## AN ABSTRACT OF A DISSERTATION

# DECOMPOSITION OF SPRING TIME SERIES BY DISCRETE WAVELET TRANSFORM FOR CHARACTERIZATION OF FRACTURED ROCK AQUIFERS AND HYDROLOGIC FORECASTING WITH ARTIFICIAL NEURAL NETWORKS

John Francis Pescatore

Doctor of Philosophy in Engineering

Characterization of a fractured rock aquifer, from which a spring emanates, represents an inverse (system identification) problem. The aquifer or system may be characterized by analyzing the output (spring discharge) using digital signal processing techniques. Spring data from eight sites were decomposed by discrete wavelet transform (DWT). For one-dimensional discretely sampled data, the DWT was implemented as a hierarchical filter bank producing wavelet (detail) coefficients that represent variation (energy) of the output signal in a time-scale plane. Two versions of the DWT were used employing Haar-2 and Daubechies-4 wavelets. Wavelet spectra, the sum of squared detail coefficients for each time scale, indicated multiple variance changes and characteristic time scales influencing variability. Aquifer characterization or classification can proceed directly from examination of normalized multi-scale energy (NME) or by training and testing an artificial neural network (ANN) with wavelet energy norms. The combination of DWT and ANN methodologies provided greater utility and flexibility for system identification than either linear (time-invariant) kernel functions or frequency domain analysis used in previous studies of fractured rock aquifer/spring systems. One spring site having a long-term discharge record was selected for hydrologic forecasting by ANN. Trials were performed with three types of delay vectors as input, namely lagged versions of mean daily (1) flow, (2) flow and precipitation, and (3) flow and estimated available percolation water. A hydrologic budget algorithm was developed to compute daily recharge. A feed forward neural network with error backpropagation conducted the nonlinear mapping between input and output for 1-day ahead predictions. An adaptation of a globally recurrent neural network for hydrologic forecasting was also tested. Ancillary investigations completed as part of this study included data compression and reconstruction by wavelets and Fourier analysis to study the timescales characterizing groundwater discharge at a selected spring, and phase space reconstruction by delay coordinate embedding.

The contribution of this research extends the state of the art in spring time series analysis and characterization techniques for fractured rock aquifers.