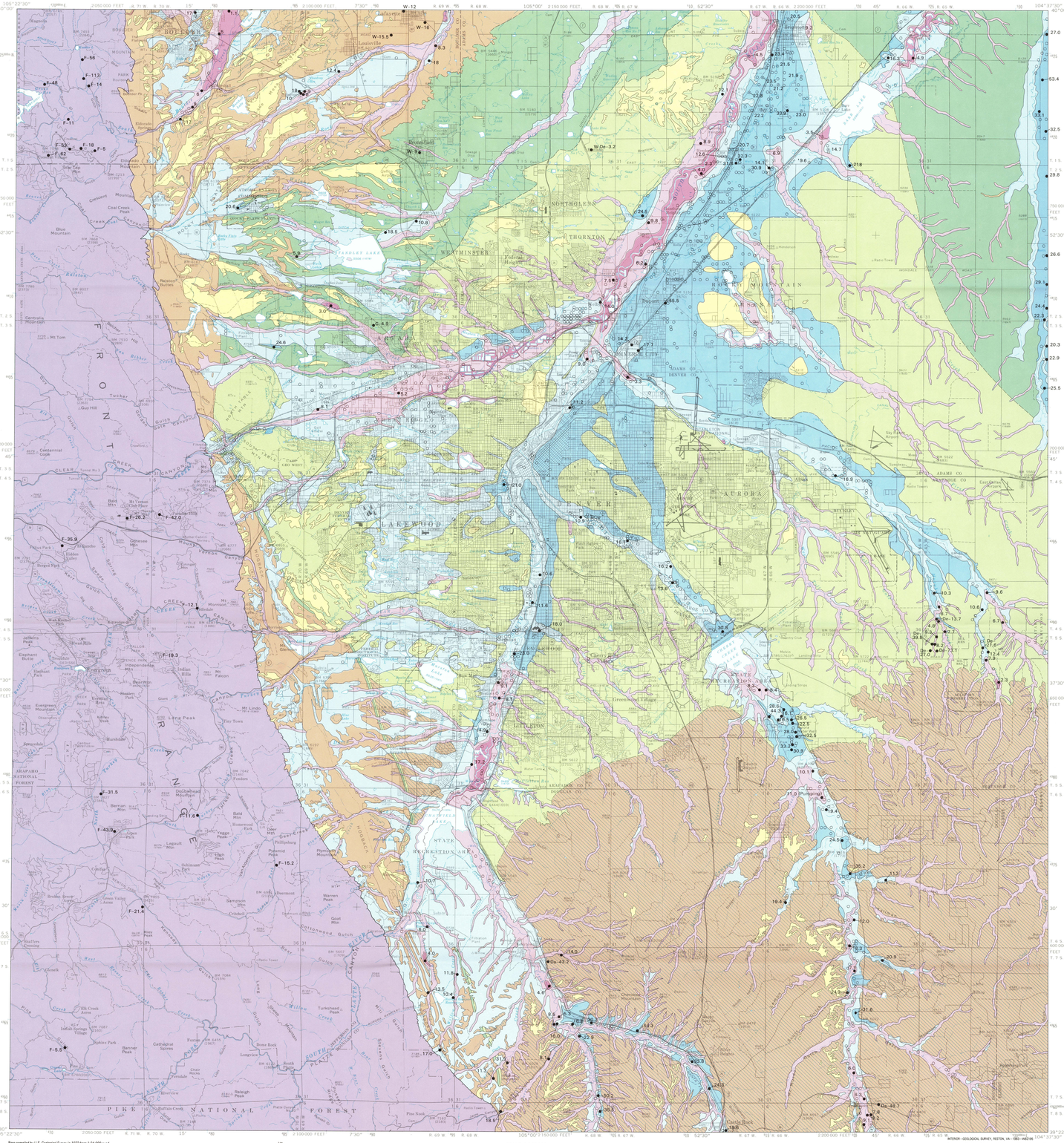


EXPLANATION

DEPTH TO WATER TABLE IN UNCONSOLIDATED ALLUVIAL DEPOSITS[1], IN FEET BELOW LAND SURFACE

- Less than 5
- 5 to 10
- 10 to 20
- Greater than 20

AREAS WHERE UNCONSOLIDATED ALLUVIAL DEPOSITS ARE NOT PERENNIALLY SATURATED; DEPTH TO SEASONAL WATER TABLE GENERALLY RANGES FROM 5 TO 20 FEET—Where areas are not irrigated, the deposits usually are drained by midsummer. Where areas are irrigated, seasonal water table may remain through the growing season with drainage of deposits occurring during the autumn

AREA WHERE WATER-TABLE CONDITIONS PREDOMINATE IN THE DAWSON AQUIFER; DEPTH TO WATER-TABLE GENERALLY MORE THAN 20 FEET AND COMMONLY MORE THAN 100 FEET—Shallowest depths to water table generally occur along stream valleys and in colluvial deposits

AREA WHERE WATER-TABLE CONDITIONS PREDOMINATE IN THE DENVER AQUIFER; DEPTH TO WATER-TABLE GENERALLY MORE THAN 20 FEET AND COMMONLY MORE THAN 100 FEET—Shallowest depths to water table generally occur along stream valleys and in colluvial deposits

AREA WHERE WATER-TABLE CONDITIONS PREDOMINATE IN THE ARAPAHOE AQUIFER; DEPTH TO WATER-TABLE GENERALLY MORE THAN 20 FEET AND COMMONLY MORE THAN 100 FEET—Shallowest depths to water table generally occur along stream valley and in colluvial deposits

AREAS WHERE LOCALIZED WATER-TABLE AQUIFERS OCCUR IN COLLUVIAL, LANDSLIDE, AND WINDBLOWN DEPOSITS, AND IN CONSOLIDATED SEDIMENTARY ROCKS WHERE ROCKS NEAR LAND SURFACE ARE FRACTURED AND WEATHERED—*Aquifer* materials may not be perennially saturated; depth to water table generally ranges from 5 to 20 feet; depth to seasonal water table generally less than 10 feet

AREA WHERE LOCALIZED WATER-TABLE AQUIFERS OCCUR IN FRACTURED CRYSTALLINE ROCKS—Fractures may not be perennially saturated; depth to water table may be more than 100 feet

CONTACT—Dashed where approximately located

EASTERN OUTCROP LIMIT OF FRACTURED CRYSTALLINE ROCKS

C–4.9 WELL WHERE DEPTH TO WATER TABLE WAS MEASURED IN 1976 OR 1977—Number is depth to water table, in feet below land surface
C, Well completed in colluvial deposits
Da, Well completed in Dawson aquifer
De, Well completed in Denver aquifer
F, Well completed in fractured crystalline rocks
W, Well completed in windblown deposits
All other wells completed in unconsolidated alluvial deposits

19.6 WELL COMPLETED IN UNCONSOLIDATED ALLUVIAL DEPOSITS WHERE DEPTH TO THE WATER TABLE WAS MEASURED FOR AT LEAST 3 YEARS DURING 1972–75—Number is average depth to the water table for the period, in feet below land surface (data from Major, Kerbs, and Penley, 1975)

WELL COMPLETED IN UNCONSOLIDATED ALLUVIAL DEPOSITS WHERE DEPTH TO THE WATER TABLE WAS MEASURED BETWEEN 1976 AND 1976

[1]Depth to water table generally less than 20 feet in localized areas of unconsolidated alluvial deposits (not shown on map) occurring in stream valleys traversing fractured crystalline rocks

INTRODUCTION

Knowledge of the depth to the water table is useful to State and local officials in making decisions on land use in the rapidly urbanizing greater Denver area (index map). This report presents the results of a 2-year investigation to determine the depth to the water table, water-table fluctuations and trends, and to relate the results of the investigation to urban planning in the greater Denver area. The report is one of a series of geologic and hydrologic reports prepared by the U.S. Geological Survey to demonstrate the usefulness of Earth-science information in urban planning.

In the greater Denver area, the principal water-table aquifers are found in unconsolidated alluvial deposits of Quaternary age and in three groups of consolidated sedimentary rocks—the Dawson, Denver, and Arapahoe Formations—of Paleocene to Late Cretaceous age. The alluvial aquifers, which principally consist of saturated, permeable sand and gravel, occur in present stream valleys, ancestral stream valleys, and terraces both along present stream valleys and on slopes of the foothills east of the Front Range (diagrammatic section). The Dawson, Denver, and Arapahoe aquifers, which principally consist of saturated, permeable conglomerate and sandstone interbedded with less permeable shale and siltstone (Trimble and Machette, 1979), underlie most of the area east of the Front Range (diagrammatic section). Most of the conglomerate and sandstone beds are lenticular and generally do not extend laterally for appreciable distances. Ranges in depth to the water table shown on the map were delineated only for the unconsolidated alluvial deposits because the depth to the water table in the Dawson, Denver, and Arapahoe aquifers generally is more than 20 feet and commonly will not be a factor affecting urban planning.

Although both water-table (unconfined) and artesian (confined) conditions occur within the Dawson, Denver, and Arapahoe aquifers, water-table conditions generally predominate where the aquifers crop out or are overlain by: (1) Alluvial deposits, (2) windblown deposits, (3) isolated areas of extrusive igneous rocks (North and South Table Mountains), and (4) isolated areas of consolidated sedimentary rocks (Green Mountain and areas in Douglas County) (Trimble and Machette, 1979). Artesian conditions generally predominate where the Arapahoe is overlain by the Denver and where the Denver is overlain by the Dawson. For the purposes of this investigation, it was assumed that only water-table conditions existed where the Dawson, Denver, and Arapahoe aquifers crop out or are overlain by alluvial deposits, windblown deposits, and isolated areas of igneous and sedimentary rocks. It also was assumed that only artesian conditions existed where the Arapahoe is overlain by the Denver and where the Denver is overlain by the Dawson.

The Laramie-Fox Hills aquifer, which is older than the Arapahoe aquifer, consists of the basal sandstones of the Laramie Formation of Late Cretaceous age and the Fox Hills Sandstone of Late Cretaceous age and is the principal artesian aquifer in the area. Although water-table conditions locally exist where this aquifer crops out or is overlain by alluvial and windblown deposits in northern Jefferson and southern Boulder Counties, the extensive faulting in the area (Trimble and Machette, 1979) precluded accurate delineation of areas of water-table conditions. For this reason, the aquifer was considered to be artesian throughout the study area.

Locally, saturated permeable materials that yield water to wells also occur in: (1) Upper weathered and fractured zone of other consolidated sedimentary rocks older than the Laramie-Fox Hills aquifer that form the foothills east of the Front Range; (2) colluvial and landslide deposits that occur on the slopes of the consolidated sedimentary rocks; and (3) windblown deposits that occur throughout the area east of the mountain front. In the crystalline rocks that form the Front Range in the western part of the area, water occurs locally in fractures to a depth of about 300 feet below land surface (diagrammatic section). Because of the localized occurrence of these water-table aquifers and because some of the aquifer material and fractures are drained for part of the year, these aquifers were not studied in detail during this investigation. Where water levels were measured in wells completed in these localized aquifers, only the location of the wells and the measured depths to water are shown on the depth-to-water map.

Water levels were measured once in 180 wells during 1976 or 1977 to determine the depth to the water table. Additional information about these wells is included in reports by Hiller, Schneider, and Hutchinson (1979) and Robson (1977). A comparison between water levels measured during 1976–77 and water levels measured by the U.S. Geological Survey since the middle 1950's in areas where ground-water pumping is greatest indicated that, with two exceptions—one in the northeasternmost part of the study area and one about 3 miles southeast of Cherry Creek Lake, no significant upward or downward change in the position of the water table has developed in the area during the past 20 years. In other than these two areas, water levels during 1976–77 were about the same as during the middle 1950's. Therefore, water levels reported by Major, Kerbs, and Penley (1975), McConaghy, Chase, Boettcher, and Major (1964), and Jenkins (1961) and water levels reported by well drillers were used to supplement the 1976–77 data in the compilation of the depth-to-water map in all but these two areas. The data reported by drillers were obtained from the files of the Colorado Department of Natural Resources, Division of Water Resources, Office of the State Engineer.

Physiography and geology (Trimble and Machette, 1979) also were used in the compilation. For example, along the South Platte River and its principal tributaries, the scarps of the terraces commonly were used to map the boundary between the shallow water table in the flood plains and the deeper water table in the terraces. Also, the presence of swamps was used to delineate areas where the depth to the water table is less than 5 feet.

Appreciation is extended to the many owners of wells and springs in the greater Denver area for permitting access to their wells and springs for the purpose of collecting the data used in this report.

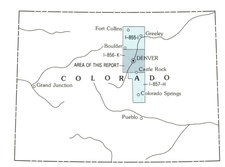
RELEVANCE TO URBAN PLANNING

The depth to the water table is a relevant factor in planning for urban development, as indicated by the following examples:

A. Depth to the water table is less than 5 feet either seasonally or annually:
1. The effectiveness of individual-domestic waste-disposal systems could be decreased and untreated wastes could enter the ground-water system. Some of the biochemical reactions necessary for the proper functioning of individual waste-disposal systems occur in the unsaturated zone below or adjacent to the system. Because the reactions do not occur in the saturated zones, the greater the depth to the water table, the greater the possibility that these reactions will complete the conversion of wastes to an effluent that is not a health hazard.
2. Road and highway stability could be affected. Access to lands might be limited where marshy ground exists.
3. Soil-salinity problems could develop. The types of vegetation that could be grown in these areas would be dependent on the degree of the salinity, but, even without any salinity problems, many types of vegetation could not grow in these areas.
4. Unstable soil structure, which commonly limits the use of the land, could exist.
5. Construction of structural or building foundations could be hampered by the flow of ground water into the construction excavations.
6. Basements could be subject to collapse resulting from water pressure and flooding.

The situations described in items 4, 5, and 6 also could occur in areas where the depth to the water table is not more than 10 feet either seasonally or annually.

B. Depth to the water table related to depth of installation:
1. Liquid wastes or leachates from solid wastes could be introduced directly into the ground-water system by water moving through landfills and similar facilities, resulting in degradation or pollution of the ground water. The possibility of degradation or pollution generally would be dependent on site preparation, the type of wastes, the depth of burial of the wastes, and the seasonal or annual depth to the water table in the area of the landfill or similar facility.
2. Ground water could enter leaky sanitary sewers, resulting in a significant increase in the volume of wastes to be processed by waste-treatment facilities. The volume of water entering a leaky sanitary sewer generally would be dependent on the depth of burial of the sewer, the permeability of aquifer material, and the seasonal or annual depth to the water table.
3. The placement of electric and telephone utility lines below ground and the type of insulation and conduits required for below-ground installation would be, in part, dependent on the depth to the water table.



MAP SHOWING AREA OF FRONT RANGE URBAN CORRIDOR

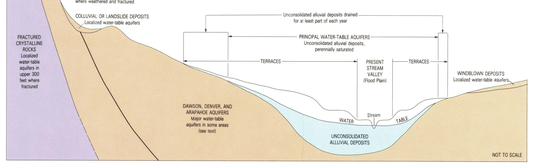
DEPTH TO THE WATER TABLE

Measured depths to the water table during 1976–77 in the unconsolidated alluvial deposits ranged from 1.1 to 55.5 feet. Generally the depth to the water table in the flood plains of present perennial and most ephemeral streams was less than 10 feet and commonly it was less than 5 feet. However, along the flood plains of the South Platte River and Cherry Creek, where channel improvements have been made (generally within the Denver city limits) and along the flood plain of Sand Creek (an ephemeral stream), the depth to the water table generally was between 10 and 20 feet. Also, in the flood plain of Cherry Creek about 3 miles southeast of Cherry Creek Lake, the depth to the water table was greater than 20 feet as a result of extensive pumping during the drought of 1975–77. The depth to the water table in ancestral stream valleys, such as in the vicinity of Barr Lake, and in the terraces ranged from less than 5 feet to 55.5 feet.

The depth to the water table in the Dawson, Denver, and Arapahoe aquifers generally is more than 20 feet and commonly it is more than 100 feet, especially in the Dawson aquifer. The shallowest depths to the water table generally occur along stream valleys and in colluvial deposits. The depth to the water table in the windblown deposits ranged from 3.2 to 16 feet; and in the fractured crystalline rocks, it ranged from 5 to 113 feet.

CONVERSION FACTORS

Multiply	By	To obtain
foot	0.3048	meter
mile	1.609	kilometer



DIAGRAMMATIC SECTION SHOWING OCCURRENCE OF WATER-TABLE AQUIFERS

WATER-TABLE FLUCTUATIONS AND TRENDS

Annual fluctuations of the water table in all the aquifers except the fractured crystalline rocks generally are less than 10 feet although the maximum fluctuation is not known. Both seasonal and annual fluctuations generally are smaller in the aquifers underlying the flood plains of perennial streams because of the hydraulic connection between the streams and the aquifers. Because of the limited storage capacity of the fractures in crystalline rocks, seasonal and annual fluctuations of the water table in these rocks may be greater than 10 feet.

In areas that are not extensively irrigated, the depth to the water table generally is shallowest during the spring and early summer when the aquifers are being recharged by snowmelt and rain. The greatest depth to the water table generally occurs during late autumn when recharge by thunderstorms is minimal and water in the aquifers has been partly depleted by pumpage from wells, evapotranspiration, and by natural discharge to lakes, ponds, springs, streams, and swamps. In areas that are extensively irrigated with surface water, the depth to the water table may remain within a few feet of the land surface throughout the growing season because part of the applied water percolates through the soil and recharges the aquifer.

Water-table trends are shown both by the hydrographs and the data in the table. Water-level data for construction of hydrographs are available only for wells completed in alluvial deposits along the South Platte River between Denver and Brighton. The hydrographs present water-level measurements made at approximately the same time each year (generally during the spring) to eliminate the effects of seasonal fluctuations of the water table. Measurements made at times other than the spring of the year are indicated on the hydrographs. The hydrographs indicate that no significant upward or downward trend has developed since the middle 1950's in alluvial deposits along the South Platte River between Denver and Brighton where ground water is used extensively for irrigation.

COMPARISON BETWEEN WATER LEVELS MEASURED SINCE THE MIDDLE 1950'S AND WATER LEVELS MEASURED DURING 1976-77 IN THE SAME WELLS

Location			Date	Depth to water (feet below land surface)	Date	Depth to water (feet below land surface)	Rise (+) or decline (−) in water level (feet)
Section	Township, south	Range, west					
UNCONSOLIDATED ALLUVIAL DEPOSITS							
2	1	65	8- 8-57	14.5	4-13-77	27.0	-12.5
14	1	65	7-31-57	38.8	4-14-77	53.4	-14.6
23	1	65	11- 4-57	29.3	4-14-77	33.1	-3.8
12	1	66	12- 9-57	4.7	3- 3-77	4.9	-.2
19	1	66	10-23-56	36.4	3- 3-77	33.9	+2.5
35	1	67	11-15-55	30.0	3- 3-77	31.8	-1.8
17	1	69	4-22-59	15.1	6-16-76	12.4	+2.7
24	1	70	8-14-59	6.6	4-20-77	8.0	-1.4
2	2	65	11- 4-57	23.3	4-20-77	29.8	-6.5
3	2	67	11-22-55	4.9	4-22-77	4.0	+.9
8	2	67	8- 8-56	22.2	4-20-77	24.5	-2.3
17	2	67	4-10-62	11.1	4-20-77	9.8	+1.3
20	2	67	8-16-55	1.6	4-20-77	6.2	-4.6
25	2	68	4- 1-58	7.2	4-22-77	7.5	-.3
36	2	68	6-15-56	7.0	4-22-77	14.0	-7.0
11	3	65	7-19-57	30.6	4-19-77	22.9	+7.7
33	3	66	4-13-60	12.8	5-10-77	16.9	-4.1
18	3	67	4-10-62	7.1	5- 3-77	3.3	+3.8
11	3	68	4-10-62	9.4	4-13-77	9.0	+.4
23	3	68	4-10-62	14.6	4-20-77	11.2	+3.4
21	4	67	4-11-62	17.0	4-28-77	16.2	+.8
28	4	67	4-11-62	10.3	4-28-77	13.6	-3.3
11	4	68	10-20-59	11.2	4-19-77	10.9	+.3
22	4	68	9- 9-62	9.7	5- 3-77	10.6	-.9
28	4	68	5- 2-58	9.8	5-10-77	11.6	-1.8
34	4	68	11- 8-59	18.9	4-18-77	18.0	+.9
18	5	66	4-12-62	21.1	6- 9-77	28.6	-7.5
19	5	66	4-12-62	3.7	6- 9-77	22.5	-18.8
20	5	66	4-12-62	11.8	4-27-77	28.0	-16.2
30	5	66	6-18-57	10.6	6-15-77	30.6	-20.0
30	5	66	6-26-61	10.8	3-31-77	33.2	-22.4
30	5	66	6-26-61	10.2	6- 8-77	30.9	-20.7
13	5	67	4-13-62	10.2	6-27-77	8.4	+1.8
13	5	67	4-13-62	11.4	8- 5-77	8.3	+3.1
8	5	68	7-26-59	8.6	4-15-77	9.1	-.5
17	5	68	7-27-56	9.4	5- 2-77	8.1	+1.3
20	5	68	8-22-56	9.0	4-14-77	14.9	-5.9
31	5	68	4-12-62	14.2	5- 2-77	17.2	-3.0

The data in the table indicate that the depth to the water table in most of the area was about the same during the middle 1950's as during 1976–77. Water levels in 11 of the 38 wells had declined more than 5 feet; the maximum decline was 22.4 feet. Of the 11 wells, 3 are located in the northeastern part of the study area and 6 are located in the area about 3 miles southeast of Cherry Creek Lake. The water level in only one well along the eastern border of the study area in Adams County had risen more than 5.0 feet; the rise was 7.7 feet.

A continual downward trend of water levels, which may indicate that water is being pumped or mined from the aquifer(s) at a rate that is greater than the rate of recharge to the aquifer(s), is not apparent on any hydrograph. However, data in the table indicate that ground-water mining may be occurring in the northeasternmost part of the study area due to increased pumping for irrigation, and may be occurring southeast of Cherry Creek Lake due to increased pumping for municipal supplies. Measuring water levels on a continual basis would be needed to verify if ground-water mining is occurring or if the declines were temporary due to increased pumping during the drought of 1975–77. Mining of ground water also may be occurring in other parts of the area for which continual long-term water-level data are not available.

As urban development increases in the area, the possibility of ground-water mining also will increase if water-table aquifers are used as sources of water for various aspects of the development, such as industrial or municipal supplies. Although ground-water mining could decrease or eliminate some of the adverse effects caused by a shallow water table, ground-water mining also would decrease the volume of water available for use.

If ground-water mining begins, continued pumping of existing wells at the same or increased rates will result in the following sequence of events:

A. Aquifers with limited or distant hydraulic connection to surface-water features—
1. Water levels decline, well yields decrease, and pump intakes have to be lowered in wells.
2. Wells have to be deepened, in some localities to the base of the aquifer, and pump intakes lowered to as near the bottom of the well as possible, if this has not been done previously.
3. Aquifers are virtually dewatered.

B. Aquifers with extensive hydraulic connection to surface-water features—
1. Water levels decline in aquifers and hydraulically connected surface-water features.
2. Streamflow could be depleted and lakes, ponds, and swamps could be drained.
3. The sequence of events listed under item A could occur in those parts of the aquifer most distant from the source of recharge.

Installing additional wells in areas where water is being mined only accelerates the sequence of events listed above. The existence of or the potential for ground-water mining are factors that need to be evaluated in planning for urban development.

LIMITATIONS OF THE INVESTIGATION

The users of this report need to be aware that the water-table data represent a compilation of water levels measured throughout 1976 and 1977. Because of seasonal or annual variations in ground-water recharge or discharge, the data do not necessarily represent either the shallowest or the greatest depth to the water table that could occur or has occurred. Water-level measurements would have to be made at least during the spring and late fall, and perhaps throughout the year at a specific site intended for a specific use, to determine the potential effects of water levels on the use of the site. The scale of the map in this report precludes its use for specific site selection; larger-scale, more detailed maps need to be used for this purpose. Also, shallower depths to the water table than those shown on the map occur locally, especially around the edges of lakes, ponds, and reservoirs, along irrigation canals where leakage occurs, and in the valleys of perennial streams.

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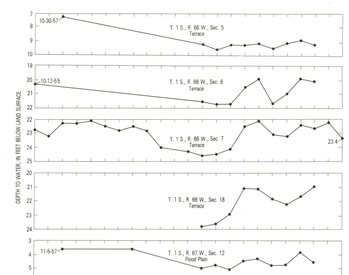

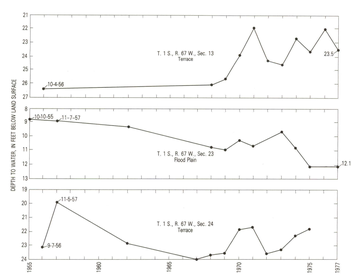

HYDROGRAPHS SHOWING WATER-LEVEL TRENDS

DEPTH TO THE WATER TABLE (1976–1977) IN THE GREATER DENVER AREA, FRONT RANGE URBAN CORRIDOR, COLORADO

By
Donald E. Hillier, Paul A. Schneider, Jr., and E. Carter Hutchinson

1983

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