Groundwater

Guest Editorial/

Groundwater Provides and Receives Hydrologic System Services

by A.T. Fisher

The concept of Environmental or Ecologic System Services (ESS) is well established in the technical, social science, and policy literatures, and is useful for assessing economic and/or social values of natural resources, and identifying potential impacts of planned or proposed management decisions. The ESS concept has been applied widely to water resources and aquatic habitats, for example, valuing coastal wetlands for mitigating hurricane damage, widening or raising river levees to reduce flood risk, and managing catchments to maximize water delivery.

I propose that the concept of Hydrologic System Services (HSS) be considered when assessing the influence and value of hydrologic systems, including groundwater resources. HSS include benefits that apply to human populations and activities (much like ESS), but HSS also include hydrologic functions, associated with flows and/or storage, that are beneficial to other hydrologic systems and/or nearby habitats. Here are a few examples that illustrate the HSS concept, applied first to surface water, and then to groundwater.

Recent surface water management projects were designed to increase the variability of controlled river and stream flows. For example, high-discharge floods were created on the Colorado River, downstream of the Glen Canyon Dam, with the goal of delivering gravel and sand trapped in tributaries into the main channel, restoring bars that had been lost after years of relatively steady flows, thereby improving recreational opportunities and riparian habitat. Dam removal is a more extreme case of restoring the range and complexity of natural flows, thereby improving HSS. Enhancing coastal and riparian wetlands can help to reduce nutrient and sediment export from basins, benefitting adjacent aquatic habitats, and improving the quality of fresh water supplies for human use.

Groundwater storage and flow can provide HSS as well. Raising groundwater levels can increase baseflow to streams, enhancing the quality of riparian and aquatic habitats. Maintaining elevated groundwater levels if there are increased outflows to streams may require additional aquifer inflows in order to maintain HSS. Thus, both groundwater storage and flow can contribute value to HSS. Reducing the delivery of fine-grained sediment to streams can provide multiple HSS. Fine sediment can clog streambeds, reducing hyporheic exchange that would otherwise benefit nutrient cycling and temperature regulation. Excessive sedimentation in losing streams can limit streambed recharge of underlying aquifers, a significant fraction of groundwater budgets in some basins. Thus controlling erosion, transport, and deposition of sediment in streams can provide HSS to groundwater.

In coastal basins, groundwater outflows to the ocean can help to limit (or mitigate) the impacts of sea water intrusion, by flushing fresh water through the mixing zone and advecting salt from an aquifer. Groundwater flows to the coastal ocean can contribute to nutrient fluxes, and may assist in development of "hard grounds" that provide aquatic habitat. Maintaining groundwater outflows in coastal basins may become more challenging in coming decades because of rising sea level and changing precipitation patterns, even in basins that have limited pumping and are otherwise being managed "sustainably" under current conditions.

I am not suggesting that all HSS or aquatic systems be assessed in the same way, or that different regions or agencies should apply identical HSS values for a given flow or storage. Rather, I propose that the HSS concept can be used as a framework by which agencies, regulators, and stakeholders can organize thinking about potential impacts of resource management options. The consideration of HSS may be particularly useful in California as many basins seek to implement the Sustainable

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Groundwater Management Act (SGMA), California's first statewide groundwater management legislation. SGMA links surface water and groundwater, explicitly recognizing connections between reservoirs that historically have been considered and managed separately.

The HSS concept can also be considered as a "call to action" for *Groundwater* readers, many of whom are highly qualified to define, investigate, and report on ways in which both groundwater storage and flows can provide a wide range of benefits.