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Moench, Allen F., 1984, Double-Porosity Models for a Fissured Ground Water Reservoir with Fracture Skin, Water Resources Research, Vol. 20, No. 7, p. 831-846.

by

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This paper constitutes a commendable effort to summarize and expand the theoretical basis for the analysis of drawdown data for fractured terrane that can be characterized by matrix blocks or spheres. The method applies porous media theory to fractured rocks by defining saturated hydraulic conductivity of the fracture system and the block system as the product of the hydraulic conductivity by the ratio of the total volume of the openings to the bulk volume of the rock (block or fracture) according to the method described by Gringarten (1982). Dr. Moench incorporates the effect of a mineralized film (skin) on the wall of the fractures where the skin has its own separate hydraulic conductivity and its own thickness. The geometries of the blocks are considered in the controlling equation for the fissured network via the control of the geometry on permeability distribution and on boundary conditions. In several respects this approach is similar to the standard approach for leaky aquifers when leakage is derived from storage in the confining layer, except for the addition of the hydraulic properties and thickness of the mineralized layer on the walls of the fractures. By manipulating the values of the hydraulic properties of the fracture system, the mineralized layer on

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the walls of the fractures, virtually any drawdown curve can be simulated by the theory. Not surprisingly the drawdown curves produced by the method (type curves) are similar in shape to standard leaky aquifer curves with or without the influence of boundaries or with or without the influence of partial penetration. The method could in fact produce curves identical to those of Hantush (1964) given appropriate geometry and the absence of a skin on the fracture.

This observation brings me to the major purpose of this critique. That purpose is to attempt to elucidate the plight (or perhaps the responsibility) of the field hydrogeologist under the current state of the art status of aquifer testing technology. I refer to the condition of the field hydrogeologist as a plight because he must conceptualize the hydrogeologic environment in some manner prior to deciding which theoretical analysis is appropriate to the particular hydrogeologic conditions with which he must deal at a specific site. I have alluded to this problem above by noting the similarity between the curves produced by this method and leaky drawdown curves affected by partial penetration and/or barrier boundaries. Dr. Moench has applied a solution to the aforementioned controlling equations to drawdown data from two wells at the Nevada Test site. Well UE-25b#1 is the pumping well and well UE-25a#1 is the observation well. The wells are only 107 meters apart. Dr. Moench points out correctly that five major zones of water entry over a depth interval of about 400 meters occur in the pumping well. These data were obtained from a borehole flow survey log of the pumping well. The borehole flow survey log was obtained using the trace ejector method while the pumping well was being pumped. Dr. Moench used the results of the third of three pumping tests as field drawdown data for matching purposes. Because the pumping test was conducted over the entire producing interval, he necessarily treated all the producing zones in the pumping well as one aquifer. This observation is pertinent for two reasons. Reason one is that partial penetration effects may have been operative because the distance between the two wells is only about one-fourth the thickness of the total aquifer. The second reason is that the borehole flow survey log shows that the third and fourth producing zones are separated by about 200 meters of very tight rock. The other producing zones are separated by between 10 and 50 meters of very tight rock. Consequently in terms of standard aquifer terminology, the borehole flow survey data show that the producing zones (whatever they may be caused by) could be interpreted as a multiple aquifer system wherein the producing zones are separated by rock with very low saturated hydraulic conductivity. Data are not yet available on the hydraulic properties of the individual producing zones (aquifers?). The importance of this second reason is that the collective behavior of the individual producing zones would produce a drawdown curve that reflects both boundaries and leakage, depending on the characteristics of the individual producing zones. It is imporant to note also that a borehole flow survey has not been run on the observation well. Consequently in the absence of knowledge about the producing zones in the observation well, Dr. Moench was forced to assume that the aquifer(s) in the observation well is identical to the aquifer(s) in the pumping well. He had no choice but to make that assumption. In this regard it is important to note that the drawdown at the end of test 3 in the pumping well was about 10.41 meters, whereas the drawdown in the observation well was only .64

meters. The pumping test lasted approximately three days at a pumping rate of 35.8 L/sec (567.5 gal/min). Because the wells are only 107 meters apart, this small drawdown in the observation well may suggest that only a portion of the producing zones (aquifers?) identified in the borehole flow survey of the pumping well responded in the observation well. Furthermore according to the data file for the two wells and Lobmeyer et al (1983), the observation well did not respond at all to pumping test 1. This test was conducted for 4 days at a pumping rate of 14 L/sec (222 gal/min). These observations illustrate further that the effects of partial penetration may have been operative at the observation well. A similar situation at an NRC licensed site has been interpreted to mean that the observation well is simply on the margin of the fault controlled aquifer in which the pumping well is located (see White and Gainer, 1984).

Dr. Moench decided to analyze the drawdown data by assuming slab shaped blocks because of "the scale of the problem and the observation that the distances between the two wells and the average distance between the zones of water entry shown in figure 9 are of the same magnitude (about 100 meters)." Dr. Moench points out that he believes more closely spaced water entries would be needed to justify the use of sphere shaped blocks. I suggest that other choices are defensible as well. Dr. Moench's choice necessarily forces the assumption that the blocks in fact exist, that the mineralized coating on the walls of the fractures is actually reflected in the pump test data, that leakage in the usual sense of the word is not occurring, and that all the water producing zones in the pumping well are reflected by the drawdown in the observation well, in spite of the high pumping rate and the low drawdown in the observation well. In this particular case, hydraulic continuity between all the producing zones in the pumping well and in the observation well is questionable and very important. It might be possible to demonstrate such continuity by packing off individual producing zones in the pumping well and in the observation well and investigating responses to pumping them separately.

Dr. Moench brings up the problem of the effects of partial penetration in his paper. However, he states that it probably is not important in this well test because the major zone of production appears to have been fully penetrated by the pumping well. He states also that there is evidence that there is good hydraulic connection between producing zones (in the pumping well). I suggest that he probably is correct that the pumping well fully penetrates all the producing zones, but it is not at all clear that the observation well penetrates all the same producing zones. I point out also that the only field evidence for good hydraulic connection between the producing zones in the pumping well consists of the fact that heads measured in each of the producing zones after isolation by packers are nearly identical. However, this observation does not mean necessarily that there is good hydraulic connection between the zones. Individual aquifers can have identical hydraulic heads with virtually no hydraulic connection between them. Core permeability data from the pumping well and slug tests in the pumping well suggest that the non-producing zones are much less permeable than the producing zones. In addition, under steady state conditions, which Yucca Mountain presumably has reached since the Pleistocene, the boundaries on a flow system determine to a large extent the hydraulic head distribution within that flow system. Dr. Moench also points out that the effects of anisotropy probably are significant. He points out correctly that a well test with data from a pumped well and a single observation well is insufficient to evaluate the anisotropy. Lastly, he points out that it is possible also that hydraulic boundaries due to major faults or intrusive dikes and sills are present within the flow regime. He points out correctly that the change in slope that occurs at 1,000 minutes on the drawdown curve might be interpreted by taking these factors into account. He states however that the change in slope is on the order of ten to one rather than two to one, the latter of which is characteristic of a single hydraulic boundary. This slope could easily be affected by the multiple aquifer system in combination with one or more boundaries. The last sentence in Dr. Moench's article (prior to conclusions) merits thought. He states "Also, as the data appear to be consistent with the assumptions of the double porosity model it is not necessary to call upon added complications." This statement merits thought because it reflects to a large extent the plight of the field hydrogeologist. If these "complications" actually exist and are not recognized in the field, then the hydraulic property values derived for the fracture system, the blocks, and the mineral coatings on the walls of the fractures will apply to some other conceptual model. They may reflect vertical saturated hydraulic conductivity values of confining layers; they may reflect multiple layered leaky aquifers; they may reflect barrier boundaries or recharge boundaries; or they may simply reflect the effect of partially penetrating wells. These questions should be resolved by some type of independent field evidence about the hydrogeologic framework of the system. Unfortunately, available technology in our profession restricts to a considerable extent the feasibility of this approach. Research is needed badly in this area.

One method of approaching the problem of obtaining reliable field data to characterize fractured aquifer systems is to study the distribution of permeability from inside the aquifer. We have attempted to accomplish this objective by gaining access to fractured aquifer systems via hard rock mines (see Williams, 1982, and Riley et al, 1984). Preliminary interpretations of water production characteristics in drifts and drill holes in the vicinity of the hard rock mines we have evaluated suggest that the major producing zones are fault controlled rather than fracture controlled. Major faults in particular drain over a long period of time whereas fractures generally drain quickly as a drift proceeds. Drill holes that intersect faults tend to discharge at a relatively steady state whereas drill holes that do not intersect faults tend to approach zero flow soon after completion. Perhaps eventually research conducted inside fractured aquifer systems will reduce the number of alternative interpretations of drawdown data observed during pumping tests and ultimately improve the "plight" of the field hydrogeologist who must fit the hydrogeologic regime to a conceptual model.

REFERENCES CITED

Gringarten, A.C., 1982, Flow-test evaluation of fractured reservoirs, in Recent Trends in Hydrogeology, Spec. Pap. Geol. Soc. Am. 189, p. 237-263.

Hantush, M.S., 1964, Hydraulics of wells, in Advances in Hydroscience, V.T. Chow, ed., Vol. 1, Academic Press, New York, p. 281-442.

Lobmeyer, D.H., Whitfield, M.S., Jr., Lahoud, R.R., and Bruckheimer, Laura, 1983, Geohydrologic data for test well UE-25b#1 Nevada test site, NYE County, Nevada, U.S. Geol. Survey, Open-File Report 83-855.

Riley, J.S., Erikson, D.L., Ralston, D.R., and Williams, R.E., 1984, The hydrogeology of an underground lead-zinc mine: Water flow and quality characteristics. Paper to be presented at the National Water Well Association Symposium on the Impact of Mining on Ground Water, to be held in Denver on August 27-28, 1984. It will then be reviewed and published in the Ground Water Journal.

Williams, R.E., 1982, Statistical identification of hydraulic connections between the surface of a mountain and internal mineralized sources, Ground Water, Vol. 20, No. 4, p. 466-478.