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memorandum

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SUBJECT: DISTRIBUTION OF "ANALYSES OF THE PM-2 AQUIFER TEST USING MULTIPLE OBSERVATION WELLS"

Enclosed is a copy of the report entitled, "Analyses of the PM-2 Aquifer Test Using Multiple Observation Wells". This report contains work completed under the Groundwater Protection Program.

If you have any questions, please contact me at 665-1721 (sgm@lanl.gov).

Enclosure: "Analyses of the PM-2 Aquifer Test Using Multiple Observation Wells" (LA-14225-MS)

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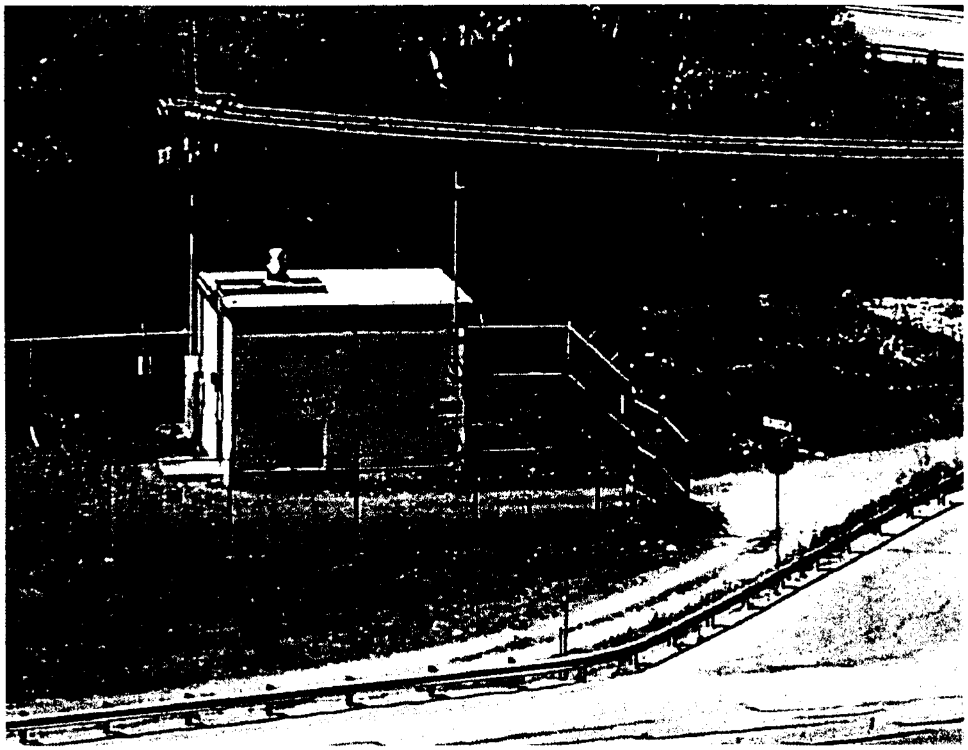
Analyses of the PM-2 Aquifer Test Using Multiple Observation Wells



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Analyses of the PM-2 Aquifer Test Using Multiple Observation Wells

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Analyses of the PM-2 Aquifer Test Using Multiple Observation Wells

by

Stephen G. McLin

ABSTRACT

A 25-day aquifer test was conducted at municipal water supply well PM-2 at a constant discharge rate of 1,249 gpm. This pumping interval was immediately followed by a 25-day recovery period. Surrounding observation wells were used to record both drawdown and recovery. These data reveal horizontal propagation of drawdown in the regional aquifer beyond 8,800 ft from well PM-2 but show a pronounced resistance to vertical drawdown propagation at shallower depths. Hydraulically, the regional aquifer behaves like a semiconfined aquifer with leaky units located above a highly conductive layer that averages about 850 ft in thickness. Classical distance-drawdown and fully confined aquifer behavior of early-time drawdown data (i.e., less than 4 days) from individual observation wells suggest that the highly conductive layer in the regional aquifer between wells PM-2 and PM-4 has a transmissivity of about 4,235 ft^2/day and a storage coefficient of about 0.00035. The corresponding hydraulic conductivity is about 5.0 ft/day. The aquifer thins between wells PM-4 and PM-5 to an effective thickness of about 490 ft, whereas the aquifer transmissivity increases to about 6,246 ft^2/day and the storage coefficient increases to about 0.00069. The corresponding hydraulic conductivity near well PM-5 is about 12.7 ft/day. Comparisons of late-time drawdown data (i.e., more than 4 days), using leaky-confined aquifer models, suggest a gradual transition from confined to leaky-confined aquifer behavior because the storage coefficient slowly increases to about 0.00180 after this time.

The test demonstrated a remarkably complex aquifer response over space and time that is not easily interpreted without a combination of fully penetrating and multiple-screened observation wells, a dynamic spinner log from well PM-4, and water-level data from selected observation wells for about one year following the aquifer test. These data also suggest the possibility that two competing conceptual models may be used to represent the regional aquifer in the central plateau area. First and more likely, aquifer drawdown data suggest that a traditional leaky-confined aquifer model is appropriate. In this model, leaky source beds in the regional aquifer are located above a highly conductive layer of variable thickness that extends between screen 3 of well R-20 and wells PM-2, PM-4, and PM-5. In a second possibility, the regional aquifer behaves like a leaky-confined model because it contains interbedded layers of alternating high and low hydraulic conductivities that are sandwiched together into a high-yielding zone. The overlying units at the top of the regional aquifer may not be a significant source of water to the municipal supply wells. This second conceptual model requires the low-conductivity layers within the alternating sequence to be leaking into the adjacent high-conductivity layers. These competing interpretations cannot be resolved without additional, deep, multiple-screened observation wells located near wells PM-4 and PM-5 that characterize vertical leakage between adjacent layers within the regional aquifer. This characterization has obvious implications for monitoring potential contaminant migration in the regional system.

I. INTRODUCTION

An aquifer test generally has several objectives, depending on the test duration and number of observation wells that are used to record drawdown and recovery. First, a traditional aquifer test is undoubtedly the most reliable method for determining average hydraulic transmitting properties that characterize the saturated porous media surrounding the well screens in both pumping wells and observation wells. If drawdown is measured only in the pumping well, then we can determine aquifer transmissivity (T). Charles Theis (1935) of the US Geological Survey's district office in Albuquerque, New Mexico, first defined T for a confined aquifer. Here, T represents the rate of flow to a pumping well in gallons per minute through a vertical cross-section of aquifer material one foot wide and extending the full saturated thickness of the aquifer that is subjected to a hydraulic gradient of one. We commonly express T in equivalent units of length squared per unit of time (L^2/T). Hydraulic conductivity (K) is determined by dividing T by the aquifer thickness (b). Values for T and K are important because they define how the aquifer will respond to stress (e.g., pumping, natural discharge, or recharge). If the well is completed into a geologic unit with a high T value, then we will get less drawdown in response to pumping, but the cone of depression will propagate radially outward much farther. High T values are generally more desirable than low T values because wells have greater yields, show less drawdown, and generally cost less to pump.

Second, if an observation well is also available to simultaneously record drawdown and recovery in response to pumping, then an aquifer storage coefficient (S) can also be obtained from the test. Here, S is defined as the volume of water yielded to a pumping well per unit area of saturated aquifer material per unit of decline in water level. As such, S is dimensionless. We can also write $S = S_s b$, where S_s is the aquifer specific storage and has units of inverse length. This relationship is analogous to $T = Kb$, which was defined above. Aquifer parameters like T and S were originally developed for confined-aquifer conditions assuming radial, two-dimensional (2-D), horizontal flow. However, in complex three-dimensional (3-D) groundwater representations, it is often best to use the parameters K and S_s because the influence of b has been removed. This report documents estimated values for T, K, b, S, and S_s.

Third, if the test is long enough, the cone of depression may expand radially outward to intersect either a recharge boundary or a barrier boundary, if one is present. These boundary effects would typically be revealed by the differences between measured drawdown in an observation well and idealized drawdown predicted at the same time and location according to an appropriate analytical aquifer model (e.g., the Theis confined-aquifer model represented by the Theis type-curve).

Finally, if we have multiple observation wells that are optimally located, we can determine horizontal and/or vertical anisotropy effects on K. Horizontal anisotropy would be revealed by an elliptically shaped cone of depression rather than a circular one. This cone expands laterally away from the production well in response to pumping and requires at least two observation wells at different locations to physically verify the elliptical shape. Horizontal anisotropy is important because it tells us that water may preferentially move toward the well more easily in one horizontal flow direction than in another. However, it is the directional hydraulic gradient combined with anisotropic porous media characteristics that ultimately determines the precise groundwater flow direction. Vertical anisotropy would be similarly revealed as different