contaminated areas may be satisfactorily abandoned using aggregate materials up to 10-15 feet below the ground surface. This would apply mainly to domestic wells, and test borings or wells not covered by existing regulations. Monitoring wells that are not covered by specific regulatory programs and are located at sites with no known contamination, might be abandoned in this manner. Above the aggregate, the casing seal should be installed. A sealant may be used over the entire depth.

7.5.3 Wells at Contaminated Sites

An abandoned, contaminated well often mixes contaminated groundwater with uncontaminated groundwater. Complete and uniform sealing of the well from the bottom to the surface is required. Therefore, proper well preparation (Section 7.3) must be done before the well is sealed with a proper sealant (Section 7.4.2).

7.5.4 Wells in Cavernous Rocks

Problems can arise when filling wells that penetrate cavernous rock. Although such wells are usually located in carbonate terrain, voids can also occur in areas that have been deep mined. Care must be taken to insure that aggregates and sealants are of a size and consistency to prevent their removal by water flowing in the void. Large voids or high flow velocities warrant placement of a bridge in competent rock over the void. Aggregate and sealants can then be placed above the bridge.

7.5.5 Multiple Aquifer Wells

The main goal in sealing wells that extend into more than one aquifer is to prevent the flow of groundwater from one aquifer to another. If no appreciable movement of water is encountered, and there is no threat of groundwater contamination, sealing with concrete, neat cement, grout, or alternating layers of these materials and aggregate will prove satisfactory. When groundwater velocities are high, the procedures for wells with artesian flow (see the next section) are recommended. If alternating plugs (or bridges) and aggregate layers are used, the plugs should be placed in known nonproductive horizons or, if locations of the nonproductive horizons are not known, at frequent intervals.

7.5.6 Flowing Wells

The sealing of artesian wells requires special attention. The flow of groundwater may be sufficient to make sealing by gravity placement of concrete, cement grout, neat cement, clay or sand impractical. In such wells, large stone aggregate (not more than 1/4 of the diameter of the hole), well packers (pneumatic or other), or wooden plugs will be needed to restrict the flow and thereby permit the gravity placement of sealing material above the zone where water is produced. If plugs are used, they should be several times longer than the diameter of the well to prevent tilting. Seals should be designed to withstand the maximum anticipated hydraulic head of the artesian aquifer.

Because it is very important in wells of this type to prevent circulation between water yielding zones, or loss of water to the surface or to the annular spacing outside of the casing, it is recommended that pressure grouting with cement be done using the minimum volume of water during mixing that will permit handling.

In wells in which the hydrostatic head producing flow to the surface is low, the movement of water may be stopped by extending the well casing to an elevation above the artesian pressure surface.

7.5.7 Wells with Complicating Factors at Contaminated Sites

Wells with one or more of the above complicating factors that are to be abandoned in areas with contaminated groundwater or in areas where the groundwater is at a high risk for future contamination, require the most rigorous abandonment procedures. In general, the entire length of these wells should be sealed.

When the threat of contamination has been established, the elimination of a potential flowpath is critical. For example, a contaminated well in a karst terrain must be carefully sealed to avoid worsening the situation. In general, the entire lengths of these wells should be sealed. In some situations, a bridge seal may have to be installed, and casing may have to be perforated. In each case, a prudent method should be selected that will eliminate all potential vertical flowpaths.

7.5.8 Monitoring Wells

Monitoring wells should be abandoned in accordance with the rules and regulations of the program under which they were installed and operated. Monitoring wells which do not fall under the jurisdiction of a regulatory program, or fall under a program that has no rules or regulations for abandonment, should be abandoned under the following guidelines.

Monitoring wells that were installed and continue to function as designed, can usually be abandoned in place. Exceptions would include wells whose design precludes complete and effective placement of sealant and wells in locations subject to future disturbance that could compromise the abandonment. In such instances all tubing, screens, casings, aggregate, backfilling, and sealant should be cleaned from the boring and the hole should be completely filled with an appropriate sealant.

Monitoring wells that are abandoned in place should be completely filled with sealant. Screened intervals can be backfilled with inert aggregate if sealant will alter the groundwater chemistry and thereby jeopardize ongoing monitoring at the facility. Intervals between screens, and between the last screen and the surface, must be filled with sealant. Generally, sealant must be emplaced from the bottom of the interval being sealed. Protective casings, riser pipes, tubing, and other appurtenances at the surface which could not be removed should be cut off below grade after the sealant has properly set. When the abandonment will be completed below the finished grade, the area of the boring should be covered with a layer of bentonite, grout, concrete, or other sealant before backfilling to grade.

7.6 EXISTING REGULATIONS AND STANDARDS

The Water Well Drillers License Act requires that the owner or consultant who is to abandon the well notify the department of the intent to decommission a well at least 10 days before the well is sealed or filled. Individual department bureaus may have specific regulations or guidelines.

The Bureau of Oil and Gas Management regulates the plugging of oil and gas wells. Plugging provisions for oil and gas wells in coal and non-coal areas are established in § 210 and § 211 of Act 223, and § 78.91 - 78.97 of Chapter 78. These sections describe methods that would stop any vertical flow of fluids or gas within the well bore. Alternate methods of plugging also are allowed if they would afford the same level of protection. Alternate methods must be approved before the plugging is initiated.

The Bureau of Mining and Reclamation regulates the abandonment of borings and wells associated with the mining of coal. Coal exploration holes must be abandoned according to the § 87.93 for surface mining of bituminous coal, § 88.83 for anthracite coal mining, § 89.54 for deep mining of bituminous coal, and § 90.93, coal refuse disposal.

The Bureau of Water Supply and Community Health uses the AWWA Standard A 100-90 for abandonment of public water supply wells. This standard is referenced in Section 3.3.5.11 of Part II of the Public Water Supply Manual.

7.7 REPORTING

All abandoned wells shall be reported to BTGS, along with any bureau that requires a report, on forms required by BTGS (and any other forms). If available, the original driller's log should be included along with the details of the well abandonment procedure. A photograph should be taken of the site, and a reference map should be made to locate the abandoned well. It also may be appropriate to survey the exact location of the well. This is especially important for wells associated with contaminated sites.

7.8 REFERENCES

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