PREPARED IN COOPERATION WITH THE
COLORADO DEPARTMENT OF NATURAL RESOURCES,
DIVISION OF WATER RESOURCES, and the
COLORADO WATER CONSERVATION BOARD

INTRODUCTION

Bedrock aquifers underlie about 9,000 square miles in northeastern Colorado and are an important source of water for many urban areas, rural communities, farms, ranches, and industries. These aquifers outcrop and subcrop in a complex pattern along the western margin of the Denver Basin. In outcrop areas, the exposed bedrock aquifers are recharged by infiltration of precipitation. In subcrop areas where the bedrock aquifers directly underlie alluvial aquifers, either recharge or discharge may occur as the result of water movement between streams, alluvial aquifers, and the bedrock aquifers.

Expansion of urban areas can adversely affect the ground-water supplies that are needed to support growth of the urban area. For example, greater population produces greater demand for ground water, yet more extensive impervious areas (streets, parking lots, and structures) reduce precipitation recharge. Additionally, overapplication of fertilizer to urban lawns can degrade the chemical quality of recharge. Rational planning for urban growth needs to incorporate an understanding of the natural resources that may be preempted, degraded, or depleted by the urban growth. The need for better information on the location and extent of aquifer outcrop and subcrop areas in the rapidly growing Colorado Front Range Urban Corridor led to the detailed mapping of the bedrock aquifers of the Denver Basin presented in this report.

This work was undertaken as part of a U.S. Geological Survey National Initiative to investigate the effects of urbanization on the availability of natural resources such as water, minerals, energy, and biota. The water-resources work presented in this report was done in cooperation with the Colorado Department of Natural Resources, Division of Water Resources, and the Colorado Water Conservation Board.

The study area extends for about 100 miles north to south along the western margin of the Denver Basin and includes outcrop areas of the Laramie–Fox Hills, Arapahoe, Denver, and Dawson aquifers of the Denver Basin aquifer system (Robson and Banta, 1995). Geophysical logs from about 1,700 oil, gas, coal, and water wells were interpreted to provide data on the structural altitudes of the top or base of various bedrock aquifer units. The data base resides with the U.S. Geological Survey, Water Resources Division, Colorado District Office. Digital-spatial data pertaining to ground-water resource maps for the Front Range area of Colorado are accessable through the U.S. Geological Survey web site at http://water.usgs.gov/public/GIS/ or through the Infrastructure Resources Project web site at http://webserver.cr.usgs.gov/frirp/.

In this report, the outcrop of a bedrock aquifer is mapped where the bedrock is exposed at the land surface or is covered by a thin mantle of unconsolidated sediment. Subcrops are mapped where the bedrock aquifer is in hydraulic connection with and directly underlies the saturated alluvium of a principal alluvial aquifer (fig. 1). Principal alluvial aquifers generally are located along the valleys of the South Platte River and its larger tributaries.

Two procedures were used to define the outcrop and subcrop of the bedrock aquifers. North of Boulder, the outcrop and subcrop of the bedrock aquifer units were defined by mapping the intersection of the land-surface topography with the shallow, eastward-dipping geologic structure of the top and base of the aquifer unit. This procedure was necessary because most bedrock outcrops north of Boulder are concealed by an extensive mantle of unconsolidated sediments (overburden). Existing geologic maps of the area generally show only scattered small outcrops of bedrock units with little definition of the concealed units in extensive areas.

South of Boulder, the overburden is thinner and bedrock aquifer units generally are better exposed in outcrops of steeply dipping beds. Better exposures and sparse well data to define the subsurface structure in the area of steep dip required the use of existing or updated surficial geologic maps to define outcrops and subcrops.

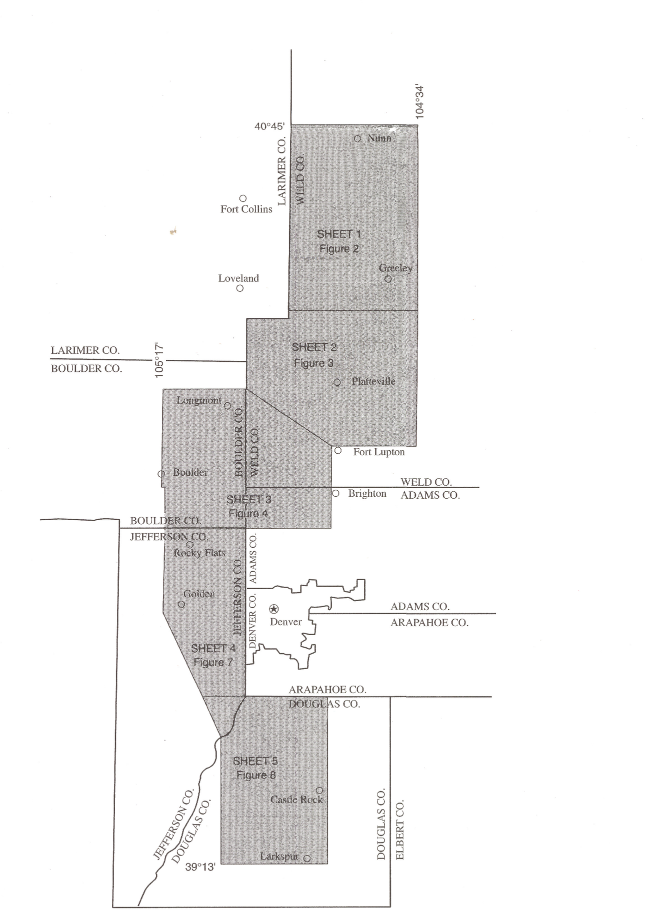
GEOHYDROLOGY

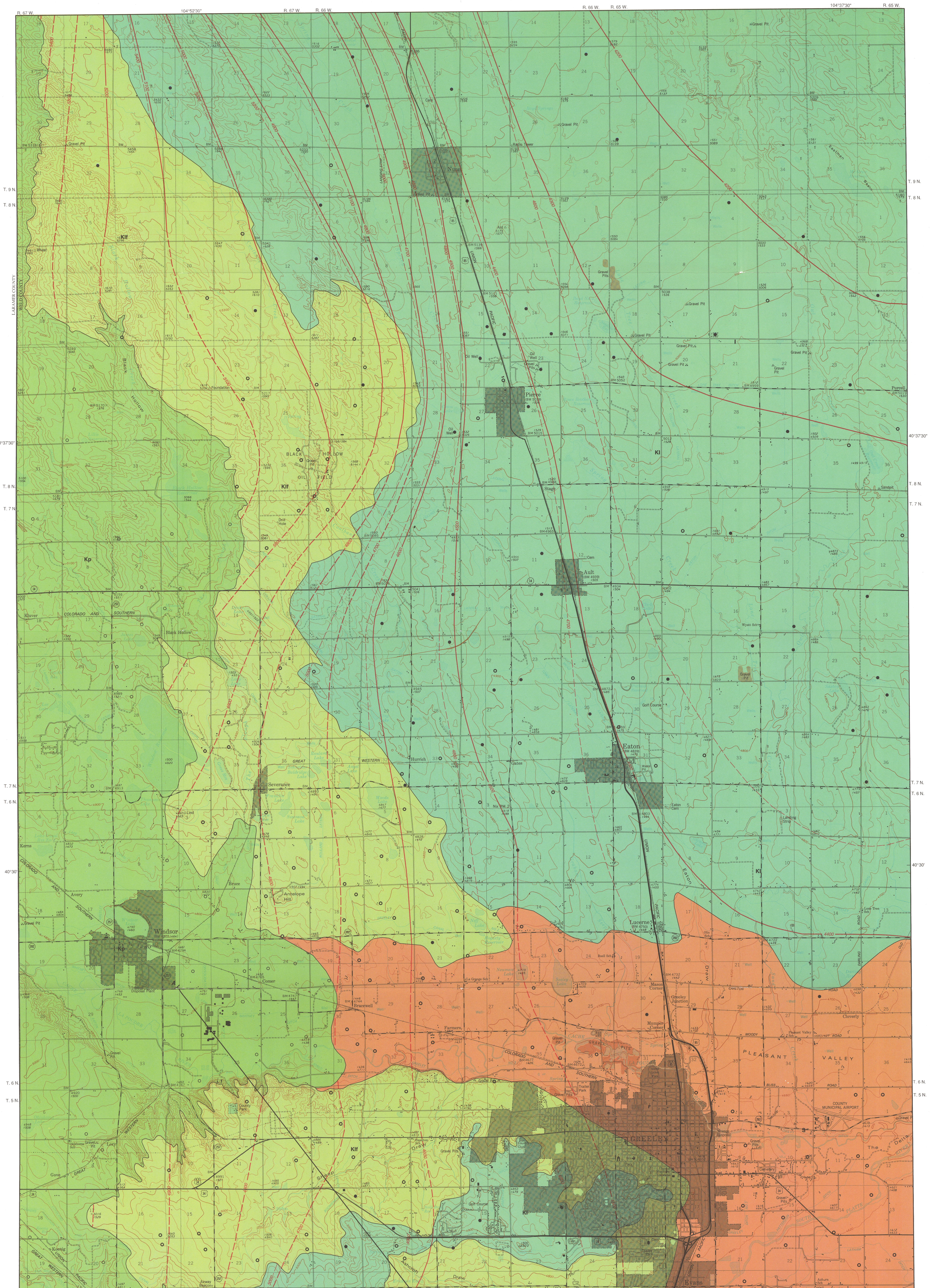
The Dawson, Denver, and Arapahoe aquifers are wholly contained within their corresponding formations, the Dawson Arkose, Denver Formation, and Arapahoe Formation (table 1). The Laramie–Fox Hills aquifer extends from the lower sandstone part of the Laramie Formation downward through the Fox Hills Sandstone and sometimes into sandstones in the upper part of the transition zone member of the Pierre Shale (table 1).

Table 1. Geohydrologic characteristics of the bedrock units in the study area

Era	System	Series	Geologic unit	Lithology	Geohydrologic unit	Unit thickness (feet)	Map symbol	Water-yielding character gpm (gallons per minute)
Cenozoic	Tertiary	Oligocene	Wall Mountain Tuff and Castle Rock Conglomerate undifferentiated	Conglomerate, sandstone, and tuff	Unsaturated Tertiary rocks	0 – 100	Tu	Does not yield water in study area.
		Eocene Paleocene	Dawson Arkose	Sandstone and conglomeratic sandstone with interbedded siltstone and shale. Sandstone is light gray to yellowish or pink, medium to very coarse grained, quartzose, arkosic, and poorly to well consolidated.	Dawson aquifer	0 – 400	Tdw	Uppermost aquifer in the Denver Basin. Water-table conditions exist in shallowest sandstone units; deeper units generally are confined. In areas of good permeability wells yield as much as 200 gpm.
Mesozoic	Cretaceous	Upper Cretaceous	Denver Formation	Shale, silty claystone, and interbedded sandstone. Sandstone is tan to olive-brown, very fine to medium grained, tuffaceous and andesitic, poorly to moderately consolidated. Beds of carbonaceous siltstone and lignite are common.	Denver aquifer	0 – 500	Tkd	Confined except in outcrop areas. Moderately permeable. Wells completed in thick sandstone intervals can yield as much as 300 gpm. More common yields range from 150 to 200 gpm.
			Arapahoe Formation	Sandstone and conglomeratic sandstone with interbedded siltstone and shale. Sandstone is light gray to orange or gray-yellow, fine to coarse grained, quartzose, and thickly bedded. Thick quartzose sandstone distinguishes this unit from more thinly bedded andesitic Denver Formation.	Arapahoe aquifer	0 – 600	Ka	Confined except in outcrop areas. Most permeable and heavily used aquifer in Denver Basin. Large-capacity wells commonly yield 750 to 1,000 gpm in most permeable area south of Denver. Of low permeability west of Denver.
			Laramie Formation — Upper part	Shale with interbedded siltstone and very fine grained sandstone. Contains seams of subbituminous coal.	Laramie confining layer	0 – 400	Kl	Generally not an aquifer. Thin discontinuous sandstones in upper part may yield 2 to 8 gpm.
			Laramie Formation — Lower part	Sandstone and siltstone with some interbedded shale. Sandstone is brown to olive gray, fine to medium grained, poorly to moderately consolidated, with pyrite and carbonaceous materials in some intervals.	Laramie–Fox Hills aquifer	0 – 400	Klf	Confined except in outcrop areas. Moderately permeable. Wells may yield 150 gpm or more in areas of thick sandstone units. Yields of less than 75 gpm with large drawdown are common in most areas.
			Fox Hills Sandstone	Sandstone, with some thin shale beds. Sandstone is tan to yellow-brown, very fine to fine grained, with thin to massive bedding. Dark brown, well indurated, calcareous or ferruginous concretions common.				
			Pierre Shale — Transition zone member	Sandstone, shale, and siltstone tan to olive gray. Sandstone is very fine to fine grained, medium to thin bedded, and interbedded with bioturbated shaley siltstone.				
			Pierre Shale	Shale, silty, medium to dark gray, dense, calcareous, bioturbated, fossiliferous, with thin laminae of carbonaceous material, with interbedded very fine to fine grained sandstone.	Pierre confining layer	0 – 8,000	Kp	Generally not an aquifer. Considered the base of the Denver Basin aquifer system. Well yields of 5 to 7 gpm may be possible from thin discontinuous sandstone units.
			Pierre Shale, and underlying undifferentiated Cretaceous rocks	Shale with scattered limestone or sandstone beds.	Pierre undifferentiated confining layer	0 – 9,000	Ku	
Paleozoic			Mesozoic and Paleozoic rocks, undifferentiated	Varied sedimentary lithology.	Mesozoic and Paleozoic rocks	0 – 3,000	MPu	Not an important aquifer in study area.
Precambrian			Precambrian rocks, undifferentiated	Granitic gneiss and schist.	Precambrian rocks	—	p€	Not an important aquifer in study area.

Modified from Romero (1976) and Robson (1987)





Base from U.S. Geological Survey
1:50,000 County map for Weld County

FIGURE 2. Structure, outcrop, and subcrop of the Laramie–Fox Hills aquifer in the Greeley area

SCALE 1:50,000

0 1 2 3 MILES

0 1 2 3 KILOMETERS

CONTOUR INTERVAL 20 FEET
DATUM IS SEA LEVEL

EXPLANATION

GEOHYDROLOGIC UNIT OUTCROP
See Table 1 for additional description

- Kl — Laramie confining layer
- Klf — Laramie–Fox Hills aquifer
- Kp — Pierre confining layer
- S — Subcrop of Laramie–Fox Hills aquifer under principal alluvial aquifer

STRUCTURE CONTOURS

- 5000 — Altitude of base of Laramie–Fox Hills aquifer. Dashed where inferred from correlated geophysical logs. Interval 100 feet. Datum is sea level.
- 5000 — Altitude of top of Laramie–Fox Hills aquifer. Dashed where inferred from correlated geophysical logs. Interval 100 feet. Datum is sea level.

GEOLOGIC CONTACT—Location inferred from intersection of structural and topographic surfaces

A A' TRACE OF GEOHYDROLOGIC SECTION—Section shown in figure 1

1 Strike and dip of beds

DATA POINTS

- ● Well with geophysical log that extends upward at least to the base of the Laramie–Fox Hills aquifer
- ○ Well with geophysical log that does not extend upward to the base of the Laramie–Fox Hills aquifer. Altitude of base of aquifer inferred by correlation to marker beds in upper part of Pierre Shale
- ○ Well where inferred base of Laramie–Fox Hills aquifer is above land surface

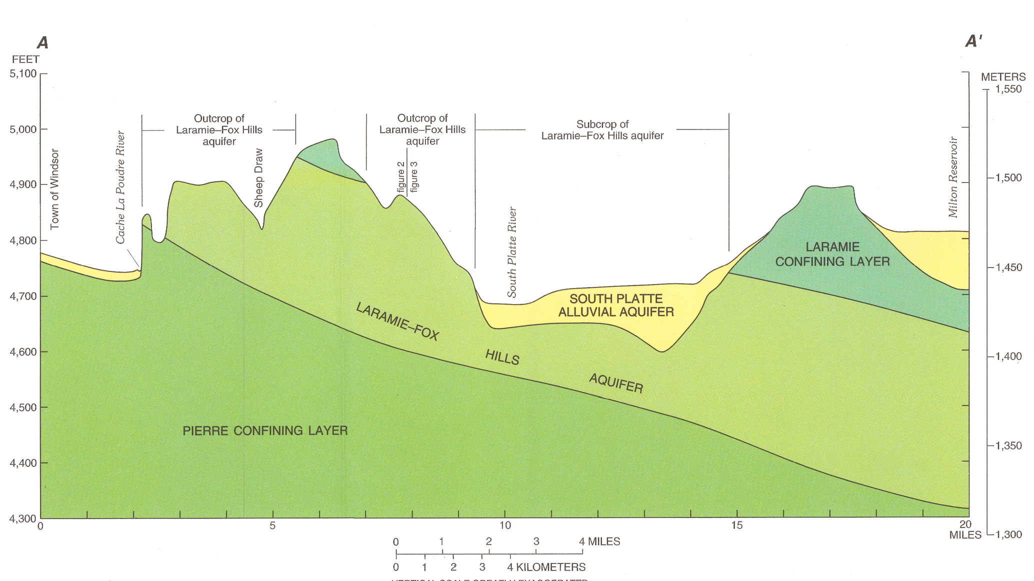


FIGURE 1. Geohydrologic section of the alluvial and bedrock aquifers south and west of Greeley.

STRUCTURE, OUTCROP, AND SUBCROP OF THE BEDROCK AQUIFERS ALONG THE WESTERN MARGIN OF THE DENVER BASIN, COLORADO

by

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