

WATER

QUALITY SERIES

Plugging Abandoned Wells

A source of clean, safe household water is important to all Kansans. Groundwater is often the only source, especially in areas with no public water supply. Groundwater is usually preferred for individual homes because it does not require filtering.

Groundwater use does require wells, and wells act as conduits for possible entrance of contaminants. Many test holes and unused (abandoned) wells are located in fields, farmsteads, industrial sites, and urban areas without being properly plugged. Not only are wells sources for potential contamination of groundwater, many are a physical hazard to animals and people, particularly children (see photo).



A 6-year-old child can easily slip through a section of 10-inch PVC pipe.

Landowners are liable for contamination or injury from unplugged wells or holes. The hazards of abandoned wells and test holes should concern everyone. They should be properly eliminated. This bulletin is provided to help landowners, service providers, and others understand the correct plugging procedure.

The Kansas Department of Health and Environment (KDHE) estimates more than 250,000 abandoned wells and test holes exist in Kansas. Kansas law defines an abandoned well as one that

- has not been used during the last 2 years;
- is in such disrepair that it cannot be used; or
- poses a groundwater-contamination hazard.

Kansas law requires that all abandoned wells and test holes be properly plugged. Proper plugging accomplishes five goals:

- restores protective barrier to minimize groundwater contamination;
- removes physical hazards by removing tempting openings for curious children and animals;
- restores stability to the land surface, (load carrying capacity);
- eliminates or reduces liability exposure; and
- protects and improves property values.

Kansas Regulations

The Kansas Department of Health and Environment administers laws regulating construction, reconstruction, and plugging of wells. Articles 12-K.S.A.82a-1212 and 1213 and 30-K.A.R. 28-30-4(a) and 28-30-7 specifically address plugging of abandoned wells. The regulations provide instructions for all types of wells and aquifer conditions. Well drillers and landowners alike are required by law to follow these procedures, which are available from KDHE.

This publication describes the easiest plugging procedure for the most-common well and aquifer conditions. If well or aquifer conditions are unknown or different from those described, landowners should contact KDHE for the proper plugging procedures. Landowners may plug wells on their property by following these procedures. Landowners also can hire a licensed water well contractor to plug a well.

The plugging procedure requires a plugging report (form WWC-5 or form WWC-5P) be filed with KDHE. These forms can be obtained by calling (785) 296-5524

and are frequently available locally through county health or Extension offices. Failure to file this report documenting proper closure leaves the owner liable for contamination. Documentation of the plugging procedure transfers the burden of proof to the complainant.

Aquifer Classification

Often times for older wells, little specific information is available about the well or the aquifer source. The type of aquifer or water formations penetrated by the well must be known for proper plugging. Sometimes this information can be obtained by asking questions of knowledgeable sources. Well logs for the actual well or nearby wells may be available from local drillers or KDHE. Geological and groundwater reports are available for most counties. Check the library or call the Kansas Geological Survey at (785) 864-3965.

A little must be know about the soil and geology (sand, gravel, clay, rock) of the well in order to ensure plugging will restore the integrity of the formation. Aquifers, the permeable water-bearing materials supplying a well, are classified based on the geology of the formation.

When water from the surface moves directly into an aquifer, it is called unconfined. Confined aquifers, on the other hand, have impervious layers that significantly restrict direct local recharge from the surface. Water in confined aquifers may be under pressure greater than atmospheric, and water rises above the restricting layer (artisan).

When the water-bearing layer is made up of individual grains of sand and gravel, the aquifer is called unconsolidated. All other aquifers are considered to be consolidated aquifers, often referred to as rock aquifers. Thus, there are four types of aquifers: unconfined-unconsolidated, unconfined-consolidated, confined-unconsolidated, and confined-consolidated.

Many aquifers are more complex than this simplified explanation. A consolidated formation may have several water-bearing zones separated by confining layers of varying permeability. Each zone may have a different yield and

water quality. Good quality may lie above, below, or between zones of poor-quality water. Experienced well drillers recognize and note these differences as the well is drilled and connect or exclude various zones, based on the quality and quantity of water needed.

The procedure described here applies when plugging wells located in unconfined aquifers with unconsolidated formations. If it is suspected the formation is rock (consolidated formation), has confining layers, or the well penetrates multiple water-bearing formations, contact KDHE before proceeding or hire a licensed well driller to do the plugging. Do not attempt to use these procedures to plug wells in conditions other than unconfined and unconsolidated.

The procedure described generally applies to the sand and gravel aquifers shown in Figure 1. Other areas may not be sand and gravel aquifers. Generally, shallow wells (less than 50 feet near streams and 100 feet on uplands), can be plugged with this procedure. Large-diameter (12 inches or more) irrigation, industrial, or municipal wells also might be best handled by a licensed well driller.

Well Classification

Wells are classified according to construction. Understanding well construction methods is important because different types of wells require different plugging procedures. The oldest type is the dug well. These are large diameter, relatively shallow, hand-dug wells, usually lined with rock or brick. Typical dug wells are 3 to 6 feet in diameter and 15 to 50 feet deep (see Figure 2). The depth depends on depth to water, and size can vary from 2 feet in diameter to larger than 30 feet.

A driven well, used mainly for shallow, unconsolidated aquifers, is named for the process of driving the suction pipe with screened section into the sandy water-bearing formation. These wells are generally small in diameter with pipe sizes of 1 to 2 inches for home water supplies and up to 6 inches for irrigation and livestock wells. Driven wells are limited to sandy formations with high water tables,

Figure 1. Sand and Gravel Aquifers

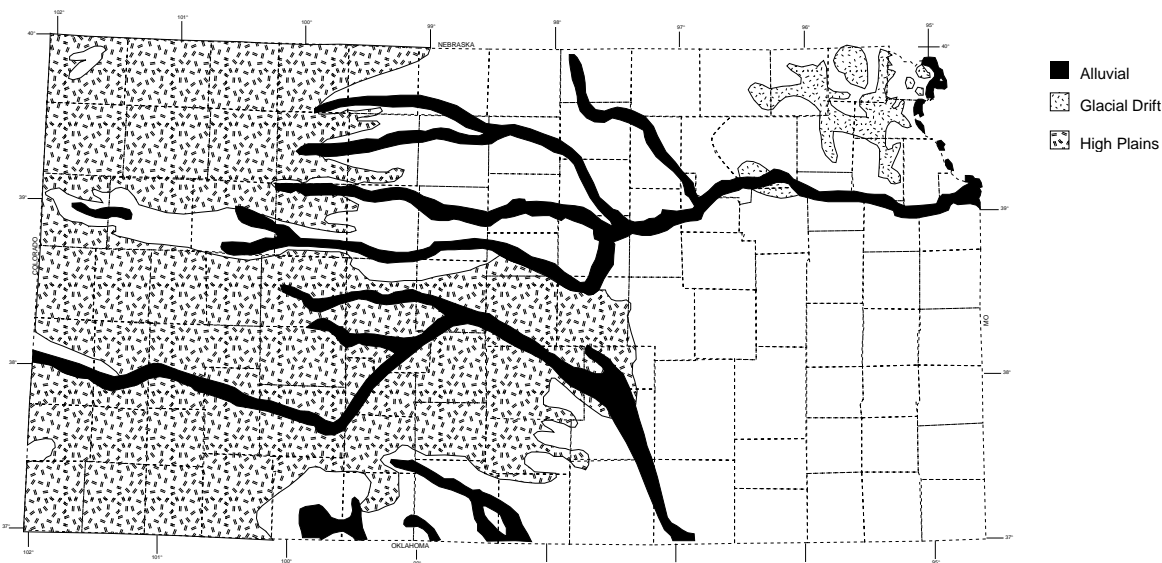
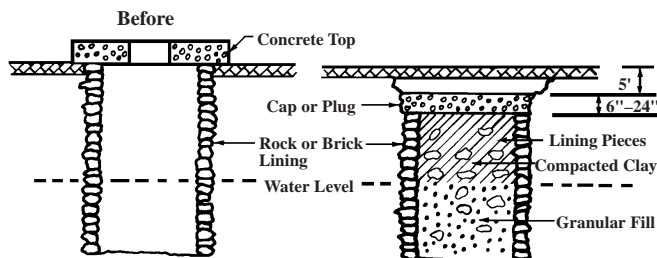


Figure 2. Plugging Diagrams for a Hand-dug Well



where centrifugal or shallow well jet pumps can be used. Driven or sandpoint wells are still being installed. To be legal, however, they must be grouted to a depth of 20 feet or to the water table. Because of shallow depths and grouting difficulties, they are discouraged for domestic use.

The drilled well is the most common type of well in Kansas (see Figure 3). Typically, a hole is drilled into the aquifer, and a casing 3 to 8 inches smaller than the bore hole is installed. Domestic and livestock watering wells are generally 4 to 10 inches in diameter, while irrigation wells generally range from 10 to 18 inches.

The depth of a drilled well varies depending on the aquifer and water depth. Depths greater than 300 feet are common in some places. The small-diameter well casings, usually 6 inches or less, are generally installed in bore holes only a few inches larger than the casing. Typically, the casing is inserted after the bore hole is drilled.

For large-capacity wells for irrigation, industrial, or municipal uses, the casing is installed into oversized holes. The space between the casing and bore hole is filled with gravel. This gravel pack allows unrestricted water flow into the perforated portion of the casing and acts as a filter to retain the aquifer particles. Near the surface, this space is filled with grout to prevent water movement from the surface along the casing.

Prior to 1975, grouting was not required and the common practice was to gravel pack to very near the surface to induce the greatest yield possible. This practice made flow along the outside of the casing an easy pathway for contaminants to enter the groundwater from the surface.

Plugging Procedure

The plugging procedure described is for wells in an unconfined-unconsolidated aquifer (figures 2, 3, and 4). If the well has more than one water-bearing layer, penetrates a confining layer (aquiclude), or is into rock, contact KDHE to make certain of the proper plugging procedure or hire a licensed well driller. Plug wells using these steps:

Step 1. Prepare site. Remove all pumping equipment and any foreign objects from the well and remove debris from the surface around the well site.

Step 2. Remove top of casing. Excavate around the casing of a drilled or driven well to a depth that allows the casing to be cut off at least 3 feet below the surface. The more casing removed the better.

Figure 3. Plugging Diagram for a Drilled Well in an Unconfined-unconsolidated Aquifer

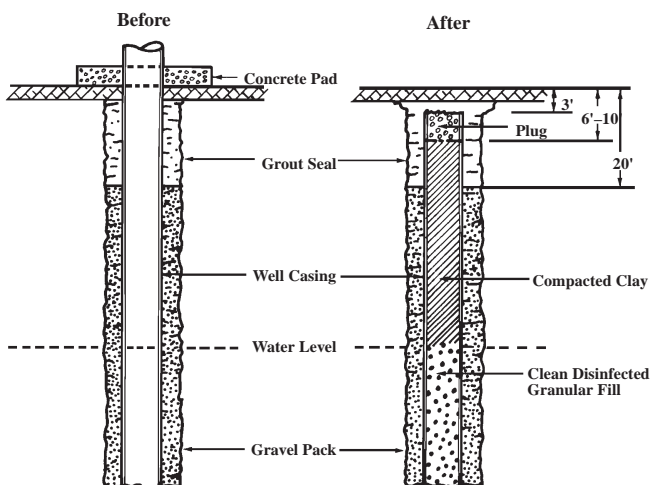
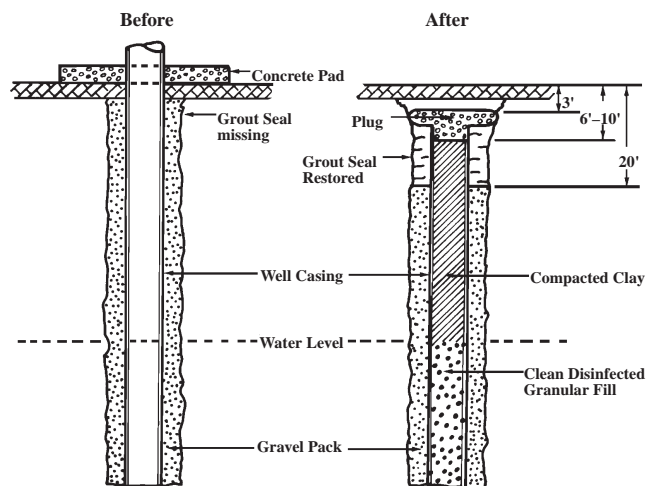


Figure 4. Plugging Diagram for a Drilled Well Without Proper Grouting in an Unconfined-unconsolidated Aquifer



When excavating around the old casing, look for evidence that the well was properly grouted (Figure 3). Establishing a proper seal is critical to preventing contaminants from migrating along the outside of the casing. When a well does not have a proper grout seal, it should be restored. This requires 20 feet of excavation around the outside of the casing to allow placement of the grout. However, if it is possible to excavate this deep, the casing should be removed to this depth rather than be grouted.

Since deep excavation of a nongrouted well is often not practical, another option is to extend the plug beyond the edges of the original bore hole at least 1 foot outside the casing in all directions. This mushroom plug, shown in Figure 4, will help prevent water movement along the out-

side of the casing. Deeper excavation than the 3-foot minimum around the casing is especially desirable when no grouting exists outside the casing.

In dug wells, the casing of the well is the rock or brick lining of the well. This lining can be used as part of the fill material. The lining for dug wells should be removed to a depth of at least 5 feet. Be certain to mix lining material with fill material (see steps 4 and 5).

Step 3. Disinfect water. Existing bacteria or bacteria carried to the water by the fill material should be killed. This helps prevent contamination of nearby wells. Determine the amount of chlorine necessary by measuring the depth of water and diameter of the well and estimating the amount of water in the well. Then use Table 1, which lists the amount of chlorine product to add to produce a solution concentration in the well of approximately 500 milligrams per liter of chlorine.

The amount of chlorine needed depends on the product concentration. Four concentrations representing various chlorine products from household bleach (5.25 percent) to dry chlorine disinfectant (70 percent) are shown in Table 1. When dry chlorine is used, dissolve it in water before adding it to the well to make certain the material does not settle to the bottom.

If no working wells are within 100 feet of the abandoned well being plugged, the concentration of chlorine could be halved since bacteria migration beyond 100 feet is unlikely.

Example: A 6-inch diameter well, 60 feet deep, has 20 feet of water present. How much chlorine is needed for disinfection?

At the intersection of the 6-inch and 5.25-percent column in Table 1, 1.8 fluid ounces of bleach is needed for each foot of water, so 36 ounces, or 2.25 pints, (1.8×20) of bleach should be added.

Step 4. Fill water zone with clean porous material. Approved fill material is sand and gravel of less than 1-inch diameter. Generally the preferred fill is washed, coarse river sand. The fill material is chlorinated when it is added to the previously disinfected water in step 3.

Table 1 also shows the volume of fill needed per foot of well for various diameter holes. The water in the well may rise as the sand is added, depending on the permeability of the formation and the fill material. Estimate the volume of fill needed to avoid filling above the normal water level. Measure the normal water level using a weighted string that just touches the water surface. Mark the string with a knot at the top of the casing. Begin adding fill, but periodically check progress of the fill. Once the weight touches the top of the fill at the marked spot, stop adding fill. Even though the water level may have risen, add fill only to the original water level. Any water above the normal water level should be removed by pumping or allowed to soak away with time. The use of coarse sand and slow addition to the well will prevent bridging of the sand at the water surface. The sound of the sand hitting the water surface should be heard.

In dug wells, more fill than predicated from the table generally is required to fill this zone because mud in the bottom of the well compresses and voids in the rock lining. It may be necessary to bring as much as 30 percent more fill than predicted from the table.

Table 1. Computing Volume of Fill Material and Disinfectant for Wells

Diameter of opening	Volume of well per foot		Amount of product to disinfect 1 foot ^(a)			
			Liquid chlorine (fluid ounces)		Dry chlorine (dry ounces)	
	gal/ft	ft ³ /ft ^(b)	5.25%	10%	65%	70%
2 inches	0.16	0.02	0.20	0.10	0.02	0.02
3 inches	0.37	0.05	0.45	0.22	0.05	0.02
4 inches	0.65	0.09	0.80	0.42	0.07	0.07
5 inches	1.02	0.14	1.25	0.65	0.10	0.10
6 inches	1.47	0.20	1.80	0.95	0.15	0.15
8 inches	2.61	0.35	3.20	1.67	0.27	0.25
10 inches	4.08	0.55	5.00	2.60	0.42	0.40
12 inches	5.88	0.79	7.20	3.75	0.60	0.55
14 inches	8.00	1.07	9.77	5.12	0.82	0.77
16 inches	10.44	1.40	12.77	6.67	1.07	1.00
1.5 feet	13.22	1.77	16.17	8.45	1.35	1.25
2.0 feet	23.50	3.14	28.75	15.05	2.42	2.25
2.5 feet	36.72	4.91	44.92	23.50	3.77	3.50
3.0 feet	52.88	7.07	64.70	33.85	5.42	5.05
4.0 feet	94.00	12.57	115.02	60.15	9.65	8.97
5.0 feet	146.9	19.64	179.75	94.00	15.07	14.00
6.0 feet	211.5	28.27	258.75	135.37	21.72	20.17
7.0 feet	287.9	38.48	352.25	184.25	29.55	27.45
8.0 feet	376.0	50.27	460.25	240.65	38.60	35.85
9.0 feet	475.9	63.62	582.25	304.50	48.87	45.37
10.0 feet	587.5	78.54	719.00	376.00	105.32	56.02

^(a) 500 mg/L concentration of chlorine; 128 oz. = 1 gallon

^(b) 27 ft³ = 1 cubic yard

Although the lining rocks can be added in either the sand or subsoil layers, it is preferable to add with the subsoil as discussed later. This will keep the water-bearing area much cleaner, as it is difficult to remove the rock lining without a lot of debris from the surface falling into the well.

In some wells, especially those less than 20 feet deep, there may not be enough volume to dispose of the rocks in the subsoil layer only. In this case, some of the rock lining should be placed in the fill. Generally, the rock or brick lining can be pried loose with large pry bars. However, a backhoe or front-end loader may be desirable for large-diameter wells. When using heavy equipment, the surface soil around the well site should be scraped away to expose the subsoil layer. As the rock walls are added, be certain to add sufficient fill material to eliminate any voids among the rocks.

Example: For the 6-inch diameter well with 20 feet of water, how much sand is required?

From Table 1, at the intersection of 6-inch diameter and the column from the left side, 0.20 cubic foot of fill is needed for each foot of the 20-foot water zone, therefore, 4 cubic feet ($0.20 \text{ ft}^3/\text{ft} \times 20 \text{ ft}$) of fill is needed. Since there are 27 cubic feet per cubic yard, 4 cubic feet equals 0.15 cubic yard.

Step 5. Add compacted subsoil above the water zone.

The casing above the water level is filled with natural subsoil clay material (subsoils low in organic matter and other potential contaminants) and compacted to form a solid column. The subsoil should be placed in a dry hole. The subsoil should be damp to allow it to compact easily. The clay fill should be placed in layers not exceeding 2 feet.

For small-diameter wells, a section of steel pipe with a cap on one end attached to a rope makes a good tamping tool. The fill should stop at least 3 feet below the top of the casing (6 feet below the surface) to leave adequate space for an approved plug.

Dug wells are filled to no more than 5 feet below the surface. At this point, the rock lining and subsoil fill should be leveled off.

Step 6. Place approved grout plug. Pour the approved grout material into the drilled or driven well casing making a plug at least 3 feet thick, the minimum required. In a dug well, the plug of approved grout material is 6 to 24 inches thick. KDHE-approved grout material includes commercial hole plug sodium bentonite clay, cement, and neat cement. Cement grout is a mixture of equal volumes of portland cement and sand. Use 10 to 12 gallons of water for each bag of cement. Neat cement is a mixture of portland cement and water, and 5 to 6 gallons of water should be used for each 94-pound bag of cement.

Sodium bentonite clay, normally sold in 50-pound bags that contain 0.7 cubic foot, is recommended for use because it is easy to handle, remains pliable, and expands when in contact with water. Because of bentonite's expansive and pliable nature, it will conform to the uneven rock edges and expand to fill voids in the wall. If any settlement should occur, the bentonite seal will not crack or lose its integrity.

Table 2 provides information to help determine the number of bags of sodium bentonite clay needed for placing the plug or filling the entire well with bentonite. A cement

Table 2. Number of Bags of Sodium Bentonite Clay Needed for Various Well Diameters

Diameter of opening (inches)	Feet of fill per bag ^(a)	Bags ^(a) per foot	Bags ^(b) per 3-foot plug
2	35.0	0.03	0.1
3	14.0	0.07	0.2
4	7.8	0.13	0.4
5	5.0	0.20	0.6
6	3.5	0.29	0.9
8	2.0	0.50	1.5
10	1.3	0.79	2.4
12	0.9	1.13	3.4
14	0.7	1.53	4.6
16	0.5	2.0	6.0
18	0.4	2.5	7.5

^(a) Table values based on 50-pound bags, which have a volume of 0.7ft³ per bag.

^(b) Additional bags are required for mushroom plugs extending outside the casing (see step 6).

plug must be much thicker and may need reinforcing to have enough strength to prevent cracking and collapse.

Example: A 6-inch diameter well is ready for the plug material. How many bags of bentonite are needed?

From Table 1, a 6-inch diameter well has a volume of 0.2 cubic feet per foot of casing. A typical bag of bentonite contains 0.7 cubic feet of material. Dividing 0.7 cubic feet per bag by 0.2 cubic feet equals 3.5 feet of casing per bag. Therefore, one bag will make a 3.5-foot plug inside the well casing. Several more bags will be needed to make the mushroom plug on top to protect the outside of the casing (see step 2).

Example: A 4-foot diameter well is ready for the plug material. How many bags of bentonite are needed?

Since bentonite is expansive, the minimum 6-inch plug will be used. Remember, the plug should extend beyond the rock lining to the original hole diameter. For this example, assume the rock lining is 1 foot thick; therefore a 6-foot diameter plug must be placed.

From Table 1, a 6-foot diameter hole requires 28.27 cubic feet of material. Since only a 6-inch plug is required, only 14.14 cubic feet of material is needed. Dividing 14.14 cubic feet by 0.7 cubic foot per bag determines that 20.2 bags (round up to 21 bags) are needed.

Step 7. Fill hole at top. Once the grout plug and mushroom cap have been completed, the remaining hole above the plug should be filled. Subsoil material can be placed in the bottom of the hole and compacted as the fill progresses in layers of 6 inches. Topsoil should be used in approximately the top foot of the hole. The fill should be mounded up at least 10 inches in the center to allow for settling and drainage away from the fill site.

Step 8. File the plugging report. Abandoned wells are an environmental and safety hazard. They are a liability. Following the plugging procedure described here and filing form WWC-5P or WWC-5 with KDHE to document the action minimizes further liability.

The well is not legally plugged until the form is filed. WWC-5 is the form used by drillers for reporting a new well.

It asks for location, property owner, physical characteristics of formation, well, casing, and the plugging procedure used. A new WWC-5P form was developed specifically for reporting well plugging. Forms are available from KDHE, but many county Extension, county health, and conservation district offices also have these forms available.

Alternative Plugging Option

For small-diameter wells, especially shallow ones, it is simpler to plug the entire casing with approved grout material or with sand fill below water and grout above water. This is a good choice for very-small-diameter wells where placement of the various layers of fill especially the subsoil fill, may be difficult. Filling the entire casing with grout may be the best option for small-diameter driven wells. A 2-inch diameter well needs only 0.02 cubic foot of fill per foot of casing. This means one bag of bentonite will fill 35 feet of well. The well water still needs to be chlorinated.

Sodium bentonite clay chips or pellets can easily be used to completely fill the casing. Bentonite clay powder or granular should never be poured into wells with water. Proper placement of powder or granular materials requires making a slurry and using a grout pump.

Placing cement grout into water. If cement or neat cement is used as grout, placement into water requires special procedures to avoid separation. A tremie pipe, which is usually about 3 inches in diameter and in sections of 5 to 10 feet long, will be needed to place the cement without passing through water. Use enough pipe to reach within a foot or two of the bottom and cut the end at a 45-degree angle. A hopper box or large funnel is attached to the top of the tremie pipe. The grout is mixed and placed in the hopper or funnel.

The mix must be thin enough to flow, but thick enough to set properly once in place. The proper ratio for neat cement grout is one 94-pound bag of cement to 5 or 6 gallons of water. For cement, use 5 or 6 gallons of water for each cubic foot of cement-sand mix. The volume of material must be monitored during placement because the tremie pipe is raised as the fill progresses. The end of the tremie must be kept below the surface of the grout at all times to prevent dilution and separation of the grout mix.

Precaution: Remember how much material is in the tremie pipe at all stages and approximately how much depth it will fill. A 10-foot section of 3-inch diameter tremie contains nearly a half a cubic foot, so 100 feet would contain 5 cubic feet. If filling an 8-inch casing, which contains 0.35 cubic feet per foot of length, ignoring the volume in the tremie would be an error of 14.3 feet. Tag or measure the progress of the plugging material as the well is filled, and pump or siphon off any excess water that is displaced as the grout is added.

Plugging Confined, Multiple-zone or Rock Aquifers

If the aquifer is known to contain confining layers or more than one water-bearing zone, a plug at each confining layer between each aquifer is required. If the outside of the casing was not grouted at those locations, as is common with old wells, the casing should be ripped and grout pumped into the gravel pack to restore a good seal at the confining layer. Most licensed well drillers have equipment to rip or puncture casing so grout can be forced into the gravel pack. Landowners are advised to hire a competent licensed water well driller to plug all confined, multiple-zone or rock aquifers and other unusual formations. In addition to having needed equipment, a driller should know the local geology, so grout plugs and other materials are placed correctly.

Oil and Gas Wells

Plugging abandoned oil, gas, or brine-disposal wells is equally important. Report these wells to the Kansas Corporation Commission to assure they are properly plugged. The KCC's district offices are in Dodge City, (316) 225-8888; Wichita, (316) 337-6231; Chanute, (316) 431-6946; and Hays, (785) 628-1200.

Conclusion

Abandoned wells are potential sources of direct contamination of valuable groundwater. Wells larger than a few inches in diameter also are a safety hazard for children and animals. All abandoned wells should be properly plugged to prevent contamination and eliminate the safety hazard. Plugging is required by Kansas law. When a replacement well is drilled, the old well, according to law, must continue to be used, upgraded to current standards, or plugged. It is not uncommon to visit a farmstead and find three or four wells with only one or perhaps two currently in use. While there is a reluctance to pay to get rid of something that has outlived its usefulness, groundwater protection, safety, and Kansas law make plugging important. Abandoned water wells can no longer be ignored.

Related References:

Plugging Cisterns, Cesspools, Septic Tanks, and Other Holes, K-State Research and Extension Publication MF-2246.

Plugging Packet, Kansas Department of Health and Environment.

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