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DEPARTMENT OF REGISTRATION AND EDUCATION


# *Planning a Domestic Groundwater Supply System*

by JAMES P. GIBB

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# PLANNING A DOMESTIC GROUNDWATER SUPPLY SYSTEM

*by James P. Gibb*

## Introduction

Groundwater is used as the source for almost all individual farm and domestic water supply systems in Illinois. Approximately 88 percent of the state's public water supplies also use groundwater as a source of supply. Altogether, groundwater supplies serve about 3,700,000 persons in the state, or approximately 34 percent of the total population.

A public water supply system usually is developed with the assistance of city and consulting engineers, the State Geological Survey, the State Water Survey, and the Environmental Protection Agency. Individuals wishing to develop a private groundwater supply can seldom afford the advice of a consulting engineer, but should take advantage of the free services available to them from the Illinois Department of Public Health, the State Geological Survey, and our organization.

Nearly 700 requests for information concerning groundwater conditions in specific locations of Illinois are answered yearly by the Illinois State Water Survey. Approximately 40 percent of these requests are from individuals seeking advice on locating, developing, or treating home or farm groundwater supplies.

Many of these requests are answered with letter-type reports prepared jointly by the State Water Survey and State Geological Survey from available geohydrologic data in their basic record files. In many cases, the use of this information on groundwater and geologic conditions at a specific site has saved considerable time, effort, and money in well construction. However, several thousand wells are constructed each year without the use of such information.

This circular presents basic information needed to plan and develop a domestic groundwater supply. A logical step-by-step planning summary is outlined. Accepted and recommended methods for a prospective owner of a domestic well to determine his water requirements and to gather meaningful information for planning his supply are presented.

Also included are brief discussions on the occurrence, movement, availability, and quality of groundwater in Illinois, and the commonly used types of wells and pumps. More detailed discussions on well development, pump installation, and water quality and treatment of domestic and farm water supply systems are presented in Water Survey Circulars 117 and 118 *(see References).*

This study is part of a continuing program of water-resource investigations being conducted by the Illinois State Water Survey under the general direction of Dr. William C. Ackermann, Chief, and John B. Stall, Head of the Hydrology Section. The report was prepared under the direct guidance of William H. Walker.

## Planning Summary

The successful development of a farm or domestic water supply system depends most heavily on the available resources at the location of interest. As would be expected, in areas where water is plentiful and easily obtained, little difficulty is encountered and the importance of preplanning is minimized. However, in areas where water is scarce or difficult to obtain, careful planning becomes more important and should be undertaken

before any development attempts are made.

Suggested steps in planning are as follows:

1) Determine your water requirements
2) Obtain all available information on the water resources in your area —
   a) Ask for written reports on the availability of groundwater in your area from the State Water Survey and State Geological Survey *(see appendix A)*
   b) Make an inventory of wells near your property (obtain depth, yield, and water quality information)
   c) Talk with several well drillers who are experienced in the type of well construction required
3) Compare the economics of possible alternatives
4) After the well construction is scheduled, contact the State Department of Public Health to see if an inspector can visit the well site during construction

In many instances a clear-cut solution to obtaining a desired water supply may not be obvious. In cases of this type, a great deal of responsibility is shifted to the driller you employ. It is therefore most important that you employ a competent driller experienced in the type of work that will be required.

To better acquaint yourself with the problems you and your driller face in developing a farm or domestic water supply system, please ask for Circulars 117 and 118. These publications give more details on wells and drilling methods, pumps and pumping systems, and water quality and treatment for small water supplies. They also provide guides for estimating the various costs involved.

## Water Requirements

A properly designed water system should provide adequate water to meet daily needs throughout the year and also should be capable of delivering water fast enough to satisfy peak demand periods occurring each day. A minimum amount of water to fight small fires also may be desirable but generally is not considered a necessity for small farm and domestic systems.

Studies conducted on water consumption in Illinois by the Farmers Home Administration and the Water Survey indicate that 35 gallons per day per person is a reasonable daily water consumption value to assume for most farm and domestic water supplies. However, for planning purposes it is suggested that 50 gallons per day per person be used. Additional daily water needs for watering livestock also can be estimated from the data in table 1.

**Table 1. Daily Water Requirements**

| | |
|---|---|
| Per producing milk cow *(includes allowance for dairy barn and milk-house sanitation)* | 35 gallons |
| Per beef cow | 15 gallons |
| Per horse or mule | 15 gallons |
| Per 100 chickens | 10 gallons |
| Per hog | 5 gallons |
| Per sheep | 3 gallons |

Peak water demand periods for farm and domestic uses seldom occur at the same time. Required flow rates for various modern agricultural and home conveniences, such as milking machines, dishwashers, washing machines, and water softeners, normally do not exceed 5 or 10 gallons per minute (gpm). It is therefore seldom necessary to equip a farm or domestic well with a pump larger than 10 gpm.

When a farm or domestic water supply system is being planned, it is most important to think in terms of daily water needs instead of the more common concept of well yields (gpm). As previously suggested, 50 gallons per day per person is a reasonable value to use, and for a family of 4, this suggests that 200 gallons per day would be desirable.

If 25 head of beef cattle are to be watered, another 375 gallons (15 gal/head X 25 head)

or a total of 575 gallons per day would be required.

If a 10-gpm well is used to produce this quantity of water, it would need to be pumped for only about 58 minutes each day. The same 575 gallons per day could be obtained from a 1-gpm well (assuming there is adequate storage to satisfy peak demand periods) if it were pumped for about 9 hours and 35 minutes. This is a relatively short time compared with the 12- or 24-hour pumping periods that are normal for municipal and industrial wells.

### Gathering Data

After the water requirements for a proposed farm or domestic water supply are known, a comprehensive search for information on the available groundwater resources in the area of interest should be undertaken. As a first step, it is suggested that the State Water Survey or State Geological Survey be contacted to obtain information from their files *(see appendix A for address and instructions).*

The letter-type reports that the Surveys provide indicate the potential for developing the desired supply in the area of interest, the types and depths of wells that are used, the type of well probably most suited, and the anticipated yield and chemical quality of water normally obtained in the area. These reports are prepared free of charge.

In addition to these reports, it would be advisable to obtain information, on wells in your area (within 1 or 11/2 miles of the property in question) from the owners or from well contractors who constructed the wells. This is needed because records of all the wells in your area may not be on file at the two Surveys. The additional facts on local wells will permit a more detailed interpretation of the information contained in the written reports.

It is also desirable to talk to several well drillers who are familiar with the groundwater conditions in your area. Questions should be asked concerning the types of wells they drill, the methods used in construction, and the prices they charge. The selection of a competent well driller equipped and experienced for the particular type of well you require is probably the most critical portion of the planning phase of your water supply.

Finally, if a well is to be constructed, the State Department of Public Health should be contacted. If the Department has advance notice of the time and place of the well construction, they will, if possible, make an inspection trip to the well site to insure that the well is constructed according to the Well Code. Advice on submitting water samples for bacterial analyses can also be obtained from the Health Department *(see appendix B for addresses of Regional Health Department offices).*

### Occurrence and Movement of Groundwater

Groundwater in Illinois begins as precipitation that seeps downward into the ground through the soils. Figure 1 shows the generalized cycle of water movement from the atmosphere as precipitation to the surface and then away from the area either through the ground or as surface runoff into flowing streams and again into the atmosphere by evaporation and transpiration of plants.

Water enters and filters slowly down through the ground until it reaches a level where all available space between soil particles is completely water filled. Water contained in this zone of saturation is *groundwater,* and its upper surface is the *water table.*

The water table throughout Illinois normally lies some 5 to 10 feet below ground level in the lowland areas along streams and rivers and perhaps as much as 25 to 50 feet below ground level in the upland areas. The

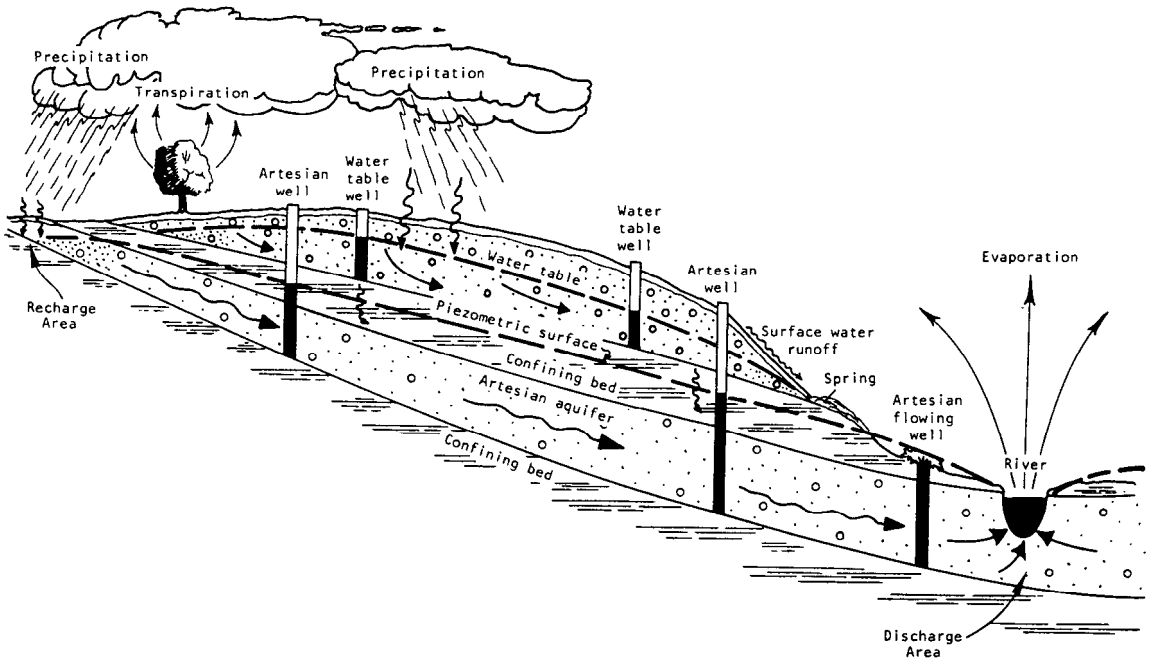


**Figure 1. Generalized cycle of water movement**

position of the water table changes by season in response to variations in precipitation.

In Illinois, practically all recharge (refilling) of groundwater reservoirs occurs between the first of November and the end of April, during periods when evaporation and transpiration losses are minimal, soil moisture needs have been satisfied, and the ground is unfrozen. Seasonal changes in water table levels should be expected to range from 5 to 15 feet during years of normal rainfall.

In glacial drift deposits or unconsolidated materials, water fills the voids between the sand, gravel, clay, and silt particles that make up the deposits. In bedrock formations, water may be contained either in the spaces between partially cemented grains of sandstone or in the fractures or solution cracks of limestone or dolomite.

A saturated formation of sand, gravel, sandstone, limestone, or dolomite that is capable of yielding water to wells in usable quantities is called an *aquifer*. Other earth materials such as clay, silt, and shale may contain abundant water in their minute pores between grains, but the flow of water through these small pore openings is restricted to such an extent that it cannot freely enter a well. Layers of these relatively impermeable materials (clay, silt, shale) may occur above or between aquifers and greatly control the movement of groundwater.

Under normal conditions, the upper glacial materials are regularly recharged by precipitation occurring in the immediate vicinity. The water continues to move freely downward under the influence of gravity and pressure to the lower drift deposits and in some areas into the underlying bedrock formations. However, when layers of almost impermeable materials such as clay or shale are present, the downward movement of water is practically stopped.

Aquifers lying below such *confining beds* obtain their water from some distant recharge area where the confining beds are missing or where the aquifer is exposed or outcrops at the land surface (figure 1).

Water entering permeable formations in an outcrop or recharge area also may become confined downslope beneath impermeable materials. In cases of this type, pressure is exerted on the groundwater in the confined aquifer by the weight of water above it.

When a well penetrates such an aquifer downslope from the recharge area, pressure forces the water to rise in the well above the top of the aquifer. The water in this instance is confined (or artesian) water, the well is an artesian well, and the upper surface of the water in the well is called the piezometric pressure surface of the aquifer. When the piezometric surface of the aquifer is above land surface, wells tapping the aquifer are called flowing artesian wells (see figure 1).

Subsurface flow of groundwater is very slow in comparison with that of overland water flow. Under normal hydraulic gradients, groundwater may travel horizontally only a few feet a day through sand and gravel or creviced limestone and dolomite, and only a few feet per year through sandstone and other finer-grain deposits such as clay and shale.

For example, in one of the most permeable water-bearing sand and gravel formations in the state at Peoria, groundwater movement was determined to be about 1800 feet in 5 months, or 12 feet per day, to a heavily pumped industrial well. On the other hand, in a silty clay formation underlying a farm in Washington County, groundwater movement was determined to be less than 200 feet in 20 years, or 10 feet per year.

### Availability of Groundwater

Groundwater for farm and domestic use throughout Illinois is obtained either from sand and gravel deposits found in the unconsolidated materials above bedrock or from sandstone or limestone units in the bedrock formations.

Thin discontinuous deposits of sand and gravel capable of yielding adequate water for farm and domestic use (1 to 10 gpm) usually are present in most parts of Illinois. In some areas these may be difficult to locate or may require special well construction to be utilized. In general, a 3-foot thick section of sand and gravel should be capable of yielding an adequate farm or domestic supply to a small-diameter (4-inch) drilled well. Sand or gravel deposits thinner than this usually are best developed by large-diameter (36-inch) augered wells.

Major sand and gravel aquifers capable of yielding municipal and industrial supplies (100 to more than 1000 gpm) are located in three general areas of the state. High yielding deposits are found along the Mississippi, Illinois, Ohio, and Wabash Rivers.

Permeable fill materials of sand and gravel also are found in ancient buried valleys, such as the Troy, Rock, Mahomet, and Cache Valleys, and in the present day valleys of the Kaskaskia, Little Wabash, and Embarras Rivers. Other high yielding sand and gravel aquifers deposited by glacial actions are scattered throughout large areas of northeastern and central Illinois.

Figure 2 roughly outlines the yield potential of sand and gravel deposits through Illinois. This generalized map may not include many small and yet undefined areas of high yielding sands and gravels. As mentioned earlier, more detailed definition of specific sites can be obtained from the State Water Survey and State Geological Survey.

In most of central Illinois, farm and domestic water supplies are obtained from sand and gravel aquifers. The underlying bedrock formations in these areas usually are not tapped unless a satisfactory supply cannot be developed in the unconsolidated materials. This is primarily because water from the bedrock aquifers in this part of the state is too highly mineralized for domestic uses.

In northern and western Illinois where the

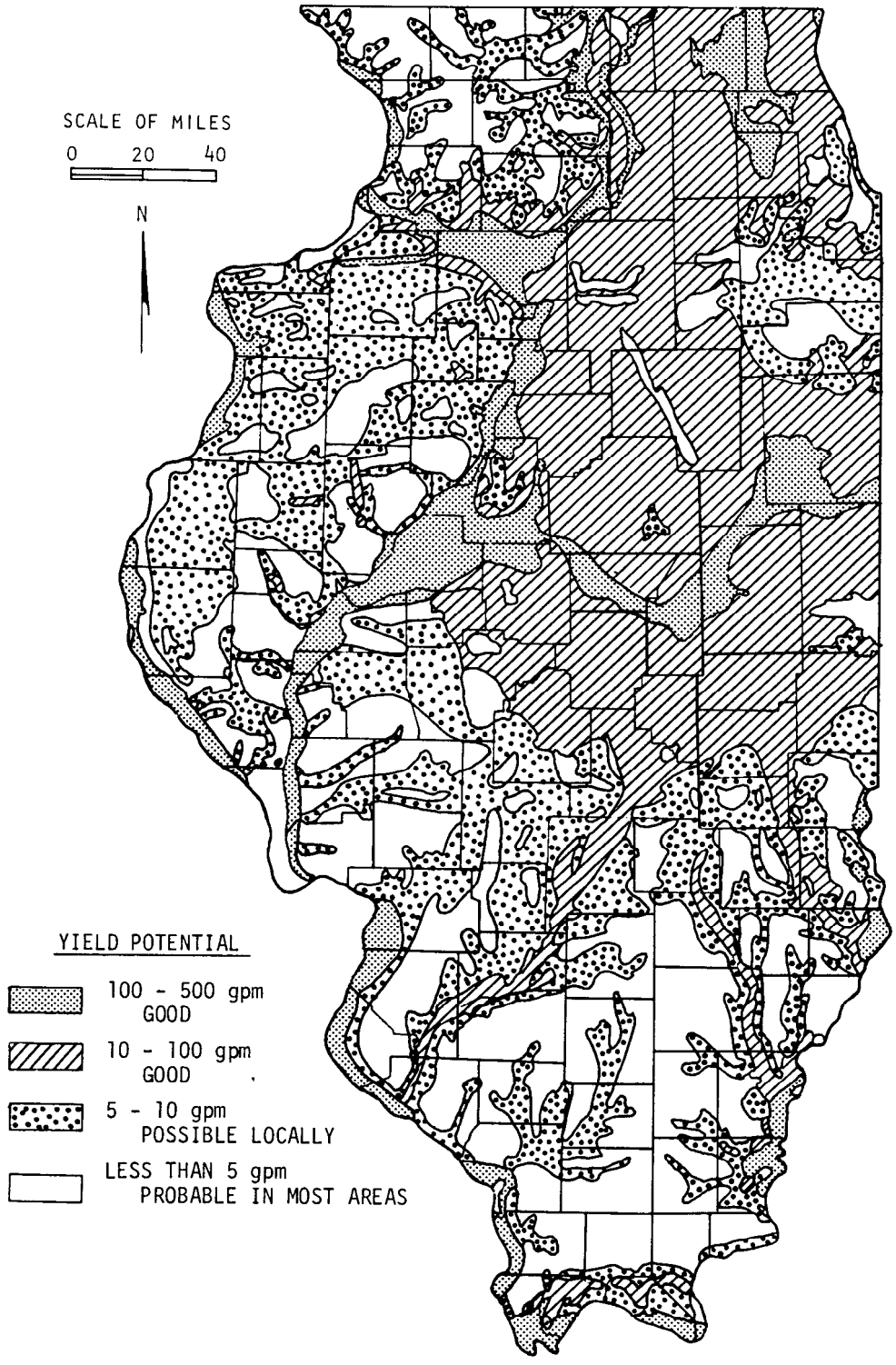


**Figure 2. Generalized yield potential of sand and gravel deposits**

uppermost bedrock units occur close to the ground surface (less than 100 feet) and are known to produce sufficient quantities of good quality water, bedrock wells are used for farm and domestic water supplies. In the remainder of Illinois only limited farm or domestic water supplies are obtainable from very thin sandstone and limestone formations.

Figure 3 roughly outlines the yield potential of the shallow (less than 600 feet) bedrock formations throughout Illinois. As with the sand and gravel deposits, this generalized map may not include small areas of higher yields, and more detailed information on specific sites may be obtained from the State Water Survey and Geological Survey.

## Types of Wells and Pumps

### *Wells*

Wells can be classified into types according to the method used in constructing the well or hole in the ground. The two most common types of wells used for farm and domestic water supply in Illinois are *drilled* and *bored* wells. The type of well most suited for a given location depends on the available aquifers in the area, the anticipated water requirements, and the economic capabilities of the farmer or home owner.

*Drilled wells,* 4 inches in diameter, are most commonly used to tap water-bearing sand and gravel and bedrock formations in much of Illinois. These wells are used in parts of the state where the aquifers are capable of replenishing water to a well almost as quickly as it is pumped. Providing the aquifer capability is adequate, a 4-inch well normally will accommodate a domestic size pump of any type and provide for adequate domestic well yields.

Drilled sand and gravel wells usually are cased with steel pipe from land surface to the top of the water-bearing sand to prevent caving of the overlying materials. A length of commercially made well screen is placed immediately below the casing and opposite the water-bearing deposit to hold back the sand particles, yet permit free entry of water into the well. If the well is finished in a water-bearing sandstone or limestone formation, the overlying unconsolidated materials are cased out to prevent caving, and an open bore hole is constructed into or through the aquifer.

*Bored wells,* 36 inches in diameter, are used in areas underlain by thin stringers of low yielding materials not capable of producing water at rates high enough to satisfy small-diameter wells. These wells provide storage of water to satisfy peak demand periods and allow for continual seepage to refill the well during times of nonpumping.

The modern day large-diameter wells are cased with sections of precast concrete pipe placed one upon the other. A layer of gravel, usually 3 to 4 inches, is placed around the casing from about 10 feet below land surface to the bottom of the well.

Both drilled and bored wells should be sealed at the top to prevent the entrance of surface water and thus minimize the occurrence of bacterial pollution. This normally is accomplished by installing a pitless adapter unit or by placing cement grout around the upper 10 feet of the well casing.

The construction and finishing techniques for each type of well are discussed in detail in Circular 117. The state rules and regulations setting specific requirements for well construction materials and methods are given in the *Illinois Water Well Construction Code* published by the Bureau of Environmental Health, Illinois Department of Public Health.

### *Pumps*

Nearly all farm and domestic wells in Illinois are equipped with electrically driven pumps of four types. These are submersible, jet, centrifugal, and piston type pumps. Approximately 90 percent of all new pumps

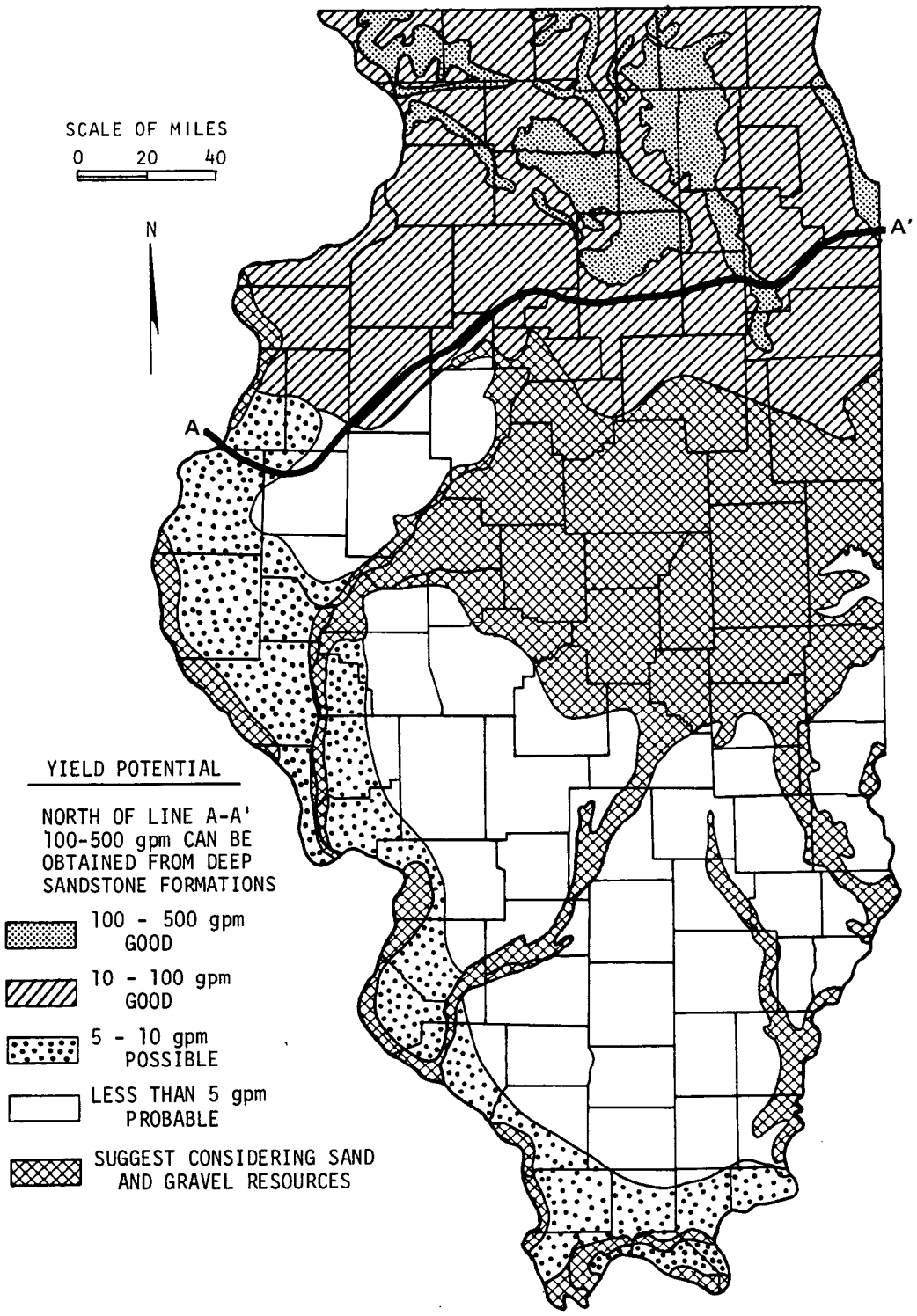


**Figure 3. Generalized yield potential of shallow bedrock formations**

installed throughout Illinois are of the submersible type.

*Submersible pumps* provide a smooth even flow of water and are available in a wide range of capacities and head ratings. They require no frost proofing or well house and have proven to be very dependable and quiet. Among the known inconveniences of this type of pump are that they are easily damaged by sand, they must be pulled from the well to be worked on, and they are limited to 3-inch or larger wells. Only one manufacturer currently is making the 3-inch pump, several make 4-inch and larger pumps.

*Jet pumps* are estimated to be the second most common type of pump used in new domestic well installations in Illinois. For pumping from depths less than about 15 feet, shallow well jet pumps commonly are used, and for deeper pumping lifts deep well jets are required. Jet pumps have relatively few moving parts, can be offset from the well, and are easily accessible for repairs and maintenance. However, they are easily damaged by sand and may require higher horsepower motors than other types of pumps to pump the same quantity of water, particularly at deep pumping lifts.

*Centrifugal pumps* are one of the simplest types of pumps and are commonly used for pumping water from depths less than 15 to 20 feet below the level of the pump. They normally produce a smooth even flow of water and will pump water containing some sand with minimum resulting damage. They also usually are reliable and have a good service life. This type of pump is almost always offset from the well and is easily accessible for maintenance purposes. Problems occasionally encountered in using centrifugal pumps are the easy loss of prime and extremely low efficiencies unless operated very close to the manufacturer's design head and speed.

*Piston type pumps* are one of the oldest types of pumps still in use in Illinois. Most of these are old installations, and only a very small number of new piston pumps are now being installed in the state. Piston pumps can pump water conataining very small amounts of sand, are particularly useful in 2- or 3-inch diameter wells, and are easily adaptable to hand operation in case of a power failure. However, they characteristically create a pulsating discharge and are limited in their practical yield capabilities.

More detailed information about pumps is given in Circular 117.

A sketch of a typical domestic well installation is shown in figure 4. This is a 4-inch diameter drilled well, 75 feet deep, finished in sand and gravel. It is equipped with a 5-foot length of screen and a 5-gpm submersible pump. This well could yield over 7000 gallons of water a day if pumped continuously. It can provide water for a family of 4 (200 gallons per day) in approximately 40 minutes.

## Water Quality

Desirable water for farm and domestic use should be free from bacteria and should contain no objectionable or dangerous concentrations of minerals or gases. Many wells in Illinois appear to be properly located and constructed and should produce water containing little or no harmful bacteria. However, it is still advisable to have periodic bacterial analyses on well water that is being used for drinking and cooking.

Water from all aquifers in Illinois commonly contain objectionable concentrations of iron and hardness. In the past, tolerance of these minerals has been the common practice. Today, however, more and more private water supply systems are being equipped with home water treatment units to remove these objectionable minerals. It is likely that the general quality of water from all private water supply systems in Illinois could be improved by such equipment.

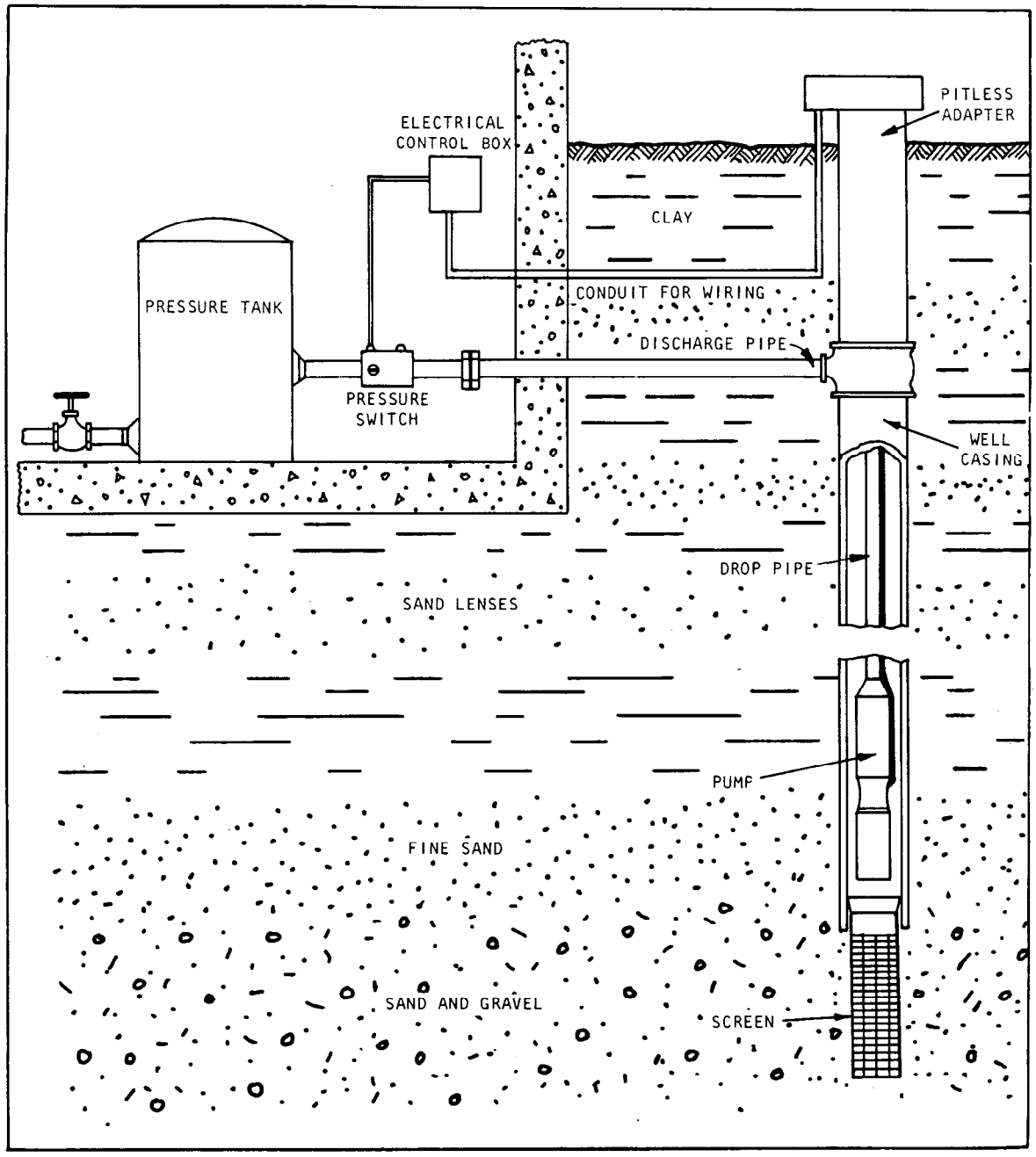


**Figure 4. Sketch of typical domestic well installation**

High concentrations of natural gases such as *methane* and *hydrogen sulfide* also are common in isolated areas of Illinois.

Wells producing a water-methane gas mixture should always be properly vented at the well and throughout the distribution system to minimize the explosion hazard of this gas. In extreme cases, aeration of the water may be necessary to safely dissipate this deadly gas.

Hydrogen sulfide, although not dangerous, does create a very offensive 'rotten egg' odor. This gas normally can be effectively removed from water for domestic use by aeration or by chlorination followed by an activated carbon filter.

More detailed discussion of water quality and types of water treatment for farm and domestic uses is presented in Circular 118.

## References


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## APPENDIX A – INFORMATION REQUESTS

Groundwater information requests should be accompanied by as much of the following data for each type of request as possible.

### For a new supply

Information requests should be accompanied by the following data:

1) **The legal location of the proposed well site to the nearest quarter of a quarter section, township, range, and county** *(for example, NE¼ of the NE¼, Section 10, T 16 N, R 6 W, Sangamon County).*

2) **Estimated daily water requirement** *(in gallons)* **or explanation of planned use** *(for example, domestic supply for 4 persons, 10 bead of cattle, and 100 bead of swine).*

3) **Information on existing wells located in the vicinity of the property** *(depth, adequacy, quality of water, etc.).*

### For existing well problems

Information requests should be accompanied by the following data:

1) **A complete explanation of the problem including any recent changes in pumping equipment, water use, etc.**

2) **Complete information on the well(s) including:**
   a) Legal location of the well to the nearest quarter of a quarter section, township, range, and county.
   b) Distances from potential sources of pollution *(septic tank, feedlots, privies, sewer lines, etc.).*
   c) Type of well *(dug, bored, drilled, etc.).*
   d) Depth of well *(in feet below land surface).*
   e) Water levels *(in feet below land surface)* before and during pumping. Include the pumping rate *(in gallons per minute or gallons per hour).*
   f) Capacity, make, and type of pump *(for example, 3 gallons per minute, Red Jacket deep well jet).*
   g) Depth to bottom of pump intake.
   h) Driller's log of well.
   i) Casing length and diameter.
   j) Screen length, diameter, and slot size.

### For water quality information or problems

Information requests concerning the chemical quality of water should be accompanied by the following:

1) **Complete information on the well as described above.**

2) **A one-quart water sample from the well.**
   a) The sample should be collected at a point in the system located on the well side of any pressure tank or water treatment equipment *(filter, softener, etc.).*
   b) Collect the sample after the well has been pumped for about 10 or 15 minutes to insure that the water sample comes directly from the water-bearing formation and *not* from storage.

Information requests to the State Water Survey should be sent to:

**Illinois State Water Survey**
**Water Resources Building**
**P. O. Box 232**
**Urbana, Illinois 61801**

## APPENDIX B – PUBLIC HEALTH OFFICES

### Regional Offices

| *Addresses* | *Counties Served* |
|---|---|
| **Illinois Department of Public Health<br>4302 North Main Street<br>Rockford, Illinois 61103<br>Phone 815-877-8051** | **Carroll, De Kalb, Jo Daviess, Lee, Ogle, Stephenson, Whiteside, Winnebago** |
| **Illinois Department of Public Health<br>5415 North University Avenue<br>Peoria, Illinois 61614<br>Phone 309-691-2200** | **Bureau, Fulton, Henderson, Henry, Knox, La Salle, Marshall, McDonough, Mercer, Peoria, Putnam, Rock Island, Stark, Tazewell, Warren, Woodford** |
| **Illinois Department of Public Health<br>Box 910<br>48 West Galena Boulevard<br>Aurora, Illinois 60507<br>Phone 312-892-4272** | **Boone, Du Page, Grundy, Kane, Kankakee, Kendall, Lake, McHenry, Will** |
| **Illinois Department of Public Health<br>1919 West Taylor<br>Room 809<br>Chicago, Illinois 60612<br>Phone 312-341-7290** | **Cook** |
| **Illinois Department of Public Health<br>4500 South Sixth<br>Springfield, Illinois 62706<br>Phone 217-786-6882** | **Adams, Brown, Calhoun, Cass, Christian, Greene, Hancock, Jersey, Logan, Macoupin, Mason, Menard, Montgomery, Morgan, Pike, Sangamon, Schuyler, Scott** |
| **Illinois Department of Public Health<br>2125 South First<br>Champaign, Illinois 61820<br>Phone 217-333-6914** | **Champaign, Clark, Coles, Cumberland, De Witt, Douglas, Edgar, Ford, Iroquois, Livingston, McLean, Macon, Moultrie, Piatt, Shelby, Vermilion** |
| **Illinois Department of Public Health<br>9500 Collinsville Road<br>Collinsville, Illinois 62234<br>Phone 618-345-5141** | **Bond, Clinton, Madison, Monroe, Randolph, St. Clair, Washington** |
| **Illinois Department of Public Health<br>2209 West Main Street<br>Marion, Illinois 62959<br>Phone 618-997-4371** | **Alexander, Clay, Crawford, Edwards, Effingham, Fayette, Franklin, Gallatin, Hamilton, Hardin, Jackson, Jasper, Jefferson, Johnson, Lawrence, Marion, Massac, Perry, Pope, Pulaski, Richland, Saline, Union, Wabash, Wayne, White, Williamson** |

### Regional Laboratories

**Illinois Department of Public Health<br>1800 West Fillmore<br>Chicago, Illinois 60612**

**Illinois Department of Public Health<br>P. O. Box 2467<br>Carbondale, Illinois 62901**

**Illinois Department of Public Health<br>134 North Ninth Street<br>Springfield, Illinois 62706**