Private Wells — Safe Location and Construction

Water for residences beyond the reach of public systems, either city or rural water district, usually is supplied by a well. Surveys of private well water quality show that on average only 40 percent meet the safe drinking water standards used for public systems. A Kansas well survey showed 51 percent contain coliform bacteria, which indicates recent exposure to the surface environment. Coliform bacteria do not thrive, or even survive, for extended periods in an aquifer.

Eighteen percent of private wells contain *E. coli* bacteria, an indicator of contamination by fecal material from sewage or animals. *E. coli* indicates a high risk of disease pathogens. One of four private wells contains nitrate above the maximum contaminant level (MCL) for public water supplies. These contaminants usually can be traced to problems with well location or well construction.

Construction and location are the most important factors in protecting private well water. Private well surveys indicate about 80 percent of wells are deficient in construction or location. The location is the separation distance and direction from potential contamination sources.

Well Regulations

The well owner or water user is responsible for the quality of water from a private well. No state or federal regulations apply to the quality of the water supplied from these wells. However, Kansas has regulated new well construction and well repairs since 1975. Anyone who constructs (drills), reconstructs (repairs), or treats wells must be licensed to perform these services. However, the owners can do the work on their own well without a license. They are required to file reports with the Kansas Department of Health and Environment (KDHE).

Well-drilling regulations and county sanitary codes specify a minimum 50-foot separation of the well from any source of possible contamination (some counties use 100 feet or more). This separation distance is based on the soil's filtering capacity for bacteria and other microbes. Many contaminants, including nitrate, volatile organic chemicals (VOCs), fuel, petrochemicals, and some pesticides, are not filtered by the soil. Substantially greater separation distances are needed to protect from contaminants not filtered by soil. Research in Kansas shows there is a low incidence of high nitrate present in wells when nitrogen sources are more than 400 feet from the well.

The best time to help assure that a well produces safe water is when a new well is being sited and drilled. This publication addresses principles of safe well location and construction. Wells also need annual maintenance and protection of the water supply, explained in a companion K-State Research and Extension publication *Private Well Maintenance and Protection,* MF-2396. Publication MF-2409, *Private Water Well Owner/Operator Manual*, outlines important well information needs and can serve as a record book to store your well information.

Groundwater and Geology

Groundwater occurs everywhere below the ground surface. It fills the spaces in sand, gravel, soil, and rock formations. When a formation contains enough water that can be removed at useful rates by a pump, it is called an aquifer. Aquifers are fractured rock, porous rock, sand, gravel, or a mixture of these. It may be a single mass, a layer, or a series of layers. Water flows through aquifers as a result of the driving force (head) and permeability.

Aquifers and Water Quality

An aquifer that receives recharge directly from the surface is called an unconfined aquifer. Because an unconfined aquifer is recharged locally, activities near a well pose a high risk to cause contamination. Most wells in western and south central Kansas and major stream valleys are in unconfined aquifers.

Confined aquifers are beneath a zone of low permeability that minimizes direct recharge from the surface. Confined aquifers are normally recharged at much greater distances from the well. Activities near a properly constructed well in a confined aquifer are much less likely to contaminate the well. Many wells in north central and eastern Kansas are in confined aquifers.

Other factors affecting potential contamination are depth to the water table, soil and geologic materials, permeability in the recharge zone, and to a lesser extent, type and condition of vegetation. Recharge passes through an unsaturated layer called the vadose zone or zone of aeration above the water table. The top portion of the vadose zone contains roots and most of the microbial activity.

Soil organisms break down many of the dissolved compounds in water, and plant roots remove nutrients, trace elements, and some other compounds. As water passes through the vadose zone, suspended particles and most organisms are filtered out. Compounds dissolved in the water may be adsorbed on soil particles, precipitated, or chemically combined to form new compounds. Healthy perennial vegetation with a deep root zone and thick vadose zone of moderate permeability are ideal to assure high quality groundwater recharge.

Water quality is greatly affected by the rate of recharge, the volume of storage, and the rate of flow through the aquifer. Slow rates of recharge allow greater root uptake and more time for soil organisms to break down dissolved and suspended materials in the water. Slow recharge also allows more time for other reactions between contaminants, soil, and rock. Minerals in the soil and rock may be dissolved into water. Large storage volumes in an aquifer help dilute contaminants and enable a well to produce during long, dry periods. Rapid flow through the aquifer makes it self-cleaning and also subjects it to water shortage during dry periods.

The water quality of an aquifer is normally variable. Deep aquifers tend to vary less in a region because of the factors previously mentioned. However, groundwater quality is not uniformly good or poor, even over relatively short distances.

Two aquifer types, discussed in the following paragraphs, deserve special attention when considering a private well. These conditions exist in Kansas. Therefore, hiring a knowledgeable, experienced, and licensed well driller is extremely important. It is a driller's business to understand and plan for these special situations.

Sand and Gravel Aquifers with similar deposits that extend to the surface are particularly difficult to protect from contamination. In many cases, the material in the unsaturated zone is the same as the aquifer and permeability can be high. Excess nitrate and other soluble compounds in the surface soil are easily transmitted to the groundwater. Plant growth is often limited by low water-holding capacity or droughty nature of sandy soil. Adsorption capacities and microbial activity is less in other soils with low organic levels common in sandy soils.

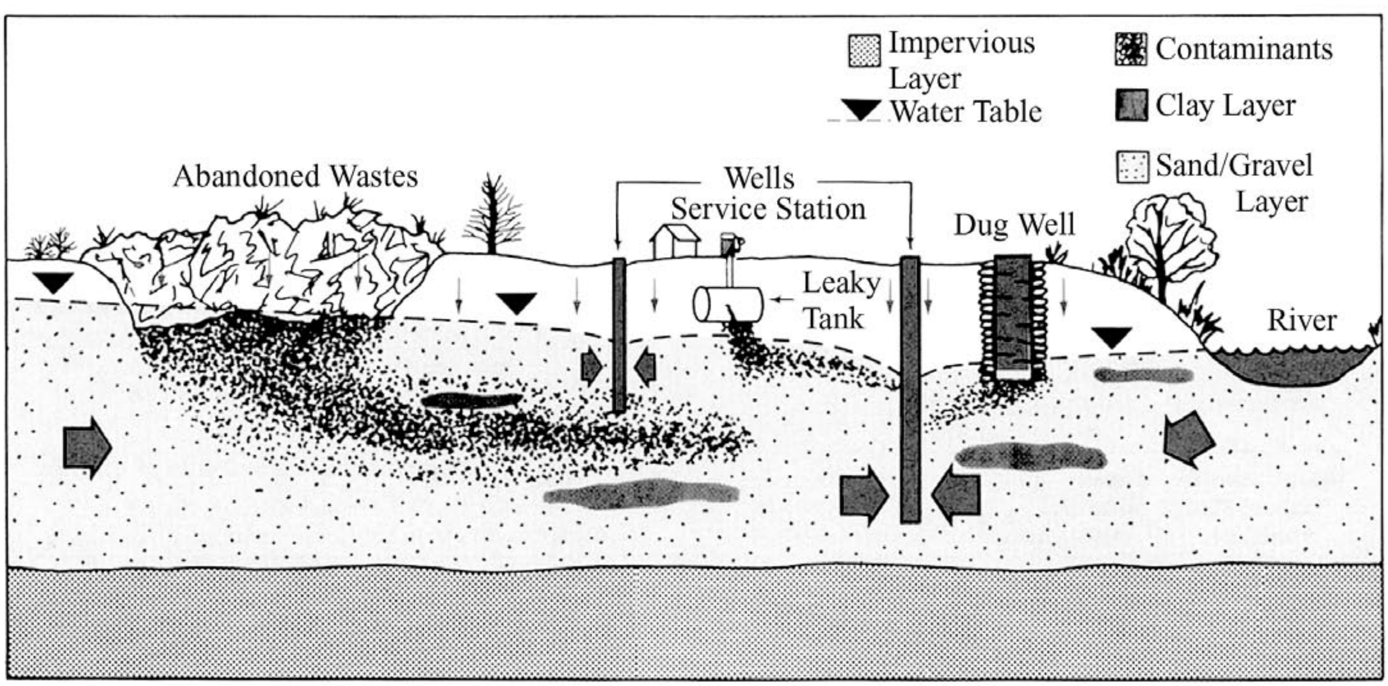
Limestone Aquifers require special attention in two situations. The first is where sink holes are common, called Karst topography. The second is where the rock is exposed or covered only by a shallow layer of soil. Sinkholes and exposed bedrock provide direct connections for contaminants to easily enter the groundwater and contaminate wells. Shallow soil layers provide only slight protection. These situations pose a serious risk for groundwater contamination.

Water in limestone aquifers is primarily in cracks, joints, and solution channels. These spaces tend to be large compared with pore spaces in other types of aquifers. As a consequence, the flow in limestone aquifers may be rapid and the filtering action poor. However, rapid flow through the aquifer tends to make contamination events of short duration.

Protect Well Water by Good Location

Locating a domestic well to safeguard water quality requires consideration of geology, topography, and potential contamination sources within at least 400 feet of the site. Historically, wells were located near the point

Figure 1. *Groundwater contamination occurs from many sources and usually moves in concentrated plumes.*



of maximum use. Because livestock required the most water at a farmstead, the well was often located in, or very near, livestock lots. This placed the well near a major contamination source. The house and shop were almost always upslope from the livestock. This meant the well was very likely downslope from other potential pollution sources. A location near and especially downslope from contamination sources increases the potential for well pollution.

The first rule for protecting well water quality is to keep the well upslope from potential sources of contamination. Current contamination sources are easy to identify. However, past activities may not always be obvious and many contaminants have a long life. An attempt should be made to determine if potentially hazardous activities occurred at or near the site. Many contaminated wells were constructed in or near old feedlots, storage facilities, disposal sites, landfills, privies, or septic systems. See relationships of sources and well in Figure 1.

The second rule for protecting water quality is adequate separation of well from pollution sources. There is no specific distance from a potential pollution site that will guarantee the well will not be affected. Recent studies indicate that 200 to 400 feet provides a high level of assurance the well will be protected (see Table 1). Thus, homesites where both a private well and an onsite wastewater system will be installed should have the two separated by at least 200 feet to lower the risk. As discussed later, a 5-acre lot is needed to achieve this separation distance.

The third rule for protecting well-water quality is to avoid high density or concentration of pollution sources. A rural-suburban development with 3-acre lots would allow more than 200 homes per square mile. If each home had a private well and an onsite sewage system, it would be difficult to select a safe location for all wells within that area. Without favorable topographic and geologic conditions, water quality problems would develop. It may take years or even decades, but eventually contaminants from septic systems, yards, households, and other sources would affect some wells.

Table 1. *Distance versus chance of well contamination in unconfined aquifers*

Distance, in Feet	Bacteria	Nitrate, Pesticide(s), Volatile Organic Chemicals (VOCs)
less than 50	moderate to high	very high
50-100	low to moderate	moderate to very high
100-200	very low to low	moderate to high
200-400	very low	low to moderate
greater than 400	very low	very low

Groundwater Flow

There is a natural movement or flow of water in the aquifer that likely follows the general slope of the surface. However, nonuniform properties in the aquifer and sloping formations can cause differences. Pumping from wells also influences groundwater flow direction and rate. As water is removed from the well, water in the aquifer surrounding the well flows toward the well creating a "cone of depression."

More of the water entering the well flows from the uphill side and the cone of depression becomes oval in shape. The size of the cone depends on the permeability and storage in the aquifer and the rate and duration of pumping. Household wells are usually pumped for a few minutes to a few hours at a time. In coarse gravel aquifers, both large storage and high permeability result in a small cone of depression. By contrast, an aquifer with lower permeability and storage values will have a larger cone of depression.

In most situations, the natural flow in the aquifer is more important than pumping in conveying contaminants toward a well. But, pumping does have some effect and long periods of pumping have more influence than short ones. The effect of pumping is greater during drought periods when groundwater levels and flow may be lower.

Where to Locate a Well

A well is best located on a well-drained site that is not subject to flooding, is upslope, and is removed as far as practical from possible contamination sources. A continuous layer of well-drained soil generally provides good protection from contamination by bacterial sources such as septic systems and animal waste. Although at least 50 feet separation distance is required by state regulations, 100 feet or more provides much better protection from microbes — especially viruses — and is required by some county codes. The vertical separation should also be considered, including the thickness of soil cover and depth to groundwater. The greater the horizontal and vertical separation of the well intake from sources of contamination, the greater is the protection from contamination.

When the soil cover over rock is shallow or very coarse, water can move rapidly to the aquifer. When soil is poorly drained, its natural filtering capacity does not function as well. Microbiological contaminants including bacteria, viruses, and cysts have a greater chance of reaching groundwater when either condition exists.

The first step in selecting a good location for a well is to inventory all potential contamination sources. These should be accurately located on a map. Next, find groundwater flow direction from groundwater publications, local driller knowledge, or use a surveying level to compare water levels in existing nearby wells. Groundwater flow usually follows general surface slope, but not nearby drainage topography. The well site should be upslope of surface drainage from all pollution sources. It should also be upgradient in groundwater flow. The preferred separation distance is at least 400 feet.

While groundwater movement direction suggests where the well protection zone should be located, a landowner may not have that specific information. Therefore, protection in all directions is a wise procedure. Table 1 shows contamination risks for various distances. Recommended minimum separation distances are 50 feet from boundaries, 100 feet from buildings and bacterial sources, and 400 feet from major nitrogen (nitrate) sources.

Ideal separation distances for a private well location are shown in Figure 2. An important aspect is that any private well should be separated from all potential contamination sources, not just those of the owner. To achieve these separation distances, lot sizes of at least 5 acres are needed when each lot has a septic system and a well. This generally allows for an adequate separation distance from the well to potential sources on the owner's property and other adjacent properties.

Current Well Construction Standards

Well construction following current standards, together with maintenance and protection, are important in maintaining a safe water supply. When the well meets KDHE construction standards, contaminants from the surface are not likely to directly enter the well or groundwater adjacent to the well. Surveys of private wells show that defects in construction, inadequate materials, and damage or lack of maintenance cause about four of five wells to be vulnerable to contamination.

Kansas regulations for water-well construction require an approved, watertight casing from at least 1 foot above the ground surface to the top of the well screen. If the location is subject to surface flooding, the casing should be extended 1 foot above the highest flood elevation. However, locations subject to flooding are discouraged.

The casing must be capped with an approved sanitary well seal or cap and the casing must be sealed into the bore hole with an approved grout. If a water pipe exits through the side of the casing, an approved pitless adapter must be used to make it watertight. Electrical wires entering the well must be contained in a conduit that does not allow contaminants to enter. The conduit must not penetrate the casing. Approved sanitary seals are designed to seal the conduit.

If the well penetrates a confining layer or terminates in the bedrock, the casing must be grouted through the confining layer and sealed into the bedrock. The surface grout seal usually begins below the pitless adapter and must extend 5 feet into the first confining shale or clay layer or at least 20 feet, whichever is greater. Finally, the ground surface should be shaped to slope away from the well for at least 20 feet in all directions (see Figure 3) and not allow ponding within 50 feet.

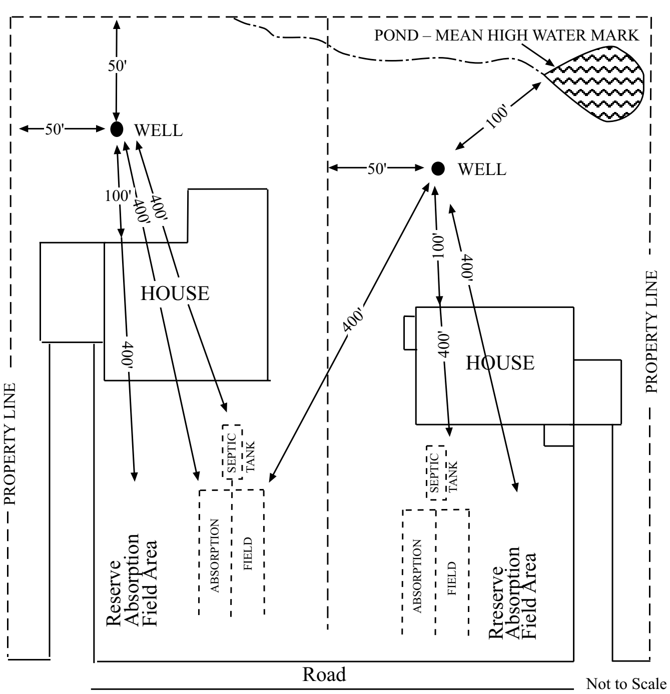


Figure 2. *Ideal private well location*

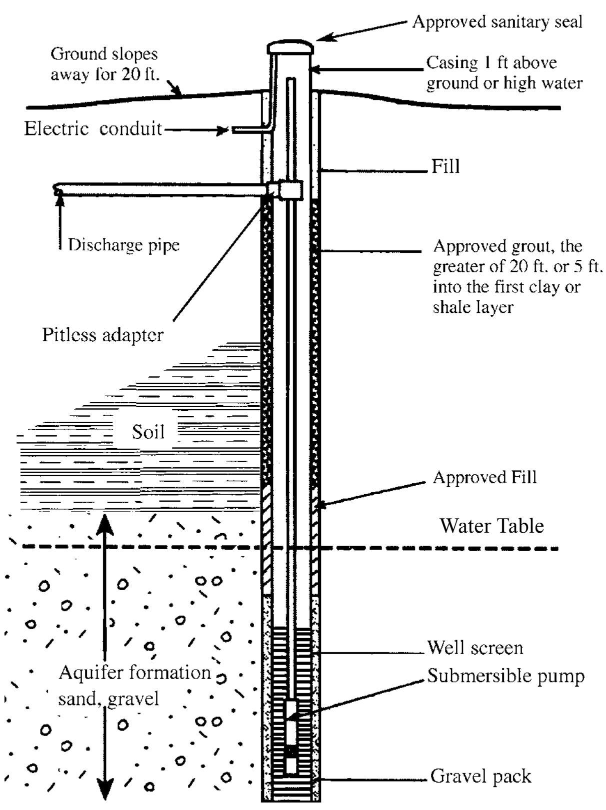


Figure 3. *Required well construction — unconfined aquifer*

State law requires that the driller follow the procedures described here. Typically there is no inspection of the work during construction or of the completed job. Thus, it is in the owner's interest to understand the principles, to make sure the driller knows the procedure, and to be sure the procedure is followed during construction. A few county sanitary codes provide for well inspection by the sanitarian or environmental health officer. However, it is very difficult to evaluate what was done underground after the well is complete.

Well Construction Details

A domestic well is normally constructed by drilling the hole 4 to 6 inches larger than the casing. The intake portion of the well is generally a screen or perforated length of pipe. The screen or perforated length of pipe is lowered into the hole and lengths of casing are connected as necessary. This is lowered until the screen or casing rests on the bottom of the hole. Centering guides may be attached to the casing to maintain a uniform space between the casing and the bore hole.

Granular material called gravel pack is placed in the space around the intake screen. Well construction standards require that grout be placed between the bore hole and casing at confining zones and at the top of the well. The driller must examine cuttings and log the position so depth of formations, the formation properties, and confining zones are known.

In some formation materials, wells are not gravel packed. When this procedure is used, the casing is extended into the aquifer and grouted to limit water movement outside the casing. A smaller hole is bored below the casing and a screen or perforated pipe is inserted into this hole and sealed to the casing.

In some rock aquifers, the intake is the open, unlined borehole. It may be smaller than the casing, the same size, or larger than the casing as in the gravel-packed well. The well owner may not know these details of construction does not and need to be too concerned about them. The driller should provide the owner with a copy of the well log or report that must be submitted to the KDHE. Details about the well, construction, and materials used should be on the well log. For any questions, the owner should ask the driller, the county health department, or the local Research and Extension office.

Case Study of Well Contamination

The importance of following construction standards can be illustrated by reviewing a case study (Kansas Geological Survey, Open File Report 85-12) of well contamination in a small Kansas community. The cross-section of a representative well (Figure 4) shows a total depth of 115 feet through several layers of soil, limestone, and shale. The producing water aquifer was below a thick layer of shale which, prior to the well being drilled, protected this confined aquifer. Each spring, during the high precipitation period, an increase in water level and a degradation of quality was observed.

The well, drilled before current construction standards, had only 10 feet of surface grouting and was gravel-packed through the confining shale layer. It is believed that other wells in the community had similar construction. The investigation concluded that the upper limestone layer, which historically produced water from dug wells, was receiving contaminated surface water recharge. The recharge migrated to the drilled wells and moved through the gravel pack to the lower water table because the grout seal did not extend into the top of the confining shale.

Wells in this community did not provide safe water because of contamination from multiple nearby sources and inadequate well construction. Correction of this problem requires properly plugging all shallow wells and restoring the continuity of the confining shale layers around each well that was not grouted through this zone. It would be very expensive to do this.

Upgrading Wells to Present Standards

Because 80 percent of private wells fail to meet one or more of the current construction and separation distance standards, it follows that well owners who are concerned about water quality should plan to upgrade or replace their wells. Some upgrading is easily accomplished and makes sense. Other action may be difficult and expensive.

The decision about whether to upgrade an existing well should be carefully considered. Important questions to answer are where the well is located, how it is constructed, whether it currently supplies enough water of adequate quality, and the type and condition of the

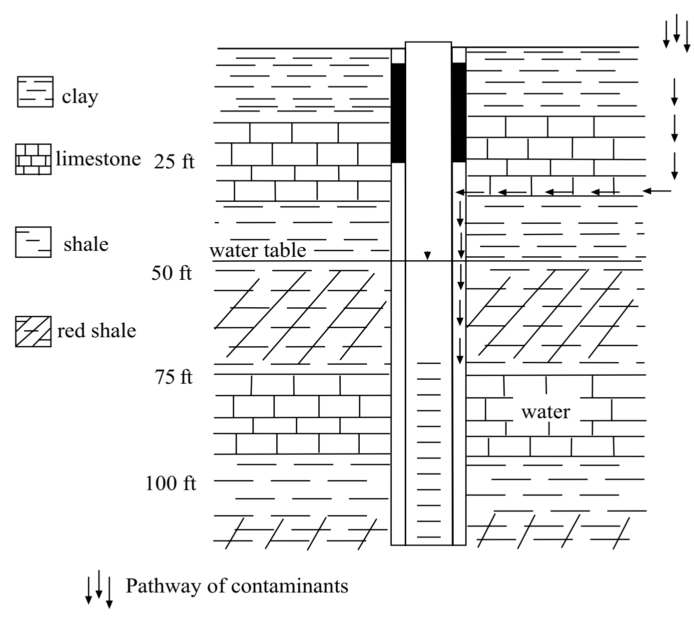
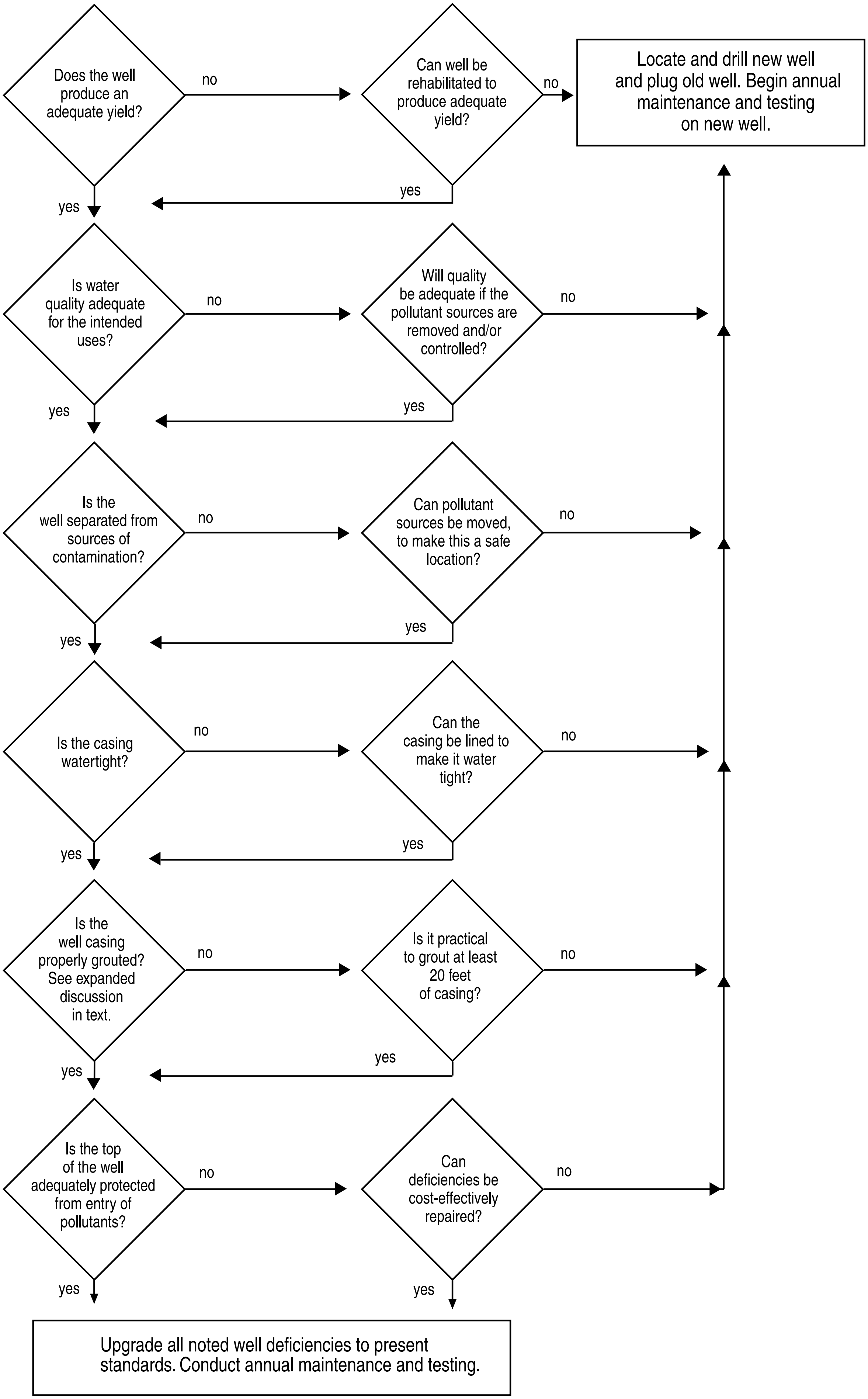


Figure 4. *Cross-section showing well construction details of an improperly grouted well*

Figure 5. *Well Upgrade or Well Replacement Decision Diagram.*



casing. These questions and answers are diagrammed on the flow chart in Figure 5. Use your judgment supplemented with the opinion of your well driller, expert advisor, and information from other nearby wells as a guide. The following paragraphs address details of the various questions.

Does the well produce an adequate yield? Upgrading a well that currently does not provide sufficient water is of no practical value. If well yield has declined as a result of clogging of the well screen, then treatment to restore capacity is often a good option. If yield has declined because the water table has declined, then treating or upgrading the existing well will not correct the problem.

Is water quality adequate for the intended uses? If the quality is poor, either from natural minerals or pollution, will a new well site or alternate water zone improve quality? If the quality issue is the result of nearby contamination because of construction deficiencies, then a new well should correct this provided existing wells are properly plugged to avoid contamination of the aquifer. For example, bacterial contamination due to a well being located in a pit should not be an issue after reconstruction.

Is the well separated from sources of contamination? Since the well currently provides a suitable water supply or one that can be cleaned up, this question deals with how easily you can isolate the well from potential pollution risks. An exclusion zone of 100 to 200 feet radius around the well — with no pollution sources such as buildings, pens, equipment, and chemical storage — is ideal. A managed zone of up to 400 feet from nitrogen sources is recommended. Publication MF-2396, *Private Well Maintenance and Protection*, discusses details about developing a wellhead protection plan. If the well site does not have an adequate protection zone, can structures and activities be relocated? Or, can measures economically be taken to assure they will not degrade water quality? Or, is a new well in a different location a better alternative?

Is the casing watertight? The casing should be of an approved material, have sealed joints, and extend to the screened area of the aquifer. A well that has an approved casing in good condition is a good candidate for upgrading. If the well was constructed of a non-approved casing, but is large enough to allow lining with an approved casing, it may still be an upgrade candidate. The approved casing could be grouted inside the old casing. Still to be determined, however, is if and how the original casing was grouted. The following paragraph will help evaluate the grouting.

Is the well casing properly grouted? Determination of the grouting depth around the outside of the casing may be a difficult task. If the well was drilled after 1974, a construction log should be available through KDHE. The report should contain information about how the well was grouted. Digging or probing around the well casing may help evaluate the presence of grouting. Usually, the grout begins just below the pitless adapter. If no grouting is present, and the well has good quality water and is in a good location, it may be worthwhile to drill grout holes around the outside of the casing and inject grout to seal the upper portion of the casing. In this case the grout depth should be placed 5 feet into the first confining layer or at least 20 feet, whichever is greater. A well driller can perform this work.

Is the top of the well adequately protected from entry of pollutants? The four components associated with the top of the well are 1) the casing, the top of which must be at least 1 foot above the ground surface, 2) the pitless adapter, 3) the sanitary seal, which must be a KDHE approved type, and 4) proper surface drainage.

Wells located in pits, basements, or other places where the casing terminates below the ground surface are a serious contamination threat. Wells in a basement or crawl space fail separation distance criteria and are difficult to inspect and service. They should be plugged. The pit should be removed and the approved casing extended to the minimum height above the ground surface. The pressure tank can be placed in a new pit at least 2 feet from the well, but the well must not terminate in a pit.

A pitless adapter makes a watertight connection through the well casing that connects the pump to the water distribution system. A pitless unit also can be used to replace the top few feet of the casing. Using the KDHE-approved sanitary seal or well cap is important to protect the well from direct surface water entry. The sanitary seal includes a connection port for the electrical conduit, which allows the electrical wires for the pump to enter without making a hole in the casing.

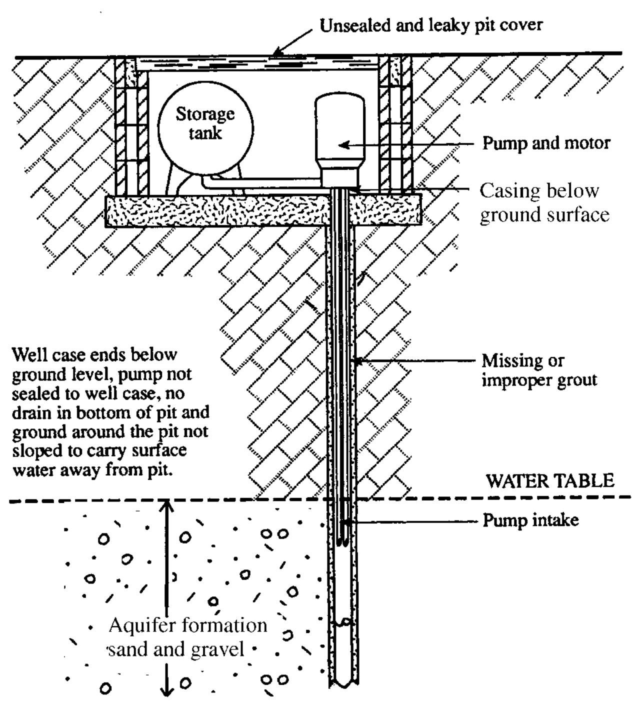


Figure 6. *This well* ***does not meet*** *many well configuration standards and allows contamination to enter.*

The ground surface around the wellhead should be graded so surface water drains away from the well at least 20 feet in all directions. There should be no surface water, either ponded or streams, within 50 feet of the well.

Can deficiencies be cost-effectively repaired? Will it cost much less to upgrade the well than to drill a new one? Figure 6 shows a section view of a well that has multiple deficiencies. It likely is less expensive to drill a new well and plug the old one rather than to upgrade it. A new well is almost always a good decision for improved reliability and reduced risk. Remember, wells are a long-term investment with a life expectancy of several decades. The initial investment cost may be high, but they can often be the most economic long-term water supply option.

Shortcuts to reduce costs often increase the risk of contamination and produce poor results. If you are depending on the advice of a well driller who is willing to cut corners, think again and get a second opinion.

All well drillers in Kansas must be licensed. A list of drillers for your area can be obtained from the Kansas Department of Health and Environment (785-296-5522 or 3565) or Kansas Ground Water Association (620-548-2669). Only you can make certain you get good value from your investment.

Summary

Obtaining and maintaining a safe well is not always easy but the principles are relatively simple.

- Locate the well away from potential sources of contaminants.
- Seal the well against all pathways through which water and contaminants may enter.
- Select quality materials that will have a long life.
- Avoid, or carefully manage, sources or activities that may contribute contaminants within at least 200 feet of the well. In sensitive areas, increase this distance to at least 300 to 400 feet.

Finally, no well is completely safe and all are subject to deterioration and damage. Annual maintenance including checking the well, doing shock chlorination, water testing, and following the protection plan, is the only way to assure the well will continue to provide safe water. If contaminants are detected, take action to locate the source, evaluate the health risk, and test more frequently to determine if there is a trend.

Selected K-State Research and Extension Water Quality Publications:

Available from county Extension offices

Related to private wells:

- *Plugging Abandoned Wells*, MF-935
- *Private Well Maintenance and Protection*, MF-2396
- *Private Water Well Owner/Operator Manual*, MF-2409
- *Shock Chlorination for Private Water Systems*, MF-911
- *Recommended Water Tests for Private Wells*, MF-871
- *Taking a Water Sample*, MF-963
- *Testing to Help Ensure Safe Drinking Water*, MF-951
- *Understanding Your Water Test Report*, MF-912

Other related topics:

- *Get to Know Your Septic System*, MF-2179
- *Kansas Home*A*Syst—An Environmental Risk-Management Guide for Homes*
- *Minimum Standards for Design and Construction of Onsite Wastewater Systems*, MF-2214
- *Nitrate and Groundwater*, MF-857
- *Organic Chemicals and Radionuclides in Drinking Water*, MF-1142

Available from Midwest Plan Service, 122 Davidson Hall, Iowa State University, Ames, IA , 50011-3010; Phone 1-800-562-3818:

- Home Water Treatment, NRAES-48
- Private Drinking Water Supplies, NRAES-47
- Private Water Systems Handbook, MWPS-14

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