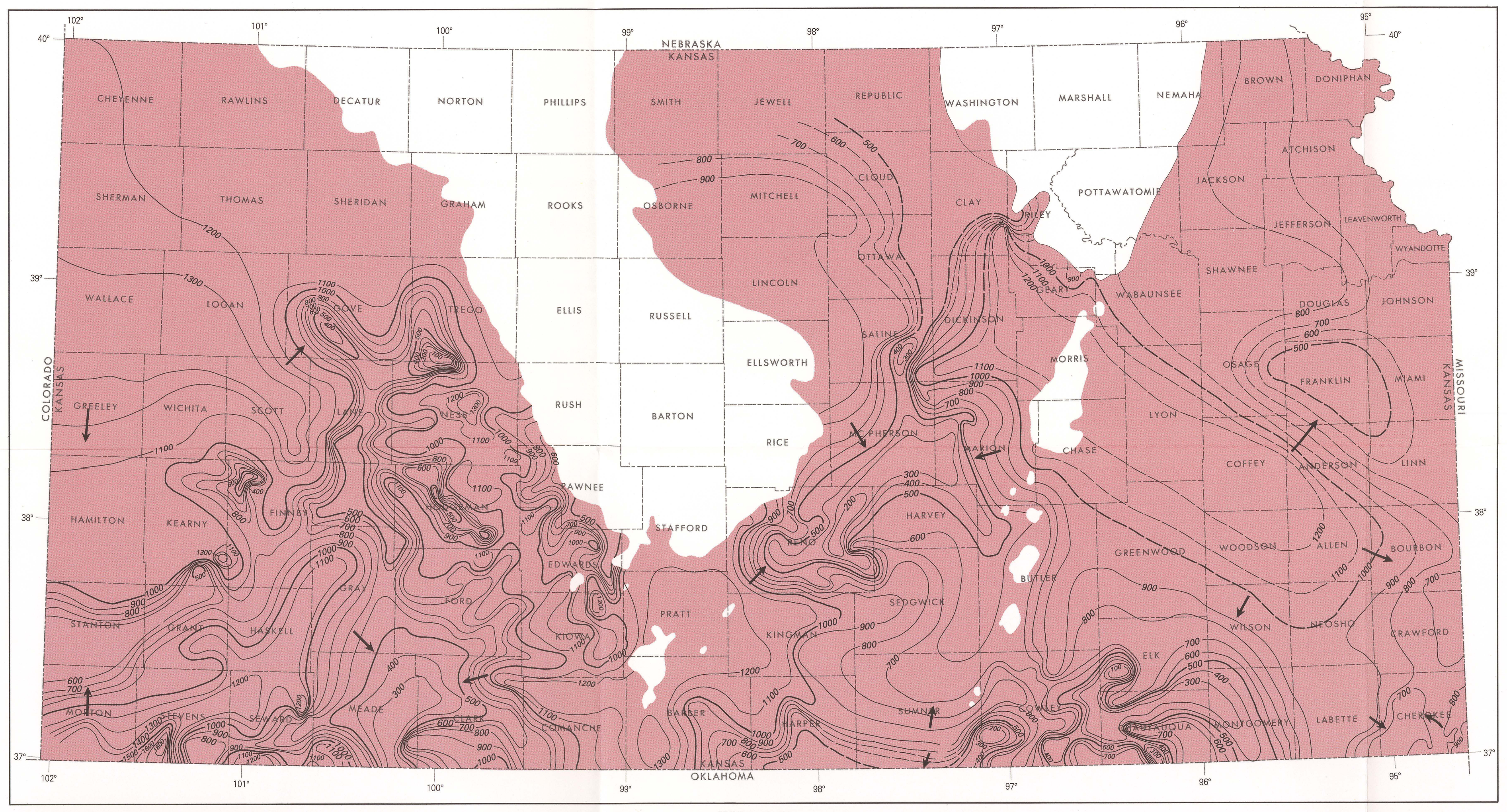

FIGURE 6.—Geohydrologic map showing equivalent freshwater head in upper aquifer unit.

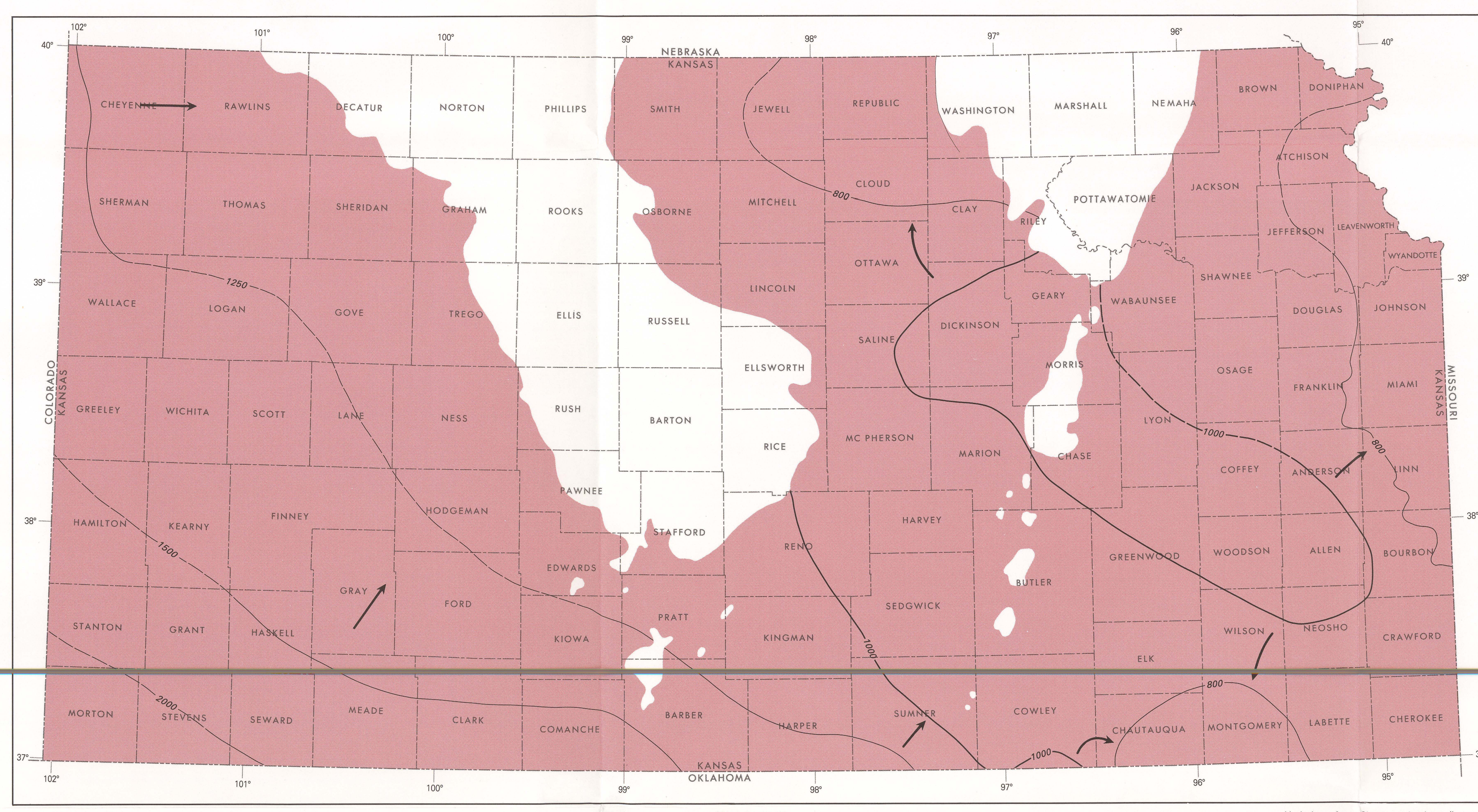

FIGURE 8.—Geohydrologic map showing predevelopment equivalent freshwater head in upper aquifer unit.

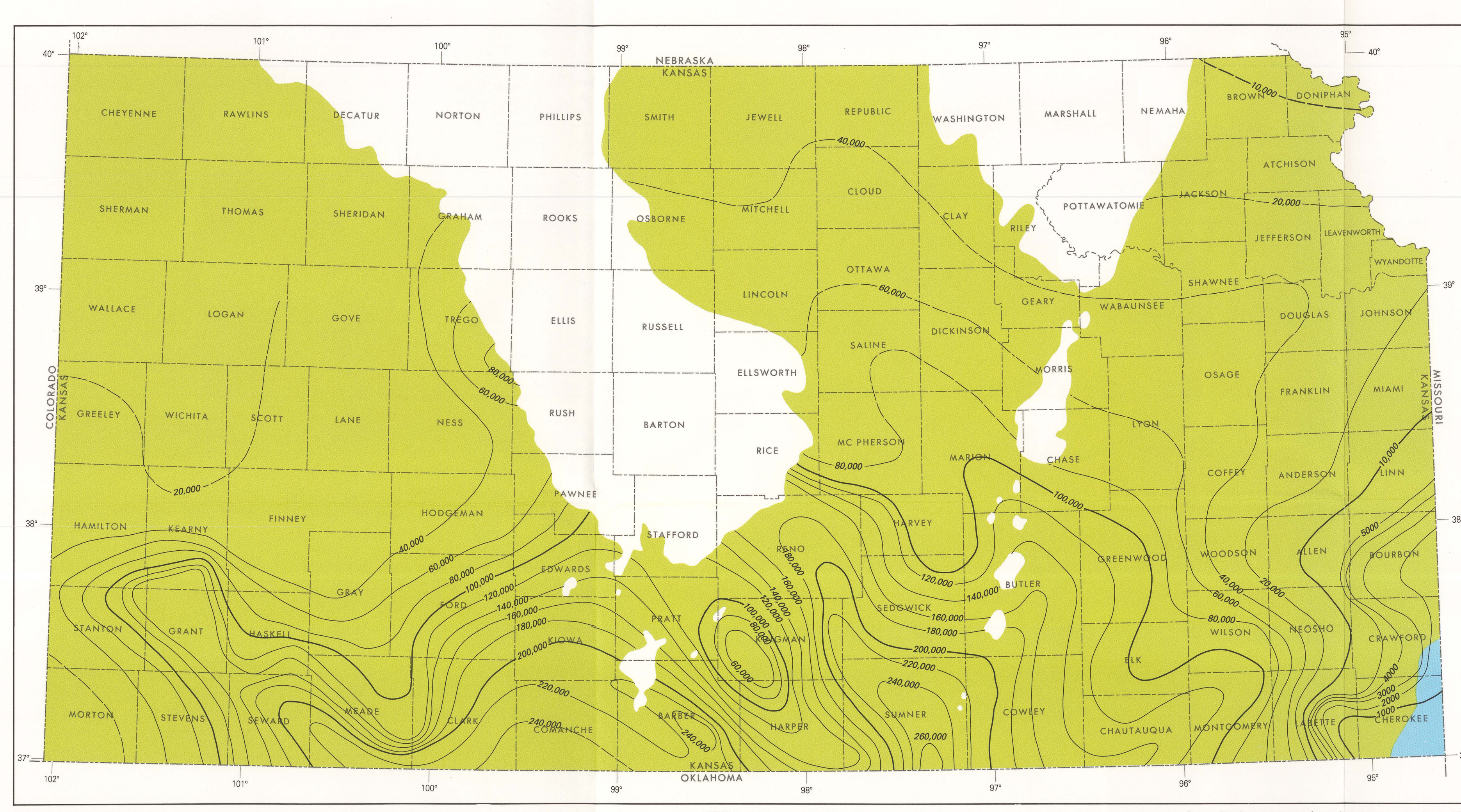

FIGURE 9.—Geochemical map showing dissolved-solids concentration and water type in upper aquifer unit.

HYDROLOGIC CHARACTERISTICS

The upper aquifer unit in the Western Interior Plains aquifer system contains two separate, laterally adjacent flow systems with opposite directions of ground-water movement and distinctly different water quality. Throughout most of the State, the unit contains saline water, generally flowing eastward; in the area of southeastern Kansas corresponding to the Ozark Plateaus aquifer, the unit contains freshwater that generally flows westward. The boundary between the two flow systems, commonly called the transition zone, is an indistinctly defined area about 25 miles wide and contains water of mixed chemical type (Jorgensen and others, in press).

Equivalent Freshwater Heads

Water in the upper aquifer unit in the Western Interior Plains aquifer system occurs under confined conditions throughout most of the State where the unit is overlain by the thick shale sequences of the Western Interior Plains confining system. Equivalent freshwater-head contours for the upper aquifer unit are shown in figure 6. About 350 data points were used to construct these contours. Equivalent freshwater head at each data point was calculated by adjusting pressures recorded on drill-stem tests for temperature and density of the fluid assumed to be present in the aquifer and relating the resulting levels to altitude of the top of the aquifer unit. The method for converting pressure data to equivalent freshwater heads is described by Jorgensen and others (1986). Because data points for the contours on this map were derived from data collected during a period of many years, there is great variability in the apparent water level in this aquifer unit areally throughout the State, vertically within the aquifer unit, and temporally.

Direction of flow in an aquifer containing variable-density fluid, such as the upper aquifer unit in the Western Interior Plains aquifer system, can be estimated by methods described by Jorgensen and others (1982). Sample testing using these methods indicates that, for the conditions in Kansas, the direction of flow over large areas in the aquifer unit is approximately orthagonal to the equivalent freshwater-head contours. General directions of flow are indicated in figure 6. Equivalent freshwater heads range from lows of about 100 feet above sea level in south-central Kansas and in other isolated areas to highs of about 1,300 feet above sea level in basin areas in western and east-central Kansas. A relation between equivalent freshwater head and oil-drilling activity is demonstrated by comparing figure 6 with figure 7, which shows past and current areas of producing oil and gas wells in the Mississippian rocks that compose the upper aquifer unit in the Western Interior Plains aquifer system. In areas of extensive activity, equivalent freshwater heads tend to be lower because of substantial reductions of pressure in response to oil and gas development.

Regional Flow

The regional trends in equivalent freshwater heads, recharge, and direction of flow are difficult to define using figure 6 because this map shows cumulative effects of many types and temporal distribution of data. More generalized equivalent freshwater-head contours in the upper aquifer unit in the Western Interior Plains system are illustrated in figure 8. This map was created by using only equivalent freshwater heads in a given area from data reflecting the highest fluid levels and pressures that do not show anthropogenic effects and thus represents a system almost unaffected by oil and gas development. The validity of this interpretation is substantiated, in part, by results of modeling by Donald C. Signor (U.S. Geological Survey, written commun., 1986). Equivalent freshwater heads shown in figure 8 range from lows of about 800 feet above sea level in north-central and eastern Kansas to about 2,000 feet above sea level in southwest Kansas. The implied direction of regional flow in the aquifer unit is from southwest to northeast and in the southeast corner of the State where the direction of flow is generally toward the south.

The upper aquifer unit in the Western Interior Plains aquifer system receives small quantities of recharge from the overlying Western Interior Plains confining system and the underlying lower aquifer unit in the Western Interior Plains aquifer system. Additional recharge from precipitation occurs in the area of Cherokee County where rocks of the upper aquifer unit are exposed and water-table conditions exist.

Ground-Water Availability

Potable water supplies are not obtained from the upper aquifer unit in the Western Interior Plains aquifer system throughout most of the State where it is overlain by the thick shale sequences of the Western Interior Plains confining system. Permeability values generally are very small in the aquifer unit where it is confined, although isolated areas of greater porosity and permeability are assumed to exist in fractured and weathered zones resulting from periods of uplift and erosion during Late Mississippian and Early Pennsylvanian time (Carr and others, 1986).

In southeast Kansas where the upper aquifer unit is not overlain by the Western Interior Plains confining system, potable water supplies are obtained from the unit except where contact with former lead and zinc mine spoils has caused mineralization of ground water. Confined and unconfined conditions exist in the upper aquifer unit in Cherokee County. Water-table conditions prevail in brecciated zones consisting of very fractured or porous material. Water movement in these zones may be rapid, and well yields may exceed 1,000 gal/min where the rocks are fractured (Abernathy, 1941). Values of transmissivity may exceed 1,000 ft^2/d in brecciated areas. Values of transmissivity are less than 100 ft^2/d in the surrounding limestone areas where water occurs under confined conditions. Water movement in dense, unfractured limestone is irregular and locally controlled by fractures, bedding planes, and solution channels (Spruill, 1987). Well yields are typically about 25 gal/min (Macfarlane and others, 1981).

Wells completed in the upper aquifer unit in the Western Interior Plains aquifer system in Cherokee County are used primarily for rural domestic and stock supplies. In general, greater quantities of water more acceptable for public and industrial supplies are available through rural water districts that pump from deeper wells in the lower aquifer unit in the aquifer system.

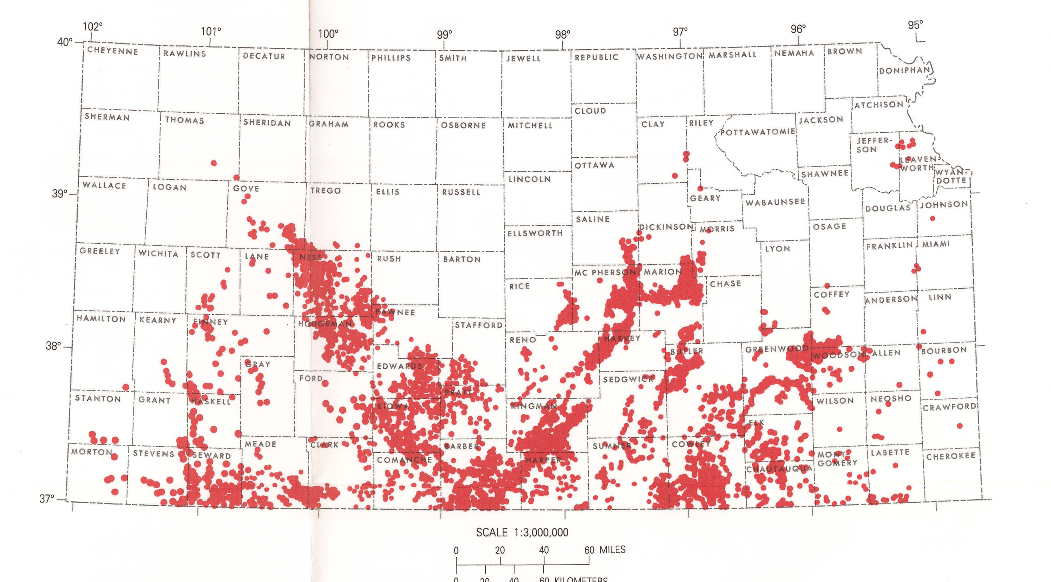

FIGURE 7.—Map showing location of past and current oil- and gas-drilling activity in Mississippian rocks composing upper aquifer unit (from Newell and others, 1987).

CHEMICAL QUALITY OF WATER

Dissolved Solids

The water quality in an aquifer commonly is indicated by the concentration of dissolved solids, which is a sum of the principal ionic constituents—calcium, magnesium, sodium, bicarbonate, sulfate, and chloride. Dissolved-solids concentrations and water types in the upper aquifer unit in the Western Interior Plains aquifer system are shown in figure 9. This map was constructed by using 55 water-quality analyses compiled for this investigation. Concentrations of dissolved solids range from less than 1,000 milligrams per liter (mg/L) in southeast Kansas to more than 260,000 mg/L in some areas of the Sedgwick Basin. Freshwater (that which contains less than 1,000 mg/L dissolved solids) occurs only in a very small part of the upper aquifer unit in Kansas. The rest of the unit contains either saline water (1,000–10,000 mg/L dissoloved solids), brackish water (10,000–35,000 mg/L), or brine (greater than 35,000 mg/L) and is unsuitable for most purposes.

Water Types

On the basis of the proportions of ionic constituents, four major water types are identified in the upper aquifer unit in the Western Interior Plains aquifer system. The occurrence of these water types divides the State into two distinct areas, as shown in figure 9. In most of the State, the upper aquifer unit contains sodium-chloride-type water. In parts of Crawford and Cherokee Counties, calcium-bicarbonate- and sodium-sulfate-type water prevail, and, in some areas of southeast Cherokee County, the upper aquifer unit yields water of calcium-sulfate-type (Jorgensen and others, 1986).

Effects of Mining on Water Quality

In some parts of Cherokee County where lead and zinc ores were mined, water in the upper aquifer unit in the Western Interior Plains aquifer system has been affected by oxidation of ore deposits in the mined areas. Water in contact with abandoned mine spoils generally contains large concentrations of sulfate and trace metals. However, there is no conclusive evidence of lateral migration of mineralized water from mine spoils to domestic well-water supplies in the upper aquifer unit (Spruill, 1987).

RELATION TO OTHER AQUIFER SYSTEMS

The upper aquifer unit in the Western Interior Plains aquifer system has very little connection to overlying aquifer systems due to the thickness and generally small permeability of the sedimentary rocks composing the Western Interior Plains confining system (see fig. 4). Below the upper aquifer unit, a confining unit forms a shaly barrier to water exchange with the lower aquifer unit in the Western Interior Plains aquifer system, except in the western one-half of Kansas and in parts of eastern Kansas where the confining unit is absent (see fig. 3). In areas where the upper and lower aquifer units in the Western Interior Plains aquifer system are not separated by the confining unit, they function as one aquifer. In areas where the confining unit is present, such as in the central part of the Sedgwick Basin, there is some indication of a potential for upward movement of fluids from the Arbuckle rocks of the lower aquifer unit. However, because of the thickness of the shale in the confining unit in this location, flow is effectively restricted (see Carr and others, 1986).

The potential exists for downward movement of water from the upper to the lower aquifer units in the Western Interior Plains aquifer system in Cherokee County, where extensive pumping from the lower aquifer unit has lowered the potentiometric surface of the lower aquifer unit to a level below that of the upper aquifer unit.

The water quality in the upper aquifer unit in the Western Interior Plains aquifer system and in overlying and underlying aquifer units differs significantly throughout the State. These differences are illustrated by the bar graphs of water-quality constituents in each of three wells sampled at different stratigraphic intervals (fig. 10). Well A penetrates the lower and upper aquifer units in the Western Interior Plains aquifer system, as well as a permeable strata of the Western Interior Plains confining system in Rice County. Each aquifer unit is separated by confining shale. Although each unit sampled contains brine, the water in the lower aquifer unit has a smaller dissolved-solids concentration than water in either the upper aquifer unit or the Kansas City Group in the Western Interior Plains confining system.

Well B penetrates the same three geohydrologic units as well A but is in Seward County where the confining unit between the upper and lower aquifer units in the Western Interior Plains aquifer system is absent. Water in the Shawnee Group in the Western Interior Plains confining system contains the largest concentration of dissolved solids of the three intervals; water from the two aquifer units in the Western Interior Plains aquifer system exhibits similar chemical composition, with the concentration of dissolved solids being slightly larger in the lower aquifer unit than in the upper aquifer unit.

Well C is located in Cherokee County where the water in the Western Interior Plains aquifer system is fresh because it is part of the Ozark flow system. Chemical analyses of water samples collected from both aquifer units at this well indicate a less mineralized water in extreme southeast Kansas, with dissolved-solids concentrations of less than 1,000 mg/l. However, the upper and lower aquifer units are separated by the confining unit in this area, and each aquifer has different water-quality characteristics. Water in the lower aquifer unit in this area has slightly smaller concentrations of dissolved solids than water in the upper aquifer unit.

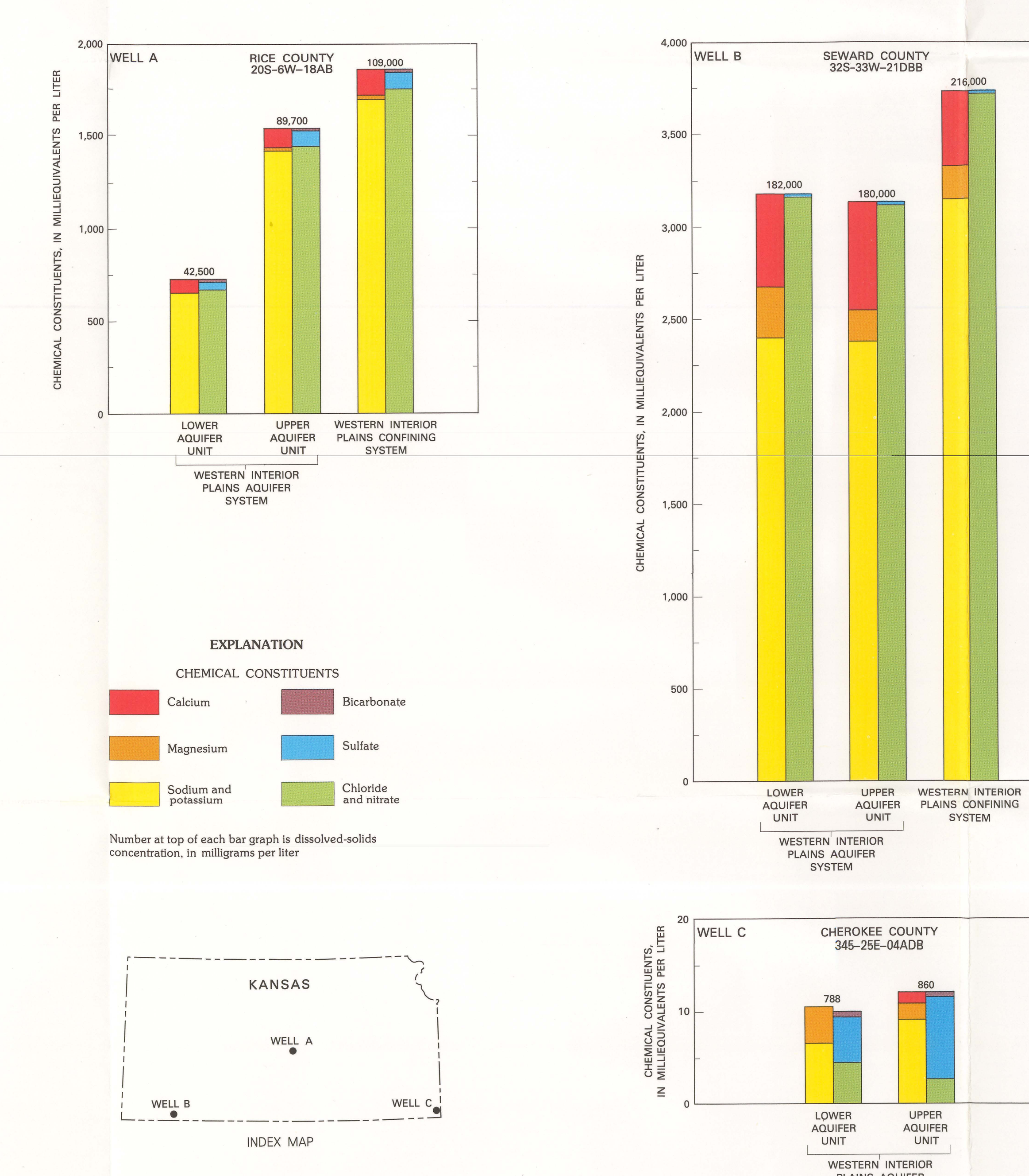

FIGURE 10.—Chemical constituents in water from different stratigraphic intervals within the same wells at three locations.

SELECTED REFERENCES

Abernathy, G.E., 1941, Ground-water resources of Mississippian and older rocks in Bourbon, Crawford, Cherokee, and Labette Counties, southeastern Kansas: Kansas Geological Survey Bulletin 38, pt. 8, p. 221–236.

Carr, J.E., McGovern, H.E., and Gogel, Tony, 1986, Geohydrology of and potential for fluid disposal in the Arbuckle aquifer in Kansas, *with a section on* Log analysis of the Arbuckle aquifer, by John H. Doveton: U.S. Geological Survey Open-File Report 86–491, 101 p.

Hansen, C.V., Underwood, E.J., Wolf, R.J., and Spinazola, J.M., in press, Geohydrologic systems in Kansas—Physical framework of the upper aquifer unit in the Western Interior Plains aquifer system, Kansas: U.S. Geological Survey Hydrologic Investigations Atlas HA-722-D, scale 1:1,000,000, 2 sheets.

Imes, J.L., 1990, Major geohydrologic units in and adjacent to the Ozark Plateaus province, Missouri, Arkansas, Kansas, and Oklahoma: U.S. Geological Survey Hydrologic Investigations Atlas HA-711-A, scale 1:750,000, 1 sheet.

Jorgensen, D.G., Gogel, Tony, and Signor, D.C., 1982, Determination of flow in aquifers containing variable-density water: Ground Water Monitoring Review, v. 2, no. 2, p. 40–45.

Jorgensen, D.G., Helgesen, J.O., and Imes, J.L., in press, Geohydrologic framework of aquifer systems underlying Kansas, Nebraska, and parts of Arkansas, Colorado, Missouri, New Mexico, Oklahoma, South Dakota, Texas, and Wyoming—Geologic framework: U.S. Geological Survey Professional Paper 1414–B.

Jorgensen, D.G., Helgesen, J.O., Leonard, R.B., and Signor, D.C., 1986, Equivalent freshwater head and dissolved-solids concentration of water in rocks of Cambrian, Ordovician, and Mississippian age in the Northern Midcontinent, U.S.A.: U.S. Geological Survey Miscellaneous Field Studies Map MF-1835-B, scale, 1:1,000,000, 2 sheets.

Jorgensen, D.G., and Signor, D.C., 1981, Plan of study for the Central Midwest regional aquifer-systems analysis in parts of Arkansas, Colorado, Kansas, Missouri, Nebraska, New Mexico, Oklahoma, South Dakota, and Texas: U.S. Geological Survey Water-Resources Investigations Open-File Report 81–206 28 p.

Macfarlane, P.A., and Hathaway, L.R., 1987, The hydrogeology and chemical quality of ground waters from the Lower Paleozoic aquifers in the Tri-State region of Kansas, Missouri, and Oklahoma: Kansas Geological Survey Ground-Water Series 9, 37 p.

Macfarlane, P.A., Whittemore, D.O., and Hathaway, L.R., 1981, The hydrogeology and chemical quality in the Lower Paleozoic aquifers in southeast Kansas and adjoining areas of Missouri and Oklahoma: Kansas Geological Survey Open-File Report 81–16, 84 p.

Merriam, D.F., 1960, Preliminary regional structural contour map on top of Mississippian rocks in Kansas: Kansas Geological Survey Oil and Gas Investigation 22, scale 1:633,600, 1 sheet.

________ 1963, The geologic history of Kansas: Kansas Geological Survey Bulletin 162, 317 p.

Newell, K.D., Watney, W.L., Cheng, S.W.L., and Brownrigg, R.L., 1987, Stratigraphic and spatial distribution of oil and gas production in Kansas: Kansas Geological Survey Subsurface Geology Series 9, 86 p.

Signor, D.C., Helgesen, J.O., Jorgensen, D.G., and Leonard, R.B., in press, Geohydrology and simulation of steady-state flow conditions in regional aquifer systems in Cretaceous and older rocks underlying Kansas, Nebraska, and parts of Arkansas, Colorado, Missouri, New Mexico, Oklahoma, South Dakota, Texas, and Wyoming: U.S. Geological Survey Professional Paper 1414–C.

Spinazola, J.M., Hansen, C.V., Underwood, E.J., Kenny, J.F., and Wolf, R.J., 1987, Index to selected machine-readable geohydrologic data for Precambrian through Cretaceous rocks in Kansas: U.S. Geological Survey Open-File Report 87–396, 32 p.

Spruill, T.B., 1987, Assessment of water resources in lead-zinc mined areas in Cherokee County, Kansas, and adjacent areas: U.S. Geological Survey Water-Supply Paper 2268, 68 p.

Wolf, R.J., Hansen, C.V., McGovern, H.E., and Spinazola, J.M., 1990, Geohydrologic systems in Kansas with emphasis on systems in Upper Cambrian through Lower Cretaceous rocks: U.S. Geological Survey Hydrologic Investigations Atlas HA-722-A, scales 1:1,500,000 and 1:2,000,000, 2 sheets.

Zeller, D.E., ed., 1968, The stratigraphic succession in Kansas: Kansas Geological Survey Bulletin 189, 81 p.

INTERIOR—GEOLOGICAL SURVEY, RESTON

GEOHYDROLOGIC SYSTEMS IN KANSAS—GEOHYDROLOGY OF THE UPPER AQUIFER UNIT IN THE WESTERN INTERIOR PLAINS AQUIFER SYSTEM

By
J.F. Kenny, C.V. Hansen, and R.J. Wolf

1993