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I wish to thank Sophocleous and Devlin for their comments; for the most part, I agree with their remarks. Ground water is generally supplied from recharge. It is clear that the larger the recharge to a ground water system, the more water there is to be captured by development. In this way, the magnitude of the recharge (and the accompanying magnitude of the natural discharge) is of importance in controlling sustainable yield.

Sophocleous and Devlin go on to argue that recharge is an essential component of ground water models, and by implication of ground water analysis. On this point, I take issue with them. The classical method of analyzing the impact of a well on a ground water system is based upon the principle of superposition. We analyze the impact of a well by (1) solving for the head change produced by the well independently, and (2) then superposing the calculated head change on the hydraulic head observed within the system. In other words, the drawdown produced by the well is determined by solving the appropriate flow equation. We need only to know the aquifer properties (transmissivity and storativity) and the boundary conditions to solve for the drawdown. (We also need an initial condition; generally assumed to be a constant head, usually zero.) Once the drawdown is determined, we add (or subtract) it from the observed hydraulic head to obtain a final solution to the problem.

In our superposition analysis, we need not know the recharge; it is irrelevant. The observed hydraulic head, before the anticipated pumping, contains the impacts of the recharge and discharge from the system. The analog model, the predecessor of today's digital models, was based upon the principle of superposition. In the analog days, we looked at the impact that pumping (or other man-imposed stress) had on the system; there was no attempt to input recharge (or discharge). The recharge was unnecessary for the analog model analysis—an analysis of the impacts of stress on the system.

I recall introducing the recharge in a digital model analysis in an effort to estimate the hydraulic conductivities. If we know (1) the magnitude and distribution of the recharge to a ground water system, and (2) we have the discharge boundaries approximated correctly, we can use the model to calculate a virgin hydraulic head. We can adjust the hydraulic conductivities within the aquifer model until the calculated virgin hydraulic head matches the observed virgin head. In this manner, we can estimate the hydraulic conductivities of the aquifer system. Conversely, if we know the hydraulic conductivities of the aquifer system, we can estimate the recharge in a similar manner. In many instances, the hydraulic conductivities and the recharge are not known precisely; we adjust both until we achieve a satisfactory model fit to the virgin hydraulic head. Often our best estimate of recharge comes from this type of model analysis. Today, the calculated virgin hydraulic head is often used as an initial condition for a transient aquifer model analysis.

Contrary to Sophocleous and Devlin's comments, recharge is not a prerequisite for model analysis. Many analyses have been made without concern to the recharge. Of the many analog model analyses made in the 1950s, 1960s, and 1970s, almost none (I hesitate to state none) used recharge as input to the analyses. Nor do any of the classical pumping test (well stress) analyses include recharge. None of these ideas are new with me; they are well-established principles of ground water hydrology—in the manner of Theis, Jacob, Hantush, Lohman, Cooper, Skibitski, et al. Theis (1940) argued that the ground water community overemphasized the role of recharge in controlling sustainable development. Sixty years later, the community continues to overemphasize recharge.

References

Theis, C.V. 1940. The source of water derived from wells: Essential factors controlling the response of an aquifer to development. *Civil Engineering* 10, 277–280.