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GROUND-WATER RESOURCES IN THE CARRIZOZO AREA, NEW MEXICO

BHASKER K. RAO
New Mexico State Engineer Office, Santa Fe, NM 87503

Abstract—Ground water near Carrizozo, New Mexico, occurs in alluvium and in consolidated aquifers of Cretaceous age. Recharge to the aquifers occurs along mountain fronts. The mountain-front recharge is estimated to be approximately 3,000 acre-ft/year or nearly 7.5% of the precipitation. Observed water-level declines indicate local ground-water mining.

PURPOSE AND SCOPE

The purpose of this paper is to describe the current ground-water conditions near Carrizozo, New Mexico, and to provide estimates of ground-water recharge and availability. Recent, unpublished hydrologic data on water levels, water quality, irrigated acreage and ground-water pumpage for the Carrizozo area were collected and analyzed. Ground-water recharge is estimated using mountain-front recharge models.

Basic hydrogeologic information for the Carrizozo area is available in previous studies (Cooper 1964, 1965 and unpubl., G.E. Hendrickson unpubl., Weber 1964). Most of the well inventory and water-level data are obtained from Cooper (1965) and U.S. Geological Survey computer databases. Data were analyzed for an area covered by T7S through T9S and R10E through R12E, which includes the village of Carrizozo and surrounding areas of ground-water development.

HYDROGEOLOGY AND HYDROLOGY OF THE CARRIZOZO AREA

Important aquifers in the Carrizozo area consist of Quaternary alluvium and Cretaceous sandstones (Weber 1964: fig. 2). Eastward-dipping Upper Cretaceous (Mesaverde Group) sandstones underlie the alluvium. Mancos Shale and Dakota Sandstone, also Cretaceous, underlie the Mesaverde. Numerous springs found in the area are either associated with Cretaceous outcrops or issue from alluvium at places where rock ledges form subsurface dams. The eastward-dipping Cretaceous strata have been intruded by igneous rocks in many places. These intrusives form barriers to ground-water movement in the Cretaceous rocks, resulting in complex hydrogeologic conditions in the areas of intrusive activity.

The alluvium ranges in thickness from a few meters west of Carrizozo to more than 30 m near the center of the Carrizozo plain (the area east of Carrizozo). From the center of the Carrizozo plain to the mountains, the alluvial thickness decreases to almost zero. The alluvium consists of heterogeneous deposits of unconsolidated clay, silt, sand, gravel, and boulders. Much gypsum is present in the clay deposits.

Ground water occurs in the alluvium under unconfined conditions. There is no indication that ground water in the Mesaverde Group is under confined conditions; and it is probable that, in part of the area, there is a hydraulic connection between the alluvium and the Mesaverde Group (J.B. Cooper unpubl.).

GROUND-WATER RECHARGE

Recharge to the alluvium is from runoff in an area of about 125 km^2 in the mountains east of Carrizozo. With an estimated average annual precipitation of about 38 cm, about 40,000 acre-ft of water are received as precipitation in this area each year (G.E. Hendrickson unpubl.). Cooper (1965) indicated that recharge to the alluvium may be only a small part of the total precipitation. High evaporation and transpiration losses are probable during hot summer months. Keith (1980) observed that winter precipitation is primarily responsible for mountain-front recharge. Near Carrizozo, more than 60% of the precipitation occurs during summer months. The percentage of precipitation that recharges the aquifer is difficult to estimate; however, some guidelines are available.

Maxey & Eakin (1949) developed a recharge model which assumes that mountain-front recharge is a function of elevation–precipitation relationships. Based on the Maxey–Eakin model, precipitation–recharge relationships were developed for the desert basins of Nevada (Watson et al. 1976). A 30–38 cm precipitation zone is estimated to contribute approximately 7% of the precipitation to recharge. Hood & Waddell (1968) estimated the average annual recharge to Skull Valley, Utah, using the Maxey–Eakin technique adjusted to the conditions of Skull Valley. The calculations indicated an average annual-recharge rate of about 6–7% of average annual precipitation.

Keith (1980) discussed the usability and soundness of different mountain-front-recharge models. The Darcy model (Beses et al. 1978) is considered most desirable where water-level contours parallel the mountain front and where transmissivity data are available. In this method, recharge is calculated as underflow across an equipotential line according to Darcy's law, $Q = TIL$, where Q = recharge, T = transmissivity, I = gradient, and L = cross-sectional width of aquifer. Because the 1957 water-level contour map for the Carrizozo area (Cooper 1965) shows water-level contours to be parallel to the mountain front, this method can be used to calculate recharge using values for T, I, and L as described below.

Reported pumping and drawdown data, along with well diameter and duration of pumping, are available for three wells (J.B. Cooper unpubl.). Calculated specific capacities ranged from 5.7 gpm/ft to 12.6 gpm/ft. Transmissivity was estimated from specific capacity using the method described by Theis (1963), assuming a specific yield of 0.2. Estimated transmissivity for a well in sec. 14, T8S, R10E was 2,000 ft^2/day and the well was screened in both alluvium and Cretaceous rocks. Estimated transmissivity for a well in sec. 21, T8S, R10E was 1,000 ft^2/day and the well was screened in Cretaceous rocks. Estimated transmissivity for a well in sec. 6, T8S, R11E was 850 ft^2/day and the well was screened in alluvium.

An equipotential line corresponding to 1,722 m water-level contour (Cooper 1965) was selected for calculating underflow. A cross-sectional width of 13 km and a gradient of 75 ft/mi were estimated and used for underflow calculation. The only available estimate of alluvial transmissivity is from a well in sec. 6, T8S, R11E and is equal to 850 ft^2/day. Because of lack of transmissivity data for the alluvium, the heterogeneous nature of the alluvium, and uncertainty over the saturated thickness, it is difficult to determine with certainty an average transmissivity value for recharge calculations. A transmissivity value of 600 ft^2/day was selected as a low estimate within a reasonable range.

When the Darcy model was applied to the Carrizozo area, it yielded recharge estimates of approximately 3,000 acre-ft/year or nearly 7.5% of the precipitation on the mountains. This compares well with the Maxey–Eakin estimates of mountain-front recharge for Nevada (Watson et al. 1976) and Utah (Hood & Waddell 1968).

Natural discharge from the alluvium occurs in the form of evapotranspiration, springs, and possibly some leakage to the Mesaverde Group. The remaining amount of the recharge is believed to flow into the malpais (lava beds located about 6 mi west of Carrizozo).

Recharge to the Mesaverde Group may occur by downward leakage from the alluvium or upward leakage from deeper Cretaceous rocks.

Deeper Cretaceous rocks (Dakota Sandstone) probably receive most of their recharge in the area to the west where they are directly overlain by the malpais. In the Carrizozo area, these Cretaceous sandstones are deeper than 1,220 m (Weber 1964: fig. 2); and significant upward leakage from these rocks to the Mesaverde Group that lies beneath the alluvium is not likely because the Mancos Shale, which is low in permeability (Weber 1964: fig. 2), separates the Dakota Sandstone from the overlying Mesaverde Group. It is also possible that most of the precipitation on the malpais may move southwest as shallow-subsurface flow along the old stream channel over which malpais are deposited and may not significantly recharge the Dakota Sandstone (J.W. Hawley oral comm. 1985).

PRESENT GROUND-WATER DEVELOPMENT

The ground-water database for the well inventory contained records for 119 wells. Of these, 59 are stock wells, 13 are irrigation wells, 10 are domestic wells, one is a public supply well, one is an industrial well, and the remaining 35 are listed as unused wells. Sixty-one wells are pumped from alluvium, 24 from rocks of the Mesaverde Group, and five from alluvium and rocks of the Mesaverde Group. No information is available for the remaining 29 wells. Information about well yields was available for only 14 wells. Yields for wells in alluvium ranged from 100 gpm to 400 gpm. Yields for wells finished in rocks of the Mesaverde Group ranged from 25 gpm to 1,080 gpm.

Wells deeper than 30 m are likely to obtain water from both alluvium and rocks of the Mesaverde Group, or from the Mesaverde Group alone where the alluvium is thin or non-existent.

According to data provided by Sorensen (1982), there were 360 acres irrigated by ground water near Carrizozo in 1980. Total ground-water withdrawal for irrigation during that year was 1,150 acre-ft. This estimate comes from calculated consumptive-use requirements and an assumed irrigation efficiency. The State Engineer Office files indicate that the ground-water discharge from stock and domestic wells is small and probably less than 150 acre-ft/year. Sorensen (1982) reported that only 17 acre-ft of ground water were withdrawn for community supply in 1980. The current estimated ground-water extraction in the Carrizozo area is, therefore, approximately 1,350 acre-ft/year.

HISTORICAL WATER-LEVEL CHANGES

The water-level database contained records for more than 100 wells in the study area near Carrizozo. The number of years for which water-level data were available varied from well to well. Data were available as early as 1957 and up to 1984. Most of the water-level measurements were made consistently during the months of January through April. Changes in water levels could be calculated for only 50 wells.

Average annual rates of water-level changes for each well were calculated for the entire period of data and for a consecutive five-year period from the latest data. When data did not permit the calculation of water-level change rates for a five-year period, another time period was chosen.

A listing of selected wells and corresponding critical rates of water-level change is provided in Tab. 1. The "critical rate of water-level change" for a given well is defined as the maximum of historical rate of change and recent rate of change. Twenty-nine wells showed critical rates of water-level change equal to or greater than 0.5 ft/year. A positive change of water level in the table indicates a water-level rise. Twenty-one wells show water-level declines ranging from 0.5 to 7.1 ft/year. The remaining eight wells show water-level rises ranging from 0.7 to 3.1 ft/year.

Water-level changes can result from a variety of hydrologic phenomena. Water levels generally respond to long-term changes in precipitation or recharge and ground-water withdrawals. The observed water-level declines probably are not due to lower-than-normal precipitation, because precipitation near Carrizozo has been close to normal during the past decade. Pumpage information for individual wells in the Carrizozo area is not available. Correlation of the observed rates of water-level changes with pumpage is, therefore, difficult.

TABLE 1—Critical rates of water-level change for selected wells near Carrizozo, New Mexico.

Well number	Period of calculation	Critical rate of change (ft/yr)
07S.11E.31.3440	1981-84	- 2.6
07S.11E.35.2100	1976-81	- 6.8
08S.10E.01.4320	1976-81	- 1.4
08S.10E.03.1000	1978-84	- 0.8
08S.10E.04.1430	1981-84	- 3.3
08S.10E.04.3000	1976-78	- 1.1
08S.10E.09.1000	1978-84	- 1.5
08S.10E.13.1330	1957-78	- 0.7
08S.10E.22.2000	1978-84	- 0.8
08S.10E.25.3110	1978-84	- 5.3
08S.10E.32.4000	1978-84	- 0.5
08S.11E.02.1430	1981-84	- 1.2
08S.11E.02.4240	1981-84	- 1.2
08S.11E.02.4310	1981-84	- 1.0
08S.11E.04.2330	1981-84	- 1.8
08S.11E.06.431a	1978-84	- 1.1
08S.11E.11.2110	1976-78	- 0.6
08S.11E.12.1130	1981-83	- 5.0
08S.11E.14.1110	1976-81	- 7.1
08S.11E.15.2220	1982-84	- 1.2
09S.10E.06.4310	1978-84	- 1.4
07S.10E.28.2000	1976-83	+ 0.7
07S.10E.29.2220	1978-84	+ 1.0
08S.10E.10.2200	1981-84	+ 2.5
08S.10E.10.4000	1976-78	+ 0.8
08S.10E.17.3430	1978-84	+ 0.7
08S.11E.06.3100	1978-84	+ 3.1
08S.11E.06.4400	1981-84	+ 3.0
08S.11E.11.4200	1981-84	+ 1.3

PROJECTIONS OF FUTURE WATER-LEVEL CHANGES

No evidence of significant recent increases in well pumpage near Carrizozo is available. However, based on water-level changes in wells over time, it is believed that, even if pumpage continues at the present level, local ground-water mining near Carrizozo probably will continue to occur.

QUALITY OF GROUND WATER

Water-quality information included 102 observations from 1911 to 1982. Water-quality data over time from individual wells were not available, precluding detection of long-term trends. For alluvial wells, sulfate ranged from 300 to 2,160 mg/l with an average of 823 mg/l. Total dissolved solids ranged from 770 to 4,960 mg/l with an average of 1,906 mg/l. For wells tapping rocks of the Mesaverde Group, sulfate ranged from 215 to 2,210 mg/l with an average of 769 mg/l. Total dissolved solids ranged from 790 to 3,320 mg/l with an average of 1,501 mg/l. Water in rocks of the Mesaverde Group seems to be of slightly better quality than water in the alluvium.

CONCLUSIONS

The mountain-front recharge occurring from the mountains east of Carrizozo is estimated to be approximately 3,000 acre-ft/year. This is the amount of renewable ground water in the alluvial and Cretaceous aquifers in the Carrizozo area. It is not possible to withdraw this amount, however, without some local mining of ground water and resulting drawdowns. Therefore, the recent rates of water-level decline, which range from 0.5 to 7.1 ft/year, should be considered in future ground-water development in the Carrizozo area.

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