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REGIONAL TRENDS IN TRANSMISSIVITY AND HYDRAULIC CONDUCTIVITY,
LOWER CRETACEOUS SANDS, NORTH-CENTRAL TEXAS¹

by

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ABSTRACT

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Depositional and structural history control the regional trends in transmissivity and hydraulic conductivity in Lower Cretaceous-age sands along the Balcones Ouachita trend in North-Central Texas. Because of scarcity of pumping tests, delineation of trends was only possible by incorporating transmissivities estimated from specific capacities. Statistical comparison of estimated and pumping-test transmissivities confirmed the validity of this approach. The resulting contour maps should be useful in the evaluation of these aquifers for potential as low-temperature-geothermal resources; the method can be applied to other aquifers to facilitate ground-water-management programs.

INTRODUCTION

Several Lower Cretaceous sandstones and carbonates in North-Central Texas show potential for use as low-temperature-geothermal-ground-water resources (Woodruff and McBride, 1979). Three of these, the Woodbine sand, the Paluxy sand, and the Hosston/Trinity sand (fig. 1), are especially interesting

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because relatively large areas of warm potable water coincide with a region which is one of the most heavily populated and intensively used in Texas (fig. 2). The study area lies along the Balcones/Ouachita hinge and is flanked by the East Texas Basin to the east and the relatively stable Texas craton to the west. The formations dip to the east-southeast and are broken by the generally down-to-the-basin faults of the Balcones-Mexia-Talco fault systems. The formations also thicken to the east-southeast, and the rate is higher east of the Balcones/Ouachita hinge. The extent of the geothermal resource is rather easily defined by the tremendous amount of chemical and temperature data collected by the Texas Department of Water Resources. The hydrologic properties of the aquifers, essential to the actual development of the resource, have been discussed very generally by Klemt and others (1975); they did not map regional trends. This is typical of most aquifers since the requisite pumping tests are expensive and not universally run on wells. Throughout most of the study area, however, the records of pumping tests and performance tests (specific capacity, gallons per minute per foot of drawdown) sufficed to allow mapping of regional trends in transmissivity and hydraulic conductivity.

METHOD

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Three types of data comprise the hydrologic properties data base (table 1). The best data come from pumping tests, usually single-point drawdown but occasionally with an observation well. For some of these tests the only information on file consisted of a graph of the results with no supporting raw data (Myers, 1969). These pumping tests were less useful since they could not be verified and since test conditions are not described. The majority of the data are estimated transmissivities calculated from performance tests in which the specific capacity is measured. Theis and others (1963) developed a method

to estimate transmissivities using specific capacity, length of test, effective well radius, and (estimated) storage coefficient. Although there are a variety of other methods estimating transmissivity (see Lohman, 1972, for summary; also Ogden, 1965; Walton, 1962; and Thomasson and others, 1960) the method developed by Theis and others (1963) compensates for nearly all the variables affecting measurement of specific capacity with the exception of delayed yield from storage.

TABLE 1: Breakdown of data base

Transmissivity type	Hosston/Trinity sand	Paluxy sand	Woodbine sand
Pumping test	71 (24%)	3 (4%)	10 (9%)
Pumping test (unverified)	48 (16%)	10 (11%)	18 (15%)
Subtotal	119 (40%)	13 (15%)	28 (24%)
Estimated	177 (60%)	71 (85%)	88 (76%)
Total	296	84	116

Frequency distributions of the estimated transmissivities and the pumping-test transmissivities for the three aquifers (fig. 3) show excellent correspondence of means and modes for the two types of data. In the Woodbine sand and especially in the Paluxy sand there are few data from pumping tests, but since the distribution is similar to that in the Hosston/Trinity, the estimated data are probably valid. In the Hosston/Trinity there are few estimated transmissivity values greater than $20,000 \text{ gal d}^{-1} \text{ ft}^{-1}$ ($250 \text{ m}^2 \text{ d}^{-1}$). This suggests that estimated transmissivities are conservative, or that there is a sampling bias. Since the aquifer deepens and thickens basinward, wells drilled to this more transmissive part of the aquifer are more expensive, more

likely to have been drilled for high yield, and more likely to have been thoroughly tested.

Another test of the validity of the estimated transmissivities is that of percent error from a pumping test value. For the best quality pumping tests for which a separate performance test for specific capacity was run, the vast majority of the estimated transmissivities were within 20% of the pumping-test transmissivities; a few values had greater than 60% error. Theis and others (1963) do not attempt to validate their estimated transmissivity method; Hurr (1966) made one such comparison with an error of about 11%; Ogden (1965) found estimated values ranging from 57% to 117% of the pumping-test value.

In general, the best correlations of pumping-test and estimated transmissivities correspond to the medium-range values. In order to compensate for the 20% error, contour intervals on the transmissivity and hydraulic conductivity maps are numerically closely spaced in the low transmissivity ranges and numerically farther apart with increasing transmissivity. Furthermore, because of the estimation method, the precision and accuracy of the estimated values decreases at low transmissivities. For mapping purposes an arbitrary value of 100 gal d⁻¹ ft⁻¹ (1 m²d⁻¹) was assigned wherever the estimated value was very low and questionable. Values of less than about 1,000 gal d⁻¹ ft⁻¹ (12 m²d⁻¹) should be considered numerically suspicious; they are low but numerically imprecise.

REGIONAL TRENDS

The contour map of the transmissivity of the Hosston/Trinity illustrates the heterogeneity of the aquifer system (fig. 4). Areas of relatively high transmissivity in the north-central and south-central parts of the study area alternate with areas of low transmissivity. In general, the transmissivities

increase basinward, away from the outcrop. In the four-county area of Denton, Collin, Dallas, and Tarrant Counties, the bifurcating geometry of the transmissivities suggests a depositional center. In Hill and McLennan Counties the strike-oriented transmissivity trends suggest that transmissivity is controlled by the Balcones fault system which disrupts aquifer continuity in this area. In Bell County there is a suggestion of dip-oriented, bifurcating transmissivity trends, whereas further south in Williamson and Travis Counties it again appears that structure is influencing aquifer properties.

In the Paluxy sand transmissivities also generally increase basinward, with rather complicated dip-oriented thickening and thinning in the western and east-central parts of the area (fig. 5). This suggests a fluvial, deltaic, or fan-delta depositional system, while strike-oriented trends in Johnson County suggest a strandplain system. Caughey (1977) described a correlative depositional history for the Paluxy sand based on sediment samples and geophysical logs.

In the Woodbine sand depositional dip was from northeast to southwest. The study area falls near the coastal-barrier/channel-mouth-bar facies-shelf facies boundary (Oliver, 1971). The low transmissivities in the west correspond to the shelf facies, and the digital transmissivities probably correspond with channel-mouth-bar systems in the delta complex (fig. 6).

The hydraulic conductivity values, based on transmissivity divided by net sand, are adjusted, where necessary, for partial penetration. Both the Paluxy and Woodbine hydraulic conductivities are distributed much the same as their respective transmissivities (figs. 7 and 8). In the Hosston/Trinity, however, hydraulic conductivity generally decreases basinward (fig. 9) whereas transmissivity generally increases basinward. This is probably the result of basinward decrease in grain size or sorting.

CONCLUSIONS

Although pumping tests are expensive and relatively scarce, regional trends in aquifer properties can be deduced from a combination of pumping-test data and transmissivities estimated from performance tests (specific capacities). Estimated transmissivities in the Hosston/Trinity sand, the aquifer with the largest areal extent and the most data, compared favorably with pumping-test transmissivities. Although there were fewer pumping tests in the Paluxy and Woodbine, the frequency distribution of estimated transmissivities in these aquifers is similar to that of transmissivities in the Hosston/Trinity, suggesting that, since the depositional histories of the aquifers are somewhat comparable, the estimated transmissivities are probably valid representations of actual transmissivity.

The regional trends in transmissivity and hydraulic conductivity are valuable in refining optimum areas for production of low-temperature-geothermal ground water, as well as in directing ground-water-management programs. In the Hosston/Trinity study area transmissivity generally increases basinward as the aquifer increases in thickness, even though the hydraulic conductivity decreases, suggesting a decrease in sediment size or degree of sorting. In the Paluxy sand both transmissivity and hydraulic conductivity and aquifer thickness increase somewhat toward the basin, which may imply that diagenesis has enhanced hydraulic conductivity in the basinward parts of the aquifer. In the Woodbine sand, although the depositional axis is nearly normal to that of the other formations, the relationships are similar to those of the Paluxy.

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Biographical Sketch

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FIGURE CAPTIONS

Figure 1. Schematic strike section showing facies and nomenclatural changes of Cretaceous units from Central Texas to North-Central Texas (from Woodruff and McBride, 1979).

Figure 2-A. Outcrop of hosting units and areas of low-salinity, low-temperature-geothermal ground water.

Figure 2-B. Major structural elements, North-Central Texas.

Figure 3-A. Frequency distribution of transmissivities in the Hosston/Trinity undifferentiated sand.

Figure 3-B. Frequency distribution of transmissivities in the Woodbine sand.

Figure 3-C. Frequency distribution of transmissivities in the Paluxy sand.

Figure 4-A. Transmissivity contours for the Hosston/Trinity aquifer, northern part of the study area.

Figure 4-B. Transmissivity contours for the Hosston/Trinity aquifer, southern part of the study area.

Figure 5. Transmissivity contours for the Paluxy aquifer.

Figure 6. Transmissivity contours for the Woodbine aquifer.

Figure 7. Hydraulic conductivity contours for the Paluxy aquifer.

Figure 8. Hydraulic conductivity contours for the Woodbine aquifer.

Figure 9-A. Hydraulic conductivity contours for the Hosston/Trinity aquifer, northern part of the study area.

Figure 9-B. Hydraulic conductivity contours for the Hosston/Trinity aquifer, southern part of the study area.

SOUTH

NORTH

EXPLANATION

- Outcrop of Hosston/Trinity sand
- Outcrop of Trinity (undifferentiated) sand
- Outcrop of Paluxy sand
- Outcrop of Woodbine sand
- Optimum area for low temperature geothermal groundwater, Hosston/Trinity sands *
- Optimum area for low temperature geothermal groundwater, Paluxy sand *
- Optimum area for low temperature geothermal groundwater, Woodbine sand *
- 90°F isothermal contour (updip extent of geothermal groundwater)
- * Delineation based on 90°F or hotter water with total dissolved solids less than 1000 ppm

EXPLANATION

- Anticline
- Syncline
- Fault zone
- Ouachita structural belt

(Figure 2)

Fig. 14A

EXPLANATION

• Well location

Contours in gpd/ft
intervals as marked, dashed were inferred.

85% X₂

(7-11)

50% Xerox

(Figure 1)

Fig. 104