Editorial

Ground Water and Climate

by William M. Alley[1]

Consideration of climate variations can be a key factor in ensuring the proper management of ground water resources. Links between climate and ground water exist at temporal scales, ranging from short-term responses to barometric changes and earth tides to millennial changes in climate that have affected past recharge and potentially affect the future safe disposal of long-lived radioactive wastes. Consider the importance of climate to ground water at seasonal to decadal time scales—a common scale of analysis in which climate variability often is neglected by ground water hydrologists.

Ground water systems tend to respond more slowly to variability in climatic conditions than do surface water systems. As a result, assessments and models of ground water resources are commonly based on long-term average climate conditions (e.g., average annual recharge) and potentially underestimate the importance of variations from the norm. Droughts are the most widely recognized climate perturbation relative to ground water and the focus of the discussion here. However, high ground water levels from extended wet periods also cause problems such as flooded basements and waterlogged lands.

Water storage is critical in dealing with climate variability. As surface water storage becomes more limited, use of ground water storage to modulate the effects of droughts increases in importance, as do potential enhancements by artificial recharge. If ground water storage is large, droughts will have a small, if any, effect on long-term water storage in an aquifer system. In contrast, where ground water storage has been substantially reduced by long-term withdrawals from wells, it may be more limited as a source of water to help cope with droughts.

Among the most important links between climate and ground water are the effects on surface water and the land. For example, ground water development may significantly affect low flows in streams, minimum levels in lakes, and the hydroperiod of wetlands. Likewise, reduced heads in response to increases in pumping during droughts can cause land subsidence as a result of compaction of aquifer materials.

The quality of ground water is also affected in many ways by climate. Changes in recharge in response to climate variability can affect contaminant transport, and lack of proper consideration of the effects of climate variability can lead to erroneous conclusions abut temporal trends in ground water quality, particularly if only a few samples have been collected. Reduced fresh water discharges to coastal areas during droughts can cause sea water to intrude into aquifers beyond previous landward limits. Inadequate consideration of the combined effects of ground water development and climate can lead to less dilution of contaminants in streams during low flow than was assumed in setting stream-discharge permits.

As predictive links between hydrology and climate improve, so must the involvement of ground water hydrologists. For example, the southwestern United States tends to be wet and the Pacific Northwest dry during El Niño conditions, and vice versa for La Niña conditions. Consideration of this phenomenon could further management pratices in which communities rely more on ground water during dry periods and more on surface water during wet periods. Decadal-scale fluctuations in wet and dry cycles, such as those related to the hypothesized Pacific Decadal Oscillation, may have even larger effects on ground water systems and their use. Human-induced climate change in the coming decades may further affect ground water resources in several ways, including changes in ground water recharge resulting from changes in the annual and seasonal distribution of precipitation and temperature, more severe and longer lasting droughts, changes in evapotranspiration resulting from changes in vegetation, and possible increased demands for ground water as a backup source of water supply. Surficial aquifers that supply much of the water in streams, lakes, and wetlands are likely to be the part of the ground water system most sensitive to climate change. However, little attention has been directed at determining the possible effects of climate change on shallow aquifers and their interaction with surface water.

Monitoring the effects of climate on ground water levels requires observation wells that are responsive to climate variability and that, ideally, are located away from the effects of pumping and irrigation. Remarkably little long-term monitoring of this type takes place. The U.S. Geological Survey operates a sparse national network of about 150 climate-response wells and a few states have drought-monitoring networks. Only a few such wells are monitored in many states. The utility of drought monitoring wells is also limited unless the observed water-level data are readily available through "real-time" electronic transmittal or other means. Increased monitoring of ground water conditions is clearly needed to develop more complete ongoing assessments of droughts and other climatic phenomena.

In conclusion, ground water and climate are linked in many ways. As ground water hydrologists, we need to be more attuned to the effects of climate. The links between ground water and climate should receive greater attention as part of drought monitoring and assessment, studies of climate change and variability, analysis of water quality, and assessment of the availability and sustainability of ground water resources.

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