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Parsimonious Hydrologic and Nitrate Response Models For Silver Springs, Florida

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Silver Springs with an approximate discharge of 25 m3/sec is one of Florida's first magnitude springs and among the largest springs worldwide. Its 2500-km2 springshed overlies the mostly unconfined Upper Floridan Aquifer. The aquifer is approximately 100 m thick and predominantly consists of porous, fractured and cavernous limestone, which leads to excellent surface drainage properties (no major stream network other than Silver Springs run) and complex groundwater flow patterns through both rock matrix and fast conduits. Over the past few decades, discharge from Silver Springs has been observed to slowly but continuously decline, while nitrate concentrations in the spring water have enormously increased from a background level of 0.05 mg/l to over 1 mg/l. In combination with concurrent increases in algae growth and turbidity, for example, and despite an otherwise relatively stable water quality, this has given rise to concerns about the ecological equilibrium in and near the spring run as well as possible impacts on tourism. The purpose of the present work is to elaborate parsimonious lumped parameter models that may be used by resource managers for evaluating the springshed's hydrologic and nitrate transport responses.

Instead of attempting to explicitly consider the complex hydrogeologic features of the aquifer in a typically numerical and / or stochastic approach, we use a transfer function approach wherein input signals (i.e. time series of groundwater recharge and nitrate loading) are transformed into output signals (i.e. time series of spring discharge and spring nitrate concentrations) by some linear and time-invariant law. The dynamic response types and parameters are inferred from comparing input and output time series in frequency domain (e.g., after Fourier transformation). Results are converted into impulse (or step) response functions, which describe at what time and to what magnitude a unitary change in input manifests at the output. For the hydrologic response model, frequency spectra of groundwater recharge and spring discharge suggest an exponential response model, which may explain a significant portion of spring discharge variability with only two fitting parameters (mean response time 2.4 years). For the transport model, direct use of nitrate data is confounded by inconsistent data and a strong trend. Instead, chloride concentrations in rainfall and at the spring are investigated as a surrogate candidate. Preliminary results indicate that the transport response function of the springshed as a whole may be of the gamma type, which possesses both a larger initial peak as well as a longer tail than the exponential response function. This is consistent with the large range of travel times to be expected between input directly into fast conduits connected to the spring (e.g., though sinkholes) and input or back-diffusion from the rock matrix. The result implies that reductions in nitrate input, especially at remote and hydraulically not well connected locations, will only manifest in a rather delayed and smoothed out form in concentration observed at the spring.