FORUM

The Policy of "Pumping the Recharge" Is Out of Control

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Hydrogeologists have spent several scientific generations in understanding the source of water to well fields and the effects of wells on the interrelated surface water system. The benchmark is by *Theis* [1940], who emphasized that some groundwater is initially mined during aquifer development and, after sufficient time, well discharge will be made up by diminution of both rejected recharge and natural discharge. Rejected recharge is water that would reside in the aquifer, except for a lack of space available. Theis advised that a perennial safe yield is equivalent to the amount of rejected recharge and natural discharge that is "feasible to utilize." His term "feasible" may have anticipated many current issues about aquifer sustainability. Papers published this year on the Ogallala aquifer in the central United States and on the global groundwater "footprint" [*Scanlon et al*., 2012; *Gleeson et al*., 2012] focus on recharge as an index of sustainability and have been featured in the popular press. However, I argue in this Forum that natural recharge rates alone cannot serve to address the core policy question regarding sustainable aquifer conditions in response to well field stresses. For the sake of users of hydrologic guidance, advisors on this topic may wish to reconsider the safe nature of "pumping the recharge."

As to the size and economic value of the groundwater resource, the United Nations Educational, Scientific and Cultural Organization (UNESCO) [*Zektser and Everett*, 2004] found that groundwater is the world's most extracted raw material at 600 to 700 billion cubic meters per year. Groundwater is extracted in volumes much greater than the next materials on the extractive industry list: sand and gravel, followed by oil. An adequate hydrologic assessment of foreseeable aquifer conditions is of obvious importance.

One indication of hydrologic sustainability [*Wada et al*., 2010; *Scanlon et al*., 2010] is the ratio of natural recharge to well field withdrawals, where natural recharge is the surplus of soil moisture that adds to the water table. Ratios more than unity are taken to indicate good status or sustainable regimes. Two dangers are exposed under any such policy. Where comparisons appear favorable, the danger is excessive drawdown and depletion coming as a surprise, and where the comparison appears unfavorable, the danger is nonuse of a needed, harmless, and available resource. Hydrologic balance for sustainable pumping depends primarily on the eventual decline in aquifer water levels required to induce sufficient feedback from interrelated surface water bodies. The timing depends on how fast the hydraulic pulse of drawdown spreads through the aquifer and on the distance to the responsive surface water sources. The recharge-oriented policy does not control these dominant aspects of sustainability.

The Problem With Aquifer Policy

Groundwater sustainability has been raised to the level of international policy attention. *The European Commission* [2009, p. 42] gives the following guidance: "annual average abstraction must not exceed long-term average recharge minus the long-term ecological flow needs." A report to the U.S. Congress [*Western Water Policy Review Advisory Commission*, 1998, p. 3.8] presented the key challenge that "groundwater is often used in excess of the rate of recharge."

Some memorable plain statements have been published on this issue. A leading commentator [*Bredehoeft*, 1997, p. 929] noted that "sustainable groundwater developments have almost nothing to do with recharge…yet the profession continues to perpetuate this wrong paradigm." South African policy makers [*Seward et al*., 2006, p. 473] report that equating groundwater sustainability to recharge "appears to be endemic…and it is conceptually incorrect." An important international stance is the Alicante Declaration (2006), endorsed by national institutions and signed by more than 200 hydrologists, who called for making hydrologic balance a goal of water management, taking into account long-term sustainability. At Alicante a perspective was released on the many dimensions of groundwater sustainability: hydrological, ecological, economic, social, legal, institutional, intergenerational, political, and ethical [*Llamas et al*., 2006]. *Llamas et al.* [2006, p. 6] recognize hydrological sustainability to include pumping in excess of recharge and dismiss the pump-the-recharge attitude as "conceptually simplistic, and potentially misleading."

Aquifers are "open" systems receiving recharge to the water table and conveying it to aquifer-fed discharge sites in the form of wetland evapotranspiration or as base flow of streams. Development is superimposed on that natural system. Aquifer storage depletion is a necessary early phase of development while water levels decline, inducing feedback from boundary sources. Hydrologic balance is reached when positive feedback from system boundaries matches negative withdrawals from pumping. Declining yield from wells in thin aquifers often aids the convergence. Then aquifer drawdown and storage depletion cease. The pumping rate controls the magnitude of drawdown, but it does not affect the timing of final equilibrium. Because natural recharge supports base flow, it is appealing at first glance to use recharge as an index of sustainability. However, recharge, being an unsaturated process lacking a feedback loop to conditions in the aquifer, cannot be a source to wells in mass balance accounting terms.

This poses a dynamic style of problem. Before attributing the sources of water that offset pumping, hydrologists must examine a transient analysis of boundary responses to superimposed stresses on the hydrologic system. For example, in a well-studied case by the U. S. Geological Survey at the Albuquerque basin in New Mexico, none of the pumping throughout the twentieth century was attributed to a source from recharge, while half was from aquifer storage depletion and half was induced from rivers or captured from evapotranspiration [*Kernodle et al*., 1995].

Information Is Needed Beyond Recharge Rates

If not recharge, what simple indicator could be used for reconnaissance of aquifer status? No rule-of-thumb appears to suffice. The sustainable amount from the well field is related to the base flow and evapotranspiration plus the rejected recharge component of direct flow minus an ecological reserve. However, such components are to be summed only inside the ex ante area of influence of the well field at a time horizon. The specific stream reaches and wetlands that may respond to well field stress remain unknown until modeled. Consideration is also given to the physical and economic limits on drawdown, together with maps of drawdown and the locations of changes in river flow for assessing impacts on downstream obligations (rights, treaties, and ecological water) [*Balleau*, 1998, p. 281].

Well fields in alluvium beside main stem rivers commonly prove sustainable in short order regardless of natural recharge. Well fields in Tertiary sediments hundreds of kilometers from surface water (the southern Ogallala or the Thar Desert) will prove unsustainable for millennia regardless of natural recharge. Most other cases will require specific study.

The idea that pumping an amount equal to natural recharge might cause instant balance with no other problems was dismissed by groundwater specialists long ago. Perhaps it is now time to abandon it from the administrative and planning functions also. The future status, good or poor, of an aquifer system is amenable to standard hydrogeological analysis. Expanded information is necessary, beyond comparison of pumping to natural recharge, to meet the broader societal objectives of basin-wide good status, aquifer health, and harmony with other requirements.

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