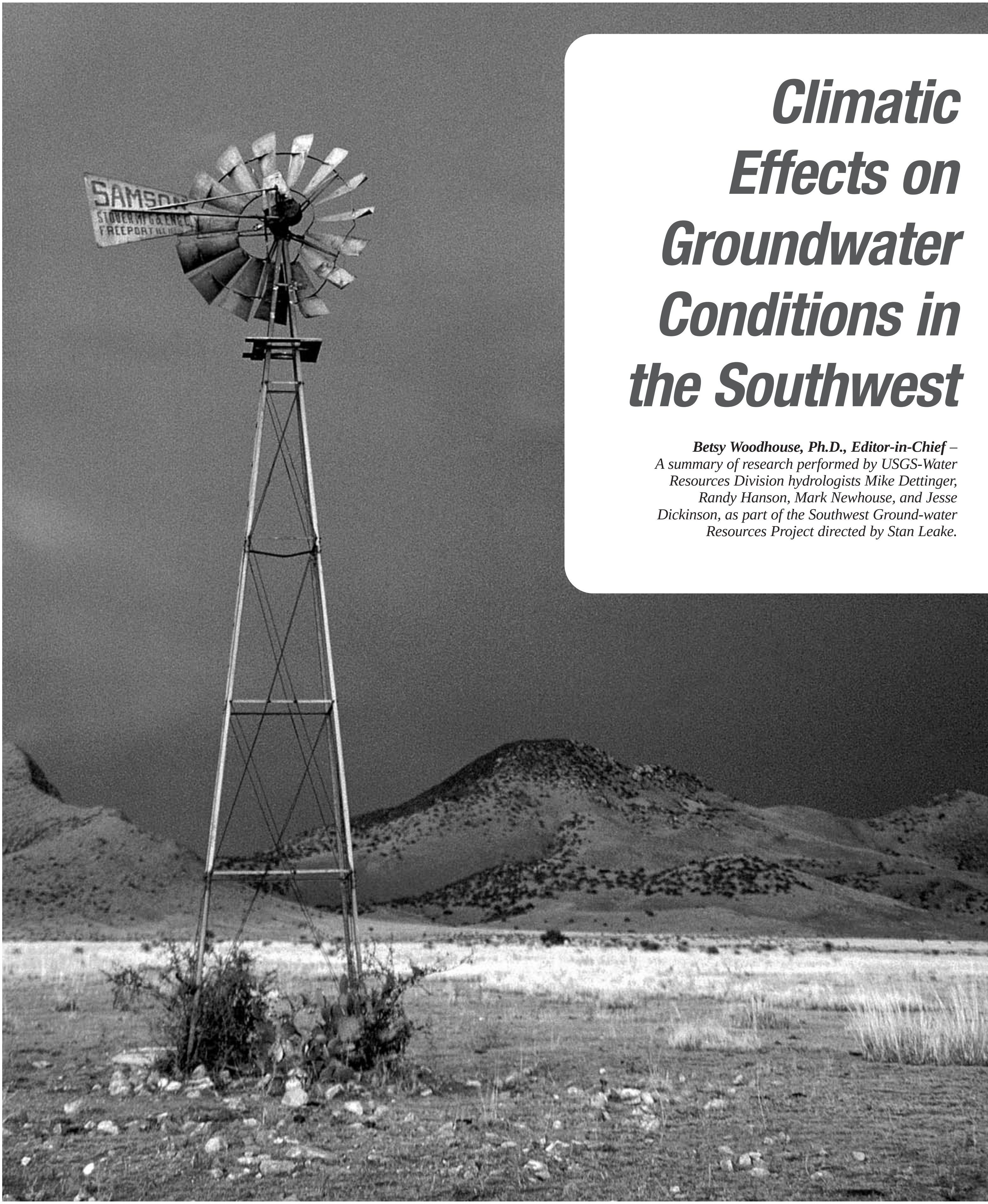

Climatic Effects on Groundwater Conditions in the Southwest

***Betsy Woodhouse, Ph.D., Editor-in-Chief** – A summary of research performed by USGS-Water Resources Division hydrologists Mike Dettinger, Randy Hanson, Mark Newhouse, and Jesse Dickinson, as part of the Southwest Ground-water Resources Project directed by Stan Leake.*

The USGS Water Resources Division is investigating the effects of climate on groundwater elevations in the Southwest. Currently, the major questions in their investigations include: which climate variations influence groundwater? And what forms do those influences take?

To understand the influences of climate on groundwater levels, researchers first need long records of groundwater levels, preferably taken from areas away from major pumping centers. In looking at such time series, researchers have observed that the history of groundwater levels in the Southwest is not one of pure overdraft; instead, trends are observed. When similar trends are detected in different basins over a widespread area, climatic effects can begin to be identified. The approach taken by the USGS is to "de-trend" the groundwater time series data by fitting a polynomial to it, to similarly de-trend the climatic indices, and then look for positive or negative correlations between the groundwater and climate data.

Patterns and Influences in Groundwater

The climatic variations influencing groundwater in the Southwest include El Niño/Southern Oscillation (ENSO), the Pacific Decadal Oscillation (PDO), the North American monsoon, and historic trends. The strongest influences in the Southwest appear to be the PDO, with a frequency of 10 to 20 years, and ENSO, with a frequency of two to six years. During El Niño and "positive" PDO periods (long-term El Niño-like regimes), winter precipitation is greater than normal in the Southwest. To investigate the impact on summer precipitation, "monsoon" indices have been developed.

In general, positive correlations between climate variations and groundwater elevations are observed: groundwater elevations tend to rise during ENSO years. Is this an indication of increased recharge, or the result of reduced groundwater pumping due to increased precipitation? Again, data taken from areas removed from human impact are needed to answer that question. The USGS looked to the surface water record, where runoff data for basins with minimal human impact are available. By looking at base flow during low-flow periods of the year, the researchers were able to identify a positive correlation between the occurrence of ENSO and PDO and higher base flow in non-developed areas, which suggests that – at least, in part – the higher groundwater levels in the Southwest are associated with increases in recharge. However, basin-by-basin groundwater pumpage totals in Arizona (the area reviewed thus far) decrease significantly during the wet El Niño episodes, so probably both increased recharge and decreased pumpage contribute to the higher Southwestern groundwater levels during El Niños.

Natural Climate Effects Run Deep

The next question to address is, how far into the aquifer do the natural climatic influences permeate? Precipitation and stream flow vary rather quickly, but the aquifer storage may act as a filter that emphasizes the lowest-frequency variations. Researchers are now trying to figure out what type of response the groundwater system has to the various time scales and strengths of the climatic influences. They are trying to quantify the responses of different aquifers in different parts of the Southwest, as well as the effects on different parts of different aquifers. To do so, historical groundwater, stream flow, precipitation, and tree ring data from 23 study basins in five states in the Southwest were collected. The approach the USGS is taking is to de-trend the data, perform spectral analyses to identify the most important frequency bands, and finally, to develop reconstructions of variations in those frequency bands.

In four of the basins, the Ventura and Mojave basins of California and the Santa Cruz and San Pedro basins of Arizona, oscillations in the groundwater records suggest a one-year lag behind climatic influences. Overall, the surface water systems in the Southwest yield one- to two-year delayed responses to climatic variations in both the 10- to 20-year PDO frequency band and the one- to four-year ENSO frequency band, and about a one-month lag behind the annual climatic cycle. A 400-year record of Mojave basin tree ring widths indicates that the PDO is a minor component and ENSO is a very minor component of climatic response compared to even longer-frequency (greater than 20 years) climatic variations; the correlation to groundwater levels is still under analysis.

In a related investigation, the USGS is modeling hypothetical climatic effects on hypothetical basins using MODFLOW modeling methods. Basin characteristics are chosen to mimic the USGS Regional Aquifer-System Analysis (RASA) characteristics of Southwest alluvial basins. Periodic recharge forcings are imposed, based on spectral analysis of precipitation, streamflow, groundwater elevation, and tree-ring data from the Southwest. The results thus far indicate that climate-controlled recharge to the groundwater models results in fluctuations in the simulated groundwater table. The greatest magnitude of head variation typically occurs near mountain fronts and recharge centers. Evapotranspiration and stream beds reduce groundwater level oscillations at basin lows and centers. The magnitude of head variation depends on the period of climatic forcing and the characteristics of the basin, including aquifer diffusivity, aquifer geometry, and the presence of groundwater sinks such as evapo-transpiration and stream beds. Aquifer diffusivity and the period of forcing affect head fluctuations primarily near mountain fronts. Evapotranspiration rates and streamflow affect head fluctuations primarily near stream boundaries.

For more information about this research, contact Randy Hanson (California District, rthanson@usgs.gov), Mike Dettinger (California District, mddettin@usgs.gov), or Stan Leake (Arizona District, saleake@usgs.gov); or visit the Southwest Ground-water Resources project home page at az.water.usgs.gov/swgwrp/Pages/Overview.html