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MORTALITY EXPERIENCE WITH ILLINOIS MUNICIPAL WELLS

by H. E. Hudson Jr. and J. L. Geils

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Mortality Experience With Illinois Municipal Wells

By H. E. Hudson Jr. and J. L. Geils

A paper presented on May 2, 1951, at the Annual Conference, Miami, by H. E. Hudson Jr., Head, and J. L. Geils, Assoc. Engr., both of the Eng. Subdiv., State Water Survey, Dept. of Registration and Education, Urbana, Ill.

DURING the past seventy years, use of ground water in Illinois has developed on an immense scale, but this rapid expansion was not accompanied by close technical examination until the last fifteen. Although the Illinois State Water Survey has been collecting information on ground water developments since 1895, many aspects of this work have not been comprehensively reviewed. The beginnings of such a review were made by J. B. Millis and H. E. Romine in 1946 and summarized in a panel discussion which was published in the JOURNAL (1). An AWWA committee previously gathered mortality data on water works components and published this information in *Survival and Retirement Experience With Water Works Facilities* (2). The methods used in that publication have been employed so far as possible in the present study of the 2,604 Illinois water wells built for municipal supply.

As part of the study, data on water well experience were classified and compiled, producing some unexpected findings in trends in service life of wells, and a statistical review of ground water practice was prepared to measure the factors that contributed to these trends and that may affect them in the future.

Growth of Ground Water Use

The increase in public ground water supplies and in population served for the period from 1868 to 1948 is shown in Fig. 1. Use of ground water received its first widespread development in the 1880's and has been increasing ever since that time. The great majority of Illinois municipalities and urban population is now served by public water supply systems. Growth in the number of these systems has been accompanied, in recent decades, by the transfer of many community supplies from ground water sources to surface water sources.

It has proved difficult to estimate trends in ground water use, as production records for ground water undertakings were not easily obtained. Production records were available from only five Illinois communities for the years 1900-1947. These cities, which, in 1950, had populations ranging from 12,000 to 93,000, were Aurora, Champaign-Urbana, DeKalb, Elgin, and Rockford. The curves in Fig. 2 were plotted from the data collected in these cities. As will be noted from the per capita production curve, there has been a definite increase for each decade since 1900 and an especially large increase since 1940.

Histories of Installed Wells

A chronologic record of wells built, abandoned, retired, kept as standby, and maintained in active service was prepared in accordance with the following definitions: Wells that were permanently removed from service by the operators or not equipped for service

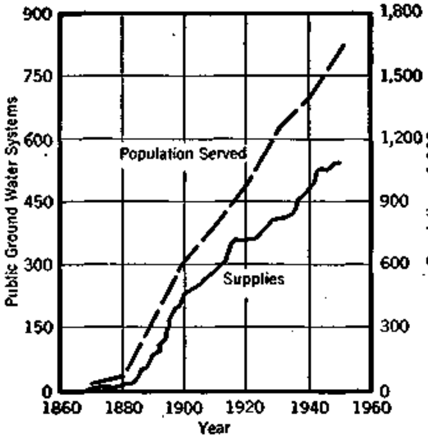

Fig. 1. Increase in Public Ground Water Supplies and Population Served

Data for period 1868-1948.

and no longer used as a part of a public ground water supply system were considered "retired." "Abandoned" and "standby" were included in the category of retired wells throughout this study except in Fig. 3, where they are necessarily shown separately. The "abandoned" wells were those which were removed from service in communities that discontinued the use of ground water. "Standby" wells were those still equipped with pumps but rarely used. Many standby wells were poorly equipped for pumping and no longer able to supply the public demand. Not all of them were maintained in condition for service and the majority were slated for retirement. Only 6 per cent of the wells in this category contributed to the public supply, and most of these furnished only 1-5 per cent of the total.

Figure 3 shows a decline in number of wells in active service after 1918. The population-served curve in Fig. 1 and the curve of the trend in per capita production in Fig. 2 both show increases. Nevertheless, there are fewer

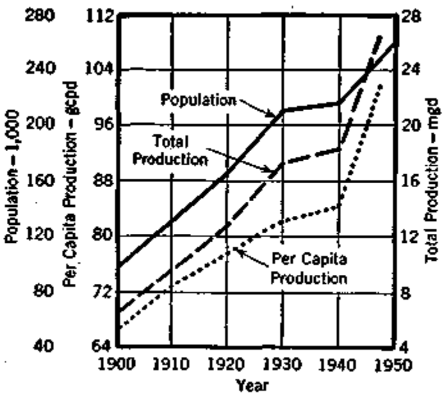

Fig. 2. Trend in Ground Water Production in Five Illinois Cities

Data for Aurora, Champaign-Urbana, DcKalb, Elgin, and Rockford for years 1900-47.

wells in active service today than there were 35 yr ago. This unexpected discovery indicated the need for a more detailed production analysis. Production data were supplied by the Div. of San. Eng., Illinois Dept. of Public Health from surveys of public water supplies in 1938, 1940, 1944, and 1948. These values, shown as small circles in Fig. 4, were used in computing the per capita production for the corresponding years.

Per capita production for the state as a whole was somewhat below that shown in Fig. 2 for five of the larger Illinois communities. The five-decade curve in Fig. 2 was therefore proportionately lowered to match the 1938 and 1940 per capita figures for the entire state. This modification produced an estimated statewide per capita production curve from 1900 to 1950 that permitted estimating total production from 1900 to 1938 as shown in the curve in Fig. 4.

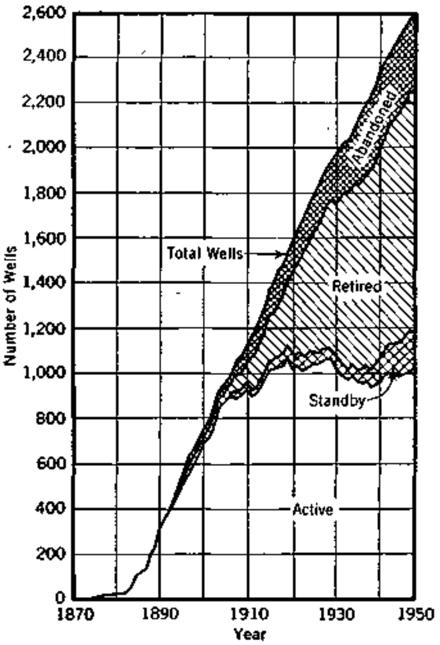

Fig. 3. Chronologic Record of Wells in Illinois Public Ground Water Supply Systems

A decline in wells in active service since 1918 is noteworthy.

From a combination of the production estimate and the data of Fig. 3 on the number of wells in active service, the curve in Fig. 5 which shows that individual-well production on a 24-hr basis increased from 38 gpm in 1900 to 94 gpm in 1948 was derived.

Water-Bearing Formations

The principal water-bearing formations* in Illinois are listed in summary form in Table. 1. The figures used in this table are not the extreme limits of the characteristics of the formations, but they indicate the limits generally encountered. A few drift wells, for example, are more than 300 ft deep. The hydraulic characteristics of the unconsolidated materials and various limestones are extremely variable, whereas the sandstone materials display more uniform characteristics.

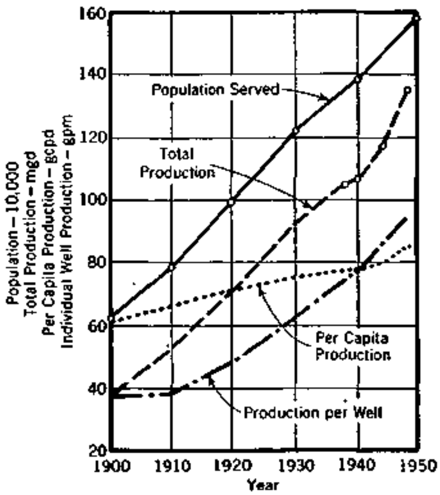

Fig. 4. Demands on Illinois Municipal Wells

Data from State Department of Public Health surveys in 1938, 1940, 1944, and 1948.

Almost all Illinois wells drilled in limestone or sandstone operate without

* In this study, the formation names that classified these wells are those given by the Illinois State Geological Survey as the bottom formation penetrated by each of the wells.

screens. Liners, or casing sections, are sometimes necessary through caving strata. Certain wells drilled into sandstones, particularly the Cambrian sandstones, have been improved by the use of explosives, or shooting. Although the upper limit of the coefficient of transmissibility for Ordovician sandstone is shown in Table 1 to be 50,000 gpd per ft, this value is attained only in certain limited areas. Ordovician material usually offers a productive capacity that is no better than that of the Pennsylvanian and Mississippian sandstones.

Types of Wells

The rates of installation of wells of various types in Illinois are shown in Fig. 5, which gives data on wells in unconsolidated materials, and in Fig. 6. which gives data on wells drilled into bedrock. Of significance is the fact that the open-bottomed wells, represented by Curve *A* in Fig. 5, which were widely used in the 1890's, are now rarely found. Dug wells, too, have lost their popularity. There has been a steady demand for the regular tubular wells, represented by Curve *B* in Fig. 5. Gravel-packed wells, porous-concrete-

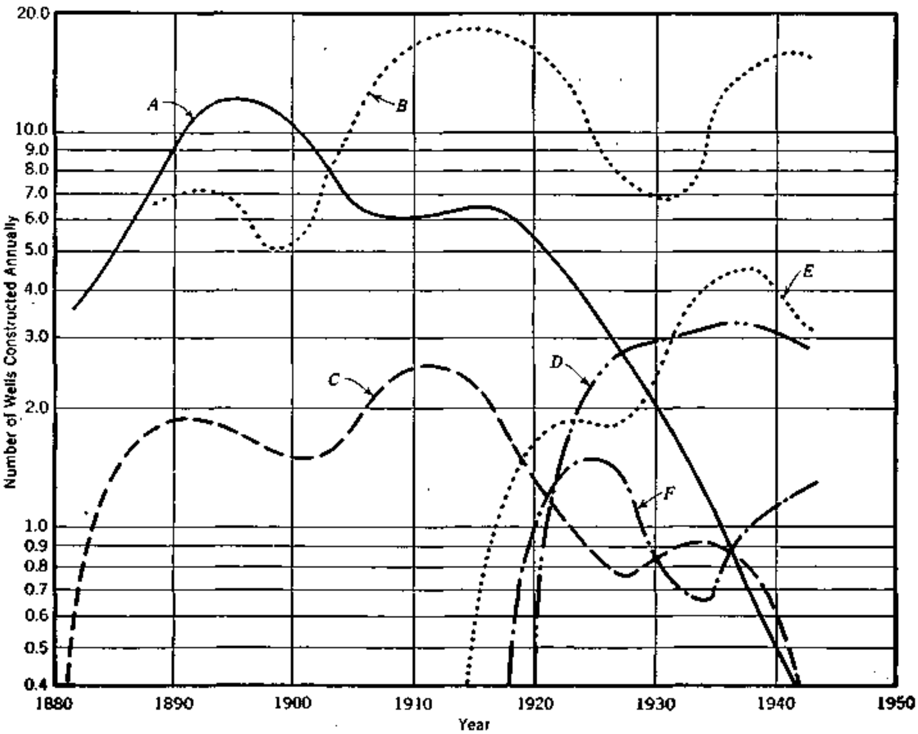

Fig. 5. Trends in Wells Constructed in Unconsolidated Materials

Figures are given in moving 10-yr averages. Curve A represents unscreened wells with metallic casings; Curve B, *screened wells without gravel pack; Curve* C, *dug wells; Curve* D, *wells with porous-concrete screens; Curve* E, *screened wells with gravel packs; and Curve* F, *wells with perforated-concrete pipe.*

screen wells, and perforated-concrete-pipe wells, not widely used until after 1915, are sometimes favored.

Of bedrock wells, those drilled in the limestones and into the Ordovician and Cambrian sandstones have been in sustained demand. Wells drilled in the Pennsylvanian formations, introduced in the early 1900's, have been less widely used. Those drilled into Mississippian sandstones constitute a small fraction of the total number installed each year and have been constructed in appreciable numbers only during the last two decades.

Mortality Experience

In determining the mortality rates of the various types of wells, 1-yr intervals were used. Wells were considered to have been placed in service in the middle of the calendar year. Retirements of these wells were then considered to have had a life of ½ yr. If the well was retired during the second year, it was considered to have had a 1½-yr service life, and so on. The definitions used were:

1. *The service life* of a well is the period between the date on which the well was placed in service as a part of the supply system and the date on which it was retired from service in that system.

2. *The median service life* is the number of years that is greater than the life, at retirement, of half the wells, and less than the life of the other half.

3. *A mortality-survival curve* is a graphic representation that shows the proportion of survivors in a group of wells, from year to year, throughout the period of record.

TABLE 1

Characteristics of Formations Developed for Public Ground Water Supply in Illinois

Formation	Well Production During Test *Spm*	Well Depth *ft*	Field Coefficient of Transmissibility	Field Coefficient of Storage	Thickness of Water-Bearing Stratum *ft*
Unconsolidated Materials	5-5,000	20-300	?-500,000	0.0001-0.10	5-200
Limestone	5-2,500	50-700	—	—	—
Sandstones					
Pennsylvanian	5-50	75-300	500-4,000	0.00002-0.0003	10-150
Mississippian	5-75	100-450	250-5,000	0.00005	10-100
Ordovician	25-1,000	150-1,500	500-50,000	0.00005	50-250
Cambrian					
Galesville	250-1,500	750-2,800	3,000-25,000	0.00003-0.0006	50-150
Mt. Simon	50-800	1,100-2,300			50-500

Mortality-survival experience is summarized in Fig. 7 for all wells used for municipal supply in Illinois and for the three major categories of formation—limestone, sandstone, and unconsolidated. Median service lives of these wells and of those drilled into various bedrock formations are given in Table 2.

Figure 8 shows the mortality-survival curves for wells drilled in unconsolidated formations. The most significant curve in Fig. 8 is Curve *C*, for wells with unscreened metal casings or for those with open bottoms. Median service life for these wells was 21 yr; for other types it was greater. As noted later, the data shown for wells with porous-concrete screens are not wells appear approximately similar. As the use of dug wells has been generally discontinued and as they were used in the earlier years when lighter demands were placed on them, it may be estimated that dug wells will have shorter service lives than will tubular

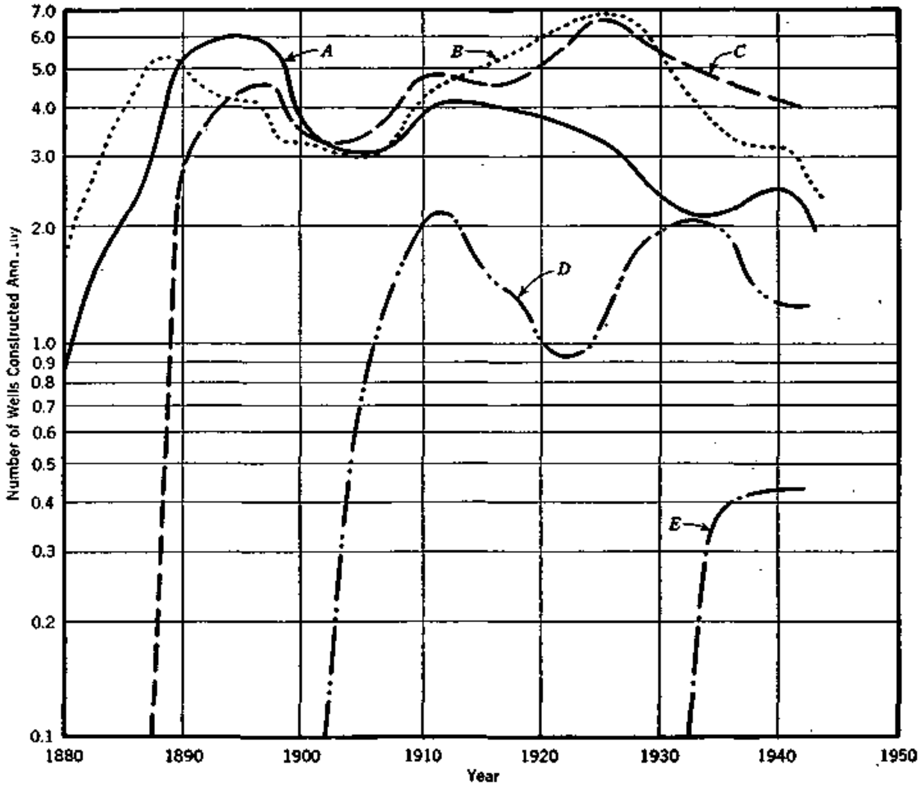

Fig. 6. Construction Rate for Wells Constructed in Illinois Bedrock Formations

Curve A *represents wells drilled in Ordovician formations; Curve* B, *in Cambrian; Curve C, in limestone; Curve* D, *in Pennsylvanian; and Curve* E, *in Mississippian.*

representative of general experience in Illinois.

Since less than one-third of the gravel-packed wells have been retired, the experience provided is too brief to establish their longevity definitely, but the mortality-survival curves for gravel-packed wells and for tubular-screened or gravel-packed, drilled wells.

The mortality-survival curves for wells drilled in the bedrock are shown in Fig. 9, a comparison of which with Fig. 8 indicates that the mortality experience with wells constructed in unconsolidated materials by almost any method is better than the experience gained with the Mississippian or Pennsylvanian formations.

Causes of Retirement

As part of the survey, the records of the 2,604 wells under study were reviewed and classified according to the cause of retirement for each well. These data are partially summarized by well types in Table 3, which provides a great deal of information, especially when it is compared with Table 1. A review of the detailed observations on this subject, however, cannot be made available here.

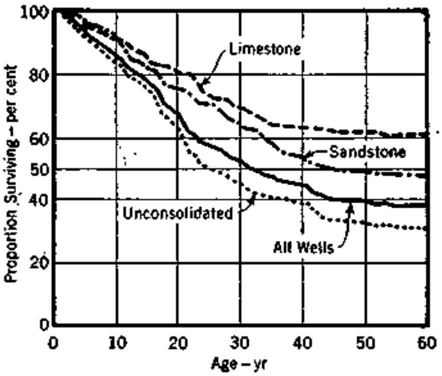

Fig. 7. Mortality-Survival Experience With Illinois Wells

Wells in Illinois public ground water supply systems were studied from records covering the period 1875-1948.

The overall summary of retirement causes shows the most important group to be that involved with the water-producing formation: interference, overproduction, and formation depletion. Second in importance is the group including mechanical stoppages, such as entrance of sand into the well or well loss due to formation movement. All other causes combined produced less retirement than either of these two. Thus, it is indicated that more than half the retirements were caused by troubles involved with the water-producing formation. One-quarter of the retirements were due to well losses, most of which were caused mechanically by sand movement. The remainder of the retirements were attributable to miscellaneous causes. But the basic cause appears to be use of the well rather than its construction.

Trend in Service Lives

There has been a growing feeling in the water supply industry that the new techniques now employed in the design and construction of water wells have increased their service lives. An attempt has been made to determine, from the mortality-survival data, the trend in median service lives of wells. For this analysis, retirement and survival information was sorted into a number of construction-time periods, for each of which a separate mortality-survival curve was prepared. From these curves, the medians in Fig. 10 were plotted.

TABLE 2

Median Service Lives of Wells

Formation	Median Service Life *yr*
Unconsolidated	25.0
Limestones	60 +
Sandstones	46.5
Pennsylvanian	18.3
Mississippian	11.8
Ordovician	41.8
Cambrian	60 +

In Part *A* of Fig. 10 is shown the trend in service lives of all the wells. It will be noted that there was a general decline in service lives from the earliest record until 1920. Although an apparent increase in service life after 1920 was indicated, it is questionable whether this increase actually took place or was the result of an in-correct method of analysis. Some increase might result from improved design and construction, but this improvement may be offset by the increased demands shown in Fig. 4.

In Part *B* of Fig. 10 are shown the This difference is probably more apparent because of the relatively short lives of wells in unconsolidated materials compared with those of wells drilled in bedrock. Combination of the year of construction and the median

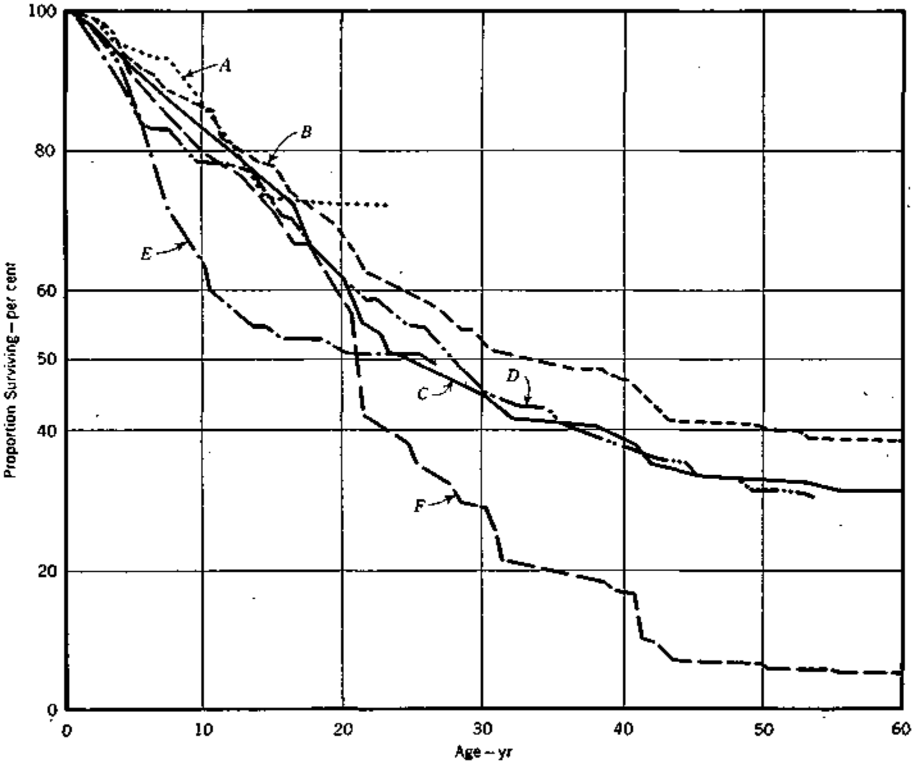

Fig. 8. Mortality-Survival Experience With Illinois Wells in Unconsolidated Formations

Wells in Illinois public ground water supply systems were studied from records covering the period 1875-1948. Curve A *represents screened wells with gravel packs; Curve* B, *metal-screened wells without gravel packs; Curve* C, *all unconsolidated wells; Curve* D, *open-bottom wells with dug masonry walls; Curve* E, *wells with porous-concrete screens; and Curve* F, *unscreened wells with metal casings.*

service lives of unconsolidated wells, which represent 65.5 per cent of all wells built in the state. The decline in median service life for those built shortly after 1900 is much more marked than is the decline for all wells studied. service life shows that at some time between 1920 and 1930 some factor caused a considerable decline in the service lives of existing wells.

It was impossible to prepare similar studies for the wells constructed in specific bedrock formations, because the number constructed was too small to provide representative values, and the actual service lives were of such great length that the series does not yield median values.

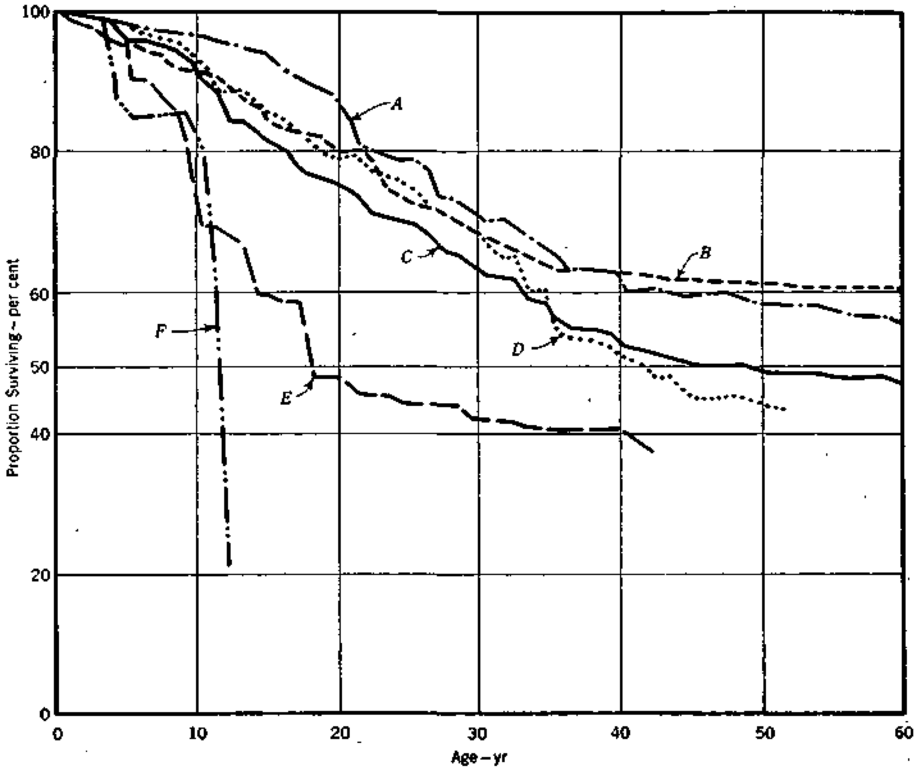

Fig. 9. Mortality-Survival Experience With Wells in Bedrock

Wells in Illinois public ground water supply systems were studied from records covering the period 1875-1948. Curve A *represents wells drilled into Cambrian formations; Curve* B, *all limestone wells; Curve* C, *all sandstone wells; Curve* D, *wells in Ordovician formations; Curve* E, *in Pennsylvanian; and Curve* F, *in Mississippian sandstone.*

The data in Fig. 10 disclose a period of marked decline in service life for the wells retired after 1923. Two distinctive service-life regimes are apparent: (1) the construction period from the earliest records to approximately 1900, when the service lives were approximately 30 yr, and (2) the construction period after 1910, when service lives were somewhat less than 20 yr.

Figure 4 shows that demands on wells have been increasing since 1910. Available data do not permit a more precise estimation of the increase in pumping rates during the mid-1920's, at which time a sharp production increase may have hastened well retirements.

TABLE 3

Reasons for Abandonment and Retirement† of Wells*

Well Group and Subdivisions	Type of Construction	Total Wells: No. Constructed	Total Wells: No. Abandoned	Total Wells: No. Retired	Total Wells: Proportion Abandoned and Retired *per cent*	No. Wells Abandoned or Retired for Various Reasons‡: A Clogging	B Inadequacy	C Screen or Casing	D Quality	E Construction	F Miscellaneous	G Unknown
Unconsolidated												
Drilled	Unscreened casing, open bottom	353	45	280	92.1	121	137	15	41	8	1	2
	Metallic screen, no gravel pack	728	109	258	50.4	130	147	20	37	9	21	3
	Metallic screen, gravel pack	89	3	14	19.1	6	6	1	—	4	—	—
	Perforated ferrous casing	88	18	46	72.7	10	42	8	3	—	—	1
	Porous-concrete screen	83	4	31	42.2	28	—	6	—	1	—	—
	Perforated-concrete pipe	36	7	4	30.6	1	8	—	2	—	—	—
Dug	Masonry wall, open bottom	101	14	51	64.4	4	45	—	12	3	1	—
Driven points	Screened sand points	192	—	131	68.2	64	—	67	—	—	—	—
Infiltration galleries	Lateral tile and collection wells	12	3	1	33.3	—	4	—	—	—	—	—
Springs	Collection wells	17	—	17	100.0	—	1	—	16	—	—	—
Mine shafts	Timber	10	3	7	100.0	—	5	—	3		—	—
TOTAL		1,709	206	840	61.2	364	395	117	114	27	23	6
Limestone												
Mississippian	Ferrous casing to rock	23	—	9	39.1	—	6	1	1	1	—	—
	Springs piped from caves	5	—	1	—	—	1	—	—	—	—	—
Devonian	Ferrous casing to rock	14	1	2	21.4	1	1	—	1	—	—	—
Silurian	Ferrous metal casing to rock	199	8	54	30.7	1	49	4	—		7	—
	Springs piped from caves	3	—	—	—	—	—	—	—	—	—	—
Ordovician	Ferrous casing to rock	22	1	4	26.1	—	1	—	2		1	—
	Springs piped from caves	1	—	1	—	—	1	—	—	—	—	—
TOTAL		267	10	71	30.3	2	59	5	4	3	8	0
Sandstone												
Pennsylvanian	Ferrous casing and liner	83	28	21	59.0	1	48	—	—	—	—	—
Mississippian	Ferrous casing and liner	42	30	3	78.6	—	31	—	2	—	—	—
Ordovician	Ferrous casing and liner	234	14	84	35.8	1	66	5	21	5	—	—
Cambrian												
Galesville	Ferrous casing and liner	127	27	24	40.9	1	43	1	5	1	—	—
Mt. Simon	Ferrous casing and liner	142	30	23	35.9	—	38	1	12	2	—	—
TOTAL		628	129	155	45.2	3	226	7	40	8	—	—
TOTAL (ALL GROUPS)		2,604	345	1.066	54.2	369	680	129	158	38	31	0

* Abandoned wells constitute all wells in abandoned public ground water supply systems.

† Retired wells are wells retired from existing public ground water supply systems.

‡ Key to detail of reasons for abandonment or retirement:

A—Sand filling; clogged screens, blocked formation.
B—Inadequate supply; declining capacity; recession; depletion; influence of other wells.
C—Corrosion, disintegration, or defects of screens or casings.
D—Objectionable quality and contamination.
E—Cave-in; lost tools and pump parts; construction difficulties.
F—Site location; uneconomical operation; decreased demand.
G—Unknown causes.

Types of Pumps

Some idea of the demands placed on wells may be obtained by studying the method used for removing water from them. Data on the pumps and methods used for taking water from 2,402 wells, by type of pump and year of installa-

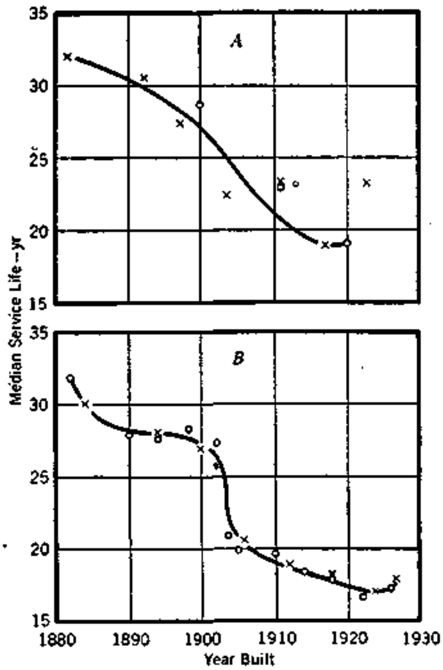

Fig. 10. Moving Trend in Service Life of Wells

Part A *shows the curve for service lives of all wells built in Illinois; and Part* B, *of unconsolidated wells built in the state. Circles indicate moving 8-yr medians; and* "X's" *moving 12-yr medians.*

tion, are summarized in Table 4, and shown graphically in Fig. 11, using 8-yr moving averages.

The number of free-flow wells consistently declined. Suction-lift pumps, drawing either from single wells or from groups of wells, were commonly used in the 1890's and were of some prominence around 1920, but they appear to be less generally used today. Air-lift equipment, often found between 1895 and 1925, is now apparently rare. Plunger pumps, widely employed in the 1890's, declined in acceptance in the early 1900's but regained wide popularity upon the development of the double-acting plunger pump. This equipment continued to gain favor until the middle 1920's, when it began to decline rapidly. Probably the greatest single factor causing the decline in use of all these methods was the development of the high-capacity, vertical-

TABLE 4

Water-Removal Methods

Method	No. of Wells
Turbines	1,065
Plungers	582
Air lifts	276
Suction lifts	332
Free flow	129
Jet pumps	18
TOTAL	2,402

turbine pump. A few of these pumps were installed before 1910, but they were not widely used until 1920. Since then, they have been a major factor in making possible the increase in production rates of wells.

In Illinois, the tendency toward greater production rates for each well has been offset by the increased understanding of ground water development during the past 15 yr. This understanding is leading to more conservative design and to attempts to forestall early well retirements by installation of wells pumping at moderate rates. The recent increased use of jet pumps, which are useful in smaller communities and are generally of smaller capacity than vertical-shaft turbine pumps, illustrates this tendency. Conservative well exploitation by state agencies and engineers has led to the reintroduction of some plunger pumps for small wells. Also, submersible motor-driven pumps have attained considerable use in recent years. These developments, however, have been too recent to show their effect in Fig. 11.

Summary and Conclusions

In Illinois, the number of public ground water systems and the quantity of water provided from ground water sources have expanded rapidly, but, since 1915, the number of wells in active service has decreased. An analysis of production estimates indicates that wells are being exploited more intensively than they were in 1910.

More than half of all retirements

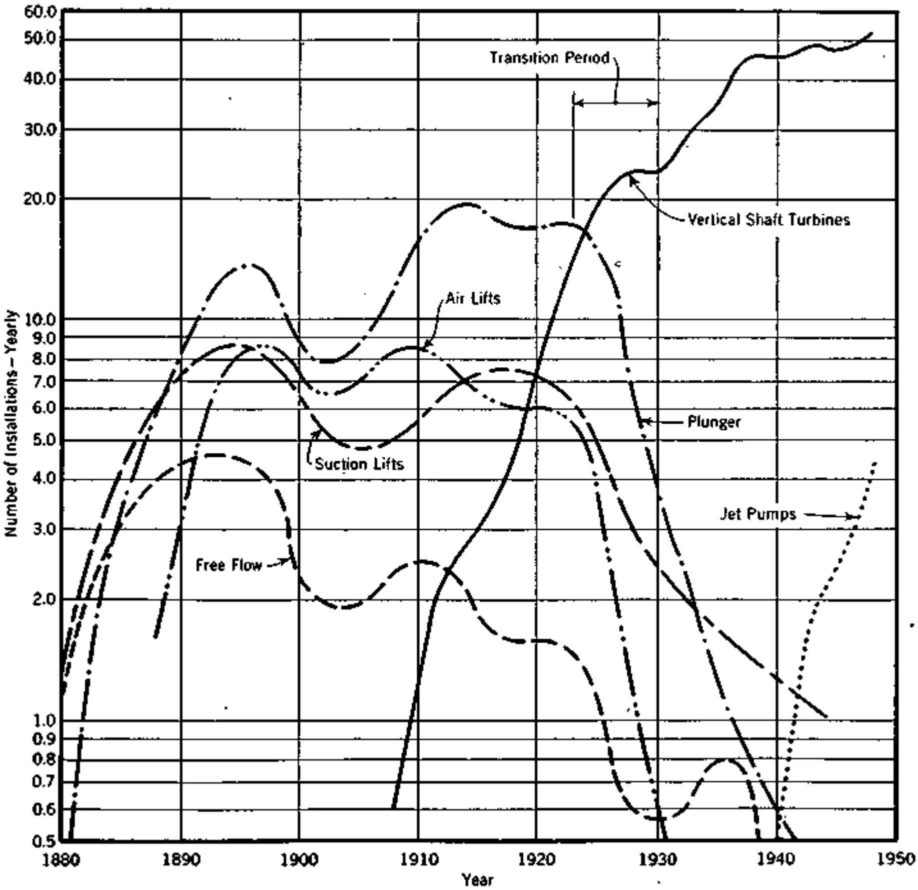

Fig. 11. Methods of Removing Water From Illinois Wells

Moving 8-yr averages used in computing graph. It should be noted that plunger type pumps during the 1890's were predominantly single-action and from 1910 to 1920 were predominantly double-action.

were found to be attributable to formation problems, such as interference, recession, overproduction. Less than half were due to failure of the wells. Although the data do not give a clear picture of trends since 1925, analysis of the data reveals a marked decline in the service lives of wells. Either development in construction procedures during the first decade of the Twentieth Century or changes in well use during the third decade are apparently responsible for the decline in service life. No significant change in construction practice is known to have been widespread, but the vertical-shaft turbine pump came into wide use during the 1920's, replacing previous lower-capacity equipment. The decline in service lives of wells is attributed to their increasingly intensive exploitation.

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2. *Survival and Retirement Experience With Water Works Facilities.* Am. Water Works Assn., New York (1947).

Discussion

William A. McEllhiney

President, J. P. Miller Artesian Well Co., Brookfield, Ill.

It is a far-sighted policy that the state of Illinois has followed in setting up its various agencies dealing with wells, well water supplies, and related geology. Far-sighted, too, has been the policy of keeping these agencies completely state-controlled and operated, with no dependency on federal money or departments.

The State Water Survey has done an outstanding job of maintaining statistics through the years, making available a precise record of the constantly changing status of well water supplies. Only because such data have been collected, tabulated, correlated, and published is a study such as that presented above possible.

Another agency, the State Geological Survey, maintains complete records of well logs, and has interpreted the information in terms of its bearing on the problems of fresh water supplies. Much factual data has been recorded, and the survey is continuously improving its understanding of underground strata and their bearing on water production.

The two surveys, with their competent personnel, have been the good friends of well contractors in Illinois. No responsible driller would fail to file logs, furnish samples, or provide test data, despite the fact that there is no effective law of the state which requires such action.

The study published here is a signal contribution to the subject of well mortality and is so well authenticated that no disagreement with the data presented is possible. Some comments concerning deep wells in consolidated bedrock formations, including a historical review of some of the changes in well practice since 1868, may be of value.

Water Levels

Eliminating from consideration wells in Mississippian and Devonian limestone, as well as in Pennsylvanian and Mississippian sandstone, the writer may note that he has found very little "change in the static water levels of first-bedrock aquifers. This source has always seemed able to sustain production with very little change. Artificial modification, such as overproduction and allowance of interflow near single top-aquifer wells, alters conditions. For units near single top-aquifer wells, declining capacity is hardly a reason for abandonment. Many such wells need only careful and intelligent engineering attention to give further useful service.

Because first- or top-bedrock wells usually could not provide adequate supplies for increasing needs, deeper drilling was necessary to tap additional aquifers. This step precipitated many well problems which led eventually to premature retirement. Before 1900, the deeper Ordivician and Cambrian sandstone wells were drilled to take advantage of their strong natural flows. Contractors were very careful to tube the finished well properly for flow. In other words, they installed a string of pipe with a packer on the bottom from the ground surface to the impervious strata below the top aquifer. If this practice were not followed, the top bedrock would steal the water, and natural flow would not result. Well owners, water works superintendents, and engineers were thus alerted to the defect and no time was lost in making repairs to restore flow.

The static levels of deep sandstone formations, have, on the other hand, dropped gradually. In northern Illinois, and particularly in the metropolitan Chicago area, the water levels had, by 1910, receded below the static water level of the top-bedrock source. For several decades before and after 1910, deep sandstone wells were constructed with a minimum of casings. Liners were generally installed only opposite formations that were likely to cave in. This practice, together with the continuous lowering of the sandstone water table, directed the interflow downward from the top formation —usually limestone—into the deep sandstone sources—an unfortunate condition which deteriorates progressively until it corrects itself naturally. In such wells, the upper water is usually quite highly mineralized, but, in flowing down the well bore—often in cascades—is aerated, thus becoming unstable. By this means the water loses some of its mineral compounds, which filter through the exposed sandstone surfaces of the bore. This action will, in time, seal the sandstone so effectively that it will neither take nor deliver water, thereby causing the retirement of another well or, even more serious, the search for another source of supply.

As soon as interflow ceased to give visible evidence of defect, many people dealing with the well water supply problems became complacent. Maintenance was neglected, and more wells of the same type were constructed. Not until 1930 were specifications changed to reflect an intelligent understanding of these fundamental problems. And only since then has consideration been given to the confinement of aquifers, effective well plugging, and the development of single-aquifer wells.

Reasons for Retirement

The authors were historically correct in explaining the reason for well retirement, but additional reasons, equally real and relevant, are:

1. Wells are retired because of the lack of overall planning and study of the water supply sources—that is, deep wells are drilled where glacial-drift wells should have been drilled, and limestone wells with complete treatment are constructed instead of wells in deep sandstone. The availability of softer, deep-well water may cause the

retirement of sources that produce harder water.

2. Wells are retired long before they have fulfilled their life expectancy because of improper maintenance or too little engineering thought to the factors involved. The geology of the given situation is regarded as just so many facts that are not applied to the hydraulics and the hydrology of maintenance problem. Makeshift repairs, or attempts at repairs, which offer little relief are made. Cement and sand have been poured around a well liner, and the owner or engineer has been satisfied that a proper cementing job was performed. The same owner or engineer, however, would, rightfully, not allow the footing for an elevated tank to be poured into a pit that was full of water. Attempts to repair wells have failed because the differences in pressure between formations were not taken into account. In the Joliet area, for instance, a differential pressure of almost 400 ft has been found between the Mt. Simon and Galesville sections of the Cambrian sandstones.

3. Good wells are retired because of political expediency. In some localities, inadequacy of the water supply systems is blamed on the failure of wells, the lowering of water tables, the caving in of formations, the need for development. Public opinion is thereby guided, for political purposes, toward discontinuing the use of wells.

Conclusions

Today, many kinds of specialists are devoting time and thought to well retirement problems, and their studies will definitely alter retirement practices. Undoubtedly, when the figures in the preceding paper are plotted beyond 1948, favorable changes may be expected in some of the curve gradients.

Instruments for obtaining information on the behavior of wells have been and are being developed and used to advantage. Various geophysical instruments have disclosed much information. Special flowmeters for interflow investigations, temperature-caliper studies, and numerous other specialists' tools have been most helpful.

Employment of better techniques by contractors, new drilling methods, new procedures in well development by "shooting", and new procedures for cementing of casings and liners have all been adopted as a result of knowledge gained from the experience of the oil industry. Chemical treatment of wells, acidizing, and application of polyphosphates for the removal of objectionable constituents are in early stages of development.

However much progress has been made to date, though, there is no question but that much improvement is still possible in planning, construction, and maintenance of wells to provide longer periods of trouble-free performance.