DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY
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MISSOURI GEOLOGICAL SURVEY AND WATER RESOURCES
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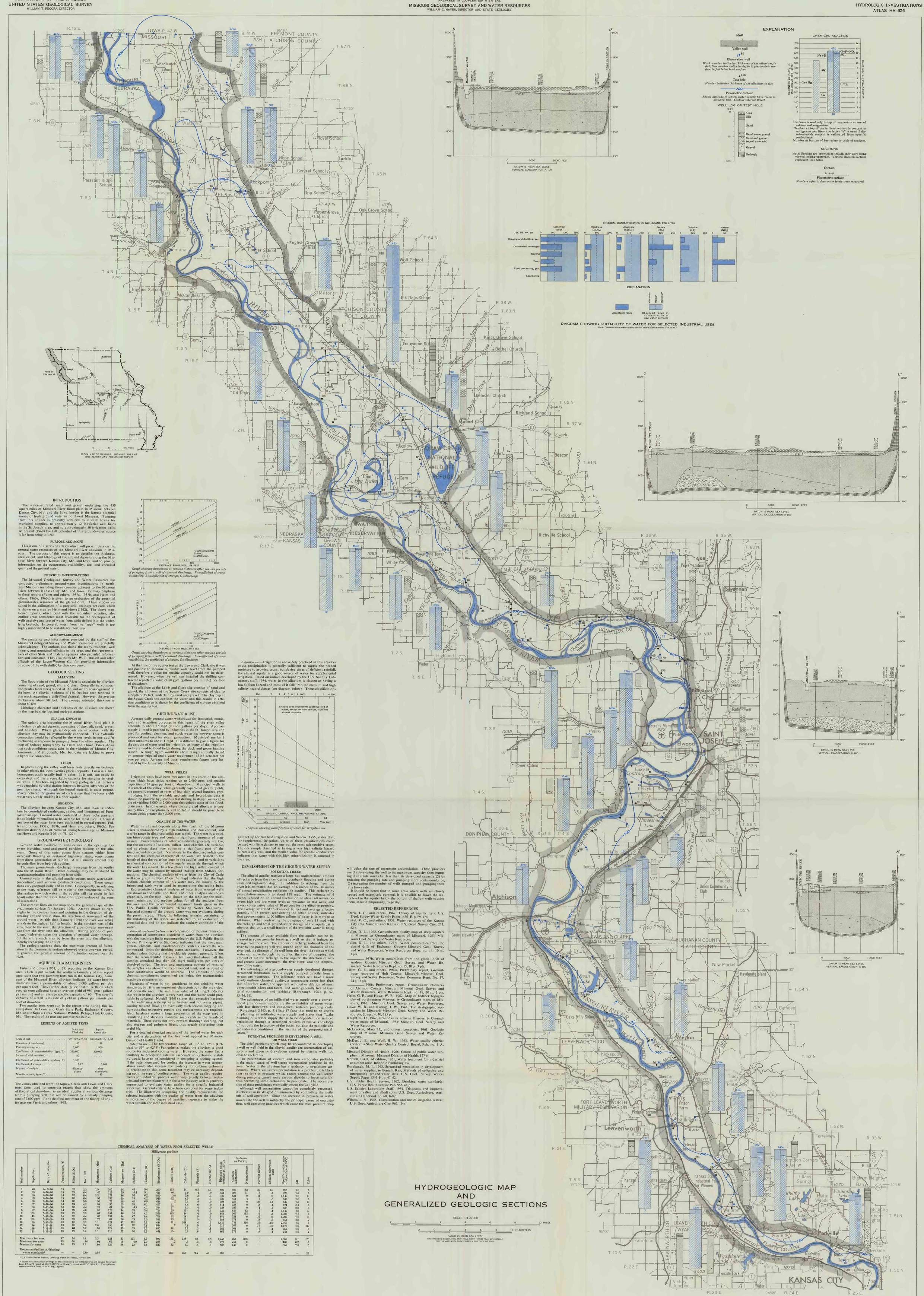
HYDROLOGIC INVESTIGATIONS
ATLAS HA-336



INTRODUCTION

The water-saturated sand and gravel underlying the 450 square miles of Missouri River flood plain in Missouri between Kansas City, Mo. and the Iowa border is the largest potential source of fresh ground water in northwest Missouri. Pumping from this aquifer is presently confined to 9 small towns for municipal supplies, to approximately 12 industrial well fields in the St. Joseph area, and to approximately 50 irrigation wells. At present (1968) the full potential of this ground-water source is far from being utilized.

PURPOSE AND SCOPE

This is one of a series of atlases which will present data on the ground-water resources of the Missouri River alluvium in Missouri. The purpose of this report is to describe the thickness, areal extent, and lithology of the alluvial deposits along the Missouri River between Kansas City, Mo. and Iowa, and to provide information on the occurrence, availability, use, and chemical quality of the ground water.

PREVIOUS INVESTIGATIONS

The Missouri Geological Survey and Water Resources has conducted preliminary ground-water investigations in northwest Missouri including those counties adjacent to the Missouri River between Kansas City, Mo. and Iowa. Primary emphasis in these reports (Fuller and others, 1957a, 1957b, and Heim and others, 1966a, 1966b) is given to an evaluation of the potential ground-water resources of the glacial drift. These studies resulted in the delineation of a preglacial drainage network which is shown on a map by Heim and Howe (1962). The above mentioned reports, which deal with the individual counties, also outline areas considered most favorable for the development of wells and give analyses of water from wells drilled into the underlying bedrock. In general, water from the "rock" wells is too highly mineralized to be suitable for most uses.

ACKNOWLEDGMENTS

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GEOLOGIC SETTING

ALLUVIUM

The flood plain of the Missouri River is underlain by alluvium consisting of sand, gravel, silt, and clay. Generally its composition grades from fine-grained at the surface to coarse-grained at the base. An alluvial thickness of 160 feet has been reported in this reach suggesting a drift-filled channel. However, the average thickness is about 90 feet. The average saturated thickness is about 80 feet.

Lithologic character and thickness of the alluvium are shown on the map by strip logs and geologic sections.

GLACIAL DEPOSITS

The upland area bordering the Missouri River flood plain is underlain by glacial deposits consisting of clay, silt, sand, gravel, and boulders. Where glacial deposits are in contact with the alluvium they may be hydraulically connected. This hydraulic connection would be reflected by the water levels in one aquifer fluctuating in response to pumping from the other aquifer. The map of bedrock topography by Heim and Howe (1962) shows that such conditions could exist in the vicinities of Mound City, Amazonia, and St. Joseph, Mo. but data are lacking to prove a hydraulic connection.

LOESS

In places along the valley wall loess rests directly on bedrock; in other places the loess overlies glacial deposits. Loess is a fine, homogeneous silt usually buff in color. It is soft, can easily be excavated, and has a remarkable capacity for standing in vertical walls. It has been suggested by many geologists that the loess was deposited by wind during intervals between advances of the great ice sheets. Although the loessal material is quite porous, spaces between the grains are of such a size that the loess yields water very slowly, making it a poor aquifer.

BEDROCK

The alluvium between Kansas City, Mo. and Iowa is underlain by consolidated sandstones, shales, and limestones of Pennsylvanian age. Ground water contained in these rocks generally is too highly mineralized to be suitable for most uses. Chemical analyses of the water have been published in several reports (Fuller and others, 1957a, 1957b, and Heim and others, 1960b). For detailed descriptions of rocks of Pennsylvanian age in Missouri see Howe and Koenig (1961, p. 78–122).

GROUND-WATER HYDROLOGY

Ground water available to wells occurs in the openings between individual sand and gravel particles making up the alluvium. Some of this water comes from streams, either from overbank flooding or sustained high-river stage; some comes from direct penetration of rainfall. A still smaller amount may be underflow from bedrock aquifers.

The main ground-water discharge is seepage from the aquifer into the Missouri River. Other discharge may be attributed to evapotranspiration and pumping from wells.

Ground water in the alluvial aquifer occurs under water-table (unconfined) and artesian (confined) conditions. These conditions vary geographically and in time. Consequently, in referring to the map, reference will be made to the piezometric surface (the surface to which water in the aquifer will rise under its full head) rather than the water table (the upper surface of the zone of saturation).

The contour lines on the map show the general shape of the piezometric surface for January 1968. Arrows drawn at right angles to the contour lines and pointing in the direction of decreasing altitude would show the direction of movement of the ground water. At this time (January 1968) the river was acting as a drain throughout half its length. In the northern part of the area, close to the river, the direction of ground-water movement was from the river into the alluvium. During periods of prolonged high-river stage the direction of ground water throughout the entire reach may be from the river into the alluvium, thereby recharging the aquifer.

The geologic sections show the maximum amount of fluctuation in the piezometric surface observed over a one-year period. In general, the greatest amount of fluctuation occurs near the river.

AQUIFER CHARACTERISTICS

Fishel and others (1953, p. 29) reporting on the Kansas City area, which is just outside the southern boundary of this report area, state that two pumping tests run in the Kansas City, Kans. part of the Missouri River alluvium indicate the water-bearing materials have a permeability of about 3,000 gallons per day per square foot. They further state (p. 29) that "...wells on which records were collected have an average yield of 980 gpm (gallons per minute) and an average specific capacity of 60. The specific capacity of a well is its rate of yield in gallons per minute per foot of drawdown."

Two aquifer tests were run in the report area during this investigation: In Lewis and Clark State Park, Buchanan County, Mo. and in Squaw Creek National Wildlife Refuge, Holt County, Mo. The results of the tests are summarized below.

RESULTS OF AQUIFER TESTS

	Lewis and Clark site	Squaw Creek site
Date of test	3/31/67–4/3/67	10/10/67–10/12/67
Duration of test (hours)	63	48
Pumping rate (gpm)	2,600	1,900
Coefficient of transmissibility (gpd/ft)	250,000	220,000
Saturated thickness (feet)	80	
Coefficient of permeability (gpd/sq ft)	3,100	
Coefficient of storage	0.17	0.001
Method of analysis	distance-drawdown	time-drawdown
Specific capacity (gpm/ft)		85

The values obtained from the Squaw Creek and Lewis and Clark tests were used to construct graphs that show the amounts of theoretical drawdown in an ideal aquifer at various distances from a pumping well that will be caused by a steady pumping rate of 2,000 gpm. For a detailed treatment of the theory of aquifer tests see Ferris and others, 1962.

Graph showing drawdown at various distances after various periods of pumping from a well of constant discharge. T=coefficient of transmissibility, S=coefficient of storage, Q=discharge

Graph showing drawdown at various distances after various periods of pumping from a well of constant discharge. T=coefficient of transmissibility, S=coefficient of storage, Q=discharge

At the time of the aquifer test at the Lewis and Clark site it was not possible to measure a reliable water level from the pumped well, therefore a value for specific capacity could not be determined. However, when the well was installed the drilling contractor reported a value of 80 gpm (gallons per minute) per foot of drawdown.

The alluvium at the Lewis and Clark site consists of sand and gravel; the alluvium at the Squaw Creek site consists of clay to a depth of 35 feet, underlain by sand and gravel. The clay cap at the Squaw Creek site confines the water and this results in artesian conditions as is shown by the coefficient of storage obtained from the aquifer test.

GROUND-WATER USE

Average daily ground-water withdrawal for industrial, municipal, and irrigation purposes in this reach of the river valley amounts to about 15 mgd (million gallons per day). Approximately 11 mgd is pumped by industries in the St. Joseph area and used for cooling, cleaning, and stock watering; however some is processed and used for steam generation. Municipal use by 9 cities amounts to about 1 mgd. It is difficult to give a figure for the amount of water used for irrigation, as many of the irrigation wells are used to flood fields during the duck and goose hunting season. A rough figure would be about 3 mgd annually, based on acreage irrigated and a water requirement of 0.5 acre-feet per acre per year. Acreage and water requirement figures were furnished by the University of Missouri.

WELL YIELDS

Irrigation wells have been measured in this reach of the alluvium which have yields ranging up to 2,600 gpm and specific capacities of 85 gpm per foot of drawdown. Municipal wells in this reach of the valley, while generally capable of greater yields, are generally pumped at rates of less than several hundred gpm.

Judging from the available geologic and hydrologic data it should be possible by judicious test drilling to design wells capable of yielding 1,000 to 2,000 gpm throughout most of the floodplain area. In some areas where the saturated alluvium is unusually thick or exceptionally well sorted, it should be possible to obtain yields greater than 2,000 gpm.

QUALITY OF THE WATER

Water in alluvial deposits along this reach of the Missouri River is characterized by a high hardness and iron content, and a wide range in dissolved solids (see table). The water is a calcium bicarbonate type and contains significant amounts of magnesium. Concentrations of other constituents generally are low, but the amounts of sodium, sulfate, and chloride are variable, and at places these may comprise a significant part of the dissolved-solids content. Variations in the dissolved-solids content and the chemical character of the water are related to the length of time the water has been in the aquifer, and to variations in chemical composition of the aquifer materials through which the water has moved. In a few places the high sulfate content of the water may be caused by upward leakage from bedrock formations. The chemical analysis of water from the City of Craig well (bar graph number 12 on the map) indicates that the high sodium chloride content of this water may be caused by the brines and wash water used in regenerating the zeolite beds.

Representative chemical analyses of water from selected wells are shown in the table, and these and other analyses are shown graphically on the map. Also shown on the table are the maximum, minimum, and median values for all the analyses from the area, and the recommended maximum limits given in the U.S. Public Health Service's "Drinking Water Standards." Bacterial content of the ground water was not evaluated during the present study. Thus, the following remarks pertaining to the suitability of the water are restricted to an evaluation of chemical data and do not indicate the sanitary condition of the water.

Domestic and municipal use.—A comparison of the maximum concentration of constituents dissolved in water from the alluvium with the maximum limits recommended by the U.S. Public Health Service Drinking Water Standards indicates that the iron, manganese, chloride, and dissolved-solids contents exceed the recommended limits for drinking water standards. However, the median values indicate that the chloride content generally is less than the recommended maximum limit and that about half the samples contained less than 500 mg/l (milligrams per liter) of dissolved solids. The iron and manganese content of most of the samples was above the recommended limit, and removal of these constituents would be desirable. The amounts of other chemical constituents determined are below the recommended maximum concentration.

Hardness of water is not considered in the drinking water standards, but it is an important characteristic to the municipal and domestic user. The minimum value of 241 mg/l indicates that water in the alluvium is very hard and this water could profitably be softened. Nordell (1961) states that excessive hardness in the water may scale up water heaters and hot water piping, causing reduced flows and eventually such serious clogging and burnouts that expensive repairs and replacements are required. Also, hardness wastes a large proportion of the soap used in laundering and deposits insoluble soap curds in the laundered materials. These curds not only prevent thorough cleaning, but also weaken and embrittle fibers, thus greatly shortening their useful life.

For a detailed chemical analysis of the treated water for each city and a description of the treatment applied see Missouri Division of Health (1966).

Industrial use.—The temperature range of 13° to 17°C (Celsius) or 55° to 62°F (Fahrenheit), makes the alluvium a good source for industrial cooling water. However, the water has a tendency to precipitate calcium carbonate so carbonate stability would have to be considered in designing a cooling system. If the water were used for cooling the increase in water temperatures would also increase the tendency for calcium carbonate to precipitate so that some treatment may be necessary depending upon the type of cooling system. The water quality requirements for industrial process water vary greatly between industries and between plants within the same industry so it is generally impractical to evaluate water quality for a specific industrial water use. General criteria have been compiled for some industries. The illustration comparing the quality requirements for selected industries with the quality of water from the alluvium is indicative of the degree of treatment necessary to make the water suitable for some industrial uses.

Irrigation use.—Irrigation is not widely practiced in this area because precipitation is generally sufficient to supply the needed moisture to growing crops, but during times of deficient rainfall, the alluvial aquifer is a good source of water for supplemental irrigation. Based on indices developed by the U.S. Salinity Laboratory staff, 1954, water in the alluvium is classed as having a low sodium hazard and most of it falls into the medium and high salinity hazard classes (see diagram below). These classifications

Diagram showing classification of water for irrigation use

were set up for full field irrigation and Wilcox, 1955, states that, for supplemental irrigation, water of these classifications could be used with little danger to any but the most salt-sensitive crops. The one sample classified as having a very high salinity hazard is from a city well, and the median value for specific conductance indicates that water with this high mineralization is unusual in the area.

DEVELOPMENT OF THE GROUND-WATER SUPPLY

POTENTIAL YIELDS

The alluvial aquifer receives a large but undetermined amount of recharge from the river during overbank flooding and during sustained high-river stage. In addition to recharge from the river it is estimated that an average of 6 inches of the 34 inches of annual precipitation recharges the aquifer. This recharge by precipitation amounts to about 128 mgd. The estimate of 6 inches is based on an annual fluctuation of about 60 inches between high and low-water levels as measured in test wells, and a very conservative value of 10 percent for the effective porosity. The average saturated thickness of 80 feet and average effective porosity of 15 percent (considering the entire aquifer) indicates that approximately 1,100 billion gallons of water is in storage at all times. When contrasting the pumpage of only 15 mgd with the recharge and total ground-water storage of the aquifer, it is obvious that only a small fraction of the available water is being utilized.

The amount of water available from the aquifer can be increased in some areas by locating a well so that it induces recharge from the river. The amount of recharge induced from the river by the pumping well will depend upon the character of the river bed, the distance of the well from the river, the rate at which water can move through the aquifer, the rate of pumping, the amount of natural recharge to the aquifer, the direction of natural ground-water movement, the river stage, and the temperature of the water.

The advantages of a ground-water supply developed through streambed infiltration over a supply pumped directly from a stream are numerous. The infiltrated water will have a more nearly uniform chemical quality, a temperature range less than that of surface water, the apparent removal or dilution of most objectionable odors and tastes, and water generally free of bacterial contamination and turbidity (Rorabaugh, 1963, p. 52, 55–56, 61).

The advantages of an infiltrated water supply over a conventional ground-water supply are the availability of more water, with less drawdown and consequent reduced pumping costs. Rorabaugh (1963, p. 51) lists 17 facts that need to be known in planning an infiltrated water supply and states that "...the planning of a water supply that is to be dependent on induced percolation through a streambed requires extensive knowledge of not only the hydrology of the basin, but also the geologic and ground-water conditions in the vicinity of the proposed installation."

POTENTIAL PROBLEMS IN DEVELOPING A WELL OR WELL FIELD

The chief problems which may be encountered in developing a well or well field in the alluvial aquifer are encrustation of well screens and excessive drawdowns caused by placing wells too close to each other.

The precipitation of calcium and iron carbonates probably is the major cause of well-screen encrustation problems in the area. Water in the alluvium has a tendency to precipitate carbonates. Where well-screen encrustation is a problem, it is likely that the drop in pressure which occurs around the well screen during pumping causes some carbon dioxide to leave solution, thus permitting some carbonates to precipitate. The accumulation of these precipitates eventually lessens the well yield.

Although well encrustation cannot be completely prevented, its effects can be delayed or minimized by controlling the methods of well operation. Since the decrease in pressure as water moves into the well is indirectly the principal cause of encrustation, well operating practices which cause the least pressure drop will delay the rate of encrustant accumulation. These practices are (1) developing the well to its maximum capacity then pumping it at a rate somewhat less than its developed capacity (2) by reducing the pumping rate and pumping more continuously or, (3) increasing the number of wells pumped and pumping them at a lower rate.

It should be noted that in some areas where wells are closely spaced and extensively pumped, it is possible to lower the water level in the aquifer below the bottom of shallow wells causing them, at least temporarily, to go dry.

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CHEMICAL ANALYSES OF WATER FROM SELECTED WELLS

Well number	Depth, feet	Date of collection	Temperature, °C	Silica (SiO_2)	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids (residue at 180°C)	Hardness as $CaCO_3$: Calcium, Magnesium	Hardness as $CaCO_3$: Noncarbonate	Percent sodium	Sodium adsorption ratio	Specific conductance (micromhos at 25°C)	pH	Color
				Milligrams per liter																			
1	70	5–9–66	13	20	3.3	1.9	105	34	46	5.4	390	133	34	0.5	1.1	602	402	82	29	1.0	905	7.6	5
2	65	5–10–66	13	29	6.4	.40	116	25	6.4	5.1	441	46	1.9	.4	.0	454	393	31	3	.1	726	7.5	5
3	30	5–10–66	14	32	6.4	3.3	177	46	36	6.2	830	3.8	2.8	.3	.1	722	631	0	11	.6	1,140	7.6	10
4	83	5–10–66	14	30	6.4	.90	133	29	13	4.2	546	32	4.5	.3	.1	522	451	4	6	.2	845	7.8	5
5	30	5–10–66	14	30	5.5	.90	73	18	40	6.5	414	.2	7.1	.5	.0	398	256	0	25	1.1	640	7.5	10
6	87	5–10–66	14	24	4.2	.59	90	25	23	6.1	457	11	4.4	.6	.0	414	328	0	13	.1	674	8.1	5
7	30	5–11–66	16	32	4.4	.23	67	28	4.9	4.1	344	17	1.0	.4	.0	328	282	0	4	.1	528	8.0	6
8	92	5–11–66	14	29	4.8	.80	178	44	23	5.4	724	65	12	.4	.1	737	626	32	7	.4	1,140	7.6	10
9	100	5–12–66	13	26	3.9	.04	151	46	16	4.1	526	123	24	.4	.0	669	566	135	6	.3	1,020	7.7	5
10	40	5–12–66	14	28	4.4	.60	137	44	47	6.4	708	22	18	.5	.1	670	524	0	16	.9	1,080	7.6	10
11	100	5–12–66	13	25	2.5	.70	67	26	19	2.0	342	43	16	.5	.0	388	274	0	13	.5	651	8.0	2
12	90	5–12–66	13	30	3.9	1.1	224	47	191	5.2	484	21	538	.4	.3	1,450	753	356	35	3.0	2,360	7.6	5
13	26	5–12–66	13	28	3.4	2.0	156	42	32	5.8	844	.2	5.8	.5	.1	716	562	0	17	1.0	1,170	7.6	20
14	128	5–13–66	13	34	5.2	.80	129	45	19	5.7	650	18	5.2	.3	.1	562	508	0	7	.4	952	7.6	5
15	30	5–13–66	13	27	5.4	1.1	110	25	16	5.6	468	35	0.9	.6	.1	466	378	0	8	.4	741	7.6	7
Maximum for area			17	34	6.4	3.3	224	47	191	6.5	892	152	538	0.6	3.9	1,450	753	356	—	—	2,360	8.1	20
Minimum for area			13	20	.14	.04	67	18	4.9	2.0	288	.2	.8	.3	.0	270	241	0	—	—	436	6.2	2
Median for area			14	29	3.4	.80	129	34	23	5.4	529	32	3.0	.4	.1	532	448	0	—	—	858	7.8	5
Recommended limits, drinking water standards[1]			—	—	0.30	0.05	—	—	—	—	—	250	250	[1]1.7	45	500	—	—	—	—	—	—	20

[1] U.S. Public Health Service, Drinking Water Standards, Revised 1962.

[1] Varies with the annual average of maximum daily air temperatures and ranges downward from 1.7 mg/l (ppm) at 10.0°C (50°F) to 0.8 mg/l (ppm) at 32.1°C (90.0°F). The optimum concentration is from 1.2 to 0.7 mg/l (ppm).

Base from U.S. Geological Survey, 1:250,000
Nebraska City, 1958 and Kansas City, 1960

RECONNAISSANCE OF THE GROUND-WATER RESOURCES OF THE MISSOURI RIVER ALLUVIUM BETWEEN KANSAS CITY, MISSOURI AND THE IOWA BORDER

By
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