PREPARED IN COOPERATION WITH THE
COLORADO DIVISION OF WATER RESOURCES,
OFFICE OF THE STATE ENGINEER

HYDRAULIC CHARACTERISTICS

POTENTIOMETRIC SURFACE, 1965

The configuration of the potentiometric surface for 1965 indicates that the flow of water, which is perpendicular to the contours, was generally to the north in the eastern one-half of the study area and was generally to the northwest in the western part of the study area east of Plum Creek and the South Platte River. West of these streams, the flow was generally to the northeast. (See map showing approximate altitude of potentiometric surface, 1965.) The gradient of the surface was related partly to the aggregate-sand thickness. The gradient was 20 to 40 ft/mi (4 to 8 m/km) where the aggregate-sand thickness is greater than 200 ft (60 m) and increased to 40 to 100 ft/mi (8 to 19 m/km) where the aggregate-sand thickness is less than 200 ft (60 m).

Recharge to the Arapahoe aquifer occurred from the outcrop-subcrop area and from the overlying Denver aquifer. West of Plum Creek and the South Platte River, the aquifer was recharged by water infiltrating through the outcrop-subcrop area and by downward vertical percolation of water from the overlying Denver aquifer. East of Plum Creek and the South Platte River in the west-central part of the study area, recharge to the Arapahoe aquifer occurred by downward vertical percolation from the overlying Denver aquifer. The average annual amount of water recharged to the Arapahoe aquifer in the west-central part of the study area was calculated by Darcy's law (Ferris and others, 1962) using the data in the table summarizing the hydraulic characteristics. Recharge ranged from 0.28 to 0.38 in (7.1 to 9.7 mm) and averaged 0.32 in (8.1 mm).

SUMMARY OF HYDRAULIC CHARACTERISTICS

[Sources of data are ground-water consultants' reports, except for data collected by the U.S. Geological Survey indicated in blue]

Well number on map	Transmissivity, in feet squared per day		Specific capacity after pumping 1 hour, in gallons per minute per foot[1]	Hydraulic conductivity, in feet per day	Storage coefficient
	Pumping data	Recovery data			
1	490	460	2.8	2.1	--------
2	1,400	1,400	6.7	5.6	--------
3	710	740	3.8	3.4	--------
4	1,800	--------	8.2	6.9	--------
5	1,800	1,900	4.3	8.7	0.00042
6	--------	340	-----------	1.6	--------
7	--------	940	-----------	3.9	--------
8	--------	780	-----------	3.1	--------
9	2,200	1,600	5.9	7.8	--------
10	--------	1,300	-----------	3.6	--------
11	--------	1,500	-----------	3.8	--------
12	--------	1,200	-----------	3.5	--------
13	710	--------	6.7	4.8	--------
14	1,300	--------	17.0	5.2	--------
15	3,500	2,700	12.0	8.8	--------
16	1,600	1,500	11.0	6.8	--------
17	230	--------	2.6	.9	--------
18	100	--------	.9	.3	--------

[1] One-hour rather than 24-hour specific capacities are reported because discharge was varied during several of the tests and in order to minimize the effects of boundaries and leakage.

Discharge from the Arapahoe aquifer is indicated by the V-shaped contours that extend upstream in the vicinity of Plum Creek and the South Platte River. Water from the Arapahoe was discharged by upward vertical percolation into the overlying Denver aquifer. Depending on the head difference between the Denver aquifer and the alluvial aquifers of Plum Creek and the South Platte River, water may have flowed from the Denver aquifer into the alluvial aquifer. Discharge from the Arapahoe also occurred by downward vertical percolation into the underlying Laramie-Fox Hills aquifer in most of the study area.

POTENTIOMETRIC SURFACE, 1975

The configuration of the potentiometric surface and flow system of the Arapahoe aquifer has changed significantly as a result of pumping by existing wells and new wells installed from 1965 through 1975. (See map showing altitude of potentiometric surface, 1975.) Flow in 1975 was to the northwest in most of the study area. The gradient of the potentiometric surface also has been altered by the effects of withdrawals. In 1975, the regional gradient ranged from 15 to 100 ft/mi (3 to 19 m/km); locally, around centers of pumping, the gradient was larger.

The general decline of water levels resulting from pumping has masked the effects of recharge from the overlying Denver aquifer. Recharge to the Arapahoe aquifer by downward vertical percolation from the Denver is still occurring. Depending on the difference in altitude of the potentiometric surfaces for the Denver and Arapahoe aquifers, the rate of recharge to the Arapahoe may have increased.

Discharge from the Arapahoe aquifer to the overlying Denver aquifer still occurs in the northwestern part of the study area as indicated by the persistence of the V-shaped contours that extend upstream along the South Platte River. However, the rate of discharge from the Arapahoe to the Denver by upward vertical percolation has decreased because of the general decline of water levels in the Arapahoe. Depending on the difference in altitude of the potentiometric surfaces for the underlying Laramie-Fox Hills and the Arapahoe aquifers, the rate of discharge from the Arapahoe to the Laramie-Fox Hills by downward vertical percolation also may have decreased.

DECLINE OF THE POTENTIOMETRIC SURFACE, 1965–75

The potentiometric surface has declined throughout the study area. (See map showing decline of potentiometric surface, 1965–75.) Declines of 200 to 300 ft (60 to 90 m) have occurred in the central part of the study area. The areas of maximum decline are almost bisected by Interstate Highway I–25. The large declines are the result of increased development along this principal transportation corridor. The average yearly rates of decline for 1965–75 in the areas of maximum decline has been 18 to 27 ft (5.5 to 8.2 m).

The decline of the potentiometric surface indicates that water in the Arapahoe aquifer is being "mined." That is, discharge of water, principally by wells, is greater than recharge from all sources and water is being removed from storage within the aquifer. Continued decline of the potentiometric surface will result eventually in the potentiometric surface intersecting the top of the aquifer. Once the potentiometric surface intersects the top of the aquifer, the hydraulic characteristics of the aquifer will then change, from a confined aquifer to an unconfined or water-table aquifer in the area where the intersections occur. The effect of this change will be that the long-term yield of wells penetrating the aquifer in the unconfined area will be reduced as the aquifer is dewatered. Long-term yields would range from about 20 gal/min (1.3 l/s) where the aggregate-sand thickness is 100 ft (30 m) to about 250 gal/min (15.8 l/s) where the aggregate-sand thickness is 400 ft (120 m). Maximum recharge to the aquifer also will occur under water-table conditions. However, continued lowering of the water level in the aquifer will not increase recharge to the aquifer.

FLOWING WELLS

Flowing wells completed in the Arapahoe aquifer were known to exist in the Cherry Hills area in 1898 (McConaghy and others, 1964). Prior to 1950, flowing wells were reported in the Louviers area in 1906 and additional flowing wells were reported in the Cherry Hills area in 1923, 1930, and 1940 (McConaghy and others, 1964). The number of flowing wells increased significantly in the 1950's as more wells were drilled and completed in the aquifer. The areas in which flowing wells could have been completed in 1965 are delineated on the map showing the approximate altitude of the potentiometric surface, 1965.

Only one flowing well was observed by the authors during the current study. This well is about 1 mi (1.6 km) northeast of Chatfield Lake. (See map showing altitude of potentiometric surface, 1975.) The observed flow from the well was estimated to be about 3 gal/min (0.2 l/s). The decrease in the number of flowing wells has resulted from increased development of and withdrawal from the aquifer. These two factors have caused the potentiometric surface to decline below the land surface, except in the area northeast of Chatfield Lake in the South Platte River valley.

SUMMARY

Aggregate-sand thickness in the Arapahoe aquifer ranges from less than 100 ft (30 m) in the northwest part of the study area to 560 ft (170 m) in the central part. The greatest aggregate-sand thicknesses occur in a northeast-trending band from near Louviers to east of Interstate Highway I–25. Depth to the base of the aquifer ranges from about 500 ft (150 m) under Chatfield Lake to about 2,500 ft (760 m) along the southern boundary of the study area near Castle Rock.

Two types of water, calcium bicarbonate and sodium bicarbonate, are found in the Arapahoe aquifer in most of the study area. Calcium sulfate or sodium sulfate water occurs in the northwestern part of the study area. The calcium bicarbonate type occurs generally west of Plum and East Plum Creeks. The sodium bicarbonate type occurs in most of the remaining part of the study area. Concentrations of dissolved solids, fluoride, iron, manganese, and sulfate exceed the recommended limits of the Colorado Department of Health (1971) for drinking water in some wells. Hardness may be a problem, depending on the use of the water.

The configuration of the potentiometric surface for 1965 indicated that ground-water flow was principally to the north and northwest. The gradient of the potentiometric surface ranged from 20 to 100 ft/mi (4 to 19 m/km). Recharge to the Arapahoe aquifer from the overlying Denver aquifer was occurring principally in the west-central part of the study area. Recharge ranged from 0.28 to 0.38 in (7.1 to 9.7 mm) and averaged 0.32 in (8.1 mm). Water discharged from the Arapahoe aquifer upward into the overlying Denver aquifer along Plum Creek and the South Platte River. Water also discharged from the Arapahoe downward into the underlying Laramie-Fox Hills aquifer in most of the study area.

The configuration of the potentiometric surface and flow pattern in the Arapahoe aquifer in 1975 was significantly different from that in 1965. Ground-water flow in most of the study area was to the northwest. The regional gradient of the potentiometric surface ranged from 15 to 100 ft/mi (3 to 19 m/km). Water-level declines have masked the effects of recharge from the overlying Denver aquifer although the rate of recharge may have increased depending on the difference in altitudes of the potentiometric surfaces in the Denver and Arapahoe aquifers. Discharge from the Arapahoe to the Denver is now limited to the South Platte River valley, and the rate may have decreased because of the general decline of water levels in the Arapahoe. Discharge from the Arapahoe to the underlying Laramie-Fox Hills aquifer may have decreased also.

The potentiometric surface declined throughout the study area from 1965 to 1975. Declines of 200 to 300 ft (60 to 90 m) have occurred in the central part of the study area. The average yearly rates of decline for 1965–75 in the areas of maximum decline have been 18 to 27 ft (5.5 to 8.2 m) per year. The decline of the potentiometric surface indicates that water in the Arapahoe aquifer is being "mined." Eventually, as increasing amounts of water are removed from storage, the potentiometric surface will intersect the top of the aquifer. When this occurs, the aquifer will cease to function as a confined aquifer and will have the characteristics of an unconfined or water-table aquifer in the area where intersection has occurred. The effect of this change will be that long-term well yields in the unconfined area will be reduced as the aquifer is dewatered. Long-term well yields would range from about 20 gal/min (1.3 l/s) where the aggregate-sand thickness is 100 ft (30 m) to about 250 gal/min (15.8 l/s) where the aggregate-sand thickness is 400 ft (120 m).

Flowing wells completed in the Arapahoe aquifer were known to exist in the study area in 1898 (McConaghy and others, 1964). The number of flowing wells increased significantly in the 1950's as more wells were drilled and completed in the aquifer. However, increased development of and withdrawal from the aquifer have lowered the potentiometric surface so that it is below the land surface in most of the study area, and the wells have stopped flowing. Only one flowing well in the vicinity of Chatfield Lake, was observed during the study. The flow from this well was estimated to be about 3 gal/min (0.2 l/s).

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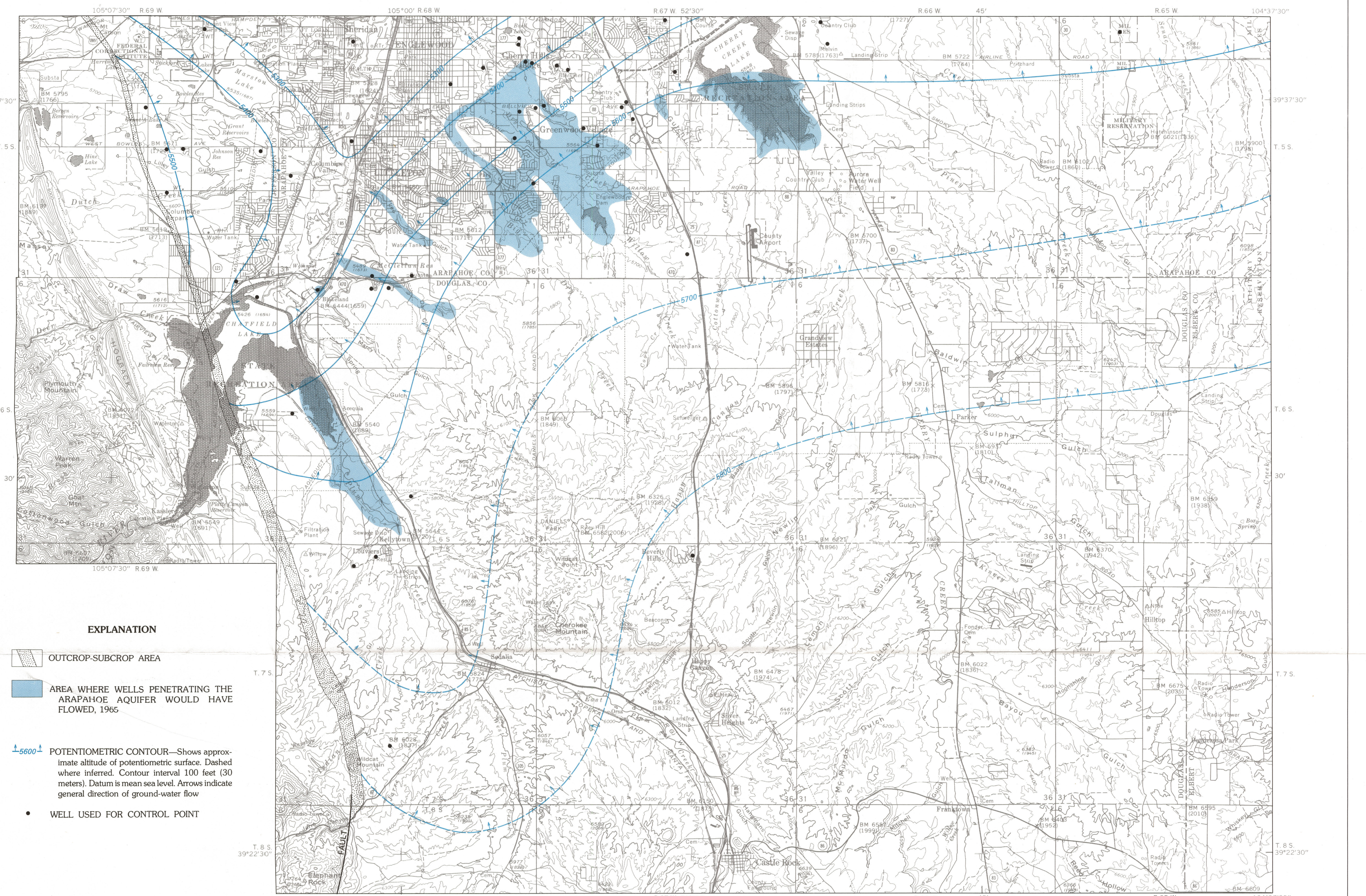
METRIC CONVERSION TABLE

The English units used in this report may be converted to metric units by the following conversion factors:

To convert English units	Multiply by	To obtain metric units
Inches (in)	25.40	Millimeters (mm)
Feet (ft)	.3048	Meters (m)
Miles (mi)	1.609	Kilometers (km)
Feet per mile (ft/mi)	.1894	Meters per kilometer (m/km)
Gallons per minute (gal/min)	.06309	Liters per second (l/s)
Feet per day	.3048	Meters per day (m/d)
Gallons per minute per foot	.2070	Liters per second per meter [(l/s)/m]
Feet squared per day	.09290	Meters squared per day (m^2/d)
Pounds per square inch	6,895	Pascals (Pa)



EXPLANATION

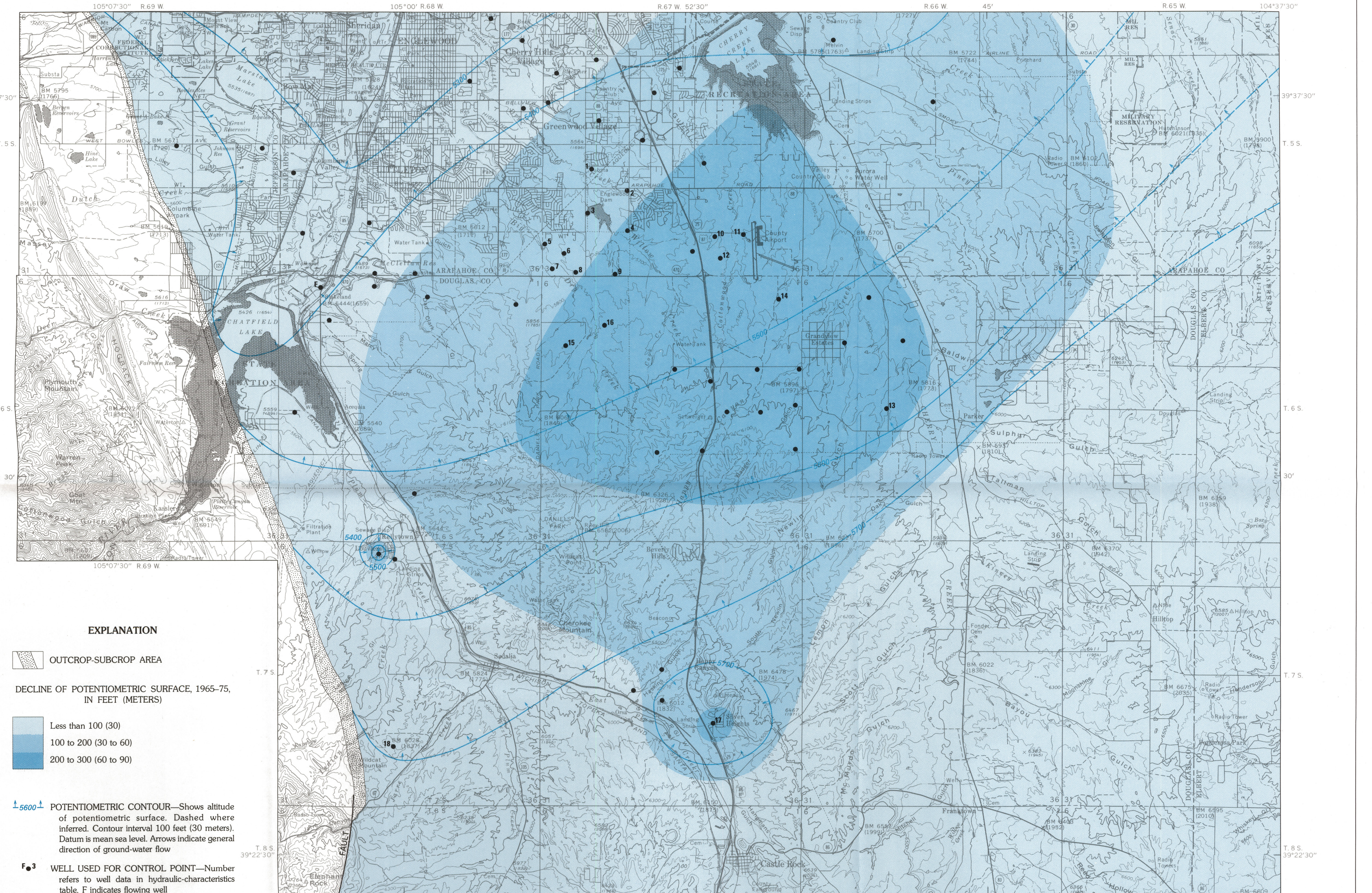
OUTCROP-SUBCROP AREA

AREA WHERE WELLS PENETRATING THE ARAPAHOE AQUIFER WOULD HAVE FLOWED, 1965

5600 POTENTIOMETRIC CONTOUR—Shows approximate altitude of potentiometric surface. Dashed where inferred. Contour interval 100 feet (30 meters). Datum is mean sea level. Arrows indicate general direction of ground-water flow

WELL USED FOR CONTROL POINT

MAP SHOWING APPROXIMATE ALTITUDE OF POTENTIOMETRIC SURFACE, 1965



EXPLANATION

OUTCROP-SUBCROP AREA

DECLINE OF POTENTIOMETRIC SURFACE, 1965–75, IN FEET (METERS)

Less than 100 (30)

100 to 200 (30 to 60)

200 to 300 (60 to 90)

5600 POTENTIOMETRIC CONTOUR—Shows altitude of potentiometric surface. Dashed where inferred. Contour interval 100 feet (30 meters). Datum is mean sea level. Arrows indicate general direction of ground-water flow

F 3 WELL USED FOR CONTROL POINT—Number refers to well data in hydraulic-characteristics table. F indicates flowing well

MAP SHOWING ALTITUDE OF POTENTIOMETRIC SURFACE, 1975, AND DECLINE OF POTENTIOMETRIC SURFACE, 1965–75

Base from U.S. Geological Survey Front Range Urban Corridor Maps; Greater Denver Area and Colorado Springs—Castle Rock Area, 1972

SCALE 1:100 000

1 ½ 0 1 2 3 4 5 MILES

1 .5 0 1 2 3 4 5 KILOMETERS

CONTOUR INTERVAL 100 FEET (30 METERS)
DOTTED LINES REPRESENT 50-FOOT (15-METERS) CONTOURS
DATUM IS MEAN SEA LEVEL

INTERIOR—GEOLOGICAL SURVEY, RESTON, VA.—1978—W76469

Outcrop-subcrop area adapted from Chase and McConaghy (1972)

HYDROLOGY OF THE ARAPAHOE AQUIFER IN THE ENGLEWOOD—CASTLE ROCK AREA SOUTH OF DENVER, DENVER BASIN, COLORADO

By
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1978