Prepared in cooperation with the
U.S. ARMY-ROCKY MOUNTAIN ARSENAL, U.S. DEPARTMENT OF ENERGY-ROCKY FLATS FIELD OFFICE,
COLORADO DEPARTMENT OF PUBLIC HEALTH AND ENVIRONMENT, COLORADO DEPARTMENT OF
NATURAL RESOURCES-STATE ENGINEERS OFFICE, DENVER WATER DEPARTMENT, LITTLETON-
ENGLEWOOD WASTEWATER TREATMENT PLANT, EAST CHERRY CREEK VALLEY WATER AND
SANITATION DISTRICT, METRO WASTEWATER RECLAMATION DISTRICT, WILLOWS WATER DISTRICT,
AND CITIES OF AURORA, LAKEWOOD, AND THORNTON



## INTRODUCTION

The Denver metropolitan area is underlain by shallow layers of water-bearing sediments (aquifers) consisting of unconsolidated gravel, sand, silt, and clay. The depth to water in these aquifers is less than 20 feet in much of the area, and the aquifers provide a ready source of water to numerous shallow, small-capacity wells. The shallow depth to water also makes the aquifers susceptible to contamination from the land surface. Water percolating downward from residential, commercial, and industrial property, spills of hazardous materials, and leaks from underground storage tanks and pipelines can cause contaminants to enter the shallow aquifers. Wet basements, unstable foundation materials, and waterlogged soils also are common in areas of very shallow ground water.

Knowledge of the extent, thickness, and water-table altitude of the shallow aquifers is incomplete. This, coupled with the complexity of development in this large metropolitan area, makes effective use, management, and protection of these aquifers extremely difficult. Mapping of the geologic and hydrologic characteristics of these aquifers would provide the general public and technical users with information needed to better use, manage, and protect this water resource. A study to map the geohydrology of shallow aquifers in the Denver metropolitan area was begun in 1994. The work was undertaken by the U.S. Geological Survey in cooperation with the U.S. Army-Rocky Mountain Arsenal, U.S. Department of Energy-Rocky Flats Field Office, Colorado Department of Public Health and Environment, Colorado Department of Natural Resources-State Engineers Office, Denver Water Department, Littleton-Englewood Wastewater Treatment Plant, East Cherry Creek Valley Water and Sanitation District, Metro Wastewater Reclamation District, Willows Water District, and the cities of Aurora, Lakewood, and Thornton.

This report presents the results of a systematic mapping of the extent, thickness, and water-table altitude of the shallow aquifers in a 700-square-mile part of the greater Denver metropolitan area (fig. 1). The five sheets in this report (figs. 2–7) show (1) the thickness and extent of the unconsolidated sediments that overlie bedrock formations in the area, (2) the altitude and configuration of the buried bedrock surface, (3) the altitude of the water table and direction of ground-water movement, (4) the saturated thickness of the shallow aquifers, and (5) the depth to the water table in the shallow aquifers. The maps primarily are intended to indicate the general trends in altitude and thickness of the aquifers and are not intended to define conditions at specific sites.

The boundaries of the study area are: the Arapahoe/Douglas County line on the south; Gun Club Road on the east; the Boulder/Jefferson County line and the Weld/Adams County line on the north; and the approximate eastern edge of the Dakota Hogback and the Laramie Hogback on the west. North Table Mountain, South Table Mountain, and Green Mountain are within the western boundary of the study area, but are not included in the mapping because shallow aquifers generally are not present in these areas of steep topography. Most of the study area is urban, although some rural areas are present along the eastern and western margins.

Data used in this study consist of water-level measurements in wells and lithologic logs of wells and test holes. These data were obtained from records of wells and test holes constructed between about 1945 and 1992. Principal sources of data include the Colorado State Engineers Office, the U.S. Geological Survey (McConaghy and others [1964], Hillier and others [1979]), the U.S. Army-Rocky Mountain Arsenal, the U.S. Department of Energy-Rocky Flats Field Office, the Colorado Department of Public Health and Environment, the Denver Water Department, and the Colorado Department of Highways. Much of the data compiled in an earlier study of Denver soils (Committee on Denver Subsoils, 1954) also was used in this study. Numerous other governmental agencies and private companies also provided data. About 7,000 data points were compiled for use in mapping and entered into a computer data base for storage and retrieval.

## MAP ACCURACY AND RESOLUTION

Maps in this report were prepared by the use of ARC/INFO as part of the geographic information system. (The use of trade, product, industry, or firm names is for descriptive purposes only and does not imply endorsement by the U.S. Government.) ARC/INFO is a computer-software package that enables the computerized production of maps through digital processing of map features. Maps such as those showing the altitude of the land surface (U.S. Geological Survey topographic quadrangles), thickness of the unconsolidated sediments, and altitude of the water table were digitized for use in the geographic information system. These maps were produced directly from data and herein are considered to be first-order maps. The vertical accuracy of a topographic quadrangle map with a contour interval of 10 feet is such that more than 90 percent of the altitudes tested will be within 5 feet of the actual land-surface altitude. Maps of the thickness of the unconsolidated sediments and altitude of the water table were constructed with contour intervals of 10 and 20 feet and probably have a vertical accuracy of about 10 feet. These two maps were plotted by the geographic information system as figures 2 and 5 of this report, but were not computed by the geographic information system.

The map of the altitude of the bedrock surface was computed by the geographic information system as the difference between the altitude of the land surface and the thickness of the unconsolidated sediments. The map of the depth to water was computed as the difference between the altitude of the water table and the altitude of the land surface. These maps herein are considered to be second-order maps because they are computed from two first-order maps. The second-order maps likely have vertical accuracies between 10 and 15 feet.

The map of the saturated thickness of the aquifers was computed by the geographic information system as the difference between the altitude of the water table (a first-order map) and the altitude of the bedrock surface (a second-order map). The map of the saturated thickness is a third-order map because it is computed from a first- and second-order map. The vertical accuracy of this map likely is between 20 and 25 feet.

The resolution of a map pertains to the minimum size of features that can be distinguished on the map. All the altitude and thickness mapping in this report have a resolution of about 0.02 square mile. Thus, features smaller than about 0.15 mile on a side cannot be resolved on these maps.

## GEOLOGY

Most of the study area is underlain by bedrock of the Arapahoe Formation of Cretaceous age and the Denver Formation of Tertiary and Cretaceous age (Trimble and Machette, 1979). Along the western margins of the area, smaller subcrops of Niobrara Formation, Pierre Shale, Fox Hills Sandstone, and Laramie Formation of Cretaceous age are present. The Niobrara, Pierre, and upper Laramie units consist of shale or mudstone with localized beds of sandstone. The Fox Hills, lower Laramie, Arapahoe, and Denver units primarily consist of poorly to moderately consolidated interbedded sandstone and mudstone. The western extent of the subcrop or outcrop of the Niobrara Formation defines the western limit of the study area south of Green Mountain. North of Green Mountain, the Niobrara Formation has been faulted out, and the limit of the study area is based on the approximate western extent of the subcrop or outcrop of the Fox Hills Sandstone. In the southeastern part of the study area, Dawson Arkose of Tertiary age is the uppermost bedrock unit. This formation primarily consists of poorly to moderately consolidated conglomerate, arkosic sandstone, and mudstone.

Unconsolidated sediments overlie most of the bedrock in the study area. The sediments tend to be thinner in the western part of the area where bedrock outcrops are prevalent. Unconsolidated sediments are of Quaternary age and are comprised of alluvium, colluvium, and eolian deposits.

The oldest alluvium (Pleistocene age) in the study area consists of the Rocky Flats Alluvium, Verdos Alluvium, and Slocum Alluvium (Trimble and Machette, 1979). These deposits are bouldery-cobble gravel near the mountain front and decrease in grain size to the east. The alluvium is prevalent near Rocky Flats and in the area between Green Mountain and the South Platte River. Younger alluvium (upper Pleistocene age) consists of Louviers Alluvium and Broadway Alluvium. These deposits are composed of gravel, sand, and silt and are present on terraces along the margins of most of the principal stream valleys in the area. This alluvium also is more coarse grained near the mountain front. The youngest alluvium (Holocene age) in the area consists of Piney Creek and post-Piney Creek Alluvium composed of gravel, sand, silt, and clay along the valleys and flood plains of the principal streams. Deposits along Bear Creek, Clear Creek, and the South Platte River are coarse, cobbly gravel near the mountain front, but decrease in grain size downstream. Deposits in small tributaries and along streams east of the South Platte River primarily are sand or interbedded sand, silt, and clay.

Colluvium composed of landslide, slump, earthflow, and slope-wash debris overlies the bedrock in many areas of steep topography in the northwestern and southeastern parts of the study area. The colluvium, of upper Holocene to mid-Pleistocene age, ranges from boulders to clay and commonly is derived from the underlying bedrock.

Eolian deposits, of lower Holocene to upper Pleistocene age, composed of windblown sand and loess, have covered much of the land surface to the east of the South Platte River. Windblown sand is fine to medium grained and generally was derived from alluviated valleys and transported to the east and southeast by prevailing winds. Loess, consisting of silt, fine sand, and clay, has been transported downwind, primarily from areas of windblown sand.

The contact between the bedrock and unconsolidated sediments is distinct and easily identified in some areas, but is transitional and difficult to identify in other areas. Along the South Platte River and in the broader valley near Barr Lake, gravel and cobbles commonly are present at the base of the unconsolidated sediments, and the contact with the mudstone of the underlying bedrock is readily discerned. In most other parts of the study area, however, the contact is difficult to identify because the upper part of the bedrock has been weathered to form a transitional zone, the upper part of which is nearly indistinguishable from overlying fine-grained sediments. In such cases, differences in grain size, color, hardness, rate of drill penetration, and degree of fracturing are used to estimate the position of the contact. Because of the indistinct contact, unconsolidated weathered bedrock likely has been mapped with the unconsolidated sediments in most areas.

### Thickness and Extent of Unconsolidated Sediments

The map of the thickness and extent of the unconsolidated sediments (fig. 2) was prepared by a combination of hand contouring and plotting using the geographic information system. Hand contouring was used to better interpret the varied and inconsistent data values that sometimes resulted from local irregularities in the bedrock surface, the imprecise bedrock contact, mislocated data points, or conflicting data. Thickness contours generally were drawn using the preponderance of data in a local area and do not necessarily agree with each individual data value. Large earthen structures such as dams, gravel pits, and highway embankments generally were disregarded when constructing the contours. The general thickness and extent of the unconsolidated sediments in the study area are shown in figure 2; readers who need site-specific information can consult the data base or undertake drilling to obtain data at a specific site.

Unconsolidated sediments are thickest along the upper valley of Cherry Creek, the lower valley of the South Platte River, and along paleovalleys formed by the ancestral Cherry Creek, First Creek, Sand Creek, and South Platte River (fig. 3). Thickness of unconsolidated sediments exceeds 100 feet in Cherry Creek Valley near Cherry Creek Dam and in the South Platte Valley near the northwestern boundary of the Rocky Mountain Arsenal. Sediment thickness exceeds 80 feet along parts of an ancient and now abandoned valley of lower Cherry Creek. This paleovalley diverges from the present valley of Cherry Creek near the southwestern corner of Lowry Air Force Base and extends northward to the valley of the South Platte River. A second thick paleovalley (First Creek/Sand Creek paleovalley) is about 3 miles north of the present valley of Sand Creek and approximately parallels Sand Creek. A third thick paleovalley (South Platte River paleovalley) extends northeastward from the South Platte Valley through Barr Lake.

Beyond the principal stream valleys and paleovalleys, the thickness of the unconsolidated sediments generally is less than 20 feet. However, on parts of the high terraces in the northwest corner of the study area near Rocky Flats, thickness of the unconsolidated sediments exceeds 80 feet.

Outcrops of bedrock are prevalent in the southeastern, western, and northwestern parts of the study area. Geologic maps used to define the extent of the bedrock outcrops include the 1:24,000-scale mapping of Malde (1955), Scott (1962, 1972), Maberry and Lindvall (1972, 1977), Van Horn (1972), Bryant and others (1973), Machette (1977), Lindvall (1978, 1979, 1980a, 1980b), and Shroba (1980) and 1:100,000-scale mapping of Trimble and Machette (1979). Sediment thickness in outcrop areas commonly ranges from zero to a few feet.

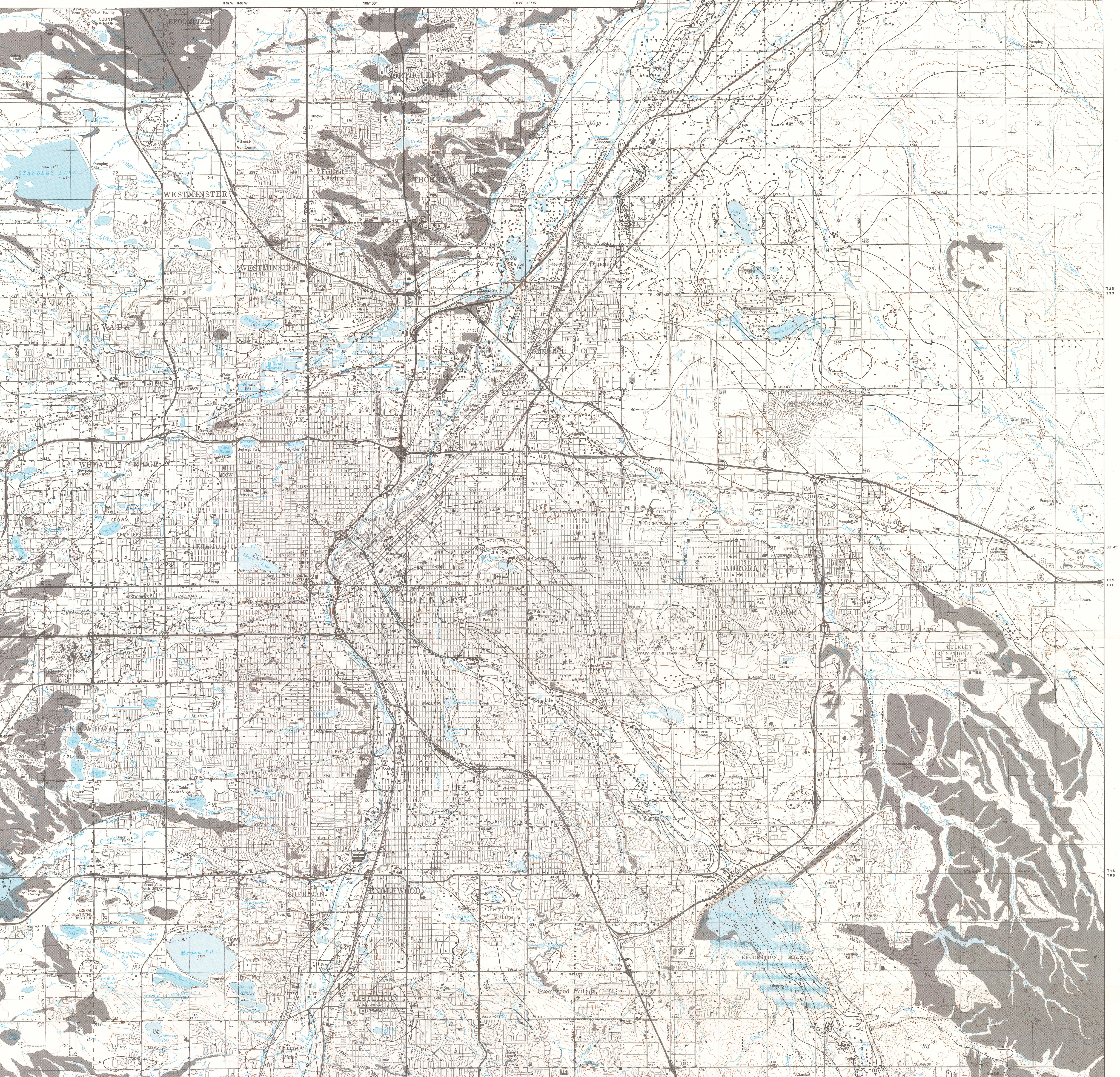


FIGURE 2 — Thickness and extent of unconsolidated sediments

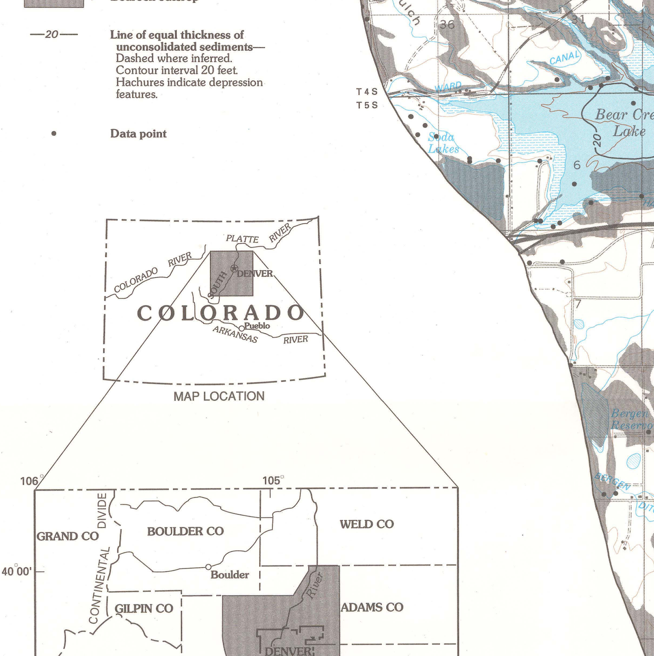


FIGURE 1 — Location of the study area

Base from U.S. Geological Survey 1:50,000 County Maps for Adams, Arapahoe, Denver and Jefferson Counties

SCALE 1:50,000
1 1/2 0 1 2 3 4 MILES
1 1/2 0 1 2 3 4 5 KILOMETERS
CONTOUR INTERVAL 20 AND 80 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929

INTERIOR—GEOLOGICAL SURVEY, RESTON, VIRGINIA—1996

# GEOHYDROLOGY OF THE SHALLOW AQUIFERS IN THE DENVER METROPOLITAN AREA, COLORADO

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