Ground-Water Resources of the Hopkinsville Quadrangle, Kentucky

By EUGENE H. WALKER

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GROUND-WATER RESOURCES OF THE HOPKINSVILLE QUADRANGLE, KENTUCKY

By Eugene H. Walker

ABSTRACT

This report is one of a series designed to furnish useful information to the present and prospective users of the ground water in Kentucky. It was prepared in cooperation with the Agricultural and Industrial Development Board of Kentucky.

The Hopkinsville quadrangle lies in south-central Kentucky near the boundary with Tennessee. This portion of Kentucky is a rolling plain developed on thick limestones. Sinkholes are abundant and over most of the area drainage is by underground streams. Precipitation averages about 49 inches per year, temperature about 58°F, and the growing season generally lasts more than 6 months. This is rich farming country; a very high percentage of the acreage is used for crops and pasture, and woods occur only as scattered clumps.

Sedimentary strata of Mississippian age underlie the entire quadrangle and incline gently northward. The St. Louis limestone of early Mississippian age, about 300 feet thick, is the oldest formation reached by water wells. It lies at a depth of about 150 feet in the southern part of the quadrangle. Upon it lies the Ste. Genevieve limestone, about 200 feet thick, also of early Mississippian age. The overlying Renault formation of late Mississippian age is a limestone about 70 feet thick. All three of these limestones resemble each other closely and can hardly be distinguished except by the use of characteristic fossils. The youngest formation is the Bethel sandstone of late Mississippian age, which crops out along the north edge of the quadrangle. This fine-grained sandstone is about 20 feet thick and forms a low plateau because it resists erosion more than the limestones do. A thick blanket of red and yellow residual soil covers all the area underlain by limestone.

Ground water is obtained almost wholly from wells drilled into the limestones. The Bethel sandstone yields very little water to wells. Drillers set casing firmly in the bedrock at the base of the soil, and then proceed with an open hole until they strike a water-bearing crevice. Few wells are more than 100 feet deep. About four out of five wells obtain supplies adequate for home and farm needs. Recorded yields average about 9 gallons per minute (gpm), and range from mere trickles to 40 gpm. Still larger yields may be derived from a few wells in the lowlands that tap crevices connected with underground or surface drainage channels.

Most dug wells do not penetrate bedrock more than a few feet and derive very small yields from the thick surface clays.

Many springs occur in the quadrangle, but most of them flow only during the seasons of high ground-water level. The springs of most reliable flow are found in the bottom lands, close to the Little River.

A small amount of data indicates a daily usage of about 57 gallons per person in the rural part of the quadrangle. This is not all the water used, for cisterns and ponds are fairly important sources.

Ground water occurs in a system of crevices developed along joints and bedding planes in the limestone. Very few openings large enough to be called caves are known in the quadrangle. Most of the crevices seen in quarry faces and reported in wells are only a few inches wide. Statistics show that below about 80 feet of depth the frequency of crevices declines rapidly.

Normally the ground water exists under water-table conditions. However, during the winter season of high water levels, in the lower parts of the area water may occur under artesian pressure beneath the thick blanket of residual clay.

Measurements over a period of 3 years show water levels to be highest in winter and early spring, to decline sharply in late spring, and then to decline more slowly through summer to a yearly low in early autumn. Recharge occurs principally in the seasons when vegetation is not growing. In the nongrowing season the soil becomes saturated and permits excess water to pass downward. In the growing season a soil-moisture deficit exists and the vegetation discharges most of the precipitation.

The relations between ground-water discharge and decline of water levels during dry periods indicate a storage coefficient in bedrock of about 0.005, which is equal to about 0.5 percent of the volume of the rock. This signifies that the addition of 1 inch of water raises water levels an average of about 17 feet. Close to the surface the storage coefficient probably is larger, and it certainly decreases at depth.

Discharge of ground water is mainly into streams through springs and seeps. The amount of water pumped from wells is insignificant compared to the amount naturally discharged. It is thought that the discharge of ground water by evaporation and transpiration is very small because during the warm growing season water levels over most of the area are well below the reach of plant roots.

Precipitation and stream-gage records show that on the average 29 inches of water is evaporated and transpired per year and 20 inches is discharged by streams. Most of the water discharged by evapotranspiration never was ground water in bedrock crevices, but was stored temporarily as soil moisture before being transpired by plants.

The waters are mainly of the calcium-magnesium bicarbonate class. Hardness averages 230 parts per million (ppm) and ranges from 30 to 790 ppm. Most of the waters are to be classed as hard or very hard. Iron content averages 0.4 ppm. With increasing depth the water becomes more mineralized. About half the crevices encountered at a depth of 150 feet yield water of poor to unusable quality.

Contamination from barnyard and domestic sewage is widespread and about 12 percent of the wells sampled show nitrate in excess of that considered safe for infants. Close to half of the wells sampled in the 5-year period, 1948–52, by the Kentucky State Department of Health show contamination by the colon type of bacteria.

INTRODUCTION

This report describes the occurrence and quality of the ground water in the 7½-minute Hopkinsville quadrangle, Christian County, Ky. (See index map, fig. 1.) The quadrangle covers about 58 square miles in the central part of the county and includes in its northwest corner most of Hopkinsville, the county seat. The report is one of a series resulting from field studies in Kentucky by the U. S. Geological Survey; other localities in the State where reports on the occurrence of ground water have been published or where work is

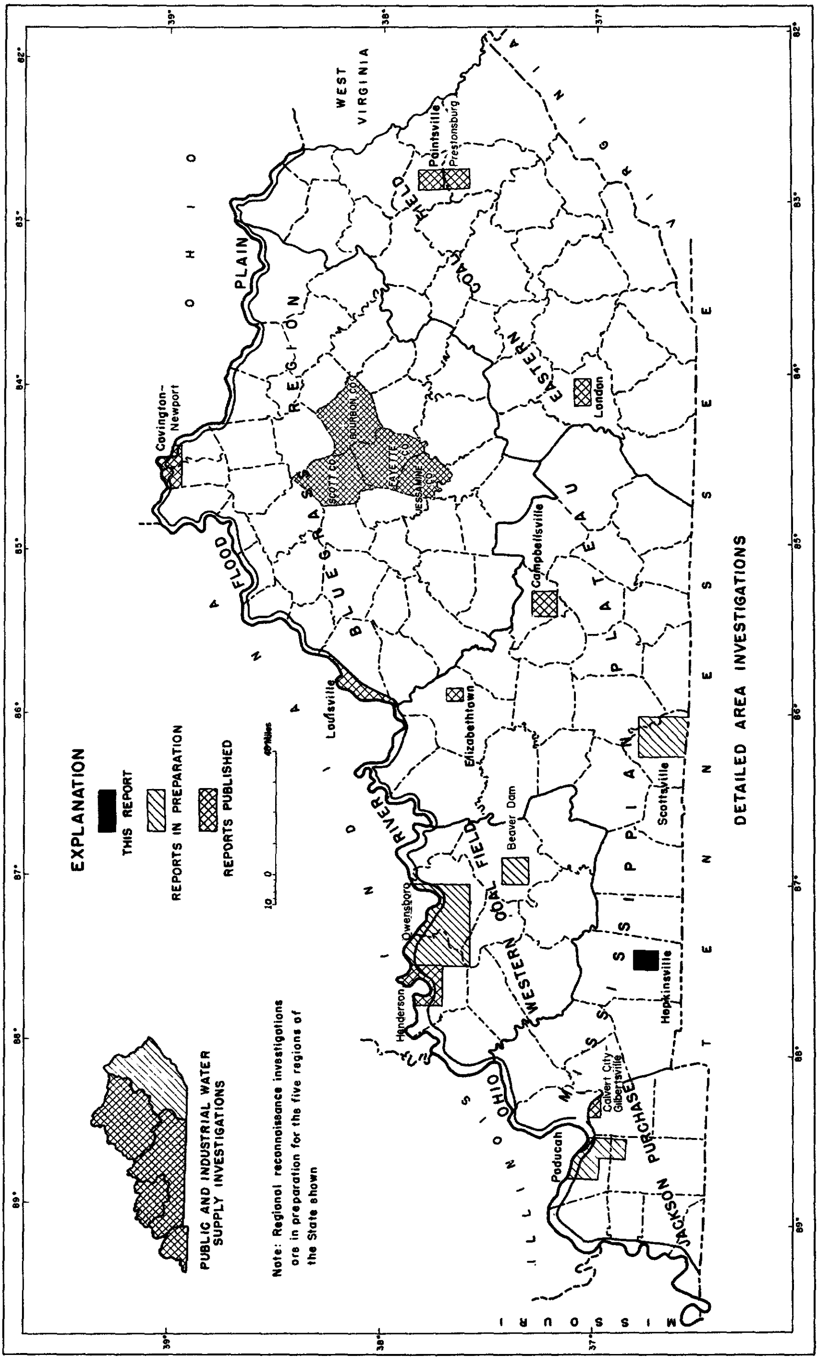

Figure 1. —Index map of Kentucky showing progress of ground-water investigations.

in progress appear on the index map. The program is cooperative between the Agricultural and Industrial Development Board of Kentucky and the U. S. Geological Survey.

These reports are designed to provide information on the occurrence, quantity, and quality of ground water available throughout the State, and to serve individuals or companies using or intending to use this important natural resource. The Hopkinsville area was chosen for close study because it is typical of much of the surrounding region; the information gained locally is in general applicable to the surrounding region.

Fieldwork beginning in October 1949 consisted of an inventory of all wells and springs in the quadrangle, taking samples of water to be analyzed chemically, making periodic measurements of water levels in selected wells, and geologic study of the water-bearing formations.

Ground-water investigations are under the general supervision of A. N. Sayre, chief, Ground Water Branch, and locally under M. I. Rorabaugh, district engineer in Kentucky. J. H. Kietzman, inventoried most of the wells and springs, took many of the samples for chemical analysis, and began the water-level measurements. P. U. Martin continued the water-level measurements. W. B. Hopkins also measured water levels and collected much of the information on usage of ground water.

The laboratory of the U. S. Geological Survey at Columbus, Ohio, under W. L. Lamar, district chemist, made the chemical analyses and was consulted on the preparation of the section on quality of water.

The Surface Water Branch of the Geological Survey, F. F. Schrader, district engineer for Kentucky, furnished the discharge record of the South Fork Little River at Hopkinsville.

Acknowledgment is made to all the individuals who gave information on their wells and springs, and especially to those who permitted repeated access to their properties for water-level measurements.

Mr. Harry Settle, of the Kentucky Geological Survey, provided much information on the characteristics and boundaries of the local geologic formations. The boundaries on plate 1 are taken from the map of this quadrangle by Mr. Settle (1952).

Mr. F. C. Dugan, Director of the Division of Engineering, Kentucky State Department of Health, furnished data on the sanitary

analyses of ground water in Christian County, made in the years 1948–53.

Wells and springs are numbered in the system used through Kentucky by the Ground Water Branch. The State is divided into rectangles, each measuring 5 minutes of longitude east-west and 5 minutes of latitude north-south, and each rectangle takes its number from the longitude and latitude at its southeast corner. The well 8725-3645-1 is the first well to have been inventoried and numbered in the rectangle bounded on the east by longitude 87°25' and on the south by latitude 36°45'. Springs are numbered with the wells, but for convenience they are listed in a separate table.

No previous studies of ground water have been made in this area. A. M. Piper (1932) described the occurrence of ground water in the neighboring parts of Tennessee to the south, where the water-bearing formations are much the same as in the Hopkinsville quadrangle. E. G. Otton[1] briefly described the occurrence of ground water at Elizabethtown, Ky., where somewhat similar geologic conditions exist.

The bedrock geology of the Hopkinsville quadrangle has recently been presented on a preliminary map by the Kentucky Geological Survey (Settle, 1952). Stuart Weller (1923), J. M. Weller (1927), and A. H. Sutton (1929) have described parts of the surrounding region in several papers named in the list of references. The Geology of Kentucky, by A. C. McFarlan (1943) presents an excellent survey of this as well as the other regions of the State.

GEOGRAPHY

The Hopkinsville quadrangle consists mostly of a rolling lowland, which is bordered on the north by steeper slopes that rise about a hundred feet to a smooth upland (pl. 1). The lowland, known to geographers as the Pennyroyal Plain, follows a belt of pure limestones that runs east-west across this part of the State. The Bethel sandstone, though thin, resists erosion more strongly than the limestones of the plain and upholds a plateau whose southern margin is a south-facing slope called the Dripping Springs escarpment.

The broad valleys and gentle slopes of the Pennyroyal Plain lie mostly between 500 and 600 feet above sea level. The highest point in the quadrangle, however, at elevation 727 feet, is a hill that stands isolated on this plain, capped by an outlying remnant of the Bethel sandstone. As shown on plate 1, many shallow depressions

[1] Otton, E. G., 1948, Ground-water resources of the Elizabethtown area, Kentucky: Ky. Dept. Mines and Minerals, Geol. Div., 27 p. [Duplicated rept.]

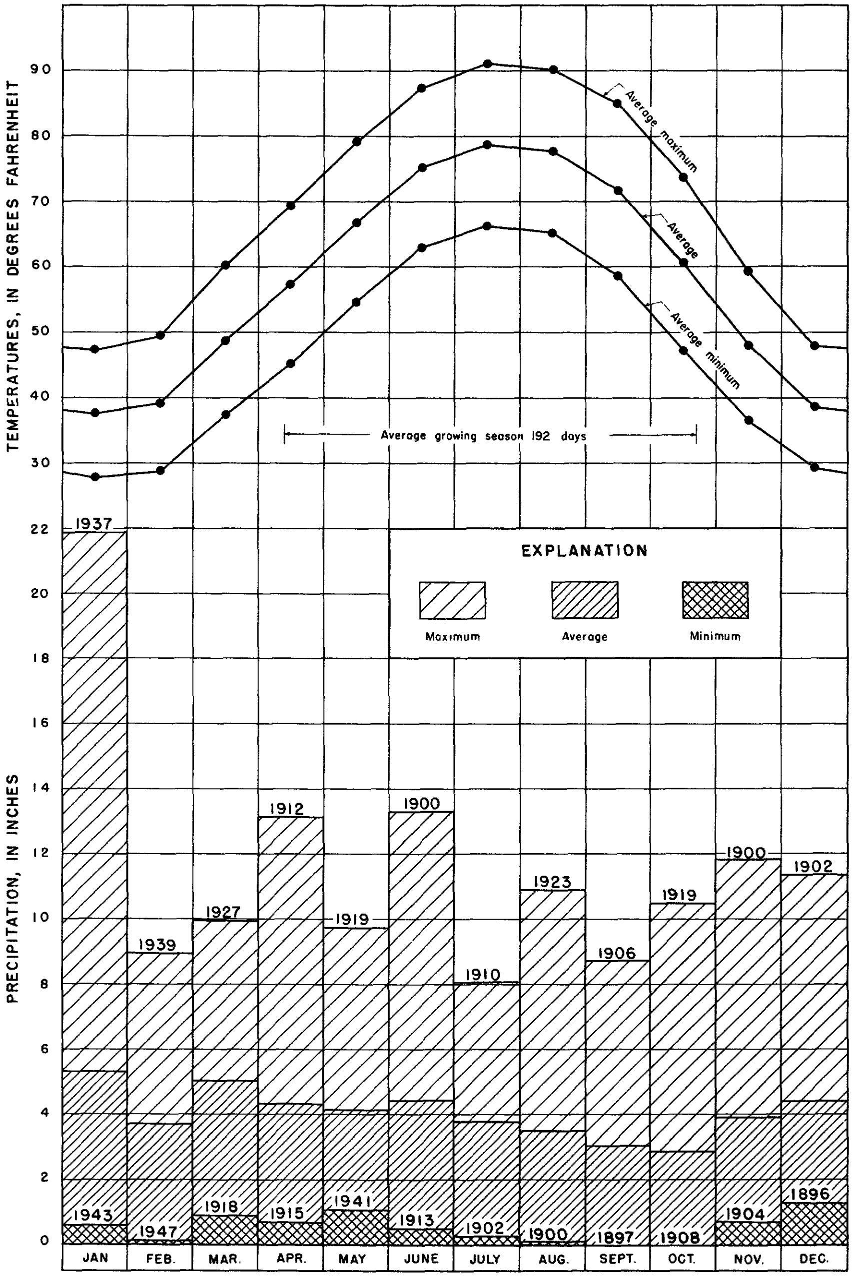

Figure 2.—Graph showing monthly temperatures and precipitation at Hopkinsville, Ky.

or sinks—some dry, some filled with water—lie scattered on the plain. These are the usual features of a limestone belt where the surface of the land is slowly being lowered by solution of rock and downslumping of the soil. Most of this lowland is crop or pasture land, with only scattered patches of woods.

The upland has a general elevation of about 650 feet. Except along the escarpment the slopes are gentle and most of the land is cleared, although the soils are thinner and sandier than those of the lowland.

The South Fork Little River, referred to hereafter as the South Fork, crosses the quadrangle from east to west and then turns southward; except for the short stretch of the North Fork Little River which flows through Hopkinsville the South Fork is the only stream in the quadrangle that flows all year round. As in other limestone areas, there are few tributaries and most of them are dry except after heavy rains or during the winter. Much of the drainage from average rains finds its way down sinkholes into the system of underground channels and reappears as springs near or in the bed of the South Fork.

The climate (see fig. 2) is warm to temperate. Average monthly temperature ranges from 37.6° F in January to 78.8°F in July. The daily maximum and minimum temperatures, averaged by months, run about 10 degrees above and below the general average. The summers are hot, the winters mild with many warm days and the infrequent snows never persist on the ground for more than a few days. The frost-free growing season usually extends from about the middle of April to near the end of October, more than 6 months.

The precipitation 1897–1952 inclusive (fig. 3) averages 48.6 inches. There is generally more precipitation in the winter than in the summer and fall months (fig. 2); the average for January is more than 5 inches, for October about 3 inches. The variations from average in any month and in any year may be considerable, because much of the rainfall comes from the air masses that move northeast from the Gulf of Mexico, at unpredictable intervals. Heavy rains are not rare; in 4 of the 12 months of the year rains of more than 5 inches in 24 hours have been recorded. Rains of somewhat lesser intensity may cause violent floods in the small stream basins. The rainfall of 21.86 inches in January 1937 came in the prolonged storms over the Ohio River basin that caused the disastrous flood of that year on the Ohio River.

The precipitation from 1897 through 1952 (fig. 3) has ranged from 32 inches in 1930 to 74 inches in 1923. The cumulative-departure graph is a method of showing the periods of years that

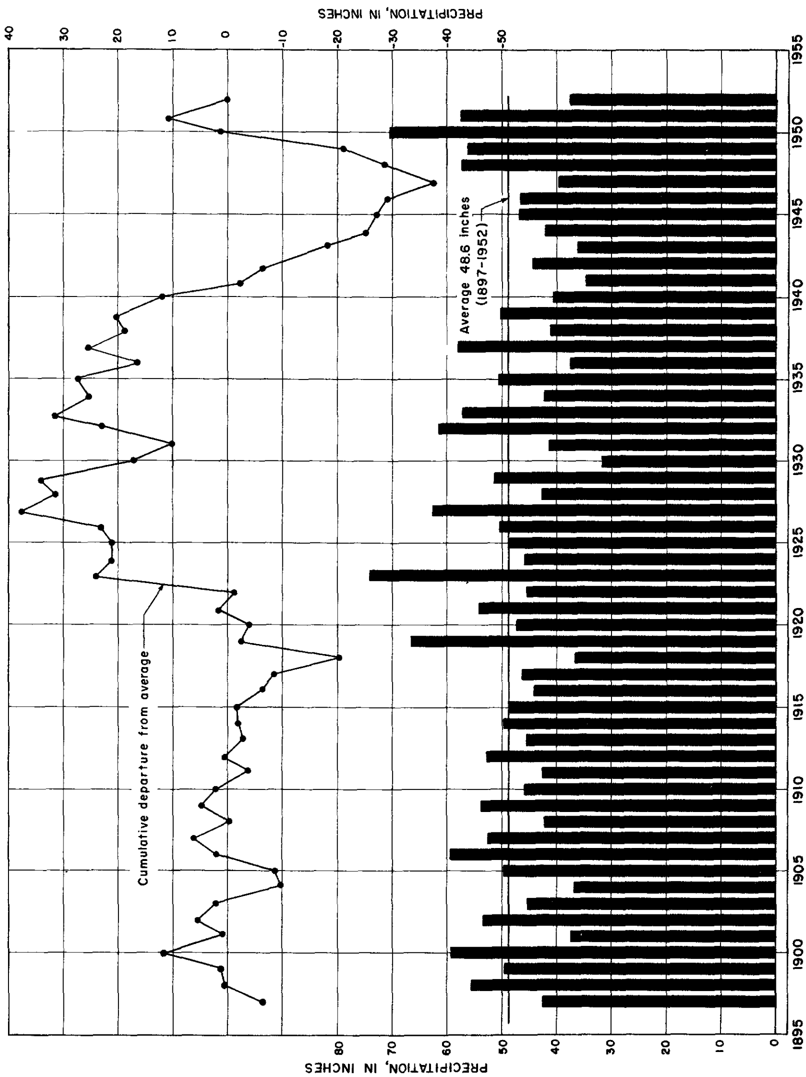

Figure 3. —Graphs showing precipitation and cumulative departure from the average at Hopkinsville, Ky., 1897-1952.

are wetter or drier than the long-time average. A rise in the curve indicates wetter-than-average conditions; a decline indicates conditions drier than average. For example, in 1922 the curve lies 1 inch of rainfall below the zero line; this indicates that the sum of all the precipitation 1897–1922 was 1 inch less than if those years had averaged 48.6 inches. The wet years ending in 1927 brought the total precipitation 1897–1927 to 37 inches more than if those years had averaged 48.6 inches.

The curve shows that precipitation was more than average from 1918 to 1927, below average from 1937 to 1947, and above average from 1947 through 1951. The ground-water levels reflect such groups of wet and dry years, as will be shown later.

The cumulative-departure curve does not offer any evidence that over the whole length of record the climate is getting progressively drier or wetter.

Over most of the area red clay soil lies thick upon the bedrock limestone from which it was derived. All the limestones contain small amounts of silt and clay, and a few chunks of flint or chert, which are relatively insoluble and remain behind while the percolating ground water slowly dissolves and carries away the calcareous portion of the rock. This residual soil is usually several feet thick and in many places more than 30 feet thick. At depth the clay is dense and stiff, stained red or yellow with iron oxide, and strewn with angular fragments of chert. Ground water has leached practically all the calcium carbonate from the clays so that they have an acid reaction, and for good development of many crops crushed limestone needs to be added to the soil.

The red or yellow clay soil exposed in the average field is the subsoil and not the original topsoil, as is true in many other parts of this country that have been tilled for more than a century. The original topsoil, to be seen in a few places long protected from farming, such as cemeteries or road rights of way, is a brown loam, in some places a foot thick, free of chert and particles larger than silt. This topsoil undoubtedly originated as loess wind blown from the Ohio Valley during the waning stages of the last glaciation.

The name "Barrens" lies across this region of Kentucky on many early maps, because the first travelers found on the uplands a prairie of tall grass with only a few clumps of woods, though the bottom lands were thickly wooded. After settlement the forest began to spread over the grasslands, showing that something other than soil and climate had favored the prairie grasses. Sauer (1927, p. 128–129) gives an interesting review of the early accounts of the region by travelers and settlers. Their theory, a reasonable one, was that the Indians, by burning the grasslands yearly, had reduced an original forest to remnants, and that when such burning stopped after settlement, the forest began to spread. Therefore, the woods which at present cover less than a fifth of the area are not second- and third-growth remnants of a primeval forest but a development of the last 150 years. The forest natural to the region is the oak-hickory type which includes many other hardwood species, walnut especially, on these deep soils. Growth is constantly harvested and only about a fifth of the trees are of sawlog size (Forest Survey Organization, 1950).

Settlement dates from the late 1700's and in 1796 Christian County was detached from Logan County. Hopkinsville was established as the county seat in 1804 near a large spring that emptied into the North Fork Little River at the foot of the Dripping Springs escarpment. At the time of the first town census in 1860, the population was 2,289. It increased to 9,419 in 1910; since then growth has been somewhat slower and the figure was 12,526 in 1950. According to the United States Census of 1950 the rural population of Christian County was 29,833, about 70 percent of the total for the county. Total density per square mile was about 58, rural density about 41.

Since its founding Hopkinsville has been a center for trade in farm products, located as it is in the richest farmland in Kentucky west of the Blue Grass around Lexington. In early days farm products for export, notably tobacco, went by cart westward to Canton on the Cumberland River in Trigg County. There were rail connections before the Civil War, and now the Illinois Central, the Louisville & Nashville, and the Tennessee Railroads lead north, south, east, and west. Nine surfaced highways converge on Hopkinsville. No part of the quadrangle is more than a mile from the county or farm roads, many of which are surfaced with crushed stone.

The wealth of Christian County is based on farming and stock-raising on the excellent soils. The first settlers naturally relied on subsistence farming, but it soon became apparent that the area was exceptionally fitted for raising tobacco. According to Sauer (1927, p. 196) production in 1840 was about 3.4 million pounds; in 1920, 24.8 and in that year the Hopkinsville warehouses handled 35 million pounds of dark tobacco, three-quarters of the total production of dark tobacco in the State. There is now less emphasis on tobacco; in 1950 production in Christian County was about 8.7 million pounds.

According to the 1950 Census of Agriculture, close to 30 percent of the area is harvested cropland. In terms of acres planted the principal crops are corn, small grains, and then tobacco, burley dominating over the dark type favored in the past. The principal stock animals are cattle, hogs, and sheep. During the last few years there has been a marked trend toward more livestock raising so that much land formerly tilled has been converted to improved pasture.

The average farm in the county is about 140 acres but the range in size is great. Many of the farms are much larger and were originally of the plantation type, centering on imposing mansions surrounded by smaller buildings.

Agricultural development will no doubt bring more stockraising and more intensive cultivation of vegetables, fruits, and berries and specialty crops, which will cause more demand for water for sprinkling and irrigation. At present only about 2 acres in the county are reported as irrigated, though a good deal of water is intermittently used on vegetable gardens.

As mentioned earlier, the woodland is new growth upon land that was fairly open prairie 150 years ago. Probably timber is being cut faster than it grows at present and cannot furnish a basis for a growing industry.

No metallic minerals or coal occur in this area, and the few tests drilled so far have failed to find oil or gas. However, the discovery of the Hermon pool in April 1950, just 20 miles southeast of Hopkinsville in Todd County (Settle, 1951), indicates that oil possibilities exist in Christian County.

Limestone is quarried at several localities along the steep slopes below the Bethel sandstone in the northern part of the area. Certain zones in the limestones are exceptionally pure (Stokley and McFarlan, 1952) and have promise for further development. The quarries now produce mainly crushed stone for road construction, concrete building blocks, and agricultural purposes. The clays resulting from decay of the limestones are used in a small way for brickmaking.

The Kentucky Industrial Directory, 1951–52, lists about 1,350 people as employed in industries in Hopkinsville. Food processing accounts for 310, clothing and leather manufacture for 727, lumber milling for about 150, the stone and clay industries for about 120, and miscellaneous occupations for the rest. The largest single plant, the International Shoe Co., employs 330 persons. During the winter months there is employment for about 450 people in the tobacco warehouses. Further information on the industrial development in Hopkinsville may be found in the publication on the

Economic and Industrial Survey of Hopkinsville, Ky., prepared in 1951 by the Chamber of Commerce of Hopkinsville and the Agricultural and Industrial Development Board of Kentucky.

GEOLOGY

GEOLOGIC HISTORY AND STRUCTURE

The sedimentary formations at the surface here and those known to exist at depth are the record of long-continued deposition in ancient seas, interrupted only occasionally by emergence of the sea floor and erosion. Formations older than the St. Louis limestone of early Mississippian age lie no closer to the surface than several hundred feet. They probably are several thousand feet thick and consist mainly of limestone with some shale and small thicknesses of sandstone. Settle (1951) gives details on the formations penetrated by an oil test 2, 241 feet deep in the small Hermon pool about 20 miles southeast of Hopkinsville, in Todd County.

The water in the formations below the St. Louis limestone in this quadrangle is saline and often sulfurous, and unusable for ordinary purposes. These lower formations and the water in them will not be dealt with further in this report.

Formations of Mississippian age from the St. Louis limestone upward yield water in the Hopkinsville quadrangle. Table 1 is a summary of these formations and their water-bearing characteristics; plate 1 shows their general distribution and attitude locally. The St. Louis limestone, the Ste. Genevieve limestone, and the Renault formation are almost wholly limestone with few and thin beds of shale. They resemble each other so closely that only after some experience in the field can a person distinguish one from another, and then mainly by finding characteristic fossils. All three formations record shallow and probably warm seas in which innumerable organisms built shells of calcium carbonate and left them to accumulate on the sea floor. Perhaps the area was far from land, for beds of shale testifying to muddy currents are few and thin. The only break in this orderly sequence occurs between the Ste. Genevieve limestone and the Renault formation, where a bed of limestone pebbles indicates some uplift of the sea floor and erosion by waves or currents.

These quiet conditions ended when invigorated currents swept the sands of the Bethel sandstone into the area. Deposition of sediments took place for a long time after this, continuing through the Pennsylvanian, a period of coal formation. The Pennsylvanian formations remain farther to the north but have been eroded away

Table 1.—*Water-bearing formations of the Hopkinsville area, Kentucky*

System	Series and group	Formation	Thickness	Description	Water-bearing characteristics
Quaternary	Recent and Pleistocene	Soil and clay	0-40	Red to yellow residual clay with fragments of chert. Originally covered by about 1 ft of brown loess loam.	Low permeability; yield to dug wells only a fraction of a gallon per minute.
Mississippian	Chester group	Bethel sandstone	35-40	Sandstone, fine-grained, thick- to thin-bedded.	Low permeability; wells yield less than a gallon per minute.
		Renault formation	95-100	Limestone, oolitic and fragmental, occasionally fine grained; thick-bedded and fairly pure. Thin shale partings between beds. Scattered chert zones.	Yields from crevices range from little or nothing to more than 40 gpm; typical yield in short tests is near 8 gpm. Water is hard to very hard.
	Meramec group	Ste. Genevieve limestone	220-260		
		St. Louis limestone	350	Limestone, gray and crystalline; thick bedded with thin shale partings. Some beds are dolomitic. Chert is common.	

in this area. Finally, at some undetermined date, this whole section of the continent rose, and erosion set to work to make the present landscape.

During the regional uplift the formations became somewhat warped, so that in this quadrangle they incline gently northward. In general they descend in that direction (pl. 1) about 14 feet per mile, though Settle (1951) shows minor deviations from this overall trend. The structure is revealed in the main feature of the landscape, the Dripping Springs escarpment, here supported by the erosion-resistant Bethel sandstone. Farther to the south, where the sandstone was higher, all of it but a few remnants (pl. 1) were eroded away long ago.

DESCRIPTION OF FORMATIONS

ST. LOUIS LIMESTONE

The St. Louis limestone of early Mississippian age occurs in the States of the Ohio and Mississippi Valleys, and in Kentucky it crops out as a broad belt surrounding the Western Coal Field. The formation does not appear at the surface in the Hopkinsville quadrangle but is exposed a short distance to the south. The cross section, plate 1, shows that it lies at a depth of about 150 feet at the southern boundary of the quadrangle. The thickness of the formation in Kentucky ranges from 250 to 500 feet according to Weller (1927 p. 93–94); here it is probably close to the 300 feet that Settle (1951, p. 12) believed to exist in wells at the Hermon pool in Todd County.

As its name implies, the formation is mostly limestone, though careful examination reveals scattered beds of dolomitic or magnesian limestone. Freshly broken surfaces of limestone are gray and dark gray; and weathered surfaces a chalky white. The dolomitic beds tend to have a brownish tinge. Most of the beds are crystalline, that is, the unaided eye can see the individual grains and the rock looks granular. Only rarely are the beds oolitic, made up of little rounded pellets of calcium carbonate; this feature helps to distinguish the St. Louis limestone from the overlying Ste. Genevieve limestone in which oolitic limestone is very common.

Chert in large nodules is probably more common in this formation than in the Ste. Genevieve limestone.

The individual beds that can be seen in natural exposures and quarries are from one to several feet thick, separated from each other by films or thin partings of dark or greenish shale.

A silicified coral, *Lithostrotion proliferum,* known locally as a petrified hornet's nest because of the general resemblance, occurs only in the St. Louis limestone. The occurrence of this fossil together with the gray color of the limestone, the scattered beds of brown dolomite, and the relative lack of oolitic beds all serve to distinguish the formation from the Ste. Genevieve limestone.

The landscape developed on the St. Louis limestone here is rolling and subdued, with many sinks and well-developed underground drainage. Limestone rock crops out rarely, because of the gentle slopes and the thick cover of red and orange clay soil, strewn with fragments of chert.

At the outcrop and to depths of more than 100 feet solution has enlarged original planes of weakness, forming crevices that yield water to wells and feed many springs. The formation is an important source of water through the farm belt it underlies.

STE. GENEVIEVE LIMESTONE

The Ste. Genevieve limestone has the same regional distribution as the St. Louis limestone and adds width to the Pennyroyal Plain belt in Kentucky. As indicated on the cross section (pl. 1), the Ste. Genevieve limestone is the bedrock beneath soil through most of this area. The boundary between the Ste. Genevieve limestone and the overlying Renault formation has not been shown on the geologic map, plate 1, because this study revealed no differences in occurrence, quantity, or quality of ground water in the two formations.

J. M. Weller (1927, p. 99) found the Ste. Genevieve to be 180 feet thick near Mammoth Cave in Edmonson County to the east; Stuart Weller (1923, p.25–26) reported 200 to 300 feet near Princeton in Caldwell County to the west. Probably the thickness here is close to 200 feet.

Three types of limestone can be distinguished after careful examination of the sparse natural outcrops and the few quarry exposures in the central part of the quadrangle. The commonest beds are a white to light-gray limestone composed of rounded pellets or oolites about one-fiftieth of an inch in diameter. These oolites were formed by the slow precipitation of calcium carbonate on the surface of tiny grains which currents shifted continually so that even coatings were built up. Inclined bedding within individual strata records the currents that moved the grains on the sea floor. A second type of limestone is made of fragments of shells, rolled by currents and broken before coming to rest. A third type of lime-

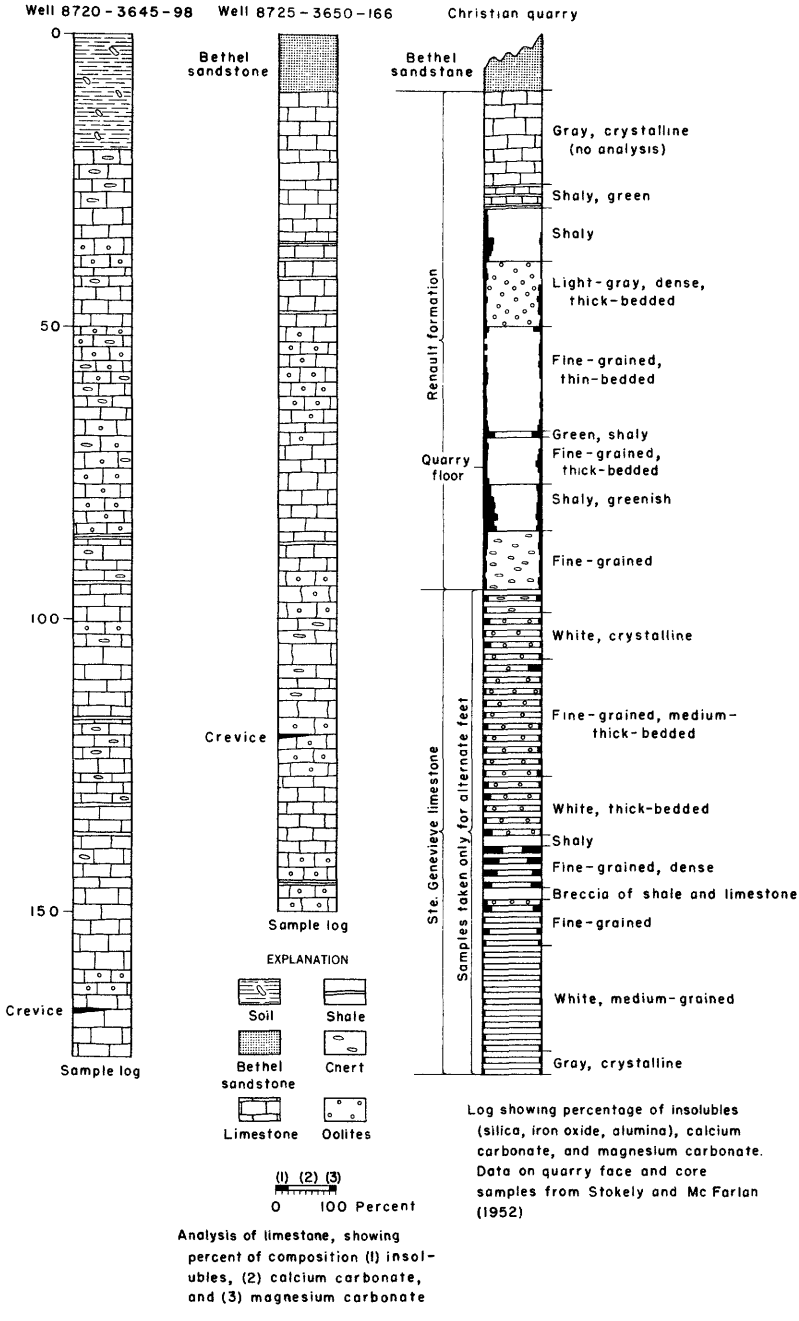

Figure 4.—Typical geologic sections in wells and a quarry in the Hopkinsville quadrangle.

stone was originally a calcareous mud or ooze and is the fine-grained type commonly called lithographic. Beds of this type are yellower than others and more shaly. All the types described may grade into each other and form beds of mixed nature. Individual beds range from less than a foot to several feet thick and are separated by layers of shale usually thin as paper, rarely an inch thick.

Chert of a bluish color when fresh, creamy white when weathered, occurs through the limestones but seems to be rarer than in the St. Louis limestone.

The sample log of well 8720-3645-98 (fig. 4) shows the succession of massive beds of limestone, some oolitic, some cherty, and the shaly partings penetrated by a typical well wholly in the Ste. Genevieve limestone. On this same figure is shown graphically the analyses of core samples from the formation. With the exception of certain shaly zones, these limestones have less than 7 percent of insoluble residues and in certain zones are high calcium limestones with 95 percent or more of calcium carbonate, as revealed by the investigations of Stokley and McFarlan (1952).

The beds of this formation, on casual examination, closely resemble those of the St. Louis limestone, though they are more oolitic. However, beds can be identified as Ste. Genevieve if one can find in them the small crinoid *Platycrinus penecillus*. Martin (1931) found that the residues of these limestones, after treatment with acid, were characterized by the silicified shells of tiny gastropods or snails.

The formation weathers and erodes to a topography of gentle slopes underlain by thick, reddish to yellowish soil with chert fragments. Sinks and underground drainage are characteristic, and the formation is an important source of water to wells and springs.

RENAULT FORMATION

The belt of outcrop of the Renault formation lies north of that of the formations just described. In western Kentucky (Weller and Sutton, 1951) the formation is 20 to 100 feet thick and quite shaly; here it is about 70 feet thick and mainly limestone with a few inconspicuous beds of shale. The best exposures are along the escarpment, especially in the working quarries there.

The limestones are of the same types as in the Ste. Genevieve limestone beneath—oolitic, fragmental, fine-grained, and mixtures of the three. Shale is more prominent, for certain beds are 4 or more inches thick and can be traced from place to place along the escarpment. The Christian quarry section and the upper part of the log of well 8725-3650-166, graphically represented in figure 4, show typical Renault formation. The index fossil by which this formation is identified is the crinoid of the genus *Talarocrinus*.

As mentioned in the review of geologic history, a lapse of some time and slight erosion occurred between the deposition of the Ste. Genevieve limestone of Meramec age and the Renault formation of Chester age. The Aux Vases sandstone occurs between the two formations to the west in Illinois but thins out and disappears eastward toward Kentucky. Here the only evidence of the interruption is a thin band of limestone pebbles, inconspicuous, yet usually found after careful search.

The Renault formation weathers as do the limestones already described and like them yields water to wells and springs.

BETHEL SANDSTONE

The youngest consolidated formation in this area is the Bethel sandstone, found beneath and along the rim of the upland in the north and on a few hilltops in the central part of the area. According to Sutton (1929, p. 200), in the Dawson Springs area the sandstone is about 40 feet thick; because it thins to the east and disappears at the Todd County line, it is here probably not thicker than 20 or 30 feet. Good exposures are not common because at the margin of the upland the limestones of the underlying Renault formation have yielded to solution, and the sandstone has slumped as disordered blocks.

The sandstone is moderately fine grained and weakly cemented by silica; beds range from thin and slabby to thick and massive. Scattered ripple marks and inclined crossbedding within the thicker beds testify to the currents that spread the sand. The only fossils commonly seen are imprints of plant remains. The formation weathers to light and dark-brown colors.

Only small openings exist as crevices and as pore spaces between the fine grains of the Bethel sandstone; the formation, therefore, is a poor aquifer yielding only small supplies to a few dug wells.

GROUND WATER

The precipitation, mostly rain, that falls here in the average year is enough to cover the ground 4 feet deep. This amount is ample to account for all the water that feeds springs and streams, that is drawn from wells, and that is consumed by plants and evaporation. There is no need to call upon other sources such as underground streams coming from a distance.

Part of the water from an average rainfall leaves the area quickly as surface runoff. Some of the water moves only a short distance over the surface before gathering into surface channels which lead it to the South Fork or some other main drainage line. This is the direct surface runoff. Some of the water moves a short distance on the surface, then enters the ground through sinks and, running quickly through large passages at shallow depths, empties from storm-swollen springs into the surface drainage. This is the storm subsurface runoff. Both types of runoff cause the South Fork to rise quickly, but the river goes down only a little less quickly as the storm runoff passes downstream. Many such sharp rises and falls due to individual rains appear on the graph of river discharge (pl. 2).

Another part of the water from a rainstorm leaves the area much more slowly. This is the part that finds its way into the small and crooked openings in soil and rock. Drawn by gravity, it moves down under the slopes to the valleys, moving slowly because of the smallness of the openings it goes through. This delayed runoff keeps the springs and large streams running through dry spells and is the water tapped by wells.

During any normal year less water runs off in the South Fork than falls over the stream basin, because evaporation and transpiration by plants return much water to the air. Some water evaporates from the ground surface, some from ponds and streams, and some from foliage right after a rain. A much larger quantity, however, is discharged by transpiration. Plants are very effective in discharging water during the growing season, for their roots spread through soil to depths of many feet. Streamflow records over 11 years show that evaporation and transpiration have returned to the air an average of about 59 percent of the total precipitation. During individual years the evaporation and transpiration have ranged from about 43 to 90 percent of the yearly precipitation.

The section that follows describes the subsurface openings that store ground water while permitting it to move at various rates to points of discharge. The occurrence and movement of the water are then described, and calculations of the amount of storage space in the rocks are given. Another section covers the chemical quality of the ground water. Description of the development of water, well yields, and usage concludes the report.

STORAGE SPACE

PRIMARY OPENINGS IN ROCK

Some open space exists between the rounded grains of oolite and the fragments of shells which compose so many of the beds of limestone. Certain zones of oolitic limestone known to drillers as the McClosky sands produce oil in pools north of this area. No doubt much water occurs in the pore spaces, but the connections between them are so small and the rate of flow so slow that there is little or no yield to wells.

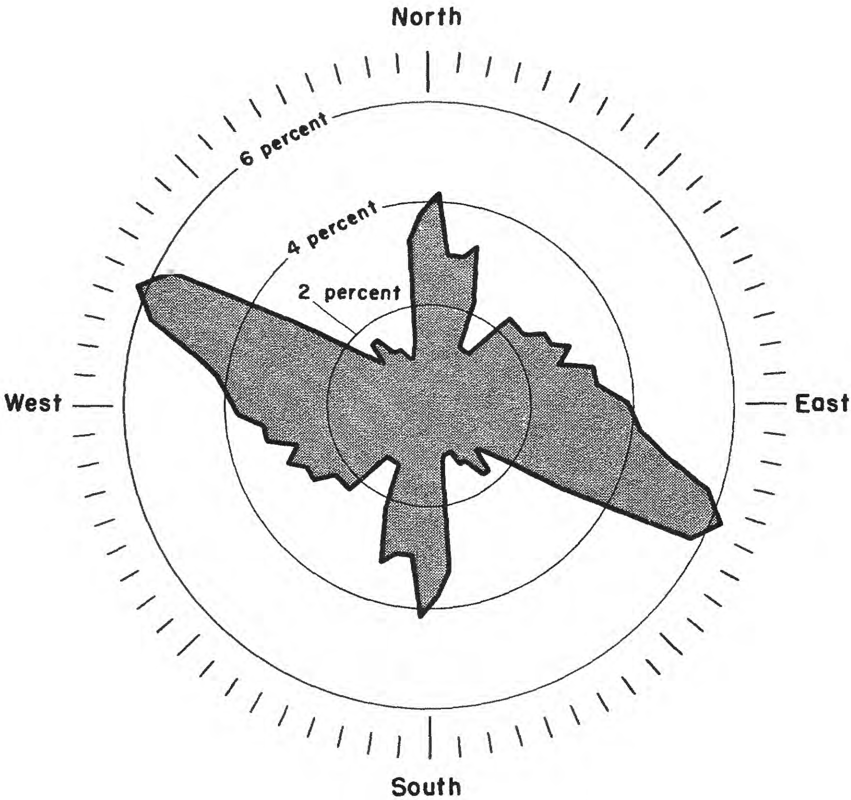

Figure 5. —Diagram showing principal directions of jointing in limestone in the Hopkinsville quadrangle (296 measurements).

The planes of stratification between adjacent beds usually are not openings but planes of weakness. The weak acids generally present in freshly recharged ground water prefer to work along these planes, as will be described.

Limestone is a fairly brittle rock and, when these limestones were lifted to their present position, tilted, and slightly warped, they broke along innumerable fracture planes. The joints are almost vertical and are spaced closely enough so that several can be found on outcrops of limestone only a few yards square. Often one must look closely to find them because at the surface they may be paper-thin cracks filled with veinlets of calcium carbonate. Usually they are made evident by the pits and grooves that are etched by solution.

The pattern that the joints follow is shown on figure 5. Most of the joints trend west-northwest; a smaller group trend north to slightly east of north, and only a few run at random. This pattern reflects the direction of the stresses placed on the rock long ago. Described most simply it seems that there was tension along a line trending north-northeast. The prevailing orientation of joints to the west-northwest is about parallel to the faults that displace strata north and west of the Hopkinsville quadrangle.

SECONDARY OPENINGS

The special features of such a limestone area as the Pennyroyal Plain—the deep residual soil, sinkholes, and underground drainage—all stem from the solubility of limestone in ground water. About 95 percent of the substance of these limestones consists of calcium carbonate and small amounts of calcium magnesium carbonate which were dissolved in the water of ancient seas. A host of marine creatures extracted the carbonates to build the hard parts and shells which accumulated to form rock. Under proper conditions the carbonates will dissolve again.

Pure rainwater dissolves limestone extremely slowly but water containing acid works much faster. As rainwater seeps down through the soil it dissolves some of the carbon dioxide produced in the soil by countless organisms and by decay of organic matter. The carbon dioxide combines with water to form carbonic acid. The water also dissolves organic acids from the soil. The concentration of acid is small but geologic time is long. Solution is most active at the base of the soil where soil water first encounters bedrock. The carbonates dissolve and the insoluble constituents remain to form residual soil. The water moves into the body of the rock along the crevices and seams, dissolves the walls, and widens the openings. Swinnerton (1942) summarizes the chemistry of the process and Meinzer (1923a) gives an excellent discussion of ground water in limestone; both authors provide extensive lists of references on these subjects.

In the beginning of this process, when stream erosion removes a protecting bed of shale and lays bare a limestone underneath, the cracks in the limestone provide a very small amount of open space. When rain falls, little of it can enter the ground and the larger part necessarily runs off in the surface channels. In the course of time the dissolving action of the ground water forms larger and larger drainage channels. Eventually so much water enters the ground and moves by subsurface channels that tributary drainage lines on the surface rarely carry water. Sections of a stream may be abandoned—for example, where a surface stream suddenly disappears into a sinkhole. Around Hopkinsville the underground drainage is well developed, but in the region around Bowling Green and Mammoth Cave it is still better developed and surface streams are fewer.

The frequency of crevices produced by the circulating ground water decreases with increasing depth, as will be shown. This is evidence that the circulation of water dies away at depth. In this quadrangle crevices due to circulating ground water exist to depths of at least 200 feet below the surface of the ground.

OPENINGS IN SOIL

Two principal types of openings exist in the soil and clay—minute spaces between the particles, and tubular openings made by roots. These openings and passages are of considerable importance to storage of water in and movement of water through the clay which blankets most of the area. Probably the clay blanket was originally continuous over the whole area except along a few streams such as the South Fork and in the centers of sinks. Now there are many manmade exposures of rock in quarries and road cuts and badly eroded slopes. Well logs show that soil and clay are as much as 40 feet thick in some of the broad depressions. They may average 10 feet thick on level lands, and less on slopes.

The open space between soil and clay particles probably amounts to 15 to 40 percent (and locally perhaps more) of the total volume, depending on the compactness. Such spaces are so small that most of the water will not drain out of them, though root hairs can draw some of it out. This storage space does not yield water to wells, yet the degree to which it is filled has much influence on the recharge of ground water to rock below, as will be described in the section on "Occurrence and movement of water."

In almost any fresh cut into soil 5 to 10 feet deep one can see many tubular openings, generally leading downward. They are as large or small as the roots and root hairs which opened them and later rotted away, but most are less than a twentieth of an inch wide. They extend well down beyond the shallow zone of soil loosened by burrowing insects and worms and appear to be the principal channels by which water trickles down through the soil to rock.

These root tubes are most plentiful under forest or grass that has not been disturbed for many years. Clearing and tilling of land and pasturing of heavy stock all tend to compact the upper layer of soil and to close the openings and to decrease the permeability. The permeability of these clay soils can be reduced to almost nothing by compacting, as is frequently done by harrowing and rolling to seal the floors of farm ponds.

SINKS AND SUBSOIL CHANNELS

The sinks that abound in this area are evidence of limestone beneath, though thick soil hides bedrock. The even distribution of sinks seems to show that the Renault formation and the Ste. Genevieve limestone are equally soluble.

Almost all the sinks are broad and shallow, ten or more times wider than deep. Those in the southern part of the map area are larger and shallower than these farther north, probably because they are older. A few have near their centers open throats or swallow holes leading down to and sometimes into rock. No doubt a larger proportion of the sinks once had such openings, but occupation of the land tends toward stopping them up. Farmers fill them in with rocks and dirt and brush because children or stock may fall in, because they interfere with cultivation, or to convert them into ponds. Unintentionally they get plugged if too much trash is dumped in them or if storm runoff from bare ground washes much sediment into them.

The sinks are depressions formed by solution of underlying limestone. When the surface of bedrock dissolves the insoluble residue occupies only about one-tenth of the space the rock did; open space would develop except that the soil mass slumps downward and the surface with it. Solution proceeds faster at some places than at others because the rock is more soluble or joints are more closely spaced, and slight depressions appear. Once formed the depressions tend to grow larger because local surface runoff collects in them and more water then seeps down to attack the bedrock under them than elsewhere in the vicinity. Innumerable dimples of this type occur in addition to the ones shown on plate 1 which mostly are 5 feet or more deep. Solution concentrated at the center finally brings about the infall of soil blocks and the development of a swallow hole.

A sink formed by dissolving of the surface of bedrock is called a solution sink. Many of the sinks around Mammoth Cave formed when the roofs of caves fell in; these are collapse sinks. Probably few, if any, of the broad sinks around Hopkinsville formed in this spectacular manner. The bedrock strata that one occasionally sees in the swallow holes are horizontal or almost so, not tipped as they would be if large and small blocks and collapsed downward. No wells drilled in sinks in this area have encountered caverns or collapsed caverns full of water.

Another type of sink is relatively rare but attracts attention by appearing suddenly. A farmer may find a deep pit interrupting the furrows he plowed the day before; the writer heard a farmer tell how his cow suddenly fell down a few feet where a moment before there was apparently firm turf. Such dramatic occurrences are very uncommon. These sinks are usually not more than 10 or 20 feet across, but steep sided and sometimes 10 feet or more deep. They occur along broad and shallow drainageways leading to the main streams. They are significant because they mark the courses of shallow underground streams and because they prove that active solution and vigorous flow at the base of the soil can there create and maintain openings of considerable size.

The best evidence of the existence of the underground drainage passages at shallow depth below soil and on top of bedrock is the sight or the sound of water running through the bottoms of the small sinks just described and through the bottoms of a few wells dug to rock. The flow and the sound are generally most evident during the winter season of high water levels.

The swiftness with which, in some areas, storm water enters the ground through swallow holes and then swells the springs with turbid water is circumstantial evidence of capacious channels leading directly to outlets. Evidence presented later seems to show that in most of the quadrangle the openings in bedrock are not large enough to receive and to discharge so swiftly the storm runoff that is known to move by underground routes.

Such fairly large openings at shallow depth furnish the best explanation for certain fish stories local residents tell. It is said that when water stands at high levels in winter, fish enter some of the sinks near the South Fork, coming up through the open swallow holes. Later in the season, as the water drains from the sinks, some of the fish are stranded and left behind. One hears much speculation on whether the fish come by underground routes from the Cumberland River, which is more than 20 miles to the south, but certainly the South Fork a mile or less away is a more logical source.

The shallow channels beneath topographic depressions leading to the river probably develop in the following manner. The erosion by solution, so concentrated beneath depressions, carves a very irregular surface on rock, as one can see in many road cuts. Pinnacles and mushroom-shaped rocks project up into soil, and tongues of soil reach down into pits and troughs in rock. Some of the sculpturing is so complicated with overhangs of rock that soil does not always settle freely and a few openings exist. In the winter when the water level is high and water is locally confined beneath clay, solution acts vigorously and water under pressure continually seeks openings. Eventually a set of isolated openings may become connected. When circulation has developed, the vigorous flow after heavy rains not only enlarges the openings but can sweep away, or find a route around, the masses of clay that occasionally slump in and produce the small sinks that mark the underground passages.

CREVICES IN BEDROCK

Crevices in bedrock are of prime importance because they are the openings that store ground water and yield it to springs, streamflow, and drilled wells. To be successful a drilled well must encounter one or more water-bearing crevices. Furthermore, the lower openings contain water in late summer, long after all available water has drained from the higher openings described so far. The sources of information on bedrock crevices are exposures in quarries, well records, and deductions made from data on water-level fluctuations and on the volume of streamflow yielded by the ground-water reservoir.

Near Hopkinsville the quarry faces as much as 70 feet high provide excellent opportunities to see the results of solution. At the top of the quarries the irregular surface of bedrock under soil in general follows the contours of the surface. Here and there wedges of red clay extend down into rock and mark the position of vertical joints widened by solution. Such clay-filled openings usually reach only a few feet into rock, rarely as much as 50 feet, before pinching to inconspicuous cracks as thin as paper. Below the zone of clay-filled openings one must search to find the crevices along joint and bedding planes, because they are few and inconspicuous.

The cracks that continue below the clay wedges, and other cracks not so marked at the surface, widen to slits or gashlike openings or to a series of pockets when they cross certain beds. Obviously these beds dissolve more readily than the neighboring beds because of differences in texture or composition, though the eye usually cannot detect any difference.

Only about 2 or 3 such vertical openings appear in several hundred square yards of quarry face. A well 100 feet deep probably has less than one chance in a hundred of striking such a vertical crevice, but about 8 out of 10 wells drilled in the quadrangle find water-bearing crevices before reaching 100 feet. Therefore it seems clear that most of the wells strike and get water from the horizontal crevices developed along the bedding planes.

Places where horizontal openings may be found are at the base of limestone beds, just above the thin partings of shale that separate beds, or just above the beds of fine-grained and earthy limestone. The openings seen in quarries are well scattered rather than being restricted to a few distinct horizons. Most of the openings are rounded on top and flat on the bottom against a bedding plane. Some appear isolated; others are tubelike and extend back crookedly into the rock along the bedding planes.

Where joints meet bedding planes, extremely irregular openings may develop which are a combination of the two types described.

Only a few bedding-plane openings occur per thousand square feet of quarry face. They are the openings commonly struck in wells because their long dimensions are at right angles to the direction of the hole, rather than parallel as they are with openings along vertical joints.

The many openings that appear to be isolated are evidence that water does seep downward along cracks that, to the eye, do not seem open and widens them where they cross more soluble beds. Joints are less well developed in soft, earthy limestones than in hard, brittle ones, and are interrupted in soft and plastic shales such as occur along bedding planes. Where joints become narrow or disappear in soft beds the downward movement of water is slowed or locally stopped, and the water seeks to move laterally along the joint or out along the bedding planes. In the leisurely course of geologic time, openings widen out where there is most circulation. Figure 6 shows the network of openings thought to exist in limestone, with the size of the openings much exaggerated.

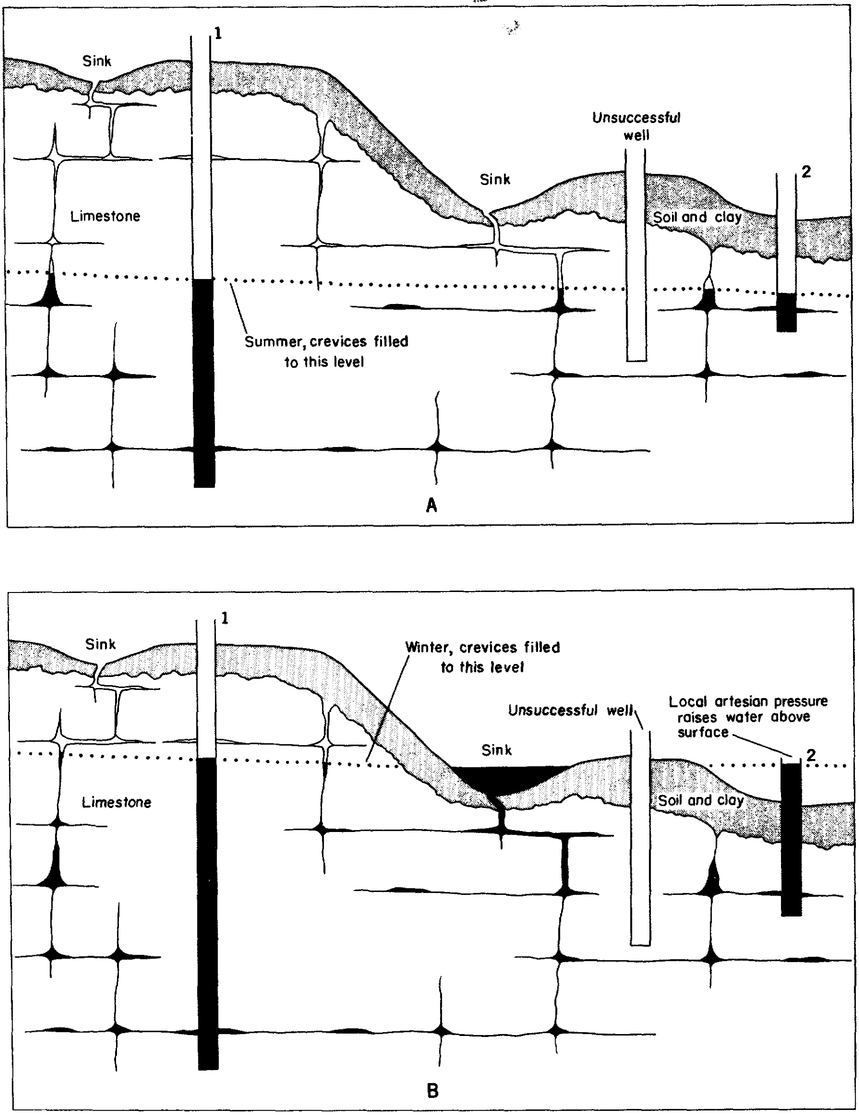

Figure 6.—Diagrams showing crevice system and occurrence of water under water-table and artesian conditions in the Hopkinsville quadrangle.

All the drillers in this area say that the crevices they meet in wells are fairly small and that their drilling tools rarely drop more than a few inches into them. The largest opening reported was 4 feet deep and considered exceptional. More valuble is the information obtained from well records on the distribution of crevices horizontally through the quadrangle and vertically with increasing depth.

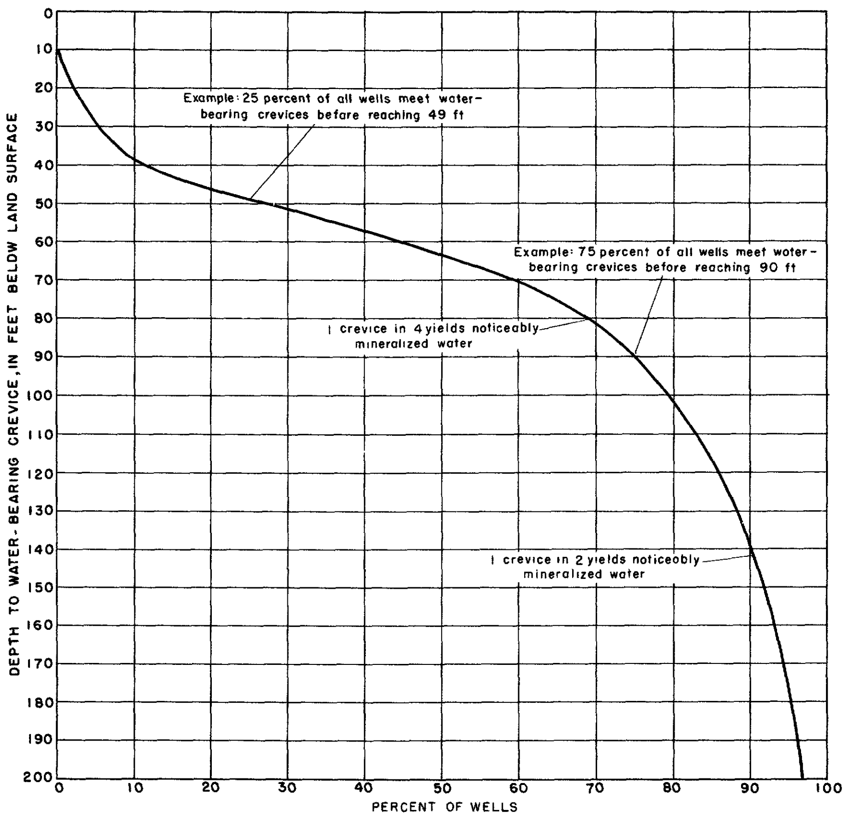

Figure 7. —Curve showing relation between depth and percent of wells that have encountered water-bearing crevices.

Wells that yield little or no water, because they did not strike a good water-bearing crevice, may occur anywhere in the quadrangle. Their distribution does not furnish any evidence that crevices are smaller or less frequent in one sector of the quadrangle than in another. It is possible that crevices are more common beneath lowlands than beneath uplands, but not enough evidence is available to prove that this relationship to the topography exists.

Owners or drillers were able to give the depths to water-bearing crevices in 146 drilled wells, 46 percent of all the wells drilled in the quadrangle. Figure 7 presents this information as a cumulative curve showing the percentage of wells that have encountered crevices at or before reaching various depths. It shows, for example, that 25 percent of these 146 wells met water-bearing crevices at or before reaching 49 feet of depth, and that 75 percent of the wells met water-bearing crevices at 90 feet or less. The lower portion of the curve is drawn to indicate that only about 1 or 2 wells in a hundred will fail to strike water before reaching 200 feet, because only about that percentage of all the wells in the area went deeper in attempts to find crevices.

In examining this curve one should keep in mind that with increasing depth to crevices beyond 80 or 100 feet the chances are much greater that the water will be too mineralized to be wholly satisfactory; this is apparent in figure 16. The appearance of poor water at depth is the principal reason why drillers usually prefer to abandon a well that is still dry at 100 to 150 feet and to try drilling another a short distance away.

A calculation explained later in this report reveals that open space capable of storing and yielding water occupies about 0. 5 percent of the rock; that is, there are 5 parts of open space as crevices per 1, 000 parts of rock taken as a whole.

Apparently solution has opened crevices to a considerably greater depth in these limestones than in the limestones that underlie the Blue Grass region of Kentucky. In the Blue Grass region Hamilton (1950, p. 28–29) found that very few wells encountered water-bearing crevices below 90 to 100 feet, and he concluded that in general the base of solutional activity lay at a depth of about 80 feet below the land surface. The explanation is probably that in the Blue Grass region few limestone formations reach thicknesses of more than about 80 feet before being interrupted by layers of shale, whereas thicker sections of pure limestone occur in the Hopkinsville area.

OCCURRENCE AND MOVEMENT OF WATER

TYPES OF OCCURRENCE

Not all the water below the surface of the ground is ground water. The water in the zone where soil and rock are merely damp or wet is called soil moisture and suspended water. The ground water is that which occurs deeper, in the zone of saturation, where all openings are filled with water. This distinction is clear to the man who digs a well down through damp material but gets no water until his well enters the saturated zone. The water stored as soil moisture is unavailable for wells and streamflow but is the main source that plant roots draw on. Under most of the area the ground water lies below the reach of roots, but moves slowly toward springs and is available to wells.

Much of the description that follows is patterned after the work of Meinzer (1923b), in which may be found a full discussion of the occurrence of water in various types of openings under different conditions, and definitions of the descriptive terms in common use.

SOIL MOISTURE

After heavy rains have thoroughly wetted the soil, some of the water drains away downward through root holes and the larger pores. This, known as gravitational water, goes to replenish the ground water at depth. After it has drained away, there still remains much water in the smaller openings and as films on particles of soil. Gravity will not remove this retained water any more than it will remove all the water from a damp sponge.

The amount of water a soil retains after the gravitational water has drained away is the field capacity of that soil. The field capacity depends on the nature of the soil. A loose sandy soil may retain only 5 percent of water, but clayey soils such as occur in this area may retain, in the first foot or two from the surface, water amounting to 40 percent or more of the volume of the soil. Only about half this water is available to plants; Olmstead and Smith (1938) show that about half the retained water in clayey soils similar to these is so tightly held in chemical combinations and adhering to soil particles that plant roots cannot extract it. In these soils, after they have been thoroughly wetted, the available water probably amounts to as much as or more than the 4 inches that Thornthwaite (1948) found to be the average for soils in general. As plants use this water during rainless periods in the growing season, they create a soil-moisture deficiency below the field capacity. As long as such a deficiency exists, there can be no general recharge through soil to ground water. For example, if plants use half an inch of water from the soil, creating a soil-moisture deficiency of that amount, then the soil will absorb most or all of a rain of half an inch and there will be little or no excess to move downward as gravitational water to the ground-water zone. If rainless weather lasts several weeks plants will use almost all the available water, perhaps 4 inches or more, creating that much deficit which must be filled by rainfall before recharge can occur through the soil blanket. As Meinzer (1942) writes: "Thus the belt of soil moisture functions as a formidable hindrance to ground-water recharge. It is like an upstream reservoir that in general must be filled before water will pass through it to the downstream reservoirs, which in this case are the aquifers of the underlying terrane." Actually some of the rain here falls on ground that is bare or of low permeability and runs overland to sinks and streams. As will be shown, however, rains in summer when moisture deficiencies prevail in the soil are far less effective in recharging ground water than rains in winter when the soil is usually wet to field capacity and added water drains through.

WATER-TABLE CONDITIONS

The water table is the surface of the zone of saturation. Usually the depth to water in any well in this area is the depth to the water table at that place and time. The depth to the water table at any place fluctuates continually because of the discharge of water which goes on all the time, and of the occasional recharge from rains. From place to place the depth to the water table differs, mainly because of differences in topography. The geologic section, plate 1, shows how the water table in September 1952 was highest under hills but also at greatest depth beneath the surface, and came to the surface in the valley of the South Fork. The diagrams on plate 1 show how the depth to water varied during 1951 in a number of wells.

Many people in the area of this report would say that their wells were artesian, because the water rose in the wells after the drillers struck the water-bearing crevices. Drillers tell of how "rivers of water" surge out of some of the larger crevices they strike. Strictly speaking, however, an artesian well is one in which the water rises and stands above the water-saturated zone. Such is the case in only a few wells, for water occurs under water-table conditions almost everywhere in the quadrangle. Figure 6 shows why it is normal for water to rise after being met, even though water-table conditions prevail. The crevices are so few and scattered that only very rarely would a well find one right at the water table. The average well reaches the level of the water table and continues some distance in tight rock before meeting a crevice. The water in it is under pressure and rises in the hole, but only to the level of water in nearby openings such as crevices or wells, which is the water table. Naturally some wells find crevices a shorter distance below water table than others in the vicinity; water rises most in the wells that go deepest below the water table to find a crevice.

Here and there in the area one finds entirely different water levels in wells not far apart, giving evidence of two water tables, one above the other. This situation frequently exists on the northern upland. The water level in a well dug into the Bethel sandstone may stand some tens of feet above the water level in a nearby well drilled through the sandstone into the creviced limestone beneath. The cause is a thin shaly zone at the base of the sandstone, which prevents water from moving downward freely. Enough water accumulates above the shaly zone to provide a small supply to dug wells. The water in the limestone beneath enters at some place not far away where the shaly zone is missing, either because the shale was not deposited or because erosion has cut down into the limestone. The upper of the two water tables is called a perched water table.

ARTESIAN CONDITIONS

Artesian conditions exist in many wells during the winter. Water may stand above the zone of saturation and even flow at the surface. Such conditions are most likely to occur in wells located in lowlands, and figure 6 illustrates a typical case. The water level in the left half of diagram *B* is higher than the ground surface at well 2 where the clay soil imprisons the water in the rock. Thus the water in well 2 rises above the aquifer and above the surface; it would flow at the surface if the casing were lower.

RECHARGE AND DISCHARGE

It has already been mentioned that the ground water is in continual movement because of the discharge which continually drains water from the ground-water reservoir and to the recharge which

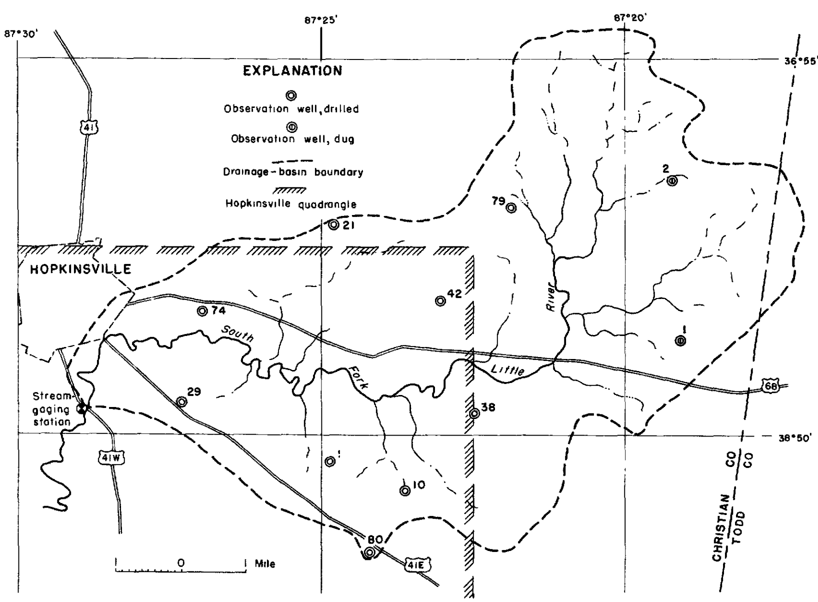

Figure 8. —Map showing location of observation wells in the drainage basin of the South Fork Little River.

occasionally replenishes the supply. In all but a few places the circulation down to more than 100 feet is enough to keep the water from becoming objectionably mineralized by long contact with soluble rock minerals.

The amount of water stored at any time depends on the rates at which discharge and recharge have been occurring in the past weeks or months. A fall in water level shows a decrease in stored water, due to discharge alone or to discharge in excess of the recharge; a rise in water level and amount of water in storage occurs only when recharge exceeds discharge. A series of measurements of water levels reveals the periods and seasons of storage gains and

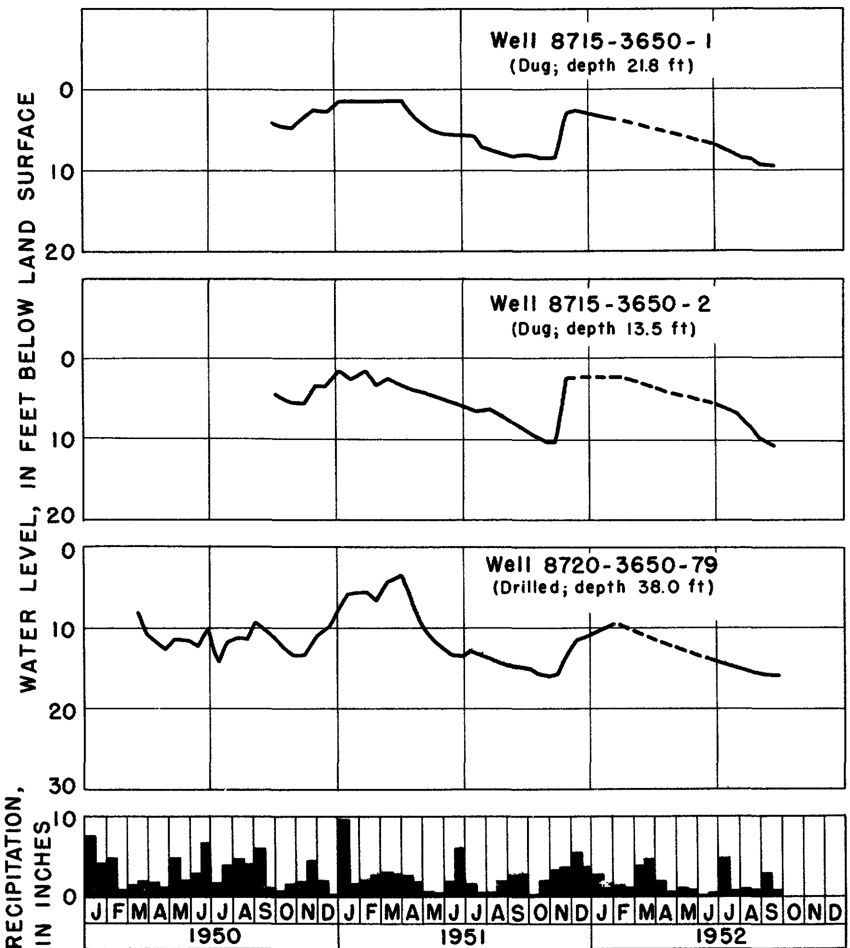

Figure 9. —Hydrographs of three wells outside the Hopkinsville quadrangle, in the South Fork basin.

losses, and those features of the weather which are the causes then become evident.

Basic data on changes in water level were obtained from the measurements of water levels made about every 2 weeks in about 28 wells in the quadrangle and an additional 3 wells in the part of the drainage basin of the South Fork (fig. 8) that lies north and east of the quadrangle. Almost all the measurements were made by tape; for a short period recording gages were installed on two of the wells to get a record of day-to-day fluctuations. Plate 3 and figure 9 show as hydrographs the changing water levels in the observation wells. The hydrographs for 17 wells in 1951 are plotted on plate 1 to give an overall view. The composite hydrograph of 11 wells in the drainage basin of the South Fork (fig. 8) is compared on plate 2 with the precipitation and the discharge of the South Fork. Table 2 presents for purposes of record some brief or interrupted sets of measurements in 12 wells.

Table 2.—*Water levels in observation wells in the Hopkinsville area with short or interrupted records*

[Depth to water level given in feet below land-surface datum. Hydrographs for regular observation wells shown in plate 3. For location of wells see plate 4. For information concerning depth, diameter, water-bearing formation, etc., see table 6]

Well no.	Owner	Date	Depth to water level
8720-3645-12	Mrs. Abbie Macrae	Nov. 18, 1949	29.6
		May 31, 1950	24.55
		Sept. 7, 1950	11.64
		Jan. 17, 1951	2.69
		July 26, 1951	27.95
		Sept. 4, 1951	29.50
		Feb. 14, 1952	12.16
		Sept. 25, 1952	29.72
8720-3645-24	E. E. Wimpy	Nov. 23, 1949	46.80
		Jan. 21, 1950	31.77
		Feb. 3, 1950	18.39
		Feb. 16, 1950	19.57
		Apr. 12, 1950	45.25
		May 31, 1950	45.70
		Sept. 7, 1950	42.14
		Jan. 17, 1951	8.50
		July 26, 1951	46.54
		Sept. 4, 1951	46.69
		Feb. 14, 1952	45.90
		Sept. 24, 1952	46.56
8720-3650-15	E. J. Graves	Nov. 7, 1949	25.2
		Jan. 6, 1950	19.04
		Jan. 20, 1950	22.55
		Feb. 3, 1950	22.60
		Feb. 17, 1950	22.32
		Apr. 12, 1950	28.92
		May 31, 1950	29.20
		Jan. 18, 1951	22.06
		Sept. 25, 1952	44.08
8720-3650-16	O. K. Strode	Nov. 10, 1949	39.9
		May 31, 1950	36.39
		Sept. 7, 1950	37.39
		Jan. 18, 1951	32.50

Table 2.—*Water levels in observation wells in the Hopkinsville area with short or interrupted records*— Continued

Well no.	Owner	Date	Depth to water level
8720-3650-16	O. K. Strode	July 26, 1951	38.57
		Sept. 4, 1951	38.87
		Feb. 14, 1952	35.16
		June 27, 1952	41.06
		July 25, 1952	43.64
		Aug. 8, 1952	48.22
		Aug. 19, 1952	44.26
		Sept. 11, 1952	41.27
		Sept. 25, 1952	41.97
8720-3650-69	Dr. D. H. Erkelidian	Feb. 7, 1950	48.13
		May 31, 1950	48.39
		Sept. 7, 1950	48.22
		Jan. 18, 1951	48.13
		July 27, 1951	48.68
		Sept. 4, 1951	49.79
		Feb. 14, 1952	52.54
		June 27, 1952	48.74
		July 25, 1952	49.23
		Aug. 8, 1952	50.32
		Aug. 18, 1952	51.07
		Sept. 11, 1952	52.76
		Sept. 25, 1952	52.28
8725-3645-93	William Doris	Mar. 30, 1950	36.77
		May 31, 1950	41.75
		Sept. 6, 1950	30.39
		Jan. 19, 1951	25.73
		July 27, 1951	45.04
		Sept. 4, 1951	48.05
		Feb. 14, 1952	37.86
		June 27, 1952	46.98
		July 25, 1952	47.23
		Aug. 8, 1952	46.23
		Aug. 19, 1952	47.30
		Sept. 11, 1952	47.13
		Sept. 24, 1952	47.36
8725-3645-114	Enis Haddock	Jan. 24, 1950	9.39
		May 31, 1950	13.38
		Sept. 7, 1950	12.69
		Jan. 18, 1951	.40
		July 26, 1951	14.04
		Sept. 4, 1951	16.35
		Feb. 14, 1952	13.51
8725-3645-116	J. B. McCain	Jan. 24, 1950	8.66
		May 31, 1950	12.23
		Sept. 7, 1950	8.60
		Jan. 18, 1951	2.54
		July 26, 1951	12.50
		Sept. 4, 1951	13.35
		Feb. 14, 1952	10.17
		Sept. 24, 1952	12.50
8725-3650-19	W. H. McRenolds	Jan. 17, 1950	45.63
		May 29, 1950	45.2
		Sept. 6, 1950	46.52
		Jan. 17, 1951	45.20
		Aug. 2, 1951	48.24
		Sept. 4, 1951	49.74
		Feb. 14, 1952	46.85
		June 27, 1952	48.58
		July 25, 1952	49.75
		Aug. 8, 1952	50.85
		Aug. 19, 1952	49.64
		Sept. 11, 1952	51.70
		Sept. 24, 1952	52.38

Table 2.—*Water levels in observation wells in the Hopkinsville area with short or interrupted records*— Continued

Well no.	Owner	Date	Depth to water level
8725-3650-75	Jack Doudy	Feb. 8, 1950	51.05
		Mar. 3, 1950	52.43
		Mar. 17, 1950	51.10
		Mar. 31, 1950	51±
		Apr. 12, 1950	51.65
		Apr. 29, 1950	55±
		May 11, 1950	51.24
		May 30, 1950	51±
		June 15, 1950	52.79
		June 17, 1950	51.58
		July 17, 1950	53.05
		July 26, 1950	52.46
		Aug. 11, 1950	52
		Aug. 27, 1950	52
		Jan. 18, 1951	50.04
		July 27, 1951	53.28
		Sept. 4, 1951	55.20
		Feb. 15, 1952	42.54
		June 27, 1952	54.06
		July 25, 1952	53.82
		Aug. 8, 1952	64.78
		Aug. 18, 1952	55.32
		Sept. 11, 1952	54.98
		Sept. 26, 1952	54.68
8725-3650-140	Lucien Payne	Mar. 16, 1950	18.37
		May 29, 1950	17.14
		Sept. 6, 1950	5.99
		Jan. 19, 1951	1.10
		Sept. 23, 1952	83.45
8725-3650-145	Hedley Robertson	Mar. 16, 1950	34.95
		May 29, 1950	25.36
		Sept. 7, 1950	34.51
		Jan. 19, 1951	34.36
		July 27, 1951	47.54
		Sept. 3, 1951	48.53
		Oct. 30, 1951	48.96
		Feb. 13, 1952	41.74
		June 27, 1952	48.81
		July 24, 1952	47.85
		Aug. 8, 1952	48.26
		Aug. 19, 1952	48.60
		Sept. 11, 1952	48.74
		Sept. 23, 1952	48.98

THE ANNUAL CYCLE

The water levels in all wells are highest at sometime in winter and early spring, they decline in late spring, and reach their lowest point in late summer or early autumn. However, the movement of water level in each well varies somewhat from this overall pattern, owing to natural causes such as topography or to artificial ones such as pumping. The irregularities of individual wells largely disappear in the composite hydrograph of 11 wells (pl. 2), so it serves as a good example for description of the annual fluctuations and their causes.

In 1951, water levels stood highest in January because of the heavy rains in that month; in the average year water levels will be highest in this, the wettest month (fig. 2). A hydrograph constructed from daily measurements would show rises after nearly every rain, as does the graph of stream discharge. During February and March the water levels declined slowly, because of the lesser amounts of precipitation in these months. In all the cool months the soil is thoroughly wet, and at times it is saturated with gravitational water moving downward to recharge the ground-water reservoir. Little water is discharged by evaporation and transpiration.

A faster decline in water levels began in April and continued until early in June. Thereafter water levels declined gradually to a low point in October, though heavy summer rains produced occasional small rises. In November water levels began a sharp rise to the high levels of winter.

The sharp decline of water levels in spring coincides with the beginning of the warm season during which plants grow vigorously and transpire much water, and the rate of direct evaporation also is much greater than in cold weather. The return of water to the air jointly by these two processes is known as evapotranspiration. There is little doubt that here far more water in transpired by plants than is evaporated. In spite of the many ponds, open water surface makes up a very small fraction of the area of the quadrangle, and it has been shown repeatedly (Weaver and Clements, 1938) that direct evaporation of water from soil is negligible after the first few inches of soil is dry.

In this region the growth of plants causes lowering water levels by preventing recharge, not by drawing upon the ground water itself. As plate 2 shows, the average depth to water ranged from 20 to 27 feet during the growing season, and the roots of few plants reach down that far. The roots of corn, according to Weaver and Clements (1938) ordinarily reach down as far as the plant is high, but the roots of trees by no means reach as deep as the tree is high. Moreover, few of the plants in this region are of the type (phreatophytes) with roots that can live in and use water from the saturated zone. As described previously, the plant roots use soil moisture and thereby create moisture deficiencies in the soil. If the moisture deficiency exceeds the amount of the next rain, essentially all the water from that rain will be absorbed and little or none will pass through. During a dry spell of several weeks the plants are probably capable of creating deficiencies of close to 4 inches, a figure that is not surprising when one realizes that growing corn, in creating one pound of dry material, transpires 300 to 400 pounds of water (Hildreth, Magness, and Mitchell, 1941, p. 302).

Rainfall decreases slightly through spring and summer months, but clearly the ineffectiveness of spring and summer rainfall to recharge ground water is the main cause of the lowering in water levels. For example (pl. 2), in April 1950, when water levels dropped so sharply, there was almost as much rain as in March; the rain in September that did not halt the decline of water levels was almost as much as that which in November, at the end of the growing season, raised water levels about 9 feet.

Only a small amount of recharge occurs in summer, even from heavy rains. Most of this recharge probably enters through sinkholes. The small amount of recharge demonstrates that in summer there is generally little surface runoff into the sinks.

LOSSES BY EVAPORATION AND TRANSPIRATION

Even if the rainfall averaged more in summer than in winter months it is fairly certain that water levels would show marked decline in summer. Transpiration by plants and evaporation returned to the air the equivalent of only about 7 percent of the precipitation on the drainage basin of the South Fork in the period November 30, 1950, to May 1, 1951, but about 97 percent of the precipitation from August 22 to October 30, 1951 (fig. 10). The values given are fairly accurate for the particular periods studied but naturally will differ in other years when precipitation and numbers of warm and cool days are different.

The calculation of the figures just presented rests on the idea that all precipitation leaves the area as streamflow or water vapor transpired and evaporated; underflow is believed to be negligible, or, at least, to come into the basin as fast as it leaves. The quantity of water involved in any error in this assumption would be negligible in comparison to the quantities discharged by runoff and evapotranspiration.

Because part of the water discharged by runoff was ground water recharged before November 30, 1950, it is necessary to consider storage. The composite hydrograph, plate 2, shows that on May 1, 1951, the average ground-water level in the drainage basin of the South Fork was almost the same as on November 30, 1950; on both dates the amount of water stored in the ground-water reservoir was essentially the same. Therefore the precipitation of 27.13 inches during the period equals the quantity discharged by runoff and evaporation and transpiration.

Expressed as an equation

$$\text{Precipitation} = \text{runoff} + \text{evapotranspiration}$$

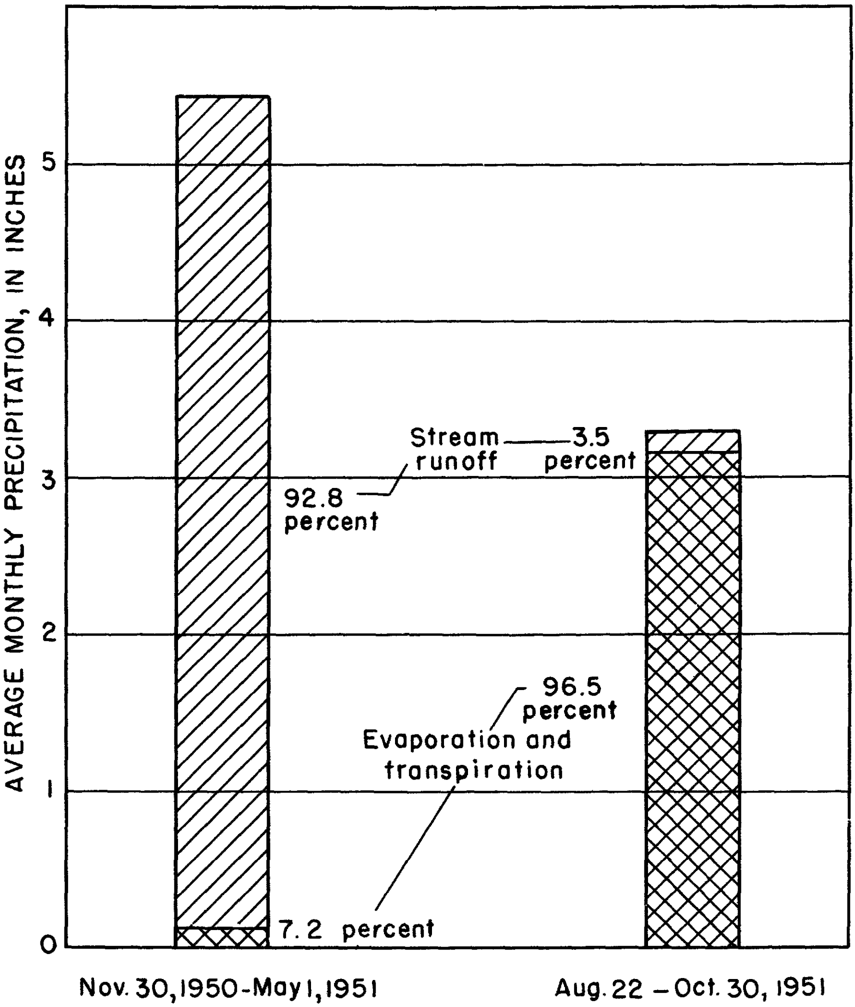

Figure 10. —Graphs comparing the precipitation, runoff, and evapotranspiration in parts of the growing and nongrowing season, 1950-51.

Substituting the known values for precipitation measured at Hopkinsville and runoff gaged where U. S. Highway 41-E crosses the South Fork,

$$27.13 = 25.19 + \text{evapotranspiration},$$

or

evapotranspiration = 1.94 inches, which is 7.2 percent of the precipitation.

This period unavoidably includes almost a month of early spring growing weather; the evapotranspiration loss for nongrowing weather was therefore less than this 7 percent.

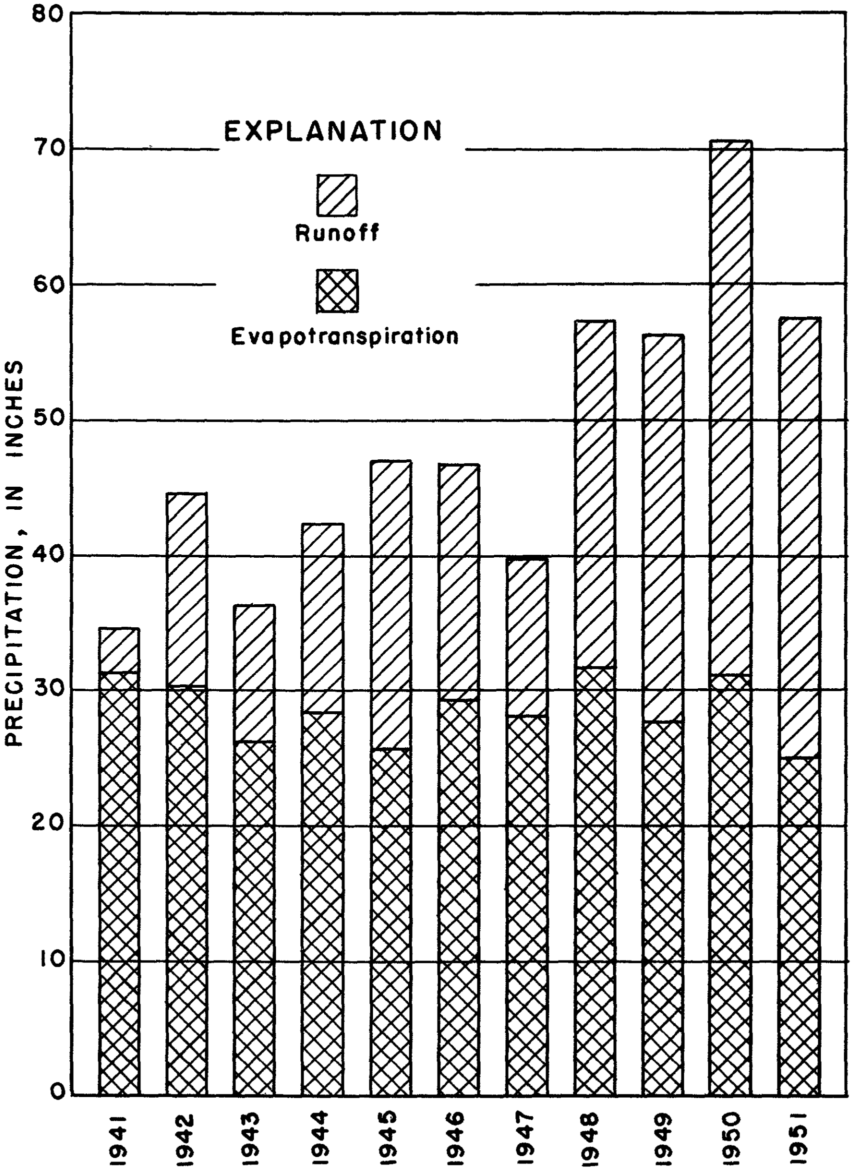

Figure 11. —Graphs showing precipitation, runoff, and evapotranspiration, Little River basin, 1941-51.

In the summer of 1951 the water levels on August 22 and October 30 were the same (pl. 2); therefore during the period the precipitation was equal to the runoff and the evaporation and transpiration. In this period the rainfall was 7.49 inches. Stream runoff was only

0.26 inch. The remainder, 7.23 inches, which is 96.5 percent of the rainfall, was returned to the air by plants and evaporation.

The average yearly evaporation and transpiration of water in this region and the range from year to year are shown far better by the 11-year record of runoff from the entire Little River basin (fig. 11) than by the 2-year record available for the basin of the South Fork. Precipitation measured at Hopkinsville is applicable to both basins, and the runoff per square mile in both was almost the same in 1950 and 1951, the 2 years of joint record. A close correspondence would be expected because the basin of the Little River, with an area of 249 square miles, is just a larger model of the basin of the South Fork, so similar is the topography and geology.

Figure 11 demonstrates that the evapotranspiration ranged only from 25.0 to 31.8 inches of water in the 11 years of record, although the precipitation ranged from 34.6 to 70.7 inches. It is apparent that year after year evaporation and transpiration consume about the same amount, averaging some 28 to 29 inches of water. Differences in consumption from year to year arise principally from differences in the length and warmth of the growing season and in the amount and distribution of precipitation. For example, if less rain than average fell during the growing season, the evapotranspiration would be less than average. If rains were heavy through a growing season that was longer and warmer than usual, evapotranspiration would exceed the average.

Runoff comes from and equals the precipitation in excess of the water evaporated and transpired. In a dry year such as 1941, with only 34.6 inches of precipitation, the runoff amounted to only 3.4 inches. In 1950, a wet year with 70.7 inches of precipitation, the runoff was 39.6 inches. Runoff in 1950 thus was about 12 times that in 1941, though precipitation was only twice as much.

The runoff approaches zero as precipitation in very dry years approaches 28 or 29 inches. However, there would always be some runoff no matter how dry the year. Inevitably some precipitation falls in the cool months when evapotranspiration takes little toll of the water.

FLUCTUATIONS OF WATER LEVELS IN WELLS

The water levels in most of the observation wells respond quickly to rain and dry periods, at least during the nongrowing season. The hydrographs obtained by recording gages (8725-3650-29 and -74 from August 1951 onward, pl. 3) mark every rain with sharp rises and falls.

The level of the water table fluctuates more abruptly and rapidly in this limestone reservoir than in the ground-water reservoirs of sand and gravel or sandstone that are so important in other parts of the State. The water in the deposits of sand and gravel along the Ohio River moves through a vast number of relatively small openings, usually at rates of a few inches to a few feet a day. The openings in limestone here are few and scattered but, on the whole, so large that water can move tens or hundreds of times faster than through typical sand and gravel. Water entering the limestone shortly after rains moves quickly from place to place to give abrupt rises in water level, and drains away fairly rapidly also.

In this area a water level that shows little response to individual rains may indicate that the well has a low yield from water-bearing openings smaller than average. For example, the water-level fluctuations are small and sluggish in dug wells bottomed in soil such as 8720-3645-41 and 8725-3645-39 and -148, plate 3. At least two of the drilled wells in which the fluctuations of water level are sluggish, 8720-3645-11 and -100 (pl. 3) are not used because they yield only small amounts of mineralized water. Apparently these wells tap small openings poorly connected with the crevice system that carries fresh water.

Topographic position has a great deal to do with the total range of water-level fluctuations in a well through the year; generally the water levels fluctuate over a shorter distance in lowland wells than in those upon uplands or hills. The reason is that all year round the water level lies at shallow depth beneath the lowlands and of course comes to the surface in running streams such as the South Fork. In wells on uplands, water levels stand close to the surface in winter, but in summer approach the water levels under the adjacent lowlands, the more so when the underground passages provide good connection, so that considerable ranges exist. Wells 8725-3650-29 and -74, plates 1 and 3, illustrate the contrast. In well 29 on the upland south of the valley of the South Fork the depth to water ranges from 10 to about 48 feet. Well 74 is in the bottom land a few hundred yards from the South Fork and the depth to water ranges from about 8 to 18 feet. The water-level range in the upland well is four times that in the lowland well. A few of the other hydrographs for 1951 that are plotted on plate 1 illustrate similar relations.

Pumping inevitably causes lowering of water level in the vicinity of the pumped well. The amount of lowering depends upon a variety of factors, the principal of which are the rate and duration of pumping and the amount of storage space and freedom of movement of water through passages. Many of the observation wells are used during at least part of the year, or wells near them are used; in such wells at least a part of the lowering of water level during summer is due to pumping. Probably only a small part is due to such pumping, for the hydrographs of used and unused wells do not show much difference. Because the hydrographs are constructed from measurements at intervals of 2 weeks, most of them do not show the short-term drawdowns that result from pumping any more than they show the brief rises with every heavy rain. However, it may take more than 2 weeks for the water level in a well of low yield to recover from heavy pumping, and a few drawdowns in such wells register on the hydrographs. For example, pumping in late September or early October of 1951 resulted in the downward break in the hydrograph of the dug well 8725-3645-39 (pl. 3); heavy pumping in July 1951 depressed for 2 or 3 weeks the water level in the drilled well 8725-3650-125. In the dry summer of 1952 enough water was drawn from the dug well 8725-3645-148 to lower its water level more than 10 feet below what it had been in the previous 2 years of record.

The hydrographs based on measurements from early in 1950 to the latter part of 1952 show that water levels have been getting lower and lower. This is the result of decreasing rainfall during these 3 years (fig. 3) and certainly is not evidence of gradual exhaustion of ground-water supplies because of overuse. The total precipitation in 1952 was less than that which fell in the growing season in 1950; consequently the water levels were significantly lower in 1952.

It is likely that the ranges in water level shown by the hydrographs are near the extremes that can be expected in the future. The water moves so freely through this reservoir that the water level depends on the weather of the immediately preceding months and weeks, and there have been exceptionally dry and wet periods in the time covered by the hydrographs. The winter of 1950–51 was one of the wettest on record here, and 1950 was the second wettest year in the record since 1897 with only about 3 inches less precipitation than the maximum recorded in 1923. The drought in the summer of 1952 was severe enough to cause unprecedented losses on crop and pasture land, and the year as a whole was the fourth driest of record.

STORAGE CAPACITY OF THE LIMESTONES

The calculations of the coefficient of storage and of storage capacity that follow depend on the relations between the level of ground water in the basin of the South Fork and the discharge of the stream when fed only by ground water during periods of little or no rain. The curve of figure 12 follows a number of points taken

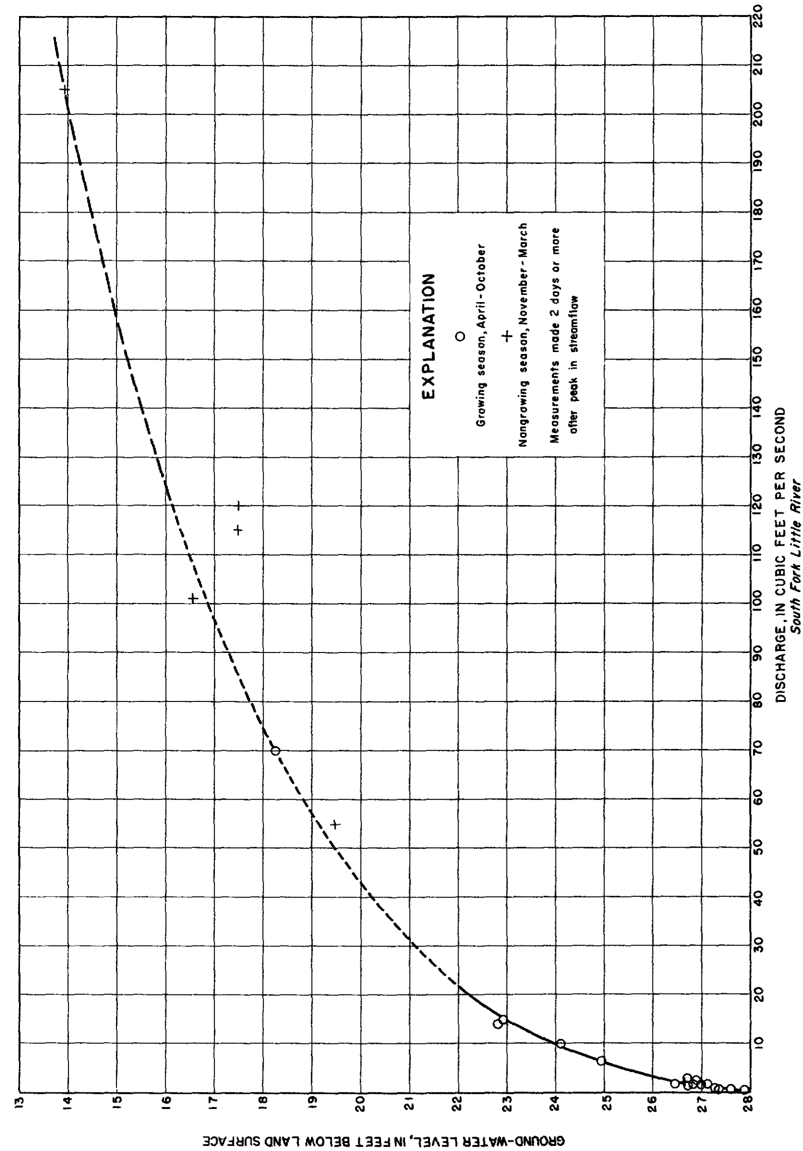

Figure 12. —Curve showing relation between ground-water level and the discharge of the South Fork Little River.

from plate 2. Only those measurements are plotted that were made 2 days or more after peak flows in the stream due to precipitation. In large part this selection eliminates the storm runoff, most of which drains from the basin within a couple of days after a rain.

The shape of the lower portion of the curve apparently confirms the statement made earlier that storage in general is under water-table rather than artesian conditions. If artesian conditions existed the points should define a straight line, showing an equal decrease in discharge for every foot of decline in water level. Only the upper part of the curve is relatively straight. This part of the curve is based on measurements in winter when the level of ground water is high and artesian conditions such as illustrated in figure 6 do exist in many places.

CALCULATION OF VALUES

It is evident that during dry weather, when ground water is discharging from the bedrock crevices and there is no recharge, the following relations exist:

Volume of storage space emptied = volume of streamflow + volume of water transpired and evaporated.

Evapotranspiration consumes little of the ground water stored in bedrock crevices because plants draw upon the water stored in the soil, except in the limited areas where the water table lies within a few feet of the surface. For the time being evapotranspiration will be considered negligible. The equation then becomes

Volume of storage space emptied = volume of streamflow.

Then, from the record of stream discharge, one can determine the volume of storage space emptied during a dry spell.

The coefficient of storage is the amount of water, expressed as a fraction of a cubic foot, discharged from storage in each vertical column of the aquifer having a base of 1 square foot as the water level falls 1 foot (Wenzel, 1942, p. 87). It can be calculated as follows:

The volume of streamflow during a dry period, between two measurements of ground-water level, is expressed as inches of water over the entire basin. These inches of water equal the inches of storage space drained during the decline of water level between the two measurements over the entire basin. Then,

$$\text{Storage coefficient} = \frac{\text{Stream discharge, inches}}{\text{Decline in ground-water level, inches}}$$

A typical calculation is given for the period between the water-level measurements of May 15 and May 30, 1951 (pl. 2).

Depth to water, May 15	feet..	22.94
Depth to water, May 30	do..	24.94
Decline in water level	do..	2.00
	...inches..	24.00
Stream discharge, May 15–30, over entire basin	do..	.12

$$\text{Storage coefficient} = \frac{\text{Stream discharge}}{\text{Decline in water level}} = \frac{0.12}{24.00} = 0.005$$

On plate 2 appears, for 5 periods, the values for stream discharge, decline of ground water, and the calculated storage coefficients. The average value is 0.0053; the range, from 0.0018 to 0.0087.

RANGE OF VALUES

The considerable range in the calculated values, from 66 percent under to 64 percent over the computed average, no doubt rises from errors introduced by the two preliminary assumptions—that the water-level measurements show correctly the average depth to water over the whole basin, and that the measured stream discharge equals the discharge of ground water.

According to the calculations of the Geological Survey, the South Fork drains an area of 46.2 square miles. Therefore, each of the 11 observation wells shown on figure 8 is taken to represent the water level over 4.2 square miles. Because the rock is similar over the basin and the relief slight, this density is considered satisfactory for a study such as this which does not pretend to great accuracy.

Almost all the wells in which one can measure water levels are close to farmhouses. Pumping from the measured wells or others close by may lower the water more than it would decline normally. Three of the fourteen wells originally measured were eliminated, mostly because of such manmade disturbances, but some effects of pumping remain in the record. Except in one case it is thought that pumping did not cause significant error. The lowest figure derived for storage is 0.0018 for the period in the middle of August (pl. 2). Toward the end of this period almost a month had passed without rain and farmers were pumping all the water they could from their wells, undoubtedly causing local drawdown in some of the observation wells. The decline of water level determined by measurements in these wells thus probably was more than the true decline over the basin corresponding to the natural discharge. This error makes the calculated storage coefficient too low, and is a satisfactory explanation of the low value of 0.0018.

One cannot calculate storage values by the method used without making the assumption that stream discharge in these periods of little or no rain equals ground-water discharge. The assumption can be justified if the errors so introduced are small.

Any single measurement of stream discharge may be in error by as much as 10 percent, but the errors in the overall record amount to much less. In the expression of discharge as inches over the whole basin there may be errors introduced if the area of the basin is not measured correctly. Here, where slopes are gentle and most of the tributary drainage runs in underground passages, it is hard to judge the position of the drainage divide. However, errors in drawing the boundary of the basin are likely to compensate and not to amount to a significant error in the end.

Hopkinsville gets its city water supply from the North Fork Little River and furnishes water to homes and to the large Western State Hospital in the basin of the South Fork. Thus an undetermined amount of water, though probably small in comparison with streamflow, enters the stream as sewage and waste. Offsetting this is the small amount of water farmers pump from the river during summer, for consumptive uses.

The operation of a small dam and reservoir markedly affects the discharge of the South Fork during periods of low flow. Intermittently the operators open this dam to flush the reservoir, and a wave of water in excess of natural discharge moves downstream past the gage; then they close the dam to refill the reservoir and temporarily cut off the streamflow above the dam. A sharp drop in stream discharge in the middle of July 1951 (pl. 2) is the result of filling this reservoir, and the release of this water apparently caused the sharp crest on July 24. In order that the water so released would not appear as an addition to ground-water discharge in the period July 25 to August 9, the first day of that period was omitted and the decline in water level for the remainder of the period was interpolated. The storage coefficient so calculated was 0.0073 (pl. 2); without the correction the value would have been 0.0085.

Small amounts of rain fell during 3 of the 5 periods for which calculations were made, and these rains probably made some contribution to stream discharge. The soil undoubtedly absorbed most of these rains and negligible amounts went to streamflow, with one exception. Slightly more than half an inch of rain fell in the first days of the period from May 1 to 15. The soil was still fairly wet this early in spring and probably some of this rainwater caused stream runoff (perhaps after moving through the ground) and the high computed storage value of 0.0087. The difference between this value and the average of 0.0053 represents only 0.17 inch of runoff.

The assumption that little or no ground water is lost by evaporation and transpiration rests on the argument that ground water is within the reach of plant roots and of evaporation in only a small fraction of the area. The amount of this loss remains unknown, but the loss tends to reduce the calculated storage coefficient. That is, more ground water was actually discharged than was measured as streamflow. Therefore the calculated yield per foot of drop in water level is less than the actual yield.

In summary, one finds that rain or dam regulation increased the computed values in two periods, usage near observation wells decreased the values in one period, and in all five periods evapotranspiration loss made the values too low. Probably the true value for storage coefficient is slightly more than the average of 0.0053, but the value of 0.005 is adopted as reasonably correct, though conservative.

QUALITY OF WATER

All natural waters contain substances dissolved from air, soil, or rock. Rainwater contains little except some of the gases or dust particles from the atmosphere. Ground water contains much or little of various substances depending on the climate, type of soil and bedrock of the area, and the length of time the water has been in contact with soil and rock material.

Under natural conditions in most areas ground water usually has about the same composition at one place year after year because it moves slowly and follows about the same routes through soil and ground. In most areas, therefore, one analysis suffices to show reasonably well not only what the water is like at that time but what it will be like in the future. However, in the Hopkinsville area, water that moves freely in the larger openings common near the surface changes somewhat in composition, being diluted with pure water after rains and taking on more dissolved solids during dry periods. For example, note the considerable fluctuation in temperature and in the concentration of certain constituents in the analyses for wells 8720-3645-51, 8725-3645-157, and 8725-3650-137 in table 3. Fluctuations in temperature and iron content could reflect, at least in part, variations in time of storage of water in pipes and tanks, but variations in the other constituents probably show actual changes in quality of the water in the ground. However, little if any of the ground water even from shallow sources has as changeable a composition as water of surface streams such as the Little River. After heavy rains the discharge of the stream is mainly rainwater having a very low content of dissolved solids, but during dry periods the character of the river water comes to resemble that of the ground water discharged through springs and seeps.

ANALYSES OF GROUND WATER

Table 3 presents analyses of water from 44 wells and 6 springs; altogether there are 60 analyses because water from 4 wells was sampled 2 or more times. Fifteen of the analyses are comprehensive—that is, they show the concentration of all the constituents and characteristics commonly determined in water. The remaining 45 are partial analyses reporting only the more important constituents and characteristics. The source and significance, to the user, of the elements and substances dissolved in water are set forth briefly in table 4. Table 5 summarizes the quality of the water, giving maximums and minimums, and the median values. The median is the point or value in a series of numbers that has half the numbers on one side of it and half on the other side. For example (fig. 13), the average hardness of all the samples of water is 230 ppm, but the median is 205. The median is a more typical value than an average, which is much influenced by very high or very low values. The amounts of dissolved substances in the waters are given in parts per million by weight. These figures can be converted to grains per gallon by multiplying by 0.0584.

The analyses give values for several characteristic properties of water. The pH, an expression of the concentration of hydrogen ions, is useful in determining the scale-forming or corrosive tendencies of the water. Absolutely pure water has a pH value of 7.0, but water containing considerable amounts of dissolved solids also may have a pH of 7.0. Water is alkaline when the pH is more than 7.0; acid when pH is less than 7.0. Specific conductance is a measure of the ability of the water to conduct electric current. It varies with the type and quantity of dissolved material.

The dissolved-solids content represents the residue that remains after the water has been evaporated and the residue dried at 180°C for 1 hour.

The average user of water takes more interest in the hardness than in any of the foregoing characteristics (fig. 13). Everyone

Table 3.—*Chemical analyses of water from wells and springs in the Hopkinsville area by U. S. Geological Survey*

[Chemical constituents given in parts per million. Water-bearing formation in Mississippian limestone except for well 8720-3650-27 which is in Bethel sandstone]

Well no.: For location of wells and springs see plate 4.

Well no.	Depth of well (feet)	Date of collection	Temperature (°F)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na) and potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Hardness as $CaCO_3$: Total	Hardness as $CaCO_3$: Noncarbonate	Specific conductance (micromhos at 25°C)	pH
8720-3645-5	101	Jan. 26, 1950	56	......	0.47	......	......	......	262	7	2	......	11	......	195	......	421	......
8	Spring	Jan. 27, 1950	48	......	2.6	......	......	......	148	11	4	......	7.6	......	123	......	248	......
19	107	Jan. 26, 1950	52	......	.41	......	......	......	106	5	5	......	16	......	99	......	219	......
27	65	.....do.........	56	......	.16	......	......	......	288	42	23	......	29	......	302	......	623	......
35	20	Jan. 25, 1950	58	......	.50	......	......	......	192	8	20	......	98	......	250	......	545	......
50	Spring	Jan. 27, 1950	55	......	1.5	......	......	......	285	844	172	......	.0	......	790	......	2,300	......
51	90	Jan. 26, 1950	66	......	1.8	......	......	......	183	17	6	......	7.5	......	173	......	355	......
		June 7, 1950	62	8.2	.19	69	11	2.8	227	25	5.8	0.2	3.4	240	217	31	393	7.8
		Feb. 15, 1952	80	......	.85	......	......	......	204	20	4.5	.2	5.2	......	182	......	360	......
		Sept. 26, 1950	......	......	1.7	......	......	......	263	110	23	.7	.0	......	314	......	671	......
68	14	Jan. 27, 1950	58	......	.31	......	......	......	187	18	12	......	32	......	182	......	434	......
76	102	Jan. 26, 1950	56	......	.79	......	......	......	222	5	5	......	4.2	......	172	......	357	......
77	65	June 7, 1950	60	......	.25	......	......	......	290	11	28	.3	35	......	283	......	598	......
93	139	Jan. 27, 1950	48	......	.41	......	......	......	296	47	12	......	7.0	......	66	......	605	......
94	130	Jan. 25, 1950	56	......	.73	......	......	......	125	15	12	......	76	......	178	......	398	......
102	25	Mar. 8, 1950	52	......	.67	......	......	......	281	27	10	.1	17	......	246	......	547	......
8720-3650-1	55	Mar. 9, 1950	56	......	.77	......	......	......	208	17	5	.5	4.2	......	172	......	360	......
19	60	June 7, 1950	60	10	.12	64	12	7.6	228	15	13	.5	4.3	231	209	22	388	7.9
21	40	Jan. 26, 1950	55	......	2.1	......	......	......	148	52	14	......	44	......	193	......	444	......
27	Spring	.....do.........	55	......	1.4	......	......	......	134	10	6	......	17	......	126	......	266	......
42	69	Mar. 9, 1950	53	......	.47	......	......	......	302	18	9	.8	9.8	......	280	......	536	......
43	125	June 8, 1950	65	......	.25	......	......	......	254	13	12	.1	18	......	251	......	500	......
51	Spring	.....do.........	57	......	.24	......	......	......	212	6	6	.1	8.3	......	184	......	360	......
8725-3645-10	76	Jan. 25, 1950	52	......	.76	......	......	......	236	8	28	......	252	......	408	......	893	......
18	100	June 7, 1950	58	......	.25	......	......	......	196	3	4	.0	12	......	198	......	334	......
19	65	Jan. 25, 1950	56	......	.08	......	......	......	234	16	2	......	9.6	......	207	......	411	......
24	65	June 7, 1950	60	8.0	.27	40	24	4.2	204	29	3.5	2.0	.1	211	198	31	352	7.9
25	58	Jan. 25, 1950	61	6.4	.13	120	12	31.0	238	55	64	.7	88	497	349	154	801	7.4
32	22	.....do.........	56	......	.22	......	......	......	124	12	13	......	38	......	140	......	325	......
41	23	.....do.........	54	4.6	.16	62	4.5	.2	190	9.3	2.8	.2	4.6	189	173	18	320	7.3
52	52	.....do.........	58	12	.57	66	17	21.0	61	5.4	32	.0	222	398	235	......	605	6.7

55	Spring	June 7, 1950	58	13	.86	48	4.1	20.0	190	8.2	3.5	.3	12	200	137	0	317	7.5
58	Spring	Jan. 25, 1950	58	......	.69	......	......	......	162	11	4	......	15	......	149	......	303	......
61	156	June 7, 1950	60	......	.26	......	......	......	213	32	12	.2	30	......	229	......	471	......
65	75	.....do......	64	8.8	.23	51	19	9.6	234	13	5.0	1.0	14	233	205	14	388	7.8
71	108	.....do......	60	......	.16	......	......	......	306	34	15	.5	29	......	286	......	589	......
79	85	Mar. 8, 1950	51	......	.92	......	......	......	180	75	66	.0	126	......	354	......	914	......
80	64	June 7, 1950	61	7.2	.17	70	7.7	15.0	228	23	10	.0	17	254	206	19	408	7.5
103	67	Jan. 26, 1950	56	......	1.5	......	......	......	189	57	10	......	26	......	204	......	466	......
126	65	Mar. 7, 1950	58	......	.21	......	......	......	256	31	11	.0	25	......	269	......	548	......
143	27	June 7, 1950	59	......	.45	......	......	......	180	9	9	.1	32	......	185	......	380	......
157	73	Mar. 7, 1950	58	7.2	.19	31	22	75.0	282	68	5.6	4.5	11	357	168	0	607	8.0
		June 7, 1950	62	......	.25	......	......	......	282	65	6	4.2	2.3	......	196	......	581	......
		Feb. 15, 1952	72	......	.15	......	......	......	284	64	5.5	4.5	2.7	......	164	......	576	......
		Sept. 26, 1952	......	......	.37	......	......	......	286	62	3.8	3.7	2.5	......	172	......	574	......
8725-3650-2	44	Jan. 27, 1950	54	......	2.2	......	......	......	182	71	5	......	13	......	185	......	416	......
6	86	.....do......	54	......	.38	......	......	......	274	32	4	......	3	......	222	......	548	......
15	65	June 7, 1950	63	7.0	.59	6.2	3.5	94.0	214	48	5.5	.6	.5	274	30	0	431	7.7
17	77	Jan. 27, 1950	66	......	1.6	......	......	......	272	42	14	......	.0	......	227	......	525	......
		June 7, 1950	......	......	.15	......	......	......	263	32	16	4.4	.4	......	227	......	501	......
21	136	Mar. 8, 1950	52	......	.43	......	......	......	300	69	11	3.2	5.4	......	111	......	648	......
43	59	.....do......	46	......	.21	......	......	......	208	19	4	.4	6.9	......	195	......	375	......
57	58	Mar. 9, 1950	57	......	.91	......	......	......	354	1	5	.7	1.8	......	274	......	542	......
134	75	June 7, 1950	......	6.5	.37	45	11	155.0	324	162	32	.2	19	605	158	0	862	7.4
137	130	Mar. 8, 1950	54	7.6	.53	134	10	16.0	283	139	13	.1	18	514	375	144	748	7.7
		June 8, 1950	61	......	.21	......	......	......	291	152	21	.1	17	......	400	......	772	......
		Feb. 15, 1952	49	......	1.5	......	......	......	304	133	8	.2	14	......	388	......	742	......
		Sept. 26, 1952	......	......	.24	......	......	......	300	142	68	.2	14	......	422	......	937	......
8730-3645-6	93	June 7, 1950	63	7.8	.12	62	24	7.5	302	11	5.5	.7	1.4	267	253	6	477	7.8
11	90	.....do......	59	13	.28	54	41	129.0	254	318	13	1.0	30	760	303	95	971	7.7

Table 4.—*Elements and substances commonly found in ground water*

Constituent	Source	Significance
Silica (SiO_2)	Siliceous minerals present in all formations.	Forms hard scale in pipes, boilers. Inhibits deterioration of zeolite-type water softeners.
Iron (Fe)	The common iron-bearing minerals present in most formations.	Oxidizes to a reddish-brown sediment. More than about 0.3 ppm stains laundry and utensils reddish brown, is objectionable for food processing, beverages. Larger quantities impart taste and favor the growth of iron bacteria.
Manganese (Mn)	Manganese-bearing minerals.	Rarer than iron; in general same objectionable features; brown to black stain.
Calcium (Ca) and magnesium (Mg)	Minerals that form limestone and dolomite and occur in some amount in almost all formations. Gypsum also a common source of calcium.	Cause most of the hardness and scale-forming properties of water, soap consuming.
Sodium (Na) and potassium (K)	Feldspars and other common minerals, ancient brines, sea water, industrial brines, and sewage.	In large amounts give salty tast; objectionable for specialized industrial water uses.
Bicarbonate (HCO_3) and carbonate (CO_3)	Action of carbon dioxide in water on carbonate minerals.	In combination with calcium and magnesium forms carbonate hardness which decomposes in boiling water with attendant formation of scale and release of corrosive carbon dioxide gas.
Sulfate (SO_4)	Gypsum, iron sulfides, and other rarer minerals; common in waters from coal-mining operations and many industrial wastes.	Sulfates of calcium and magnesium form hard scale.
Chloride (Cl)	Found in small amounts in all soils and rocks; natural and artificial brines, sea water, sewage.	In large enough amounts gives salty taste; objectionable for various specialized industrial uses of water.
Fluoride (F)	Various minerals of wide-spread occurrence, in minute amounts.	In water consumed by children, about 1.5 ppm and more may cause mottling of the enamel of teeth, and up to about 1.0 ppm seems to reduce decay of teeth.
Nitrate (NO_3)	Decayed organic matter, sewage, nitrate fertilizers, nitrates in soil.	Values higher than the local average may suggest pollution. There is evidence that more than about 45 ppm NO_3 may cause methemoglobinemia ("blue baby") of infants, sometimes fatal; thus waters of high nitrate content should not be used for baby feeding.

Table 5.— *Summary of chemical quality of ground water in the Hopkinsville area, Kentucky*

[Parts per million, except pH and specific conductance]

Characteristics and substances	Maximum	Minimum	Median[1]	Number of determinations
Silica (SiO_2)	13	4.6	7.8	15
Iron (Fe)	2.6	.08	.40	60
Calcium (Ca)	134	6.2	62	15
Magnesium (Mg)	41	3.5	12	15
Sodium (Na) and Potassium (K).	155	.2	16	15
Bicarbonate (HCO_3)	354	61	234	60
Sulfate (SO_4)	844	1	24	60
Chloride (Cl)	172	2	10	60
Fluoride (F)	4.5	.0	.3	39
Nitrate (NO_3)	252	.0	12.5	60
Dissolved solids	760	189	274	15
Hardness as $CaCO_3$				
Total	790	30	205	60
Noncarbonate	154	0	19	14
Specific conductance (micromhos at 25° C).	2,300	219	489	60
pH	8.0	6.7	7.7	15

[1]See p. 49 for explanation.

recognizes water that is hard, by the large amount of soap needed to make suds and the insoluble scum or scale that forms when the water is heated. Compounds of calcium and magnesium cause most of the hardness of these waters, but iron and manganese and certain other substances contribute some hardness. Carbonate or temporary hardness is due to the bicarbonates of calcium and magnesium; it can be eliminated by heating the water, but in the process scale forms on pipes, pots, and boilers. The noncarbonate or permanent hardness can be removed by chemical treatment.

The analyses given in table 3 were made to determine only the chemical nature of the water and do not disclose the sanitary characteristics of the water. However, the values for nitrate provide some evidence of pollution, as will be described.

Figure 14 shows graphically the nature of a few typical ground waters in the area. The units of the bar graphs are equivalents per million, the chemical combining weights of the substances, rather than parts per million. In most natural waters the cations or "bases" (calcium, magnesium, sodium, and potassium) exist in an equilibrium with the anions or acid radicals (bicarbonate, sulfate, chloride, and nitrate). When expressed in terms of chemical combining weights the sum of the cations equals the sum of the anions, within the limits of accuracy of analysis, and the left-hand column of cations is of the same height as the right-hand column of anions.

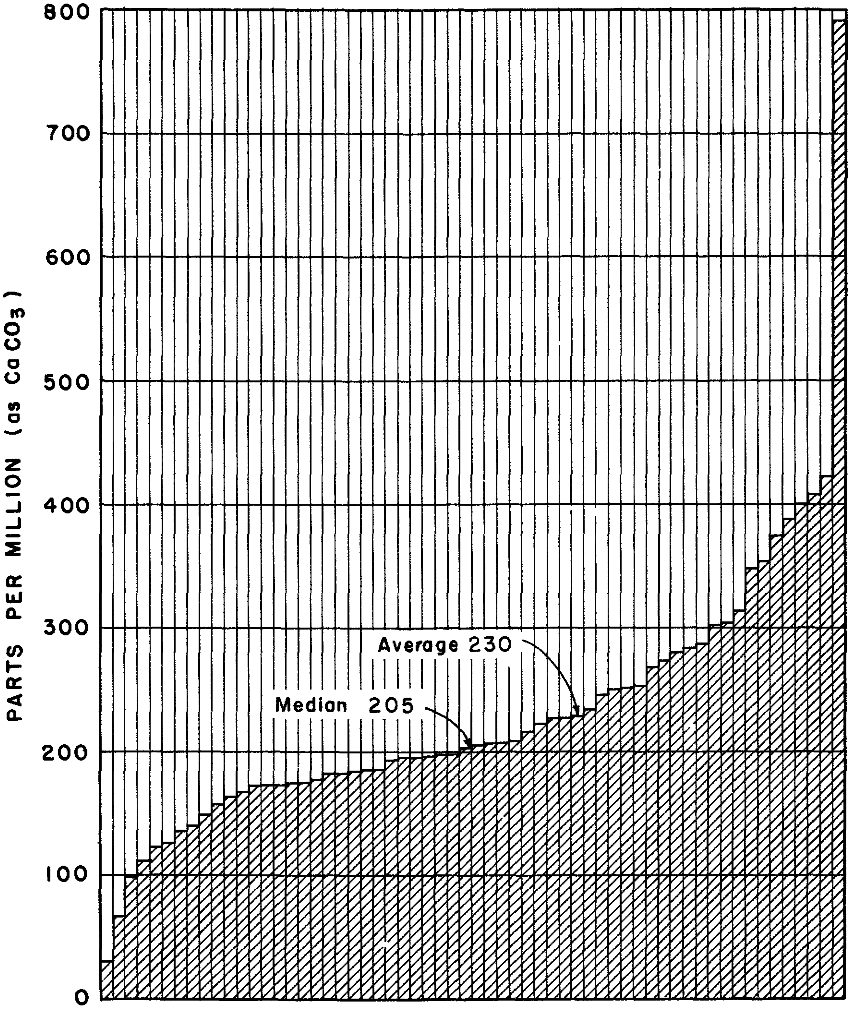

Figure 13. —Diagram showing range in total hardness of 60 samples of ground water.

GENERAL FEATURES OF THE WATER

Most of the ground water is of the calcium-magnesium bicarbonate class that is common in moist temperate regions. The water contains much dissolved calcium and magnesium because it occurs in limestone. The analyses given by Stokely and McFarlan (1952) of the limestones in the quarries near Hopkinsville show, on the average, 90.8 percent calcium carbonate and 4.2 percent magnesium carbonate. The bicarbonates of calcium and magnesium compose, by weight, about half the dissolved solids in the average ground water. That the carbonates occur in smaller proportions in the dissolved solids than in the rock shows that the

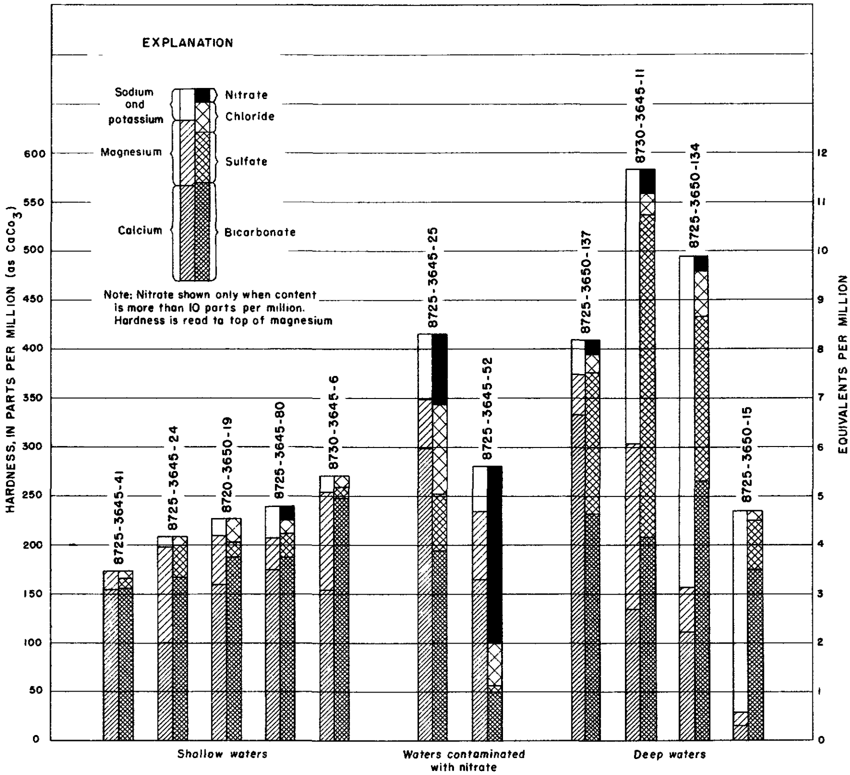

Figure 14. —Diagrams showing chemical character of typical samples of ground water.

ground water dissolves some minor substances in the rock and soil more readily than the main constituent of the rock, the calcium carbonate.

The other principal ions in the ground water are sodium and potassium, sulfate, chloride, and nitrate. As their concentration increases the water becomes distasteful or unusable.

Iron is generally present in mildly objectionable amounts. The median value is 0.4 ppm, so that many of the waters will cause slight staining of clothes and utensils.

Fluoride, which in ground waters generally is of natural origin, is of particular interest. Considerable evidence indicates that up to about 1.0 ppm of fluoride in water decreases the incidence of dental caries (decay of teeth) when the water is consumed by children during the period of formation of the teeth (Dean and others, 1941). More than 1.0 ppm of fluoride in water is associated with dental fluorosis (mottled enamel) if the water is used for drinking by children (Dean, 1936), though the effect is not pronounced until the content rises considerably higher. The U. S. Public Health Service (1946) specifies 1.5 ppm as the maximum.

The hardness of the waters sampled ranges from 30 to 790 ppm (fig. 13). Below is the scale commonly used to describe the hardness of water, and the percentage of samples falling into each category.

Hardness in ppm	*Description*	*Percent of samples*
0-60	Soft	2
61-120	Medium hard	5
121-200	Hard	43
201+	Very hard	50

The water from a great many of the wells and especially that from the springs becomes turbid with particles of sediment after heavy storms have provided much recharge. The more quickly turbid water appears in a well after a storm, the more likely it is that water enters freely through nearby sinks and then moves through large passages to the well. Such wells obviously are more likely to be contaminated by bacteria than others. The water in certain wells near streams becomes turbid after storms swell the streams, showing fairly good connection between well and stream. However, turbid water in a well does not always mean the entrance of muddy surface runoff. The increased flow after recharge occasionally dislodges clay from underground crevices and flushes it along. For example, it is customary to bail or pump heavily a newly completed well to dislodge clay from the local water-bearing crevices.

A few people state that the water in their wells never becomes turbid or at all cloudy, winter or summer. This suggests that recharge locally enters by filtering through the soil and not through large openings, or that tortuous and narrow passages, probably at considerable depth, feed water slowly to the well.

A principal defect of ground water in the limestones of this region is the ease with which it may become contaminated. As described later, a large percentage of these wells show contamination by bacteria.

The temperature of the ground water averages around 57° F, which is approximately the average of the year-round air temperature. The reason is that from a depth of a few feet to 100 feet or more the ground temperature is about the same as the annual air temperature and changes very little, and the water, whether from warm or cold rain, assumes this temperature after short contact with soil and rock. Some people claim that their well water is cooler in summer than winter, but the most likely explanation is that the water seems distinctly cool compared to summer air and warm compared to winter air but is at about the same temperature summer and winter. A few exceptions of course are to be expected, for where water has easy and quick access into the ground the ground-water temperatures will show some reflection of the cold rains of winter and warmer ones of summer.

The differences in the chemical quality of water from one well to another are usually much greater than the changes that take place in one well from the winter season of recharge to the summer season of depletion. Quality varies from well to well mainly because of the local differences in topography and crevices which determine how long the water is in contact with soil and rock before moving on. Close to the surface the water is good, except when contaminated, but with increasing depth it becomes poorer in quality. Sulfurous compounds are the most objectionable substances. Apparently the passages become fewer and smaller at depth, circulation decreases, and the water is long in contact with the rock and its dissolved solids increase correspondingly.

A review of the analyses, especially the 15 comprehensive analyses, shows that one can distinguish three types of water. The first type is the water of generally satisfactory quality, characterized by high proportions of bicarbonate. It will be referred to as the shallow water because it prevails in the upper part of the zone of crevices. The second type is the water of less satisfactory to unusable quality, characterized by a higher mineral content and a higher proportion of sulfate than exists in the shallow water. It will be referred to as the deep water because it prevails in the deeper part of the creviced zone. A third type, contaminated water, contains substances which create a hazard to health. Figure 14 presents graphically some examples of these three types.

This classification has been made only to facilitate description. No attempt has been made to define the three types rigidly, for this would require setting up artificial limits that are of little true significance because the types of water grade into each other. For example, in many places the position of a boundary between satisfactory and unsatisfactory water would depend either on the tolerance of the user for various dissolved substances or on the purpose to be served by the water. Or, because of the content of nitrate a small percentage of these waters are contaminated and therefore are unsafe for the preparation of food for babies but are safe for adults.

SHALLOW WATER

Water from about three-quarters of the sampled wells and springs has neither objectionably high mineral content nor obvious contamination with nitrate. However, waters from a large proportion of these wells may show bacterial contamination.

The principal substances in solution in this type of water, as the diagrams of figure 14 show, are the bicarbonates of calcium and magnesium. They make up about 90 percent of the dissolved solids, leaving only 10 percent for varying amounts of sodium and potassium, sulfate, chloride, and nitrate. The dissolved solids average 232 ppm in the 8 complete analyses available of this type of water. Hardness in these 8 samples averaged 200 ppm, of which 18 parts was noncarbonate or permanent hardness.

The concentration of dissolved substances increases somewhat from the winter season of recharge to the summer season of discharge and depletion. Figure 15 demonstrates the changes that occurred in the water from well 8720-3645-51 during 1952. In late summer the value for sulfate was 110 ppm, more than five times the winter value, bringing the water of late summer into the deep-water type. The changes in the water of this well were greater than those in water from other wells that were repeatedly sampled (8725-3645-157, 8725-3650-137), presumably because sulfurous water is present in the vicinity and issues from spring 8720-3645-50 about 500 feet away. Nevertheless, many farmers report that the water from their wells not only becomes harder toward autumn but acquires a distinctly sulfurous taste or odor. In all such wells the water freshens each winter.

The main reason why dissolved substances increase late in summer is that water then drawn from wells has been in contact with rock longer than water drawn in winter. Most of the recharge halts at the beginning of the growing season. As the water level declines, water comes from the deeper openings which are smaller than those nearer the surface, permit less rapid flow, and keep the water longer in contact with rock. Moreover, it is believed that after the water level falls and water has drained from the larger openings, a little water that has been in intimate contact with rock in small openings continues to trickle down to the water table. Finally, pumping a well sets up flow from below as well as laterally, so the poorer water from below moves toward the well.

The depth to water that drillers or owners of wells report as "bad," "sulfurous," or "mineralized," and more or less objectionable for domestic use during at least part of the year, varies much from place to place. Sulfurous water flows at the surface from the

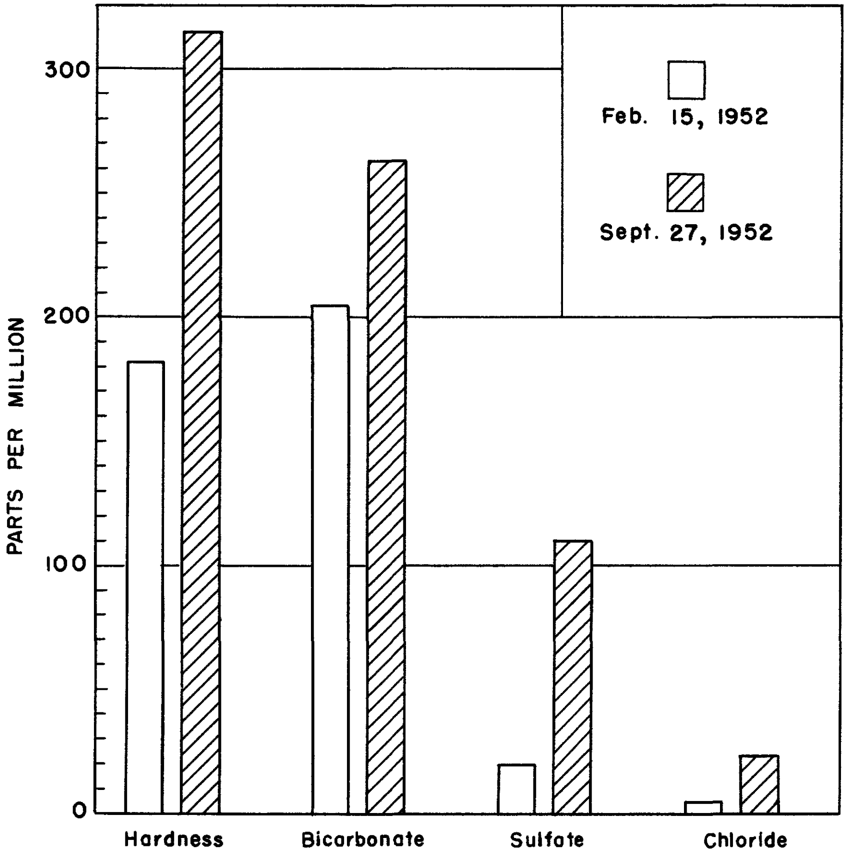

Figure 15. —Diagrams showing change in chemical quality of water from well 8720-3645-51 from winter to summer.

spring 8720-3645-50 close to the Pembroke Benevolent Home, yet elsewhere in the area two or three wells are reported to obtain water of acceptable quality from crevices more than 200 feet below the surface.

Figure 16 shows, by depth, the number of crevices reported to yield water of good quality, and the number reported to yield water of poor quality. The curve gives the percentage yielding water of poor quality. The data on crevices are the same used to compile figure 7, which should be compared. The curve in figure 16, which is a smoothed or running average, shows how with increasing depth a larger and larger percentage of the crevices yield water of poor quality. At a depth of 40 feet only about 1 crevice in 10 yields water of poor quality; at 80 feet about 1 crevice in 4 yields water of poor quality. The curve has not been extended below 150 feet, for very few wells penetrate deeper and the information is not only scanty

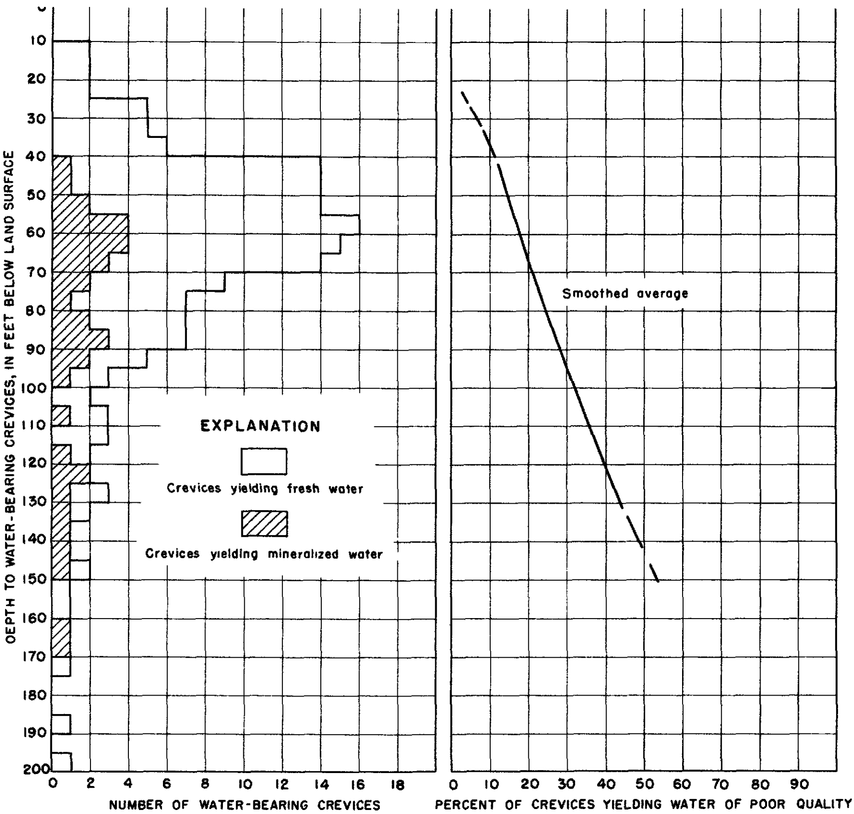

Figure 16.—Diagram and curve showing deterioration in chemical quality of water with increasing depth to crevices.

but somewhat unreliable. In a few cases satisfactory water has come from crevices as deep as 200 feet; in others the good water reported from such depths may have come from seeps farther up the hole which escaped the notice of the driller.

Some of the reports of poor water seem to indicate pockets of poor circulation here and there, in places close to the surface, rather than the base of the fresh water zone. For example, some wells are known to have yielded sulfurous water when they were completed, but later after pumping the water freshened and was satisfactory. Apparently, the crevices near these wells and the water in them were somewhat isolated from the surrounding crevice system, perhaps because the openings in rock were naturally small or because clay partly clogged them. Pumping that withdrew the stagnant water and in some places flushed clay out of passages, permitted fresher water to enter.

The increase, from near the surface to depth, in percentage of crevices yielding poor water shows how circulation gradually dies away downward. This curve (fig. 16), like that in figure 7, seems to show that circulation extends deeper in the limestone of this region than in the limestone of the Blue Grass region of the State. According to Hamilton (1950), in the Blue Grass region the water from crevices more than 100 feet below the surface is, with only rare exceptions, poor because of high content of hydrogen sulfide and salt. Here in the Hopkinsville quadrangle only about a third of the crevices at 100 feet yield poor water. The difference is due, as explained previously, to difference in geology; scattered thin beds of shale in the limestones of the Blue Grass region have impeded the process of solution and development of openings.

DEEP WATER

About 14 percent of the samples of water that were analyzed may be assigned to the deep type of water, because of high content of dissolved solids and taste or odor. Waters of this type may be considered poor in this region but they are not always too poor to be used. Many people use this deep water because it happens to be the type yielded by their wells, and they are unable or unwilling to spend more money on additional attempts to get better water at shallower depth. Furthermore, most people quickly grow accustomed to water having a taste that at first seems objectionably strong to them; later they do not notice this taste unless very strong.

Dissolved solids averaged 502 ppm in 5 comprehensive analyses of deep water, but only 232 ppm in 8 comprehensive analyses of the shallow waters. Sodium, potassium, and sulfate make up a much larger proportion of the dissolved solids of deep than of shallow water, as shown by the diagrams of figure 14. Sulfate content averages 147 ppm in the deep water but only 17 ppm in the shallow water. The sulfate so prominent in the analyses of the deep water probably comes from gypsum or from anhydrite, minerals likely to occur in small amounts distributed through limestone.

The hardness of deep water is generally higher than that of shallow water. However, a great range is exhibited from the highest to the lowest values. Noncarbonate or permanent hardness of the deep water averages 48 ppm, approximately three times the value for shallow water.

The tastes present in deep water arise from hydrogen sulfide and from large concentrations of various other dissolved substances, principally sodium, magnesium, chloride, and sulfate. The sulfurous odor occasionally noted is due to the gas hydrogen sulfide.

Most of this gas and the odor it causes can be removed by simple aeration of the water.

The very soft sodium bicarbonate water from well 8725-3650-15 is plotted with the deep waters (fig. 14) though it is quite unlike them. This water is unusual for a limestone area. It is the only one of its kind found in the quadrangle and is a very local feature that is due to unknown causes.

CONTAMINATED WATER

The term contaminated water usually signifies water containing substances that may endanger health. If one uses as a guide only the mineral analyses presented in this report, water from about an eighth of the sampled wells may be considered unsafe for babies to drink, because it contains more than 45 ppm of nitrate. The bacterial analyses made by the Kentucky State Department of Health show that the water from a considerably larger percentage of wells has potential hazards for adults as well as children.

Small babies develop the condition called "blue baby" (infant cyanosis or methemoglobinemia) if the water given them to drink or used in their formulas has excessive amounts of nitrate (Maxey, 1950). The amount that is harmful naturally varies from one baby to another but 45 ppm is currently set as the danger point. Figure 17 and table 3 show that 6 of the 60 wells and springs sampled yield water containing more than 45 ppm of nitrate.

The generally high values of nitrate in these waters suggest contamination by human and animal wastes, for nitrate is a principal product of the decomposition of such wastes. The average value of 26 ppm and the median value of 12.5 ppm are higher than would be expected from natural causes. According to Schreiner and Brown (1938, p. 361–376), the rain yearly washes out of the air and onto each acre of ground about 5 to 7 pounds of nitrogen. This would give only a fraction of a part per million in the ground water. Most of the nitrate that occurs naturally in ground water, rarely more than a few parts per million, comes from the normal decay of organic matter on the surface and in the soil. Probably a little more nitrate is to be expected in the ground water of the limestone reservoir than in a sand or sandstone. As water trickles down through soil the roots of plants and the microorganisms that live in soil extract much of the nitrogen for their own use. Here some of the water moves through sinks to the ground-water reservoir, bypassing the slower route through soil where some nitrate would be lost, and contributes it all to ground water. Nevertheless, it

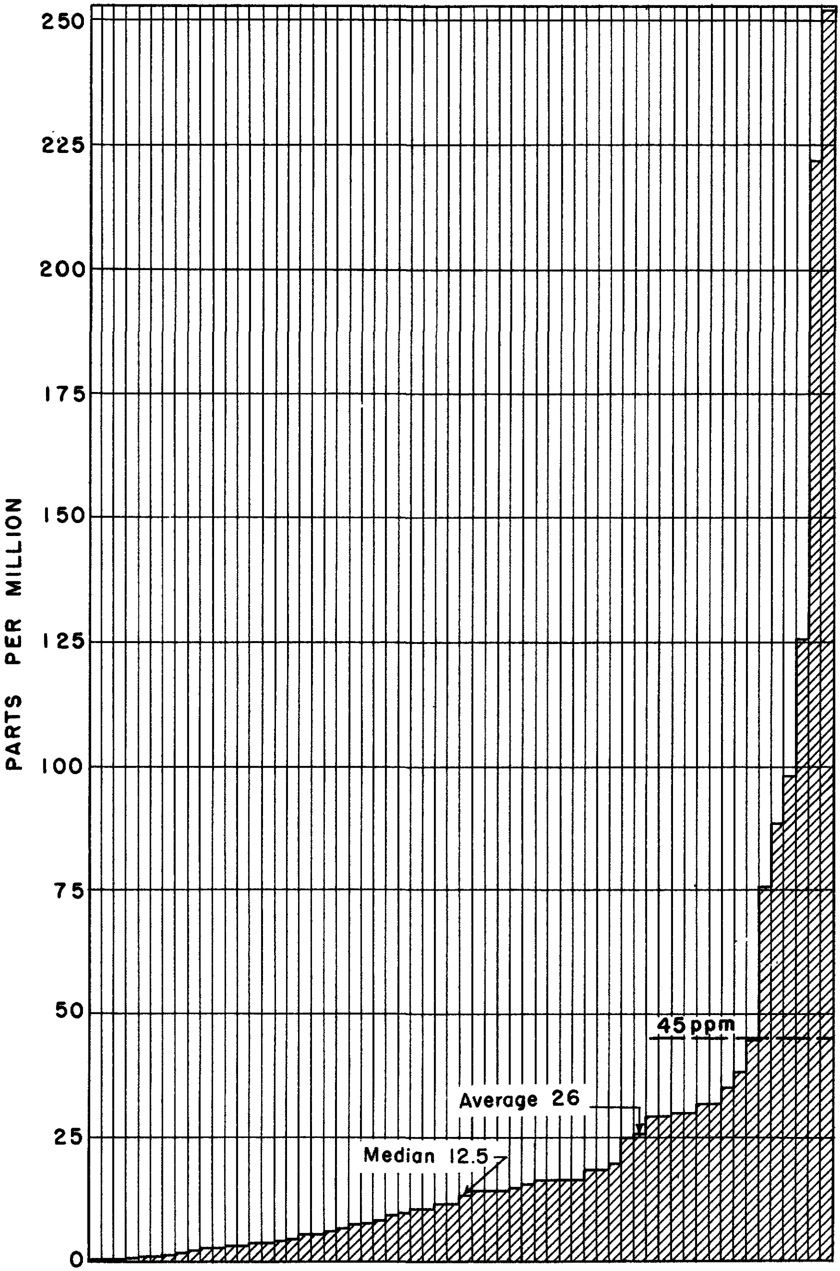

Figure 17. —Diagram showing range of nitrate content in 60 samples of ground water.

is very likely that values of nitrate over 5 ppm, and especially those over 10 ppm, result from the activities of man.

Bacterial analyses of the ground waters of Christian County made by the Kentucky State Department of Health show frequent contamination with bacteria and more or less prove that animal and human wastes cause the high nitrate values. Of 520 analyses of ground water made during the years 1948 through the first part of 1953, 270 or 52 percent showed bacteria of the colon group. These bacteria are common in the intestinal tracts of man and animals; where water spreads the colon bacteria it can also spread the dangerous types of bacteria if they are present. These 520 analyses do not represent the same number of wells, for some wells were sampled more than once. Nevertheless, it is evident that contamination by sewage is both frequent and widespread, and this is a satisfactory explanation for the abnormally high nitrate values. Inspection of the Health Board analyses shows that when nitrate exceeds 45 ppm usually the colon bacteria are present; on the other hand, the bacteria are also present in many waters having less than 45 ppm of nitrate.

In the limestone area where open crevices permit quick circulation of water, contamination of a large percentage of wells is inevitable as long as wells are not far from the barnyard and stock, and the sanitary facilities. A well that is shielded from surface runoff and tightly cased is less likely to be contaminated, but still the Health Department analyses show contamination of many wells more than 100 feet deep. There is no reason why contamination cannot move long distances in limestone, not just hundreds of yards but even miles, though of course the contamination becomes more diluted and less dangerous with increasing distance from its source.

To avoid contamination as much as possible, new wells should be located upslope and as far as possible from the barnyard and house. Whether the well is old or new, samples of the water should be analyzed. If contamination is found it may be possible to reduce or eliminate it by leading wastes away some distance instead of permitting them to enter the ground near the well.

DEVELOPMENT OF WELLS

TYPES OF WELLS

In this area 57 dug wells were found; this is 15 percent of the total of 368 wells (fig. 18). Many of these dug wells are old, dating

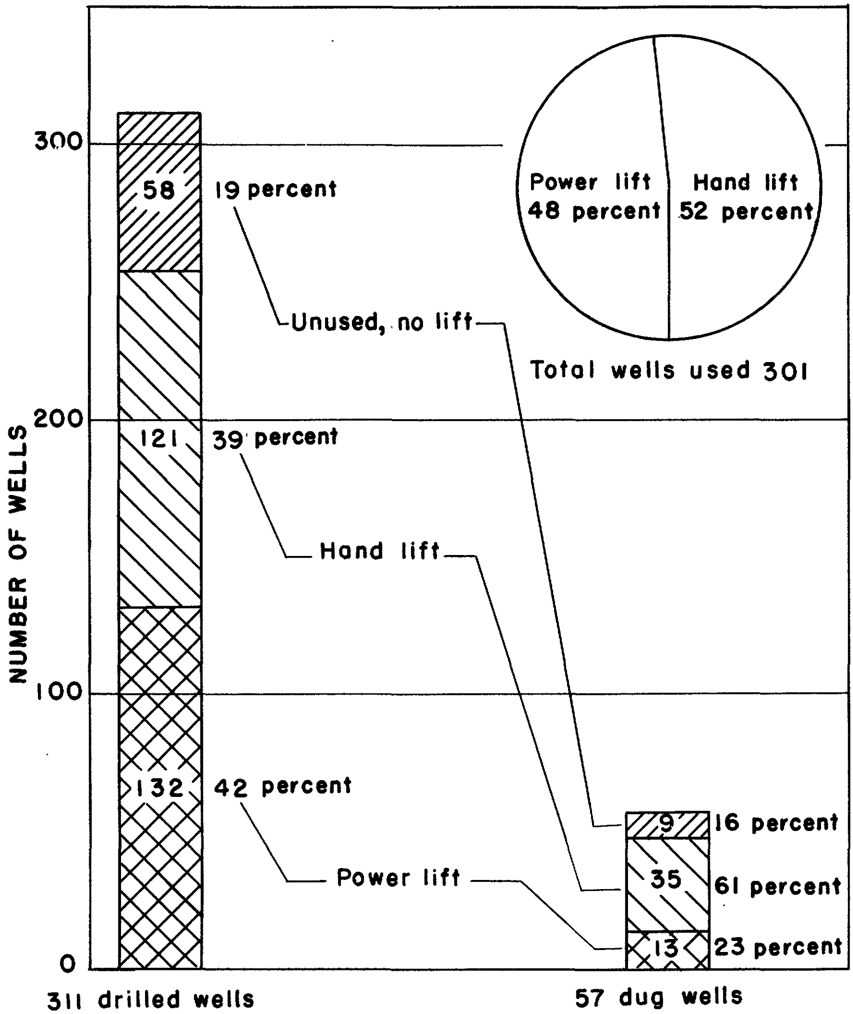

Figure 18. — Graphs showing types of wells and lift employed.

back into the last century according to their owners, for almost all new wells are drilled rather than dug. Dug wells may be as much as 6 feet in diameter, but 3 to 4 feet is more common. The walls usually are lined with brick or with fragments of limestone laid dry, but clay pipe of large diameter has been used in a few wells dug recently. Unless a dug well is soundly walled in near the surface, it is bound to receive surface runoff from the vicinity in heavy rains. Such runoff seems to be the main source of supply to some shallow and neglected dug wells. With surface runoff comes greater likelihood of pollution, one of the reasons for the gradual abandonment of dug wells.

A small percentage of dug wells are bottomed in the thick clay soil above limestone bedrock, and tap only the small seeps of water encountered in the clay. Such wells have among the lowest yields noted and, if used, indicate very small demand for ground water by their owners. Most of the dug wells end on bedrock or perhaps were blasted a few feet into bedrock. These wells usually get water from the seeps that occur on the top of bedrock, but a few encounter the underground streams described earlier and have large yields during much of the year.

The inventory lists 311 drilled wells, 85 percent of the total (fig. 18). At the current cost of labor it is cheaper at most sites to drill than to dig a well, and faster. Drilled wells penetrate farther below the water table than dug wells and are less likely to go dry in summer; if properly cased they are less subject to pollution from the surface. The construction of drilled wells here is very simple. Casing is set down through soil into the first firm rock. The driller deepens the hole with percussion tools in rock until the drill encounters a crevice yielding a supply that appears satisfactory to him. Usually he drills a few feet more hole, known as basement, for storage, for material that may settle out of the water, and perhaps to permit the deepest possible pump setting. The hole generally is left uncased in the firm limestone. Diameters of surface casing run from 4 to 12 inches, but 6 inches is by far the most common.

METHODS OF LIFT

About 82 percent of the wells in the area are used during all or part of the year (fig. 19). Water is lifted from slightly more than half the used wells (fig. 18) by hand. The simplest form of hand lift is the bucket raised from a dug well by rope or chain and pulley, occasionally with a windlass. A special long and narrow bailer of galvanized iron, with a valve on the bottom, is standard in drilled wells. The pitcher or suction pump is used where the depth to water is not more than about 25 feet, and the "deep well" piston or force pump where summer water levels lie deeper. As figure 18 shows, hand lift is most common on the dug wells, reflecting the lower yield of this type of well.

Power pumps are installed on about 42 percent of the drilled wells and 23 percent of dug wells. Most of these are jet pumps which by forcing a small stream of water at high speed into a submerged pipe lift water to the surface. Electric motors of about

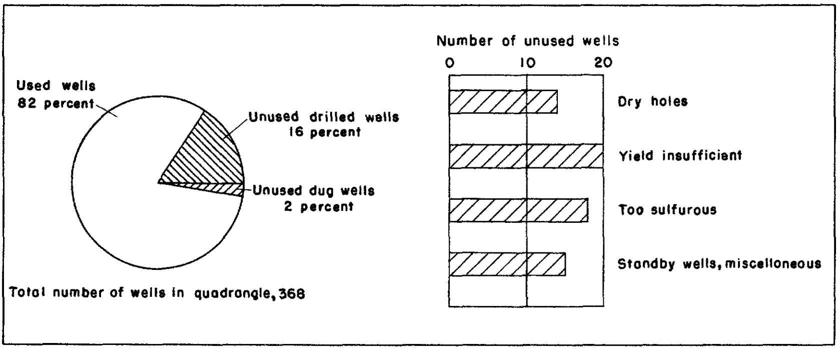

Figure 19. —Graphs showing percentage of total wells unused and reasons for lack of use.

one-half horsepower drive these pumps. Piston pumps with small gasoline or electric motors are used on a few wells. Only one windmill was recorded; they were more common before electrification of the area.

YIELDS OF WELLS

The sustained yield of a well (sometimes called its capacity) is the maximum rate of continuous pumping that will not exhaust the supply. Few owners of wells here, or anywhere else, know the sustained yields of their wells, mainly because they have no need to pump them continuously. With or without automatic controls, their pumps operate only intermittently. Between times water moves toward the wells and water levels recover more or less from the drawdown caused by pumping.

Many well owners can give pumping rates which are short-term yields. For example, they may know rates of pumping that do not exhaust their wells over periods of several hours or days, or rates that do exhaust the wells over similar periods. They occasionally know how long it took for the water level to recover after a large, known amount of water was pumped, perhaps to fill tanks. All such reported rates are likely to be considerably greater than the sustained yield, except when there are reliable reports that the pumping caused very little lowering of water level.

Such reports have value because they reveal what farmers and householders have come to expect of their wells when, now and then, they need as much water as they can get. To some extent the reported rates are conservative, for most of them were determined

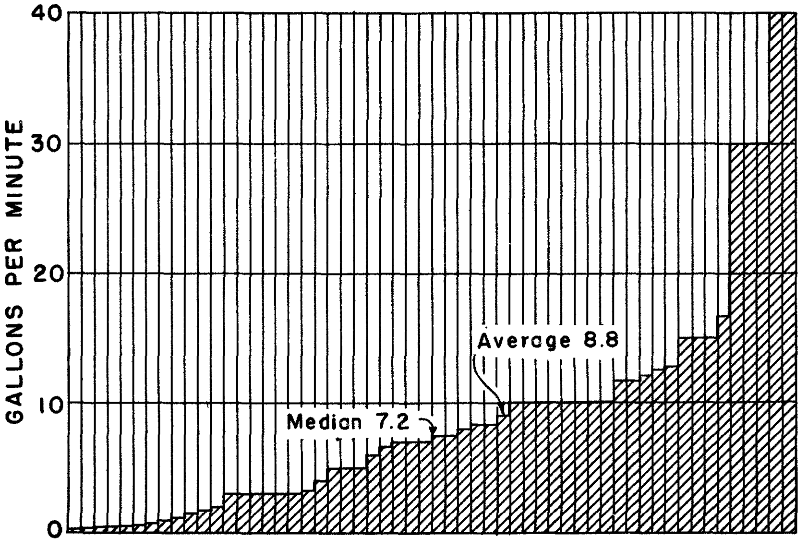

Figure 20. —Diagram showing reported capacities of 56 wells over at least 24 hours.

in the summer season of low water levels when wells were pumped to their limits for irrigating gardens or watering stock. Yields in winter would naturally be greater.

Figure 20 shows for 56 wells the pumping rates that, according to the owners, did not exhaust the wells in less than about a day. The rates range from about 1/3 to 40 gpm. The average is 8.8 but the more representative median is 7.2 gpm.

These 56 values are all that could be obtained in the area from well owners, but it is suspected that they do not truly represent the entire range of well yields. Some wells undoubtedly can yield more than 40 gpm over 24 hours; others certainly yield less than a third of a gallon a minute over 24 hours.

Many wells, especially certain dug wells, are usable sources of water only because they store the water which trickles in very slowly. A dug well 4 feet in diameter can store 94 gallons for every foot of depth; a 6-inch drilled well stores the same amount in 64 feet. Many of the rural households use no more than 50 gallons of water a day, and a well yielding only a thirtieth of a gallon a minute can supply this much.

In all the area, only about 5 wells were reported to have capacities of 20 gpm or over. It is likely that somewhat more may have such capacities. Most people do not need so much water and the much-used 1/2-horsepower pump, working against the heads normal in the area, pumps somewhat less than 20 gpm. If such pumpage does not exhaust the well, the capacity of the well may be considerably greater. However, yields of 20 gpm probably can be obtained only in certain parts of the area and, even in these parts, after several tries.

Almost all the wells having reported yields of more than 20 gpm are in the valley bottom lands. Well 8725-3650-134 in Hopkinsville can be pumped at 40 gpm for a day or more, it is reported, without much drawdown. This well lies only a few hundred feet east of the North Fork Little River. Well 8725-3650-137, considerably farther from the river in Hopkinsville, can be pumped dry in 24 hours, at about 100 gpm. Two of the three wells said to have capacities of 30 gpm are located away from the river but on principal lines of drainage; the third is on the upland, but only about 60 feet above river level. Pumping of this last well, 8725-3645-158, at about 30 gpm for 3 days showed a specific capacity of about 2 gpm per foot of drawdown.

No reason appears why more wells having short-term yields of 20 gallons or more a minute could not be developed in and close to the river valleys, and in places along the courses of tributary drainageways. The underground drainage flows to and along these lines; beneath them solution has apparently developed a more open system of crevices in which water moves more freely and stands closer to the surface than under the higher land.

Anywhere in the area a single well may fail altogether to find a crevice in the fresh-water zone, so even in the valleys it may be necessary to drill more than one well to get a small usable supply. To get a supply of 20 gallons a minute or more a fairly large crevice will have to be found and this may take several attempts. Few data are available on the probabilities. At least two wells (8725-3650-71 and -72) were drilled near the river in an unsuccessful attempt to develop water for the Western State Hospital.

The computed figure for the storage coefficient in bedrock crevices, about 0.005, gives some idea of the total amount of water available to wells. With this amount of space about 1 inch of water is stored for every 17 feet below the water table. Over an acre this inch comes to about 27,000 gallons of water, which at 10 gpm could be pumped in slightly less than 2 days. These data are given only to show the general magnitude of the figures. Pumping develops a depression or cone in the surface of the water level and the margin of this cone spreads out to distances that depend on rate and time of pumping and the size of the water-yielding openings.

The amount of water stored in the bedrock reservoir in the range between the high water levels of winter and the low water levels of late summer probably does not exceed 2 inches. In a year (1950–51) with winter rains and water levels higher than average, and summer rains and water levels about normal, the range of average water level in the basin of the South Fork was only 13 feet (pl. 2). This 13 feet would correspond to storage of a little less than an inch of water, if the coefficient of 0.005 applied through this range. Because the openings grow somewhat larger near the surface, 2 inches is a more reasonable estimate of the amount of water stored in this interval in winter. Naturally the amount stored in the interval between high and low water level varies from place to place, because water levels range over a greater distance in some parts of the quadrangle than in others, as the hydrographs on plate 1 clearly show. The range in these wells gives only a rough idea of the actual range in inches of storage, for the storage coefficient of 0.005 is the average for 11 wells and only generally applicable; the value at any one place may be much more or much less than the average.

Considerable water remains in storage and available to wells even after water levels have declined so far in late summer that natural discharge to springs and streamflow becomes very small. The amount can only be estimated. It has been shown (fig. 16) that at somewhere around 100 to 110 feet below the surface the quality of the water begins to deteriorate rapidly.

Because the average depth to water in the summer is more than 25 feet, in the basin of the South Fork the zone of acceptable water can be taken to extend perhaps 80 or 85 feet below the level of water in summer. About 5 inches of acceptable water would be stored if the coefficient of 0.005 applied to the full remaining depth of 80 to 85 feet. However, it seems evident that both the size and the frequency of these openings decrease with depth, if only because the circulation of water from the surface downward developed the openings. One must also consider that pumping draws water upward from below as well as in from the sides, so that it would not be possible to pump off the layer of usable water down to its ill-defined base. Because of the many reports of deterioration of the quality of well water in late summer, it may be that recoverable water of satisfactory quality stored in crevices below summer water levels amounts to no more than half the total storage of 5 inches—say, $2\frac{1}{2}$ inches.

If the water available in summer amounts to $2\frac{1}{2}$ inches and that in winter to perhaps as much as 2 inches more, the storage capacity of the ground-water reservoir is close to that of the soil which in an earlier section has been estimated as probably no less than about 4 inches. During a drought heavy pumping all over the area might supply enough water to restore at least a major part of the depleted soil moisture over the same area. In irrigating, of course, a farmer will concentrate on an area of a few acres the ground water developed by lowering the water level beneath a much larger area. And, of course, it would never be practical to lower the water level uniformly beneath the whole area.

USAGE

Practically all the ground water pumped in the quadrangle is for home and farm supplies. It is used for domestic purposes, for watering stock, and occasionally for irrigating small gardens. Commercial establishments in and near Hopkinsville use only small amounts of ground water. A few wells are pumped for air conditioning and cooling, and one for ice making. The ground water is cooler in summer than the water delivered by the city water plant from the North Fork Little River and storage reservoirs. This advantage is offset for many purposes by the higher mineral content and hardness of ground water, by its tendency to become turbid after heavy rains, and by the likelihood that it may become contaminated.

In the rural part of the area the usage of ground water for all purposes appears to be about 57 gpd per person. This estimate is based on information from only 12 farms supplied by power pumps, and 7 by hand-drawn water. A larger amount of basic information could not be gathered readily, for very few people whose water is not metered have any idea how much they use.

Estimates of ground-water pumpage from wells equipped with power pumps ranged from 968 to 9 gpd per person. The estimate of 968 was obtained at a farm where many cattle are watered. These estimates (for wells having power pumps) average 187 gpd per capita, but the median is 107. For wells without power pumps the estimates ran from 1 to 25 gallons per person per day; both average and median were about 12. This lower figure of course reflects the greater effort of drawing water by hand and the lack of bathrooms and perhaps other conveniences, such as washing machines, in the homes. The medians of 107 and 12, weighted according to the proportions of wells pumped by hand and by power (fig. 18), give the figure of 57. The figure, of course, is only an estimate because of the sparse data used to derive it. Also, it represents only ground-water usage, not total usage of water, for a large percentage of the stock drink from ponds, springs, and streams. Water from cisterns still is much used in homes because it is so soft.

At 57 gallons per person the daily pumpage in the rural part of the area amounts to about 77,000 gallons, for it has a rural population of about 1,350, to judge from the 1950 census figure on density of rural population over all Christian County.

For comparison, the 16,531 persons supplied by the Hopkinsville water system used in 1950 about a million gallons per day, or 60 gallons per person, according to data gathered by the Geological Survey (Lohr and others, 1952, p. 26). These figures include industrial as well as domestic usage.

RECORDS OF WELLS AND SPRINGS

The well and spring records that follow, tables 6 and 7, include most of the data obtained by the Geological Survey during this investigation. The wells and springs are listed in order, although separately, according to the numbering system explained in the introduction, and are located on the map, plate 4.

In table 6 are listed 369 wells by identification number, followed by the location of the well and the names of the owner, and driller, if applicable. Depths of wells and depths to water were measured unless noted "reported." Depths to water-bearing crevices, indicating the probable horizon of the source, and estimated yields were reported by the owner or driller. Other information is included under "Remarks."

Table 7 lists 76 springs by identification number, followed by the location, owner or name, topographic setting, improvements, flow, and remarks. The flow data were estimated or measured by Survey personel. Other information is included under the remarks column.

Table 6.—*Records of wells in the Hopkinsville area, Kentucky*

Well no.: For location of wells see plate 4.
Type of well: Dr, drilled; Du, dug.
Depth of well and water level: Measured by the U. S. Geological Survey except those preceded by letter "R", which are reported.
Type of lift: B, bucket; H, hand; J, jet; W, windmill.
Remarks: Except when otherwise noted, water-bearing formation is limestone, and water is used for domestic and stock purposes.

Well no.	Location	Owner or name	Driller	Type of well	Depth of well (feet)	Depth to water-bearing crevices, reported (feet)	Water level: Below land surface (feet)	Water level: Date of measurement	Type of lift	Estimated yield, reported (gpm)	Remarks
8720-3645-1	1.5 miles northeast of Casky.	Ivo Thompson....	B. F. Jones....	Dr	97.8	93	53	Jan. 25, 1949	B	....	4 ft cave near top of bedrock. Observation well.
2	.......do..........	J. L. Mielke.....	....	Du	24.7	....	22.3	.......do......	H	....	
3	.......do..........	J. W. Sholar.....	....	Du	16	....	12	.......do......	J	....	
4	2.5 miles northeast of Casky.	R. H. Clarke....	....	Du	35	....	25	Nov. 7, 1949	J	3-5	
5	3 miles east-northeast of Casky.	D. H. Ricchuite	Jack Doudy....	Dr	101.6	....	32.9	October 1949	J	....	Analysis available.
6	2.5 miles northeast of Casky.	A. T. Winstad...	....	Dr	110	....	....	....	H	¼-2	
7	2 miles east of Casky...	Raymond Long...	R. H. Clarke..	Dr	....	....	....	....	H	6	
10	2.5 miles east of Casky.	.......do..........	B. F. Jones.....	Dr	R69	....	17	Sept. 5, 1950	B	....	Observation well. Sulfurous.
11	4.7 miles southeast of Casky.	H. B. Bolinger...	J. H. O'Dell...	Dr	127	116	52.8	Nov. 16, 1949	B	....	Do.
12	3.5 miles east-southeast of Casky.	Abbie Macrae....	....	Du	31	....	29.6	Nov. 18, 1949	H	....	Observation well.
13	3.4 miles east-southeast of Casky.	O. E. Yancey....	....	Dr	R68	....	....	....	H	1	
19	3.2 miles southeast of Casky.	Austin Fleming..	F. C. Jones....	Dr	R107	107	30	Nov. 21, 1949	J	10-20	Analysis available.
23	3.6 miles southeast of Casky.	J. E. Maddux....	Jack Doudy....	Dr	R75	50	....	....	J	6-10	
24	2.7 miles southeast of Casky.	E. E. Wimpy.....	....	Dr	63	....	15.2	Nov. 23, 1949	H	3	Observation well.
25	.......do..........	.......do..........	C. Blaylock...	Dr	R101	80 95	45	.......do......	J	6-10	
26	2.5 miles southeast of Casky.	Ollie Vronade....	....	Dr	R130	....	....	....	H	....	

Table 6.—*Records of wells in the Hopkinsville area, Kentucky*—Continued

Well no.	Location	Owner or name	Driller	Type of well	Depth of well (feet)	Depth to water-bearing crevices, reported (feet)	Water level: Below land surface (feet)	Water level: Date of measurement	Type of lift	Estimated yield, reported (gpm)	Remarks
8720-3645-27	2.3 miles southeast of Casky.	D. W. Dulin.....	B. F. Jones....	Dr	R65	48	R30	November 1949	J	3-5	Analysis available.
29	3 miles east of Casky...	George Knight...	....	Du	19.7	19	16	Nov. 14, 1949	B	....	Water on top of bed-rock.
30	4.4 miles south-southeast of Casky.	Mrs. W. B. Belote.	....	Dr	100	....	....	....	H	6-10	If pumped heavily, water becomes sulfurous.
31	3.8 miles south-southeast of Casky.	H. E. Beebe......	....	Du	R22	20	....	....	H	3-5	Water at top of bed-rock.
34	3.9 miles southeast of Casky.	A. D. Dossett...	Charles Price..	Dr	50	18	9.1	Dec. 5, 1949	H	6-10	
35	4.2 miles south-southeast of Casky.	W. R. Petty.....	....	Du	R20	30	3	Jan. 5, 1945	J	6-10	Analysis available.
47	4 miles southeast of Casky.	Harry Macrae....	....	Du	15	15	7.21	Jan. 11, 1950	J	6-10	Muddy after rain.
48	3.9 miles southeast of Casky.	M. P. Spicer.....	....	Dr	38.5	....	9.45	.......do.......	J	3-5	Observation well.
49	.......do........	S. B. McGhee...	....	Du	R45	....	R10-12	......do.......	H	....	
51	.......do........	Pembroke Benevolent Home.	....	Dr	R90	87	....	....	J	20-30	Analysis available.
52	.......do........	City of Pembroke	....	Dr	R20	....	....	....	H	¼-2	
53	4.4 miles south-southeast of Casky.	Holland Garnet..	....	Dr	....	....	....	....	.....	Dry	3 dry holes drilled in vicinity, to 275, 300, and 410 ft.
54	5.4 miles south-southeast of Casky.	Will Garnet.......	....	Dr	R60	30 50	R30	January 1950	J	....	
56	3.6 miles east-southeast of Casky.	W. F. Bracy......	J. R. Norris...	Dr	R33	16	R12	Summer 1947	H	6-10	
58	.......do........	R. W. Jeffries...	.....do.........	Dr	R67	50	6	Jan. 12, 1950	H	....	
59	.......do........	W. Sergent.......	....	Du	16.5	16	....	....	.....	6-10	
60	3.4 miles east-southeast of Casky.	Clarke Frith......	....	Dr	56.6	....	16.66	Jan. 13, 1950	B	....	Muddy after rain.
61	.......do........	Mrs. G. B. Fuller	....	Du	15.5	4.7	4.71	......do.......	B	....	

62	......do......	......do......	....	Dr	28.0	....	6.78	......do.....	B	....	Observation well. Sulfurous.
63	3.2 miles east-southeast of Casky.	......do......	....	Du	12.5	12	1.50	......do.....	.....	6-10	
64	3.4 miles east-southeast of Casky.	Alex Jackson....	....	Du	20.0	....	5.00	......do.....	B	1-2	
65	3.2 miles east-southeast of Casky.	C. B. Harned....	....	Dr	....	....	R16.00	Summer 1949	H	3-5	
66	......do......	......do......	Jack Doudy...	Dr	R42	42	R22	......do.....	J	6-10	
67	......do......	W. B. Stump....	J. H. O'Dell..	Dr	51.5	....	2.53	Jan. 13, 1950	B	3-5	Murky after rain.
68	......do......	......do......	....	Du	R14	14	R11	......do.....	J	10-20	Analysis available.
69	......do......	......do......	....	Dr	R35	17	R18	Summer 1949	H	3-5	
70	......do......	Mrs. Floyd Macrae.	....	Dr	R15	....	R10	Fall 1949	J	6-10	
72	2.4 miles east-southeast of Casky.	R. L. Vaughan..	Trout........	Dr	R56	....	R25	January 1950	B	....	
73	......do......	......do......	Jack Doudy...	Dr	R36	13	R6	Summer 1949	H	....	
74	......do......	D. B. Rogers....	....	Du	R25	....	R2-3	January 1950	B	6-10	
75	2.0 miles east-southeast of Casky.	V. C. Iglehart..	....	Dr	R120	....	R50	......do.....	J	1-3	Sulfurous.
76	2 miles east-southeast of Casky.	......do......	Jack Doudy...	Dr	R102	85	R50	Spring 1947	J	6-10	Analysis available.
77	2.2 miles east-southeast of Casky.	S. L. Powell.....	....	Dr	R65	....	....	....	J	6-10	Do.
78	2 miles east-southeast of Casky.	Boyd Gray.......	....	Dr	R65	....	....	....	H	3-5	
80	......do......	B. V. Goolsby...	C. Blaylock..	Dr	66	50	21.3	Jan. 16, 1950	B	3-5	Observation well.
82	1.5 miles east-southeast of Casky.	F. D. George....	....	Dr	37	....	26.98	......do.....	B	3-5	
84	......do......	J. E. Low, Sr...	....	Dr	101	....	29.68	......do.....	B	....	
85	......do......	A. L. Pritchet..	Veech........	Dr	65	....	2.21	......do.....	B	1-2	
86	2.3 miles south-southeast of Casky.	D. W. Dulin....	....	Du	R14	....	....	....	W	6-10	Muddy after heavy rains.
87	......do......	......do......	....	Dr	R90	....	R72	November 1949	H	....	
93	1.2 miles east-southeast of Casky.	Wilson Bros......	Pat Robinson..	Dr	R139	125	....	....	J	10-20	Reported to be corrosive. Analysis available.
94	5.4 miles southeast of Casky.	Dr. W. L. Trabue.	B. F. Jones....	Dr	130	40 130	....	....	J	6-10	Analysis available.
95	4.8 miles southeast of Casky.	H. B. Bolinger.	....	Dr	125	....	....	....	.....	Dry	

Table 6.—*Records of wells in the Hopkinsville area, Kentucky*—Continued

Well no.	Location	Owner or name	Driller	Type of well	Depth of well (feet)	Depth to water-bearing crevices, reported (feet)	Water level: Below land surface (feet)	Water level: Date of measurement	Type of lift	Estimated yield, reported (gpm)	Remarks
8720-3645-96	4.8 miles southeast of Casky.	H. B. Bolinger..	....	Du	16	....	....	....	......	....	Observation well.
97	2.7 miles east-northeast of Casky.	D. H. Ricchuite	....	Dr	....	....	....	....	J	10-20	
98	4.8 miles southeast of Casky.	H. B. Bolinger..	Charles Price.	Dr	R175	165	....	....	......	1	"Soda" water taste. Log shown in figure 4.
100	1 mile east of Casky....	W. H. Boyd......	....	Dr	65	....	36.53	Jan. 16, 1950	B	3-5	Observation well.
101	2 miles south-southeast of Casky.	Mrs. Dan Perry..	....	Dr	R131	60 130	R40	July 1949	J	3	Sulfurous supply at 130 ft.
102	3.3 miles south-southeast of Casky.	J. A. Chiles, Jr.	....	Du	25	....	0	Feb. 2, 1950	J	10	Observation well. Analysis available.
103	5 miles south-southeast of Casky.	Temple Cook....	....	Dr	60	....	....	....	H	6-10	
104	3.5 miles southeast of Casky.	D. Shelton........	C. S. Price...	Dr	150	50	....	....	......	3	
105	5.4 miles south-southeast of Casky.	J. D. Claggett...	....	Dr	100	72 100	R20	1942	J	6-10	
106	2.5 miles northeast of Casky.	J. E. Clarke......	C. Blaylock...	Dr	185	180	17.77	July 26, 1951	B	3-5	Oil seep at 50-60 ft. Sulfurous.
8720-3650-1	5.5 miles east-southeast of Hopkinsville.	Bly Galladay.....	....	Dr	55	....	R26	October 1949	J	10-20	Analysis available.
2	.......do..................	.......do...........	....	Dr	R180	....	....	....	J	6-10	Salty and sulfurous.
3	5 miles east-southeast of Hopkinsville.	Pat Major.........	....	Dr	R80	43 60	40	October 1949	J	¼-2	
4	.......do..................	Mrs. Beasley.....	....	Dr	125	92	66.8	Nov. 3, 1949	J	....	
6	4 miles east of Hopkinsville.	R. W. Watts.....	Jack Doudy...	Dr	R80	....	R70	November 1949	H	....	Sulfurous.
7	4.5 miles east of Hopkinsville.	Harry Watts......	.......do.......	Dr	R75	....	....	....	H	1	Do.
8	.......do..................	.......do...........	.......do.......	Dr	R75	....	R70	Nov. 4, 1949	J	1	
13	6 miles east of Hopkinsville.	E. A. Strode......	....	Du	18.2	....	16.8	Nov. 7, 1949	B	0-2	Dry for several months in summer.

15	6 miles east of Hopkinsville.	E. J. Graves	Ewing Harned	Dr	39		25.8	do	B		Observation well.
16	5.5 miles east-southeast of Hopkinsville.	O. K. Strode	Colman Blaylock.	Dr	65	55	40.7	Nov. 10, 1949	B		Observation well. Sulfurous.
19	5 miles east-southeast of Hopkinsville.	Roy Winstad	Roy Winstad	Dr	R60		R25	November 1949	J	5	Analysis available.
20	do	T. F. Thompson.		Dr	29		7	Nov. 14, 1949	B		Muddy for several days after rainfall.
21	2.6 miles east-northeast of Western State Hospital.	Edgar Foster		Dr	R40		29.6	Nov. 29, 1949	B		Observation well. Analysis available.
25	5 miles east of Hopkinsville.	Chester Hobson	Jack Doudy	Dr	R126		R104	do	J	3-5	
29	do	W. T. Killybrew.		Dr	R100	85	R54	Spring 1942	J		Sulfurous.
30	do	do		Dr	85		R40	1942	J		Do.
32	5.5 miles east of Hopkinsville.	Walter Davy	Jack Doudy	Dr	50	43			B		
34	4 miles east of Hopkinsville.	E. Harned	C. Blaylock	Dr	78	70 75	R25	December 1949	J	10	Trace of oil at 76 ft.
35	do	Mrs. E. Harned	Tucker	Dr	R60		R6	January 1913		1-2	Salty taste.
37	do	do		Du	9	9	3	Dec. 15, 1949			Dry in summer.
38	6.5 miles east of Hopkinsville.	G. D. Rose	Jack Doudy	Dr	60.2		15.92	Jan. 6, 1949	B	2-4	Observation well.
41	6 miles east of Hopkinsville.	Murphey Davis		Du	29.5		24.5	Apr. 15, 1950	H		Observation well. Muddy after rain.
42	do	do		Dr	69		16.18	Feb. 2, 1950	J	6-10	Observation well. Analysis available.
43	do	Otis Rhea		Dr	R125	20	R20	February 1950	J	1-2	Analysis available.
44	do	do		Dr	R125				H	1-2	Sulfurous.
45	do	do		Dr	R60	50	R20	February 1950	B		
48	do	do		Dr	25	25	R15-20	do	B	6-10	
49	5.5 miles east of Hopkinsville.	Dr. E. B. Rhea		Dr	R65	60	R20	do	J	10-20	Muddy after heavy rains.
50	do	do		Dr	R70	60	R20	do	B	3-5	
52	5 miles east of Hopkinsville.	C. A. Thomas	J. H. O'Dell	Dr	60		36.64	Feb. 6, 1950	B	1	
53	do	do	do	Dr	78.0	70	36.29	do	B	1	
54	5.5 miles east of Hopkinsville.	do		Dr	R69				H	6-10	
59	5 miles east of Hopkinsville.	A. B. Lacy	Jack Doudy	Dr	R93	60 90	R57	Spring 1949	J	6-10	Sulfurous.

Table 6.—*Records of wells in the Hopkinsville area, Kentucky*—Continued

Well no.	Location	Owner or name	Driller	Type of well	Depth of well (feet)	Depth to water-bearing crevices, reported (feet)	Water level: Below land surface (feet)	Water level: Date of measurement	Type of lift	Estimated yield, reported (gpm)	Remarks
8720-3650-60	5 miles east of Hopkinsville.	E. H. Cobb...	C. Blaylock..	Dr	R75	...	R56	Summer 1949	J	6-10	
61	...do...	F. C. Harned...	Jack Doudy...	Dr	R200	100 150 200	R65	October 1949	J	6-10	Sulfurous at 200 ft.
62	...do...	...do...	...	Dr	R60	...	R20	Summer 1949	H	1	
63	...do...	...do...	...	Dr	R40	...	20	Feb. 6, 1950	H	...	Muddy after rainfall.
64	...do...	...do...	...	Dr	R60	...	48	...do...	J	10-20	
68	...do...	...do...	...	Dr	R90	...	...	...	...	1	Dry in summer.
69	4.5 miles east of Hopkinsville.	D. H. Erkelidian	...	Dr	60.6	...	49.13	Feb. 7, 1950	B	6-10	Observation well.
70	...do...	J. B. Warren...	...	Dr	R75	...	...	...	J	10-20	Sulfurous.
72	4 miles east of Hopkinsville.	Pat Major...	...	Du	R43	...	R40	February 1950	...	3	
124	6.5 miles east of Hopkinsville.	D. Gray...	Charles Price..	Dr	R125	75	...	...	J	6-10	
128	4 miles east of Hopkinsville.	R. W. Watts...	B. F. Jones...	Dr	R65	50	...	...	J	...	
129	3.8 miles northeast of Casky.	G. D. Rose...	Charles Price..	Dr	R112	...	R35	May 23, 1952	J	...	
8725-3645-7	3 miles south-southeast of Hopkinsville.	E. H. Cunningham.	...	Dr	75	...	...	...	J	7	Sulfurous.
9	3.5 miles south-southeast of Hopkinsville.	W. J. Glover...	J. H. O'Dell..	Dr	R176	60	...	...	...	3	Do.
10	...do...	...do...	...do...	Dr	R76	43 60	...	...	J	7	Analysis available.
11	...do...	T. W. Garnet...	Tom West...	Dr	R145	100	...	...	H	...	Sulfurous.
12	4 miles south-southeast of Hopkinsville.	...do...	...	Dr	R145	...	...	...	H	$\frac{1}{4}$-2	
13	...do...	...do...	...	Dr	R304	100	...	...	...	3-5	
14	6 miles south-southeast of Hopkinsville.	J. R. Green...	...	Dr	R86	...	...	...	H	...	

16	6.5 miles south-southeast of Hopkinsville.	K. [illegible] Reynolds..	....	Du	R12	....	....	....	H	....	
18	6 miles south of Hopkinsville.	Joe Toms..........	....	Dr	R90	....	....	....	J	3-5	Analysis available.
19	5.5 miles south of Hopkinsville.	D. M. Cannon...	J. H. O'Dell..	Dr	R65	52	....	....	J	5	Do.
21	5 miles south of Hopkinsville.	J. E. Ramsey....	B. F. Jones....	Dr	R60	45	....	....	.....	1	
22	.......do....................	.......do............	.......do........	Dr	R30	....	....	....	.....	Dry	
23	.......do....................	.......do............	....	Dr	R65	60	....	....	J	2	
24	.......do....................	.......do............	B. F. Jones....	Dr	115	65 112	....	....	J	5	Analysis available.
25	6.5 miles south of Hopkinsville.	W. B. Anderson..	Winfrey.........	Dr	R58	55	....	....	J	10-12	Do.
26	.......do....................	.......do............	....	Dr	R75	....	....	....	H	¼-2	Sulfurous.
27	7 miles south of Hopkinsville.	F.M. Clarke......	....	Dr	R96	....	R20	May 1949	H	....	
28	6.5 miles south of Hopkinsville.	W. K. Van Cleave.	....	Dr	R65	....	....	....	J	6-10	
29	.......do....................	.......do............	B. F. Jones.....	Dr	R200	....	....	....	.....	....	
30	.......do....................	.......do............	.......do........	Dr	R100	....	....	....	.....	Dry	
31	.......do....................	.......do............	Billy Moore.....	Dr	....	....	....	....	.....	....	Sulfurous.
32	6 miles south of Hopkinsville.	Holland Garnet...	....	Du	22	....	15.3	Dec. 21, 1949	J	30	Observation well. Analysis available.
33	.......do....................	.......do............	....	Du	32	....	31.32	.......do.......	.....	....	Stream at bottom.
34	5 miles south of Hopkinsville.	W. W. Bruce.....	....	Dr	60	40	....	....	J	....	Several dry wells drilled in vicinity.
35	4.5 miles south of Hopkinsville.	Mrs. Fred Pool..	....	Dr	R65	....	....	....	H	¼-2	
37	.......do....................	J. H. Greer.......	....	Dr	R60	....	....	....	J	....	
39	5 miles south of Hopkinsville.	J. L. Rives........	....	Du	27	....	17.34	Dec. 21, 1949	H	....	Observation well.
40	.......do....................	.......do............	B. F. Jones.....	Dr	R50	17 35 50	R12	Dec. 10, 1949	J	....	Water becomes murky after rain.
41	.......do....................	.......do............	D. West.........	Dr	R23	12	R7	Dec. 21, 1949	J	30	Analysis available.
42	5.5 miles south of Hopkinsville.	R. L. Reeves.....	.......do.........	Dr	R65	....	R50	1939	H	3-5	Sulfurous.
43	6 miles south of Hopkinsville.	C. W. Foard......	....	Dr	R61	58	....	....	J	10	Do.
44	.......do....................	.......do............	C. Blaylock....	Dr	R81	....	....	....	.....	....	Observation well. Sulfurous.

Table 6.—*Records of wells in the Hopkinsville area, Kentucky*—Continued

Well no.	Location	Owner or name	Driller	Type of well	Depth of well (feet)	Depth to water-bearing crevices, reported (feet)	Water level: Below land surface (feet)	Water level: Date of measurement	Type of lift	Estimated yield, reported (gpm)	Remarks
8725-3645-45	6.5 miles south of Hopkinsville.	C. W. Foard		Dr	R80				J	6-10	
46	do.	Hugh Clayborne	M. O. Kimmerling.	Dr	R80	90			J	6-10	
47	5 miles south of Hopkinsville.	Roy Milam	J. E. Ramsey	Dr	170	70 130 170			J	5-6	
48	3.5 miles south of Hopkinsville.	J. J. Robertson		Dr	R87	83 87			J	10	Sulfurous.
49	3 miles south of Hopkinsville.	Leslie West		Dr	R70				H		
50	2.5 miles south of Hopkinsville.	John Edmuns		Dr	R50	45			J	6	
52	2 miles south of Hopkinsville.	W. O. King		Dr	R52	52	R30	July 1943	J	10	Analysis available.
53	do.	do.		Dr	R48				J	10	Observation well.
54	do.	Mrs. Roberta Boyd.		Dr	27.0		20.2	Jan. 9, 1950	H	$\frac{1}{4}$-2	
56	do.	L. A. Tates		Dr	75		R55	July 1949	J	6-10	
57	do.	C. E. Sivley		Dr	60.3		10.95	Jan. 4, 1950	H	3-5	Observation well.
60	7 miles south of Hopkinsville.	F. C. Miller		Dr	R190		160	August 1949	J	1-2	Sulfurous.
61	do.	do.		Dr	R156		R116	do.	J	1-2	Sulfurous. Analysis available.
62	do.	do.		Dr						Dry	
65	7.5 miles south-southeast of Hopkinsville.	Myron W. Pool		Dr	75	52			J	5	Analysis available.
66	4.5 miles southeast of Hopkinsville.	S. E. Kirkman	C. Blaylock	Dr	R200	190	96	July 1949	J	$\frac{1}{4}$-2	Sulfurous.
67	do.	A. W. White	do.	Dr	R115	100 110	R25	April 1948	J	$\frac{1}{4}$-2	
69	do.	J. L. Brown		Du	R23		R10	January 1950	H		
71	4 miles southeast of Hopkinsville.	William Doris	Jack Doudy	Dr	R108	33 65			J	3-5	Analysis available.

72	3.5 miles southeast of Hopkinsville.	Ewin Lacy	do	Dr	R100	50	R20	January 1950		$\frac{1}{4}$-2	
73	do	do	J. W. Jones	Dr	R201	50			J		
74	do	do	C. Blaylock	Dr	R300	40 160					Extremely sulfurous at 160 ft.
75	do	do	do	Dr	R90	62	R20	Summer 1949	J		
76	do	J. M. Bronaugh	B. F. Jones	Dr	R150	60 135	15	July 1949		$\frac{1}{4}$-2	
77	do	do		Dr	76.4	65	6.70	Jan. 17, 1950			
78	do	do		Du, Dr	32	16	16	January 1950		$\frac{1}{4}$-2	
79	2.5 miles south-southeast of Hopkinsville.	H. D. Courtney		Dr	R85	70			J	10-20	Analysis available.
80	do	William Peden		Dr	R64				J	10-20	Do.
81	3 miles south-southeast of Hopkinsville.	F. B. Culver	Jack West	Dr	32		16.59	Jan. 18, 1950	B		Sulfurous.
82	do	M. G. Williams.		Dr					H		
83	3.5 miles south-southeast of Hopkinsville.	John Williams		Dr	R75					6-10	
85	4 miles south-southeast of Hopkinsville.	R. A. Gill	C. Blaylock	Dr	R100	60				Dry	Sulfur seep.
86	do	do	do	Dr	R60	55				Dry	
87	do	E. White		Dr	R148	142	12.30	Jan. 19, 1950	B	$\frac{1}{4}$-2	
88	4.5 miles south-southeast of Hopkinsville.	J. T. Stump	B. F. Jones	Dr	R87	80			J	6-10	
89	do	do		Dr	R40		30	Summer 1949	H	3-5	Sulfurous.
90	5 miles south-southeast of Hopkinsville.	Newell Clarke		Dr	R119	50 115	R40-50	do	J	3-5	
91	do	do		Du	R70		R63		H	$\frac{1}{4}$-2	
93	4 miles southeast of Hopkinsville.	William Doris		Dr	61.5		36.77	Mar. 30, 1950			Observation well.
94	do	do	Jack Doudy	Dr	103	65	20.68	do			
95	do	do	do	Dr	45	48					20 ft cave at 25 ft. Sulfur water at 48 ft.
97	Casky	Mrs. B. F. Davis		Dr	45	30	13.35	Jan. 24, 1950	B		
98	do	J. W. Sholar	C. Blaylock	Dr	50				J	$\frac{1}{2}$	Flows during rainy weather in winter.
99	do	do	do	Dr	R150	70	12.95	Jan. 24, 1950		$\frac{1}{4}$-2	
100	do	Mrs. Ida Cunningham.	do	Dr	R53		12.74	Feb. 17, 1950	B		
102	do	John Warren		Dr	R36		R31	Summer 1949	H	6-10	Muddy.

Table 6.—*Records of wells in the Hopkinsville area, Kentucky*—Continued

Well no.	Location	Owner or name	Driller	Type of well	Depth of well (feet)	Depth to water-bearing crevices, reported (feet)	Water level: Below land surface (feet)	Water level: Date of measurement	Type of lift	Estimated yield, reported (gpm)	Remarks
8725-3645-103	Casky	H. M. Clark	C. Blaylock	Dr	R67	54	R40	...	J	10-20	Analysis available.
106	do	C. Watkins	...	Dr	32.3	...	7.07	Jan. 24, 1950	H	5	Observation well. Muddy after rain.
107	do	Herbert White	...	Du	R30	...	...	...	H	¼-2	
108	do	T. N. Powell	...	Du	39.2	...	28.26	Jan. 24, 1950	R	...	
109	do	Casky Baptist Church.	...	Dr	52	37 52	...	...	H	¼-2	
110	do	J. M. Clarke	...	Dr	R45	...	...	...	H	¼-2	
111	do	do	...	Dr	R105	90	R32	Summer 1949	J	6-10	Sulfurous.
114	do	Enis Haddock	...	Du	23.9	...	11.39	Jan. 24, 1950	J	3-5	Observation well.
116	0.5 mile south of Casky	J. B. McCain	...	Du	17.10	17	11.66	do	H	3-5	Do.
117	1 mile southeast of Casky	do	...	Dr	R76	9 55	R1.0	Summer 1949	B	3-5	Sulfurous.
119	3.5 miles southeast of Hopkinsville.	E. C. Lacy	...	Dr	R212	...	...	...	H	...	
120	do	do	...	Du	R50	...	R25	Summer 1949	J	3-5	
121	do	do	...	Du	25	...	2	January 1950	H	...	
122	1.5 miles south of Casky	W. T. White	...	Dr	R200	...	R100	do	J	¼-2	Strongly sulfurous.
123	do	do	C. Blaylock	Dr	R85	16 50	R20	Summer 1949	J	3-5	
124	do	do	...	Du	9	9	R1-2	Winter 1949-50	H	...	
125	1 mile south of Casky	Charles Garnet	...	Dr	79.5	27 50	0	Feb. 1, 1950	B	6-10	Observation well.
126	do	do	...	Dr	R65	30 50	...	...	J	6-10	Analysis available.
127	do	do	C. Blaylock	Dr	R60	30 50	0	February 1950	H	6-10	
130	1.5 miles south of Casky	Robert Garnet	...	Dr	R50	...	R1-2	do	H	3-5	
131	do	do	...	Dr	R65	56	0	do	J	10-15	
132	do	do	...	Dr	R60	...	0	do	H	¼-2	
133	2 miles south of Casky	James Garnet	...	Dr	R40	...	0	do	H	¼-2	

135	......do......	......do......	......	Dr	R300	290	......	......	J	......	Sulfurous.
137	......do......	......do......	B. F. Jones.....	Dr	R175	......	......	......	......	......	Do.
138	......do......	Charles Garnet..	......	Dr	R60	30 50	0	February 1950	......	½-2	
139	......do......	......do......	......	Dr	R65	30 50	......	......	H	3-5	
140	2 miles south-southeast of Casky.	Robert Garnet...	......	Dr	R70	50	0	Feb. 1, 1950	J	3-5	
141	......do......	......do......	......	Dr	R40	......	36.65	May 1950	B	½-2	
142	......do......	......do......	......	Dr	R40	......	......	......	H	½-2	
143	......do......	L. S. Petty......	......	Dr	R27	......	0	Feb. 1, 1950	J	3½-5	Analysis available.
145	2.5 miles south-southeast of Casky.	Joe Radford......	......	Dr	R225	80 220	......	......	J	10-20	
146	......do......	......do......	......	Dr	......	......	......	......	......	......	
147	......do......	......do......	......	Dr	......	......	......	......	......	......	Sulfurous.
148	1 mile southeast of Casky	G. D. McCain..	......	Du	32.9	......	12.8	Feb. 2, 1950	B	......	Observation well.
149	......do......	......do......	......	Dr	150	100	71.69	......do......	B	6-10	Do.
150	......do......	......do......	......	Dr	R100	65	......	......	H	6-10	
151	......do......	......do......	......	Dr	R100	......	R35	Summer 1949	J	10-20	
152	5 miles south of Hopkins-ville.	W. W. Bruce....	......	Dr	R125	......	......	......	......	Dry	
153	......do......	......do......	......	Dr	R120	......	......	......	......	1	
154	......do......	......do......	......	Dr	R125	......	......	......	......	Dry	
156	6 miles south of Hopkins-ville.	T. C. Lollar....	Jack Doudy......	Dr	R80	75	26.28	Mar. 1, 1950	B	...1...	
157	3.5 miles south of Hop-kinsville.	W.G. Duncan III	......	Dr	R73	65	......	......	J	40	Sulfurous. 3 analyses available.
158	......do......	......do......	Frank Jones......	Dr	R125	65 100	R32	Summer 1949	J	40	Sulfurous.
159	......do......	......do......	......	Dr	R65	......	R42	......do......	J	½-2	Do.
162	3 miles south of Hopkins-ville.	H. D. Carlos....	......	Dr	R60	......	......	......	H	6-10	Muddy after rain.
166	4 miles south of Hopkins-ville.	M. C. Boyd......	B. F. Jones.....	Dr	R47	40	R38	Fall 1949	H	......	
167	4.5 miles south of Hop-kinsville.	W. C. Drake....	......do......	Dr	R60	30 50	R20	Summer 1949	J	6-10	
169	......do......	......do......	......	Dr	......	......	......	......	......	Dry	
170	0.5 mile west of Casky..	John White......	......	Du	R20	20	......	......	H	6-10	
171	Casky......	Bailey Bronaugh	......	Du	27.7	27	6.20	Mar. 31, 1950	H	6-10	
172	0.5 mile northeast of Casky.	William Doris...	......	Dr	R60	......	......	......	......	½-2	
173	3 miles southeast of Hop-kinsville.	O. L. Barnes....	C. Blaylock....	Dr	95	43 60	......	......	J	......	

Table 6.—*Records of wells in the Hopkinsville area, Kentucky*—Continued

Well no.	Location	Owner or name	Driller	Type of well	Depth of well (feet)	Depth to water-bearing crevices, reported (feet)	Water level: Below land surface (feet)	Water level: Date of measurement	Type of lift	Estimated yield, reported (gpm)	Remarks
8725-3645-174	2 miles south-southeast of Casky.	Harold Lile...	B. F. Jones...	Dr	R60	...	...	...	J	3-10	
175	2.5 miles south of Hopkinsville.	Matt Watkins...	...	Dr	R58.3	...	34.28	Mar. 3, 1950	B	¼-2	
176	4.5 miles southeast of Hopkinsville.	John Keller...	Jack Doudy...	Dr	150	90	67.07	July 27, 1951	J	...	
177	0.5 mile south of Casky...	J. B. McCain...	C. Blaylock...	Dr	R93	...	10.54	Feb. 14, 1952	H	...	
178	3 miles southwest of Casky.	Mrs. Fred Pool...	Louis Orten...	Dr	R150	...	45.34	June 17, 1952	J	10	
8725-3650-1	4 miles east of Hopkinsville.	E. J. France and Otis Kennedy.	...	Dr	70.3	...	R48	...	J	...	Observation well. Sulfurous.
2	...do...	Mrs. Minnie Walker.	...	Dr	R44	...	...	...	H	...	Analysis available.
3	...do...	H. L. Harden...	...	Dr	R65	...	...	...	H	...	
4	...do...	...do...	...	Dr	R30	...	...	...	H	3-5	
6	2 miles east of Hopkinsville.	G. E. Hightower.	Jack Doudy...	Dr	86.2	75	44.8	Nov. 14, 1949	B	¼-2	Observation well. Analysis available.
7	...do...	C. Blaylock...	C. Blaylock...	Dr	93.8	18 80	72.1	...do...	B	10-12	
8	...do...	C. H. Shelton...	B. F. Jones...	Dr	R125	90 110	...	...	J	10-15	Sulfurous at 90 ft.
10	2 miles southeast of Hopkinsville.	Tom Leville...	...do...	Dr	75	72	...	...	J	10-12	
11	3.5 miles east-southeast of Hopkinsville.	Mrs. Georgia Lacy.	J. H. O'Dell...	Dr	67.3	55	33.4	Nov. 28, 1949	B	10-15	
12	1.5 miles southeast of Hopkinsville.	Howard Henderson.	Charles Price...	Dr	R70	43	...	...	J	10	
13	2 miles east-southeast of Hopkinsville.	C. G. Boyd...	Dick West...	Dr	R65	...	...	...	...	3-5	
14	...do...	...do...	Jack Doudy...	Dr	R60	...	...	...	...	Dry	
15	...do...	...do...	B. F. Jones...	Dr	R65	...	...	...	J	10-20	Analysis available.
16	...do...	...do...	...	Du	R30	...	...	...	...	...	

17	1.5 miles south of Hopkinsville.	A. R. Vartley	J. H. O'Dell and Charles Price.	Dr	R77	70			J	10-20	Sulfurous. Analysis available.
18	3 miles southeast of Hopkinsville.	W. H. McRenolds.		Dr	R145	145	R50	December 1949	J	6-10	Sulfurous.
19	do.	do.		Dr	R165	140 165	46.43	Jan. 17, 1950	B		Sulfur stream at 140 ft is cased off. Observation well.
20	do.	do.		Du	R25		R5	do.	H		
21	do.	O. L. Barnes	Jack Doudy	Dr	R136	130			J	6-10	Analysis available.
22	do.	do.		Dr	R116	110	51	Summer 1949	J	6-10	
23	do.	do.		Dr	R40				J	3-5	
24	2.5 miles southeast of Hopkinsville.	J. P. Thompson		Dr	R165				J		
25	do.	E. A. Carpenter	B. F. Jones	Dr	R107	60			J	$\frac{1}{2}$-2	
26	do.	H. H. Goalie		Du	R15				J	3-5	Water very muddy after rainfall.
27	do.	Mrs. H. H. Goalie.		Du					J	3-5	Tiled to connect with well 8725-3650-26.
28	2 miles southeast of Hopkinsville.	W. G. Harvey		Du					H	6-10	
29	do.	do.		Dr	80.65		11.01	Jan. 18, 1950			Observation well.
30	do.	J. L. Fagin	C. Blaylock	Dr	100	41			J	6-10	
31	do.	J. L. Fagin and R. Heltsley.		Dr	100				J	$\frac{1}{2}$-2	
32	1.5 miles southeast of Hopkinsville.	R. Heltsley	B. F. Jones	Dr	R85	70	35.07	Mar. 31, 1950	B		Sulfurous.
33	do.	do.		Dr	R65				J	6-10	Gets turbid after rain.
34	do.	do.		Dr	35.8		35.00	Mar. 31, 1950			
35	do.	do.	B. F. Jones	Dr	R50		R20		J	6-10	
36	do.	Ike Garret	J. H. O'Dell	Dr	R100	90	R68.00	October 1949	J	6-10	
37	2 miles southeast of Hopkinsville.	Joe Bance	Sam Maddux	Dr	R70	60	R30	January 1950	J	3-5	
38	1.5 miles southeast of Hopkinsville.	R. L. Collins		Dr	R60		R45	August 1945	J	6-10	
39	do.	John Schmidt		Dr	R85	65	R60		J	6-10	
40	do.	R. W. Lacy		Dr	R85	60			J	6-10	Muddy in rainy weather.
41	do.	do.		Dr	R44		R40	January 1950	J	6-10	Muddy after rain.
42	1 mile southeast of Hopkinsville.	W. J. Lyle	B. F. Jones	Dr	R57		R22	Summer 1950	J	6-10	
43	do.	L. E. Underwood.	do.	Dr	R59	49	R27	Fall 1946	J	6-10	Analysis available.

Table 6.—*Records of wells in the Hopkinsville area, Kentucky*—Continued

Well no.	Location	Owner or name	Driller	Type of well	Depth of well (feet)	Depth to water-bearing crevices, reported (feet)	Water level: Below land surface (feet)	Water level: Date of measurement	Type of lift	Estimated yield, reported (gpm)	Remarks
8725-3650-44	1 mile southeast of Hopkinsville.	Mrs. Williamson		Du	R70				J	6-10	
45	2 miles south-southeast of Hopkinsville.	E. D. Gough		Dr	R75				H	6-10	
53	3.5 miles east of Hopkinsville.	R. Parker		Dr	R56				J	6-10	
54	do	Powell Moats		Dr	R65				H	½-2	
55	do	do	B. F. Jones	Dr	R177	167	42.14	Feb. 7, 1950	B	3-5	
57	3 miles east of Hopkinsville.	J. E. Lowe	do	Dr	R58	48			J	6-10	Analysis available.
58	do	do		Du					B		
59	do	K. Heltsley		Dr	R60	40			H	4	Sulfurous.
60	do	do		Dr	95.0	60	36.20	Feb. 7, 1950	B	½-2	
62	2.5 miles east of Hopkinsville.	W. J. Burns		Dr					J		
63	do	J. E. Morris		Dr	R80	70 80	R40	Oct. 25, 1950	J	6-10	Sulfurous.
64	do	do		Dr	R100	55			J		
65	do	E. T. Morris		Dr	R64	60			J	10	Sulfurous.
69	1.5 miles east of Hopkinsville.	Western State Hospital.	M. O. Kimmerling.	Dr	R125	125	R10	September 1930			Salty and sulfurous.
71	do	do	do	Dr	R77	75				½-2	
72	do	do	do	Dr							
74	do	do	do	Dr	85	65	13.5	Feb. 8, 1950		1	Observation well. Obstruction in well at 41 ft depth.
75	do	Jack Doudy	Jack Doudy	Dr	98.5	60 85	52.05	do	B	6-10	Observation well.
76	do	George Butler	do	Dr	100.3	85	54.3	do	B		
77	do	Dr. Erkelidian		Dr	72.3	65	53.11	do	B		
78	do	Charles Winders		Dr	98.9	26 78 90	54.15	do	B		

79	do	Jim Johnson	Jack Doudy	Dr	100	85	55.9	do	B	6-10	
80	do	E. L. Stokes	do	Dr	100	85	54.3	do	B	6-10	
81	do	C. W. Burkhart	do	Dr	100	85	...	...	H	...	
82	do	Jim Fuller	do	Dr	60.9	85	54.83	Feb. 8, 1950	B	...	
83	do	Lee Rogers	...	Dr	101.8	85	56.7	do	B	...	
84	do	Francis Parker	...	Dr	R110	...	...	...	J	6-10	
85	do	Eugene Dickerson.	...	Dr	88.1	65	40.34	Feb. 8, 1950	B	...	
86	do	W. K. Morris	...	Dr	36	34	...	...	J	10-20	
90	2 miles southeast of Hopkinsville.	E. D. Gough	...	Du	R25	...	R20.0	Feb. 9, 1950	B	3-5	
92	Greenville Road, Hopkinsville city limits.	R. C. White	...	Du	31.5	...	30.0	Feb. 15, 1950	B	...	
94	do	Elgin Brown	...	Du	26.3	...	11.68	do	B	...	
95	do	Howard Evans	...	Du	29.1	...	17.19	do	B	...	
96	do	Otis Evans	...	Dr	R104	...	...	...	B	3-5	
97	do	Sylvester Silvers	...	Du	R60	...	...	...	...	½-2	
98	do	Oscar Sims	...	Du	31.0	...	24.44	Feb. 15, 1950	B	...	
99	do	Bell Hicks	...	Du	36.5	...	31.56	do	B	...	
100	do	R. Level	...	Du	33.3	...	23.5	do	B	½-2	
101	do	Frank Ship	Jack Doudy	Dr	R42	...	...	...	...	...	
125	0.8 mile north of Western State Hospital.	Duke Banton	Will Dugat	Dr	68.3	65	18.69	Feb. 21, 1950	B	...	Observation well.
126	1.5 miles east of Hopkinsville.	Western State Hospital.	...	Dr	R85	...	...	...	...	...	
131	3 miles east of Hopkinsville.	W. T. Dougherty.	...	Dr	R65	50 65	...	...	J	10-20	Sulfurous.
132	do	do	...	Du	R15	...	...	...	H	1	Small yield, well converted to a cistern.
134	Hopkinsville	Frank Cayce and E. H. Higgins.	Louis Orten	Dr	R75	42 63	...	...	J	40	Analysis available.
135	do	Cayce-Yost Hardware Store.	do	Dr	R80	...	...	...	J	10-20	
136	do	Ellis Ice Co.	...	Dr	R80	...	...	...	J	125	
137	do	do	...	Dr	R130	...	...	...	J	125	3 analyses available.
138	do	do	...	Dr	R125	...	...	...	...	...	
139	do	do	...	Dr	...	...	...	...	...	...	
140	2 miles northeast of Hopkinsville.	Lucien Payne	Jack Doudy	Dr	100.1	...	19.37	Mar. 16, 1950	B	½-2	Observation well.
141	do	do	...	Du	15	...	1.00	do	B	...	In Bethel sandstone.
142	do	do	...	Du	17.5	...	7.05	do	B	1	Do.

Table 6.—*Records of wells in the Hopkinsville area, Kentucky*—Continued

Well no.	Location	Owner or name	Driller	Type of well	Depth of well (feet)	Depth to water-bearing crevices, reported (feet)	Water level: Below land surface (feet)	Water level: Date of measurement	Type of lift	Estimated yield, reported (gpm)	Remarks
8725-3650-144	1.5 miles northeast of Hopkinsville.	H. G. Johnston	Jack Doudy...	Dr	77.0	57	R30	March 1950	B	$\frac{1}{4}$-2	
145	......do......	Hedley Robertson.	......do......	Dr	59.9	....	35.75	Mar. 16, 1950	B	$\frac{1}{4}$-2	Observation well.
146	......do......	Frank Ross......	....	Dr	72.1	....	18.26	......do......	B	1	
147	......do......	M. D. Austin..	Jack Doudy..	Dr	170	150	48.87	Jan. 20, 1950	B	1	
148	......do......	......do......	....	Dr	120.7	....	27.65	Mar. 15, 1950	B	1	
149	......do......	......do......	....	Dr	79.1	....	68.75	Mar. 16, 1950	B	1	
150	......do......	......do......	....	Dr	108.9	....	43.11	......do......	B	1	Sulfurous.
153	East of Hopkinsville city limits.	Earl Carter......	....	Dr	108	....	R60	Summer 1950	H	5	In Bethel sandstone.
154	Hopkinsville......	M. H. Denton..	Charles Price	Dr	R180	....	....	....	.....	Dry	
155	......do......	......do......	....	Dr	R60	....	....	....	.....	Dry	
156	......do......	Louis Waide....	....	Dr	R40	....	....	....	.....	Dry	
159	1 mile southeast of Hopkinsville.	L. A. Barnett..	Jack Doudy..	Dr	R50.2	37	27.0	Mar. 17, 1950	J	30	
164	Northwest of Hopkinsville city limits.	Dalton Brick Co.	....	Dr	R90	....	....	....	H	3-5	
166	Greenville Road, near Hopkinsville city limits.	L. Jamerson....	Charles Price	Dr	150	120 145	125	Apr. 12, 1950	B	1	Sulfurous. Log shown in figure 4.
168	1.5 miles east of Hopkinsville.	Lem Overton...	Jack Doudy..	Dr	R100	45 97	....	....	B	....	
170	Northeast of Hopkinsville city limits.	B. B. Duke.....	Roy Blaylock	Dr	110	100	73.98	July 27, 1951	B	5	
171	......do......	C. E. Powell...	......do......	Dr	112	108	75.49	......do......	B	5	
8730-3645-6	3.8 miles west of Casky...	J. G. Peden....	Charles Price	Dr	R93	47 93	....	....	J	....	Analysis available.
11	4.0 miles west-southwest of Casky.	Harvey S. Johnston.	J. H. O'Dell	Dr	R90	60	....	....	J	....	Do.
8730-3650-1	1.8 miles southwest of junction U. S. 68 and 41E.	N. N. Lindsey..	....	Du	R35	30	R5	Summer 1936	.....	....	Water flows through well.
2	2.1 miles southwest of junction U. S. 68 and 41E.	V. D. Bohannon.	....	Dr	....	....	9.87	May 29, 1950	H	....	

3	2.2 miles southwest of junction U. S. 68 and 41E.	Eural P. West..	....	Dr	121.9	....	55.98	March 1950	B	....	Slight hydrogen sulfide odor.
4	South Virginia St., Hopkinsville.	R. C. Owen Lumber Co.	B. F. Jones..	Dr	R387	....	....	....	......	....	
5	......do....................	......do........	......do......	Dr	R155	....	R25	Mar. 7, 1950	......	....	
6	......do....................	......do........	......do......	Dr	146.5	....	31.83	......do......	......	....	Observation well.
7	1.2 miles west-northwest of junction U. S. 68 and 41E.	T. A. King....	....	Dr	....	....	....	....	......	....	Sulfur water.

Table 7.— *Records of springs in the Hopkinsville area, Kentucky*

Spring no.: For location of springs see plate 4.
Estimated flow: M, measured.
Remarks: Water is used for domestic and stock purposes unless otherwise indicated.

Spring no.	Location	Owner or name	Topographic situation	Improvements	Estimated flow (gpm)	Date	Remarks
8720-3645-8	2 miles east of Casky......	Raymond Long	Lowland................	None................	200	November 1949	Vertical solution channel. Analysis available.
15	3.2 miles east of Casky....	John Edmun....	Near bottom on slope	.......do.............	10	November 1949	Solution channel.
28	2.2 miles southeast of Casky.	D. W. Dulin..	Lowland................	.......do.............	10	November 1949	Vertical solution channel. Fills pond.
32	3.6 miles southeast of Casky.	B. F. Fiese....	.......do................	Concrete enclosure and hand pump.	50	January 1950	Estimated summer yield 2 gpm.
33	4.1 miles southeast of Casky.	G. W. McQuary.	.......do................	None................	50	January 1950	Estimated summer yield 5 gpm.
38	4 miles southeast of Casky.	D. C. Dawson	.......do................	.......do.............	30	January 1950	Solution channel.
50	3.9 miles southeast of Casky.	S. B. McGhee	Near bottom..........	Tile pipe enclosure.	1-2	Jan. 11, 1950	Sulfurous. Analysis available. Use: medicinal.
71	2.6 miles east-southeast of Casky.	Mrs. Floyd Macrae.	Bottom near gully....	None................	100±	January 1950	
79	2 miles east of Casky......	Boyd Gray.....	Lowland................	Concrete block enclosure, electric pump.	100	Jan. 13, 1950	Vertical solution tube.
81	2 miles southeast of Casky	B. V. Goolsby	Bottom of high hill...	None................	25	Jan. 16, 1950	Frequently dry in summer, muddy after rain.
83	1.7 miles east of Casky.....	F. D. George.	Near foot of slope....	.......do.............	10	.......do.......	Horizontal solution channel.
88	2.1 miles southeast of Casky.	D. W. Dulin..	Lowland................	.......do.............	10±	November 1949	Fish in spring hole.
89	2.2 miles southeast of Casky.	.......do.......	Lowland basin........	.......do.............	10+	November 1949	Solution channel.
8720-3650-5	4 miles east of Hopkinsville.	R. W. Watts..	Slope near bottom land.	Rock enclosure with board cover.	50	Nov. 3, 1949	Do.
14	6.5 miles east of Hopkinsville.	E. A. Stroud..	Slope near Little River.	None................	300	Nov. 7, 1949	Sinkhole (large).
17	6 miles east of Hopkinsville.	O. K. Stroud..	Riverbank..............	.......do.............	15	Nov. 10, 1949	Solution channel.
18	6.5 miles east of Hopkinsville.	.......do........	.......do................	.......do.............	10+	.......do.......	Do.

27	4.5 miles east of Hopkinsville.	F. C. Harned..	Upland..................	Concrete spring house.	10+	Dec. 9, 1949	Seep from Bethel sandstone. Analysis available.
28	.......do.........................	.......do.........	.......do..................	None.................	5-	.......do.........	Seep from Bethel sandstone.
33	.......do.........................	Walter Davy...	Near foot of escarpment.	.......do..............	0	.......do.........	Sinkhole.
36	4 miles east of Hopkinsville.	E. Harned......	Flatland................	.......do..............	50	Dec. 15, 1949	Underground stream flowing on bedrock.
46	6 miles east of Hopkinsville.	Otis Rhea......	Sinkhole in bottom land.	Walled with concrete.	100+	Feb. 2, 1950	Horizontal solution channel. Estimated summer yield 5 gpm.
47	.......do.........................	.......do........	Rolling flatland.......	Pitcher pump........	25	.......do.........	Sinkhole.
51	5 miles east of Hopkinsville.	C. A. Thomas	Foot of steep slope....	Rock enclosure, electric pump.	500	.......do.........	Horizontal solution channel. Muddy during rainfall. Analysis available.
55	.......do.........................	W. M. Walker	.......do..................	Well house and concrete enclosure.	50	Feb. 6, 1950	Horizontal solution channel.
56	.......do.........................	.......do.........	Foot of limestone cliff	None.................	25	.......do.........	Horizontal solution channel. Estimated summer yield 1 gpm.
57	.......do.........................	.......do.........	.......do..................	.......do..............	20	.......do.........	Horizontal solution channel.
58	.......do.........................	.......do.........	.......do..................	.......do..............	50	.......do.........	Sinkhole.
65	4.5 miles east of Hopkinsville.	F. C. Harned.	Gentle slope...........	Concrete enclosure	10	.......do.........	Solution channel.
66	5 miles east of Hopkinsville.	.......do.........	Riverbank..............	None.................	100	.......do.........	Solution channel. Estimated summer yield 5 gpm.
67	.......do.........................	.......do.........	Gentle slope...........	.......do..............	50	.......do.........	Solution channel. Estimated summer yield 10 gpm.
71	4.5 miles east of Hopkinsville.	J. B. Warren..	Bottom land...........	.......do..............	100	.......do.........	Vertical solution channel.
15	3.5 miles southeast of Hopkinsville.	E. H. Cunningham.	Hill slope..............	.......do..............	20	Dec. 14, 1949	Solution crevice.
15	3 miles south of Casky.....	John Green....	Foot of small limestone cliff.	.......do..............	10	Dec. 16, 1949	Dry in summer.
20	5.5 miles south of Hopkinsville.	D. M. Cannon	Lowland near sink.....	.......do..............	40	Dec. 19, 1949	Do.
36	4.5 miles south of Hopkinsville.	Mrs. Fred Pool	Rolling flatland.......	.......do..............	100+	Dec. 21, 1949	
38	5 miles south of Hopkinsville.	J. H. Greer...	.......do..................	.......do..............	10	.......do.........	
55	4 miles south of Hopkinsville.	Mary Bronaugh	Valley slope...........	.......do..............	M13	Sept. 30, 1952	Analysis available.
58	2 miles south of Hopkinsville.	C. E. Sivley...	Hillside near river.....	Concrete enclosure	M5	.......do.........	Do.

Table 7.—*Records of springs in the Hopkinsville area, Kentucky*—Continued

Spring no.	Location	Owner or name	Topographic situation	Improvements	Estimated flow (gpm)	Date	Remarks
8725-3645-59	2 miles south of Hopkinsville.	C. E. Sivley..	Hillside near river...	None..............	25	Jan. 4, 1950	Dry 2 months in summer.
64	4 miles south of Casky......	Myron Pool....	Wooded bottom land	Concrete enclosure.	2-3+	Jan. 9, 1950	
68	0.5 mile north of Casky.....	A. W. White..	Foot of high hill.....	.......do............	10±	Jan. 17, 1950	Dry in summer months.
70	1 mile northeast of Casky...	J. L. Brown...	Flatland...............	.......do............	5+	.......do........	
84	0.5 mile west of Casky......	John Williams	Lowland................	Electric pump, 1-½ hp.	25+	Jan. 18, 1950	Limestone solution channel. Supplies 3 farms, 12 to 15 persons.
92	0.5 mile south of Casky.....	Newell Clarke	Bottom..................	None.................	Small	....	Sinkhole. Dry in summer.
96	1 mile northeast of Casky..	William Doris	Bank of stream branch.	.......do............	100±	Jan. 23, 1950	Vertical solution channel.
101	Casky........................	Mrs. Ida Cunningham.	Bottom land...........	Walled up with logs.	25	Jan. 24, 1950	
105	.......do......................	Luther Grant..	Head of stream branch.	Walled up with limestone.	5+	.......do........	
112	.......do......................	J. M. Clarke.	Bottom land near stream.	None.................	M5	Sept. 30, 1952	Solution channel.
113	0.5 mile southeast of Casky	.......do.......	Gentle slope..........	.......do............	50	Jan. 24, 1950	
115	Casky........................	Enis Haddock	Streambank............	.......do............	50±	.......do........	
118	0.5 mile southeast of Casky	J. B. McCain	.......do................	.......do............	10	.......do........	Vertical solution channel. Dry in summer.
136	2 miles south of Casky.......	James Garnet..	....	Concrete enclosure.	50	Feb. 1, 1950	Solution crevice. Estimated summer yield 6 gpm.
155	2.5 miles southeast of Hopkinsville.	William Peden.	....	None.................	200	Feb. 9, 1950	"Blue hole." Vertical joint in sinkhole. Estimated summer yield 10 gpm.
160	4 miles south of Hopkinsville.	W. G. Duncan	Valley slope...........	.......do............	25	Mar. 2, 1950	Solution channel. Dry in summer.
163	3 miles south of Hopkinsville.	H. D. Carlos..	Rolling upland........	.......do............	5+	Mar. 15, 1950	
164	1.5 miles southeast of Casky.	Mrs. Dan Perry.	Sinkhole................	.......do............	25	Feb. 2, 1950	
165	1.8 miles south-southeast of Casky.	.......do.......	....	.......do............	25	.......do........	Dry in summer.
168	3 miles south of Hopkinsville.	W. C. Drake	Valley slope...........	Ponded..............	500+	Mar. 15, 1950	Solution channel. Estimated summer yield 10 gpm.

8725-3650-9	4 miles east-southeast of Hopkinsville.	S. L. Watts...	Lowland...............	Walled in with limestone.	0	Nov. 25, 1949	
46	2 miles south-southeast of Hopkinsville.	H. D. Courtney	Rolling flatland......	None.................	10	Jan. 18, 1950	
49	4.5 miles east-southeast of Hopkinsville.	W. R. Dorris	Bottom land..........	.......do.............	10	Oct. 25, 1949	Several small seeps and springs. Estimated summer yield 1 gpm.
51	.......do.........................	.......do........	.......do.................	.......do.............	....	.......do........	Estimated summer yield 1 gpm.
56	3 miles east of Hopkinsville	Robert Winders.	Lowland...............	.......do.............	Small	Feb. 7, 1950	Sinkhole.
61	2.5 miles south-southeast of Hopkinsville.	K. Heltsley..	Near riverbank......	.......do.............	Small	.......do........	
66	2 miles east of Hopkinsville	J. E. Morris..	Lowland...............	.......do.............	25	.......do........	Horizontal solution channel.
70	.......do.........................	Western State Hospital.	Near riverbank.......	.......do.............	M28	Sept. 30, 1952	Solution channel.
88	1.5 miles northeast of Hopkinsville.	.......do........	Foot of escarpment..	.......do.............	300	Feb. 9, 1950	Estimated summer yield 25 gpm.
89	2.5 miles east-northeast of Hopkinsville.	.......do........	Bottom of gully.......	Walled in with rock and brick.	100	.......do.........	Do.
93	Greenville Road, Hopkinsville city limits.	R. E. Haddock.	Escarpment slope.....	Walled up with limestone.	Small	Feb. 15, 1950	
133	3 miles east-southeast of Hopkinsville.	W. T. Dougherty.	Valley bottom........	None.................	....	....	
143	1.5 miles northeast of Hopkinsville.	Carlis France	....	Concrete enclosure.	10-20	....	
151	Northeast of Hopkinsville city limits.	Lions Club...	Foot of escarpment..	.......do.............	200	Mar. 16, 1950	Horizontal solution channel. Use: recreational.
152	.......do.........................	Gilbert Harned	Limestone cave beneath sandstone.	.......do.............	200	.......do........	Horizontal solution channel. Estimated summer yield 25 gpm.
157	Old Route 68, Hopkinsville city limits.	Mattie Rite...	Near foot of escarpment.	Rock wall enclosure.	50	February 1950	Estimated summer yield 10 gpm.
158	1 mile east of Hopkinsville	A. C. Clarke	Foot of escarpment..	None.................	50	Mar. 26, 1950	Estimated summer yield 5 gpm.

CONCLUSIONS

The supply of ground water in the area is more than adequate to serve the demands that currently exist. Most wells yield satisfactory supplies for homes and farms. Wells that are unsatisfactory or are failures because of insufficient yields do not necessarily indicate a lack of ground water in their vicinity; they are wells that encountered very small crevices or none at all. The probabilities are high that a successful well could be developed at no great distance from the unsuccessful one. In dry summers the yields of wells diminish, and some wells go dry; however, enough water to satisfy needs can be developed within the limits of the usual farm and little water is hauled even in dry summers.

It remains to be seen how fully the supply of ground water will be able to satisfy future demands. Here, as in the rest of the Nation, the demand for water is rising as more and more water-using equipment is installed about the home and farm. Furthermore, interest is being shown in the possibilities of supplemental irrigation of pastures and crops to avoid the losses that drought causes every few years.

The chief factor limiting the amount of ground water available in any spot is the thinness of the zone that is saturated with water of acceptable quality. As described previously, this zone averages only about 85 feet thick during the summer season of water need. Crevices exist from the surface of bedrock to depths of more than 200 feet, but the depth to water in summer averages more than 25 feet below the land surface, and near a depth of about 110 feet the overall quality of the water is probably poor. Probably no more than a few inches of recoverable water are stored in this fresh-water zone in the summer. Heavy pumping at one spot soon reduces the local supply, unless the well is located along a drainage course which concentrates the underground flow from the upstream area.

Obtaining the greatest possible yield of ground water calls for two types of procedures. First, the water naturally in storage should be developed as fully as possible. Second, steps should be taken to increase the amount of recharge to the ground-water reservoir over that which occurs naturally.

A great deal more of the water in storage could be recovered if certain of the wells now in existence were spaced farther apart than they are. Plate 4 shows that the pumpage at many farms comes from two or more wells located close to each other in the farmyard near house and barns. Two wells produce more than one, but when wells are close to each other the cones of depression caused by pumping overlap (the wells interfere with each other), and the total yield of the two wells is less than if the wells were a considerable distance farther apart. On many farms it would be possible to locate a well specifically for the stock, some hundreds of yards away from the well pumped for household use. It is also apparent from the map that even if the existent wells were more evenly scattered, broad tracts far from the effects of pumping would still remain, and therefore many more productive wells could be drilled.

Wells should be located in low topographic positions wherever possible, because the underground drainage tends to follow the surface drainageways. The water is nearer the surface in such low topographic positions, and pumping salvages water that is on its way out of the area. Pumping is the only method of salvaging the water moving out of the area, for obviously it is impossible to dam the many springs and seeps through which the water continually escapes, and the country is not well adapted to the construction of storage dams along the streams.

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