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Water Quality and Treatment of Domestic Groundwater Supplies

by JAMES P. GIBB

ILLINOIS STATE WATER SURVEY
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WATER QUALITY AND TREATMENT OF DOMESTIC GROUNDWATER SUPPLIES

by James P. Gibb

Introduction

This circular presents basic information on water quality and treatment of domestic and farm groundwater supplies. It describes tests and practices that assure a safe sanitary water quality, and discusses in detail the common minerals and natural gases that are of concern to home water supplies in Illinois. It describes water treatment procedures and equipment for disinfection, iron removal, softening, methane and hydrogen sulfide gas removal, and their costs.

Each year the Illinois State Water Survey receives numerous requests from individuals for advice on locating, developing, or treating home or farm water supplies. This report on water quality and treatment is one of three circulars designed to provide commonly needed information. Circular 116 tells step-by-step how to plan a domestic water supply and discusses briefly how groundwater occurs and where it is available in the state. Circular 117 covers wells and pumping systems used for small water supplies.

Answers to specific problems not covered in these publications may be obtained by contacting the State Water Survey at Urbana. Appendix A gives the address and instructions.

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.

Water Quality

Groundwater in Illinois begins as precipitation which falls on the land surface and slowly seeps downward into the ground. Before reaching the ground the snow or rain is relatively free of bacteria, suspended solids, and dissolved minerals and gases. After it reaches the ground it picks up various bacteria and soil particles, and begins dissolving minerals and gases that it contacts as it moves over or through the earth materials. Soil particles in suspension are readily noticed as 'cloudy' or 'turbid' water.

As the water continues seeping downward, the soil particles and bacteria picked up at the land surface are filtered out by the earth materials. In most cases, by the time the water has reached a depth of 5 or 10 feet, it has been effectively filtered of all bacteria and suspended solids.

However, as the water continues moving through the ground, it dissolves more minerals and gases from the earth materials, and none of these are being filtered out. In general the deeper the water penetrates, or the farther it moves from the point of recharge (entry into the ground), the more mineralized it becomes.

Sanitary

Desirable water for farm and domestic use should be free of harmful bacteria and of safe sanitary quality. The most commonly used indicator of the presence of disease-producing bacteria is coliform bacteria. When present in water, this germ indicates that the water may be polluted by human or animal waste. This means that the water may contain disease-producing organisms that live in the intestinal tracts of man and warm-blooded animals. Water from a well is considered safe to drink only when tests show that it contains no harmful coliform bacteria.

To test for the presence of bacteria, a water sample should be submitted to the Department of Public Health, Division of Laboratories, in a specially prepared bottle which they will furnish. There is no charge for this laboratory service. A list of laboratory locations and addresses where such samples can be submitted is given in appendix B.

Proper location and construction of a well and water system generally assures continuous protection from water-borne diseases. However, coliform bacteria often are introduced into a well during the drilling process or when installing or repairing a pump. Batch chlorination or disinfection *(described in a later section)* following construction or repair of a well, pump, or distribution system is therefore recommended.

Continuous chlorination of private water supply systems in Illinois currently is not a common practice and usually is not necessary. The majority of the wells in the state appear to be properly located and constructed, and are adequately protected from the entrance of surface water and bacterial contamination. However, if water from a well is muddy or murky, particularly after periods of heavy rain, it is probable that surface seepage is entering the well.

In such cases, the water should be tested for bacterial contamination, and if pollution is detected, the well should be repaired to eliminate the entry of surface seepage or it should be abandoned and filled. Continuous chlorination is not recommended unless a satisfactory (pollution free) well cannot be constructed. Then the assistance of the State Health Department should be obtained.

Mineral

Only a few of the many minerals normally present in groundwater are of interest or concern to the majority of people using a well as a source of domestic or farm water supply.

The mineral constituents considered in most Water Survey chemical analyses are: iron, manganese, calcium, magnesium, bicarbonate, nitrate, chloride, sulfate, fluoride, and total dissolved minerals. Gas analyses also are made on waters suspected of having objectionable or dangerous concentrations of carbon dioxide, oxygen, nitrogen, hydrogen sulfide, and methane.

Among these constituents, the ones most commonly of concern to homeowners are *iron and manganese* which cause red, brown, or black staining; *calcium and magnesium* which cause hardness and sometimes scale; high concentrations of *iron, chloride, hydrogen sulfide, and total minerals* which give a bad taste to the water or may be harmful to health; and *nitrates* which in excessive concentrations may be harmful to infants and create health problems with livestock.

The results of chemical analyses made by the Water Survey are expressed in milligrams per liter (mg/l), a term replacing the older equivalent expression of parts per million (ppm) that refers to the pounds of a specific mineral constituent per million pounds of water. Analyses made by private chemical laboratories sometimes are reported in terms of grains per gallon (gpg). One grain per gallon is equivalent to 17.1 mg/l. For example, a report of 350 ppm hardness would be the same as 350 mg/l hardness, and would be 20.5 gpg hardness.

The interpretations of any water analysis must of necessity depend on the intended use of the water. The following discussions pertain mainly to the use of water for general household purposes. Recommended upper limits of the various chemical constituents as outlined in the *U. S. Public Health Service Drinking Water Standards* in 1962 are given to serve as a guide to well owners in evaluating the relative quality of their groundwater supply.

Iron. Iron in groundwater occurs naturally in the soluble (ferrous) state and is commonly called ‘clear water iron’ because it cannot be seen. However, when exposed to air, the iron becomes oxidized into the ferric state and forms fine to fluffy reddish-brown particles that will settle to the bottom of a container if allowed to set long enough. Water containing this type of iron commonly is called ‘red water iron .’

The presence of iron in quantities much greater than 0.1 to 0.3 mg/l usually causes reddish-brown stains on porcelain fixtures and laundry. In some cases the presence of iron also supports the growth of ‘iron bacteria,’ usually noted as a slimy red, brown, or black substance which may accumulate in and eventually clog the well, treatment units, and distribution pipes.

The effectiveness of domestic water softeners often is greatly reduced by the presence of iron. Generally speaking, only moderate concentrations of non-oxidized iron (2 to 3 mg/l) can be removed by softeners.

The *Drinking Water Standards* recommends a maximum limit of 0.3 mg/l iron to avoid staining. In Illinois, about 75 percent of the wells have water containing more than 0.3 mg/l of iron. These wells tap all types of aquifers (sand and gravel, limestone or dolomite, and sandstone).

Manganese. Manganese in groundwater occurs in the soluble state, and when exposed to air, oxidizes causing annoying brownish or black stains on porcelain fixtures and laundry. The stains caused by manganese generally are harder to remove than those caused by iron. Manganese normally occurs in low concentrations, but even then it and manganese bacteria, a slimy substance similar to iron bacteria, can contribute to the clogging of treatment units and water pipes.

The recommended upper limit of manganese given in *Drinking Water Standards* is 0.05 mg/l. It is estimated that only about 30 percent of the wells in Illinois produce water exceeding this limit.

Hardness. Hardness in water is caused by calcium and magnesium. These hardness-forming minerals generally are of major importance to the user since they affect the consumption of soap and soap products and produce scale in water heaters, pipes, and other parts of the water system.

Hard water is objectionable for most domestic uses. For example, laundry washed in hard water may appear gray rather than white, dishes and glassware may appear dingy from unsightly and perhaps unsanitary deposits, washed and rinsed hair may feel sticky and stiff, and water heaters may ‘plug up’ or ‘burn out’ sooner than usual. Hard water scale also may cause overheating of automotive, truck, and tractor cooling systems.

The *Drinking Water Standards* does not recommend an upper limit for hardness. The distinction between hard and soft water is relative, depending on the type of water a person is accustomed to. Someone used to a relatively hard (300 to 350 mg/l) untreated groundwater source would find most surface water (150 mg/l) to be soft, while a person used to home zeolite softened water (0 to 25 mg/l) would find the surface water hard.

The Water Survey has categorized water from 0 to 75 mg/l as soft, 75 to 125 mg/l as fairly soft, 125 to 250 mg/l as moderately hard, 250 to 400 mg/l as hard, and over 400 mg/l as very hard.

Hardness determinations for over 15,000 groundwater samples in Illinois from sand and gravel and bedrock aquifers indicate that hardness concentrations of 200 to 600 mg/l are most common throughout the state.

Figures 1 and 2 illustrate regional trends in the hardness of water from sand and gravel and bedrock aquifers, respectively. If water softening is being considered, it is advisable to have a mineral analysis conducted to accurately determine the hardness content from a particular well. Procedures for submitting water samples for an analysis are described in a later section.

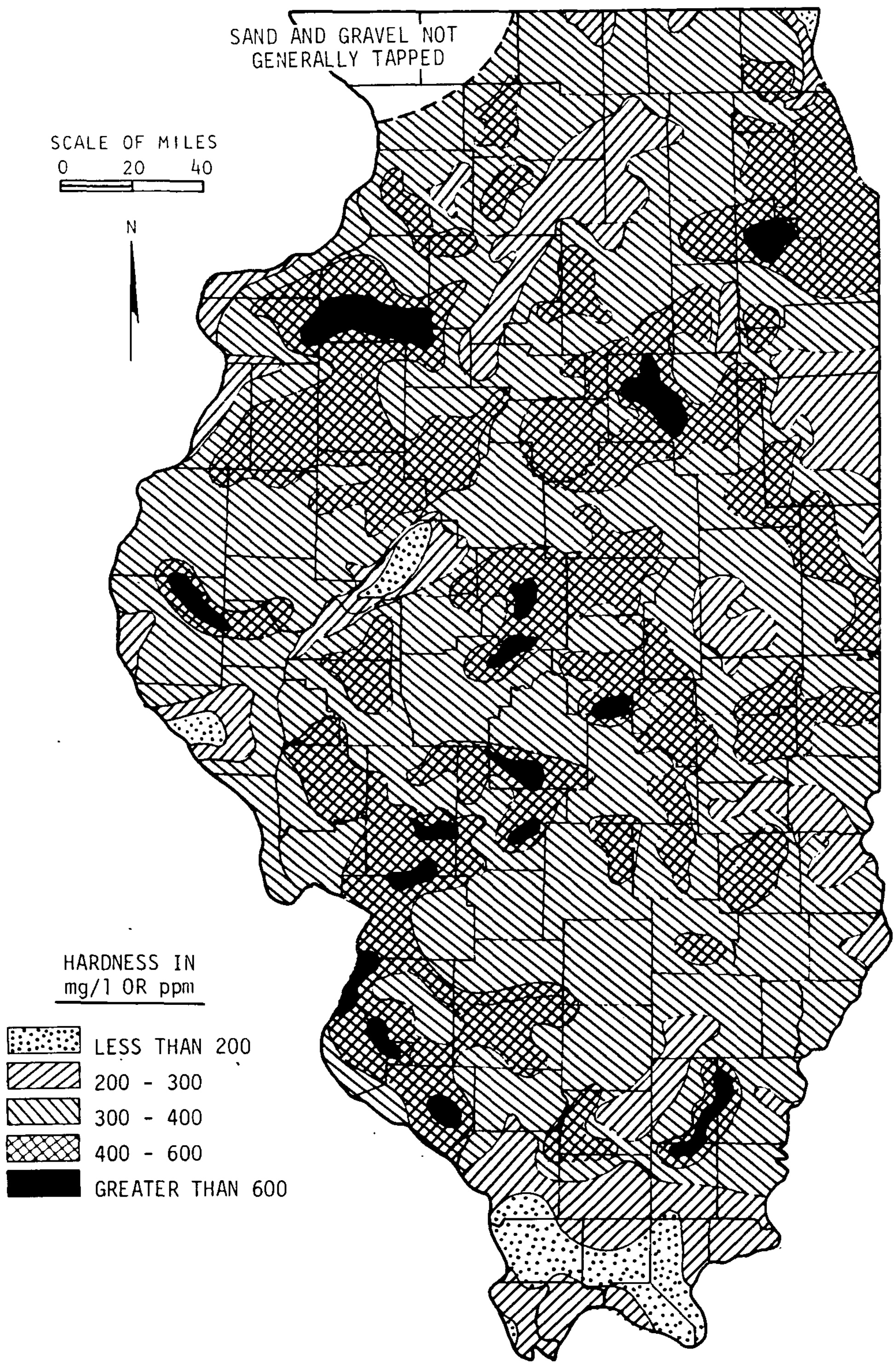

Figure 1. Average hardness of water from sand and gravel aquifers

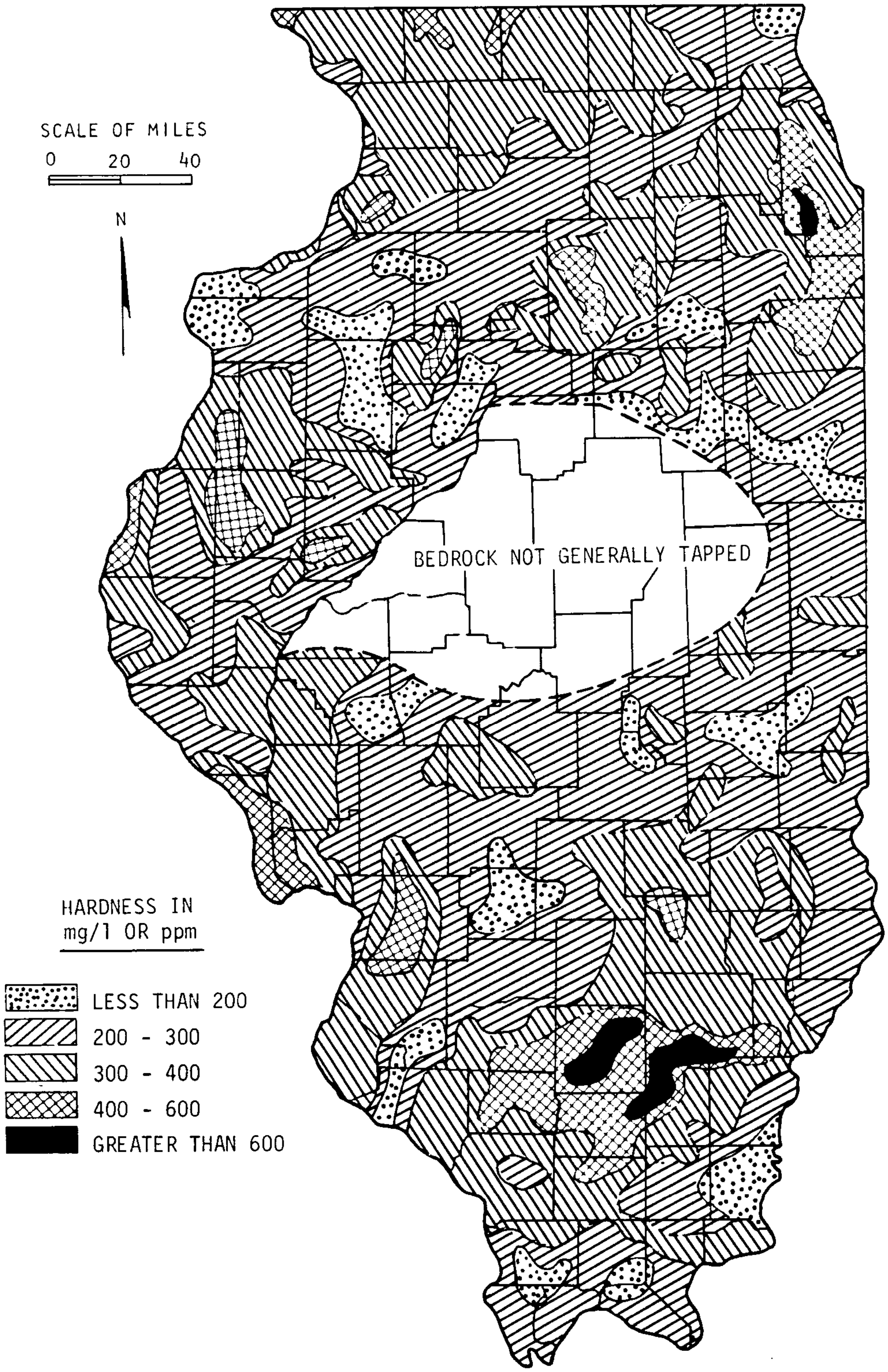

Figure 2. Average hardness of water from bedrock aquifers

Alkalinity. Alkalinity in Illinois groundwaters normally is present almost entirely in the form of bicarbonates. On heating, bicarbonates are converted to carbonates by loss of carbon dioxide. These carbonates, being incompatible with calcium contained in water, form a precipitate or scale of lime or calcium carbonate. If both alkalinity and hardness are present in high concentrations, excessive formation of scale will occur when the water is heated.

Zeolite softening of such waters usually will eliminate the scale formation. However, the carbon dioxide released in this process may cause the treated water to be corrosive to water pipes and heaters requiring more frequent replacements.

The *Drinking Water Standards* does not recommend an upper limit for alkalinity. Most groundwaters in Illinois have alkalinity concentrations between 200 and 400 mg/l. Concentrations in this range normally are not considered excessive.

Nitrates. Nitrates are considered harmful if present in drinking water supplies in excess of 45 mg/l, or the approximate equivalent of 10 mg/l nitrogen. Excessive nitrate concentrations in water may cause 'blue babies' (methemoglobinemia) when such water is used in the preparation of infant feeding formulas. A few cases have been reported where high concentrations in livestock groundwater supplies have resulted in exceptionally high mortality rates in baby pigs and calves and in abortion instances in brood animals.

In Illinois practically all of the wells contaminated with nitrates are less than 50 feet deep, cased with brick or clay tile, poorly sealed, and situated down-slope from nearby surface sources of nitrogen such as feedlots, septic tanks, and privies. Inorganic nitrogen fertilizer also has proven to be a source of nitrate pollution in some shallow aquifers, and may become an even more significant source in the future as ever-increasing quantities are applied to the farm.-lands of the state.

The treatment of water containing excessive concentrations of nitrate poses a difficult problem. Boiling the water *does not help,* but rather results in concentrating the nitrates. Although nitrates can be reduced or removed by demineralization, this type of treatment generally is too expensive for domestic water supplies. Where conditions permit, it usually is easier and more economical to abandon the poor quality water source and attempt to find an unaffected location for a new well.

Any well located near a surface source of nitrogen should be periodically checked to insure that the level of nitrates in the water always is below the *Drinking Water Standards* limit of 45 mg/l.

Chlorides. Chlorides generally are present in groundwater as sodium chloride or calcium chloride. Concentrations greater than about 250 mg/l usually cause the water to taste 'salty.'

Chlorides occur in earth materials in a soluble form that is the source for normal concentrations of this mineral in water. Some domestic and industrial wastes also contribute additional and sometimes proportionately large amounts of chlorides to localized parts of shallow aquifers. Sewage effluent, softener regeneration waste water, road salt, and leachates or liquid wastes from oil fields, chemical plants, garbage dumps, and mining operations are all common man-made sources of chloride pollution in Illinois.

The *Drinking Water Standards* recommends an upper limit of 250 mg/l for chlorides. In the sand and gravel aquifers throughout most of the state, chloride concentrations are usually less than 10 mg/l. However, groundwater from bedrock aquifers over major portions of the southern and western parts of the state may contain water too salty for most domestic purposes. Such waters occur below depths of about 250 feet in the south and 350 feet in the west.

Sulfates. Sulfates generally are present in groundwater in one of three forms: as magnesium sulfate, sometimes called Epsom salt; as sodium sulfate called Glauber's salt; or as calcium sulfate called gypsum. Water with a high sulfate concentration has a medicinal taste and a pronounced laxative effect on those not accustomed to it.

Sulfates also occur in earth materials in a soluble form that is the source for natural concentrations of this compound. Man-made sources similar to those for chlorides also can contribute to sulfate concentrations locally. Coal mining operations particularly are a common source of sulfate pollution, as are industrial wastes.

The *Drinking Water Standards* recommends an upper limit of 250 mg/l for sulfates. In most of Illinois sulfates are well below this standard. However, any highly mineralized water should be checked for high sulfate concentrations.

Fluoride. Fluoride in drinking water has been shown to be associated with the occurrence of both dental cavities and mottled tooth enamel or dental fluorosis. The amount of dental cavities decreases as fluoride concentrations increase, but above concentrations of 1.0 mg/l, the incidence of fluorosis or darkened and mottled teeth increases.

State legislation was enacted on July 18, 1967, requiring that all municipal and public water supply systems in Illinois maintain a fluoride content in their finished water between 0.9 and 1.2 mg/l. However, this type of treatment is expensive and generally impractical for individual home water supply systems.. A more practical method for obtaining the dental health benefits of fluoride probably would be to have periodic fluoride treatments from a dentist.

The *Drinking Water Standards* recommends 1.0 mg/l as the optimum concentration of fluoride. The fluoride content of groundwater from most sand and gravel or dolomite bedrock aquifers of the state normally is less than the optimum level. However, fluoride concentrations between 2 and 5 mg/l, well above the recommended level, are not uncommon in groundwater from the deep sandstone and limestone aquifers in parts of western Illinois, particularly in Fulton, Knox, and Peoria Counties.

Total dissolved minerals. The total dissolved mineral content in groundwater is a measure of all the mineral ingredients in the water. Water with a high mineral content may taste salty or brackish depending on the types of minerals in solution and their concentrations. The taste of water also depends to some degree on the quality of water an individual is accustomed to.

In general, water containing more than 500 mg/l total dissolved minerals will taste slightly mineralized. However, the general public can become accustomed to the tastes of water up to concentrations of 2000 mg/l. Water containing more than 3000 mg/l generally is not acceptable for domestic use, and at 5000 or 6000 mg/l total dissolved minerals livestock may not drink the water. At about 15,000 mg/l total dissolved minerals, water becomes harmful to humans and animals and could be fatal if used continuously. Sea water contains about 34,000 mg/l total dissolved minerals.

Most samples that contain more than 1000 mg/l of total dissolved minerals have been from wells tapping deeply buried aquifers that are isolated from effective fresh-water recharge sources by thick and relatively impermeable overlying materials. Throughout most of central and southern Illinois, groundwater from below depths of about 400 feet generally is too highly mineralized for most domestic uses. In the northern one-third of the state, however, groundwater of acceptable mineral content may be obtained to depths of 1500 feet or more.

The *Drinking Water Standards* recommends that water should not contain more than 500 mg/l total dissolved minerals. Total dissolved mineral determinations for over 16,500 groundwater samples from sand and gravel aquifers and 14,200 groundwater samples from bedrock aquifers throughout Illinois show that 50 percent of the samples from both types of aquifers contained less than 500 mg/l; 45 and 39 percent, respectively, contained between 500 and 1000 mg/l; and 5 and 11 percent had greater than 1000 mg/l.

Natural Gases

Gases in groundwater are important to the user only when they are present in concentrations sufficient to create an explosion hazard, to be offensive in taste or odor, or to be corrosive. Methane and hydrogen sulfide are the gases most likely to be present in objectionable quantities in Illinois groundwater.

Methane gas may be encountered in some groundwaters in Illinois (see figure 3) and, if not properly handled, can present an explosion hazard. This gas is colorless, odorless, and tasteless; it is lighter than air and flammable.

When methane is allowed to escape from water and mixes with air to concentrations of 5 to 15 percent methane, the resulting mixture is highly explosive if ignited. For this reason, if methane is present in a water supply, all possible points of gas accumulation such as the well house, pressure tank, water heater, treatment units, and high points in the distribution system should be vented. All vents should extend to the outside because an inside vent can easily lead to a 5 to 15 percent explosive methane-air mixture.

In areas of methane gas occurrence, all new wells should be checked for this gas by the driller before they are placed in service. Furthermore, because of the danger of asphyxiation, no one should ever enter a large-diameter bored or dug well without first checking for the presence of methane or other potentially harmful gases such as carbon dioxide.

The occurrence of methane in groundwaters appears to be associated with water from the sand and gravel deposits above the bedrock. How ever, in a few isolated cases methane has been produced by wells that tap dolomite or limestone aquifers directly overlain by sand and gravel. Methane is believed to be derived from buried soil zones and organic matter within the glacial drift. It is contained beneath impermeable till and clay zones typically present in such deposits. Recorded occurrences of methane usually have coincided with the end moraines of the Wisconsinan period of glaciation illustrated in figure 3.

Hydrogen sulfide when present in water in concentrations greater than 0.2 mg/l causes the water to have a mild to strong odor of rotten eggs. It is not explosive. This gas is more commonly found in water obtained from wells tapping limestone or dolomite bedrock formations. Hydrogen sulfide normally is removed by chlorination or aeration.

Water Treatment and Costs

Plans for treating groundwater for domestic or farm uses generally should include consideration of: disinfection to insure a safe sanitary quality, iron removal to prevent staining of porcelain fixtures and laundry, softening to remove objectionable concentrations of calcium and magnesium, and aeration to eliminate offensive or harmful gases. In some cases, where the groundwater is too highly mineralized for human consumption, demineralization of limited quantities of the water for drinking and cooking may be justifiable.

To accurately determine the type of treatment that may be desired, water samples should be submitted for bacterial and mineral analyses. Instruction for submitting samples for bacterial analysis can be obtained from the Illinois Department of Public Health *(see appendix B).* Water samples for mineral analysis can be submitted to the State Water Survey.

More than 26,000 chemical analyses of water samples from wells in Illinois have been made by the State Water Survey since 1895. Presently about 1000 groundwater analyses are made each year by Water Survey chemists. This service is free to citizens of Illinois.

To submit a water sample for mineral analysis to our organization, the following procedure should be followed and the appropriate information supplied :

1) Collect the sample in a clean (not necessarily sterile) quart size *glass* jar.
2) If possible, collect the water before it enters the pressure tank.
3) Let the water run for a period of 10 or 15 min-

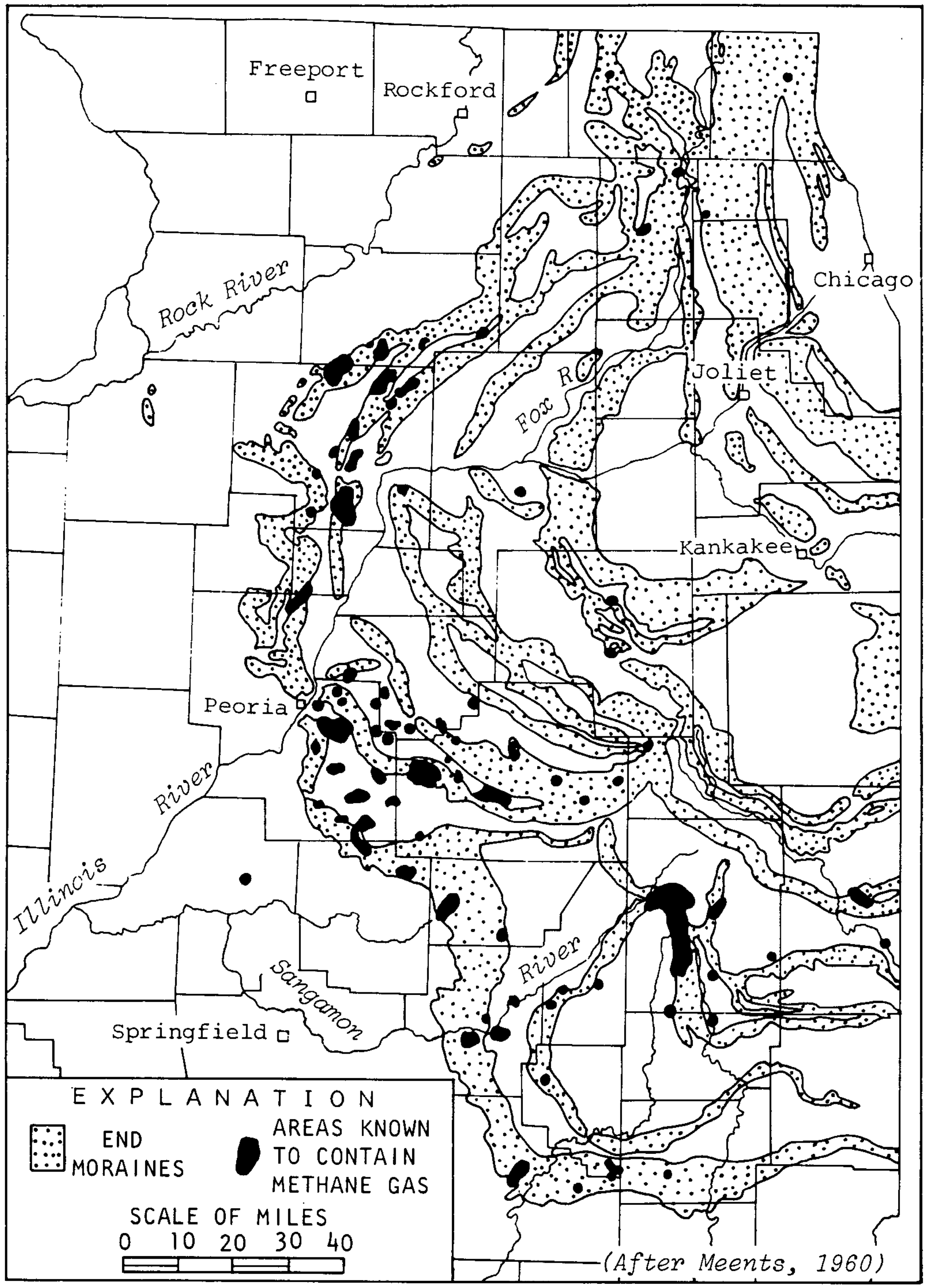

Figure 3. Areas where methane gas is commonly found

utes to insure that the water collected is representative of water from the well, and not water that has set in the pressure tank for a period of time.

4) Rinse out the jar with the running water and collect the sample and seal it for shipping.
5) Mail the sample to:

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

6) Include your name and address, the legal location of the well sampled (the nearest quarter of a quarter section, township, range, and county), the depth of the well, and the date collected.
7) If you are interested in a particular mineral constituent, also indicate which one and why.

Disinfection

New wells, or old installations after rehabilitation, usually are bacterially contaminated and should be disinfected prior to being placed in service.

The Illinois Department of Public Health recommends disinfection procedures that are based on use of a strong chlorine laundry bleach (batch or shock chlorination). The correct amount to use can be determined from table 1, as explained in the instructions that follow.

1) Measure the depth of water in the well if possible. If this cannot be done, consider the well full of water, for in most cases a slight overdose of chlorine does no harm.
2) Determine the amount of laundry bleach (from table 1) and mix this quantity in about 10 gallons of water. For example, a 6-inch well with 75 feet of water would require 3 cups of laundry bleach (5.25 percent chlorine). If the well depth is not known, use ½ gallon bleach for a drilled well and 1 gallon for a bored well.
3) Pour this solution into the well between the casing and the drop pipe. (This will involve removing the cap from the pitless adapter unit.)
4) Connect one or more hoses from faucets on the discharge side of the pressure tank to the top of the well, and while pumping the well, let water from these flow back into the well for at least 15 minutes. Then open each faucet in the system and let the water run until a chlorine odor or taste is noted. Close all faucets. Seal the top of the well.
5) Do not use the system for several hours, preferably overnight, to insure adequate contact time.
6) Flush out the system by discharging water from all outlets until all chlorine odor and taste disappear. Faucets or fixtures discharging to septic tank systems should be throttled to a low flow, or temporarily diverted to an outside discharge point, to avoid overloading the disposal system.

Table 1. Recommended Chlorine Dosages for Well Disinfection

Diameter of well *(inches)*	Amount of chlorine *(cups)* for given depth of water in well *(feet)* 5	10	25	50	75	100
2	0.5	0.5	0.5	0.5	0.5	0.5
3	0.5	0.5	0.5	0.5	1.0	1.0
4	0.5	0.5	0.5	1.0	1.5	2.0
6	0.5	0.5	1.0	2.0	3.0	4.0
8	0.5	1.0	2.0	3.5	5.5	7.0
10	1.0	1.5	3.0	6.0	9.0	12.0
12	1.0	2.0	4.0	8.0	12.0	16.0
18	2.0	3.5	9.0	18.0	27.0	36.5
24	3.0	6.5	16.0	32.5	48.5	64.5
30	5.0	10.0	25.0	50.5	76.0	–
36	7.0	14.5	36.0	72.5	–	–
48	13.0	26.0	64.5	–	–	–
60	20.0	40.3	–	–	–	–

Chlorine always should be used outdoors or in well-ventilated places because breathing the fumes is dangerous. In heavy concentrations, chlorine also is harmful to skin and clothing.

Continuous chlorination of domestic or farm water supply systems is not a common practice in Illinois. As previously mentioned, most wells in the state are properly located and constructed so that they are adequately protected from the entrance of surface water and bacterial contamination. However, if constant protection from bacterial contamination is necessary, continuous chlorination can be investigated. The Illinois Department of Public Health should be consulted for advice on this subject.

Continuous disinfection requires equipment that will inject or add chlorine to all water drawn from the source. The chlorine must be thoroughly mixed with the water, and then sufficient chlorine contact time must be provided to kill all disease-causing and nuisance organisms. A minimum of 15 minutes of contact time usually is recommended in a private water system. A chlorine residual should be present after the 15-minute contact time. Whenever continuous chlorination is used, it is advisable to measure the chlorine residual in the treated water every few days to insure that the system remains bacteria free. Chlorine residual test kits are inexpensive and contain detailed instructions that should be followed exactly.

Several types of chlorinators are available, but the most reliable is the water-flow-actuated positive displacement type. This type uses a pump to inject the chlorine solution, can be adjusted during operation and synchronized with the well pump, and is especially desirable in systems where the water pressure is low and fluctuating. A positive displacement chlorinator that feeds chlorine solution in proportion to the actual flow rate maintains a more uniform chlorine residual than a chlorinator that is electrically operated when the pump starts and stops. A water-flow-actuated chlorinator should always be used when two or more pumps discharge into a single intermediate storage reservoir.

Nonpositive displacement chlorinators generally are not reliable because of the varying flow rates and pressure conditions and because of frequent clogging with deposited minerals. All chlorinator equipment should be frequently checked to insure proper operation.

Commercially available chlorinators or chemical feed pumps normally cost about $200. Amortized over a five-year period (the expected service life) at an interest rate of 8 percent and adding $10 a year for operating and chemical costs results in an annual cost for continuous chlorination of about $60.

Iron Removal

More than 75 percent of the groundwater supplies in Illinois contain iron concentrations in excess of the recommended 0.3 mg/l level. In such supplies, improvement of water quality almost always can be realized by the use of iron removal equipment.

The most commonly used iron removal process for domestic use in Illinois is an oxidizing iron filter unit. Other types of units include chlorination-filtration and aeration-settling.

In all of these processes, soluble (ferrous) iron is converted into its precipitated (ferric) form by some type of oxidizing agent (manganic oxide, chlorine, or air) and then removed by settling or filtration. Ion exchange water softening equipment rarely is successful in removing the quantities of iron commonly present in Illinois groundwaters.

In the *oxidizing iron filter* process, raw water is forced through a filter bed of manganese green sand that has a manganic oxide film on the filter grains. This film is created by treating the filter material with potassium permanganate. Soluble iron is precipitated by the manganic oxide and retained on the filter material. Periodic backwashing of the filter is required to remove the accumulated iron oxide. Regeneration of the filter material with potassium permanganate is usually required after 4 or 5 backwashings.

In the *chlorination-filtration* process, chlorine is added as the water is pumped from the well to oxidize the iron. Then the oxidized iron is removed with a sand or carbon filter. Either of these filters will remove the oxidized iron. However, a carbon filter has an added advantage of also removing most objectionable tastes and odors.

In the *aeration and settling* process, the dissolved iron is exposed to oxygen in a forced air or gravity aerator before it enters a storage tank. The added oxygen causes the iron to precipitate and settle to the bottom of the tank for periodic removal. If this method of iron treatment is used, frequent sampling of the treated water is recommended to detect if bacteria is entering the water during aeration.

Efficient iron removal units can be purchased from reputable water conditioning equipment dealers throughout the state. Many of these dealers also install and service iron removal equipment on a rental basis at a nominal charge. If large concentrations of iron and manganese are present in the water supply, it is often advisable to rent the treatment equipment for a considerable time before purchase to insure that it will effectively remove the quantities of mineral involved.

Iron bacteria problems also may arise in water containing excessive iron concentrations. Bacterial slime accumulation will cause rapid clogging and exhaustion of iron filter and water softening units. Occasionally it may slough off the inside of the plumbing system and cause discharges of extremely turbid red water. Iron bacteria sometimes can be eliminated from a well and water system by well reconstruction and shock chlorination. However, most infected systems will require either periodic shock chlorination or continuous chlorination.

The various types of iron removal equipment available vary in cost depending on their size and effectiveness. It is quite possible that the setup for a basic aeration and settling process could be constructed from existing equipment at a very small cost. Commercially available oxidizing iron filter units may range from $475 to $700 depending on the manufacturer and size of units. The annual cost for operating and maintaining an oxidizing iron filter unit is estimated to be from $140 to $200. These values include the amortized cost of the initial investment, regeneration chemicals and water, and maintenance costs.

Softening

The hardness-forming minerals in groundwater from nearly all aquifers in Illinois generally are high enough to be objectionable. These minerals (calcium and magnesium) usually can be removed from a domestic water supply system with an ion exchange type home water softener.

The ion exchange softener works like this. As hard water passes through the exchange material in the softener tank, calcium (Ca^{++}) and magnesium (Mg^{++}) are exchanged for sodium (Na^{+}) on the surface of the synthetic resin. The water leaving the unit still contains essentially the same amount of dissolved minerals, but the hardness-forming minerals have been replaced with sodium.

When the softening material's ability to exchange sodium for calcium and magnesium is exhausted, it must be 'regenerated' by running a given amount of salt brine (sodium chloride) through the softener tank. The exchange material trades back its load of calcium and magnesium taken from the hard water for sodium from the salt brine. The spent brine solution, now containing the calcium and magnesium, is flushed from the softener tank by backwashing and the unit is ready to start its regular cycle once more.

Brine from the regeneration of a fairly large capacity household softener may be discharged into the average septic tank and tile field, if the septic tank is properly sized. However, if the septic tank is unusually small, it may be advisable to install a smaller softener unit. A smaller softener will require less brine solution during each regeneration cycle so that shock overloading of the sewage disposal system will be minimized.

The effectiveness of a softener can be reduced substantially when the water contains iron. The softener's exchange material may become coated with iron deposits, which reduces the softener's overall efficiency. If the water contains iron in excess of about 2 mg/l, an iron removal unit should be used ahead of the softener, for optimum operation.

Persons with hypertension or high blood pressure are sometimes placed on 'low sodium' or 'sodium-free' diets by physicians. Should the question of drinking softened water containing sodium salts arise, a calculation of the small amount of sodium taken into the body through drinking and cooking with softened water can be made by the patient's physician.

Another point of caution about softened

water from a domestic type softener should be noted. As the hardness of water approaches 0 mg/l (often produced immediately after recharging of a domestic softener) the tendency for the water to become corrosive increases.

Home water softeners generally are rated by the total grains of hardness they can remove from the water before the exchange materials must be regenerated. Most domestic sized softeners used in Illinois have rated capacities between 10,000 and 20,000 grains per regeneration cycle. For a typical hardness content of 350 mg/l (about 20 grains), a 20,000 grain softener should be capable of softening about 1000 gallons of water before regeneration would be necessary. This amount of softened water would furnish an average family of 3 or 4 persons (using 50 gpd per person) approximately 5½ days.

Commercially available water softening units may be expected to cost from $425 to $625. The annual cost of operating and maintaining an ion exchange home water softening unit for water containing 350 mg/l hardness is estimated to be from $106 to $160. This includes the amortized cost of the initial investment, regeneration chemical and water, and maintenance costs.

Methane Removal

Methane gas can be removed from a domestic water supply system by several methods. However, it is recommended that the advice and services of a drilling contractor or plumber experienced in treating water containing methane be obtained to insure that the explosion hazard which can result from the presence of this gas will be minimized.

One generally accepted method for removing methane is aeration. An aerator consisting of 3 or 4 metal trays with perforated bottoms positioned one over another at about 1-foot spacings can be used. Each tray is filled to a depth of about 8 or 10 inches with pieces of coke having an average size of about 1½ inches. For good design the total tray area should be about 1 square foot for each 2 gallons per minute pumped from the well. Provisions for a heater to eliminate freezing during cold periods also should be considered. The aerator should have a water-tight roof but the sides should be left open except for a covering of fine mesh screen (24 meshes per inch) to protect the water from direct contamination of flying insects and debris.

Water is pumped directly from the well to the top tray of the aerator and is allowed to trickle down through each tray of coke. The methane is released to the air and is dissipated through the sides of the aerator. Water at the bottom of the aerator collects on a watertight tray and flows by gravity into a storage reservoir. A small pressure pump may then pick up the water from the storage tank and place it under pressure in the normal type pressure tank. Water treated in this manner should be tested frequently to determine if any air-borne contamination is occurring during aeration.

Hydrogen Sulfide Removal

The most commonly used method for removing hydrogen sulfide gas is continuous chlorination followed by an activated carbon filter. This method can handle relatively large quantities of hydrogen sulfide and does not release odor to the air. Some manufacturers have recommended using only the activated carbon filter. However, this type of treatment is capable of handling only very small concentrations of hydrogen sulfide and it is suspected that the filters have relatively short life span.

Hydrogen sulfide gas also can be removed from water for domestic uses with the same type of aerator described for removing methane gas. However, because of the bad odor given off by this method, it is not always a desirable way of removing hydrogen sulfide.

Summary

Desirable water for general domestic use should be of a safe sanitary quality and should contain no objectionable or dangerous concentrations of minerals or gases. Many of the wells in Illinois appear to be properly located and constructed and produce water containing little or no harmful bacteria. It is still advisable, however, to have periodic bacterial analyses run on well water that is being used for drinking and cooking. If bacterial pollution persists, a search for a safe sanitary supply should be undertaken.

Objectionable concentrations of iron and hardness are common in waters obtained from all aquifers in Illinois. In the past, tolerance rather than treatment of high concentrations of these minerals has been the common practice. Today, an increasing number of private water supply systems are being equipped with commercially available home treatment units. It is most probable that the general quality of water from all private water supply systems could be improved with the installation of similar equipment.

High concentrations of objectionable natural gases such as methane and hydrogen sulfide have been noted in isolated areas in Illinois. Adequate ventilation throughout the distribution system, aeration, or chlorination normally can remove these objectionable gases.

The cost of producing raw groundwater for domestic use has been estimated to be about $3 per 1000 gallons or $219 per year for a family of 4 persons using 50 gpd per person. The additional yearly costs of softening and iron removal varies considerably depending on the quality of water to be treated and size of treatment units used.

For a typical water (hardness of about 350 mg/l and iron content of 3.0 mg/l or more), the annual costs for relatively small capacity units is estimated at about $140 *each* for softening and iron removal. Annual costs of larger units may be as high as $200 for each type of treatment. The annual cost for continuous chlorination is about $60.

Finished water from a private groundwater supply system incorporating all three types of treatment is estimated to cost about $7.75 per 1000 gallons, or about $560 per year for the family of 4.

References

A new world of softness. 1969. Sears, Roebuck and Company.

Buswell, A. M., and T. E. Larson. 1937. *Methane in ground water.* Journal of American Water Works Association v. 29(12): 1978-1982.

Gibb, James P. 1973. *Planning a domestic groundwater supply system.* Illinois State Water Survey Circular 116.

Gibb, James P. 1973. *Wells and pumping systems for domestic water supplies.* Illinois State Water Survey Circular 117.

Gilliland, Edwin R. 1965. *The current economics of electrodialysis.* U. S. Department of the Interior.

Hydrogen sulphide removal from well water. 1968. Soil and Water 2. Agricultural Engineering Extension, Ohio State University, Columbus.

Iron removal from well water. 1968. Soil and Water 3. Agricultural Engineering Extension, Ohio State University, Columbus.

Larson, T. E., and H. A. Spafford. 1947. *Water treatment for the small homes or farms.* Illinois State Water Survey Circular 25.

Larson, T. E. 1963. *Mineral content of public ground-water supplies in Illinois.* Illinois State Water Survey Circular 90.

Meents, Wayne F. 1960. *Glacial drift gas in Illinois.* Illinois State Geological Survey Circular 292.

Private water systems. 1968. Cooperative Extension Service, Iowa State University, Ames, Iowa.

Salinity and livestock water quality. 1959. South Dakota State College Agricultural Experiment Station Bulletin 481.

Spafford, H. A., and C. W. Klassen. 1937. *Hazards of methane gas in water wells and suggested method for elimination.* Illinois Department of Public Health mimeograph report.

Strawn, Bernice. 1963. *Iron in your water supply.* Cooperative Extension Service, Oregon State University, Corvallis, Oregon.

Water conditioning technical manual. 1965. F. E. Meyers & Bro. Co.

Water system and treatment handbook. 1965. Water Systems Council, Chicago, Illinois.

Water treatment. 1961. Technical Manual 2. Water Systems Council, Glenview, Illinois.

Water well construction code, rules and regulations. 1967. Illinois Department of Public Health.

Water well pump installation code, rules and regulations. 1967. Illinois Department of Public Health.

Wilke, Harvey, and Ruth Hutcheson. 1962. *Water softening for the home.* Cooperative Extension Service, Purdue University, Lafayette, Indiana. Extension Circular 505.

Wilke, Harvey, and Ruth Hutcheson. 1965. *Iron water control for the home.* Cooperative Extension Service, Purdue University, Lafayette, Indiana. Extension Circular 507.

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 head of cattle, and 100 head 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 4302 North Main Street Rockford, Illinois 61103 Phone 815-877-8051	Carroll, De Kalb, Jo Daviess, Lee, Ogle, Stephenson, Whiteside, Winnebago
Illinois Department of Public Health 5415 North University Avenue Peoria, Illinois 61614 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 Box 910 48 West Galena Boulevard Aurora, Illinois 60507 Phone 312-892-4272	Boone, Du Page, Grundy, Kane, Kankakee, Kendall, Lake, McHenry, Will
Illinois Department of Public Health 1919 West Taylor Room 809 Chicago, Illinois 60612 Phone 312-341-7290	Cook
Illinois Department of Public Health 4500 South Sixth Springfield, Illinois 62706 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 2125 South First Champaign, Illinois 61820 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 9500 Collinsville Road Collinsviile, Illinois 62234 Phone 618-345-5141	Bond, Clinton, Madison, Monroe, Randolph, St. Clair, Washington
Illinois Department of Public Health 2209 West Main Street Marion, Illinois 62959 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
1800 West Fillmore
Chicago, Illinois 60612

Illinois Department of Public Health
P. O. Box 2467
Carbondale, Illinois 62901

Illinois Department of Public Health
134 North Ninth Street
Springfield, Illinois 62706