GROUND WATER RESOURCES OF BIG BLUE AND KANSAS RIVER VALLEYS FROM MANHATTAN TO WAMEGO, KANSAS

by

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TABLE OF CONTENTS

INTRODUCTION

History and Purpose of this Investigation

The investigation of the ground-water resources of Kansas was begun by the State Geological Survey of Kansas and the United States Geological Survey in 1937 in conjunction with the Water Resources Division of the Kansas State Board of Agriculture and the Division of Sanitation of the Kansas State Board of Health. The purpose of this program is to determine the availability and quality of ground-water supplies in the major river valleys and irrigation areas. To date, most of these surveys in Kansas have been of individual county areas.

For many years there has been an increase in the use of ground-water for industrial, municipal, agricultural, irrigation, and military purposes. As a paradox to this increasing demand for ground water in the Kansas River Valley, a cycle of relatively "dry" years, 1952 through 1957, has limited the quantity, quality, and availability of ground water and surface water in the Kansas Valley. Much public attention has been focused upon the present ground-water levels as a result of the long bitterly debated Tuttle Creek Dam project. The extent which the reservoir may affect the future levels and availability of ground water in this vicinity, and the value of the structure for flood control, recreation, and commerce remains to be seen.

The Kansas River Valley has been studied from its mouth at Kansas City to the west boundary of Range 10 East, near Wamego. The portion of the investigation described in this thesis was begun in the spring of 1959 and extended the study to the Manhattan and Tuttle Creek Dam vicinities.

The purpose of this study was to determine the present ground-water conditions, and to help guide future ground-water development and measures which may be necessary to safeguard the availability and quality of the future as well as the present supplies.

Location and Extent of Area

The area of Kansas River Valley covered in this report extends from one mile east of the western boundary of Range 10 East, about one mile west of Wamego in Pottawatomie County, to the second section line west of the eastern boundary of Range 7 East, which is about two miles west of Manhattan in Riley County, a distance of 15 miles east to west. The northern and southern boundaries of the area were governed by the topography and the configuration of Kansas River meanders, and of the junction formed by the Kansas and Big Blue Rivers (Figure 1). The main valley floor of the Kansas River in this area is approximately 32 square miles, and the area for the Big Blue River approximately 12 square miles. A total of about 90 square miles was investigated.

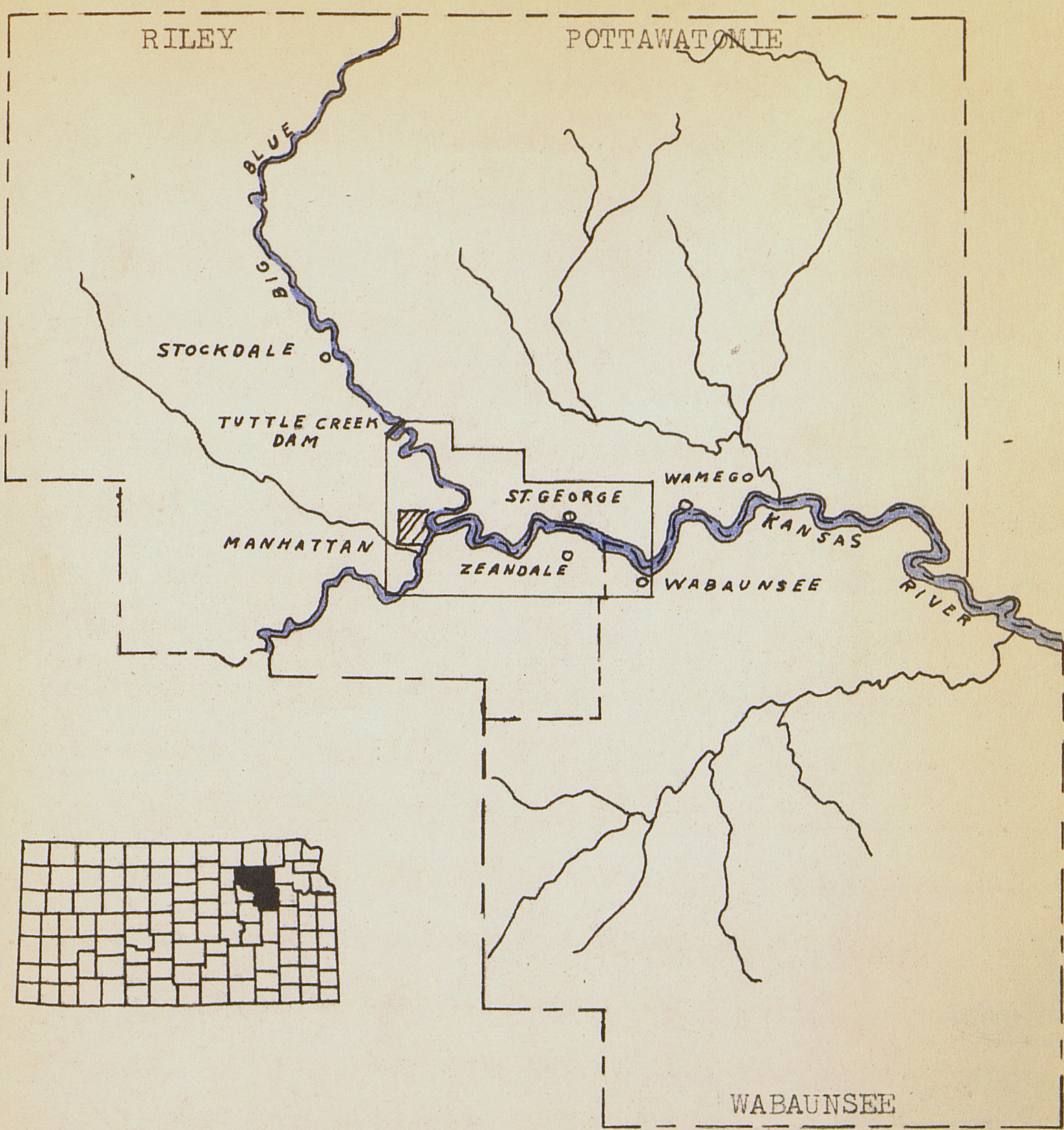


Figure 1. Index map of Kansas showing location of area covered in this thesis.

Previous Investigations

In some related areas detailed work has been done. Moore (1918) in his description of Camp Funston and Fort Riley, briefly discussed the importance and quality of the ground water in that part of the Kansas River Valley. Ground-water studies were made in eastern Kansas by the Kansas Emergency Relief Committee in 1934 and by the Federal Works Progress Administration in 1936. The surveys were primarily interested in locating ground-water supplies for upland communities. A hydrologic study of the Kansas River Valley was also made for the U. S. Army Corps of Engineers by Wyman (1935). As a result of the World War II crisis, Moore and others (1940) prepared a general report on the ground-water resources of Kansas. A report on the ground-water conditions in the Kansas River Valley in the Lawrence vicinity was made by Lohman (1941). Also Lohman and others (1942) investigated the availability of ground water for national defense industries in Kansas. This report very generally described the ground-water conditions in the Kansas River Valley and the valley of the Big Blue River.

Fishel (1948) studied the ground-water conditions in the Kansas River Valley in the Kansas City area. Davis and Carlson (1952) mapped and described the geology and the ground-water resources between Lawrence and Kiro along the Kansas River Valley. More recently Dufford (1958) described and mapped the Quaternary sediments and ground-water conditions in the Kansas River Valley between Bonner Springs and Lawrence. Later, Beck (1959) mapped and described the geology, geography, and ground-water resources of the Kansas River Valley from Kiro to the west boundary of Range 10 East which is one mile west of Wamego. In Kansas, as of June 1959, ground-water reports have been published for 44 complete counties and for portions of another 22 counties. In addition 18 more studies are in progress.

Methods of Investigation

Five weeks during the early summer of 1959 were spent in the field collecting data upon which this report is based. Approximately 300 locations were visited and data on the location of wells, depth to water, total depth, flow, yield, type of well, adequacy, quality, and other pertinent information was obtained. The Standard Well Schedule Form 9-185 used by the Water Resources Division of the United States Geological Survey was completed for 197 wells where the information was accurate.

Elevations of the measuring points of the wells were determined from topographic maps and by use of a hand level. Samples of rock materials were taken from several wells to determine the nature of the equifers. Water samples were taken from 11 randomly selected wells, and chemical analyses of these samples were made by the Kansas State Board of Health (Table 1).

The depth to the static water level and drawdown was measured using a Fisher M-Scope Water Level Indicator Model WL. This instrument consists of a free rotating reel with 300 feet of electric line marked at five-foot intervals. Attached to the lower end of the line is a weighted electrode assembly which is shorted upon making contact with the water surface. A milliamper meter is attached to one side of the reel and the upper end of the electric line and registers the magnitude of conductivity of the water when contact is made. While in use care was taken to prevent entangling the line down the well and to prevent lacerating the line on the sharp edges of the pump equipment. When not in use the switch was turned off for protection of the battery, and the line and electrode assembly was thoroughly cleaned and dried.

Well Numbering System

The wells shown on Plate I and Tables 1 and 2 were given a field number corresponding to the order in which they were visited within each county. The field number consists of the abbreviated county name followed by the well number for that county. For each well shown on Plate I the first number above the line corresponds to the number of the well in the well tables for that county and the second number indicates the depth to the water level below the surface. The number below the line indicates the elevation of ground-water level.

Well locations are given according to the General Land Office System of land description (Figure 2). The components for this system are: townships from north to south, ranges from east to west, section, quarter-sections, and quarter-quarter sections.

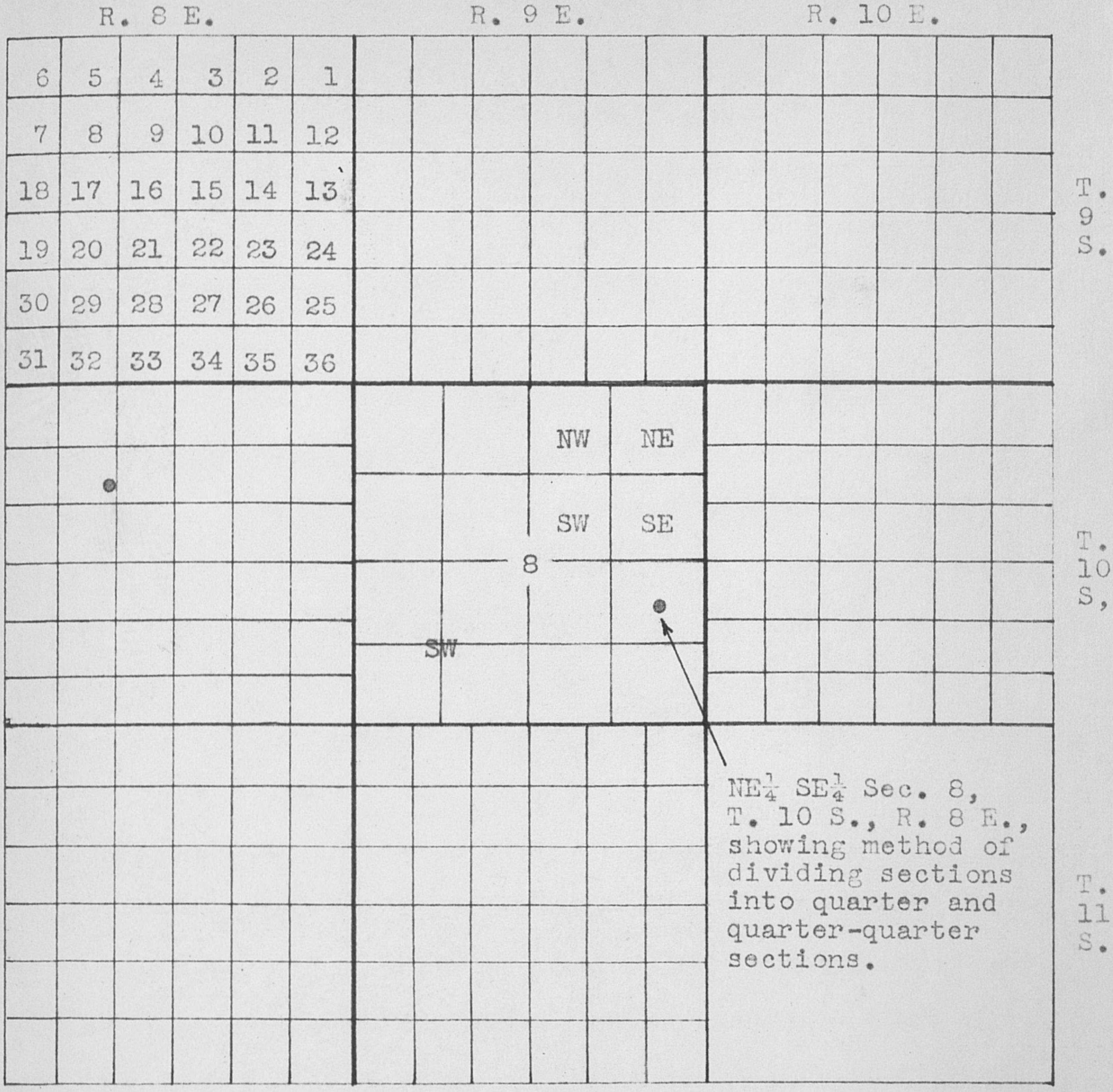


Figure 2. The United States General Land Office System of land descriptions.

TOPOGRAPHY AND GEOLOGY

The area of the Kansas River Valley from Salina eastward to Kansas City lies within the Central Lowlands Physiographic

Province. This portion of the Kansas River Valley also forms the boundary between the Dissected Till Plains section to the north and the Osage Plains on the south as defined by Fenneman (1931), Moore (1940), and Fenneman and Johnson (1946). Raisz (1957) places this area between the Drift Hills on the north and the Wichita Prairie to the southwest and Oread Escarpment of the Flint Hills to the south and east.

The most notable topographic features are the broad flat eastwardly winding Kansas River and the narrower meandering southward flowing Big Blue River. Both valleys are bounded by moderately dissected erosional escarpments of westward dipping Permian limestone and shale formations. The lower Permian rocks belonging to Admire and Council Grove groups of Wolfcampian Series have been extensively eroded by major alluvial drainageways in this area.

The erosion was accomplished in part by the southern edge of the Kansan Ice sheet which generally terminated along the Kansas River Valley. Melt water deposited up to 40 feet of drift in this area as the glacial front receded northward. Till now caps scoured and eroded Paleozoic strata along the north side of the Kansas River Valley. Boulders range from a few inches in diameter to large irregularly shaped quartzite masses one-third the size of the average automobile (Smith, 1959). A prominent deposit of these boulders, or erratics, termed "niggerheads" by the drillers, can be seen during low water stages along the north bank of the Kansas River west of St. George. The provenance of the erratic pinkish quartzites and granites according to Frye and Leonard (1952) is southeastern South Dakota and northwestern Iowa.

In the eastern half of this area, from the western boundary of Range 9 East to the Riley-Wabaunsee County line, the Kansas River Valley is asymetrical as a result of the river cutting exclusively on the north side of its valley. From Zeandale to Wabaunsee, Deep Creek flows eastward paralleling the Kansas River. The northward cutting of the river here has increased the gradients and also the erosional power of the smaller tributaries to the north. Therefore the Kansas River Valley has steeper bluffs and a more rugged topographic character adjacent to the north side of the river in the St. George vicinity. Terrace deposits are lacking on the north side of the river in the St. George vicinity because of increased gradient. However unusual Pleistocene loess deposits occur two miles west and one-half north of St. George (Smith, 1959).

A wide channel-scarred flood plain adjacent to the river is bordered by remnants of Newman terrace deposits at the base of uplands on the south side of the river from west boundary of Range 9 East to Wabaunsee. This terrace has been largely eroded by Deep Creek. Wisconsinan and Recent terrace remnants border the narrow entrenched meandering valley of Deep Creek.

The Kansas River meanders centrally within its valley from the east boundary of Range 8 East to Manhattan and the confluence of the Big Blue River with the Kansas River. However, the south valley wall forms a much steeper bluff as a result of increased gradient caused by the added volume from the Big Blue River. Newman Terrace remnants are present on both sides of the valley, but are most prominent below Fremont Point where the upper terrace level may be the Buck Creek Terrace.

The valley of the Big Blue River being narrower and having a steeper gradient does not have as extensive flood plain as the Kansas River Valley. Newman Terrace deposits are fairly extensive in this portion of the Big Blue River Valley. The valley walls are abrupt due to the channel paralleling the resistant westward dipping limestones and shales, except on the west side between Rocky Ford and Manhattan.

One notable feature of the Big Blue River is coarser river bar gravels with abundance of glacial quartzite, flint and gypsum pebbles. This is a result of the glaciated region which it drains and the gypsum deposits near Blue Rapids. The Kansas River in this area generally deposits coarse sands along the inside of the meanders and on abundant river bars.

The outer margins of Kansas River Valley are well drained in this area by drainage ditches. Many small ponds in the old meander scars on the flood plain are being used for stock and irrigation water supplies. One of these ponds is illustrated in Plate II. During wet cycles such as this year, the bluffs abound with springs (Plate IV, Figure B).

The total relief of the area is approximately 435 feet and local relief is commonly between 150 and 250 feet. The lowest

EXPLANATION OF PLATE II

Depression in the flood plain of the Kansas River Alluvium, south of Wamego, Kansas. (NW$\frac{1}{4}$ SE$\frac{1}{4}$ Section 16, T. 10 S., R. 10 E.). The water surface of the pond coincides with the ground-water table, therefore the water level is more stable and less susceptable to seasonal fluctuations. This pond is used for both irrigation and stock water supplies.

point is about 965 feet above mean sea level along the Kansas River near Wabaunsee in the eastern extremity of the area. Fremont Point, the highest peak in the area, has an elevation of 1397 feet and is opposite the mouth of the Big Blue River.

CLIMATE

The Kansas River Valley is well supplied with abundant sunshine and precipitation during the average 172 day growing season in Riley County and 183 day season average in Pottawatomie County. The United States Weather Bureau records show the months of July and August are warmest with daily maximums often exceeding 100° F. The highest temperature recorded for Manhattan was 116° F., and 114° F. for Wamego, both on August 13, 1936. The coldest months are December through February with occasional cold waves of -10° F. to -27° F., such as was experienced during the winter of 1958-1959 at Manhattan. The coldest ever recorded at Manhattan, which has continuous temperature records since 1856 and the longest temperature records in the Great Plains region, was -32° F. on February 12, 1899. The coldest officially recorded at Wamego was -22° F. on January 22, 1930. The annual mean temperature for Manhattan and Wamego is 55.4° F.

Most precipitation falls during the months of May, June, August, and September. The yearly normal is 32.03 inches at Manhattan and 32.94 at Wamego. Normal annual snowfall at Manhattan is 17.6 inches. The greatest snowfall recorded in a 24 hour period was 18.0 inches at Manhattan and 24 inches at Wamego, both on February 27, 1900. In 1915 which is the wettest

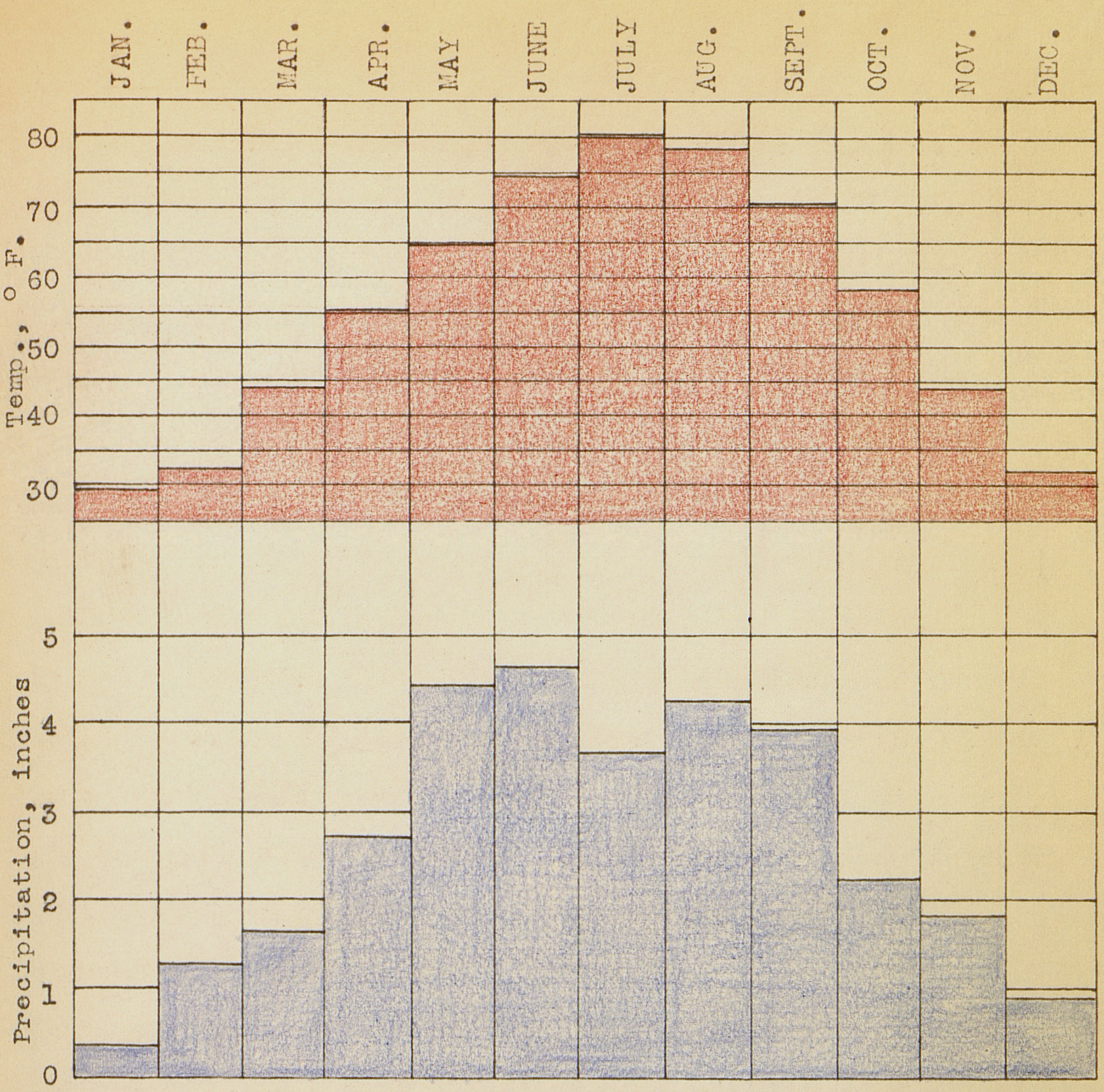


Figure 3. Graph showing normal monthly precipitation and temperature at Manhattan.

year on record for this area, 56 inches of snow fell at Manhattan. Figure 3 illustrates the temperature and precipitation relationship for this area.

GROUND WATER

In order to present a better understanding of the aspects associated with ground-water occurrence and movement, certain basic principles of ground-water hydrology are discussed in the following pages. This discussion in part has been adapted from Meinzer (1923), Tolman (1937), and Moore and others (1940). For a more detailed treatment of all phases of ground-water the reader is referred to these publications.

Summary of the Principles of Occurrence and Movement

The following three paragraphs which very well summarize the terminology and movement of ground-water have been adapted from Beck (1959).

Water beneath the surface of the earth is termed subsurface water. Below a certain level in the earth's crust, porous and permeable rocks generally are saturated with water. The saturated rocks are called "the zone of saturation" and subsurface water in the zone of saturation is called "ground water". The subsurface water above the zone of saturation is called "suspended subsurface water", or "vadose water". The upper surface of the zone of saturation is the "ground-water table" or simply "water table". The above relationships are illustrated by Figure 4.

When water joins the water table it moves down gradient by force of gravity toward a point of discharge. The water table generally slopes in the same direction as the land surface but

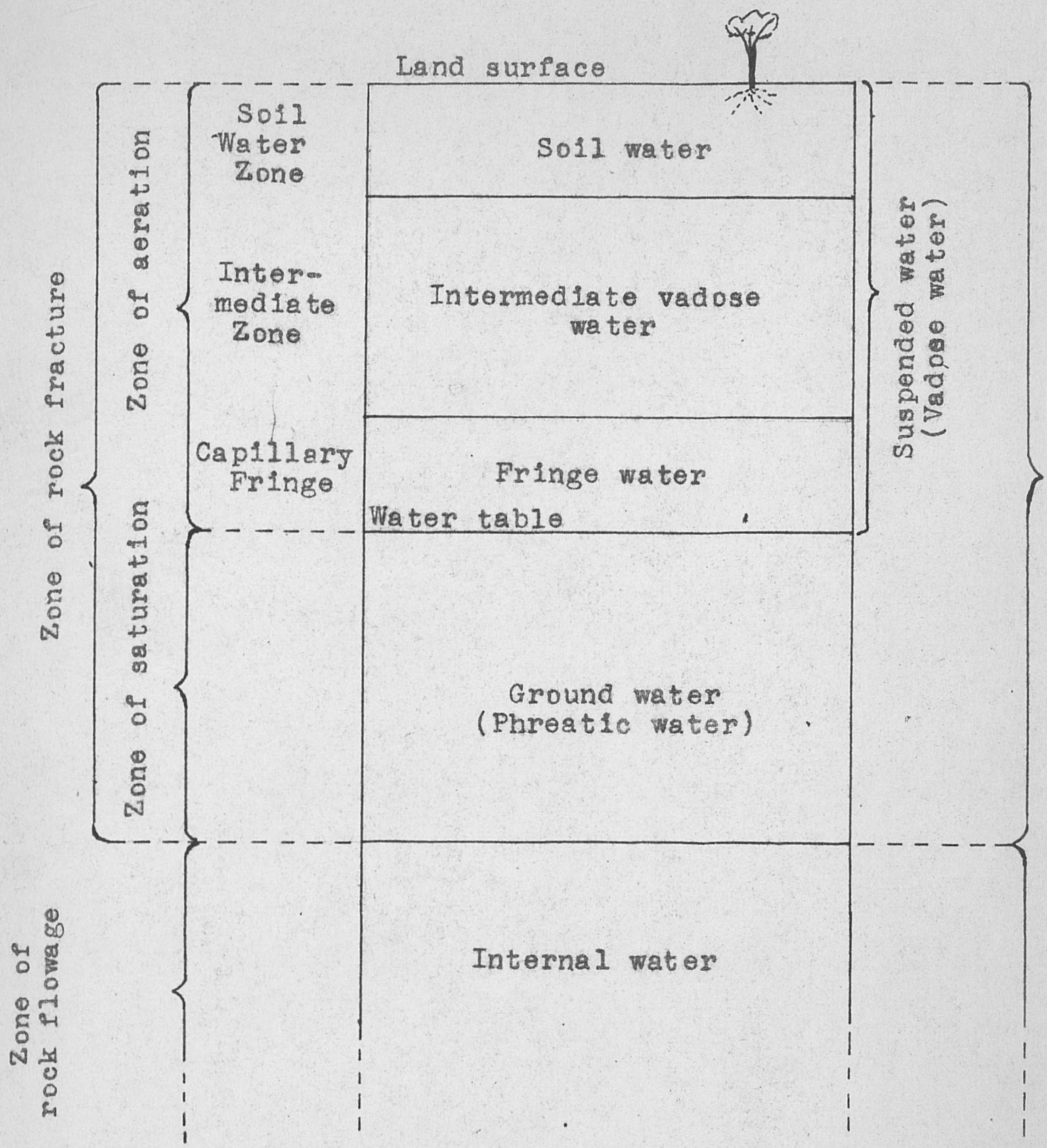


Figure 4. Diagram showing divisions of subsurface water. (after Meinzer)

less steeply. Water moves down grade at right angles to the water-table contours. In the Kansas River Valley (Plate I) general movement is down stream and toward the river, thus ground water is being discharged into the Kansas River.

The ground water available to wells in the Kansas River

Valley is derived from precipitation which falls within the area or in areas upstream. Part of the precipitation runs off the surface and is discharged as stream flow, part of it evaporates or is absorbed by growing vegetation and transpired into the atmosphere, and part of it which escapes runoff, evaporation, and transpiration percolates slowly downward until it joins the water table. However not all water infiltrating the soil reaches the water table; some of it adheres to the soil particles, and only the excess reaches the water table.

Hydrologic Properties of the Water-Bearing Materials

The rocks and soils which form the outer crust or mantle of the earth contain numerous open pores or voids called "interstices". A certain amount of the precipitation which falls on the earth's surface passes into these interstices. The portion of the water which is absorbed by these interstices varies with the porosity of the material which covers the surface. The volume, size, shape, and arrangement of the interstices in these materials depends upon the character of the rocks. Therefore, the occurrence of ground-water in any area is determined by the geology and climate of that area.

Porosity. The size of the voids in rocks range from minute microscopic pores to huge caverns which have been dissolved in some limestones. These openings may be individually isolated, as in some lavas, where fluids may be trapped and are not able to pass from one void to the next. Generally the voids are interconnected and will allow the fluids to percolate through them.

Absolute Porosity. The absolute porosity of a rock is the percentage of total volume of that rock which is occupied by voids. A rock is said to be "saturated" when all its interstices are filled with a fluid. Absolute porosity determines only the amount of fluid a given rock may retain.

Effective Porosity. The effective porosity is that percentage of the volume of total voids which are interconnected and will allow the fluid to be transmitted from one void to another.

Permeability. The permeability of a rock material is its ability to transmit a fluid under a hydraulic gradient. It is measured by the rate at which the fluid will be transmitted through a given cross-sectional area and distance under a given difference of head. According to Wenzel (1942), the coefficient of permeability for water in Meinzer's units, is the rate of flow in gallons per day through a cross-sectional area of one cubic foot under a 100 percent hydraulic gradient at a temperature of 60° F.

A rock having very small interstices may be very porous, but it would be difficult to force water through them, whereas a rock with less porosity but with larger voids may transmit the water very readily. Therefore it can be seen that permeability is dependent upon effective porosity and not upon absolute porosity. When both the effective porosity and the permeability are relatively high, in a water-bearing material, so that water can migrate freely through it, the rock is said to be a good "aquifer".

Specific Yield. The capacity of a rock to retain water is dependent upon its porosity, whereas the rocks capacity to yield water to a well is determined by its permeability. Water will be held on the grain surfaces in finer grained rocks with very small interstices by surface tension and molecular attraction which will be greater than the force of gravity. This type of water is known as adsorbed water or pellicular water and is not available to wells. The adsorptive nature of water is very usefully applied in water flooding methods of secondary recovery of oil.

The specific yield of a rock or soil, with respect to water, is the ratio, stated in percent, of (1) the volume of water that it will yield by gravity after being fully saturated to (2) its total bulk volume. The percentage of water retained by the material is known as the "specific retention" for that material. Therefore, specific yield is a measure of the volume of water yielded by a saturated material when the water table in that material is lowered.

Source

All the water-bearing rocks are sedimentary in origin in the Kansas River Valley and in most other river and stream valleys of Kansas. This means they were all deposited by the wind (loess and fine silts), large prehistoric bodies of water (limestones, dolostones, shales, sandstones, and coals), or by rivers and streams (silts, sands, and gravels), both ancient and recent. The interstices which hold the water in these sedimentary rocks are either open voids between the rock grains and the bedding planes, or are fractures that have resulted from deformation and enlarged by solution after the rock became indurated.

Ground water in this area of Kansas is derived entirely from precipitation, in the form of rain, snow or hail which falls directly on the surface of the land. In alluvial valleys adjacent to rivers and streams the ground water may be replenished by seepage from the rivers if the ground-water table falls below the stream level. In such case the stream is said to be "influent", that is, it is supplying water to the surrounding rock material which is below the river level. When the reverse occurs, such as when the ground water in the adjacent areas is higher than the stream level, the stream is then being fed by the ground water and is said to be "effluent". During periods of high water and flooding as shown in Plate III, Figure B, the Kansas and Big Blue rivers are influent immediately adjacent to their channels. The temporary influent water is known as "bank storage" and will be drained back into the river under normal conditions.

At present this area of the Kansas River Valley has received abundant rainfall causing the ground-water surface in the adjacent areas to be above the water surface in the rivers. Therefore the Kansas River and its two major tributaries in this area, the Big Blue River and Deep Creek, are effluent streams.

EXPLANATION OF PLATE III

Fig. A. Ox-bow pond on the Newman Terrace of the Kansas River Valley (N½SE¼ Section 9, T. 10 S., R. 8 E.). The terrace deposit is underlain by an impervious silt and clay layer which will retain the water.

Fig. B. Northeastwardly view of the Kansas River from the Manhattan Bridge (SW¼ SW¼ Section 17, T. 10 S., R. 8 E.) showing high water stage of the river during this investigation. During periods of high water and flooding bank storage will occur in the alluvium adjacent to the river channel.

A

B

The upland wet weather streams are also effluent and are thus draining the perched water tables in the upland areas.

Valley floor areas generally are the greatest reservoirs of ground water and are also the most accessible. One of the chief aquifers is the Pleistocene and Recent alluvium which forms a thick flood plain and the Newman Terrace gravels as it nears the walls of the valley. This alluvium is late Wisconsinan to Recent in age and ranges from a few feet to 85 feet in thickness depending upon the configuration of the eroded bedrock channel which it overlies. The alluvium is at present saturated within 18 feet of the surface in most places in this area. In a few localities water has collected in depressions in the Newman Terrace where it forms ox-bow lakes and marshes, one of which is shown by Plate III, Figure A.

In normal periods of precipitation one sand point driven 20 to 25 feet into the alluvium will yield adequate water for the average household in the valley floor area. Two or more shallow sand points may be required to provide an adequate supply for stock, chickens, small gardens, or lawn watering. It is best to go deeper into the alluvial gravel to obtain a larger quantity of water. The deeper wells are generally more economical because fine silt in the upper portion of the alluvium has a strong abrasive effect upon the pump bearings and other moving parts besides plugging the points so that they seldom last longer than two years under normal usage.

For a larger supply of water such as is needed for large stock herds, irrigation, community and industrial use, the alluvial gravels are the best available source.

Gravel of Newman Terrace furnishes the most abundant source of ground water present in this area. It is silty to sandy in the upper part and grades into coarser sand and coarse gravel downward. The sands may be composed of a great variety of minerals since the Kansas River and its tributaries drain a large area which includes all of northern Kansas and portions of Nebraska and Colorado. Samples of the gravel generally consisted of a mixture of rounded quartzites, limestones, cherts, and iron-cemented sandstones from about one-quarter of an inch up to six or eight inches in diameter. The size and shape of gravel depends upon the distance transported and the hardness of the material. Gravel fill may be found from a depth of 28 feet below the flood plain surface up to 70 feet thick depending upon the irregularities of its surface when it was deposited in late Pleistocene times.

In one locality (sections 1 and 12, T. 10 S., R. 9 E.) an iron sandstone was found to be the aquifer. Generally a loosely cemented, well sorted sandstone is an excellent source of water. However the areal extent of this sandstone is not known as it was penetrated only in three wells. The sandstone seemed to furnish an adequate supply of water but was reddish and hard making it undesirable for domestic use.

The general character and lithology of the rocks commonly varies locally. There may be a lensing of gravel, sand, shale, or clay which is very common in alluvial and gravel deposits in major drainage ways. These lenses may therefore increase or decrease the water yield locally from one well to the next.

Artesian Conditions

Flowing artesian wells are those which flow on to the surface freely by natural means. Such conditions may exist where an aquifer is confined or overlain by a relatively impermeable unit of material that dips generally away from the outcrop areas toward the area of discharge. Precipitation and ground water which enter the updip area of the confined aquifer will percolate down dip by gravity action. The hydrostatic head developed by the weight of the confined column of water may have enough pressure to force the water to the surface down dip when the overlying confining formation is penetrated. If the water in a well does not rise to the surface artesian conditions still exist. The column of water which will rise within the well hole will be proportional to the pressure developed by the water in the aquifer updip.

Artesian conditions do exist in many wells which were inventoried in this area. However none were of the flowing artesian type. Most of the wells reported to be artesian were in the intermediate area between the uplands and the flood plain. When a certain "white limestone" was penetrated water gushed into the wells and rose to within 25 to 35 feet of the surface. It was generally reported by the users to be very good tasting and fairly soft. The source area for the confined aquifer would have to be to the east generally because the strata are dipping westward in this area.

An exception to the above statement is caused by the local structure known as the Zeandale Dome which is located on the south side of the Kansas River just southeast of the community of Zeandale from which its name was derived. The consolidated Permian rocks which formed the crest of the dome have been eroded thereby forming an elliptical outcrop pattern. Direct precipitation along with surface water enters these formations in the outcrop area. The aquifer here was determined to be the Tarkio limestone member of the Wabaunsee group of the Virgilian Series of the upper Pennsylvanian system. The Tarkio limestone generally does not yield much fresh water, but in this case of the updip area, it is locally a source of a moderate supply of water which is adequate for the households of the local residents. Farther down dip the Tarkio limestone yields salt water. The Tarkio limestone is confined between the Pierson Point and Willard shales which are relatively impervious. This limestone locally is thinly bedded, three to five feet thick, highly fossiliferous with large fusulinids, weathers a yellowish-brown, and is medium gray-brown on fresh surface.

The Configuration of the Water Table

The water table has been defined as the upper surface of the zone of saturation. This zone of saturation however is not a stationary nor flat plane but fluctuates gently in response to the addition or withdrawal of water from the ground-water reservoir. The water table generally slopes with the topography of the land surface, but more gently, and is constantly changing with many irregularities. The direction of movement, gradient and elevation of the ground-water table can be shown by constructing static water-table contours on a map of the area under study. This was done for this area and is shown on Plate I.

The permeability of the aquifers within the area have a characteristic effect upon the configuration of the water table. In areas where conditions are favorable for a high rate of recharge, such as the alluvial valley floor areas of the Kansas and Big Blue Rivers, the water will be absorbed into the loose alluvium and gravel faster than it can spread out thereby causing a mound in the water table. In the area parallel to an influent stream the water table surface would be an inverted trough form. This is shown by Figure 5. In such areas the flow in streams may be observed to diminish and even disappear entirely when running over very porous and permeable unsaturated portions of their bed, such as alluvium, sandstones, and cavernous limestones. In the event of an effluent stream, the resulting form of the water table will be a trough (Figure 5).

If water is withdrawn by pumpage from the zone of saturation faster than it can flow laterally through the water-bearing formation, a funnel shape depression as illustrated in Figure 6

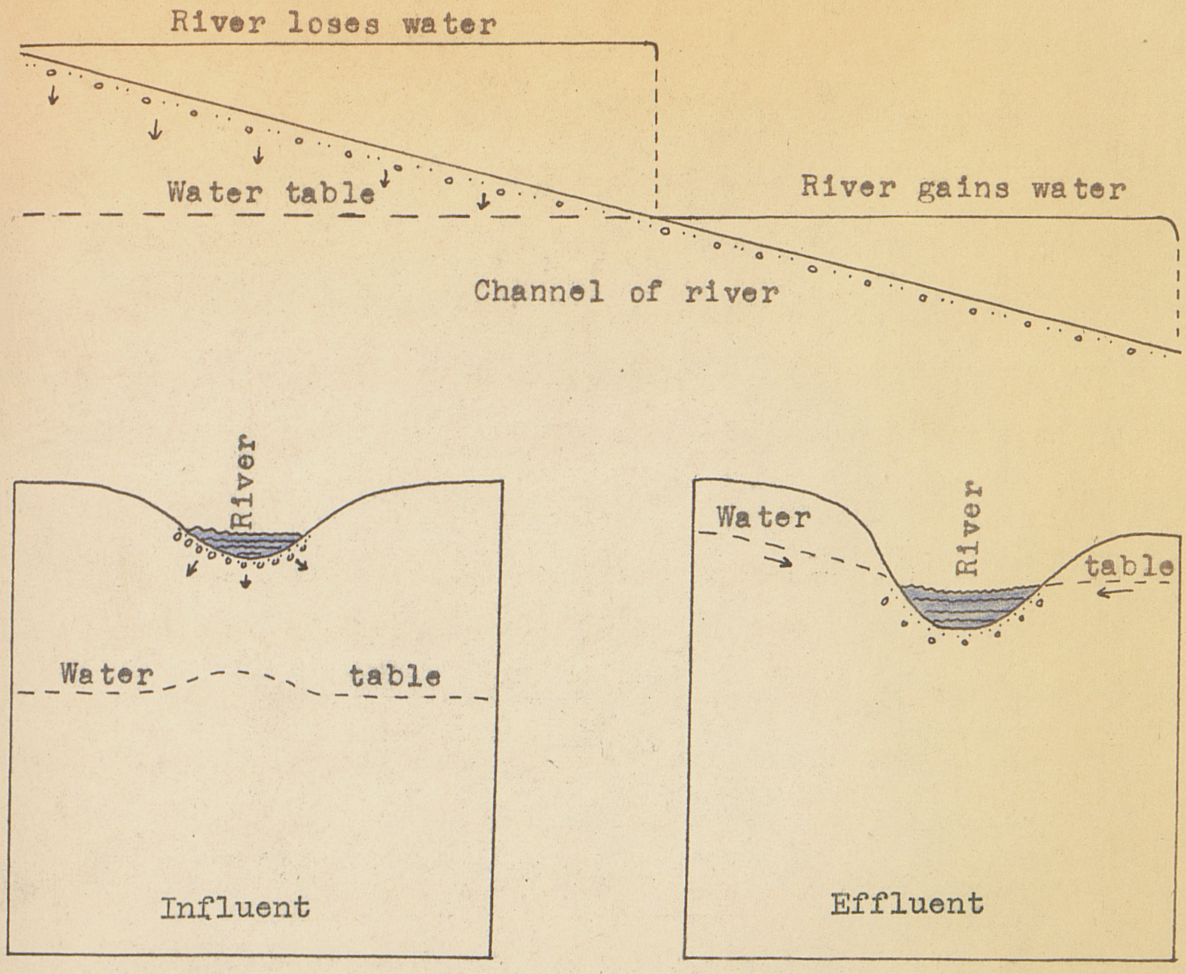


Figure 5. Diagrammatic sections showing influent and effluent streams.

may be formed.

In Riley, Pottawatomie, and Wabaunsee Counties the Kansas River may be both an influent and effluent stream depending upon the fluctuating climatic conditions. Generally the river in this area is fed by the ground-water table.

In the uplands the water is principally retained in limestones that are fractured, caverned, porous, or form an impervious subsurface table which will not allow the ground water to percolate downward below its surface. This condition is known as a "perched water table".

The glacial drift that overlies many of the upland sections on the north side of the Kansas River Valley in Riley and Pottawatomie counties holds an abundant water supply during wet years. The water table is then almost as near the surface on the hilltops that are blanketed by the drift as it is in some of the smaller valley areas. The glacial drift becomes drained as the water table lowers and the shallower wells are dry during dry years. Therefore the shallow wells in the uplands obtain water from a perched or semiperched water table and their contours will not correlate with the water table contours in the lower valley areas. The upland perched water table will tend to feed the lower water table due to gravitational seepage.

The water table contours shown on Plate I were based on water levels measured during a period of relatively abundant precipitation as illustrated by Figure 3. The present water table is this area, as measured in most of the wells, is the highest since 1951. In some wells which were drilled and measured during the summer of 1955 through 1957 the water level has risen as much as ten feet. In a few wells in the upland area northwest of St. George, measurements were taken in March 1959 and again checked later in June 1959. During this period of about three months the water level was found to have dropped three to five feet locally. This was because of moderate precipitation along with low evaporation, transpiration, and runoff during the winter months followed by increased domestic and stock use during May and June in the immediate vicinity of the wells and the outcrop areas of the aquifers.

Davis and Carlson (1952, p. 233) reported normal fluctuations in the water table, between Lawrence and Topeka, were no greater than five feet a year at a distance of 3,000 feet from the Kansas River, unless the water table was affected by pumping or water flooding the entire valley.

The wells showing the greatest fluctuation were of the dug type with native rock lining. The larger diameter and porous rock lining allows a greater surface area from which water may be collected. However, this type of well construction is more susceptable to water loss during the dry periods and also provides a greater chance for surface drainage entering the wells and polution occurring from surface runoff and organic debris.

Recharge

The processes of adding water to the zone of saturation is known as ground-water recharge. The normal annual precipitation in this area is about 32 inches, but only a small percentage of this amount reaches the water table. The portion of precipitation which does not transpire from plants, evaporate, or run off the surface may infiltrate into the rock material and percolate downward until it is added to the water table.

The quantity of precipitation which is infiltrated underground depends upon several factors: the intensity, frequency and kind of precipitation, type of soil or rock present, amount and type of vegetation, the surface topography and the time of day and year. An article by George S. Knapp in the Kansas State Board of Agriculture Report (1948) discusses the effects of temperature upon water supplies.

Water passes underground in a variety of ways, of which the following are the most prominent: direct absorption of rainfall and other forms of precipitation, the lateral spreading of streams into the porous and permeable deposits in their valleys, the seepage of water from oceans, lakes, swamps, and ponds into the materials which bound them, and the sinking of surface flows, caused by springs or artesian conditions, as they pass over zones of unsaturated permeable and porous materials.

The most favorable localities for recharge in this area are those which are relatively level and underlain by permeable material. This would include the valleys of the Kansas River, Big Blue River, and Deep Creek. Much of the surface of these valleys is rather flat. The sandy surficial material and the gentle gradients of these areas reduce runoff to a minimum. The depressions on the flood plain and terraces collect the water and allow much of it to infiltrate to the water table rather rapidly.

Some depressions are underlain by a clayey impervious layer, especially the scars on the Newman Terrace (Beck, 1959, p. 47) and may retain water for a long time hence losing moisture by evaporation. One of these many depressions is shown in Plate III, Figure A. Other depressions are below the ground-water level thus causing their water levels to coincide and fluctuate with the ground-water table, Plate II.

The rate and amount of recharge was not determined in this area. Lohman (1941, p. 45) reported that ground-water recharge for Lawrence in the eastern part of the Kansas River Valley amounts to as much as 10 percent of the annual precipitation. On this basis the average annual recharge for this section of the Kansas River Valley would be about 3.2 inches. The recharge rate would vary depending upon the cycles of wet and dry years. The amount of recharge in upland areas would be much less because the underlying limestones and shales are not as porous nor permeable and there would be more runoff on the steeper slopes.

One important characteristic of alluvial ground-water reservoirs is that material beneath the surface does not have equal permeability. This is because of the lensing of various materials that may occur. It is also noteworthy to observe that in narrow stream valleys, such as Deep Creek in this area, the best source of ground water is where the deepest erosional channel has been carved into the bedrock. The coarsest sands and gravels were deposited in these deeper channel cuts. The coarsest and most pervious portions of the valley fill is best located by test holes using an auger, sand bucket, or drill. This procedure is necessary because these deposits were formed in sinuous, anastromosing patterns thousands of years ago similar to those being formed today in river areas.

Recharge in upland areas adjacent to the Kansas and Big Blue Rivers is directly from precipitation that falls on the surface in the area, from ponds in the area, and from the outcrop area updip to the east. The amount of recharge in the uplands from ponds and direct precipitation is much less than recharge in alluvial areas of the valley. Floors of properly constructed ponds are composed of impervious swelling clays which cut seepage to a minimum, thus increasing the amount of surface water lost by evaporation.

Ground-Water Discharge

When water is removed from the zone of saturation by any method, the loss is known as discharge. In the Kansas River Valley, the Big Blue River Valley, and adjacent areas, ground water is constantly being discharged in one or more ways.

Discharge by Transpiration and Evaporation. Transpiration is a process essential to plants whereby water is removed from the soil zone by plant roots and is discharged into the atmosphere through tiny pores in the plant foliage. The depth from which plants extract ground water varies with plant species and soil types. Most grains and grasses do not send root systems more than three or four feet in search for water and support. However, plants with extensive root systems, such as alfalfa and bindweed, may penetrate the ground as deep as 30 to 35 feet. Therefore in valley areas where the water table is relatively close to the surface, these plants and many trees may easily derive water from the capillary fringe zone and the water table.

Direct loss of ground water by evaporation can only occur where the water table lies within two or three feet of the surface. This would probably limit this loss to areas adjacent to springs, seeps, streams, and marshy flood plain areas.

Discharge by Wells. The quantity discharged by wells will become an increasingly important factor in all areas of Kansas and most of the Great Plains as irrigation, industrial, and community needs increase. Wells are the major source of water supply for municipal, industrial, irrigation, stock, and domestic uses. Wells used for industrial and municipal supplies in this area are exclusively located in the floor of the major valleys. This location of wells is obvious because larger streams, having larger drainage areas would be expected to contain the greatest and most accessible supply of water. Some individuals in upland areas adjacent to the valley have drilled as deep as 250 feet in order to obtain an adequate and permanent supply of water for stock and domestic use. Most of the upland wells in this area are 90 to 150 feet and yield from 0.5 to 2.0 gallons per minute of water for domestic use.

The average maximum pumping rate of irrigation wells that were inventoried in the Big Blue and Kansas River valleys, is about 950 gallons per minute. None were operating at their maximum rate during this investigation, but during the hot months of July and August they generally pump at their maximum capacity

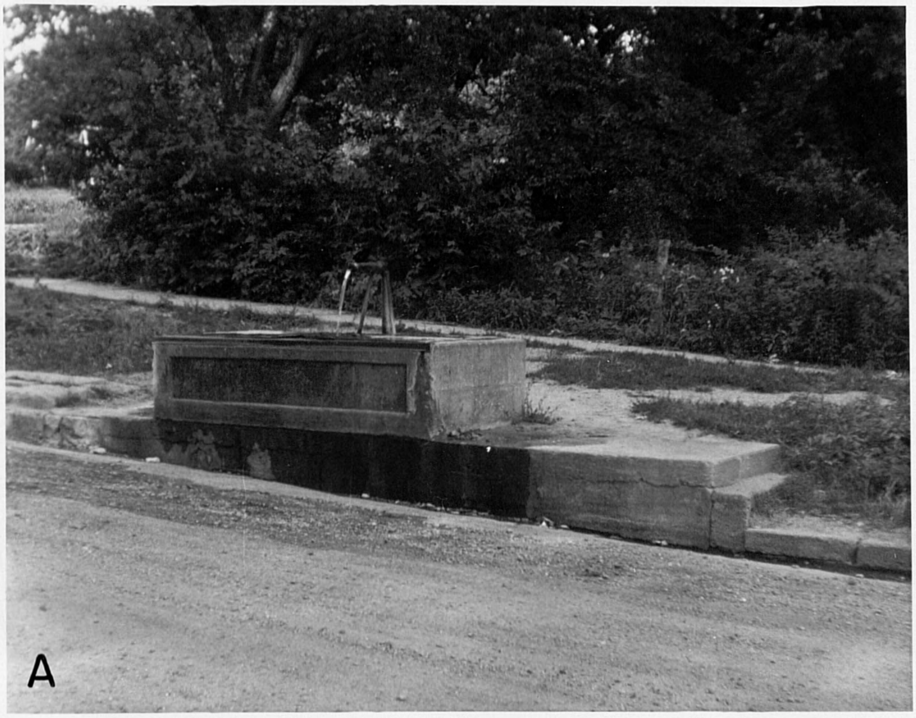
24 hours a day. One well operating at this average maximum rate for one day would withdraw about 1,368,000 gallons of water from the ground-water reservoir. In addition there are many other wells in the Manhattan area which supply commercial and industrial users. One of the major uses of these private wells is for air-conditioning purposes. Therefore it can easily be foreseen that as more demand is made upon ground water in the Kansas River Valley by industrial, irrigation and community wells the discharge rate from these wells may exceed the annual recharge in this area.

Other Forms of Discharge. Along the valley walls of major drainage ways the water is discharged from springs that crop out on the hillsides and bluffs between the rock layers. Springs are generally the result of ground water being entrapped by the rock unit farther back in the hill. The water then percolates slowly by gravity down gradient until it reaches the truncated area of that rock unit where it then seeps out to the surface forming a spring. Plate IV, Figure B illustrates one of the many seeps in this area at present because of the abundant rainfall during the last six months. Some springs are fed from aquifers of large areal extent that are buried many tens of feet under the hills. Springs which have such sources generally are permanent and flow during the dry years but with diminishing volume. One of the best known permanent springs in Kansas is Blackjack Spring located in St. George (Plate IV, Figure A).

EXPLANATION OF PLATE IV

Fig. A. The famous Blackjack Spring in St. George, Kansas ($SW\frac{1}{4}$ $SW\frac{1}{4}$ Section 9, T. 10 S., R. 9 E.). Water is piped from a nearby perched water table seep in the limestone and shales of the Richardson subgroup of the Wabaunsee group. This is one of the better known permanent and public springs in Kansas.

Fig. B. One of many ground-water seeps which are present along road cuts and bluffs in bedrock outcrops in this area. Here ($NW\frac{1}{4}$ Section 23, T. 10 S., R. 7 E.) ground water migrates downdip toward the outcrop area of the Threemile basal limestone members of the Wreford limestone formation.


A


B

The perennial streams which feed the Big Blue and Kansas Rivers and Deep Creek get their entire flow from springs and seeps within the uplands in this area, except for short periods during and after precipitation, when surface runoff occurs. A considerable quantity of ground water may be lost from reservoir rocks in this way.

At several places in the upland areas residents reported the water level in their wells dropped as much as two feet and the water became cloudy possibly caused by the flushing action created by the increased gradient of the water table produced locally by combined pumping of irrigation wells on Gooch's Juniata Ranch and other private irrigation wells in the Blue River Valley below Tuttle Creek Dam. This widespread and relatively drastic influence attributed to irrigation wells seems unfounded because of the location and the very permeable nature of the alluvium from which the irrigation wells are pumping.

Most residents in the Big Blue River Valley within about one mile of Tuttle Creek Dam site reported that on days when blasting occurred in the dam site area the water in their wells became cloudy and dirty. The water would clear again in about 24 to 36 hours after the blasting had ceased. The contamination would result from the vibration of the alluvium causing displacement of particles of silt and mud contained in the alluvial sands and gravels and/or trapped on the screens of wells in the area which obtain their water supply in the alluvium.

Recovery

The atmospheric pressure on the surface of the water in a well is equal to pressure imposed on the ground water outside the well provided the water remains at a relatively constant level and has not been pumped recently. A difference in pressure is created when water is withdrawn from a well. As pumping is continued the ground-water table immediately surrounding the well develops a "cone of depression" the lowest point being inside the well and extending upward in the general shape of a funnel. An increase in the pumping rate will produce a larger depression and greater "drawdown" whereas the cone of depression and drawdown will decrease when pumping is reduced. Recovery may be rapid at first but will diminish, and several days may be taken for the water to rise again to its original level in the well.

The "yield" or "capacity" of a well is the maximum continuous rate at which the well will produce water after stored water in the well has been removed. The "specific capacity" of a well is determined by dividing the rate of yield in gallons per minute by the drawdown in feet.

The above relationship pertaining to pumping water wells is illustrated by Figure 6. These relationships are controlled by the character of the water-bearing material, construction and diameter of the well, and the rate of pumping. The coarser, well sorted water-bearing materials will yield large quantities

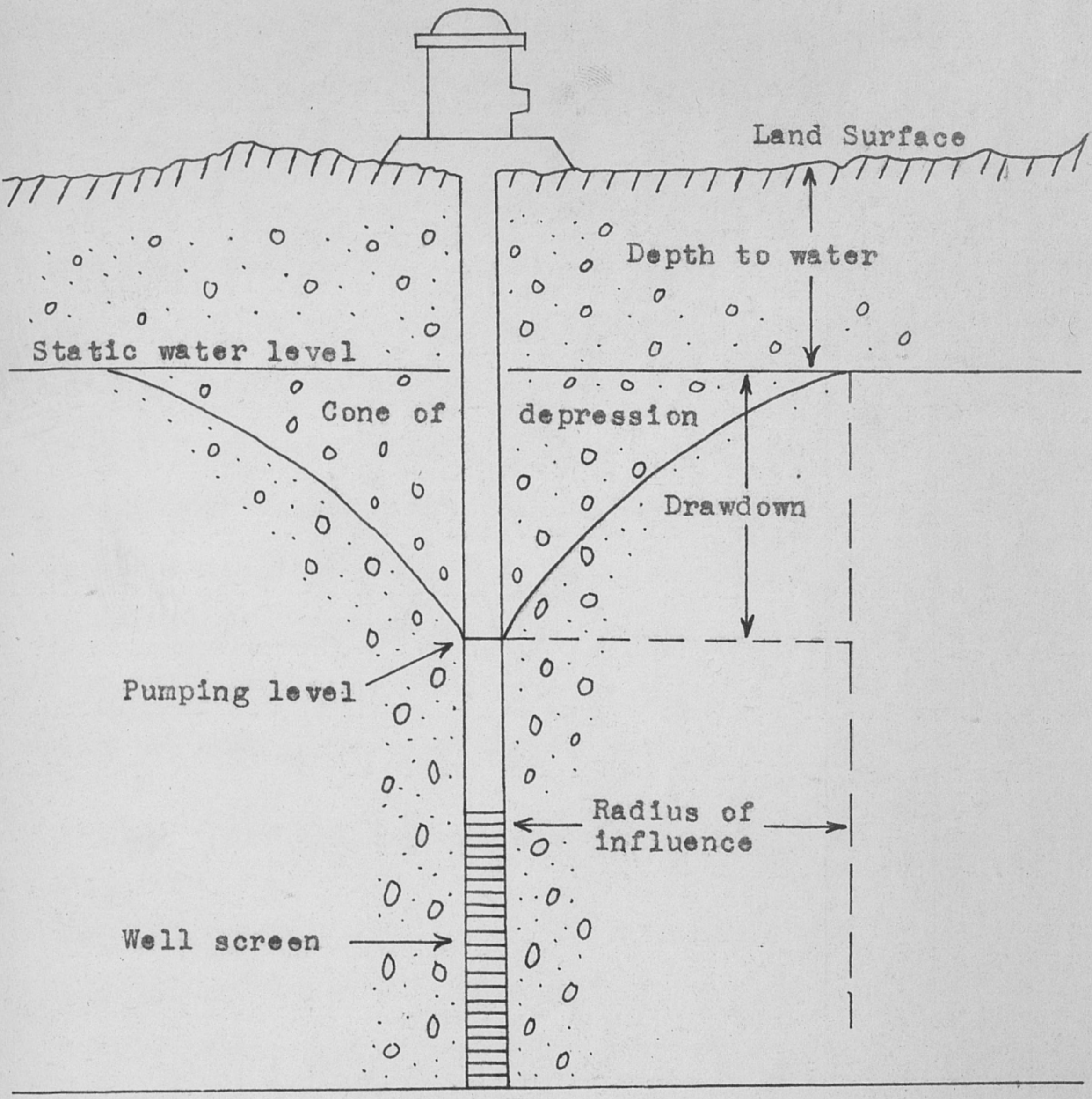


Figure 6. Diagrammatic section of well that is being pumped, showing drawdown, cone of depression, and radius of influence.

of water easily, hence there will be a minimum of drawdown. Conversely, if the aquifer material is fine, consolidated or poorly sorted causing poor permeability, the movement of water will be very slow producing a steep cone of depression. The capacity, pumping rate and drawdown was determined for some of the wells in this area and are given in Table 2 (in pocket) under "remarks" column.

Lohman (1941, p. 34-37) determined that permeability of alluvial material in the vicinity of Lawrence was about 1,700 Meinzer units. Similar high permeability is indicated for the alluvium in this part of the Big Blue and Kansas River Valleys by the yield of the present irrigation and municipal wells in these valleys. Lohman and others (1942, p. 32-33) concluded that continuous supplies of one to five million gallons per day are available from some wells in the Big Blue Valley, while supplies of 10 to 20 million gallons per day are obtainable in most parts of the Kansas River Valley.

Utilization of Wells and Springs

Domestic and Stock. About 95 percent of the wells in the alluvial valley areas used for domestic purposes are of driven and augered types combined. Wells of this type are usually constructed by augering into the zone of saturation by hand. A well point with screens is then attached to the lower end of the desired length of one and one-quarter to two inch pipe and driven farther into the sand or gravel. These wells are usually driven in pits or basements so that the pump cylinder can be placed as near the water table as possible, and to prevent freezing in winter. About half of this type of well in this area are cased. Casing helps prevent silt and sand from clogging the point and facilitates cleaning and repairing of the pump. Most of these wells supply an adequate amount of water for ordinary household use. Many farms have two or more wells of this type using one for the house and/or for drinking and others for stock. The ease and inexpensiveness of this type of well makes them particularly useful where relatively small quantities of water are required.

During wet seasons many farms in the valleys and lower upland areas have natural springs or seeps which are ponded for stock use. Some spring water is collected and stored in reservoirs and piped into the house for drinking and washing purposes. Many people prefer spring water because it is better tasting, less hard, and colder in most cases.

To obtain an adequate and fairly permanent supply of water in the upland areas some farms have several ponds to collect surface runoff. This ponded water is primarily used for stock, but in some places a shallow dug well has been located below the dam or adjacent to the stream bed in order to collect water that seeps into the ground under the dam or stream bed. When the pond or intermittent stream in the immediate vicinity of the well becomes dry, the reservoir well will also dry. This is a good conservation practice provided the ponds are fenced from animals and kept cleaned of organic debris. Where the water is to be used for drinking purposes the drainage area should be cultivated with sod waterways and no cattle allowed in fields nor a manure fertilizer used in areas above the well. Most water is considered to be of drinking quality if it has been filtered through a distance of 20 feet of porous silty material. However it must be realized that through continued filtration, the filtering material will have collected a great amount of impurities and these may actually pollute the water to a great degree.

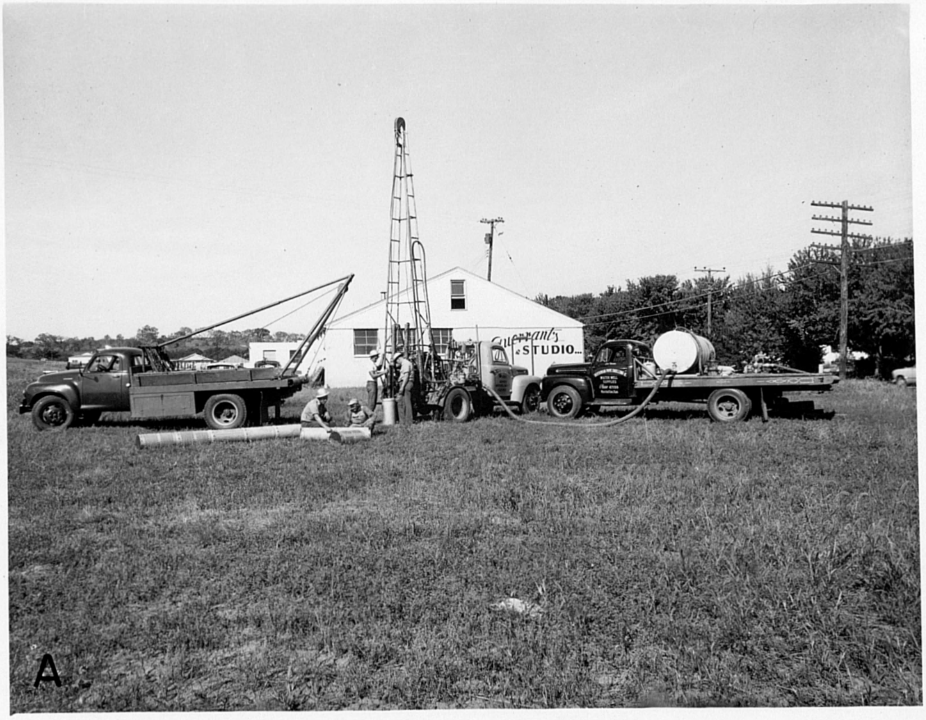
A drilled well is required for the best possible permanent source of water for stock and domestic use in the upland areas. These usually furnish a moderate supply but in some reported local areas up to a dozen are needed. Rotary and cable-tool methods (Plate V, Figure A and Plate VI) are employed, and can be used in all areas successfully. Only in a few instances were there complaints about contamination of the water caused by drilling muds and sealers used in the rotary method. In two cases water was tested and was not suitable for drinking, so the wells were abandoned. Salt water has been obtained in quantity in one deep water area where an adequate supply of good water was difficult to locate. In some instances where the quantity of salt water was not too great, it was possible to seal the salt water off and collect the good water from shallower portions of the hole.

Some bed-rock wells in the area are open, that is, they are uncased except in the upper portion to seal out surface drainage, and in portions of the well to seal off undesirable aquifers and caving rock units. The majority of drilled wells in upland areas are cased with six inch galvanized casing which

EXPLANATION OF PLATE V

Fig. A. Typical set up for drilling a well by the rotary method. The portable equipment consists of the rotary drill on the derrick truck, an A-frame utility truck, and a water tank truck. (Courtesy of A. W. Hoerman Drilling Company and Guerrant Studio).

Fig. B. Aquifer pumping test of a prospective irrigation well on the H. Mertz farm in the Kansas River Valley (NW$\frac{1}{4}$ SE$\frac{1}{4}$ Section 22, T. 10 S., R. 8 E.). Here the alluvium yielded 2000 gpm. from a 10-inch orifice.

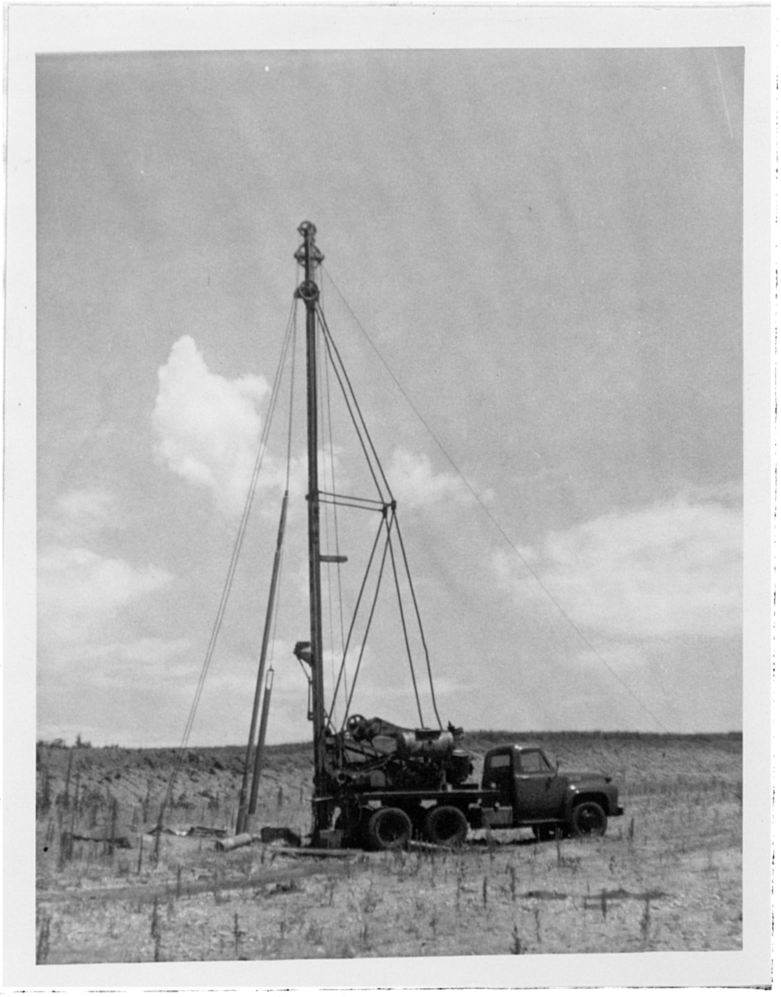


A

B

EXPLANATION OF PLATE VI

Cable tool rig used for drilling wells. This type of portable drilling equipment is especially efficient in limestone bedrock areas. A bailer (needle eyed pipe) is used to remove the excess drilling mud and cuttings from the drill hole.



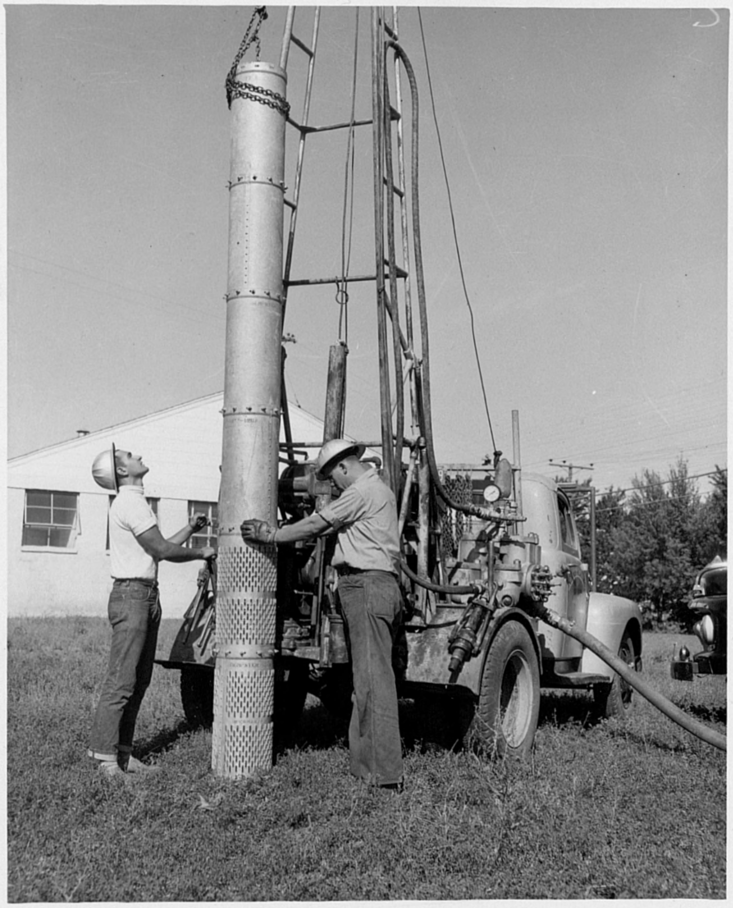
is screened or perforated adjacent to the desired aquifer. The bottoms of a few wells have been enlarged by acidizing or fracturing. This enlarged portion is then gravel packed around the casing and provides a larger reservoir for maximum quantity and efficiency. The added expense of gravel packing in most cases is not justified except where larger herds of stock or irrigation needs warrant the use of larger quantities of water.

There are many dug wells in this area and most are lined with native rock. Most dug wells were constructed between 1860 and 1910. Many of the dug wells in the uplands exceed 80 feet while those in valley areas are generally about 35 feet deep. Many of these wells which went dry during the dry years of 1934 through 1936 and 1954 through 1956, have been deepened by modern drilling methods and are still in full use. This type of well also provides a convenient enclosure for the installation of electric pressure pump systems, when tightly sealed around the top by concrete.

Irrigation. Prior to 1952 there were only a few irrigation wells in this area. During the five year drought period which followed many farmers investigated the possibilities of irrigation. At least 25 wells in this section of the Kansas River Valley and lower Big Blue River Valley are used in part or entirely for irrigation. The yield of these wells ranges from 20 to 2,000 gallons a minute. Because of the small pumps on most of these wells the actual potential yield is usually not attained. Plate V, Figure B shows the set up for a typical

EXPLANATION OF PLATE VII

Illustration showing slotted galvanized casing used for casing water wells. The aquifer zone is cased with the slotted portion so that water may pass into the well. The caving and undesirable portions of the drill hole are sealed off by using the non-perforated portion of the casing. This large diameter casing is used for larger capacity wells such as are needed for irrigation, municipal and commercial purposes.



aquifer test.

Irrigation wells inventoried in this area penetrate the full section of alluvium at their location. Most have a 14 to 20 inch perforated casing (Plate VII), are gravel packed, and are equipped with gasoline-powered turbine pumps.

Industrial. The majority of the ground water used for industrial purposes in this area is in the Manhattan vicinity. Most of it is used for air conditioning and various types of cleaning or processing. Only a few of the industrial wells were inventoried so an accurate statement cannot be made about their consumption. Logs were obtained from a few of these users and are presented in the well logs section of this report.

Municipal and Public. All public water supplies obtained in this area are from wells in the alluvium of the Kansas and Big Blue Rivers. Most of the wells are regularly treated with chlorine. Samples are taken regularly for the purpose of detecting any chemical changes or contamination which may occur. There has not been any serious contamination reported in any wells in this area since World War II when several wells in the Ogden vicinity were found to be contaminated with typhoid.

Manhattan, the largest city in the area, obtains its water from seven wells located a short distance north of the confluence of the Big Blue River and the Kansas River. Wells of the City of Manhattan pump a combined daily average of about 4,500,000 gallons to about 19,000 consumers both residential and commercial. The Manhattan Water Department had 5,274 accounts in February 1959 when the last census was taken. Each well has a concrete block house which houses the pump and regulating equipment. The water is pumped into the municipal water plant about three-quarters of a mile west of the wells where it is treated. The wells may be pumped individually or combined when more water is needed. Pumping of the wells is generally rotated every five or six hours depending upon the demand for water. The rotation of pumping allows the equipment for each well to be more evenly used and serviced, and also prevents stagnation of water in the wells. Logs and recent chemical analyses are given in Table 1 for wells of the City of Manhattan.

The southeast section of Manhattan, south of the Kansas River obtains its supply of water from the Fairmont Water Company's well (RL-86) which is located in the Kansas River alluvium about half way between the south side of the river and its southern valley wall. It supplies a daily average of 200,000 gallons to approximately 50 users of which 95 percent are residential. Also a well owned and operated by Mr. A. F. Woodman furnishes an average of 125 families in the Fairmont Trailer Courts and other nearby residents. This well is regularly chlorinated and tested. Data for it is given in Table 2, Well RL-24.

In the Oak Grove Community most residents have their own private well. There are two wells in the community which are for public use. One well (RL-35) supplies five families and is located at the base of the terrace. The second well (RL-36) supplies water for about 50 students and teachers in the Oak Grove Community School. Data on both of these wells was accurately furnished by Mr. Kenneth Hinson, Director of the Oak Grove Community School Board, and is included in Table 2. A sample was taken from the school well. Both wells are sealed and regularly chlorinated and sampled.

The Rockford community has a well (RL-15) in the alluvium of the Big Blue River, which is operated by the Kansas Power and Light Company at the electrical power plant for this area. This well supplies about ten houses in the community besides the relatively light needs of the company. It is located in a flat area adjacent to the west bank of the Big Blue River. The well is regularly checked and cleaned by employees of the electrical plant. Accurate information for the well was furnished by Mr. William Yates, superintendent of the power plant. The other residents in the community have private wells.

The Rocky Ford Trailer Camp is also supplied by a well (Pt-68) in the alluvium of the Big Blue River. The well is owned and operated by Mr. Vincent Borg. It was tested when drilled in September 1956 and has been redone and cleaned lately.

The Zeandale community does not have a community well as the residents have their own private wells. There is however a well which supplies the new district school. It was reported that the Kansas State Public Health Service regularly tests this well.

In the Swamp Angel community there is no public well. The only well which is used by more than one household is the well operated by the C. K. Dehydrating Association's dehydrating unit. It supplies the relatively small amount of water used for processing plus four residences in the immediate vicinity of the plant.

At St. George there is no community water system. Most residents of the community have their own private wells or several families will share a private well.

The Blackjack Spring (Plate IV, Figure A) located along old U. S. Highway 24 near the west edge of town supplies many residents and visiting travelers with a cool drink. An interesting condition in the occurrence of ground water at St. George has caused considerable expense and inconvenience for some of the residents of the community. It seems ground water is not available on the south side of the old highway. Many wells have been drilled south of the old highway with negative results. North, across the highway on the hillside which forms the valley wall, water seems to be plentiful. An explanation for the condition may be that a perched water table exists which is truncated by the slope of the valley wall which happens to coincide with the highway area. The water table would be fairly close to the surface on the hillside and the water which moves down dip toward this area is collected by the wells on the north side of the road. Any excess water may percolate downward fairly rapidly along the truncated zone and pass into the rock units below the alluvium on the south side of the highway. The steepness of the valley wall in this area, along with relatively impervious rock material would cause a steep slope in the water table as shown on Plate I.

Wabaunsee has a community well (Wb-14) which is operated by Wabaunsee County. It is located just east of the Beecher Rifle and Bible Church memorial along the north side of Highway K-29 in Wabaunsee. The well supplies many residents whose own private wells are in unusable condition. It is also used by many residents in the highlands to the south who have to haul water for their supply. The Wabaunsee Trailer Courts owned and operated by Mr. Dave Sullivan has its own well (Wb-12) which supplies an average of five families. The drillers log for the Wabaunsee Community School well (Wb-15) is given in the well log section. Data furnished by A. W. Hoerman for these wells is given in Table 2.

Quality

The chemical quality of ground water in the Kansas River Valley and lower Big Blue River Valley and adjacent upland areas is shown by analyses of 13 samples of water collected from water wells. Samples were taken about every four miles as uniformly as possible throughout the area. This was done to determine the dissolved mineral content of the ground water in this area and does not denote the sanitary conditions of the water.

The analyses given in Table 1 were made in the Sanitary Engineering Laboratory of the Kansas State Board of Health located in Topeka, Kansas.

The following discussion of hardness and mineral content has been adapted from Chemical Analysis of Water Report Form used by the Kansas State Board of Health.

Hardness. Water is said to be hard when it requires an excessive amount of soap before a suds or lather can be produced. Soap reacts with the mineral salts of calcium and magnesium to produce an insoluble sticky curd which adheres to sides of containers and is removed with difficulty from fabrics laundered in such water. Calcium and magnesium cause virtually all the hardness of ordinary waters. These constituents are also the active agents in the formation of the greater part of the scale in steam boilers and in other vessels in which water is heated or evaporated.

In addition to total hardness the table of analyses shows the carbonate hardness and the noncarbonate hardness. The carbonate hardness is that due to the presence of calcium and magnesium bicarbonates. It is almost completely removed by boiling. In some reports this type of hardness is called temporary hardness. The noncarbonate hardness is due to the presence of sulfates or chlorides of calcium and magnesium, but it cannot be removed by boiling and has sometimes been called permanent hardness. With reference to use with soap there is no difference between the carbonate and noncarbonate hardness.

In general the noncarbonate hardness forms harder scale in steam boilers.

Mineral Content. The mineral content and hardness of a water are important in determining suitability of water for general domestic purposes and its hygienic and physiological qualities. If a public water supply is highly mineralized, very hard or of unpleasant taste or appearance, consumers may use water from private sources, which though softer or more palatable, may be of questionable purity for drinking.

Highly mineralized water may have a physiological effect on the human system, especially water containing sodium sulfate (Glauber's Salts) or magnesium sulfate (Epsom Salts). Such water may act as a laxative for people not accustomed to drinking it.

Iron or manganese, when present in an amount greater than 0.2-0.3 parts per million, may cause staining of plumbing fixtures and laundered fabrics, and may produce a reddish yellow or black water which is unpleasant in appearance. Manganese and iron also present problems in the chlorination of water. Both may interfere with the orthotolidine test for residual chlorine, and both may exert a chlorine demand, resulting in difficulty in attaining a lasting chlorine residual. An excessive concentration of chloride (one of the constituents of common salt) will cause an unpleasant saline taste, itching, or burning.

A flouride concentration greater than 1.5 parts per million may cause the defect known as "mottled enamel" in the teeth of children using the water. Concentrations substantially less than one part per million will not afford optimum protection from dental decay in children.

The excessive concentration of nitrate in drinking water may result in cyanosis (blue babies) of infants to which the water is being fed. Water containing more than 90 parts per million of nitrate should not be used in formula preparation or as drinking water for babies under three months of age. Boiling will not remove the nitrate.

TABLE 11 .—*Analyses of water from typical wells in* Kansas River Valley between Wamego and Manhattan vicinity.

Analyzed by Howard A. Stoltenberg   Dissolved constituents given in parts per million[a], and in equivalents per million[b] ~~(in italics)~~

No. on plate	Location	Depth (feet)	Geologic source	Date of collection.	Temperature (°F)	Dissolved solids	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Hardness as $CaCO_3$: Total	Hardness as $CaCO_3$: Carbonate	Hardness as $CaCO_3$: Non carbonate
SE	Manhattan Mun. Airport NE Sec.32,T 10 S,R 7 E	57	Alluvium	3-25-59		399	36	0.03	91	12	33	361	30	10	0.2	8.4	276	276	0.0
SW	Big Blue River SW Sec. 9,T 10 S,R 8 E	...	Raw River Water	5-23-59		145	7.5	...	31	6.5	11	112	22	6	0.2	5.8	104	92	12
Pt-92 abc	Manhattan City Wells SW Sec. 8,T 10 S,R 8 E	65-72	Alluvium	5-7-59		586	25	5.5	126	23	56	420	6.7	82	0.2	0.4	409	344	65
SW	Manhattan Water Dept. SW Sec. 7,T 10 S,R 8 E	...	Treated Water	3-27-59		358	17	0.05	41	10	66	72	101.0	86	0.7	0.8	143	59	84

ANALYSES OF NINE OTHER WATER SAMPLES TAKEN WERE NOT AVAILABLE FOR THESIS DEADLINE DATE.

a. One part per million is equivalent to one pound of substance per million pounds of water or 8.33 pounds per million gallons of water.

b. An equivalent per million is a unit chemical equivalent weight of solute per million unit weights of solution. Concentration in equivalents per million is calculated by dividing the concentration in parts per million by the chemical combining weight of the substance or ion.

LOGS OF WELLS AND PUMPING TESTS

On the following pages are the drillers logs of 12 wells which were drilled in this area. The holes were drilled chiefly in areas of alluvial deposits and were for the purpose of locating a suitable water supply for the individual land owners. Most of the holes were drilled with a portable rotary rig.

In the drillers records it is stated that shale "slopes" or "dips" so many feet. It would more likely be the slope is a result of shale having been eroded in the original channel before the gravels and sands were deposited. The geologic classification was not given in the drillers records.

RL-84-a. Drillers log of H. F. Roepke test hole No. 1 in the SE$\frac{1}{4}$ SE$\frac{1}{4}$ Section 18, T. 10 S., R. 9 E., Riley County; drilled by A. W. Hoerman, February 17, 1957. Surface elevation about 994 feet.

QUATERNARY - Late Pleistocene to Recent

Alluvium	Depth below surface in feet
Top-soil, black	1-5
Clay, dark brown	5-10
Sand, fine, light tan	10-15
Sand, medium-coarse, dark blue	15-20
Clay, dark gray	20-22
Clay and coarse sand	22-25
Sand, coarse	25-32

PENNSYLVANIAN - Virgilian, Wabaunsee group, Richardson subgroup

Shaly clay, light gray	32-35
Shale, dark blue-gray	35-40

Remarks: Static water level 16.6 feet below ground level.
Yield approximately 250 gpm.
Shale dips south about 4 feet 9 inches.

RL-84-b. Drillers log of H. F. Roepke test hole No. 2 in the SE$\frac{1}{4}$ SE$\frac{1}{4}$ Section 18, T. 10 S., R. 9 E., Riley County; drilled by A. W. Hoerman, February 17, 1957. Surface elevation about 1006.7 feet.

QUATERNARY - Late Pleistocene to Recent

Alluvium	Depth below surface in feet
Top-soil, black-dark tan	1-5
Clay, silty, black	5-10
Clay, silty, tan	10-15
Clay, light tan	15-20
Sand, fine, tan	20-22
Sand, medium fine, tan	22-25
Sand, medium coarse, tan	25-30
Sand, medium coarse, gray	30-35
Sand, medium coarse, gray	35-37
Sand and gravel, very coarse	37-40
Sand and gravel, very coarse	40-49'6"

PENNSYLVANIAN - Virgilian, Wabaunsee group, Richardson subgroup

Shaly clay, greenish gray	49'6"-51
Shale, blue gray	51-52

Remarks: Static water level 29'6" below ground level.
Location 393 feet south and 30 feet east of No. 1.
Yield approximately 450 gpm.
Ground level elevation 12'9" above test hole No. 1.

RL-84-c. Drillers log of H. F. Roepke test hole No. 3 in the SE$\frac{1}{4}$ SE$\frac{1}{4}$ Section 18, T. 10 S., R. 9 E., Riley County; drilled by A. W. Hoerman, February 18, 1957. Surface elevation about 1004.7 feet.

QUATERNARY - Late Pleistocene to Recent

Alluvium	Depth below surface in feet
Top-soil, black to brown	1-5
Clay, brown	5-10
Clay, silty, dark tan	10-15
Quick-sand, fine gray	15-20
Sand, medium fine, tan	20-25
Sand, medium coarse, tan	25-30

RL-84-c, concl.

	Depth below surface in feet
Sand, coarse, tan	30-35
Sand, coarse, gray to green	35-40
Sand, coarse, gray to green	40-51

PENNSYLVANIAN - Virgilian, Wabaunsee group, Richardson subgroup

Shale, dark gray	51-52

Remarks: Static water level 29'6" below ground level.
Location 264 feet south of No. 2.
Ground level elevation 2 feet lower than No. 2.
Shale slope 3'6" from No. 2.
Shale slope 8'3" from No. 1.

RL-84-d. Drillers log of H. F. Roepke test hole No. 4 in the SE¼ SE¼ Section 18, T. 10 S., R. 9 E., Riley County; drilled by A. W. Hoerman, February 18, 1957. Surface elevation about 1005 feet.

QUATERNARY - Late Pleistocene to Recent

Alluvium	Depth below surface in feet
Top-soil, brown	1-5
Clay, brown	5-10
Clay, brown	10-15
Clay, silty, tan	15-20
Sand, fine, tan	20-25
Sand, medium coarse	25-30
Sand, coarse with little clay, blue	30-35
Sand and gravel, coarse, greenish	35-45
Sand and gravel, very coarse, greenish	45-55

PENNSYLVANIAN - Virgilian, Wabaunsee group, Richardson subgroup

Clay, blue	55-57'2"
Shale	57'2"-59

Remarks: Static water level 30.6 feet.
Shale slope -
Yield approximately 650 gpm.
Location west 300 feet of test No. 3.

RL-84-g. Drillers log of H. F. Roepke test hole No. 7 in the SE$\frac{1}{4}$ SE$\frac{1}{4}$ Section 18, T. 10 S., R. 9 E., Riley County; drilled by A. W. Hoerman, February 19, 1957. Surface elevation about 1005 feet.

QUATERNARY - Late Pleistocene to Recent

Alluvium	Depth below surface in feet
Top-soil, black	1-5
Clay, tan	5-10
Silt, fine, dark tan	10-15
Sand, fine, dark tan	15-20
Sand, medium fine, tan	20-25
Sand, coarse, tan	25-30
Sand, coarse, tan turning to gray	30-35
Sand and gravel, very coarse, gray-greenish-gray	35-40
Sand and gravel, very coarse, greenish-gray	40-56'3"

PENNSYLVANIAN - Virgilian, Wabaunsee group, Richardson subgroup

Limestone, gray	56'3"-58'5"
Shale, blue	58'5"-59

Remarks: Yield estimated approximately 750 gpm.
Location 350 feet south of test No. 4 or northwest corner of yard.
Best test, using as irrigation well. Actually the yield was 950 gpm.
This well is same as RL-47a which is now being used for irrigation.

RL-84-h. Drillers log of H. F. Roepke test hole No. 8 in SE$\frac{1}{4}$ SE$\frac{1}{4}$ Section 18, T. 10 S., R. 9 E., Riley County; drilled by A. W. Hoerman, February 19, 1957. Surface elevation about 1007 feet.

QUATERNARY - Late Pleistocene to Recent

Alluvium	Depth below surface in feet
Top-soil, black	1-5
Clay, tan	5-20
Sand, fine, tan	20-25
Sand, medium coarse	25-30
Sand, medium coarse with clay-10gpm	30-35

RL-84-h, concl.	Depth below surface in feet
Sand, coarse-20 gpm.	35-40
Sand, coarse-30 gpm.	45-54'6"

PENNSYLVANIAN - Virgilian, Wabaunsee group, Richardson subgroup

Shaly clay	54'6"-56
Shale	56-57

Remarks: Yield approximately 550 gpm.
Location 300 feet east of test No. 7 or northeast corner of yard.

RL-85. Drillers log of Wilford Johnson test hole No. 1 in SW$\frac{1}{4}$ SW$\frac{1}{4}$ Section 23, T. 10 S., R. 8 E., Riley County; drilled by A. W. Hoerman, September 5, 1957. Surface elevation about 1024 feet.

QUATERNARY - Late Pleistocene to Recent

Alluvium	Depth below surface in feet
Top-soil and clay, dark brown-gray	1-30
Clay, dark blue	30-42
Sand, fine, dark gray	42-47
Sand, medium coarse	47-65
Sand and gravel, very coarse, dark gray	65-75
Sand and gravel, very coarse, dark gray	75-83'6"

PENNSYLVANIAN - Virgilian, Wabaunsee group, Richardson subgroup

Shale, blue	83'6"-84'6"

Remarks: Static water level 16 feet below ground level.

RL-85-a. Drillers log of Wilford Johnson test hole No. 2 in SW$\frac{1}{4}$ SW$\frac{1}{4}$ Section 23, T. 10 S., R. 8 E., Riley County; drilled by A. W. Hoerman, September 5, 1957. Surface elevation about 1020 feet.

QUATERNARY - Late Pleistocene to Recent

Alluvium	Depth below surface in feet
Top-soil and clay	1-25

RL-85-a concl.	Depth below surface in feet
Clay, sandy	25-30
Clay, gray	30-40
Sand, fine, gray	40-45
Sand, very coarse	45-55
Sand and gravel, small amount clay showing	55-60
Sand and gravel, very coarse	60-80

Remarks: None

Drillers log of Manhattan Municipal Airport test hole No. 1 in the SE$\frac{1}{4}$ NE$\frac{1}{4}$ Section 32, T. 10 S., R. 7 E., Riley County; drilled by A. W. Hoerman. Surface elevation about 1060 feet.

QUATERNARY - Late Pleistocene to Recent

Alluvium	Depth below surface in feet
Top-soil or overburden	1-15
Sand, fine	15-20
Sand, medium fine with slight clay	20-30
Sand, medium coarse	30-45
Gravel, coarse	45-50

PERMIAN - Wolfcampian

Limestone	51-52
Shale	52-57

Remarks: Location SE corner of main hangar.
Yield approximately 50 gpm.
This well is in use. Jet pump, 5 hp., 6" steel casing, 6' screens. Date not available.

Drillers log of Manhattan Municipal Airport test hole No. 2 in SE$\frac{1}{4}$ NE$\frac{1}{4}$ Section 32, T. 10 S., R. 7 E., Riley County; drilled by A. W. Hoerman. Surface elevation about 1060 feet.

QUATERNARY - Late Pleistocene to Recent

Alluvium	Depth below surface in feet
Top-soil and clay	1-12
Clay, loose	12-15
Sand, fine	15-20
Sand, medium fine	20-30
Sand, medium coarse	30-35

Manhattan Municipal Airport test hole No. 2, concl.

	Depth below surface in feet
Sand, fine	35-38
Sand, medium coarse	38-48
Sand, coarser than medium	48-53

PERMIAN - Wolfcampian

Shale, soft	53-55
Limestone	55-56

Remarks: Static water level 18 feet below ground level.
Location 400 feet northeast of test No. 1.
Drilling date not available.

Drillers log of Kansas State Agronomy Farm Test hole No. 4 in Section 2, T. 11 S., R. 7 E., Riley County; drilled by A. W. Hoerman, January 25, 1957. Surface elevation about 1025 feet.

QUATERNARY - Late Pleistocene to Recent

Alluvium	Depth below surface in feet
Top-soil, black	1-5
Loam, sandy, dark gray	5-10
Sand, fine, light gray	10-15
Sand, medium coarse, tan	15-20
Sand, medium coarse to coarse, tan	20-25
Sand, very coarse, dark tan	25-30
Sand, very coarse, greenish gray	30-35
Sand, very coarse, greenish gray	35-40
Sand, very coarse, greenish gray	40-44
Sandstone, greenish tan	44-45
Gravel, coarse with small amount blue clay	45-46'6"

PERMIAN - Wolfcampian

Clay, tan	46'6"-47
Shale, blue	47-48'6"

Remarks: Static water level 21 feet below ground level.
Test No. 1 - 50' depth.
Test No. 2 - 50' depth.
Test No. 3 - 51' depth.

Wb-15. Drillers log of Wabaunsee Community School well in SE$\frac{1}{4}$ SW$\frac{1}{4}$ Section 30, T. 10 S., R. 10 E., Wabaunsee County; drilled by A. W. Hoerman, August 27, 1956. Surface elevation about 1025 feet.

Quaternary - Late Pleistocene to Recent

Alluvium	Depth below surface in feet
Top-soil, black brown	1-5
Sand and silt, grays and tan	5-60
Gravel, finer on top grading to coarse	60-74

Remarks: Static water level 60 feet below ground level.

Pt-92-c. Pumping test of the City of Manhattan well No. 11 in SW$\frac{1}{4}$ SW$\frac{1}{4}$ Section 8, T. 10 S., R. 8 E., Pottawatomie County; drilled by George Braaf, Layne Western Company, Summer 1954. Surface elevation about 1002 feet.

Pumping test data:
Pump-gasoline powered, 10 inch by 8 inch orfice.
Screen-30 feet of 18 inch stainless steel No. 4 mesh shatter type.
Casing-inside: 42 feet of 18 inch standard pipe with welded connections.
outside: 21 feet of 38 inch Armco pipe with riveted connections.
Packing-gravel, 20 yards size 1/4 to 3/4 inch.

Note: Measurements were taken from top of casing which is 1.0 feet above ground level. The fluctuations of the water level are caused by other nearby existing wells which were operating while test was in progress.

Time	GPM	Drawdown	Pumping Level
2:00 pm	1248	0.0	0.0
2:30	1248	6.0'	26.0"
3:00	1248	5'11"	25'11"
3:30	1248	6.0'	26.0"
4:00	1248	6.2'	26.2"
4:30	1248	6.2'	26.2"

Pt-92-c, concl.

Time	GPM	Drawdown	Pumping Level
5:00	1248	6.2'	26.2"
5:30	1248	6.2'	26.2"
6:00	1248	6.2'	26.2"
6:30	1248	6.2'	26.2"
7:00	1230	6.1"	26.1"
7:30	1230	6.1"	26.1"
8:00	1248	6.2"	26.2"
8:30	1230	6.4½"	26.4½"
9:00	1230	6.4½"	26.4½"
9:30	1230	6.4½"	26.4½"
10:00	1230	6.4½"	26.4½"

Recovery in five minutes - 20'6".
Recovery in 30 minutes - 20'5".
Static water level - 20 feet.

RECORDS OF TYPICAL WELLS

Information pertaining to the water table and 197 wells in the valleys of the Kansas and Big Blue Rivers and adjacent uplands in the area between the vicinity of Wamego and Manhattan-Tuttle Creek Dam vicinity is tabulated in Table 2 contained in folder. Numbers in the first and second columns were determined by the well numbering and location systems described on page five.

CONCLUSIONS

Several general conclusions may be inferred from this investigation of the ground-water resources in this portion of the Kansas River and Big Blue River valleys.

The Kansas till deposits which cap some of the upland areas north of the Kansas River may yield a moderate amount of water during wet periods. This glacial deposit forms a perched water table and is not a consistent aquifer.

Pleistocene terrace deposits of Illinoian, Wisconsinan, and Recent age are fairly extensive in this area. The Buck Creek Terrace may yield moderate amounts of water in areas where the terrace is kept supplied by surface drainage, and springs from the perched water tables. Newman Terrace gravels and the Recent alluvium provide the most widespread, abundant and permanent ground-water supply. The Newman Terrace extends into many of the larger minor alluvial tributary valleys, but is most extensive in the major alluvial valley areas. Wells within Wisconsinan and Recent alluvial materials may yield large quantities of water for industrial, municipal, irrigation, domestic and stock uses.

Ground water in the Pleistocene materials is generally hard but of good quality for domestic, municipal and irrigation uses. It was found that water in the City of Manhattan municipal wells is not derived from the Big Blue River. The ground-water body which supplies these wells is continuous with the ground water in the old river channel fill northwest of the city. This was determined from the water table contours constructed on Plate I and comparison of chemical analysis of water taken from the Manhattan wells, Big Blue River, and the Kansas State University animal husbandry farm.

Conductivity of the ground water indicated by the M-Scope readings is generally higher (8.0 to 10.0+ milliampers) in the alluvial areas. The average conductivity for ground water in the upland areas is about 5.0 milliamperes.

The Kansas and Big Blue Rivers and Deep Creek are effluent. Smaller tributaries which drain into these major streams are also effluent, deriving their water from local runoff and the perched water tables.

Two unusual areas of local recharge were discovered in the Kansas River Valley in the vicinity of Zeandale and Swamp Angel. Recharge is from local precipitation which falls on the alluvial areas. These local recharge areas probably are not consistent and are most pronounced during wet cycles.

In the Zeandale dome area it was discovered that the Tarkio limestone yields moderate amounts of fresh water to wells which are updip near the outcrop area and salt water in deeper wells down dip. The fresh water is derived from precipitation on the outcrop area and from minor surface streams being influent where they transverse the aquifer. Artesian conditions do exist in the area but no flowing artesian wells were reported.

The amount of ground water available for future expansion of municipal, industrial, and agricultural needs is adequate provided wells are spaced and constructed in accordance with their geologic conditions.

It was found that most residents in this area know little about the characteristics or formation of rocks, and the general occurrence and movement of ground water. Many residents are very negligent in maintaining decent water well conditions and surroundings, and these unsanitary well conditions need to be publicly emphasized in order to make all people realize the necessity of improving and maintaining sanitary well conditions and environment.

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REFERENCES

Beck, H. V., (1959) Geology and Ground Water Resources of the Kansas River Valley Between Wamego and Topeka Vicinity: Kansas Geol. Survey Bull. 135; pp. 1-88.

Darton, N. H., (1905) Preliminary Report on the Geology and Underground Water Resources of the Central Great Plains: U. S. Geol. Survey Prof. Paper 32, pp. 1-433.

Davis, S. N., and Carlson, W. A., (1952) Geology and Ground Water Resources of the Kansas River Valley between Lawrence and Topeka, Kansas: Kansas Geol. Survey Bull. 96, pt. 5, pp. 201-276.

Dufford, A. E., (1958) Quaternary Geology and Ground Water Resources of the Kansas River Valley Between Bonner Springs and Lawrence, Kansas: Kansas Geol. Survey Bull. 130; pt. 1, pp. 1-96.

Fenneman, N. M., (1931) Physiography of Western United States: McGraw-Hill Book Co., New York, pp. 1-534.

Fenneman, N. M., and Johnson, D. W., (1946) Map of the Physical Divisions of the United States, scale 1:700,000:U. S. Geol. Survey.

Fishel, V. C., (1948) Ground Water Resources of the Kansas City, Kansas, Area: Kansas Geol. Survey Bull. 71, pp. 1-109.

Frye, J. C., and Leonard, A. B., (1952) Pleistocene Geology of Kansas: Kansas Geol. Survey Bull. 99, pp. 1-223.

Frye, J. C. and Walters, K. L. (1950) Subsurface Reconnaissance of Glacial Deposits in Northeastern Kansas: Kansas Geol. Survey Bull. 86, pt. 6, pp. 141-158.

Haworth, Erasmus (1913) Special Report on Well Waters in Kansas: Kansas Geol. Survey Bull. 1, pp. 1-103.

Jewett, J. M. (1941) Geology of Riley and Geary Counties, Kansas: Kansas Geol. Survey Bull. 39, pp. 1-164.

Jewett, J. M. and Schoewe, W. H., et al. (1942) Kansas Mineral Resources for Wartime Industries: Kansas Geol. Survey Bull. 41, pt. 3, pp. 69-180.

Kansas State Board of Agriculture Staff (1948) Climate of Kansas: Report of the Kansas State Board of Agriculture, vol. LXVII, No. 285, pp. 1-320.

Knapp, G. S., et al., (1940) A Kansas Water Program: Report of Kansas Governor's Water Commission, State of Kansas, pp. 1-66.

Lohman, S. W. (1941) Ground Water Conditions in the Vicinity of Lawrence, Kansas: Kansas Geol. Survey Bull. 38, pt. 2, pp. 17-64.

Lohman, S. W., et al, (1942) Ground Water Supplies in Kansas Available for National Defense Industries: Kansas Geol. Survey Bull. 41, pt. 2, pp. 21-68.

Meinzer, O. E. (1923) The Occurrence of Ground Water in the United States with a Discussion of Principles: U. S. Geol. Survey Water Supply Paper 489, pp. 1-21.

Metzler, D. F., and Stoltenberg, H. A. (1950) The Public Health Significance of High Nitrate Waters as a Cause of Infant Cyanosis and Methods of Control: Kansas Acad. Sci. Trans., v. 53, pp. 194-221.

Moore, R. C. (1918) The Environment of Camp Funston: Kansas Geol. Survey Bull. 4, pp. 1-81.

Moore, R. C. (1940) Ground Water Resources of Kansas: Kansas Geol. Survey Bull. 27, pp. 1-112.

Moore, R. C., et al, (1951) The Kansas Rock Column: Kansas Geol. Survey Bull. 89, pp. 1-132.

Moore, R. C. and Landes, K. K. (1937) Geologic Map of Kansas, scale 1:500,000:Kansas Geol. Survey.

Raisz, Erwin (1957) Map of the Landforms of the United States, Ginn and Company.

Schoewe, W. H. (1939) Evidences for Relocation of the West Drift Border in Eastern Kansas: Kansas Acad. Sci. Trans., v.42, p. 367. Also published (1930) by Journal of Geology, v. 38, pp. 67-74.

Smith, J. T. (1959) Surface Reconnaissance of Selected Areas of Pottawatomie and Riley Counties, Kansas: Unpublished Report, Dept. of Geology, Kansas State University.

Todd, J. E. (1909) Drainage of the Kansas Ice Sheet: Kansas Acad. Sci. Trans., v. 22, pp. 107-112.

---- (1923) Map of Pleistocene Formations of Northeastern Kansas: Pan-American Geologist, v. 40, p. 104-105.

Tolman, C. F. (1937) Ground Water: McGraw-Hill Book Co., Inc. New York, pp. 1-565.

U. S. Public Health Service (1946) Drinking Water Standards: Public Health Rept., v. 61, No. 11, pp. 371-384.

U. S. Salinity Laboratory Staff (1954) Diagnosis and Improvement of Saline and Alkali Soils: U. S. Dept. Agriculture, Agriculture Handbook No. 60, pp. 1-160.

Wenzel, L. K. (1942) Methods of Determining Permeability of Water-Bearing Materials with Special Reference to Discharging Well Methods: U. W. Geol. Survey Water Supply Paper 887, pp. 1-192.

Wyman, Theodore (1935) Report on the Kansas River, Kansas, Colorado and Nebraska: 73rd Congress, 2nd Session., House of Representatives Document No. 195, pp. 1-331.

GROUND WATER RESOURCES OF BIG BLUE AND KANSAS RIVER VALLEYS FROM MANHATTAN TO WAMEGO, KANSAS

by

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AN ABSTRACT OF A THESIS

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The geography and hydrologic conditions of the Kansas River Valley, lower Big Blue River Valley and adjacent uplands are described in this thesis. The area comprises approximately 90 square miles extending from the west boundary of Range 10 East in Pottawatomie County to the vicinity of Manhattan and Tuttle Creek Dam in Riley County. This area is one of the major agricultural and potential industrial areas in the state.

The purpose of the investigation was to determine the configuration of the ground-water table in major valleys in this area and its relationship to the perched water tables in the adjacent uplands. Data obtained in this study may serve as a basis for comparing any future effects created by the Tuttle Creek Reservoir upon the occurrence and quality of ground water in this area.

Field data used in mapping the water table was collected by inventorying 197 wells during the spring of 1959. This is the first time a Fisher M-Scope Water Level Indicator has been used exclusively for measuring a large number of wells in Kansas. The data is considered to be very accurate because of the sensitive measuring apparatus, and the uniform climatic conditions existing while field work was being done. Water samples from selected wells and the Big Blue River were collected and analyzed. In addition drillers logs and pumping test data are given in the tables.

Unconsolidated sand and gravel deposits of Wisconsinan and Recent age form the principal aquifer in the area. The fluviatile deposits are thickest and most extensive in the valley of the Kansas and Big Blue Rivers. Recent alluvium extends into the lower portions of many minor tributaries in the area and is also a fairly good aquifer. The Newman Terrace and the Recent floodplain deposits yield the most abundant supply of ground water for municipal, irrigation and commercial needs.

All the consolidated sedimentary rocks outcropping in the area belong to the Wabaunsee Group of the upper Pennsylvanian System and the Admire and Council Grove groups of the lower Permian System. Limestones and shales in these groups form a steep valley wall which generally borders the meandering alluvial Kansas and Big Blue Rivers. The limestones furnish an abundant source of rock aggregate and some form very important reservoirs for small amounts of water yielded to upland wells. During periods of abundant precipitation, such as the case during the investigation, many springs occur along the outcrops of these relatively impervious rocks.

Ground-water recharge in the area is principally from local precipitation. The major streams being effluent form the main type of ground water discharge in the area. Ground water is hard in most of the area and is principally used for municipal, domestic, and irrigation purposes. All irrigation and municipal water supplies are obtained from wells in the alluvium. Data indicates abundant ground-water supplies are available in this area for geologically planned irrigation and industrial expansion.

Table 2.

Records of wells and test holes.

6½x9½

PEERLESS
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James T. Smith

TABLE 2 .—*Record of wells* and test holes.

Well No. (1)	Location	Owner or Tenant	Type of well (2)	Depth of well (feet)	Diameter of well (in.)	Type of casing (3)	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic source	Method of lift (4)	Use of water (5)	Measuring point: Description	Measuring point: Distance above land surface (feet)	Measuring point: Height above mean sea level (feet)	Depth to water level below measuring point (feet)	Date of measurement	Remarks (Yield given in gallons a minute; drawdown in ft.)
	T. 9 S., R. 7 E.															
RL-1	SW SW sec. 24	G. Freeman	Dg	...	30	R	Creek Sand	Alluvium	Cy H	D, S	Pump base	1.0	1101	10.0	6-15-59	
2	SE NW sec. 26	D. Merritt	Dr	73	6	GI	Ls, & shale	Council Grove gr.	J E	D	Land surface	0.0	1140	13.0	10- 56	1.0 gpm yield
3	SE NW sec. 25	R. Chandler	Dg	24	34	R	Creek sand	Alluvium	N	N	Rock platform	1.0	1059	12.5	6-15-59	Abandoned
4	NE NE sec. 25	G. Hopkins	Dr	48	6	GI	Sand & gr.	do	J E	D, S	Land surface	0.0	1050	42.0	56	
5	SE NE sec. 25	G. Hopkins	Dr	63	6	GI	Sand, ls, sh.	do & Council Grove gr.	J E	D	do	0.0	1055	49.0	57	
8	NE NE sec. 36	A. Latshar	Dr	85	6	GI	Sa, gr, ls, sh.	do	J E	D	Casing top	1.0	1093	27.0	6-15-59	
9	NW SE sec. 36	Kansas St. Univ.	Dr	...	6	GI	Sand & gr.	Alluvium	N	N	do and land surface	0.0	1090	26.0	6-15-59	Abandoned
10	SW SE sec. 36	do & F. Miller	Dr	57	6	S	do	do	J E	D, S	Casing top	-3.0	1089	33.0	6-15-59	15 gpm (pump)
15	NE SE sec. 25	Ks. Power & Light Co.	Dg	10	60	R	do	do & Council Grove gr.	C E	C, D	Land surface	0.0	1072	6.0	6-15-59	50 gpm (pump)
	T. 9 S., R. 8 E.															
RL-7	NW NW sec. 31	A. & C. Hepler	Dg	35	32	R	Sand	Alluvium	C H	S	Pump base	1.5	1057	13.0	6-15-59	
13	SW NW sec. 31	M. Walton	Dr	...	6	S	Sand & gr.	do	J E	D	Casing top	-2.0	1048	13.0	6-15-59	
14	SW NW sec. 31	Standard School	Dr	...	6	S	do	do	Cy H	D	Pump base	0.5	1056	20.7	6-15-59	
16	SE NE sec. 31	G. Irvine	Dr	75	6	S	do	do	J E	D, S	Concrete platform	1.5	1022	28.0	6-15-59	
17	SW SE sec. 31	C. Drumm	Dg	40	30	R	do	do	J E	D	Concrete pit top	0.4	1021	10.1	6-15-59	
Pt-16	SE SE sec. 36	C. Woodard	Dg	32	36	R	Ls. & sh.	Council Grove gr.	Cy H	D, S	Concrete platform	0.3	1141	30.0	6- 5-59	
54	SE SW sec. 34	G. Hoerner	Dg	20	...	R	Creek sand	Alluvium	Cy G	D	Pump base	0.0	1110	8.0	6- 9-59	
55	SE SW sec. 34	G. Hoerner	Dr	80	6	N	Ls. & sh.	Council Grove gr.	Cy H	D	do	0.5	1140	13.0	6- 9-59	
56	SW NE sec. 34	O. Keller	Dg	65	36	R	do	do and till	Cy H	N	Pump base	1.5	1142	31.0	6- 9-59	Abandoned
56a	SW NE sec. 34	O. Keller	Dr	142	6	GI	do	do	J E	D	Land surface	0.0	1145	42.0	6-15-59	
57	SW NE sec. 34	O. Keller	Dr	39	6	S	do	Council Grove gr.	Cy H	N	Casing top	1.0	1101	21.0	6-15-59	Abandoned
62	SE SW sec. 32	J. Scandlin	Dg	35	32	R	Sand & gr.	Alluvium	N	N	Top crumbling r.edge	1.0	1013	22.0	6-12-59	Abandoned
63	NE SE sec. 32	J. McCoy	Dg	45	32	R	Ls. & sh.	Council Grove gr.	B H	N	Concrete platform	2.0	1092	37.0	6-12-59	Abandoned
65	NW NE sec. 32	J. Callahan	Dg	17	34	R	Creek sand	Alluvium	Cy H	N	Pump base	2.0	1062	14.0	6-12-59	Abandoned
66	SE SW sec. 29	C. Allen	Dr	...	6	GI	Ls. & sh.	Neva ls.	J E	D, S	Casing top	-5.0	1079	7.5	6-12-59	
67	NE SE sec. 30	G. & V. Borg	Dr	19	6.5-4	GI	do	do	Cy H	D, S	Pump base	1.0	1041	14.0	6-12-59	
67a	NE SE sec. 30	G. & V. Borg	Dr	39	6	GI	do	do	Cy H	N	do	0.0	1047	22.0	6-12-59	Abandoned
68	NW NE sec. 30	V. Borg	Dr	42	6	GI	Sand & gr.	Alluvium	S E	D, C	Land surface	0.0	1021	18.0	4- 59	27 gpm (pump)
69	SE NW sec. 30	J. Haines	Dr	69	16	S	do	do	T Gp	I	do	0.0	1021	25.0	6-15-59	850 gpm (pump)
70	NW SW sec. 30	G. Borg	Dr	31	6	S	do	do	J E	D, S	Casing top	-6.0	1015	19.0	6-15-59	
71	NW SW ln.sec.34	G. Irvine	Dr	130	6	GI	Ls. & sh.	Council Grove gr.	Cy W	S	Land surface	0.0	1237	106.0	fall-50	3 gpm
	T. 9 S., R. 9 E.															
Pt-18	NW SW sec. 32	R. Swart	Dg	70	38	R	Ls. & sh.	Admire gr.	J E	D, S	Pump base	2.0	1162	52.0	6- 4-59	
22	NW SW sec. 33	E. Westgate	Dr	150	6	GI	do	do	N	N	Casing top	1.0	1173	79.0	6- 4-59	Abandoned
23	SE SW sec. 33	R. Hope	Dg	...	32	R	do	do	Cy H	N	Platform lid	0.5	1128	39.0	6- 4-59	Abandoned
24	NW SE sec. 33	M. Westgate	Dr	...	6	GI	do	do	N	N	Concrete box top	0.5	1102	17.0	6-4-59	Abandoned
25	SW SE sec. 33	L. Brewer	Dr	...	10	T	Ls. & sh.	do	Cy H	D	Top of casing	1.5	1106	23.0	6-4-59	
28	NW SW sec. 36	....	Dg	...	36	R	do & cr.sand	Alluvium & Wab. gr.	Cy H	S	Top pump platform	1.0	1096	11.0	6-5-59	

(1) Well number indicates location of well as described in the well numbering system section.
(2) B, bored well; Dg, dug; Dr, drilled; Dn, driven; Sp, spring.
(3) B, brick; C, concrete; GI, galvanized iron; GP, galvanized pipe; N, none; R, rock; S, steel; T, tile; Tu, tubing.

(4) Method of lift: B, rope & bucket; C, centrifugal; Cp, cistern hand pump; Cy, cylinder; F, natural flow; J, jet; N, none; S, submersible; T, turbine.
Type of power: E, electric; G, gasoline; Gp, propane; H, hand; N, none; W, windmill.
(5) C, commercial; D, domestic; I, irrigation; N, none; P, public; S, stock.

TABLE 2 .—*Record of wells* and test holes (cont.).

Well No. (1)	Location	Owner or Tenant	Type of well (2)	Depth of well (feet)	Diameter of well (in.)	Type of casing (3)	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic source	Method of lift (4)	Use of water (5)	Measuring point: Description	Measuring point: Distance above land surface (feet)	Measuring point: Height above mean sea level (feet)	Depth to water level below measuring point (feet)	Date of measurement	Remarks (Yield given in gallons a minute; drawdown in ft.)
	T.10 S.,R. 7 E.															
RL-71	NE SW sec. 24	Blueville Nursery	Dr	42	8	GI	Sand & gr.	Alluvium	S E	D, C	Land surface	0.0	1030	19.0	6-24-59	50 gpm (pump)
77	NE SE sec. 2	L. Marker	Dr	60	6	GI	do	do	S E	D	do	0.0	1110	27.0	6-24-59	
78	SE SE sec. 2	B. West	Dr	71	6	GI	do	do	J E	D, S	do	0.0	1124	35.2	6-24-59	20 gpm (pump)
80	NW NW sec. 2	L. Cofield	Dr	106	6	GI	do	do & Council Grove gr.	S E	D	do	0.0	1118	51.2	6-24-59	30 gpm (pump)
	T.10 S.,R. 8 E.															
RL-11	NW NW sec. 6	Kansas St. Univ.	Dg	...	...	C	Sand,ls,sh.	Alluv. & C.G.gr.	Cy W	S	Concrete pump base	2.0	1042	8.5	6-15-59	
12	NE NW sec. 6	Kansas St. Univ.	Dg	...	...	C	do	do	Cy W	S	do	2.0	1038	5.1	6-15-59	
18	NE NE sec. 6	B. Brooks	Dr	70	6	S	Gravel	Alluvium	Cy E	D	Pump base	0.0	1004	17.0	6-16-59	
19	SW SW sec. 5	E. Frazier	Dr, Dn	63	...	N	do	do	J E	D	Land surface	0.0	1021	27.4	5- 59	
20	NE NE sec. 8	R. Nixon	Dn	47	...	...	Gravel	do	C W	D	Basement floor	-7.0	1001	16.6	6- 57	
21	SE SE sec. 4	H. Koon	Dr	52	6	GI	do	do	J E	D	Concrete block box	0.3	1004	23.0	6-16-59	20 gpm (pump)
22	NW NW sec. 20	G. Stevens	Dr	...	4	GI	Sand & gr.	do	Cy H	...	Casing top	1.5	1032	20.0	6-18-59	Abandoned
23	NE NW sec. 20	H. Somsen	Dr	80	6	GI	Ls. & sh.	Council Grove gr.	N	...	Casing top	0.5	1091	63.0	6-18-59	Abandoned
24	NW SE sec. 17	A. Woodman	Dr	...	6	S	Sand & gr.	Alluvium	S E	D, C	Utility room floor	0.0	1003	19.0	6-18-59	100 gpm (pumping)
25	SE SW sec. 17	A. Woodman	Dg	30	54	C	do	do	S E	D	Pump house floor	0.5	1007	18.0	su. 55	
26	NW NE sec. 20	E. Johnson	Dg	25	36	C	do	do	J E	D, C	Concrete pump base	0.3	1044	20.0	6-18-59	5.8 gpm (pump)
27	SW NE sec. 20	-- Johnson	Dr	...	4.5	S	Sand	do	J E	D	Casing top	4.1	1062	10.0	6-18-59	
28	SW SW sec. 21	V. Graves	Dr	127	6	GI	Ls. & sh.	Foraker & Red Eagle	J E	D	Land surface	0.0	1243	90.0	3- 52	17 gpm
29	SE SW sec. 21	M. Graves	Dr	78	6	GI	do	Red Eagle & Grenola	J E	D	do	0.0	1210	43.0	7- 56	5 gpm
30	SE NE sec. 21	D. Ensworth	Dr	...	4.5	GI	do	Council Grove gr.	Cy H	N	Pump base	0.5	1073	23.1	6-18-59	Abandoned
31	NW SW sec. 22	D. Reichling	Dg	45	36	R	do	do	N	N	Concrete top	0.0	1042	25.3	6-18-59	Abandoned
32	NW SW sec. 23	W. Johnson	Dn	45	12	T	Sand & gr.	Newman Terrace	Cy W	S	Pump base	1.0	1012	23.1	9- 58	7' in 1 hr.(dw dn)
33	SW NE sec. 27	Hunter & Lundberg Contr	Dr	...	4.5	GI	do	Alluvium	J E	D	Casing top	-4.0	1086	25.2	6-18-59	
34	NW SE sec. 16	N. Harwood	Dr	29	1.25	GP	do	do	J E	D, S	Pump base	-7.0	1003	16.0	3- 1-59	2.5 gpm (pump)
35	NE NE sec. 21	R. Hinton	Dr	48	7	S	do	do	TJ E	D, S	Land surface	0.0	1018	22.0	6-18-59	35 gpm (pump)
36	NW NW sec. 21	Oak Grove Sch.	Dr	46	6.5	S	do	do	S E	D	Casing top	1.0	1013	13.0	6-18-59	
37	SE NW sec. 26	R. Parks	Dr	80	6	S	Ls. & sh.	Admire gr.	J E	D, S	do	-7.0	1023	58.0	6-19-59	
38	SW SE sec. 24	W. Houston	Dr	...	6	S	Sand & gr.	Alluvium	J E	D	Land surface	0.0	1008	30.0	10- 1-58	
45	NE SW sec. 25	J. Johnson	Dg	25	30	R	Sa. & ls.led.	Buck Cr? & Admire gr.	J E	D	Concrete garage floor	0.0	1045	18.0	6-19-59	
61	SW SE sec. 22	W. Conroy	Dg	37	32	R	do	do	Cy H	D, S	Concrete platform	1.0	1046	12.5	6-25-59	
62	NW SE sec. 22	C. Moore	Dn	60	6	GI	Sand & gr.	Newman Terrace	N	N	do	0.0	1010	8.6	6-25-59	Abandoned
63	NW SE sec. 23	F. Parks	Dg	52	34	R	do	do	J E	D	do	0.0	1011	23.0	6-25-59	
64	NE NE sec. 26	E. Everson	Dg, Dr	100	12-44	T, R	Sand & gr.	Alluvium	J E	I	Top of R & T box	0.4	1010	23.0	6-25-59	
72	SE SW sec. 19	K-Man Tr. Courts	Dr	43	12	GI	do	do	J E	D	Land surface	0.0	1017	11.0	6-24-59	
73	SE SE sec. 18	Manhattan Bootery	Dn	38	8	GI	do	do	J E	C	Concrete alley park.	0.0	1019	27.0	12-30-53	
74	SE SE sec. 18	J. C. Penny Co.	Dr	70	12-8	GI	do	do	S E	C	do	0.0	1019	26.0	4- 58	90 gpm(pump)1.5(dw dn)
75	NE SE sec. 18	Manhattan Laundry	Dr	59	8	GI	do	do	S E	C	Land surface	0.0	1014	26.0	6- 59	150 gpm(pump)2.1(dw dn)
76	SW SW sec. 18	Manhattan Cut Stone Co.	Dr	30	6	GI	Coarse sand	do	J E	C	do	0.0	1013	25.0	7-6-59	
79	SE SW sec. 6	T. Neely	Dr	51	6	GI	Ls. & sh.	Grenola ls.&C.G. gr.	S E	D	do	0.0	1070	36.0	6-15-59	3.5 gpm
82	NE NE sec. 18	John's Creamery	Dr	61	8	GI	Sand & gr.	Alluvium	S E	C	Casing top	1.0	1018	24.2	5-28-57	
83	NE NE sec. 7	G. Lyons	Dr	65	6	GI	do	do	J E	D	Land surface	0.0	1024	27.6	7-6-59	
85	SW SW sec. 23	W. Johnson	Dr	85	4	N	do	do	N	N	do	0.0	1024	16.0	9-5-57	Test Hole log-1200 gpm
85a	SW SW sec. 23	W. Johnson	Dr	80	4	N	do	do	N	N	do	0.0	1020	...	9-5-57	do

TABLE 2 .—*Record of wells* and test holes (cont.).

Well No. (1)	Location	Owner or Tenant	Type of well (2)	Depth of well (feet)	Diameter of well (in.)	Type of casing (3)	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic source	Method of lift (4)	Use of water (5)	Measuring point: Description	Measuring point: Distance above land surface (feet)	Measuring point: Height above mean sea level (feet)	Depth to water level below measuring point (feet)	Date of measurement	Remarks (Yield given in gallons a minute; drawdown in ft.)
	T.10 S.,R. 8 E.(cont.).															
RL-86	SW SE sec. 17	Fairmont Heights Wtr.Co.	Dr	47	10	S	Sand & gr.	Alluvium	T E	C, D	Casing top	3.0	1008	23.0	7-6-59	150 gpm (pump)
Pt-1	SE NE sec. 11	J. D. Parry	Dg	8.0	48	C	Ls. & sh.	Admire gr.	Spring	D, S	Top concrete platform	0.5	1010	1.0	6-4-59	1.5 gpm (est)
3	NW SW sec. 1	J. Seematter	Dr	98.0	6	GI	do	do	J E	D, S	Land surface	0.0	1121	53.0	5-12-59	20 gpm
4	NE SE sec. 2	L. Welter	Dg	...	42	R	do	do	Cy H	D	Pump base	1.5	1102	40.0	5-12-59	
4	NE SE sec. 2	L. Welter	Dg	...	42	R	do	do	Cy H	D	do	1.5	1102	45.0	6-9-59	
5	SE NE sec. 2	....	Dg	...	34	R	do	do	Cy H	S	Steel Ring Liner	0.0	1100	43.0	6-9-59	
6	SE NW sec. 1	J. Seematter, Jr.	Dr.	88	6	GI	do	do	Cy E	D, S	Concrete Platform	1.5	1127	48.0	6-9-59	.03 gpm
9	NE SE sec. 1	-- Chapman	Dr	55	8	S	Creek sand	do & alluvium	Cy H	D, S	Casing top	1.3	1061	15.9	6-9-59	6.7 gpm
11	SE NE sec. 12	-- Koppenheffer	Dr	10	6	GI	Sand	Alluvium	C E	D	Pipe elbow top	-1.5	1023	1.0	6-4-59	
43	NW SW sec. 12	C. Winter	Dn	28	1.5	GP	Sand & gr.	do	J E	D	Land surface	0.0	1001	17.0	8- 55	
44	NE NW sec. 13	....	Dg	...	...	R	do	do	N	N	Concrete platform	1.5	1002	15.0	6-8-59	Abandoned
45	SE NE sec. 14	J. Ryan	Dr	...	6.5	S	do	do	Cy H	N	Wood platform	0.0	1000	14.0	6-8-59	Abandoned
46	NW SW sec. 14	J. Venier	Dr, Dn	...	1.5	GP	do	do	C E	D	Basement floor	-4.0	1005	15.0	6-9-59	
47	SE SE sec. 10	G. Glenn	Dn	20	1.5	GP	do	do	Cy W	N	Land surface	0.0	1010	17.0	6-9-59	Abandoned
48	NW SW sec. 2	L. Welter	Dg	...	...	R	Ls. & sh.	Admire gr.	Cy E	D, S	Pump base	1.0	1091	46.0	6-9-59	1 gpm
49	SE NE sec. 15	J. Venier	Dn	32	1.5	GP	Sand	Alluvium	J E	D, S	Land surface	0.0	1008	13.0	4- 59	
50	SW NW sec. 10	H. L. Gaede	Dn	44	2.0	GP	Sand & gr.	do	S E	C	do	0.0	1018	15.7	5- 59	
51	NE NE sec. 10	L. Lee	Dr	40	8	S	do	do	S E	D, S	do	0.0	1026	18.0	9- 51	
52	NE NE sec. 10	L. Lee	Dr	...	6	S	do	do	N	N	do	0.0	1054	40.0	9- 51	Abandoned
53	NW NE sec. 3	D. Irwin	Dr	...	8	Tu	Ls. & sh.	Council Grove gr.	Cy H	D	Pump base	1.0	1089	17.5	6-9-59	
58	NW NW sec. 11	P. Adolph	Dr	48	7.5	S	Gravel	Alluvium	J E	D	Land surface	0.0	1033	26.0	5- 56	
59	NE NE sec. 4	J. Richards	Dr	...	6.5	S	Ls.	Council Grove gr.	Cy H	D	Pump base	0.9	1081	39.0	6-12-59	
60	NE NW sec. 4	G. Richards	Dg	11	32	R, C	Ls.	do	Cy H	S	do	1.0	1056	6.0	6-12-59	
61	NE NW sec. 5	Walters Constr. Co.	Dn	32	1.25	GP	Sand & gr	Alluvium	Cy H	D, S	Land surface	0.0	1022	20.0	4- 58	
72	NW SW sec. 10	V. Koenig	Dr	34	6.0	S	do	do	J E	S	do	0.0	1001	14.0	6- 54	
73	SE SE sec. 9	D. Carlson	Dr, Dn	...	6	S	do	do	J E	D, S	Edge of Pit	0.7	1006	25.0	6-12-59	
92a	SE SW sec. 8-	City of Manhattan #5	Dr	65	38-24	GI, S	do	do	T E	P	Land surface	0.0	1002	17.0	6-29-29	450 gpm;2.5' dw dn-8hrs.
92b	SE SW sec. 8	City of Manhattan #8	Dr	64	38-24	GI, S	do	do	T E	P	do	0.0	1002	10.4	10-21-41	790 gpm; 5' dw dn-4hrs.
92c	SW SW sec. 8	City of Manhattan #11	Dr	72	38-18	GI, S	do	do	T E	P	Casing top	1.0	1003	20.0	su-54	1230 gpm;6.5' dw dn-8hrs.
93	SW NE sec. 10	Wilson Cab. Shop	Dr	63	...	...	do	do	J E	D	Land surface	0.0	1017	30.0	10-2-56	40 gpm (pump)
	T.10 S.,R. 9 E.															
RL-39	NW NW sec. 31	J. Akin	Dr	...	6	GI	Sand & gr.	Alluvium & Admire gr.	Cy H	N	Casing top	1.0	1091	12.0	6-19-59	Abandoned
40	SW SW sec. 31	G. Conwell	Dg	25	...	R	Creek sand	do	Cy H	D	Pump base	0.2	1075	7.4	6-19-59	
42	NE NE sec. 32	V. Thurston	Dg	50	34	R	Ls. & sh.	Admire gr.	Cy H	S	do	1.8	1020	34.0	6-19-59	
42a	NE NE sec. 32	V. Thurston	Dr	79	6	S	do	do	J E	D, S	Land surface	0.0	1022	50.0	11- 55	
43	SW NW sec. 29	J. Akin	Dr	...	6.5	S	Sand & gr.	Alluvium	Cy W	S	Casing top	2.4	1016	34.5	6-19-59	
44	NW SE sec. 30	R. Porter	Dr	70	6	GI	do	do	N	N	do	0.0	1030	23.0	6-19-59	9 gpm - abandoned
46	SW SW sec. 19	W. Morehead	Dr	45	6-5	GI	do	do	Cy W	S	Pump base	1.0	1003	27.0	6-23-59	
47	NE NW sec. 19	H. Roepke	Dn	43	6	GI	do	do	Cy W	S	do	1.0	1001	19.0	6-23-59	
48	SW SW sec. 17	T. Worrel	Dn	44	6.5	GI	do	do	J E	S	Casing top	-7.0	995	18.0	6-23-59	
49	SE NW sec. 17	B. Nixon	Dr	30	5.5	S	do & ls.	do & Brownville ls?	J E	D, S	do	-5.0	990	13.0	6-23-59	
50	SW SE sec. 17	M. White	Dn	25	1.5	GP	Sand & gr.	Alluvium	Cp H	N	Pipe top	1.8	997	19.0	6-23-59	Abandoned
51	NW SE sec. 16	R. Vail	Dr	35	16	GI	do & ls.	do & Brownville ls?	N	N	Concrete slab top	0.7	992	19.0	6-23-59	650 gpm,but abandoned

TABLE 2 .—*Record of wells* and test holes (cont.).

Well No. (1)	Location	Owner or Tenant	Type of well (2)	Depth of well (feet)	Diameter of well (in.)	Type of casing (3)	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic source	Method of lift (4)	Use of water (5)	Measuring point: Description	Measuring point: Distance above land surface (feet)	Measuring point: Height above mean sea level (feet)	Depth to water level below measuring point (feet)	Date of measurement	Remarks (Yield given in gallons a minute; drawdown in ft.)
	T.10 S.,R. 9 E. (cont.).															
RL-51a	SW SE sec. 16	R. Vail	Dr	28	6	GI	Sand & gr.	Alluvium	J E	D, S	Top Concrete slab	0.7	994	20.0	6-23-59	
52	SE NW sec. 21	L. Coon	Dr	35	6	GI	do	do	J E	D	Casing top in basement	-8.0	994	18.0	6-23-59	
53	SE SE sec. 20	E. Cowan	Dr	49	6	GI	do	do	J E	D	Land surface	0.0	1008	34.1	6-23-59	15 gpm (pump)
54	SW SW sec. 21	A. Hoerman	Dr	87	12	GI	do	do	T G	I	do	0.0	1007	28.0	6-23-59	1000 gpm (pump)
56	NW SE sec. 22	H. Mertz	Dr	66	18	GI	do	do	T G	I	do	0.0	992	16.3	6-23-59	2000 gpm (pump)
57	SW SW sec. 21	Rock Island R.R.	Dg, Dn	...	36-3.5	B, GP	do	do	Cy H	N	Pump head joint	2.5	1011	33.0	6-24-59	Abandoned
58	SW SW sec. 28	F. Moore	Dg	...	36	R	do	do	Cy N	N	Collapsing rock box	0.0	1010	28.5	6-24-59	Abandoned
59	NW NE sec. 28	C. Streeter	B, Dr	25	5.5	GI	do	do	N N	N	Casing top	1.5	993	17.0	6-24-59	Abandoned
60	NE SE sec. 22	G. Hofman	Dn	28	1.25	GP	do	do	J E	D, S	Land surface	0.0	989	15.0	6-24-59	
60a	SE NE sec. 22	-- McGehee	Dr	81	14	GI	do	do	T G	I	do	0.0	987	14.0	3- 59	1250 gpm;3-4'dw dn
65	SE SW sec. 19	G. Wilson	Dr	...	6	GI	do	do	J E	D	Casing top	-3.8	1004	26.5	6-25-59	
66	SE SW sec. 20	G. Wilson	Dr	68	5.5	GI	do	do & Brownville ls?	J E	D, S	do	-5.0	997	22.0	6-25-59	
67	SW NE sec. 29	H. Hofman	Dg	...	34	R, C	do	Alluvium	J E	D, S	Top concrete platform	1.5	1019	28.5	6-25-59	
68	SW NW sec. 33	T. Lee	Dr	...	5.5	GI	Sand,gr,ls.	do & Wabaunsee gr.	J E	D	Top barrel pit	0.2	1025	32.0	6-25-59	
70	SE SE sec. 32	J. Kimball	Dr	33	4.5	GI	Ls, sh.	Wabaunsee gr.	Cy H	N	Casing top	0.0	1030	...	6-25-59	Abandoned-muddy
81	SE NE sec. 20	Stewart & Shandy	Dn	50	1.25	GP	Sand & gr.	Alluvium	Cy,J,E	D	Cy pump base	0.0	1000	21.7	6-23-59	
84a	SE SE sec. 18	H. Roepke #1	Dr	40	4	N	do & sh.	do, Penn-Pony Cr. sh?	N N	N	Land surface	0.0	994	16.6	2-17-57	Test hole log-250 gpm
84b	SE SE sec. 18	H. Roepke #2	Dr	52	4	N	do	do	N	N	do	0.0	1007	29.6	2-17-57	do - 450 gpm
84c	SE SE sec. 18	H. Roepke #3	Dr	52	4	N	do	do	N	N	do	0.0	1005	29.6	2-18-57	do - ...
84d	SE SE sec. 18	H. Roepke #4	Dr	59	4	N	do	do	N	N	do	0.0	1005	30.6	2-18-57	do - 650 gpm
84e	SE SE sec. 18	H. Roepke #5	Dr	52	4	N	do	do	N	N	do	0.0	1005	30.0	2-19-57	
84f	SE NE sec. 18	H. Roepke #6	Dr	...	4	N	do	do	N	N	do	0.0	994	26.0	2-19-57	
84g & 47a	SE SE sec. 18	H. Roepke #7	Dr	56	18	S	do	do	T G	I	do	0.0	1005	30.6	2-19-57	Test hole log-1000 gpm
84h	SE SE sec. 18	H. Roepke #8	Dr	57	4	N	do	do	N	N	do	0.0	1007	...	2-19-57	do - 550 gpm
Pt-13	SW NW sec. 7	M. Murrell	Dr	...	6	GI	Sand & gr.	Alluvium	J E	D	Basement floor	-8.0	1032	4.0	6-4-59	
14	NW NE sec. 7	L. Dobson	Dr	103	6	GI	Ls, sh.	Admire & Wabaunsee gr.	J E	D, S	Land surface	0.0	1094	20.0	6-4-59	
17	NW NW sec. 6	-- Scritchfield	Dg	25	32	R	Creek sand	Alluvium	Cy W	S	do	0.0	1095	16.0	6-4-59	
19	SE SE sec. 6	C. Hodges	Dg	...	42	R, C	do	do & Admire gr.	Cy W	S	Wooden pump platform	0.5	1070	19.0	6-4-59	
20	SE NE sec. 7	W. Jones	Dr	69	6	GI	Ls,sh,loess	Admire and Sanborn gr.	C E	D	Casing top	-6.0	1060	45.0	6-4-59	5 gpm;10' dw dn-4 hrs.
21	NE NW sec. 8	L. Kellogg	Dr	105	6	GI	Ls, sh.	Richardson sub.gr.	J E	D	Land surface	0.0	1100	80.0	6-4-59	
26	NE SE sec. 4	R. Wullenleger	Dr	180	6	S	do	do	J E	D	Concrete platform	0.0	1165	100.0	6-5-59	
27	SE NW sec. 9	G. Dexter	Dr	130	6	S	do	do	J E	D, S	do	1.0	1111	27.0	6- 58	
29	SE NE sec. 2	E. Larson	Dr	105	6	S	do	do	J E	D	Land surface	0.0	1202	60.0	6- 55	4 gpm (pump)
30	NW SW sec. 11	A. Walter	Sp	...	1.5	GP	do	do,Dover ls,&Langdon sh	F N	D	Land surface	0.0	1100	0.0	6-5-59	1 gpm flow est.
31	NE SW sec. 11	B. Spain	Sp	...	1.5	GP	do	do	F JE	D	Land surface	0.0	1115	6.0	6-5-59	1 gpm flow est.
32	NW SW sec. 14	H. Garland	Dn	28	1.25	GP	Sand & gr.	Alluvium	C E	D	Basement floor	-5.5	986	5.0	8- 58	
33	NW NW sec. 14	S. Ball	Sp	...	1.5	GP	Ls,sh,ss.	Richardson sub.gr.Tarkio?	F N	D	Land surface	0.0	1055	0.0	6-5-59	3 gpm flow est.
34	SE NW sec. 15	R. Shurr	Dg	22	12	GI	Sand & gr.	Alluvium	Cy H	N	Casing top	1.5	1005	8.0	6-5-59	Abandoned
35	NE SE sec. 9	L. Rose	Dr	101	6	GI	Ls, sh.	Richardson sub.gr.	J E	D	Land surface	0.0	1122	50.0	4- 55	
36	SW SE sec. 3	J. Shaver	Dr	163	6.5	S	do, loess	do,&Sanborn gr.	J E	D	Casing top	1.5	1159	79.0	4-5-59	10-15-gpm;19'dw dn-4 hrs.
37	NW NW sec. 9	J. Piper	Dn	32	1.25	GP	Creek sand	Alluvium	J E	D	Land surface	0.0	1030	17.0	3- 57	
38	SE NE sec. 8	C. Dishman	Dn	15	1.25	GP	do	do	C E	D	do	0.0	1015	7.0	9- 57	
39	SE SW sec. 9	B. Motley	Dr	58	6	GI	Ls, sh.	Richardson & Nemaha sub.gr.	Cy H	D	do	0.0	1052	52.0	3- 57	
40	NW NE sec. 16	F. Howard	Dg	30	42	T	Sand & gr.	Alluvium	J E	D, S	do	0.0	1010	26.0	7- 58	15 gpm;4' dw dn-1.5 hrs.

TABLE 2 .—*Record of wells* and test holes (concl.).

Well No. (1)	Location	Owner or Tenant	Type of well (2)	Depth of well (feet)	Diameter of well (in.)	Type of casing (3)	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic source	Method of lift (4)	Use of water (5)	Measuring point: Description	Measuring point: Distance above land surface (feet)	Measuring point: Height above mean sea level (feet)	Depth to water level below measuring point (feet)	Date of measurement	Remarks (Yield given in gallons a minute; drawdown in ft.)
	T.10S., R. 9 E. (cont.).															
Pt-41	SE NE sec. 8	C. Hofman	Dg	30	34	R	Sand, ls.	Richardson sub.gr.	Cy E	S	Pump base	0.0	1050	27.0	6-8-59	
42	SE NW sec. 8	H. Seaburg	Dr	90	6.5	S	Ls, sh.	do, Nemaha sub.gr.	J E	D	Land surface	0.0	1048	35.0	8- 58	
81	NE NE sec. 12	....	Sp	...	1.5	GP	do	Rich.sub.gr.Ind.Cave ss	F JE	D	Land surface	0.0	1115	0.0	6-25-59	3 gpm flow est.
83	SE SW sec. 1	....	Dr	55	5.5	GI	do	Rich.sub.gr.	Cy H	N	Casing top	0.0	1150	28.0	6-25-59	Abandoned reserv. site
84	SW SW sec. 1	L. Richards	Dr	...	5.5	GI	do	do	Cy H	N	do	0.0	1125	14.0	6-25-59	Abandoned
85	SW SW sec. 1	L. Richards	Dg	15	40	R	Sand, ls.	do, alluvium	Cy H	D, S	Wooden platform	0.0	1112	6.0	6-25-59	
86	SE NE sec. 11	W. Stewart	Dr	...	5.5	GI	do	do	Cy H	N	Concrete blk. pile	0.0	1161	32.5	6-25-59	
Wb-1	SE SW sec. 23	I. Stewe	Dr	...	1.25	GP	Sand & gr.	Alluvium	Cy H	D	Pump base	1.0	987	13.0	6-24-59	
2	SE NE sec. 26	E. Leonard	Dr	...	6	GI	do	do	J E	D, S	Pit top	0.0	1000	26.0	6-24-59	
3	SW NW sec. 25	A. Hinson	Dr, Dn	55	6	...	do	do	J E	D, S	Pump base	0.0	1019	42.0	6-24-59	
4	SW NE sec. 25	H. Martin	Dr	60	6	GI	do	do	J E	D, S	Casing top	-3.5	1003	36.4	6-24-59	
5	NE NW sec. 25	F. Kilian	Dn	26	1.25	GP	Sand	do	J E	S	Land surface	0.0	992	22.0	6-24-59	
6	NE SW sec. 36	H. Geisler	Dr	...	5.5	GI	Ls, sh.	Nem.s.g.Wamego sh,Tarkio	N N	N	Casing top	1.0	1088	9.5	6-24-59	
7	NE SE sec. 35	V. Platz	Dg	20	48	R, C	Sh, ss.	Nem.s.g.Willard sh.	CyC N	N	Pump base	1.2	1021	3.0	6-24-59	
8	SW SE sec. 35	H. Geisler	Dg	20	36	R	Sand, sh.	do, alluvium	N N	N	Top rock wall	1.0	1035	6.0	6-24-59	
9	NE SW sec. 36	H. Geisler	Dg	25	30	R, C	Ls, sh.	Nem.sg.Wamego sh,Tarkio	J E	D	Top wooden platform	0.0	1073	0.7	6-24-59	
9a	NE SW sec. 36	H. Geisler	Dr	...	6	GI	do	do	N N	N	Top concrete base	0.7	1078	6.0	6-24-59	
	T.10S.,R. 10 E.															
Pt-80	SW SW sec. 6	V. Westergart	Dr	...	6	GI	Ls, sh.	Wabaunsee gr,Nemaha sg.	J E	D	Casing top	2.3	1172	42.3	6-25-59	
80a	SW SW sec. 6	V. Westergart	Sp	0.0	2	GP	Ls	do, Tarkio ls.	F N	N	Land surface	0.0	1106	0.0	6-25-59	0.7 gpm flow est.
82	NW NW sec. 7	J. Mayer	Dr	...	6.5	S	Ls, sh	Wab.gr.Nemaha s.g.	J E	D	Top block pit	0.0	1178	52.5	6-25-59	
87	NE NE sec. 19	D. Eriksen	Dn	24	1.25	GP	Sand & gr.	Alluvium	J E	D	Top of cave	2.5	981	16.9	3- 59	
88	SW SW sec. 19	D. Eriksen	Dn	40	12	GI	do	do	T G	I	Land surface	0.0	980	17.5	6- 59	
89	NE SW sec. 19	F. Lewis	Dn	24	1.25	GP	do	do	...	D	do	0.0	980	16.0	6-25-59	
90	NW SW sec. 17	....	Dn	...	...	...	do	do	Cy H	N	Pump base	0.8	978	16.0	6-25-59	Abandoned
91	NE SW sec. 18	....	...	...	1.25	GP	do	do	N N	N	Pipe in cellar	0.0	980	15.0	6-25-59	Abandoned
Wb-12	NE SW sec. 30	Wabaunsee Tr. Ct.	Dr	64	6	GI	Sand & gr.	Buck Cr. Terr. deposit	S E	D, C	Land surface	0.0	1018	50.2	8-28-56	25 gpm (pump)
13	SE SW sec. 30	O. Fulton	Dr	59	6	GI	do	do	J E	D	do	0.0	1012	45.0	6- 53	9 gpm (pump)
14	NE SW sec. 30	Wabaunsee Com. Well	Dr	65	...	...	do	do	J E	D, C	do	0.0	1018	52.0	6-1-56	20 gpm (pump)
15	SE SW sec. 30	Wabaunsee Com School	Dr	74	6	GI	do	do	.. E	D	do	0.0	1025	58.0	8-27-56	Log of well
	T.11 S.,R. 9 E.															
RL-41	NE NE sec. 6	E. Kimball	Dr	103	6	GI	Ls, sh.	Richardson&Nemaha sbg.	Cy H	D	Casing top	1.0	1076	67.0	6-19-59	0.75 gpm
69	SW NW sec. 4	J. Aiken	...	...	...	...	do	Richardson sub. gr.	Cy W	S	Wooden platform	1.5	1076	10.0	6-25-59	
Wb-10	NW NE sec. 1	S. Macklin	Dg	20	40	R	Top soil	Nemaha s.g.Willard sh.	N N	N	Top rock edge	4.0	1080	4.5	6-24-59	Abandoned-pond seepage
11	SE NE sec. 2	L. & W. Bowman	Dg	21	48	R	Sh.	do		D, S	Land surface	0.0	1105	5.0	6-24-59	Pond seepage

PLATE I.

Map of the Kansas and Big Blue River Valleys between Wamego and Manhattan-Tuttle Creek Dam Vicinity.

6½x9½

PEERLESS CLASP

FEDERAL ENVELOPE CO.

James T. Smith

PLATE I

MAP OF KANSAS AND BIG BLUE RIVER VALLEYS BETWEEN WAMEGO AND MANHATTAN-TUTTLE CREEK DAM VICINITY

showing water-table contours and locations of wells and test holes

by James T. Smith

1959

EXPLANATION

County boundary
Township boundary
Section line
Valley wall
Perennial stream
Intermittent stream
Water-table contours
Contour interval five feet

Heavy-duty highway
Medium-duty highway
Graded road
Ungraded road
Railroad

0 1 2
SCALE, IN MILES

Domestic or stock well
Irrigation well
Public well
Commercial well
Drilled test hole

5-20 / 980 Well number followed by depth to water below land surface
Altitude of water table, in feet
Brackets indicate chemical analysis