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**GROUND WATER**

**By**

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## INTRODUCTION

Ground water for domestic, industrial, and farm use--the water which supplies the soil with moisture without which no crops or livestock-raising would be possible--is emphatically a mineral resource. It is as much so as another earth liquid, petroleum, which in so many Kansas localities comes from sandstones and limestones like those which yield ground water.

Sometimes, water is the butt of man's ~~unreasoning~~<sup>unreasoning</sup> temper. When floods come and precious millions of gallons of water go to waste, people naturally lament the damage by currents and erosion, and demand multi-million dollar ~~storage~~<sup>or conservation measures</sup> or flood-control dams; and when ~~droughts~~<sup>droughts</sup> occur and dust bowl conditions punish both land and people, man condemns the elements and concludes that the earth is drying up. Between these extremes, when conditions are reasonably normal, people commonly take water supply for granted, sometimes unthankful for its benefits and unthinking of its pattern. Plainly the prudent course is to study and try to understand water supply--not to regard it as a mysterious, capricious thing.

Kansas--particularly western Kansas--is sometimes described as "dry plains country." In a measure this is true, but "dry" is indeed a relative term. In a recent year, an internationally-known corporation had no difficulty in picking a spot which would yield 10,000,000 or 15,000,000 gallons of ground water each day for a chemical plant, in one of the "driest" parts of western Kansas.

Ground water supply in Kansas has been under cooperative study for many years by a division of the State Geological Survey and <sup>by</sup> a part of the ground water section of the United States Geological Survey. Field studies have been made in all parts of the state and reports covering most of western Kansas--see figure 1--have been issued or are in preparation by the State Geological Survey at the University at Lawrence.

In 1950, there was <sup>a</sup> rumor which gained nationwide <sup>(-)</sup> publicity that the water table over much of the country had become lower and lower through the years. In other words, the country seemed to be in the process of drying up. Probably this impression stemmed partly from a bad water shortage in New York City which was caused mainly by the population and area served increasing greatly without parallel increase in pipelines and in water storage capacity. Anyway, hydrographs--figure 2--show plainly that the conditions in reputedly dry western Kansas were, and are, the reverse of conditions suggested by the rumor. <sup>the</sup> Water tables <sup>most parts of</sup> in Kansas in recent years <sup>have</sup> been the highest of record.

The subject of ground water is so poorly understood generally and yet of so great importance in Kansas to individuals, to industry, and to agriculture that its pattern is given in some detail in this chapter.

#### Classification of Water Resources

Water supplies are classed either as ground water or as surface water. Both depend on rainfall as an ultimate source, but the quantities of water that are available for use at given localities are by no means proportional to the rainfall--figure 3--at corresponding points. A dozen localities picked at random in western Kansas, where annual rainfall is, say, 20 inches, would be likely to give water wells of equal or considerably greater yield than a dozen random points in eastern Kansas where the annual rainfall may be 40 inches. The reasons are explained later.

Surface water mainly coming from rain is that which exists in streams, ponds, lakes, and at or near the surface of the ground and which is not a regular part of the "underground flow" below the common water table. Most surface water is run-off, and soon leaves the State; some of it sinks down and replenishes the valley fill of streams and other water storages. However, some surface water, such as that of springs, comes not directly from rain but rather from the flow of ground water reservoirs.

Ground water is defined (Moore, 1940, p. 11) as including all water beneath the earth's surface that fills the pore spaces or other openings in rocks. The term "rocks" is broadly construed also to mean formations that are pervious, including many sand and gravel zones consisting of unconsolidated sedimentary materials. Ground water does not necessarily "flow" underground; in fact, most ground water is regarded as water in storage rather than water in transit.

It is estimated that three-fourths of the public water supply in Kansas comes from wells (as ground water), the remainder from streams, lakes, ponds, and other surface sources. Furthermore, as the direct and immediate effect of rain on growing crops is ephemeral and the more lasting effect is that which arises from part of the precipitation sinking in and joining the ground water supply as a sustained source of moisture for plants, it is clear that ground water is the more important of the two main types of water supply.

#### GEOLOGY OF KANSAS GROUND WATER

Sources of ground water.--One of the two principal conditions (see also under "Kinds of ground water reservoirs" below) on which satisfactory supplies of ground water depend, is the source of water. Typically, when rain--the main source of ground water--falls on the land some of it runs off as surface water, some goes only into the shallow soil zone from which it is promptly evaporated or transpired by plants, and some sinks deeper down to become a source of ground water. It has been calculated (Moore, 1940, p. 24) that of the average of 33 inches of Kansas rainfall--figure 3--3.5 inches is the amount lost by rapid run-off in streams. Of the remaining 29.5 inches a large part soon returns to the air by evaporation and transpiration. That which does reach the water table, defined as the upper surface of the moisture-saturated zone in the ground, becomes ground water. Ground water may be "fixed" as in

hard but slightly porous rocks in which movement is mainly by capillarity and therefore slow, or "free" as in media with sufficient pore space to provide reasonable movement of the water.

Another important source of ground water is surface water in streams, lakes, and ponds which in times of heavy rainfall rises above normal levels and spills into the ground water zone below through the margins where such bodies have not silted their beds tightly. This type of recharge commonly is seasonal and although variable from year to year it yields to a "law of averages" over a long period. The regular measuring of water levels in wells and saturated ground water reservoirs in Kansas by the State and Federal Geological Surveys thus furnishes very important guides for estimating available water supplies in given areas.

Kinds of ground water reservoirs.--The other principal condition on which satisfactory ground water supplies depends is that there be a porous, underground zone or medium to hold water, to permit some movement, and to release it for use. The underground media may be beds of sand or gravel, sandstone, sandy shale, or porous limestone--or even much denser rock if it is sufficiently fractured to provide passageways for the water.

In Kansas, a comparatively level region which is covered by sedimentary formations lying flat or dipping but a few feet to the mile (mainly westward), certain well-known formations outcropping at surface or covered only by a thin soil zone, bear strongly on the destiny of rain water falling on the land surface. In general, sandstone or sandy surfaces absorb rain immediately; clays, shales, and hard rock areas shed water like an umbrella and change rain into run-off; and intermediate types, such as loess, sandy shales, and some of the glacial sediments, are compromises between the extremes noted.

Five types of Kansas surficial deposits are worthy of special mention as ground water reservoirs: valley alluvium, loess, glacial sediments, sand dunes, and the residual soil and rock mantle.

Valley alluvium includes the unconsolidated fill material of all stream valleys and terraces, and consists of stream-deposited sands, clays, silts, and gravels. Practically all of this material is water-bearing, and the alluvium of the larger rivers, like the Kaw and Arkansas, can yield very large quantities of water for municipal and industrial uses. Even the smaller streams and tributaries carry generous supplies of water in their alluvia. The quality of water from Kansas valley alluvium is quite good enough for domestic consumption when lightly treated.

Loess, mainly a wind-deposited material consisting of fine sand and silt, is rather porous, yet dense and absorbs water very slowly. It covers large areas in northeastern, north-central, and western Kansas with a thin blanket except near the larger streams where the deposit may increase to 50 or 75 feet in thickness. In the more level areas of Kansas where there is less run-off the loess absorbs considerable water and yields a slow flow into wells which are dependable but not large water producers.

Glacial sediments ranging in thickness from a featheredge to 180 feet cover much of northeastern Kansas north of the Kaw River and from the Missouri River westward for perhaps 100 miles. Such deposits, in some localities occurring as persistent blankets, consist mainly of unsorted materials including clay, sand, silt, gravel, and boulders, locally bedded and lenticular. Most of the glacial material is pervious and forms a satisfactory reservoir which supplies ample ground water for domestic and agricultural use.

The sand dune areas in several parts of western Kansas usually yield ample supplies of ground water because the sand absorbs rain water like a sponge and conveys it downward to the pervious reservoir below the water table.

A zone of residual soil and rock mantle covers much of Kansas outside the stream valleys, especially where hard rock members approach surface. Due to physical and chemical weathering, the hard rock below the soil zone is altered,

fractured and channeled to depths ranging to as much as 100 feet. Some shift of the loosened soil particles and rock material on hill slopes provides accumulations of debris with increased perviousness, so that good reservoirs for ground-water are formed. Water is collected and held in the residual soil of more level areas and released slowly by seepage into draws and into the alluvium of nearby valleys. On the whole, then, the blanket of residual soil and rock mantle is an important source of ground-water supply in the State.

In addition to the types of surficial material described above, numerous well-known deeper rock formations or sequences from Tertiary to Ordovician in geologic age are exposed at surface or are reached by water wells in Kansas. These zones must be considered in ground water studies. The most important of them are briefly described in Table "A" with data on thickness, location, and ground water possibilities.

The distribution and effect of rainfall in Kansas. --Figure 3--(Moore, 1940, p. 21) shows in inches the average amount of rainfall in the State. The amount of rainfall, as noted above, is but one factor in the filling of ground water reservoirs. Others are the topography of the land, which strongly affects the amount of run-off; the average prevailing humidity and wind velocity, which have direct effects on the amount of evaporation from the surface and from the soil zone; and the perviousness of the top or intake part of the ground water reservoir or of the materials overlying it where rain or surface water enter.

The amount of rain water that can be absorbed by the soil mantle must depend largely on the state of saturation of the soil, on the topography, and also on how rapidly the rain falls. Given a dry, level soil surface and a slow rain, all of the water may be absorbed; but with a well-saturated soil on a slope, almost all of a hard rain will run off and yield negligible moisture to the ground-water zone. In western Kansas the land is comparatively level,

TABLE "A".--Water-bearing Rock Units in Kansas. a/

<u>Material or Formation</u>	<u>Age</u>	<u>Range in Thickness (feet)</u>	<u>Principal Areas of Outcrop</u>	<u>Type of material and ground water characteristics</u>
Pierre shale	Cretaceous	Max. 1400'	W. part of Smoky Hill Valley; Valleys of Republican River; Tributaries in NW Kansas.	Principally shale and bentonite. Generally a poor aquifer but locally supplies small quantities of mineralized water.
Niobrara Chalk	"	500'-700'	W. part of Smoky Hill Valley; broad belt in N-Central Kansas.	Chaly shale and chalk. Generally impervious except for small local supplies of hard water from fractures.
Carlile shale	"	300' ±	Broad belt from Ness to Republic Counties.	Shale, thin chalky limestones, and locally sandstone near top. Codell sandstone zone yields small quantities of soft water locally.
Greenhorn limestone	"	65'-100'	Narrow belt east of Carlile shale area and along western part of Arkansas Valley.	Chalky limestone and calcareous shale. Generally not water bearing.
Graneros shale	"	20'-50'	Narrow belt along east of Greenhorn outcrop area.	Noncalcareous shale. Locally contains ferruginous sandstones which yield water.
Dakota formation	"	100'-300'	Broad belt from Ellsworth to Washington Counties. Local inliers along central Arkansas Valley and in SW Kansas.	Principally clay and shale containing many lenticular and channel sandstones. Generally yields good water supplies in outcrop area and beneath younger rocks south of Saline river. Where buried north of Saline river yields salt water to wells. Some artesian pressure in most sandstones but only local flowing wells.

<u>Material or Formation</u>	<u>Age</u>	<u>Range in Thickness (feet)</u>	<u>Principal Areas of Outcrop</u>	<u>Type of material and ground water characteristics</u>
Kiowa shale	Lower Cretaceous	60'-150'	Saline county; SE Ellsworth County; locally in south central Kansas.	Noncalcareous shale, thin limestones, and local lenticular sandstones. Locally sandstones yield moderate water supplies.
Cheyenne sandstone	"	75' max. on outcrop.	Locally in Clark, Comanche and Kiowa counties	Quartz sandstone containing silty shale beds. In subsurface generally contains highly mineralized water under artesian pressure. Yields moderate quantities of good water in Morton and Stanton counties.
"Redbeds" of Guadalupian series	Permian	300'±	Meade to Comanche Counties	Redbeds of silty shale and fine-grained sandstone containing thin beds of dolomite, anhydrite and gypsum. Generally impervious to water or contains highly mineralized water.
"Redbeds" of Nippewalla group	"	900'±	Small areas in South Central Kansas from Comanche to Reno Counties	"Redbeds" of maroon silty shale, fine sandstones, and red shale. Contains thick escarpment-forming gypsum beds, thin dolomite, and beds of white and gray sandstone. Yields small quantities of mineralized water in outcrop areas.
Stone Corral dolomite	"	6'-30'	Thin belt in Kingman, Reno, and Rice Counties.	Dolomite, anhydrite, and gypsum; contains red shale. Generally not a source of ground water.
Ninnescah shale	"	450' max.	Moderately wide belt from SE Harper County to Saline County.	Principally red silty shale. Contains gray shale, calcareous shale and impure limestone. Locally yields small quantities of mineralized water to wells.
Wellington shale	"	700'±	Broad belt from Sumner to NE Washington County.	Gray, gray-green, and variegated silty shale. Contains thick Hutchinson salt member in middle part in subsurface. Contains thin limestone beds and lenticular gypsum beds. Limestones and anhydrite beds yield local water supplies ranging from hard to "gyp."

<u>Material or Formation</u>	<u>Age</u>	<u>Range in Thickness (feet)</u>	<u>Principal Areas of Outcrop</u>	<u>Type of material and ground water characteristics</u>
Chase group	Permian	335'±	Broad belt from Cowley to Marshall County.	Massive cherty and thin-bedded limestones, separated by red and green shales. Winfield, Fort Riley, Florence and Wreford limestones are important aquifers of western Flint Hills area. Many large springs issue from outcrops at these rocks.
Council Grove group	"	325'±	Narrow belt from SE Cowley to NE Marshall County.	Alternating red and green shale and thin limestones. Locally contain gypsum, coal, and dolomitic or cherty limestone. Thin limestones furnish small quantities of water to wells and small springs.
Admire group	"	125'	Narrow belt from Cowley to Brown County and across Pottawatomie and W. Nemaha Counties.	Gray to green shale and thin persistent limestones. Contains sandy shale, lenticular sandstones, and at base prominent Indian Cave channel sandstone. Small water supplies obtained locally from thin sandstones and limestones.
Pleasanton Group	Pennsylvanian	70'-130'	Narrow belt from Labette to Miami County.	Gray to black shale, massive sandstones, and thin limestones. Sandstones supply moderate quantities of ground water.
Marmaton group	"	250'±	Belt from Labette to SE Linn County.	Thin limestone beds separated by thicker shales locally containing Bandera Quarry sandstone in middle and Englevale sandstone at base. Sandstones supply moderate amounts of ground water.
Cherokee group	"	400'-550'	Cherokee and SE Crawford County.	Light and dark colored shale, sandy shale, sandstone and thin coal beds. Sandstone zones supply water of variable quality in outcrop belt.
Mississippian limestones	Mississippi	20'± (exposed)	Southeast corner of Kansas	White granular and cherty limestones. Yield small quantities of mineralized water to wells.
Wabaunsee group	Pennsylvanian	500'±	Chautauqua County to Brown and Doniphan counties and in W. Nemaha County.	Clayey, silty, and sandy shales, thin persistent limestones, and lenticular sandstones. Sandstones, where well-developed, and locally the thin limestones, supply small quantities of water to wells.

<u>Material or Formation</u>	<u>Age</u>	<u>Range in Thickness (feet)</u>	<u>Principal Areas of Outcrop</u>	<u>Type of material and ground water characteristics</u>
Shawnee group	Pennsylvanian	325' <sup>±</sup>	Narrow belt from Chautauqua County to Doniphan County.	Cyclic sediments consisting of alternating limestone and thin shales separated by thicker shale and sandy shale units. Sandstones and coal beds are well developed in the shale formations. Locally the sandstones yield moderate supplies of water and the limestones small supplies.
Douglas	"	250' <sup>±</sup>	Belt from E. Chautauqua County to E. Leavenworth County.	Chiefly shale, micaceous shale and sandstone containing thin limestone and coal beds. Ireland and Tonganoxie channel sandstones furnish moderate supplies of soft water, containing iron, in many areas.
Pedee group	"	90' <sup>±</sup>	Very narrow belt from SE Chautauqua County to NE Leavenworth County.	Dark blue gray shale containing limestone zone at top. Grades southward into sandy shale. Generally not water-bearing.
Lensing group	"	85' <sup>±</sup>	Belt from Montgomery County to Wyandotte County.	Two prominent limestone formations separated by about 15 feet of clayey and sandy shale. Limestones are thinbedded, fine-grained, and contain thin shales and sandstones. Generally not water-bearing.
Kansas City group	"	325'-350'	Belt from Montgomery to Wyandotte County.	Alternating beds of thick limestone and shale, becoming more shaly southward in state. Limestones may be thin-bedded, warm-bedded, or cross-bedded. Channel sandstones and sandy zones occur in the shale intervals. Generally not water-bearing except locally where channel sandstones are developed.

<sup>a/</sup> Prepared by A. L. Leonard, Geologist, Groundwater division, State Geological Survey of Kansas, University of Kansas, Lawrence.

and in general there is a much greater percentage of the entire region covered at surface with an absorbtive blanket, such as the Ogallala beds or loess,--than in eastern Kansas. This, of course, is fortunate, because of the much lighter average rainfall, lower humidity and more rapid evaporation in western Kansas.

Ground-water Regions in Kansas.--It is possible and convenient to divide the State into four regions, defined by the character of the prevailing water supply conditions. These regions are shown in Figure 4. The brief description of these four water supply "provinces" by Dr. Raymond C. Moore (Moore, 1940, pp. 48-50) justifies direct quotations:

"A. The eastern Kansas region, comprising the eastern one-third of the State, is essentially characterized by outcrops of Carboniferous and Permian bedrocks that dip gently westward. The topography is characterized by a succession of eastward-facing excarpments; the land surface is moderately rough. As a whole, this region is lacking in ground-water reservoirs capable of yielding large quantities of good water, although all the larger stream valleys and a few of the bedrocks yield good supplies.

"B. The north-central Kansas region comprises chiefly the area of Cretaceous outcrops. At its eastern margin, the Dakota sandstone provides good water in many places, although in others this water is too salty for use. Otherwise, this region is very similar to the eastern Kansas province in lacking large supplies of ground-water.

"C. The south-central Kansas region, the Permian redbeds country, in which few good water supplies are obtainable from bedrocks, but in which there are adequate supplies from some of the surficial sediments.

"D. The western Kansas region includes the most widespread and one of the most reliable water reservoirs in the State. This consists of a mantle of partly consolidated sediments of comparatively recent geologic origin, which contain large quantities of water of fine quality."

It should be pointed out that the regions described above are general only and their boundaries are by no means precise. Anyone interested in water supply conditions at a certain locality in Kansas can obtain--in addition to the data published in reports mentioned above or listed at the end of this chapter--<sup>C</sup>advice and usually specific information from staff members of the ground water division of the Federal and State Geological Surveys at Lawrence.

#### THE QUALITY OF KANSAS WATER SUPPLY

*Bacteriologist* ?

Information on the quality of municipal water supply in all parts of the State can be obtained from the State Board of Health, Topeka, Kansas. More ~~comprehensive information~~ <sup>on sources and quantities available</sup> however can be obtained from the ground water division of the State Geological Survey at Lawrence, <sup>on general water conditions</sup> ~~on general water conditions,~~ its quality and quantity over a given area, say, a county or larger unity. The water supply bulletins identified in figure 1--contain numerous tables giving details of the quality and character of Kansas ground water.

It would not be accurate to say that one can lie down and drink out of any river, stream, or natural spring in the State with little fear of serious consequences from contaminated or poisoned water; however, the truth is in that direction. I have seen no streams in the State that are contaminated as are numerous streams of my acquaintance in some foreign countries, nor any Kansas springs poisoned by mineral salts as they are in some cases in our own desert states. On the whole Kansas streams, reservoirs, and ground water supplies are of good quality. Exceptions are a few areas where there is enough pyrite in the underground formations to make "sulfur" or "<sup>m</sup>Mineralized" water, and some areas underlain by gypsum beds where the ground water is "gyppy," and not potable.

Since much of Kansas is underlain by limestone, the ground water usually is classed as "rather hard." Treatment plants are common, but--judging by the number of municipalities, usually smaller ones, that do not have such plants--they may usually be classed as "desirable" rather than "essential."

As the quality of both industrial and domestic water supply available in Kansas can best be judged by the analyses of municipal supplies, data on the quality of water used in a dozen Kansas cities in all parts of the State are given in table "B". Two cities, Hutchinson and Dodge City, in the Arkansas River drainage have, respectively, 783 and 937 ppm total dissolved solids, and 326 and 498 ppm total hardness, indicating that their water supplies, are somewhat out of line on the low side in quality. However, the presence of large steam-electric generating plants near both cities indicates that the quality of the water is suitable for most industrial uses.

#### THE QUANTITY OF KANSAS WATER SUPPLIES

There is little or no waste or unoccupied land in Kansas resulting from the owners' inability to obtain sufficient water supply for domestic or ranch use at reasonable cost. (There is practically no waste or unutilized land in Kansas.) In some areas, wells up to a few hundred feet deep must be drilled to yield a satisfactory water supply. In others--see figure 5--there is a supply of artesian water.

It should be pointed out that the reputed "dryness" of parts of western Kansas stems from the comparatively small rainfall, say 15 or 20 inches per year--rather than from the lack of available ground-water supply.

Irrigation by pumping from the ground-water supply of stream valleys and locally from artesian supply in western Kansas is substantial and is on the increase. However, as the pattern of runoff, recharge, and water use are rather well understood, it is rather certain that the situation will be held under reasonable overall control so that widest use of the water will be

permitted, without the possibility of a debacle and loss of land values due to over use and water depletion, such as occurred, for example, on the Pecos River in New Mexico.

In regard to the availability of industrial water supply: in amounts, say, up to 1,000,000 gallons per day for average industries of 50 to 200 or 300 employees,--there is almost no county seat town or city with municipal water supply in Kansas which cannot--or could not, with proper facility improvements--supply such quantity of water of suitable quality.

For moderately large industrial users, say, 1,000,000 to 5,000,000 gallons per day, most cities and towns located on streams "large enough to float a row boat" and taking water out of the valley fill--could supply that quantity of water. The gathering areas might have to be carefully studied, and the pumping facilities enlarged in most cases. But it can be fairly said that there are but few towns "from a few thousand population" up which could not (and would not) make satisfactory provision for water supply for reasonable industrial expansion.

In respect to the availability of water supply mainly for "large users", such as Government ordnance plants, explosives manufacturing plants, large chemical plants, and the like, staff members of the State Geological Survey scrutinized the situation and issued a report ("Ground-water Supplies in Kansas Available for National Defense Industries," by S. W. Lohman, J. C. Frye, H. A. Waite, V. C. Fishel, T. G. McLaughlin, B. F. Latta, and G. E. Abernathy, Bull. 41, part 2, 1942) which concludes (above reference p. 26) that "Supplies of 10,000,000 to more than 20,000,000 gallons (of industrial water) a day are available for continued use from groups of wells in the Missouri, Kansas, and Arkansas River valleys, and somewhat smaller supplies are available in many other parts of the state, particularly in the western part." Figure 5--accompanied the report referred to above, and reflects conditions particularly that apply to "large users."

In eastern Kansas "large users" of industrial water may need to select plant sites (except in the area of "deep Roubid<sup>on</sup> water" in Crawford, Cherokee, and Labette Counties) near valleys of the larger streams. One area, the McPherson "filled valley," deserves especial mention, as the quality of its water is above average.

#### THE COST OF WATER SUPPLY IN KANSAS

Ask an average Kansas farmer or rancher what his water supply costs him, and the chances are about 500 to 1 that his reply will be, "Why, nothing!" Commonly farm <sup>or</sup> ranch water comes from shallow dug or drilled wells. Probably 50 percent of Kansas farms and ranches use windmills to pump water for homes and stock.

The cost of domestic water in Kansas cities and towns with municipal systems is probably about average that of the Middle West--roughly 25¢ to 40¢ per thousand gallon.

Per capita water consumption for all purposes in Kansas is estimated to range from 80 to 140 gallons per day, compared with a national average of roughly 100 gallons.

Industrial water supply from Kansas municipal systems <sup>costs</sup> ~~runs~~ roughly 5¢ to 16¢ per thousand gallons, depending on the amount taken by the user.

A large industrial water user, such as a chemical plant, located in or near the valley of a principal Kansas stream where the water table is only a dozen feet deep, and if the user pumps against a low hydrostatic head, should supply his own water for 1¢ (or for 3/4¢ under very favorable conditions)¢ per thousand gallons. ("Favorable conditions" would include an electric power rate of about 8 mills per KWH or less, use of synchronous motors for pumping, fairly shallow water table, well-constructed supply wells, fairly thick gravel section and permeability, and water quality not requiring treatment.) There is a good selection of such localities in Kansas.

g/ The opinion of F. E. Diehl, Manager of Light Power and Water supply, City of McPherson, Kansas. Personal communication.

Water treatment cost naturally varies with the treatment. Light chlorination in Kansas costs roughly \_\_\_\_\_ per thousand gallons; treatment to reduce total dissolved solids to the extreme low of \_\_\_\_\_ parts per million, (as done by one Kansas manufacturer of pharmaceutical products, costs only about \_\_\_\_\_ per thousand gallons.

Fluoridation, the addition by an automatic measuring device of about \_\_\_\_\_ parts per million of sodium calcium fluoride, to municipal water supply has begun in Kansas. Its cost is about \_\_\_\_\_ per thousand gallons or about 1¢ per person per month. The practice is recommended to assist in the prevention of dental caries mainly in children.

TABLE B. Chemical analyses of Kansas municipal water supplies. 1/

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
		T.S.	SiO <sub>2</sub>	Fe	Mn	Ca	Mg	Na	CO <sub>3</sub>	HCO <sub>3</sub>	SO <sub>4</sub>	Cl	NO <sub>3</sub>	F	T.H.	N.C.H.	T.A.
Atchison	SU <sup>2/</sup>	406.	6.0	.21	.02	58.	16.0	55.	0.0	155.	163.	21.	3.9	0.5	210.	83.	127.
Coldwater	SW <sup>3/</sup>	201.	12.	.00	.00	48.	3.6	8.3	0.0	146.	2.1	7.0	26.0	0.2	135.	15.	120.
Emporia	SU	113.	5.0	.05	.00	17.	4.0	13.	20.0	13.	21.	14.	2.0	0.2	59.	14.	45.
Garden City	DW <sup>4/</sup>	321.	15.0	.07	.00	56.	14.0	32.	0.0	188.	82.	13.	8.4	0.7	197.	43.	154.
Goodland	DW	316.	40.0	.03	.00	39.	15.0	34.	0.0	200.	23.	14.	27.0	1.5	159.	0.	164.
Hays	SW	544.	33.0	.04	.00	111.	14.0	42.	0.0	346.	53.	53.	14.0	0.2	334.	50.	284.
Kansas City	SU	368.	8.4	.07	.00	49.	13.1	52.	0.0	151.	128.	19.	3.0	0.4	176.	52.	124.
McPherson	DW	375.	25.0	.10	.00	95.	11.0	12.	0.0	305.	23.	21.	3.8	0.1	282.	32.	250.
Norton	SW	455.	27.0	.25	.16	104.	19.0	23.	0.0	393.	47.	9.5	1.1	0.4	338.	16.	322.
Pittsburg	DW	331.	6.0	.02	.00	9.6	16.0	92.	12.0	51.	85.	98.	1.3	0.5	90.	28.	62.
Topeka	SU	539.	11.0	.04	.00	23.	14.0	147.	31.0	39.	138.	145.	2.6	0.40	115.	31.	84.
Wichita	DW	265	14.0	.06	.01	27.	9.2	61.	11.0	144.	45.	37.	1.3	0.4	106.	0.	136.
<b>Average</b>		<b>351.</b>	<b>16.9</b>	<b>.08</b>	<b>.02</b>	<b>53.</b>	<b>12.4</b>	<b>47.6</b>	<b>6.1</b>	<b>177.</b>	<b>67.5</b>	<b>37.6</b>	<b>7.9</b>	<b>0.5</b>	<b>183.</b>	<b>30.</b>	<b>156.</b>

1/ Data from Division of Sanitation, Kansas State Board of Health, Topeka; analyses for year 1950

2/ Surface (streams, lakes, or impoundments).

3/ Shallow wells (less than 100 feet).

4/ Deep wells (100 feet or deeper).

Column 1 - Name of city or town.

Column 2 - Source of water supply.

Column 3 - T.S. - Total dissolved solids expressed in parts per million.

Column 4 - SiO<sub>2</sub> - Silica expressed in parts per million SiO<sub>2</sub>.

Column 5 - Fe - Total iron expressed in parts per million Fe.

Column 6 - Mn - Manganese expressed in parts per million Mn.

Column 7 - Ca - Calcium expressed in parts per million as calcium ion. (Ca<sup>++</sup>)

Column 8 - Mg - Magnesium expressed in parts per million as magnesium ion. (Mg<sup>++</sup>)

Column 9 - Na - Sodium expressed in parts per million as sodium ion. (Na<sup>+</sup>)

(Includes any potassium and lithium that may have been present in the sample analyzed.)

Column 10 - CO<sub>3</sub> - Carbonate expressed in parts per million as carbonate ion. (CO<sub>3</sub><sup>==</sup>)

Column 11 - HCO<sub>3</sub> - Bicarbonate expressed in parts per million as bicarbonate ion. (HCO<sub>3</sub><sup>-</sup>)

Column 12 - SO<sub>4</sub> - Sulfate expressed in parts per million as sulfate ion. (SO<sub>4</sub><sup>==</sup>)

Column 13 - Cl - Chloride expressed in parts per million as chloride ion. (Cl<sup>-</sup>)

Column 14 - NO<sub>3</sub> - Nitrate expressed in parts per million as nitrate ion. (NO<sub>3</sub><sup>-</sup>)

Column 15 - F - Fluoride expressed in parts per million as fluoride ion. (F<sup>-</sup>)

Column 16 - TH - Total hardness expressed in parts per million as calcium carbonate. (CaCO<sub>3</sub>)

Column 17 - NCH - Non-carbonate hardness expressed in parts per million as calcium carbonate. (CaCO<sub>3</sub>)

Column 18 - TA - Total alkalinity expressed in parts per million as calcium carbonate. (CaCO<sub>3</sub>)

Note.--Carbonate hardness is equal to total hardness minus non-carbonate hardness; i.e. carbonate hardness = TH - NCH

Grains per gallon = parts per million divided by 17.1