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Research paper

Effects of long-term water table drawdown on evapotranspiration and vegetation in an arid region phreatophyte community

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Abstract

Evapotranspiration rates and the ground water component of evapotranspiration at a site in Colorado's San Luis Valley that is dominated by shrubby phreatophytes (greasewood and rabbitbrush) were compared before and after a water table drawdown. Evapotranspiration (ET) rates at the site were first measured in 1985–1987 (pre-drawdown) when the mean water table depth was 0.92 m. Regional ground water pumping has since lowered the water table by 1.58 m, to a mean of 2.50 m. We measured ET at the same site in 1999–2003 (post-drawdown), and assessed physical and biological factors affecting the response of ET to water table drawdown. Vegetation changed markedly from the pre-drawdown to the post-drawdown period as phreatophytic shrubs invaded former wetland areas, and wetland grasses and grass-like species decreased. Lowering the water table reduced estimated total annual ET from a mean of 409.0 to 278.0 mm, a decrease of 32%, and the ground water component of ET (ET_g), from a mean of 226.6 to 86.5 mm, a decrease of 62%. Two water table depth/ET models that have been used in the San Luis Valley overestimated the reduction in ET_g due to lowering the water table by as much as 253%. While our results corroborate the generally observed negative correlation between ET rates and water table depth, they demonstrate that specific models to estimate ET as a function of water table depth, if not verified, may be prone to large errors. Both the water table drawdown and the vegetation change are continuing 20 years after the drawdown began, and it is unclear how site ET rates and processes will differ after the water table has stabilized and vegetation has adjusted to the new site hydrologic conditions.

Keywords: Ground water; Evapotranspiration; Water table decline; Phreatophytes; San Luis valley

1. Introduction

The increasing human population of the inter-mountain West has increased demand for water, making the proper management of water resources critical. Ground water models are being developed in many regions of the West to guide water management, and they must account for evapotranspiration (ET), which can be a major depletion of ground water (Emery et al., 1973; Nichols, 1994; Laczniak et al., 1999), particularly in areas dominated by

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phreatophytes, plants that obtain at least some water from shallow ground water. In arid regions, the area of non-riparian phreatophytes may be very large. For example, the native phreatophytic shrub greasewood (*Sarcobatus vermiculatus* (Hooker) Torrey) occupies an area of at least 4.8 million hectares in western North America (Shreve, 1942).

Short- and long-term water table declines can be produced by ground water pumping, the diversion of streams that recharge ground water, as well as climate variation and change. Water table depth is often cited as a principal factor controlling ET rates in phreatophyte communities (Robinson, 1958; Emery, 1970; Sala et al., 1996; Devitt et al., 2002; Nichols, 2000); however, little is known about this response. Thus, it is hard to predict changes in ET rates for any site that could result from a change in the position of the water table. Higher ET rates commonly occur in sites with the shallowest water tables, and lower ET rates in sites with deeper water tables (Robinson, 1958; Duell, 1990; Nichols, 1994). This apparently straightforward relationship has led to the use of single water table depth/ET functions (Emery, 1970), or suites of functions (Nichols, 1994; Nichols, 2000) to estimate site ET from ground water. Such functions are attractive because they make intuitive sense, are simple to apply, and they allow the estimation of annual ground water ET for any site using a simple measurement of water table depth. In addition, these functions can be applied at the landscape scale using maps of water table depth, calculated with models such as Modflow (Harbaugh et al., 2000; McDonald and Harbaugh, 2003).

The hypothetical water table depth/ET relationship has been used to quantify water that could be 'salvaged' from phreatophytes by pumping the water table to depths below plant root zones (Emery, 1970; US Bureau of Reclamation, 1987). However, this relationship does not consider other factors that can influence or control site ET rates, such as plant canopy cover (Nichols, 2000), leaf area (Sala et al., 1996), and community composition (DeMeo et al., 2003), all of which are affected by soil salinity, soil water holding capacity, and nutrient availability. In addition, most studies of water table depth/ET relationships have measured ET at multiple sites with different water table depths, and different soil and vegetation characteristics as well (Eakin, 1960; Everett and Rush, 1964; Eakin et al., 1967; Nichols, 1994; Nichols, 2000). The short-term and long-term ecological responses of phreatophyte communities to water table change have rarely been investigated.

Phreatophytes respond in a variety of ways to water table decline, but both the magnitude and rate of water table decline can affect vegetation, and thus ET response. Rapid declines of even 1 m under riparian phreatophytes, such as cottonwood (*Populus deltoides* Marshall), or mesquite (*Prosopsis* spp.), can cause significant short-term (Cooper et al., 2003) or long-term (Scott et al., 1999) changes in leaf area, branch density, or whole plant density. Lowered water tables have been found to reduce plant xylem pressure potential, and cause subsequent canopy dieback and mortality when a threshold water depth was reached (Horton et al., 2001), and root system dieback triggered branch dieback and leaf reduction (Williams and Cooper, 2005). Reductions in leaf area and plant density would likely reduce stand ET rates (Sala et al., 1996). Water table changes may not, however, affect plant density or leaf area of all species. For example salt cedar, *Tamarix ramosissima* Ledeb., may not be completely dependant upon ground water availability and is considered a facultative phreatophyte (Busch et al., 1992). Thus, depending upon the initial vegetation and depth to water table, a permanent water table decline may result in vegetation changing from obligate phreatophytes, to facultative phreatophytes, to non-phreatophytic upland species (Stromberg et al., 1996).

Less is known about the potential responses of non-riparian phreatophytes to changing water table depth. The growth and leaf area of the widespread phreatophytes greasewood and rabbitbrush (*Ericameria nauseosa* (Pallas ex Pursh) Nesom and Baird) is controlled by soil water recharged by precipitation as well as capillary water rising from the water table (Sorenson et al., 1989). However, an experiment to lower the water table in an area with shallow ground water in the Owens valley, California, found that plant cover was reduced at some sites but not for all species (Sorenson et al., 1989). In addition, Charles (1987) found that greasewood was affected by a water table decline, but rabbitbrush was not in the San Luis valley, Colorado. The response of some, but not all species, may occur because phreatophytes, such as greasewood, may use largely precipitation-recharged