Integrated Management of Multiple Aquifers with Subsurface Flows and Inter-District Water Transport

Publication

1. Pongkijvorasin, Sittidaj, and James Roumasset. 2007. Optimal conjunctive water use over space and time. Journal of Environmental Economics and Management. (under review).
2. Pitafi, Basharat A., and James A. Roumasset. 2006. "Evaluating interdependent watershed conservation and ground water management reforms," Journal of the American Water Resources Association 42(6) (December), pp. 1441-1450.
3. Pitafi, Basharat A., and James A. Roumasset. "Pareto-improving water management over space and time: The Honolulu case," American Journal of Agricultural Economics (under review).

Problem and Research Objectives

The problem of groundwater management has been studied widely in the literature. However, all of the previous studies limit their attention to the single aquifer case. In many places, water can be extracted from more than one source to supply the demand. For example, the Honolulu Board of Water Supply (HBWS) currently extracts from both the Pearl Harbor and Honolulu aquifers, pumping the resource into an interconnected pipeline serving the Pearl Harbor and Honolulu water districts. HBWS imports water extracted from the Pearl Harbor aquifer to meet Honolulu demand. This calls for a single model integrating extraction, distribution, and consumption from the two sources. This model will provide an analysis of a situation much closer to that actually observed in HBWS practices. Particularly, we aim to analyze the principle of optimal water use when water can be extracted from two sources. We also discuss various possible extraction schemes.

Methodology

First, we develop a model integrating extraction, distribution, and consumption from the two water sources. Specifically, a social planner chooses the amount of water extracted from the two different aquifers and the amount of desalinated water used in order to maximize the present value of net social benefit (i.e., the benefit from water consumption minus the costs of extracting and distributing the water). The problem is then solved by dynamic optimization. Phase-diagrams and time paths of aquifer head and water price for the different scenarios are analyzed and discussed.

By extending the Pitafi-Roumasset Honolulu study to the water districts served by the Pearl Harbor aquifer we were able to study optimal water extraction over space and time. When the aquifers are managed separately, the Honolulu efficiency price increases more quickly than the Pearl Harbor price, implying that water needs to be increasingly transferred to Honolulu. This results in the Honolulu price rising more slowly and reaching the desalination steady-state at a later time than without said transfers. Alternative pricing schemes are also compared.

Principal Findings and Significance

From the developed model, we find that, in the optimal solution:

1. Both aquifer swill be used and built up if both have lower head levels than their steady states.
2. Both aquifers will be depleted if their heads are higher than their steady states. However, if one aquifer requires a higher initial price than the other, it is optimal to extract water from only one aquifer, leaving the other to build up.
3. If one aquifer head is lower than its steady state, it is optimal not to use that aquifer but to let the head build up. The water is extracted only from the other aquifer in this case. If the building head reaches its steady state while the depleting one does not, the building one can go higher and then be depleted.
4. If an alternate source is available at a cost no more than the steady-state price that would prevail without it, the alternate source will be used in steady state.
5. If an alternate source is available at a cost higher than the steady state price that would prevail without it, the alternate will not be used in steady state. If both aquifer heads are initially lower than their steady states, both will not be used at the beginning. The alternate will be used in the beginning period, leading to the case of so-called "frontstop."
6. Marginal cost pricing is feasible when block-pricing schemes are used for natural monopoly goods. Switching to marginal cost pricing is a more effective way to increase revenues and conservation than standard price increases. Users at different elevations face different distribution costs, therefore a pricing scheme which does not take this disparity into account effectively cross-subsidizes residents at higher elevations facing higher user costs but not required to pay the difference.
7. Preliminary analysis suggests that welfare gains for integrated management of the two aquifers, relative to the status quo, are somewhat larger, even in percentage terms, than efficient, but separate, management of single districts. The use of desalination in the Honolulu district was delayed as much as 20 years in the integrated management scenario relative to status quo management.

8. When the Honolulu and Pearl Harbor aquifer models are run separately, there is a greater spatial effect in the Honolulu case. Moving from separate optimization to integrated optimization increases the tendency to import water into Honolulu. Thus, moving from status quo management to the integrated, optimized solution causes two offsetting effects. On the one hand, charging high-elevation Honolulu customers the full marginal cost reduces the need to import water from the Pearl Harbor aquifer. On the other hand, the more slowly increasing Pearl Harbor efficiency price increases the tendency toward Honolulu imports.

The following presentations reported on project findings:

1. Pongkijvorasin, Sittidaj; James A. Roumasset; Basharat A. Pitafi, 2006, How to stop worrying and learn to love bathtub economics, presented at the First Occasional Giannini Retreat on Water Economics, University of California, Davis, December 19, 2006.
2. Roumasset, James A.; M. Rosegrant, 2006, Efficient irrigation management, with return flows, groundwater recharge, and pollution, presented at the IAAE meeting, Brisbane, Australia. August 12–18, 2006.
3. Pitafi, Basharat A.; James A. Roumasset, 2006, Integrated management of multiple aquifers with subsurface flows and inter-district water transport, presented at the AAEA annual meeting, Long Beach, Calif., July 24–28, 2006.
4. Pitafi, Basharat A.; James A. Roumasset, Pareto-improving water management over space and time: The Honolulu case, presented at the 3rd World Congress of Environmental and Resource Economist, Kyoto, Japan, July 3–7, 2006.
5. Pitafi, Basharat A.; James A. Roumasset; R. Smith, When a backstop becomes a frontstop: Managing groundwater aquifers with low cost substitutes, presented at the WEAI annual conference, San Diego, Calif., June 29–July 3, 2006.
6. Pitafi, Basharat A.; James A. Roumasset, 2006, Integrated management of multiple aquifers with subsurface flows and inter-district water transport, presented at the WEAI annual conference, San Diego, Calif., June 29–July 3, 2006.
7. Pitafi, Basharat A.; Sittidaj Pongkijvorasin; James A. Roumasset, 2006, Coastal groundwater management in the presence of positive stock externalities, presentation at the WEAI annual conference, San Diego, Calif., June 29–July 3, 2006.
8. Roumasset, James A., 2006, Economic principles for Oahu’s water and watershed management, luncheon address to the Hawaiian Economic Association, Plaza Club Honolulu, Hawaii, January 26, 2006.