Water Quality

K-State Kansas State University

Private Wells — Safe Location and Construction

Water for residences beyond the reach of public systems, either cities or rural water districts, usually comes from a well. Surveys of private well water quality show that on average only 40 percent meet the safe drinking water standards for public systems. More than half, 51 percent, contain coliform bacteria, which indicates an exposure to the surface environment. Coliform bacteria does not thrive or even survive for long periods in an aquifer. Eighteen percent contain E. *coli* bacteria, which indicates contamination by sewage or animal manure. E. *coli* indicates a high risk of disease. About one in four private wells has nitrate exceeding the maximum contaminant level (MCL). These contaminants usually can be traced to problems with well location and/or well construction.

Ensuring an adequate water supply and acceptable quality is the responsibility of the owner/user of the well. Construction and location are the two most important factors in protecting private well water. Yet private well surveys indicate more than 80 percent of private wells are deficient in construction or in location — the separation distance and direction from potential contamination sources.

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 microorganisms. Many contaminants, including nitrate, volatile organic chemicals (VOCs), petrochemicals (fuel), and some pesticides, are not filtered by the soil and substantially greater separation distances are needed. Research shows when nitrogen sources are more than 400 feet from the well, there is a very low incidence of high nitrate being present.

The water owner/user is solely responsible for the quality of water consumed. There are no state or federal regulations that apply to the quality of the water taken from a private well. Kansas, however, has regulated new well construction and well repairs since 1975. Anyone who constructs (drills), reconstructs (repairs), or treats wells must be licenced and must file required reports with the Kansas Department of Health and Environment (KDHE).

The best time to help assure that a well produces safe water is when a new well is being located and constructed. This publication addresses safe well location and construction. Wells also will need annual maintenance and management to protect the water supply. K-State Research and Extension publication *Private Well Maintenance and Protection*, MF-2396 gives guidelines that help owners maintain and protect their well.

Groundwater Geology

Groundwater occurs everywhere below the ground surface. It fills the spaces in sand, gravel, and rock formations. A formation that contains enough water that can be removed by a pump at useful rates is called an aquifer. An aquifer may be sand, gravel, a mix of sand and gravel, fractured rock, or porous rock. It may be a single mass, a layer, or a series of layers. Water may flow between the layers or may be isolated between layers of low 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 are more likely to cause contamination. Aquifers that do not have hydraulic connection directly to the surface are called confined aquifers. Confined aquifers are normally recharged from more distant water sources. Activities near a properly constructed well in a confined aquifer are much less likely to contaminate the well.

Other factors affecting potential contamination are depth to the water table, permeability of the recharge zone and, to a lesser extent, type and condition of vegetation on the surface. Recharge passes through an unsaturated layer called the vadose zone, or zone of aeration. The top portion of the vadose zone contains roots and the greatest microbial activity. Soil organisms break down many of the dissolved compounds in water, and plant roots remove nutrients, trace elements and other compounds. As water passes through the vadose zone, particles and most organisms are filtered out, and compounds dissolved in the water may be adsorbed on soil particles, precipitated, or chemically combined to form new compounds. Minerals in the soil and rock may be dissolved into water. Healthy perennial vegetation with a deep root zone and deep vadose zone of moderate permeability are ideal to help assure good water quality.

The rate of recharge, the volume of storage, and the rate of flow through the aquifer also are important water quality factors. 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 and the soil or rock. Large storage volumes in an aquifer help dilute contaminants and help a well endure long, dry periods. Rapid flow through the aquifer makes it self-cleaning, but 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 given location because of the factors previously mentioned, but groundwater quality is not uniformly good or bad, even over relatively short distances. A few aquifer types deserve special attention when considering a domestic well.

Sand Aquifer

Aquifers in sand or gravel deposits with shallow depths to water are particularly difficult to protect from contamination. In many cases, the material in the unsaturated zone is the same as the aquifer, and permeability is high. Excess nitrate and other soluble compounds in the surface soil are easily transmitted to the groundwater. Plant growth is frequently restricted because of low water holding capacity or droughty nature of sandy soil. Microbial activity is less than in most other soils, and sandy soils have low adsorption capacities.

Limestone Aquifer

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 by only a shallow layer of soil.

Sinkholes and exposed bedrock provide a direct connection for contaminants to enter the groundwater, and shallow soil layers provide only slightly more 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. The rapid flow through the aquifer tends to make contamination events of short duration, but there is little protection against contamination entering the groundwater and the well.

Both of these conditions exist in Kansas, which is why 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.

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. Wells historically were located near the point of maximum use. At a farmstead, livestock required the most water so the well was often located in or very near livestock lots. This placed the well near a major contamination source. The house and shop are almost always upslope from the livestock. This meant that the well was very likely downslope from other sources. A location near and especially downslope from contamination sources is not good by current standards.

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, but past activities may not always be obvious. Many contaminants have a long life, and if the site previously was occupied, an attempt should be made to determine if potentially hazardous activities occurred at the site. Many contaminated wells were constructed in or near old feedlots, storage facilities, disposal sites, landfills, abandoned privies, or septic systems. See *Groundwater and Well Contamination*, MF-932.

The second rule for protecting well water is adequate separation from pollution sources. There is no specific distance from a potential pollution site that will guarantee the well will not be affected. But recent studies indicate that 200 to 400 feet is required for a high level of assurance that the well will be protected (see Table 1). A homesite where both a private well and onsite wastewater system will be installed should be at least 3 acres in size. However, as discussed later in this publication, a 5-acre lot is preferred.

The third rule for protecting well water is to avoid high density or concentration of pollution sources. A rural-suburban development with 3-acre lots would allow

Table 1. *Distance Versus Relative 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

more than 200 homes per square mile. If each home had a private well and onsite sewage disposal 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 might take years or even decades, but eventually contaminants from septic systems, yards, households, and other sources would reach some or many of the wells.

Groundwater Flow

There is a natural flow in the aquifer and aquifer properties are not uniform. Groundwater flow generally follows the slope of the surface. Pumping the well also influences groundwater flow. 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 oblong in shape. The size of the cone depends upon 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. A coarse gravel aquifer has both great storage and high permeability, and the cone of depression is small compared to an aquifer with lower permeability and storage values.

In most situations, the natural flow in the aquifer is more important in conveying contaminants toward a well than is pumping. But pumping has 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 removed as far as practical from possible contamination sources. A continuous layer of well-drained soil generally provides good protection from contamination from bacteria sources such as septic systems and animal waste. Although 50 feet is the minimum required by state and many local regulations, 100 feet provides much better protection from bacteria. The vertical separation also should be considered including the thickness of soil cover and depth to groundwater. The greater the horizontal and vertical separation, the greater the protection.

When the soil cover is shallow to rock or is very coarse, water can rapidly move to groundwater. When soil is poorly drained, its natural filtering capacity does not function well. In both of these conditions microbiological contaminants including bacteria, viruses, and cysts have a greater chance of reaching groundwater.

The first step in selecting a good location for a well is to inventory all potential contamination sources. They should be accurately located on a map. Next, find groundwater flow direction from groundwater publications, local driller knowledge, or using 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 should be upslope of surface drainage from all pollution sources. It should also be upstream in groundwater flow. The preferred separation distance is 400 or more feet.

While groundwater movement direction suggests where the well protection zone should be located, a landowner only occasionally has good information, thus protection in all directions is a reasonable option. Table 1 shows contamination risks for various distances. Important recommended 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 is illustrated in Figure 1.

An important aspect of the illustration 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 allows for an adequate separation radius from the well to potential sources on the owner's and adjacent property.

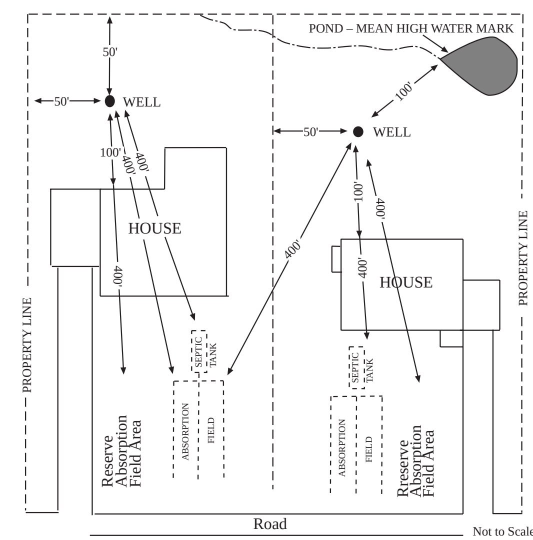


Figure 1. *Ideal Private Well Location*

Well Construction Standards

Well construction following current standards together with maintenance and protection are important in maintaining a safe water supply. If the well meets these standards, surface water cannot enter the groundwater adjacent to the well or directly into the well. Surveys of private wells show that defects in construction, inadequate materials, damage or lack of maintenance leave about four of five wells 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 must be extended 1 foot above the highest flood elevation. However, locations subject to flooding are discouraged. The casing must be capped with an approved well cap, also called a sanitary seal, 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 this opening watertight. Electrical wires entering the well must be contained in a conduit that does not allow contaminants to enter.

If the well penetrates a confining layer or terminates in the bedrock, the casing must be grouted within the confining layer and sealed into the bedrock. The grout seal in the upper portion of the casing must be at least 20 feet, usually beginning below the pitless adapter, or 5 feet into the first confining shale or clay layer, whichever is greater. Finally, the ground surface should be shaped to slope away from the well for at least 15 feet in all directions (see Figure 2).

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

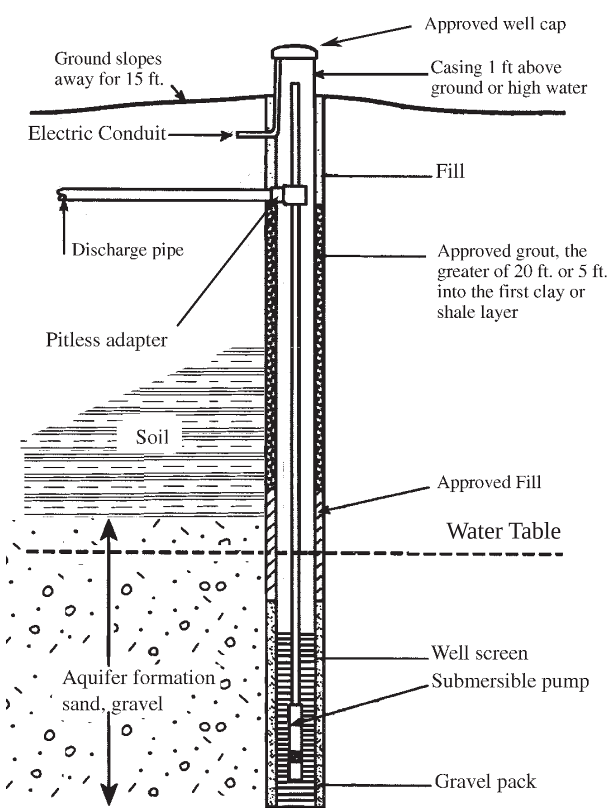


Figure 2. *Required Well Construction — Unconfined Aquifer*

Well Construction Details

Domestic wells are normally constructed by drilling holes 6 inches larger than the casing, then installing the components of the well. The intake portion of the well is generally a screen or a perforated length of pipe, but in bedrock it may be the open bore hole. The screen or perforated length of pipe is lowered into the hole and lengths of casing are connected as necessary and lowered until the intake portion of the case rests on the bottom of the hole. Centering guides may be attached to casing as it is lowered into the hole 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 portion of the casing. Grout is placed at the top and at confining zones as the well standard requires.

In some formation materials, wells are not gravel packed. When this procedure is used, the casing is extended into the aquifer where it is 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 bare bore hole and it may be smaller than the casing, the same size or oversized as in the gravel-packed well. The well owner need not be too concerned with such details and may not know details of construction.

The driller should provide the owner with a copy of the well report that must be submitted to the Kansas Department of Health and Environment. Details about the well, construction, and materials used should be listed on the report. The owner should ask any questions they have of the driller, the county health department, or the county Extension office.

Case Study of Well Contamination

The importance of sound construction techniques 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 3), 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, was protecting the 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 existed, had only 10 feet of surface grouting and was gravel packed through the confining shale. It is believed that other wells had similar construction. The investigation concluded that the upper limestone layer, which historically produced water from dug wells, was receiving contaminated surface water recharge that migrated to the drilled wells and moved down the gravel pack to the lower water table because the grout seal did not extend into the top of the 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. This would be a very expensive effort.

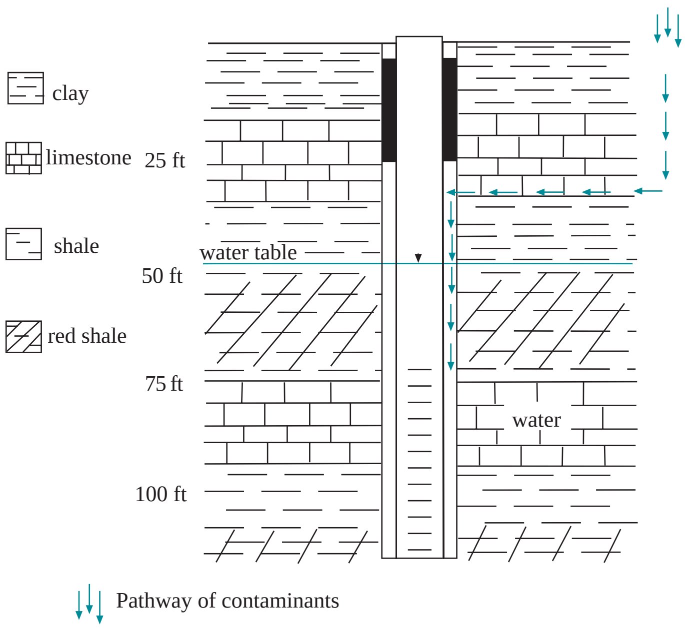


Figure 3. *Cross-section Showing Well Construction Details of an Improperly Grouted Well.*

Upgrading Wells to Present Standards

Since more than 80 percent of private wells fail to meet one or more of the current construction and separation distance standards, it follows that many well owners should immediately set into action a plan to upgrade their wells. Some upgrading is easily accomplished and makes sense. Other action may be difficult and expensive. Another good tool to help you develop a plan of action to identify and then implement correction and management is the *Farm•A•Syst* program available through K-State Research and Extension. This program is available to any private water well user.

The decision about whether to upgrade an existing well should be carefully considered. Where it is located, how it was constructed, what type of casing it has, what is its present condition, and whether it currently supplies enough quality water are all important questions. These questions and answers are diagrammed in Figure 4.

The following discussion covers details of the various decision considerations.

Does the well currently provide enough water of adequate quality? Upgrading a well that currently is not providing sufficient water is of no practical value. If quantity is not an issue but the quality is poor, either from natural minerals or pollution, the question is will a new well site or water zone improve quality? If the quality concerns are the result of local contamination due to construction deficiencies, then a new well should correct these. For example, bacterial contamination due to a well being located in a pit should not be an issue after reconstruction. Use your judgement and the opinion of your well driller, expert adviser, and information from others nearby wells as a guide.

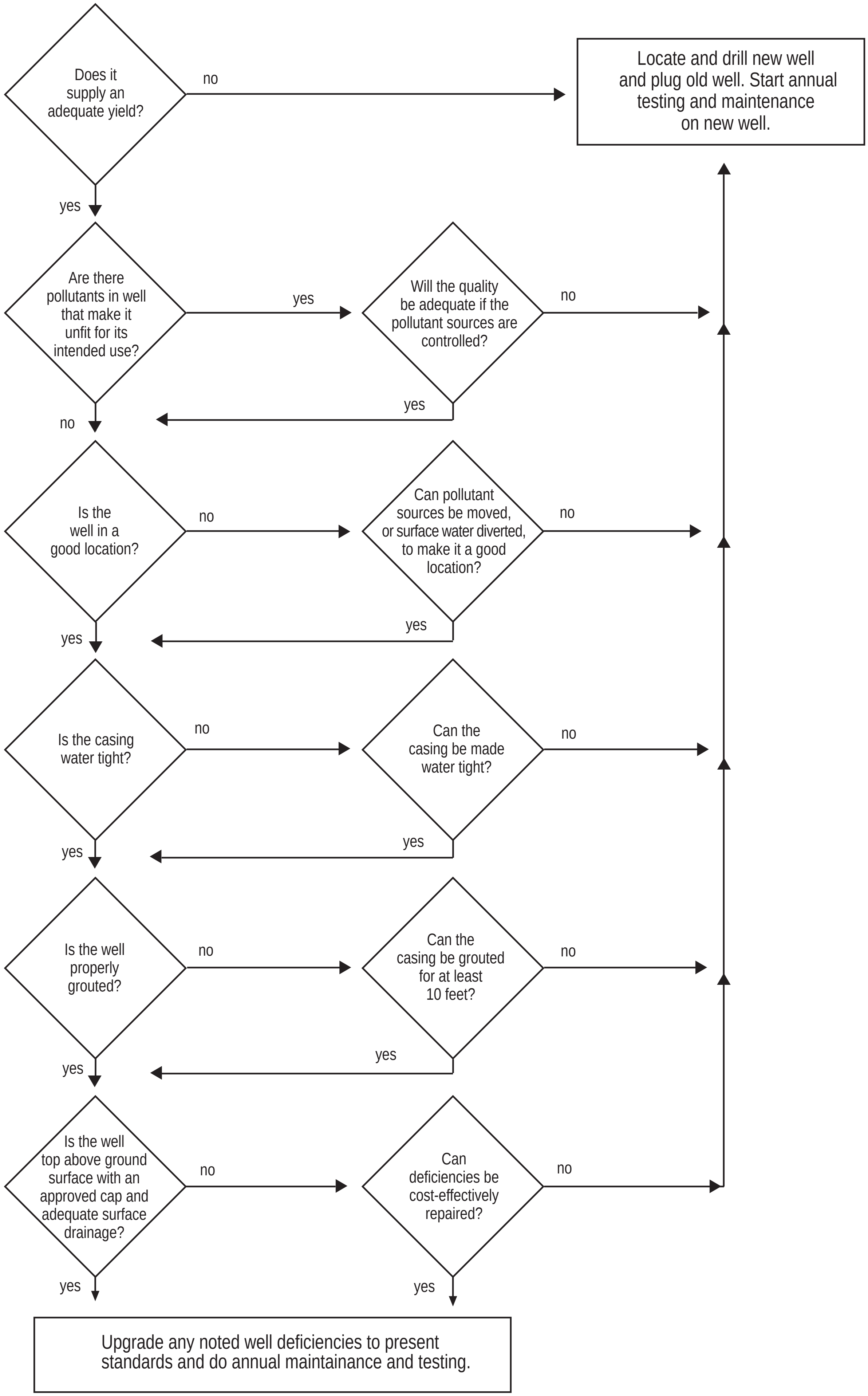
Does the well meet guidelines for location? Since the well currently provides a suitable water supply or one that can be cleaned up, this question deals with how easily you can isolate the well from potential pollution hazards. An exclusion zone of 100 to 200 feet radius around the well with no pollution sources including buildings, pens, equipment, and chemical storage is ideal. A managed zone of up to 400 feet from nitrogen sources is recommended. If the well site does not have an adequate protection zone, can structures and activities located in the zone be relocated or is relocation of the well a better option?

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 an non-approved casing but is of sufficient size as to allow insertion of an approved casing, it still might be an upgrade candidate. The approved casing could be grouted inside the old casing. However, the issue remains whether the original casing was properly grouted as discussed next.

Is the well properly grouted? Determination of the grouting depth around the outside of the casing may be a difficult task. If the well was drilled after 1975, a construction log should be available through KDHE, the report should contain information about grouting. You may be able to check if grouting is there by digging or probing around the well casing. Usually the grout begins just below the pitless adapter. If no grouting is present and the well has good quality water and is located in a good position, it may be worthwhile to drill grout holes around the outside of the casing to seal the upper portion of the casing. In this case, the grout depth should be placed to a depth of 20 feet or 5 feet into the first confining layer, whichever is greater.

Does the well casing extend at least one foot above the ground surface? Wells located in pits or basements 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. Well pits should have the pit closed, and the approved casing extended to the recommended height above the ground surface. The pressure tank can be placed in a new pit near the well site, but the well must not terminate in a pit.

Figure 4. *Well Upgrade or Well Replacement Decision Diagram.*



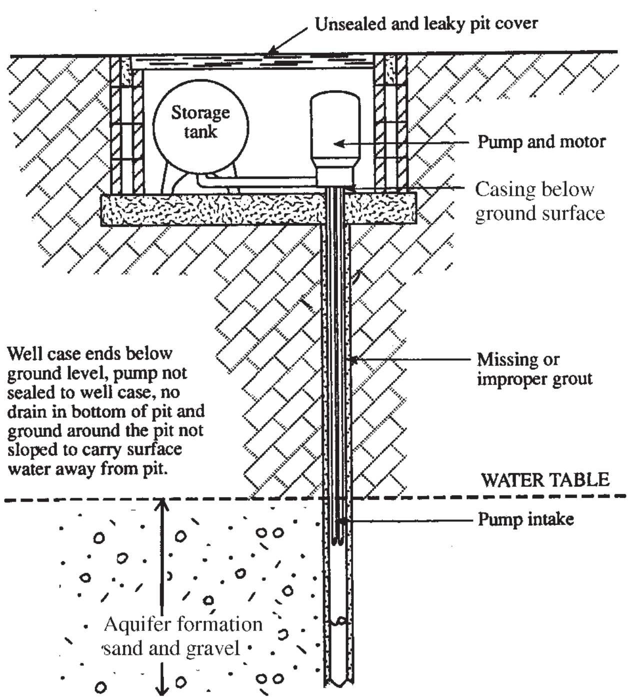


Figure 5. *Well Configuration that* ***does not Meet*** *Well Construction Standards, and Carries Contamination.*

Is the top of the well adequately protected? The three issues associated with the top of the well are 1) pitless adapter, 2) approved well cap, and 3) proper surface drainage.

A pitless adapter makes a watertight connection through the well casing that ties the pump to the water distribution system. A pitless unit can also be used to replace the top few feet of the casing. The KDHE–approved well cap is a sanitary seal that protects the well from direct surface water contamination. The sanitary seal includes a connection port for the electrical conduit allowing the electrical wires for the pump to enter without opening the inside of the well to the surface environment. The ground surface around the wellhead should be graded to permit surface water drainage from the site for at least 15 feet in all directions.

Is the cost to upgrade the well much less than the cost of a new well or alternative public water supply? Figure 5 shows a section of a well that has multiple deficiencies. It may be less expensive to drill a new well than to upgrade this one. A new well is almost always a good decision for improved reliability and reduced risk. Wells are a long-term investment, so while the initial investment cost may be high, they can often be the most economic long-term water supply option for many owners. Shortcuts to reduce costs are often shortcuts to increased risk. If you are depending on the advice of a well driller that seems to want to cut corners, think again and get a second opinion. All well drillers in Kansas must be licensed, and a list of drillers for your area can be obtained from the Kansas Ground Water Association (316-548-2669). 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.

- Isolate the well from potential sources of contaminants as much as possible.
- Seal the well against all pathways through which water and contaminants may enter.
- Select quality materials that will have a long life.
- Avoid and carefully manage activities that may contribute contaminants within at least 200 feet of the well and, in sensitive areas, increase this distance as necessary.

Finally, no well is completely safe and all are subject to deterioration and damage. Annual maintenance, including checking the well, shock chlorination, a water test, and following the protection plan, is the only way to assure that the well will continue to provide safe water. If contaminants, which may pose a health risk are found, take action to locate the source 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
- Managing the Farmstead to Minimize Groundwater and Well Contamination, MF-948
- Minimum Standards for Design and Construction of Onsite Wastewater Systems, MF-2214
- Nitrate and Groundwater, MF-857
- Organic and Radiological Chemicals in Drinking Water, MF-1142

Available from Extension Biological and Agricultural Engineering, 237 Seaton Hall, Manhattan, KS 66506:

- Home Water Treatment, NRAES 48
- Planning for an Individual Water System, AAVIM 600
- Private Drinking Water Supplies, NRAES 47
- Private Water Systems Handbook, MWPS-14
- *Farm•A•Syst: Farmstead Assessment System,* 29005
- *Kansas Home*A*Syst—An Environmental Risk-Management Guide for Homes*

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Publications from Kansas State University are available on the World Wide Web at: http://www.oznet.ksu.edu

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MF-970 August 1999