Prepared in cooperation with the
COLORADO SPRINGS UTILITIES,
WASTEWATER DEPARTMENT




Sheet 3.—Saturated thickness of the alluvial aquifer in the Fountain Creek Valley, El Paso County, Colorado, October, 1991

## SATURATED THICKNESS AND GROUND-WATER FLOW

The alluvial deposits in the study area range in thickness from 0 to more than 100 feet. In October 1991, the saturated thickness ranged from 0 to about 45 feet. The largest measured saturated thickness was just southeast of the Sand Creek channel near the northeast boundary of the study area. The areas with the greatest saturated thickness (in the buried channel of the alluvial aquifer, near Little Johnson Reservoir, Windmill Gulch, and southeast of Sand Creek) are in buried channels of ancestral Fountain Creek, Sand Creek, and the creek in Windmill Gulch.

Water flow into and out of the aquifer (underflow) was estimated for selected hydrogeologic sections at the upgradient and downgradient ends of the study area and across tributary alluvial valleys along the northeastern boundary of the study area using Darcy's equation,

$$Q=-KIA, \quad (1)$$

where steady ground-water flow (Q) through a homogeneous porous medium equals the product of hydraulic conductivity (K), the hydraulic gradient (I), and the saturated area normal to the gradient (A). The minus sign in equation 1 results from the definition of hydraulic gradient as being positive in the direction of decreasing hydraulic head (Lohman and others, 1972). If the water-table contours are not parallel to the hydrogeologic section, then the hydraulic gradient is not perpendicular to the hydrogeologic section and the flow across the hydrogeologic section is equal to the product of the cosine of the angle of incidence of the hydraulic gradient to the hydrogeologic section and the product of equation 1.

$$Q = -K I A \cos(a) \quad (2)$$

where a is the angle of incidence of the hydraulic gradient to the hydrogeologic section. If water-table contours are parallel to the hydrogeologic section, the gradient is perpendicular to the hydrogeologic section. The angle of incidence, a, is zero degrees and equation 2 reduces to equation 1. Because water-table altitudes near the boundaries of the aquifer were relatively stable during 1991-92, rates of underflow are assumed to approximate steady-state rates.

Values of hydraulic conductivity used in this analysis were estimated from 30 bail tests conducted in August 1992 (K. R. Watts, U.S. Geological Survey, written commun., 1992), from four constant-discharge tests (Wilson, 1965), and from 16 reported values (W.P. Johnson, Wenck Associates, Inc., written commun., 1992). Hydraulic-conductivity values from 30 bail tests are listed in table 1.

The alluvial aquifer is heterogeneous, and estimated and reported values of hydraulic conductivity range from about 1.4 to about 1,300 feet per day. The largest values of hydraulic conductivity generally occur in the buried channel along the main axis of the aquifer, and the smaller values generally occur near the boundaries of the aquifer. The median of the estimated hydraulic-conductivity values near the aquifer boundaries was about 60 feet per day, which is in the range of values typical for clean sand and silty gravel (Freeze and Cherry, 1979). The median value of 60 feet per day is much smaller than hydraulic-conductivity values of the buried channel of the aquifer, which range from about 700 to 1,300 feet per day (Wilson, 1965). Because slug and bail tests may be strongly affected by well construction and completion effects, results from these tests need to be considered as approximate values.

Estimated rates of ground-water flow across the upgradient and downgradient ends of the study area and across tributary alluvial valleys on the northeastern side of the study area are summarized in table 2. The median value of hydraulic conductivity from tests done near each hydrogeologic section were used in computation of estimated underflow rates. Horizontal hydraulic gradients vary considerably throughout the area, ranging from about 0.003 (18 feet per mile) in the southern part of the main aquifer to about 0.047 (250 feet per mile) on the eastern boundary. The hydraulic gradients were estimated from the October 1991 water-table map (sheet 2) and the area of saturated porous media for the hydrogeologic sections from the October 1991 saturated thickness map (sheet 3). Combined ground-water flow across hydrogeologic sections A-A', A-A", B-B', B'-B", C-C', and C'-C" and into the study area was 10.1 cubic feet per second in October 1991 (table 2). Estimated ground-water flow across section D-D' and out of the study area was 1.0 cubic feet per second in October 1991 (table 2). Estimated inflow to the study area exceeded estimated outflow from the study area by approximately 10 times.

During 1991 and 1992, the quantity of water interchanged between Fountain Creek and the aquifer was estimated by 14 gain-loss investigations. A gain-loss investigation is an accounting of all surface water entering or leaving specified reaches of a stream. Differences in streamflow that cannot be attributed to tributary inflow of surface water or diversions from the stream are attributed to an interchange between the stream and the aquifer. For this study, Fountain Creek was divided into two reaches for investigation of the gain-loss relation. Reach 1 extended from the streamflow gaging station on Fountain Creek at Janitell Road (07105530) 3.75 miles downstream to a temporary gaging station on Fountain Creek at Pinello Ranch (384540104454201); reach 2 extended from Fountain Creek at Pinello Ranch 2.75 miles downstream to the gaging station on Fountain Creek at Security (07105800) (sheet 2). Gain-loss relations were evaluated using two methods: (1) An instantaneous-discharge method, and (2) a volumetric-discharge method. For the instantaneous-discharge method, the discharge of a creek is measured at the upstream and downstream ends of a specified reach. For this study, the parcel of water was tracked using fluorescent dye. For the volumetric-discharge method, stream stage and discharge are measured over an extended period (72 hours) in a specified reach, and the mean discharge values for the upstream and downstream ends of the reach are used to estimate the gain-loss relation. Tributary contributions were monitored and accounted for in both methods. Losses due to evapotranspiration were not accounted for and could represent a substantial volume of water during the summer.

The results of the gain-loss investigations were highly variable within the two study reaches. This variability was due partly to measurement error and partly to natural variation in the gain-loss relation. On average, reach 1 was estimated to gain about 5.5 cubic feet per second (about 4,000 acre-feet per year) and reach 2 was estimated to gain about 1.3 cubic feet per second (about 930 acre- feet per year). Because these values were within the error of streamflow measurement (8 percent), they are only an approximation of the true relation. Gain-loss relations were dependent on hydraulic-head differences between the stream and aquifer; therefore, decreased water levels in the aquifer caused by drought and large aquifer withdrawals could reverse the current (1991-92) trend of ground-water discharge to Fountain Creek and cause surface water from the stream to recharge the aquifer.

Table 1. -- Estimated hydraulic-conductivity values for the alluvial aquifer

| Well location[1] | Estimated hydraulic conductivity (feet per day) |
|---|---|
| SW, NW, SE, 19, 14S, 66W | 48 |
| SW, SW, SW, 34, 14S, 66W | 9.5 |
| SE, NW, NW, 1, 15S, 66W | 330 |
| NW, NW, NW, 2, 15S, 66W | 66 |
| SW, NE, SE, 2, 15S, 66W | 330 |
| SW, SW, SW, 2, 15S, 66W | 320 |
| NE, NW, NE, 3, 15S, 66W | 480 |
| NW, NW, NW, 3, 15S, 66W | 21 |
| NE, NE, NE, 4, 15S, 66W | 91 |
| NE, NW, NE, 4, 15S, 66W | 180 |
| NW, SE, NE, 10, 15S, 66W | 86 |
| NW, SE, NE, 10, 15S, 66W | 18 |
| SE, SE, NE, 13, 15S, 66W | 16 |
| NW, NE, SE, 24, 15S, 66W | 270 |
| SE, NW, SE, 24, 15S, 66W | 110 |
| NW, NE, SE, 29, 14S, 66W | 1,300 |
| NE, SE, NE, 32, 14S, 66W | 5.3 |
| NE, NE, NE, 32, 14S, 66W | 600 |
| SE, NE, SW, 33, 14S, 66W | 43 |
| SW, NE, SE, 33, 14S, 66W | 68 |
| SW, NE, SE, 33, 14S, 66W | 100 |
| SE, SW, SW, 34, 14S, 66W | 400 |
| NE, NE, SW, 35, 14S, 66W | 330 |
| NW, SW, NW, 19, 15S, 65W | 120 |
| NE, NW, NW, 3, 15S, 66W | 43 |
| NE, SW, NE, 4, 15S, 66W | 510 |
| SW, NW, NE, 11, 15S, 66W | 830 |
| SE, SW, NE, 11, 15S, 66W | 1.4 |
| SW, SE, SW, 12, 15S, 66W | 380 |
| SW, SE, SE, 13, 15S, 66W | 140 |

[1] Well location is an abbreviated description of the 10-acre tract in which the well is located; it is described as follows: 1/4 section of the 1/4 section of the 1/4 section of the section, township, and range. For example, NE, SW, NE, 4,15S, 66W is NE 1/4, SW 1/4, NE 1/4 sec. 4, T.15 S, R.66 W., of the Sixth Principle Meridian.

Table 2. -- Selected aquifer characteristics and estimated ground-water flow across hydrogeologic sections of the alluvial aquifer, October 1991.

| Trace of hydrogeologic section name | Weighted mean hydraulic conductivity[1] (feet per day) | Weighted mean hydraulic gradient[2] | Saturated area of hydrogeologic section (square feet) | Flow rate (cubic feet per second) | Flow rate (acre-feet per day) |
|---|---|---|---|---|---|
| Inflow | | | | | |
| A-A' | 250 | 0.012 | 25,250 | 0.9 | 1.74 |
| A-A" | 200 | .013 | 106,250 | 3.2 | 6.34 |
| B-B' | 70 | .025 | 72,800 | 1.5 | 2.92 |
| B'-B" | 48 | .033 | 87,750 | 1.6 | 3.19 |
| C-C' | 52 | .027 | 147,300 | 2.4 | 4.75 |
| C'-C" | 16 | .035 | 81,900 | 0.5 | 1.05 |
| Outflow | | | | | |
| D-D' | 215 | .004 | 96,500 | 1.0 | 1.98 |

[1] Weighted mean hydraulic conductivity is the mean hydraulic conductivity weighted by saturated area of hydrogeologic section

[2] Mean hydraulic gradient is weighted by the saturated area of the hydrogeologic section

## REFERENCES

Bingham, D.L., and Klein, J.M., 1973, Extent of development and hydrologic conditions of the alluvial aquifer, Fountain and Jimmy Camp Valleys, Colorado: Colorado Water Resources Circular 16, 28 p.
Edelmann, P.E., and Cain, Doug, 1985, Sources of water and nitrogen to the Widefield aquifer, southwestern El Paso County, Colorado: U.S. Geological Survey Water-Resources Investigations Report 85-4162, 81 p.
Freeze, R.A., and Cherry, J.A., 1979, Groundwater: Englewood Cliffs, N.J., Prentice-Hall, 604 p.
Jenkins, E.D., 1961, Records, logs, and water-level measurements of selected wells and test holes and chemical analyses of ground water in Fountain, Jimmy Camp, and Black Squirrel Valleys, El Paso County, Colorado: Denver, Colorado Water Conservation Board Ground-Water Series Basic-Data Report 3, 25 p.
_____1964, Ground water in Fountain and Jimmy Camp Valleys, El Paso County, Colorado, *with a section on* Computations of drawdowns caused by the pumping of wells in Fountain Valley, by R.E. Glover and E.D. Jenkins: U.S. Geological Survey Water-Supply Paper 1583, 66 p.
Klein, J.M., and Bingham, D.L., 1975, Water quality, Fountain and Jimmy Camp Valleys, Colorado, 1973: Colorado Water Resources Circular 26, 27 p.
Lewis, Michael E., 1994, Quality of water in the alluvial aquifer and tributary alluvium of the Fountain Creek Valley, southwestern El Paso County, Colorado, 1991-1992: U.S. Geological Survey Water-Resources Investigations Report 94-4118.
Livingston, R.K., Bingham, D.L., and Klein, J.M., 1975, Appraisal of water resources of northwestern El Paso County, Colorado: Colorado Water Resources Circular 22, 75 p.
Livingston, R.K., Klein, J.M., and Bingham, D.L., 1976a, Water resources of El Paso County, Colorado: Colorado Water Resources Circular 32, 85 p.
_____1976b, Appraisal of water resources of southwestern El Paso County, Colorado: Colorado Water Resources Circular 33, 66 p.
Lohman, S.W. and others, 1972, Definitions of selected ground-water terms - Revisions and conceptual refinements: U.S. Geological Survey Water-Supply Paper 1988, 21 p.
Robinson, C.S., and Goeldy, P.L., 1973, Ground water in Windmill Gulch, El Paso County, Colorado: Denver, Charles S. Robinson and Associates, 31 p.
Schneider, P.A., Jr., and Turk, J.T., 1983, A reconnaissance of ground-water contamination at selected landfills in Colorado: U.S. Geological Survey Water-Resources Investigations Report 83-4021, 33 p.
Scott, G.R., and Wobus, R.A., 1973, Reconnaissance geologic map of Colorado Springs and vicinity, Colorado: U.S. Geological Survey Miscellaneous Field Studies Map MF-482, 2 sheets, scale 1:62,500.
Wilson, W.W., 1965, Pumping tests in Colorado: Colorado Ground-Water Series Circular 11, 361 p.

# HYDROGEOLOGIC CHARACTERISTICS OF THE ALLUVIAL AQUIFER AND ADJACENT DEPOSITS OF THE FOUNTAIN CREEK VALLEY, EL PASO COUNTY, COLORADO

By
M.J. Radell, M.E. Lewis, and K.R. Watts

1995