Hydrogeologic and Hydrochemical Framework, South-Central Great Basin, Nevada-California, with Special Reference to the Nevada Test Site

GEOLOGICAL SURVEY PROFESSIONAL PAPER 712-C

Prepared on behalf of the U.S. Atomic Energy Commission

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HYDROLOGY OF NUCLEAR TEST SITES

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UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON : 1975

level. Thus, the water table beneath this playa is 20 feet lower than the water table beneath the playa in northern Stewart Valley and is 130 feet lower than that beneath the playa in northwestern Pahrump Valley. The water table in the valley-fill aquifer in northern Stewart Valley and in northwestern Pahrump Valley thus stands well above levels in the same aquifer to the south-southeast and to the northwest. This difference in altitude and saturation of the valley fill nearly to the surface beneath the playas in Stewart and western Pahrump Valleys suggest that the ground water in these areas is ponded by some impermeable boundary, namely, the lower clastic aquitard. Such ponding does not preclude underflow of small magnitude. In contrast, the playa in southwestern Pahrump Valley is bordered on the southwest by the Nopah Range, which is composed predominantly of the lower carbonate aquifer. Malmberg's (1967) potentiometric contours for the valley-fill aquifer reproduced on plate 1 of this report indicate that ground water in this aquifer is moving toward (and into) the Nopah Range.

In summary, the preceding evidence indicates that at most only a few percent of the Ash Meadows discharge can be derived from either Stewart Valley or western and northwestern Pahrump Valley.

SOURCES OF RECHARGE TO THE LOWER CARBONATE AQUIFER

Within the basin boundary delineated on plate 1, the lower carbonate aquifer is recharged principally by precipitation in areas of high rainfall and favorable rock type and secondarily by downward leakage of water from the Cenozoic hydrogeologic units. Underflow into the basin from the northeast may also constitute a major source of recharge.

PRECIPITATION

Recharge from precipitation is probable beneath and immediately adjacent to the highly fractured Paleozoic carbonate rocks of the Sheep Range, northwestern Spring Mountains, southern Pahranagat Range (south of State Highway 25; fig. 1), and, to a lesser extent, beneath the Pintwater, Desert, and Spotted Ranges. The approximate average annual precipitation within the Ash Meadows basin is about 320,000 acre-feet on the Sheep Range, about 100,000 acre-feet on the northwestern Spring Mountains, and about 90,000 acre-feet on the southern Pahranagat Range (fig. 3). For these mountains, the 8-inch isohyetal contour roughly corresponds with the lowest outcrop of Paleozoic bedrock, Precipitation on the lower Desert, Pintwater, and Spotted Ranges was estimated only for those parts of the ranges receiving 8 inches or more rainfall. This amounted to about 60,000 acre-feet.

Thus, a total of about 570,000 acre-feet of precipitation falls annually within the basin on prominent ridges and mountains that are composed principally of the lower carbonate aquifer. This quantity is an approximation at best: precipitation that falls on carbonate-rock outcrops at low altitudes in the Spotted, Pintwater, or Desert Ranges or on the other minor hills and ridges in the region was not included; conversely, some of the precipitation included in the tabulation falls on the valley fill bordering the mountains, or on clastic rock, and not on the lower carbonate aquifer; it should be subtracted from the total. The preceding estimate could have been refined by planimetering the area of carbonate-rock outcrop for select altitude zones and by applying Quiring's (1965) altitude-precipitation curves of the region; however, such precision is unwarranted because of the approximate nature of the basin boundary.

Precipitation falling on the valley floors underlain by carbonate rocks was not estimated because recharge to either the lower carbonate aquifer or the younger aquifers beneath such areas seems improbable under present climatic conditions. Moreover, recharge to carbonate rocks beneath the valleys is controlled by the tuff aquitard.

Assuming that the spring discharge at Ash Meadows is derived principally from precipitation falling on carbonate-rock uplands within the boundaries of the Ash Meadows basin (pl. 1) and that steady-state conditions exist in the ground-water basin, the percentage of rainfall that infiltrates to the carbonate aquifer beneath the ranges can be estimated. Using the 17,100 acre-feet of measured spring discharge (average of two values given in table 7) and the precipitation estimate of roughly 570,000 acre-feet, about 3 percent of the rainfall falling on areas of carbonate-rock outcrop may infiltrate to the zone of saturation. The cited percentage of infiltration is in error in proportion to (1) the magnitude of underflow into the basin from the northeast, (2) underflow out of the basin at Ash Meadows, and (3) evapotranspiration in Ash Meadows discharge area in excess of that supported by recycled spring discharge.

UNDERFLOW FROM THE NORTHEAST

Geologic and hydrologic evidence presented in the section "Areal Extent of the Ground-Water Basin" indicates that the Ash Meadows ground-water basin may receive underflow from the northeast, but this evidence does not permit estimation of the quantity of underflow. A comparison of the deuterium content of ground water in Pahranagat Valley, along the flanks of the Spring Mountains and Sheep Range, and at Ash Meadows indicates that possibly as much as 35 percent (about 6,000 acre-ft annually) of the Ash Meadows discharge may enter the basin from the northeast. The deuterium data are discussed in the section "Underflow from Pahranagat Valley."

DOWNWARD LEAKAGE FROM CENOZOIC ROCKS

A minor source of recharge to the lower carbonate aquifer is downward leakage of ground water semiperched in the Cenozoic rocks. In Yucca Flat, the magnitude of downward leakage was estimated, on the basis of hydraulic data, to be in the range of 25–65 acre-feet per year. Downward leakage of similar magnitude is probable also in Frenchman Flat.

By analogy with Yucca and Frenchman Flats, downward leakage of water probably also occurs beneath Desert Valley, eastern Emigrant Valley, the northern two-thirds of Three Lakes Valley, and the northern two-thirds of Indian Springs Valley. These four valleys have hydrogeologic settings similar to those of Yucca and Frenchman Flats. (See section "Intrabasin Movement.") The vertical leakage of the semiperched water in these valleys may also be on the same order. The aggregate leakage beneath the six valleys is estimated, then, to be between 150 and 400 acre-feet per year, or less than 3 percent of the discharge at Ash Meadows. Calculations of leakage based on hydrochemical evidence are given below in the section "Estimates of Downward Crossflow from the Tuff Aquitard into the Lower Carbonate Aquifer."

QUANTITY DERIVED FROM NORTHWEST SIDE OF BASIN

The quantity of recharge entering the lower carbonate aquifer from the northwest side of the basin is probably only a few percent of the measured discharge at Ash Meadows. The northwestern border of the Ash Meadows basin is defined approximately by the crest of Belted Range, Rainier Mesa, and Eleana Range uplands, which receive 8 to 14 inches of annual rainfall. An estimate of the quantity of this precipitation that eventually reaches the lower carbonate aquifer within the central and southwestern parts of the basin may be obtained by calculating the eastward and southward underflow across the nearly continuous trend of clastic rocks extending from the north end of the Groom Range to western Jackass Flats (pl. 1); this trend is as much as 15 miles east of the basin boundary (pl. 1).

The annual quantity of basinward underflow through the lower clastic aquitard and into the lower carbonate aquifer between the northeast end of Groom Lake playa and northern Yucca Flat is probably less than 40 acre-feet. This value was determined by applying the following values of T, I, and L to the underflow equation ($Q=TIL$). The coefficient of transmissibility, T, assumed to be about 1 gpd per ft, was determined by multiplying the highest value of coefficient of interstitial permeability measured in the laboratory (0.0001 gpd per sq ft; table 4) by 10,000 feet, a maximum probable thickness of aquitard. The apparent hydraulic gradient, I, within the lower clastic aquitard ranges from 250 to 1,300 feet per mile (fig. 32); a gradient of 1,000 feet per mile was used to maximize the underflow. The length of underflow strip L, is about 35 miles; it is the distance measured along the inferred contact between carbonate and clastic rock between the northeast end of the playa and the northern tip of Yucca Flat (pl. 1).

Eastward underflow into the lower carbonate aquifer (east of the Groom Range) between northeastern Groom Lake playa and the north end of Groom Range may amount to about 20 acre-feet annually if hydraulic gradients as steep as those shown in figure 32 occur beneath clastic rocks of the Groom Range.

Eastward underflow through the valley-fill aquifer between the Groom and the Papoose Ranges (fig. 32) also probably reaches the lower carbonate aquifer beneath eastern Emigrant Valley after passage through the tuff aquifers and aquitards. The coefficient of transmissibility of the valley-fill aquifer is not less than 30,000 gpd per ft in two wells (91–74 and 91–74a) in western Emigrant Valley (table 3), and the hydraulic gradient may be as much as 4 feet per mile toward the playa (fig. 32). The playa is about 3 miles wide, but the clastic aquitard is above the zone of saturation locally (fig. 32). Assuming a coefficient of transmissibility of 30,000 gpd per ft, a hydraulic gradient of 4 feet per mile, and an underflow strip 1.5 mile wide, the flow across the barrier via the valley-fill aquifer is about 200 acre-feet annually. This figure is probably a maximum value because thinning of the valley-fill aquifer near the buried aquitard would probably result in a reduction in transmissibility.

Underflow through the Cenozoic aquifers elsewhere along the boundary between carbonate and clastic rock between northern Groom Range and northern Yucca Flat appears negligible. The valley-fill aquifer west of Groom Lake is nearly fully saturated only because of the damming effect of the clastic aquitard, which nearly surrounds western Emigrant Valley. However, in general, the Cenozoic aquifers are probably unsaturated because of their structurally high position; in Yucca Flat, for example, the Cenozoic aquifers are unsaturated along the borders of that valley. The tuff aquitard, however, may be saturated in a structurally high position because of its very low transmissibility; but owing to its thinness, underflow through the tuff aquitard is probably a fraction of that through the thick lower clastic aquitard.

Eastward underflow into the lower carbonate aquifer beneath central Yucca Flat can follow two routes: (1) flow through the upper clastic aquitard (pl. 2), and (2) flow through the lower carbonate aquifer underlying the upper clastic aquitard. Underflow through the Cenozoic aquifers overlying the upper clastic aquitard is unlikely