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HYDROGEOLOGY OF THE NATIONS DRAW AREA, WEST-CENTRAL NEW MEXICO

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Abstract—Due to a lack of perennial streams, the main source of water in the Nations Draw area is groundwater. Most wells obtain water from valley-fill alluvium and/or Cretaceous sandstones at or near the surface. Direct groundwater recharge by precipitation is low, 0.02–0.08 inch/yr. Recharge also occurs through transmission loss along streams, but has not been quantified. Groundwater flows westerly, in response to topography, despite the southeasterly dip of strata. Water quality is generally poor, owing to the abundance of mudstone in the sequence, and the major use is stock watering. The discovery of good-quality artesian water in the Dakota Sandstone by the Salt River Project expands the known resources of the area, but this water may not be readily available to most potential users because of its great depth (1000 ft).

INTRODUCTION

Little hydrogeologic work has been done on many sparsely populated areas of New Mexico. Exceptions are irrigated agricultural areas or areas with economically significant mineral resources, such as around Nations Draw, a west-flowing ephemeral stream approximately 12 mi north of Quemado in Catron County. Leasing and exploration activity in the Salt Lake Coal Field during the 1980s prompted various hydrogeologic studies in the Nations Draw area. Several studies were done by the Salt River Project (SRP), Phoenix, AZ, the principal lease holder (Anonymous, 1983; Seifert and Greenberg, 1985). The Energy and Minerals Department of the New Mexico Mining and Minerals Division funded a study by the New Mexico Bureau of Mines and Mineral Resources (NMBMMR) of pre-mining groundwater recharge in major landscape settings in the Cerro Prieto 7.5' quadrangle (Stone, 1984). The Salt River Project contracted with the NMBMMR to formulate a conceptual hydrogeologic model of the region surrounding their leasehold in the Salt Lake Coal field. This involved a New Mexico Tech master's thesis covering a two-quadrangle (7.5') by four-quadrangle area centered on Nations Draw (McGurk and Stone, 1986). Implications of that study for coal mining in the area were presented by Stone and McGurk (1987). This paper briefly summarizes the findings of these previous studies and their bearing on groundwater resources of the area. For more detailed information, the reader is encouraged to consult the original references.

REGIONAL SETTING

The Nations Draw area is within the Zuni-Acoma section of the Colorado Plateau physiographic province. Topography is characterized by broad mesas with gently west-sloping tops, volcanic necks and broad stream valleys. Drainage is by west-flowing ephemeral streams that feed Carrizo Wash, a tributary of the Little Colorado River. The climate is arid to semiarid with annual precipitation averaging 9–15 in. across the area and potential evaporation amounting to two to three times precipitation. Vegetation consists mainly of piñon and juniper trees on the mesas and grasses in the valleys, but cacti, yucca and forbs (weeds) also occur.

Geologically, the Nations Draw area lies within the middle Eocene Baca basin, a narrow foreland basin at the southeastern margin of the Colorado Plateau. The geology and coal resources of the area were described by Campbell (1981, 1984). Coal-bearing rocks of the Cretaceous Moreno Hill Formation (Fig. 1) lie at the surface or beneath thin alluvium throughout most of the area. Tertiary strata of the Baca Formation, lower Spears Group, and Fence Lake Formation cap the Moreno Hill Formation at higher elevations. Underlying the Moreno Hill, but not cropping out in the immediate area, is the Atarque Sandstone. Little is known of the deeper units, but drilling by the Salt River Project (1983) penetrated the Dakota Sandstone at a depth of over 1000 ft on their lease. Regional dip is gentle, <3° to the southeast, except near volcanic features. The Tejana Mesa fault, a northeast-trending zone of high-angle normal faults crossing the southeastern corner of the area, causes up to 250 ft of stratigraphic throw in places (Guilinger, 1982).

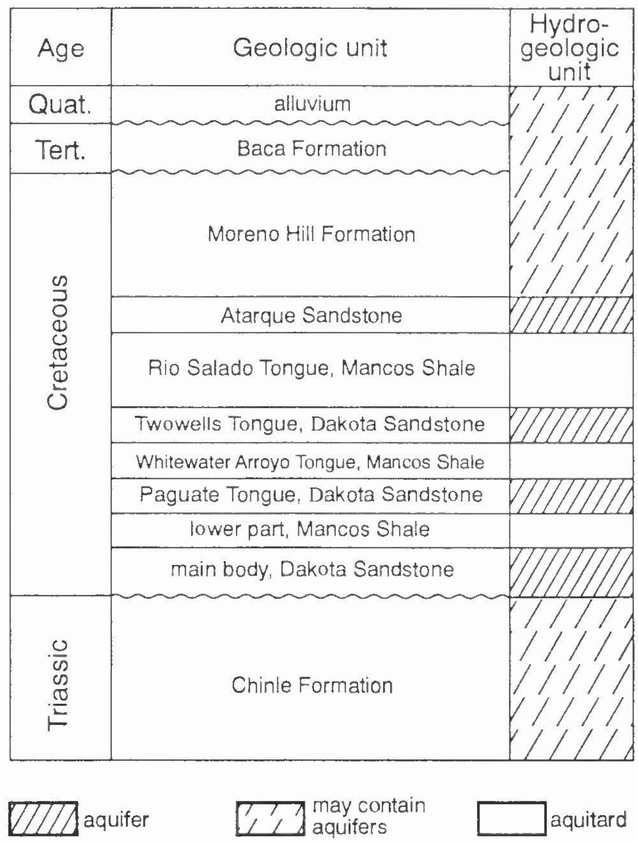

FIGURE 1. Hydrogeologic units in the Nations Draw area (McGurk and Stone, 1986). The lower Spears Group (Eocene) and Fence Lake Formation (Miocene), which are present near Nations Draw, are not shown because they generally cap mesas and lie above the regional zone of saturation. Diagram is not drawn to scale.

GROUND-WATER OCCURRENCE

Although water could be obtained from any of the Cretaceous sandstones, most wells in the area are screened in the shallower sandstones of the Moreno Hill Formation and/or the alluvium (Fig. 1). The depth to regional water table ranges from <20 ft in the major valleys in the west to >900 ft beneath higher elevations, such as Tejana Mesa. Perched water bodies may occur at shallower depths beneath mesas, especially where sandstone is underlain by mudstone.

Quaternary alluvium

The ephemeral stream valleys are underlain by unconsolidated deposits of gravel, fine- to coarse-grained sand, silt and clay. Two distinct units are generally present in this fill. The upper unit consists of

0–130+ ft of light-brown sand and sandy clay with gray sticky clay at the bottom. The lower unit consists of up to 80 ft of buried valley deposits of coarse sand and gravel. The gravel is composed of large, angular rock fragments near the base and volcanic cinders near the top. The lower unit is continuous within the buried valleys, but does not appear to extend beyond their boundaries. Between the lower unit and the underlying Moreno Hill Formation is typically a thin interval of weathered bedrock. The maximum known thickness of alluvium is 190 ft, observed near the confluence of Frenches and Nations Draw.

The alluvium is probably saturated in the center of major valleys, like Nations Draw and Tejana Draw. Saturated thickness in Nations Draw ranges from 0 to 79 ft, with the maximum occurring 1 mi southeast of Cerro Prieto windmill. In Tejana Draw saturated thickness ranges from 0 to 55 ft, with the maximum occurring 1 mi southeast of Tejana windmill.

SRP has completed a production well and several monitoring wells in the basal sand and gravel unit of the alluvium. A 15-day yield of 200 gpm was projected from test data for the production well (Anonymous, 1986). A specific capacity of 5.7 gpm/ft of drawdown was obtained by pumping at a rate of 350 gpm for 1 hr. Storativity determined at one well tested (0.000337) indicated the basal sand and gravel unit is at least partly confined by the overlying finer-grained materials of the upper unit.

Moreno Hill Formation

Nonmarine sandstones, mudstones and coal of the Moreno Hill Formation crop out everywhere in the area, except where overlain by alluvium or Tertiary deposits. These strata are believed to represent deposition in meandering to braided fluvial systems. The Moreno Hill may be divided into three members, based on the presence of a middle sandstone unit. The upper member (present only on higher mesas) consists of up to 600 ft of yellow and green siltstones and claystones with minor amounts of carbonaceous shale, coal and ledge-forming sandstones (Campbell, 1984). The middle member consists of up to 80 ft of pinkish-yellow, medium- to coarse-grained, crossbedded sandstone having little or no silt or clay matrix. The middle member pinches out in the subsurface along a northeast-southwest-trending line just east of the volcanic neck known as Cerro Prieto. East of this line, where the middle sandstone member is missing, the Moreno Hill is generally not subdivided. The lower member has a thickness of 0–600 ft and is lithologically similar to the upper member, but sandstone, carbonaceous shale and coal are more abundant.

The upper and middle members are above the regional water table and the saturated thickness of the Moreno Hill Formation (where the unit can be subdivided) is that of the lower member. Values range from zero in the northwestern part of the Nations Draw region to 1200 ft in the southwest, where regional dip takes the entire formation (undivided) below the water table. Hydraulic properties of the Moreno Hill Formation have not been extensively studied. Slug and pumping tests by SRP have provided some insight. Transmissivity (T) values from twelve tests of sandstone range from approximately 1 to 457 ft^2/day. Fractures were found to account for only 3% of the porosity of the coals but to have 20 times the conductivity of the unfractured matrix, based on response testing of piezometers. Transmissivity values obtained by SRP from five tests of coal range from 2 to 19 ft^2/day. A single measurement for shale gave a T value of approximately 4 ft^2/day.

Dakota Sandstone

In 1983, SRP penetrated the Dakota Sandstone at a depth of approximately 1000 ft in their leasehold. In this area the Dakota consists of three members separated by tongues of Mancos Shale: the Twowells, Paguate and main body, in descending stratigraphic order. The main body is 100 ft thick with coal measures at the top and fine- to medium-grained, white, quartzose fluvial sandstone at the bottom. Video logging showed the main body of the Dakota to be fractured and conglomeratic at the base. Water in the Dakota was found to be under artesian pressure and rose to a height of 191 ft above the ground surface. Pumping tests yielded T values of 709 ft^2/day and a 1-hr specific capacity of 0.86 gpm/ft (Anonymous, 1983).

GROUNDWATER MOVEMENT

Groundwater movement in any area has recharge, flow and discharge components. Recharge and discharge both include the area over which they take place, the process by which they are accomplished and the rate at which they occur. Flow includes both direction and rate of groundwater movement.

Recharge

Groundwater in the Nations Draw area is recharged in part by direct infiltration and percolation of precipitation on higher elevations and in part by transmission loss (seepage) and percolation along ephemeral stream channels. No attempt was made to measure recharge due to transmission loss: direct recharge was investigated using the chloride mass-balance method. The method gives a long-term average recharge rate and is described in various reports (e.g., Stone, 1990, 1992).

This recharge study involved sampling the unsaturated zone and determining the soil-water chloride content versus depth under five landscape settings believed to characterize the area (Stone, 1984). These settings were recognized on the basis of topography, geologic material and vegetation. They include thick alluvium, ephemeral lake, thin alluvium, bedrock/trees and bedrock/grass. The rates determined range from 0.02 inch/yr for the ephemeral lake to 0.08 inch/yr for the alluvium. Intermediate values of 0.05 inch/yr were obtained for the bedrock settings.

The volume of recharge occurring in an area is the sum of the volumes for each setting making up the area. The volumetric recharge for a given setting is calculated by multiplying its recharge rate by its area. The impact of coal mining on the hydrologic balance of an area may be determined by comparing the pre-mining and post-mining recharge volumes (Stone, 1990). This process in the Salt Lake Coal Field will be facilitated by the availability of pre-mining recharge data collected by Stone (1984).

Cumulative soil-water chloride data may be used to approximately date soil water (Allison et al., 1985). The application of this method to data from the Nations Draw area shows that the approximate age of soil water within 60 ft or so of the surface ranges from 5000 to 21,000 yrs. Recharge rates calculated for the older and deeper portions of the unsaturated profiles are generally higher than those for younger and shallower intervals. This agrees with the findings for the nearby San Agustin Plains (Markgraf et al., 1983), that the region was wetter between 8500 and 10,000 years ago, but started to dry out around 8000 yrs ago and that by 5000 yrs ago San Agustin Lake was desiccated.

Flow

Three scales and depths of groundwater flow seem likely in the Nations Draw area. Water in the Moreno Hill Formation and alluvium constitutes a local, shallow flow system. Movement is generally from upland recharge areas toward and then beneath stream valleys. Water in Cretaceous units below the Moreno Hill Formation presumably constitutes an intermediate flow system. There are too few data to determine its flow direction in any detail. However, there is an upward component, based on the artesian conditions associated with the Dakota Sandstone in SRP's deep well. Water in the underlying Permian and Triassic units probably constitutes a deep, regional flow system.

Flow rate depends on hydraulic conductivity (K) of the saturated material. Horizontal K values are greatest for the alluvium, ranging from 0.34 to 15 ft/day. The highest value is associated with the basal sand and gravel. Values for the Moreno Hill Formation range from 0.12 to 13 ft/day, with the high value corresponding to a sandstone.

Discharge

The ultimate discharge areas for all ground water in the Nations Draw area are the deeper stream valleys, especially those lying to the west. The shallow flow system discharges to stream beds not far from recharge areas. The intermediate and deep flow systems probably discharge much farther away. Production wells provide for artificial discharge of the hydrologic system. Although the rate or amount of discharge has not been quantified, it will essentially equal recharge.

GROUNDWATER QUALITY

Specific conductance, an electrical property related to the salinity of a water or the amount of dissolved solids in it, is a general measure of water quality. The larger the number, the poorer the quality. Values from the Nations Draw area show the quality of groundwater there to be rather poor. The major use is stock watering.

Specific conductance values for ground water from the Quaternary alluvium range from 211 to 1093 μmhos/cm. Analyses plot in the sodium-bicarbonate fields of a trilinear or Piper diagram. Water from the alluvium is suitable for livestock, marginally suitable for human consumption and unsuitable for irrigation.

Water from the Moreno Hill Formation is characterized by specific conductance values of 211–1250 μmhos/cm. Most analyses plot in the sodium-bicarbonate or calcium-bicarbonate fields. Some waters have subequal amounts of calcium, sodium, bicarbonate and sulfate. Shallower sandstones in the Moreno Hill provide water for stock and domestic use throughout the area. Some wells are open to both the alluvium and Moreno Hill.

Water in the Dakota Sandstone well is reported to be of good quality. Based on three readings over as many months, an average specific conductance value of 638 μmhos/cm and an average total dissolved solids content of 377 mg/L was obtained (Anonymous, 1983).

GEOLOGIC CONTROLS OF HYDROLOGY

The hydrology and water resources of the Nations Draw area are strongly controlled by its geologic setting. For example, major producible water is associated with the more porous and permeable materials such as alluvium and sandstones. Recharge is highest where the most porous and permeable of these lie at the surface. The westerly groundwater flow direction is contrary to the southwesterly dip of the strata and largely a consequence of topography/geomorphology. The poor water quality is attributable to the presence of fine-grained material in the section. Such material is characterized by a large particulate surface area and slow flow rates, both of which enhance dissolution of ions and thus salinity. The occurrence of fresher water in the Dakota Sandstone is due to its nonmarine origin here. This produced a cleaner (less fine material) aquifer than elsewhere in the region, where the Dakota is of marine origin and yields water with high total dissolved solids and elevated iron contents.

IMPLICATIONS FOR WATER RESOURCES

As there are no perennial streams in the Nations Draw area, the main source of water is groundwater in the alluvium along valleys and sandstones in the Cretaceous bedrock section. Such water is not overly abundant and care should be taken that pumping volumes do not exceed the low recharge volumes. Over-pumping the alluvium or Moreno Hill aquifers could cause water levels to drop, requiring the deepening of wells.

The discovery of good-quality artesian water in the Dakota Sandstone provides an alternative source of water for the area. However, its great depth will keep it out of reach of most potential users. When it is utilized, care should be taken so that pumping does not cause a reversal of gradient to the detriment of its water quality. Extensive pumping of the Dakota Sandstone could reduce artesian pressure such that gradients reverse, causing poor quality water from the overlying Cretaceous units to flow into the Dakota. Such a reversal occurred in the Grants region, where uranium-mine dewatering so lowered the head in the Morrison Formation that poor-quality water from the overlying Dakota Sandstone was being pumped from wells completed in the Morrison (Kelly et al., 1980).

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Day 2 Stop 5
Jordan 93