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Cost of Domestic Wells and Water Treatment in Illinois

by JAMES P. GIBB

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COST OF DOMESTIC WELLS AND WATER TREATMENT IN ILLINOIS

by James P. Gibb

ABSTRACT

This study provides cost information for private home groundwater supply systems in Illinois. Relatively accurate cost predictions for different types and depths of wells, ranging in cost from about $150 to $2400, can be made from the graphs presented. A typical domestic well in Illinois may be expected to cost about $575. Cost data for pumping systems equipped with 10-gpm submersible pumps (approximately 50 percent of all collected data) show that the average cost of these systems is about $585 with 50 percent ranging between $400 and $680.

The costs of treating water for domestic use also are summarized. Two graphs illustrate the monthly costs of softening and removing iron at varying monthly consumption rates and concentrations of hardness-forming minerals and iron. The monthly cost of continuous chlorination is calculated.

Use of the data presented makes it possible to estimate the monthly costs of raw and treated water from a domestic groundwater supply. Two maps show the probable costs of domestic raw water supply systems from sand and gravel wells and bedrock wells throughout the state. For a typical installation and domestic use rate in Illinois, the monthly cost of raw water is about $11.00, softened water $15.40, softened water treated for iron $22.00, and softened water treated for iron and chlorinated $25.00. Similar calculations for any type and depth of well, water quality, and treatment can be made from the information in this report. This material should provide adequate information for planning purposes and decision making in developing a desired domestic supply.

INTRODUCTION

Previous groundwater economic studies conducted by the Illinois State Water Survey generally have been directed toward determining the costs associated with developing large-capacity municipal or industrial water supply systems (Gibb and Sanderson, 1969). This report summarizes a study on the costs of developing and maintaining private home groundwater supply systems in Illinois. The study was based on information obtained from 19 well drillers working throughout most of the state. Cost data for 345 wells of various types constructed during 1967-1969 were collected and adjusted to a common 1969 economic level. Analyses of these data are summarized in a series of graphs showing well cost versus depth.

To make meaningful cost estimates for a given location, the user will need to know the type of well best suited for the area, its probable size, and approximate depth. To determine the type of treatment desired and its estimated cost, he also will need to know the probable hardness and iron content of the water and the anticipated monthly consumption. As a service to the people of Illinois, the State Water Survey and State Geological Survey prepare joint reports on the geology and groundwater resources at any location in the state for individuals requesting such information. These letter-type reports normally provide information on the type, size, and depth of well required and the anticipated chemical quality of the water for the supply in question. More accurate determinations of the chemical character of the water can be obtained by submitting a quart size sample of water to the State Water Survey for chemical analysis after the well is constructed.

This study is part of a continuing program designed to assist in the optimum development of the state's groundwater resources. It was conducted under the general supervision of Dr. William C. Ackermann, Chief of the Illinois State Water Survey, and Harman F. Smith, Head of the Hydrology Section. William H. Walker provided guidance from the beginning of the project and reviewed the final manuscript. Computer analysis of all data was accomplished with the assistance of Robert A. Sinclair. Mrs. Dorothy Woller typed the final manuscript, and John W. Brother, Jr., prepared the illustrations. The author also wishes to express his gratitude to the 19 drilling firms who provided the basic cost information for this project.

COST DATA

Data Adjustments

Cost information for 345 wells of various types constructed throughout Illinois during 1967, 1968, and 1969 was collected for this study. All data were adjusted to a common 1969 economic level by using a domestic and farm well index developed as a part of this study. This index, shown in figure 1, indicates the increase in the costs of farm and domestic wells in Illinois from 1913 through 1969. Figure 1 also illustrates the increase in the costs of large-capacity wells and the cost of materials such as steel and concrete normally used in construction (Engineering News Record, 1970).

Figure 1 indicates that the current costs of domestic type wells are only about 4 times the 1913 base costs. On the other hand, the costs of large-capacity

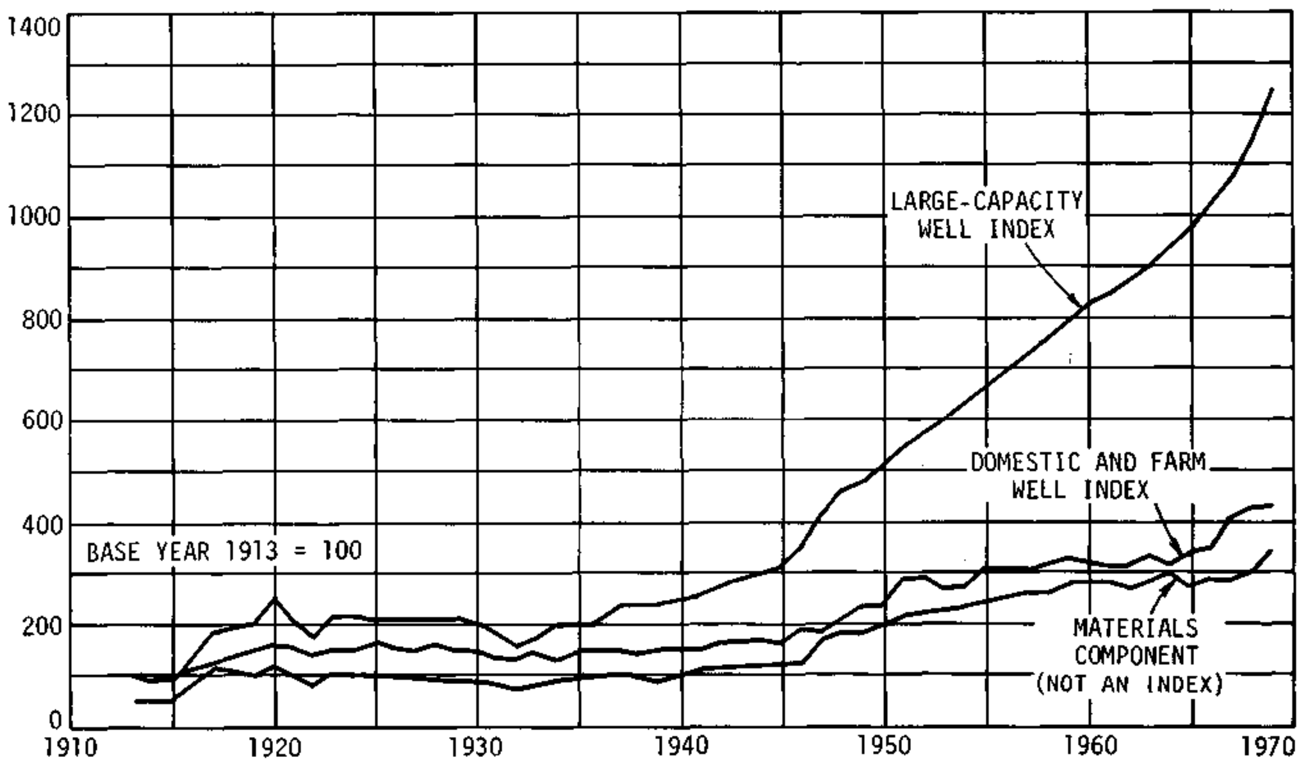

Figure 1. Well construction cost indices

wells are more than 12 times their 1913 prices. Figure 1 also suggests that the costs of domestic wells are primarily determined by the costs of the construction materials.

After the reported cost information was adjusted to the 1969 economic level, well cost data were divided into three categories according to the aquifer tapped and the type of well construction: 1) large-diameter concrete-cased augered wells finished in unconsolidated materials above bedrock; 2) commercially screened drilled wells finished in water-bearing sand and gravel deposits; and 3) drilled wells finished in water-bearing sandstones, limestones, and dolomites of consolidated bedrock formations. The wells in each category were grouped according to the inside casing diameters or nominal well diameters.

Each set of cost information was then examined to eliminate data for wells having unusual construction features or obvious inconsistencies in pricing. Data for wells where one driller acted as a subcontractor for another driller generally gave higher values and were therefore eliminated from further analysis. Information on wells equipped with slotted pipe rather than commercially made screens also was discarded from the final analysis because this type of well is considered undesirable for modern well construction in Illinois.

The final sets of data that were used represent the material and labor costs of the following as applicable: 1) setting up and removing the drilling equipment, 2) drilling the well, 3) all casings and liners, 4) grouting and sealing the annular spaces between casings and bore holes, 5) well screens and fittings, and 6) developing the well. The well costs presented in this report should therefore represent the actual cost to the consumer.

During the cost analysis for the three types of wells considered in this study, no regional variation in costs was noted. Even though different drillers reported different drilling prices (cost per foot), the fixed costs applied by each driller tended to minimize the difference in the final consumer well cost.

Method of Analysis

The method of least squares as applied in exponential curve fitting (Miller and Freund, 1965) was used in the final analyses for all sets of selected well cost data. This type of analysis permitted the development of equations for a series of lines determined from the data points relating well cost to well depth for given diameters and types of wells. These equations are of the form

$$W.C. = K + Cd$$

where

$W.C.$ = well cost, in 1969 dollars

K = a constant (a fixed cost)

C = slope of the best fit line (or cost/foot of well)

d = depth of well, in feet

Correlation coefficients ranging from 0.868 to 0.999 and averaging 0.936 attest to the validity of the chosen relationships. In this regard, the average correlation coefficient obtained indicates that 100(0.936) or about 88 percent of the adjusted well cost can be attributed to the depth of the well.

For a reasonable range of cost values for estimating purposes, 80 percent confidence limits were derived for all well cost data sets in the study. As the term confidence limits implies, these lines envelop a range of cost values which should be expected 80 percent of the time for a given depth, size, and type of well. It should be noted that the range of cost values defined by the confidence limit lines increases as the well depth deviates from the mean depth. In those segments of the graphs containing most of the data points, a narrower range of cost values can be expected at the same confidence level. The limits of prediction, or range of cost values, become increasingly wide outside the area of observed data, and for this reason, extrapolation into these areas should be done with utmost caution and good judgment.

COST OF WELLS

Cost of Large-Diameter Augered Wells

Large-diameter augered wells tapping thin stringers of water-bearing sand in the upper portions of the glacial materials above bedrock are used throughout much of western and southern Illinois as sources for farm and domestic water supplies.

These wells are normally constructed with a large-diameter auger type bucket. This type of drilling is used primarily in areas where clay formations are predominant and the bore hole will stand open until a length of casing can be installed. The casing usually consists of 3- or 4-foot sections of large-diameter concrete pipe stacked one upon another. The yields of these wells are not large (generally less than 5 gpm), and they rely on their storage and seepage capabilities to satisfy peak demand periods. In some parts of Illinois, two or more installations of this type may be required to furnish an adequate domestic water supply.

Completed cost data were collected for 40 large-diameter augered wells constructed during 1967, 1968, and 1969. The depths of these wells range from about 30 to 75 feet and average about 40 feet.

The costs of 24- and 36-inch diameter wells at varying depths are illustrated in figure 2. Correlation coefficients of 0.999 and 0.957 were obtained

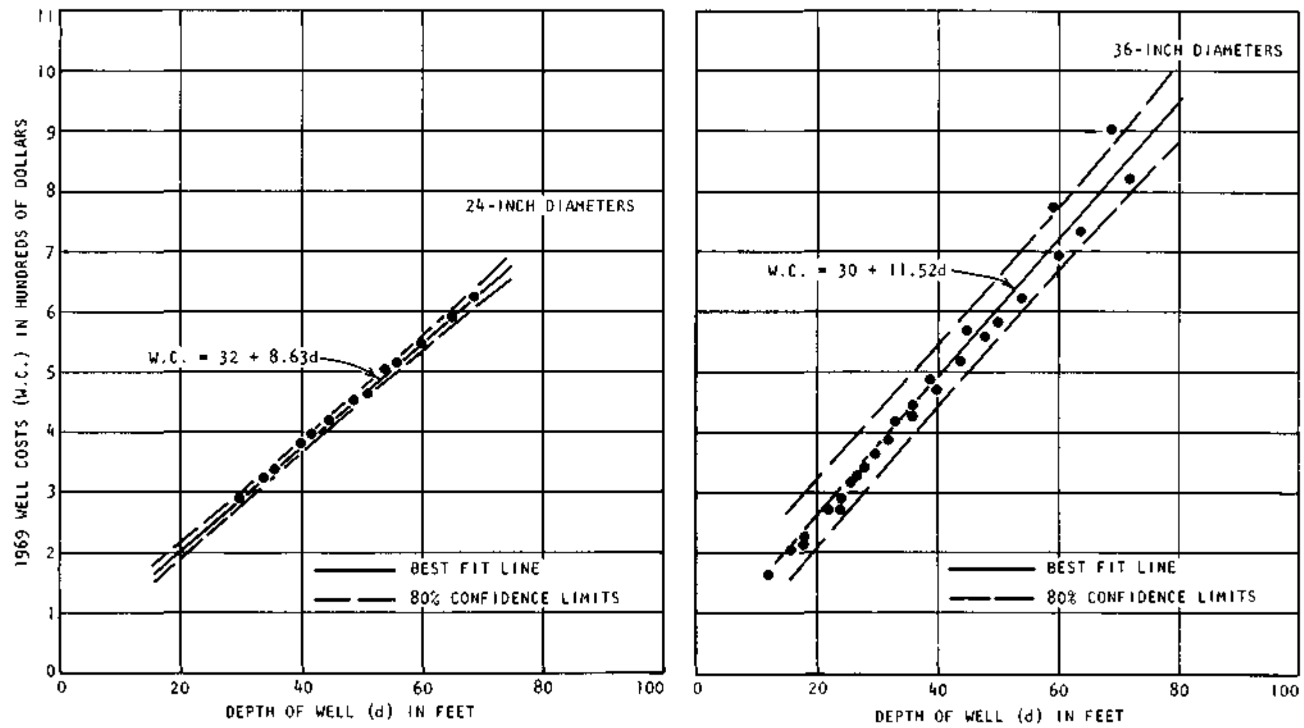

Figure 2. Cost of 24- and 36-inch augeved wells

for the depth-cost relationships developed for *2k*- and 36-inch diameter wells, respectively.

Cost of Drilled Sand and Gravel Wells

Drilled wells finished in water-bearing alluvial and glacial deposits of sand and gravel above bedrock are used throughout much of east-central and northern Illinois as a source of farm and domestic water supplies. Water-yielding sections of sand and gravel 3 or more feet thick are normally required to insure the success of this type of well for domestic use.

Domestic wells finished in these unconsolidated aquifers are usually constructed by rotary or cable-tool drilling methods. Wells are commonly cased with 4-, 5-, or 6-inch steel casing followed by a length of commercially made well screen set opposite the aquifer materials. The yields obtained from these wells generally are adequate for domestic use (5 to 10 gpm). In many instances the reported yields reflect the installed pump capacities and are not necessarily the yield capability of the aquifer tapped.

Completed cost data were obtained for 132 sand and gravel drilled wells. The reported depths of these wells range from 25 to 355 feet and average about 115 feet. Screens range from 2 to 6 inches in diameter, and from 2.5 to 15 feet in length, averaging about 4 feet in length. Screen slot sizes range from 8 to 80 (0.008 to 0.080 inches) and average 20 (0.020 inches). Installed pump capacities in these wells range from 3.5 to 25 gpm and average about 10 gpm.

The costs of 4-, 5-, and 6-inch diameter wells at varying depths are illustrated in figure 3. Correlation coefficients of 0.981, 0.827, and 0.947 were obtained for the depth-cost relationships developed for the 4-, 5-, and 6-inch diameter welIs, respectively.

Cost of Drilled Bedrock Wells

Drilled wells finished in the shallow dolomites of northeastern Illinois and the sandstone and limestone formations in northwestern, western, and southern Illinois are used as a source of farm and domestic water supplies in these areas.

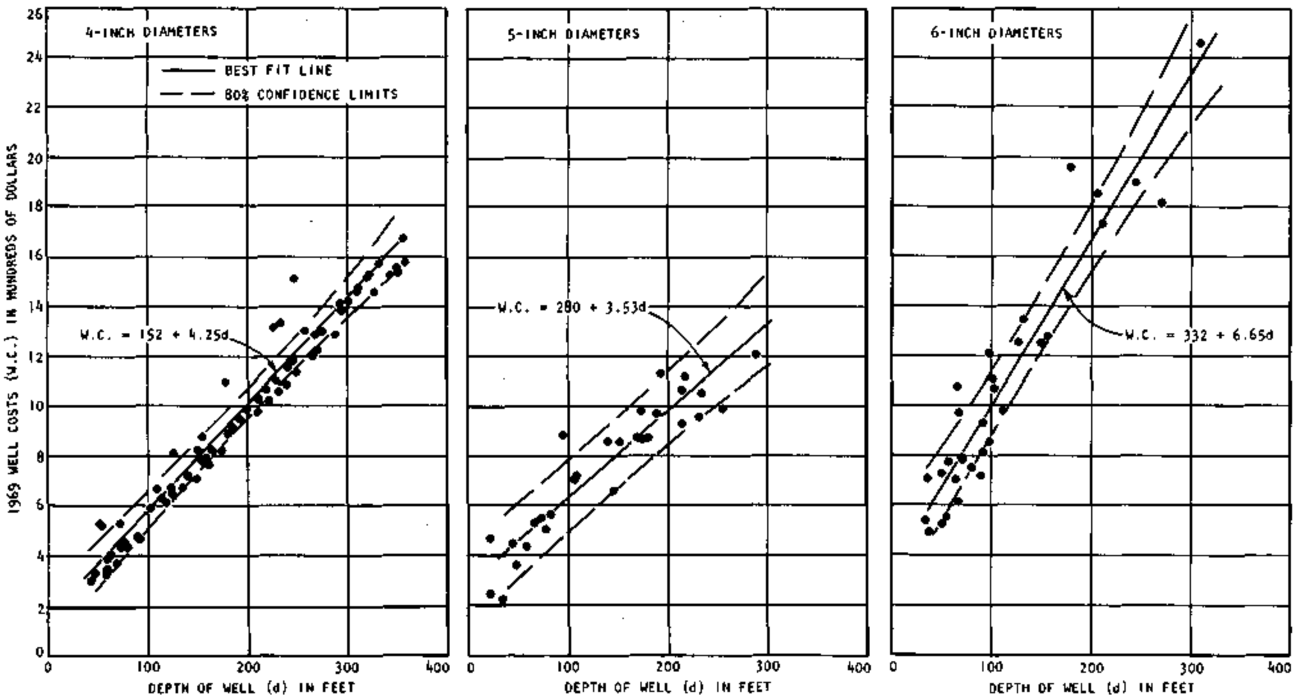

Figure 3. Cost of 4-, 5-, and 6-inch sand and gravel wells

Like the sand and gravel drilled wells, these wells also are constructed by rotary or cable-tool drilling methods. Wells are commonly cased with 4-, 5-, or 6-inch steel casing down to the consolidated bedrock formations below which an open hole is usually constructed. In some parts of the state an 8-inch casing is installed to the bedrock surface and a smaller liner (usually 6- or 4-inch) is extended into the bedrock to seal out any formations which are subject to caving.

Yields of bedrock wells differ considerably according to the region and type of formation tapped. Relatively high yielding (10 to 50 gpm) wells are not unusual in the shallow dolomite formations of Silurian age in northeastern Illinois. Sandstones and limestones of Mississippian and Ordovician age along the western edge of the state and in northwestern Illinois may be expected to yield smaller quantities of water (5 to 25 gpm). Sandstones and limestones of Pennsylvanian age occupying the major portions of western and southern Illinois yield even smaller quantities of water to wells (from 1 or 2 gpm to perhaps 10 or 15 gpm in the more productive areas).

Completed cost data were collected for 171 small-diameter drilled bedrock wells. The depths of these wells range from 40 to 425 feet and average about 200 feet. The depths to which these wells are cased range from 15 to 100 percent of the individual well depths and average about 55 percent. Installed pump capacities range from 1 to 20 gpm and average about 10 gpm.

The cost of 4-, 5-, and 6-inch wells, and of reduced diameter wells at varying depths are illustrated in figure 4. Correlation coefficients of 0.972, 0.868, 0.896, and 0.975 were obtained for these depth-cost relationships, respectively.

COST OF PUMPING SYSTEMS

Completed cost information for approximately 200 domestic pumping systems installed during 1967, 1968, and 1969 was collected from the 19 drillers cooperating in this study. These data include the installed costs of the pump, pitless adapter unit, pressure tank, and all associated piping and wiring. All pumps were of the submersible type indicating a recent trend away from the use of well houses and pits. Pump capacities range from 1 to over 20 gpm.

Pumping system cost data also were adjusted to a 1969 economic level using the farm and domestic well index (see figure 1). Preliminary analysis of the adjusted cost data revealed unexpectedly large variations in the costs of these systems. No significant relationships between the pump costs or pumping system costs and the pump capacity and depth of setting could be developed. Instead, costs appeared to vary with the installing driller in different areas of the state.

To minimize the large variation in pumping system costs and to permit a more meaningful presentation, data for those systems equipped with 10-gpm pumps were selected for further analysis. These data were chosen because the average pump capacity of all systems was about 10 gpm and more than 50 percent of all systems were equipped with 10-gpm pumps.

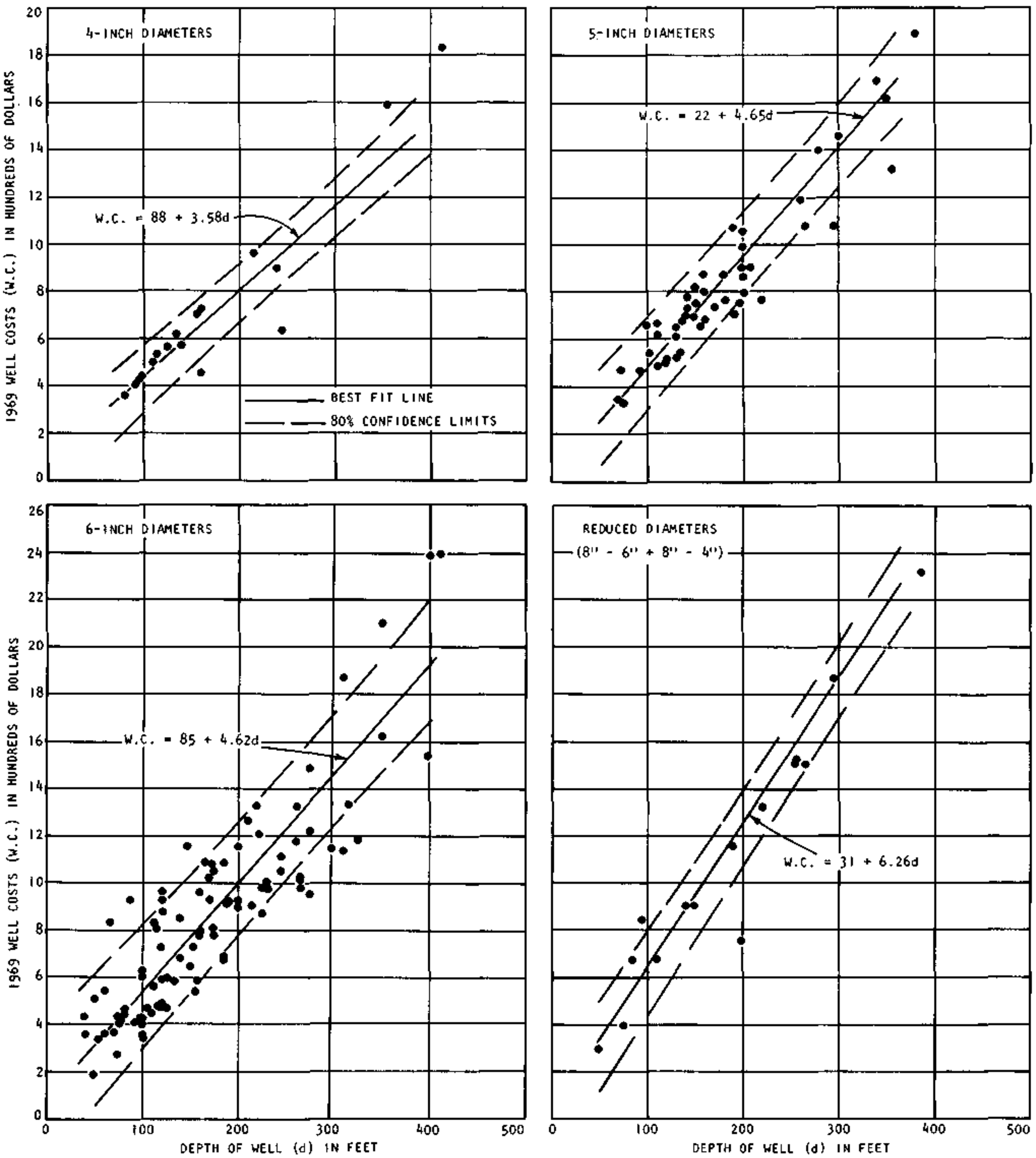

Figure 4. Cost of 4-, 5-, and 6-inch, and reduced diameter bedrock wells

The final set of pumping system cost data represents the consumer cost (labor and materials) of the following: 1) a 10-gpm submersible pump, 2) a pitless adapter unit, 3) an adequately sized pressure tank, and 4) all associated piping and wiring to deliver water to the house. The range and distribution of costs of the selected systems are illustrated in figure 5. The average cost is about $585, and 50 percent of the selected systems had costs between $400 and $680. For planning purposes it would seem reasonable to assume a cost of about $500 or $600 for a system of this size and type.

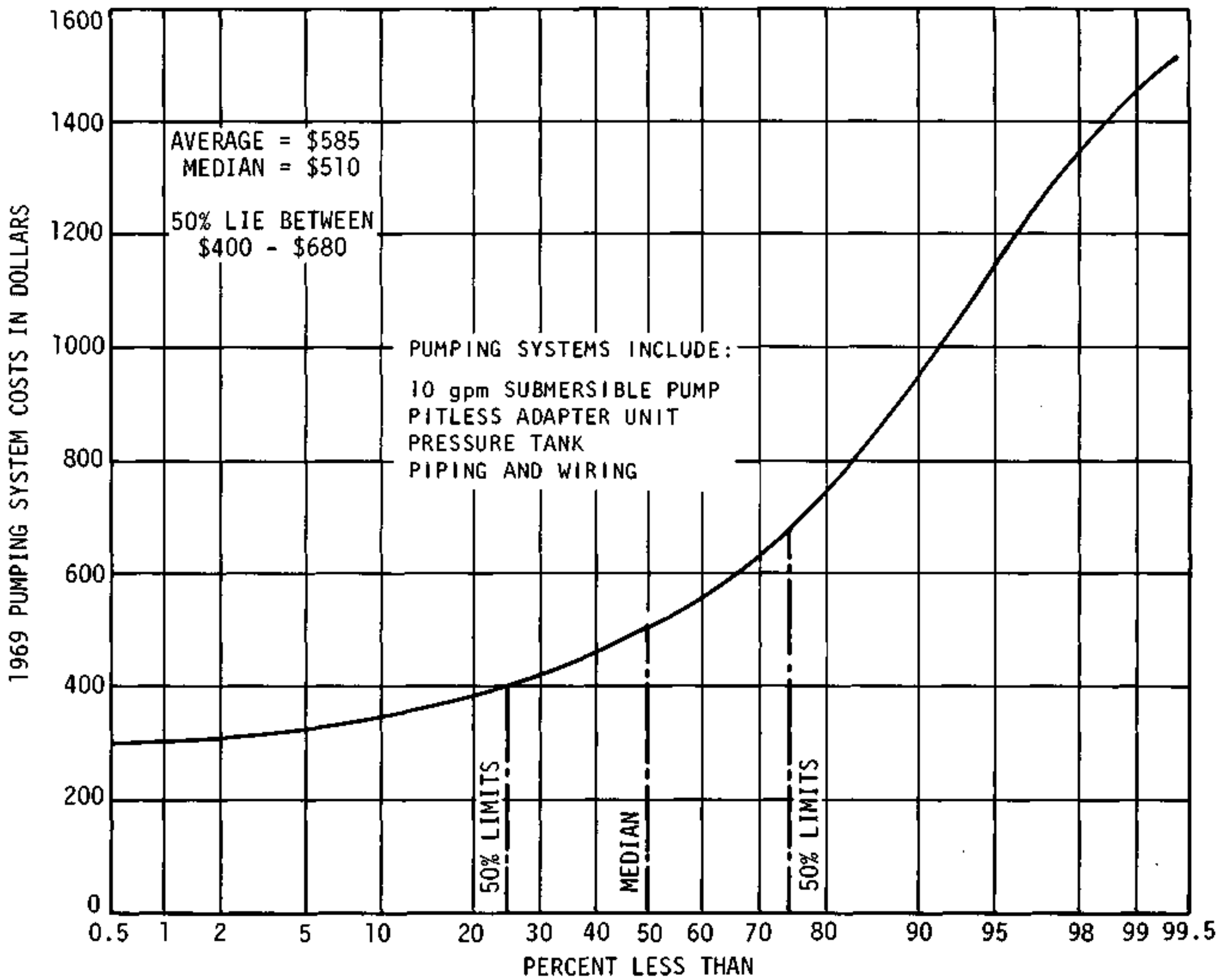

Figure 5. Cost of pumping systems

COST OF RAW WATER

If sufficient geohydrologic data are available to determine the probable type and size of well required to furnish an adequate water supply at a given location, the data presented in the preceding sections of this report can be used to estimate the initial costs of that well and a typical pumping system. Once the initial costs have been determined, these values can be reduced to a more meaningful equivalent monthly cost.

The equivalent monthly cost of a given well and pumping system is obtained by amortizing their initial costs over the expected life span of each unit. Previous studies by the Illinois Water Survey have found the median service lives of domestic wells and pumps to be approximately 20 and 10 years, respectively. Figure 6 shows the equivalent monthly costs obtained using these life spans at an interest rate of 8 percent, plus a combined annual maintenance expense of $10, for several combinations of initial well and pumping system costs.

The equivalent costs shown in figure 6 represent the monthly costs required to pay off a loan on a newly constructed well and pumping system. The loan period is the life of the well (20 years), and it is assumed that two pumping systems will be required over this period (10 years for each system). Therefore payment on the well and pumping systems is required for the entire 20-year period. The interest rate on the loan is assumed to be 8 percent.

These equivalent monthly values represent the cost of raw water from a selected well and pumping system regardless of the quantity of water pumped. The electrical power costs of pumping water are not included since Water Survey studies show power costs for pumping water for domestic use to be almost negligible. In most cases it would probably be less than $.50 per month.

The data presented in figures 2 through 6 for typical well construction practices and geohydrologic conditions in the various parts of the state have been used to construct two maps. Figures 7 and 8 illustrate the probable monthly costs of obtaining domestic raw water supplies from the unconsolidated and bedrock aquifers, respectively. In developing these maps, typical well diameters of 4 inches were used in pricing both the drilled sand and gravel

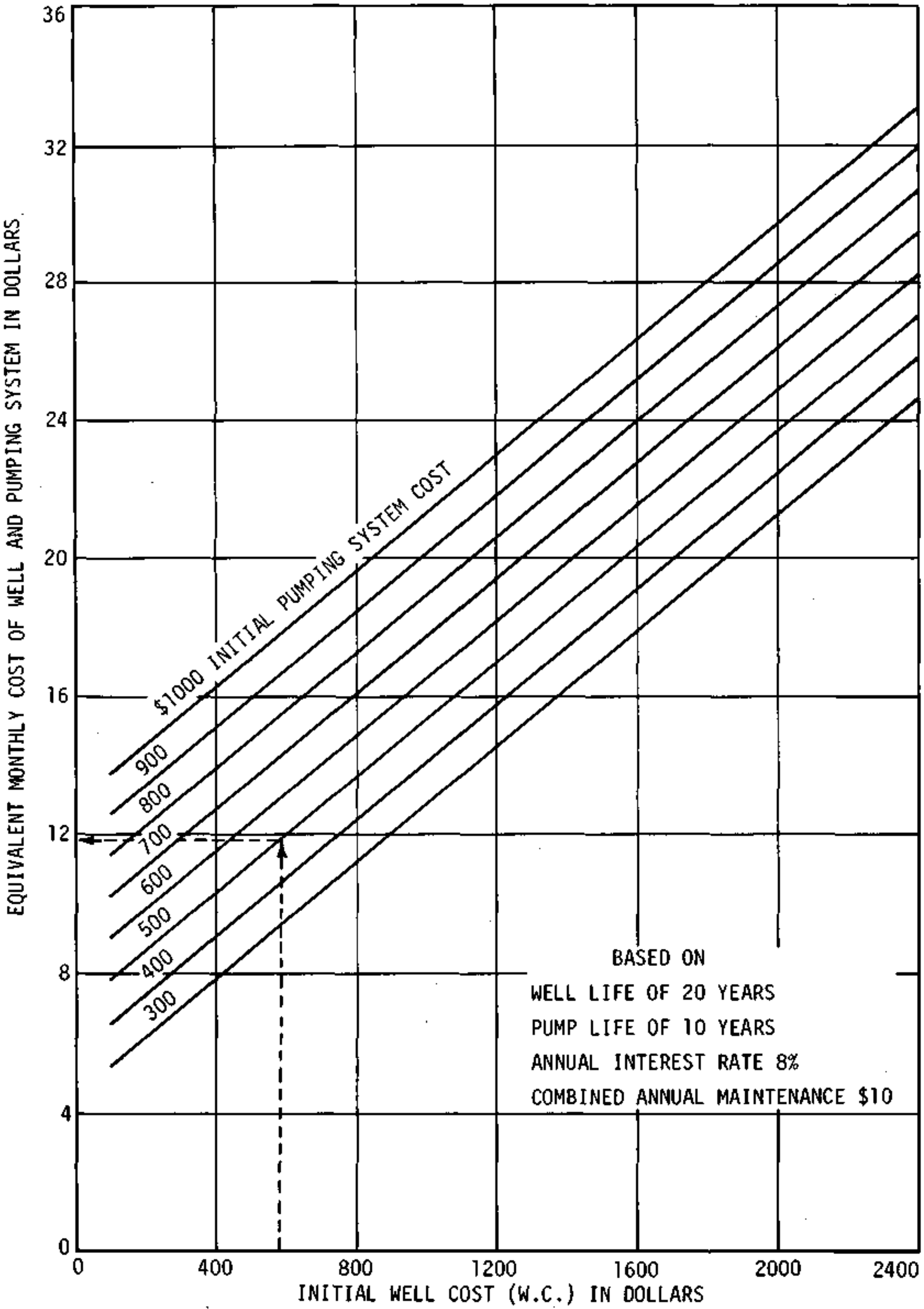

Figure 6. Monthly cost of wells and pumping systems

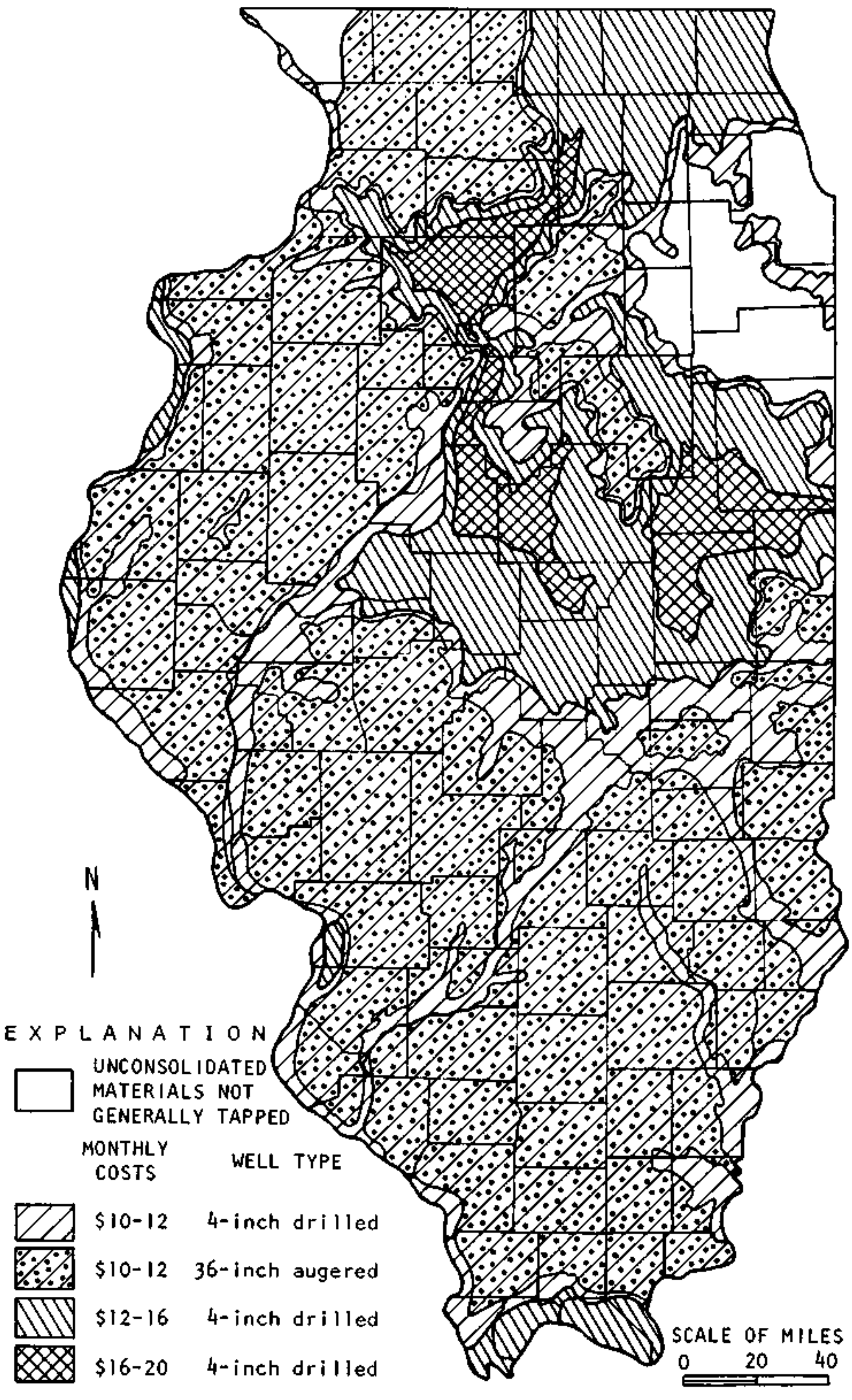

Figure 7. Probable monthly costs of domestic raw water supplies from sand and gravel wells

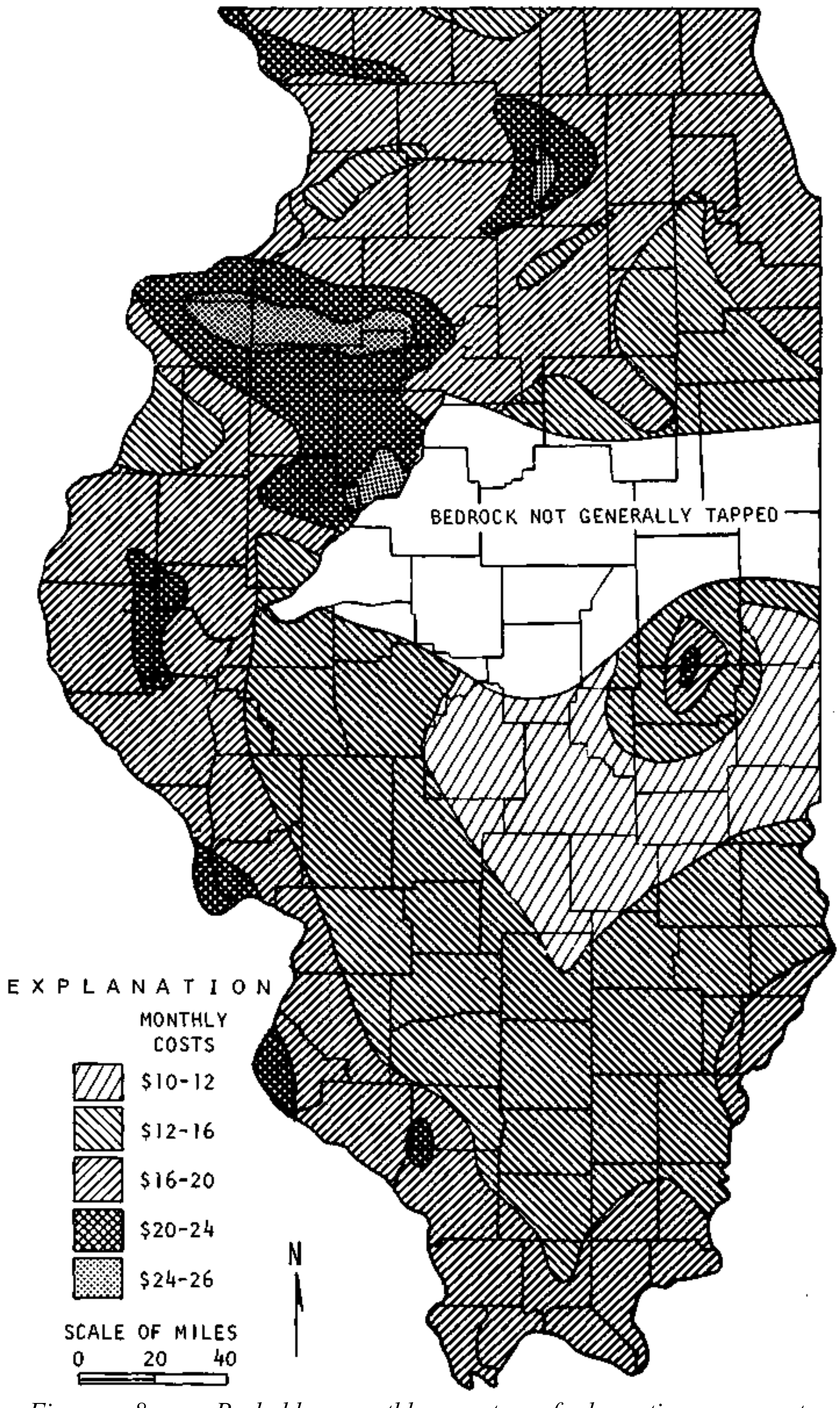

Figure 8. Probable monthly costs of domestic raw water supplies from bedrock wells

and the bedrock wells. The 36-inch diameters were used in pricing augered wells. All pumping systems were considered to cost about $500.

After the monthly cost of a basic raw water system is known, it can be used to estimate the costs of various types of water treatment.

COST OF TREATMENT

Desirable water for general domestic use should contain no objectionable or dangerous concentrations of minerals or gases and should be of a safe sanitary quality. However, objectionable concentrations of hardness-forming minerals and iron are common in waters 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 home water treatment units to soften the water, remove its iron, and where necessary chlorinate it. It is probable that the general quality of water from all private water supply systems could be improved with the installation of properly selected water treatment equipment.

Cost of Softening

Groundwater from nearly all aquifer systems in Illinois generally can be considered hard. Total hardness determinations for 15,128 groundwater samples from glacial drift and bedrock aquifers throughout Illinois show that 5 percent of the samples contained between 0 and 100 ppm; 10 percent between 100 and 200 ppm; 25 percent between 200 and 300 ppm; 30 percent between 300 and 400 ppm; 20 percent between 400 and 600 ppm; 7 percent between 600 and 1000 ppm; and 3 percent more than 1000 ppm in hardness.

Approximately 20 percent of the municipal groundwater supplies in Illinois, serving a population of about 675,000 persons, have treatment plants that produce water with 100 ppm or less of hardness (Larson, 1963). Actual data on the percent of domestic water supplies equipped with water softeners are not available. However, it is estimated that, for the state as a whole, less than 15 percent of the domestic groundwater supplies are softened before use.

The removal of hardness minerals (calcium and magnesium) from a domestic water supply system usually can be accomplished with an ion exchange type home water softener. In this type of unit, calcium (Ca++) and magnesium ions (Mg++) are exchanged for sodium ions (Na+) in the softener tank resulting in a softened water still containing essentially the same amount of total minerals. The effectiveness of this type of softener unit may be reduced substantially when the water being treated contains iron. If the water contains iron in excess of about 2 ppm, an iron removal unit should probably be used ahead of the softener to insure that optimum operation of the softening unit is realized.

Home water softeners generally are rated by the total grains of hardness they can remove from the water before they must be regenerated. The majority of the domestic-sized softeners used in Illinois have rated capacities between 10,000 and 20,000 grains. The final size selection depends primarily on the hardness content of the water being treated and the anticipated water usage.

For this study all softening cost estimates were based on a 10,000 grain unit. Available information on 11 different softeners produced by 8 different manufacturers was used in determining salt dosages and water requirements. Salt dosages for these units ranged from 0.42 to 0.72 pound per 1000 grains of hardness removed, with the larger capacity units generally being more efficient (requiring less salt per 1000 grains removed). Realizing that technological advances in the design of these units will probably lower the required salt for units of all sizes, we chose 0.45 pound per 1000 grains for our cost calculations. An average water requirement of 35 gallons per regeneration cycle also was used.

The added monthly cost of softening can be obtained by amortizing the initial investment cost of a 10,000 grain softener over its expected life (10 years) at an interest rate of 8 percent, and calculating the monthly salt and water costs. A salt cost of $.025 per pound was used, and the regeneration water cost was based on the amortized monthly cost of a well and pumping system divided by the total monthly pumpage.

The added monthly costs of softening water of various concentrations of hardness at differing use rates for a range of equivalent monthly well and pumping system costs are illustrated in figure 9.

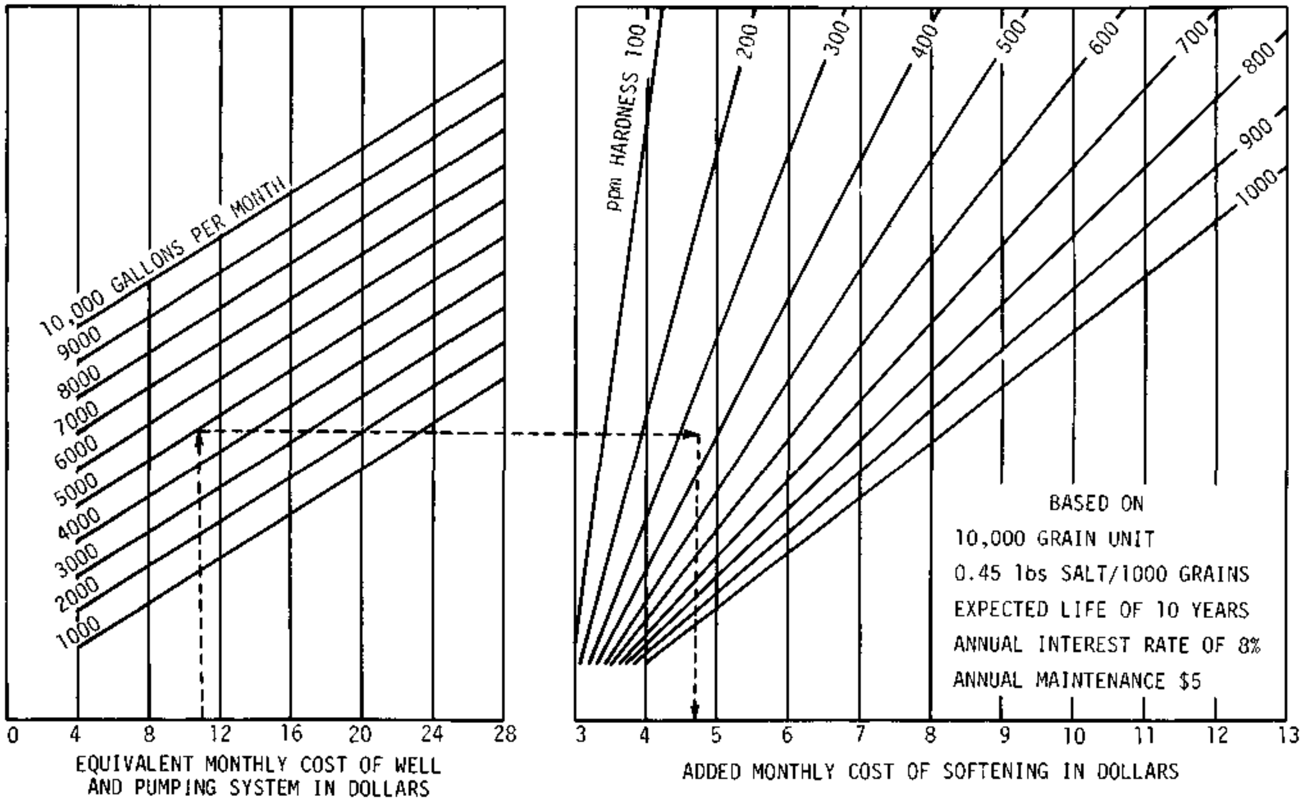

Figure 9. Monthly cost of softening

For the majority of the cases which may be encountered in Illinois (hardness concentrations from 200 to 600 ppm, use rates from about 3000 to 8000 gallons per month, and monthly well and pumping system costs from $10 to $26), the added monthly costs of softening range from about $3.70 to $9.20. For a typical case (hardness content 350 ppm, use rate 5000 gallons per month, and monthly raw water cost $11.00), the added cost of softening is estimated at about $4.70 per month.

In the typical example just mentioned, the added cost of softening could be reduced by about 10 percent if only the hot water is softened (assuming equal monthly usage of cold and hot water). However, softening of both hot and cold water for normal household use generally results in reduced maintenance cost of the distribution system and would therefore probably be justified. If a large quantity of water is to be used for watering livestock or sprinkling lawns, either provisions should be made to bypass the softening unit or separate water lines should be maintained to service these facilities.

Cost of Iron Removal

The iron content of Illinois groundwater ranges from zero to over 25 ppm. More than 70 percent of the groundwater supplies for which the Water Survey has analyses contain iron concentrations in excess of the 0.3 ppm level recommended by the U. S. Public Health Service. However, as a result of the treatment of municipal groundwater supplies, approximately 60 percent of Illinois' urban population served by groundwater systems receive iron free water (Larson, 1963). It is estimated that less than 5 percent of the domestic groundwater supplies in the state are equipped with iron removal units, even though some degree of water quality improvement could be accomplished if such units were used.

Effective iron removal from water containing more than 2 or 3 ppm iron generally requires treatment equipment specifically designed for iron removal. The most common type of home iron removal equipment used in Illinois is an oxidizing iron filter unit. In this type of unit, soluble (ferrous) iron is converted into its precipitated (ferric) form by an oxidizing agent, such as manganic oxide, and is then removed by filtering.

Oxidizing iron removal units are rated by the total parts per million of iron they can remove from the water before regeneration is needed. Rated capacities of various brands of these units are not always available to the general public.

For this study, all iron removal cost estimates are based on a 12,000 ppm unit available from one of the more prominent water treatment equipment distributors. Regeneration of this unit requires approximately 11 ounces of potassium permanganate and about 100 gallons of water.

The added monthly cost of iron removal with this unit can be obtained by amortizing the initial cost of the unit over its expected life (10 years) at an interest rate of 8 percent and calculating the monthly chemical and water costs.

Potassium permanganate was priced at $2.25 per 11-ounce container, and regeneration water cost was again based on the amortized monthly cost of a well and pumping system divided by the total monthly pumpage.

The added monthly costs of removing iron from water of varying iron concentrations at differing use rates for a range of equivalent monthly well and pumping system costs are illustrated in figure 10.

For the majority of cases which may be encountered in Illinois (iron contents from 1 to 5 ppm, use rates from about 3000 to 8000 gallons per month, and monthly well and pumping system costs from $10 to $26), the added monthly costs of iron removal range from about $5.30 to $13.20. For a typical case (iron content 2 ppm, use rate 5000 gallons per month, and monthly raw water costs $11.00), the added cost for removing iron is estimated at $6.60 per month.

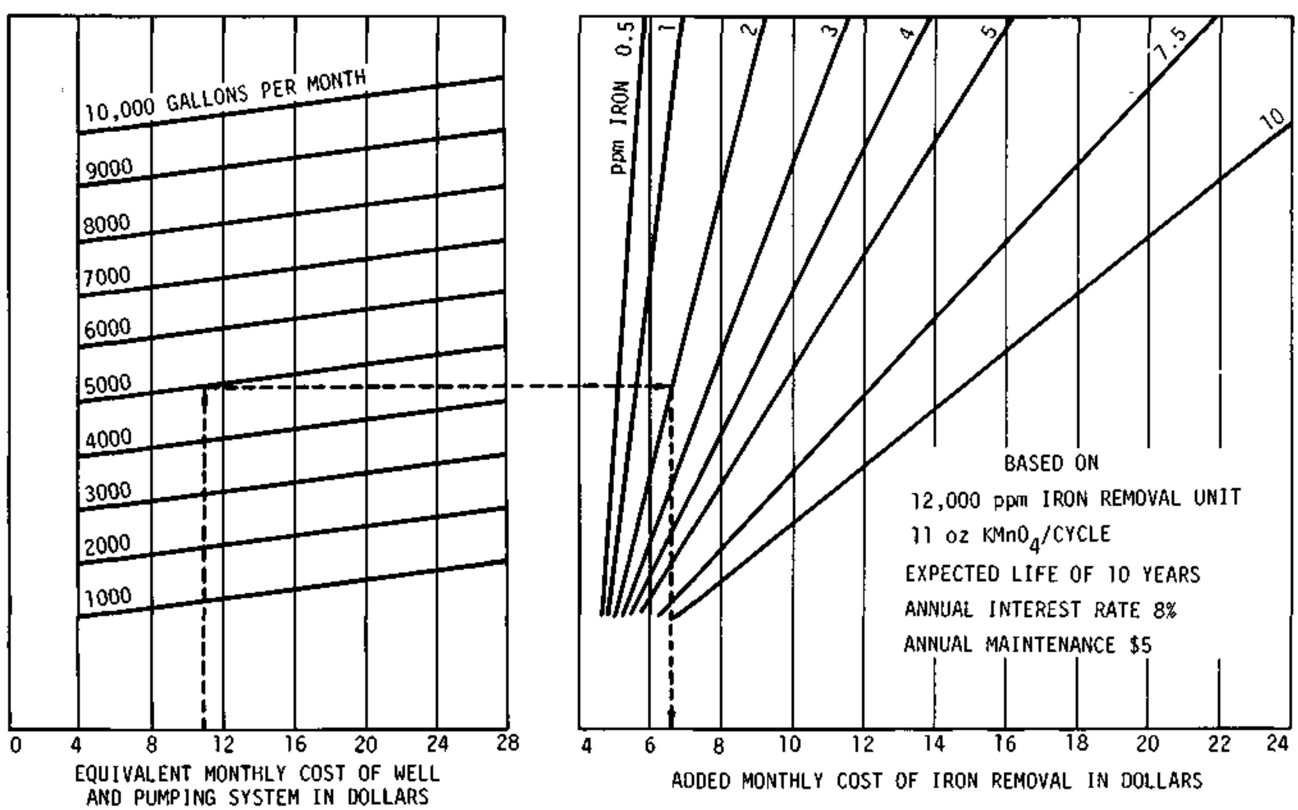

Figure 10. Monthly cost of iron removal

Cost of Chlorination

Continuous chlorination of private water supply systems in Illinois currently is not a common practice. The majority of the wells recently completed in the state appear to be properly located, constructed, and adequately protected from the entrance of surface water and bacterial contamination. However, all wells should be tested periodically for bacteria to insure a continuing safe water supply. In cases where water from a well is muddy or murky following periods of heavy rain, it is probable that surface seepage with possible contamination is entering the well and the water definitely should be tested. Analyses to detect bacterial contamination in Illinois are performed by the regional laboratories of the Illinois Department of Public Health. If harmful bacteria is detected and cannot be eliminated by well rehabilitation and shock chlorination, the well should be either abandoned or equipped with a continuous chlorinator.

Where continuous chlorination is necessary, chemical feed pumps used for this type of treatment are readily available at a cost of about $100. The added monthly cost of continuous chlorination with this type of pump, amortized over its expected life of 5 years at 8 percent, is about $3. This includes a $10 per year combined operating and chemical expense.

COMPARATIVE COST OF RAW AND TREATED WATER

The information presented in this report can be used to estimate the monthly costs of developing and maintaining a domestic groundwater supply. If the geologic conditions at the location of interest are known, the probable type, size, and depth of well required to furnish the desired supply can be determined. Then from the appropriate depth-cost curve (figures 2, 3, or 4), an estimate of the initial well cost can be made.

Once the initial well and pumping system costs have been estimated, an equivalent monthly cost can be determined by amortizing both investments over the expected service lives of the respective installations (figure 6). This expenditure is the estimated monthly cost of raw water (neglecting pumping power costs) from the proposed domestic supply system.

The additional monthly costs of softening, removing iron, and continuous chlorination also can be estimated by use of the data included in this study. After the mineral quality of the raw groundwater at the location of interest has been estimated or determined by analysis, decisions can be made concerning the type of treatment desired. The added monthly cost of softening and iron removal can be estimated from figures 9 and 10 for various priced raw water systems at different monthly consumption rates and concentrations of hardness and iron. The added monthly cost of continuous chlorination for the quantities of water normally consumed for domestic use is estimated at about $3.00.

Figure 11 summarizes the relative costs of developing and maintaining a typical domestic raw groundwater supply system as compared with the costs of the same system when treating the water for: 1) hardness, 2) hardness and iron, and 3) hardness, iron, and bacterial pollution.

The raw water costs shown in figure 11 are based on a typical 100-foot deep drilled sand and gravel well equipped with a median priced pumping system of about $500. Treatment costs are based on typical Illinois groundwater having 350 ppm hardness and 2 ppm iron. Similar comparisons for other selected domestic water supply systems also can be made from the data in this study.

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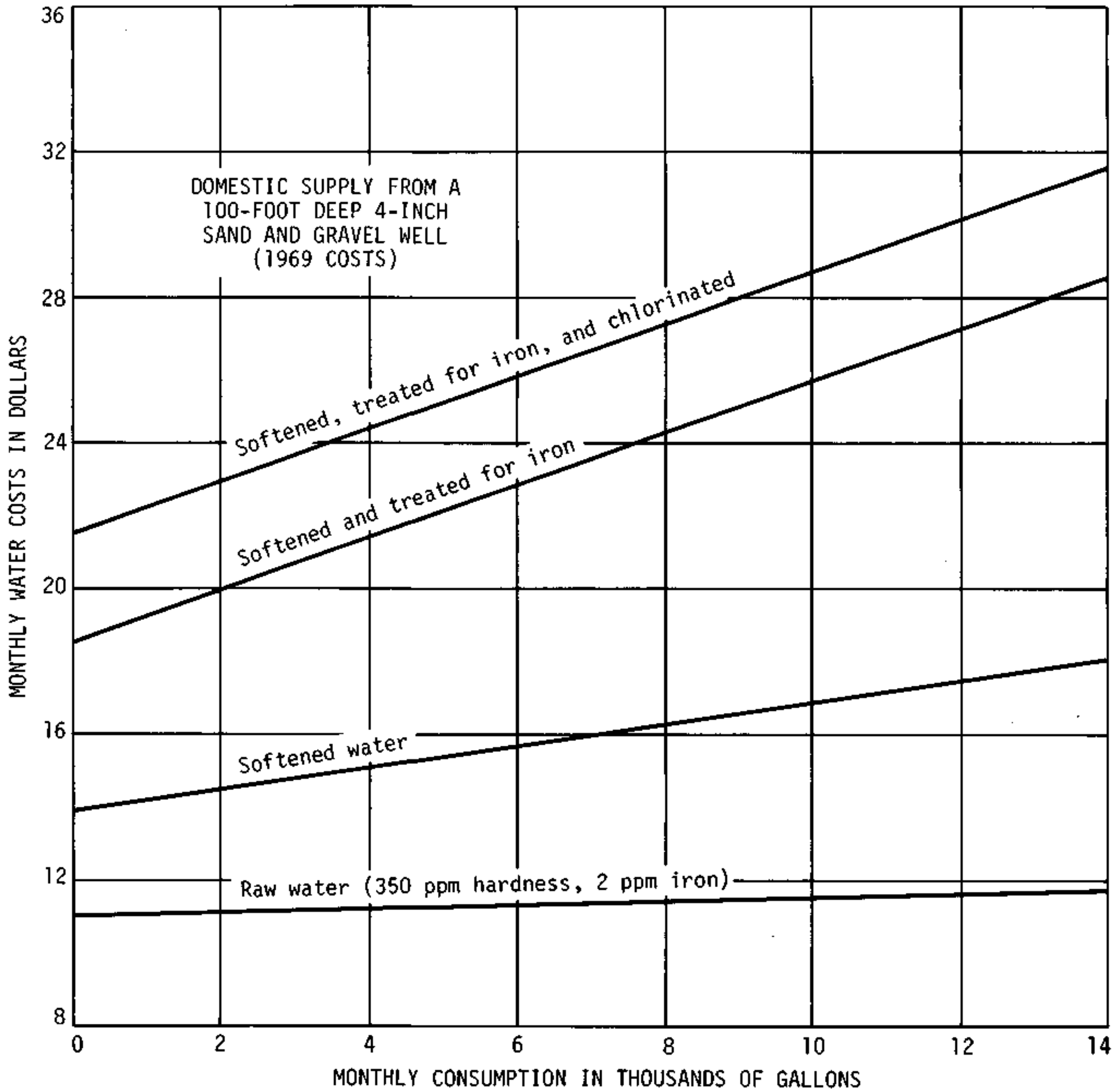

Figure 11. Summary costs of a typical domestic water supply in Illinois