PREPARED IN COOPERATION WITH THE
COLORADO DEPARTMENT OF NATURAL RESOURCES, DIVISION OF WATER RESOURCES,
OFFICE OF THE STATE ENGINEER; THE DENVER BOARD OF WATER COMMISSIONERS;
AND ADAMS, ARAPAHOE, DOUGLAS, ELBERT, AND EL PASO COUNTIES



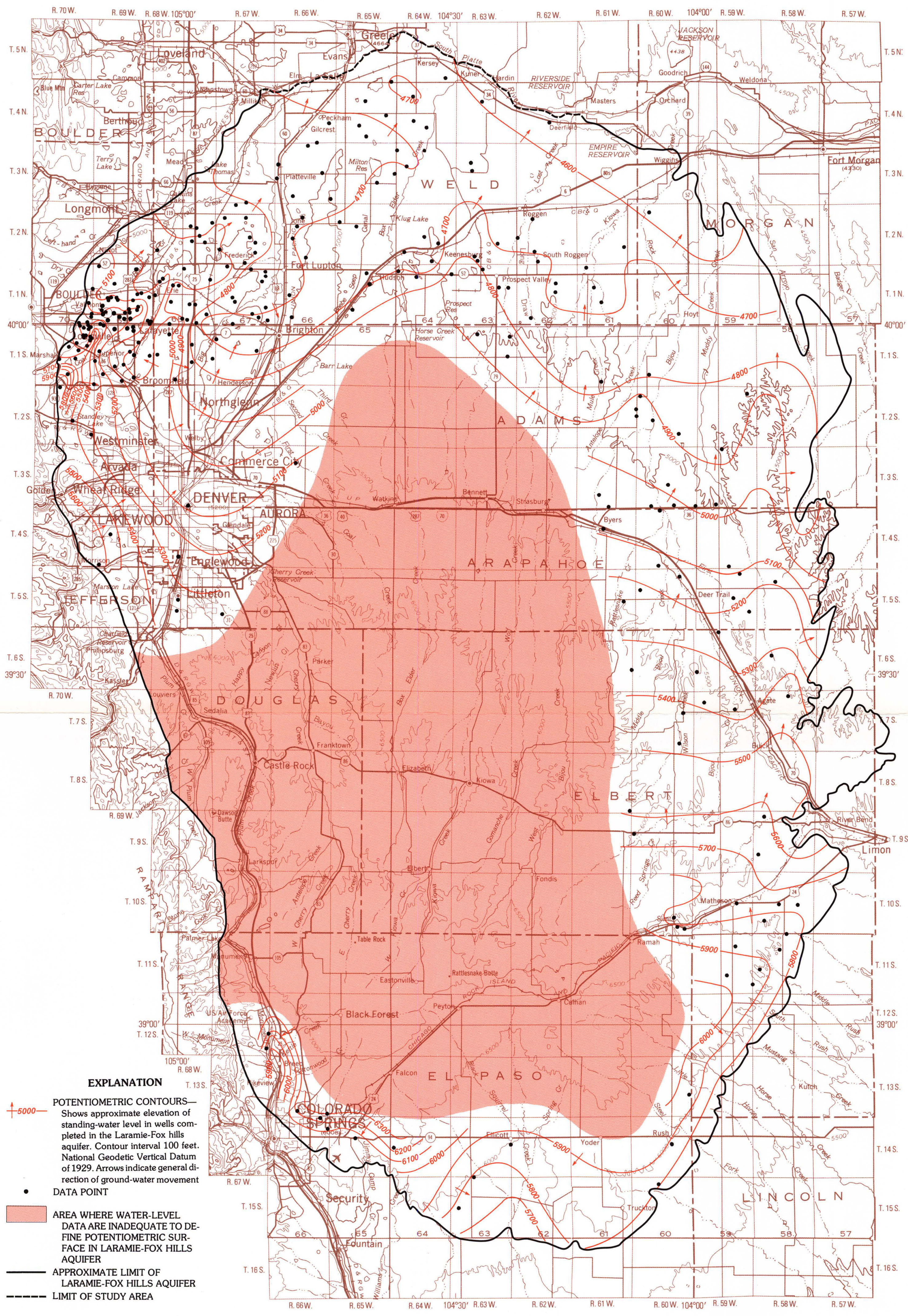



FIGURE 8.—MAP SHOWING ELEVATION OF POTENTIOMETRIC SURFACE IN THE AQUIFER, 1978

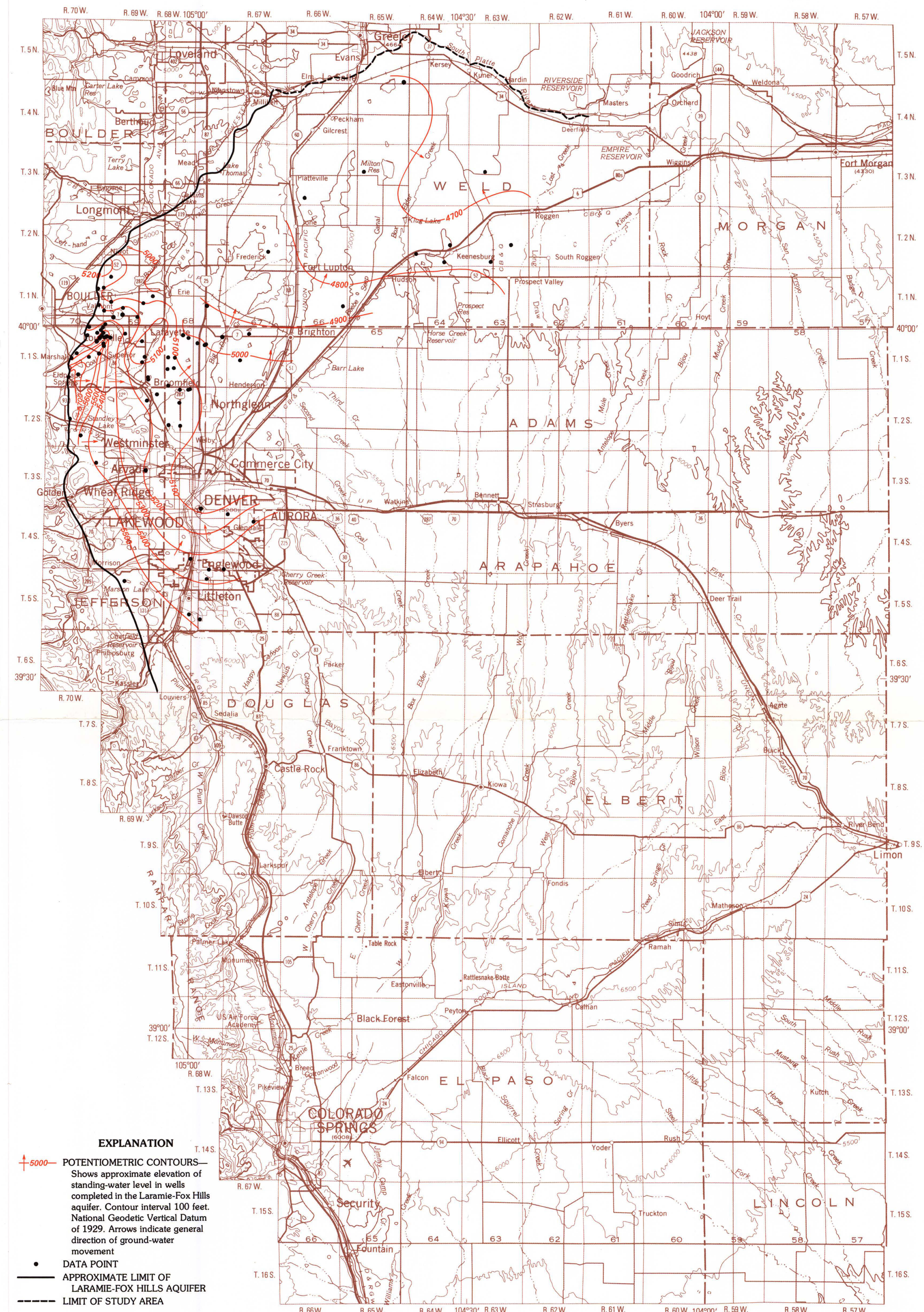
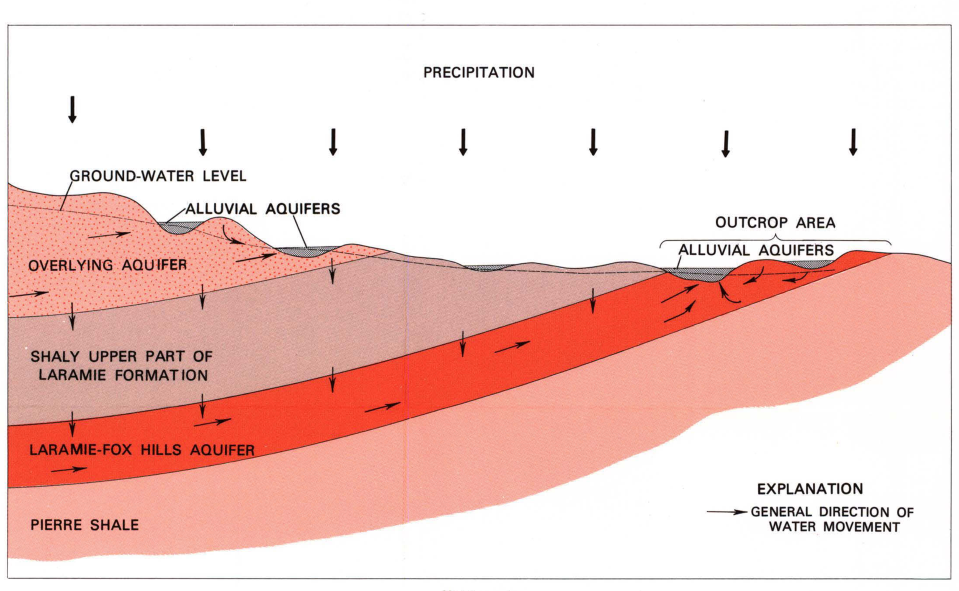



FIGURE 9.—MAP SHOWING ELEVATION OF POTENTIOMETRIC SURFACE IN THE AQUIFER, 1958




Not to scale

FIGURE 7.—DIAGRAM OF GROUND-WATER MOVEMENT

## HYDROLOGIC CONDITIONS

Most of the precipitation that falls on the land surface runs off in streams and creeks, is evaporated from the soil surface, or is consumed by vegetation. In addition, a small part of the precipitation usually percolates to depth and recharges the ground-water supply. The adjacent diagram of ground-water movement (fig. 7) illustrates three principal methods of recharge to the Laramie-Fox Hills aquifer. In the outcrop area, recharge occurs as deep infiltration of precipitation in the highland areas between stream channels, or as infiltration of water from alluvial aquifers located above the water level in the bedrock aquifer. In the central part of the aquifer, downward movement of water from overlying Laramie strata and the Arapahoe aquifer is probably the principal source of recharge in this 4,300-square-mile area.

Most of the water moves laterally through the sandstone and siltstone beds of the aquifer from areas of recharge toward areas of discharge. This can occur on both a local and regional scale. On a local scale, water moves from the highland areas in the outcrop through the aquifer to the discharge areas in nearby stream valleys. On a regional scale, water moves from outcrop recharge areas, or from the central part of the study area, into deeper parts of the aquifer and discharges in more remote stream valleys. In the stream valleys, water from the Laramie-Fox Hills aquifer discharges into streams, into the alluvial aquifers along the stream channels, or is consumed by vegetation growing in the valleys. In addition to these long-standing processes of natural discharge, relatively recent discharge occurs from pumping wells. In areas where pumping has caused significant water-level declines, natural discharge may no longer occur and pumpage may be the only form of ground-water discharge.

Perennial streams that are eroded into the Laramie Formation or Fox Hills Sandstone may be supplemented either directly or indirectly by ground-water discharge from the Laramie-Fox Hills aquifer. Streamflow is directly supplemented by springs and seeps that occur as a result of natural discharge of water from the Laramie-Fox Hills aquifer at the land surface. Streamflow is indirectly supplemented where water from the Laramie-Fox Hills aquifer first discharges into alluvial aquifers and the water in the alluvial aquifer in turn discharges into the stream.

The 1978 potentiometric-surface map (fig. 8) shows the elevation of the standing-water level during 1978 in wells completed in the Laramie-Fox Hills aquifer. The elevation of the potentiometric surface was highest in the southern part of the aquifer and lowest in the area extending from Brighton to Wiggins. Water in the aquifer moves from points of higher water-level elevation to points of lower water-level elevation along paths that are perpendicular to the potentiometric contours shown on the map. The arrows on the map indicate the general direction of this water movement. North of El Paso County, water generally is moving to the north or northeast, while south of the northern El Paso County line, water generally is moving to the south or southeast. The relatively sharp bends in the potentiometric contours near some small streams are the result of water moving from the aquifer into the stream valleys.

In and near Boulder County, local faulting has segmented the aquifer and allowed markedly different water levels to occur in adjacent segments. The resulting potentiometric surface is distorted near these segments and the direction of water movement in this area is complex (Schneider, 1980).

In the northwestern part of the Denver basin, ground water in the Laramie-Fox Hills aquifer moves toward a major trough in the potentiometric surface. This trough extends from Littleton through Northglenn and Brighton and northeast toward Masters. A similar but less extensive trough was shown by Romero (1976) to be present in this area in 1970. The trough has been formed by pumpage from wells in the area and has expanded and deepened as demands for water from the aquifer have increased.

In the partially saturated zone from Boulder to Greeley to Masters, the potentiometric surface in the Laramie-Fox Hills aquifer is generally within a few tens of feet of the water level in the alluvial aquifer in the area. To the south of this area, the Laramie-Fox Hills aquifer is overlain by the more shaley upper part of the Laramie Formation (near a line from Superior to Milton Reservoir to South Roggen) and the potentiometric surface in the Laramie-Fox Hills aquifer is 50 to 100 feet lower than the water level in the overlying alluvial aquifers. Farther to the south, the Laramie-Fox Hills aquifer is overlain by the shaley upper part of the Laramie Formation and the Arapahoe aquifer. Most of the trough in the potentiometric surface of the Laramie-Fox Hills aquifer is located south of Fort Lupton and is within this area. In the part of the trough north of Denver, the potentiometric surface in the Laramie-Fox Hills aquifer is 0 to 300 feet lower than the potentiometric surface in the Arapahoe aquifer. Between Golden and Littleton, the potentiometric surface in the aquifer is generally 100 to 300 feet higher than in the Arapahoe aquifer. This creates a potential for interaquifer flow from the Arapahoe aquifer into the Laramie-Fox Hills aquifer north of Denver and from the Laramie-Fox Hills aquifer into the Arapahoe aquifer between Golden and Littleton.

The differences in potentiometric surface elevations between adjacent aquifers indicate the direction ground water may move, but do not indicate how much movement, if any, is actually occurring. The volume of water that is moving vertically into or out of the Laramie-Fox Hills aquifer in these areas is not known, but is probably small due to the low permeability of the intervening shale layers.

In the central part of the aquifer, reliable water-level data for the Laramie-Fox Hills aquifer are unavailable and the potentiometric surface cannot be accurately defined. However, in rural areas, water levels in the Laramie-Fox Hills aquifer seem to be from 0 to 200 feet lower than the water level in the overlying Arapahoe aquifer. In the suburban area south of Denver, water levels in the Laramie-Fox Hills aquifer are from 0 to 100 feet higher than those in the Arapahoe aquifer. If, as these data indicate, the shapes of the potentiometric surfaces are generally similar in the two aquifers, then the general direction of ground-water movement in the Arapahoe aquifer also will indicate the general direction of water movement in the central part of the Laramie-Fox Hills aquifer. It thus seems likely that a ground-water divide occurs in the Laramie-Fox Hills aquifer near a line from Monument to a point about 10 miles south of Matheson. Ground water north of the divide moves in a northerly direction while water south of the divide moves in a southerly direction.

Water-level measurements made between 1956 and 1960 in wells completed in the aquifer were used to estimate the 1958 potentiometric surface. These data were adequate to define this surface only in the northwest part of the area, as shown on the adjacent map (fig. 9). The direction of ground-water movement in 1958 was similar to the direction of movement in 1978, although the major trough in the potentiometric surface is less pronounced in 1958. The difference in potentiometric-surface elevations between 1958 and 1978 is the change in water level that has occurred in the aquifer during the 20-year period. In an 80-square-mile area near Brighton, water levels declined more than 200 feet with more than 300 feet of decline occurring in part of this area as shown on the accompanying map (fig. 10). Declines in excess of 100 feet have occurred in an area extending from Westminster to Superior to Hudson and in the area near Littleton and Aurora. The 1958 to 1978 water-level change data from wells at a few scattered locations in other parts of the aquifer generally show water-level rises or declines of less than 50 feet with no consistent pattern in these areas.

The accompanying hydrograph (fig. 11) shows the elevation of the water level in a well 1.3 miles northwest of Englewood completed in the Laramie-Fox Hills aquifer. The measurements indicate that in 1948 the potentiometric surface was 145 feet above land surface and by 1964 a water-level decline of 138 feet had occurred, leaving the potentiometric surface only 7 feet above land surface. The potentiometric surface was commonly above land surface in the low-lying areas along the South Platte River prior to extensive pumpage from the aquifer. Bedrock wells in those areas commonly flowed with enough pressure at the land surface to allow the water to be used in homes, agriculture, and industry without pumping (Emmons, Cross, and Eldridge, 1896). Between 1964 and 1980 an additional 25 feet of water-level decline has occurred in this well.

Wells completed in the Laramie-Fox Hills aquifer generally yield from 0.1 to 2.0 gallons per minute per foot of drawdown. Therefore, if the water level in a well declines 100 feet while the pump is operating, the well probably would yield between 10 and 200 gallons per minute. Three factors that influence the yield of a well are: (1) the thickness of water-bearing material penetrated by the well, (2) the permeability of the material, and (3) the distance the water level in the well can be drawn down while the pump is operating. Thus, a well completed in a large thickness of permeable sandstone at sufficient depth to allow a significant water-level drawdown while pumping would yield more water than a well completed in a thin, less permeable sandstone that has a water level near the base of the sandstone.

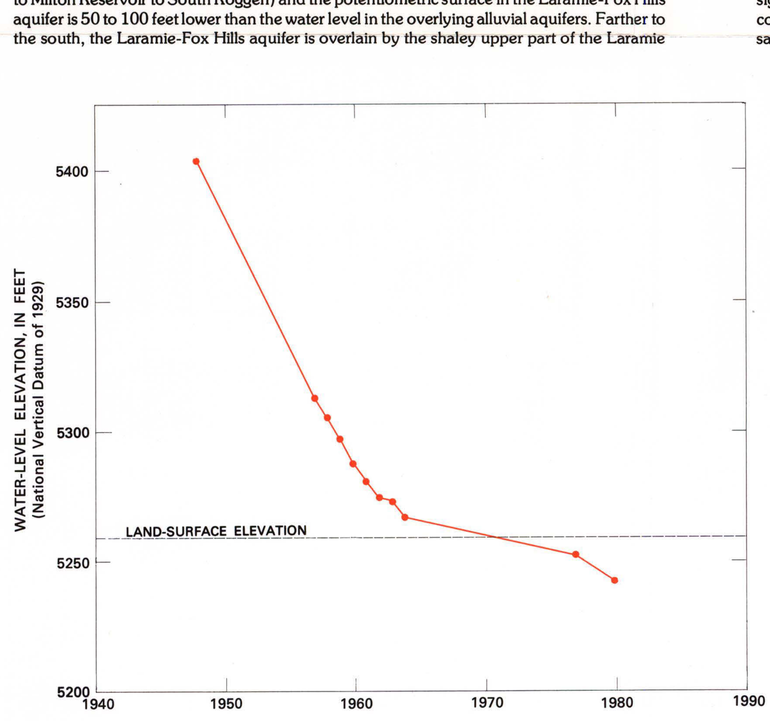



FIGURE 11.—WATER-LEVEL HYDROGRAPH FOR A WELL IN THE AQUIFER 1.3 MILES NORTHWEST OF ENGLEWOOD

### METRIC CONVERSION FACTORS

The inch-pound units used in this report may be converted to metric units by use of the following conversion factors:

| To convert inch-pound units | Multiply by | To obtain metric units |
|---|---|---|
| foot | 0.3048 | meter |
| mile | 1.609 | kilometer |
| square mile | 2.590 | square kilometer |
| gallon per minute | 0.06309 | liter per second |
| gallon per minute per foot | 0.2070 | liter per second per meter |

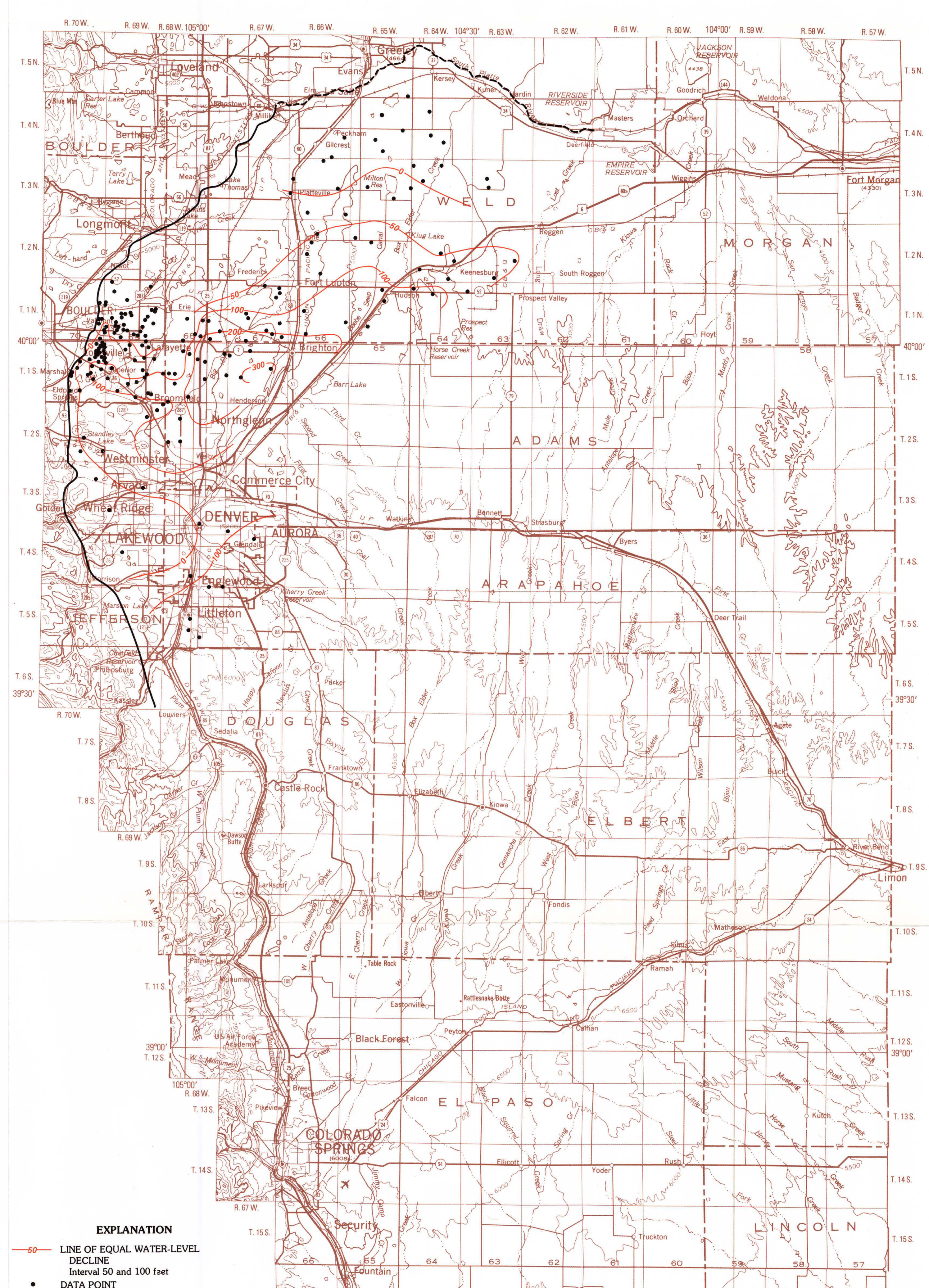



FIGURE 10.—MAP SHOWING WATER-LEVEL DECLINES IN THE AQUIFER BETWEEN 1958 AND 1978

Base from U.S. Geological Survey
State base map, 1969

SCALE 1:500 000
10 0 10 20 30 40 50 MILES
10 0 10 20 30 40 50 KILOMETERS
CONTOUR INTERVAL 100 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929

# GEOLOGIC STRUCTURE, HYDROLOGY, AND WATER QUALITY OF THE LARAMIE-FOX HILLS AQUIFER IN THE DENVER BASIN, COLORADO

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1981