How Dry Was My Valley?

Using Paleoclimate Data to Extend the Historical Record

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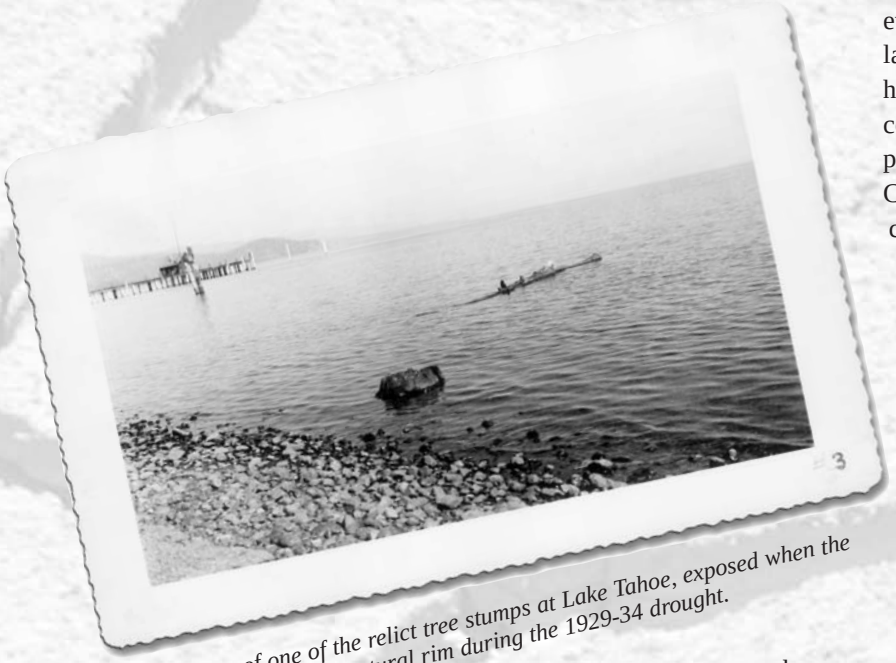
Water agency and public works managers are particularly interested in extremes of the hydrologic record – floods and droughts – because these events are used to size or evaluate their facilities. When designing structures with significant public safety importance, such as dams, levees, and other flood control works, engineers commonly use available flood hydrology data to predict a probabilistic event such as the 200- or 500-year flood. This design event may be larger than events in the measured hydrologic record. In contrast, the design or evaluation of large-scale municipal water supply facilities has generally relied on operations studies using the driest segment of the measured record.



A 1934 view of one of the relict tree stumps at Lake Tahoe, exposed when the lake dropped below its natural rim during the 1929-34 drought.

Recent Climate Relatively Stable

The record of continuously measured streamflow in California dates back to the 1890s, although only for a few sites. CALSIM, the water operations model used by the California Department of Water Resources (CDWR) and the U.S. Bureau of Reclamation to plan and evaluate operations of California's two largest water projects, employs a hydrologic record that begins in 1922. In contrast, information from the paleoclimate record indicates that California experienced sustained drought conditions within the Holocene Epoch (recent geologic or climatic time), conditions more severe than those experienced in the historical record. The brevity of the historical record masks the true natural climatic variability – a circumstance exacerbated by the twentieth century's relative climatic stability.

California experienced six statewide dry periods lasting three or more years during the last century. The single most severe event was the two-year 1976-77 period. In 1977, statewide runoff was about 20 percent of average, the driest year of the measured historical record. Impacts experienced during the 1976-77 drought – when 47 of California's 58 counties declared local emergencies – served as a wake-up call to water managers, spurring implementation of improvements to water system reliability. The six-year drought of 1929-34 is also important from a water management

standpoint, since its hydrology was used in designing the storage capacity and yield of many of the large Sierra Nevada reservoirs that constitute the backbone of California's water supply infrastructure.

Paleoclimate Data Reveals Natural Variability

Paleoclimate information collected throughout the Sierra Nevada – from age-dating relict tree stumps that remain rooted in present-day waterbodies, to tree ring chronologies and analyses of lakebed sediments and pollen – has identified periods of severe dryness relative to present conditions. Relict tree stumps submerged in Lake Tahoe, Independence Lake, and Donner Lake, for example, identify past lowstands, times when lake levels were low enough to permit growth of trees that were subsequently submerged when climatic conditions turned wetter. One group of Lake Tahoe stumps now as much as 20 feet below the present lake level dates between 6300 and 4800 BP. Other stumps submerged up to 30 feet at Donner Lake testify to a dry period circa 1400-1500 AD.

There is abundant evidence to attest to the natural (non-anthropogenic) variability of climate. Variability can be short-term – witness the so-called year without a summer in 1816, when volcanic dust from eruption of the Javanese Mount Tambora reduced temperatures throughout the Northern Hemisphere. Variability can occur over the long-term between climatic phases, as in the case of the Northern Hemisphere's Medieval Warm Period (circa 800-1100 AD) and Little Ice Age (circa 1450-1900 AD). European historical records and North American archaeological records illustrate how this long-term variability affected societies as diverse as Norse colonies in Greenland and Anasazi settlements in the American Southwest.

Dendrochronolgy, the study of tree rings, is a common approach to developing localized information for evaluating hydrologic scenarios outside the measured record. For example, CDWR funded the University of Arizona's Laboratory of Tree-Ring Research to reconstruct annual runoff in the Sacramento River Basin for about 1,000 years prior to the beginning of the measured record. The work included collecting new tree ring samples, and used existing data from sites in and near the basin. Results included identification of a single dry year circa 1580 AD whose reconstructed runoff was only about a third of that of the driest year of measured record, and identification of multidecadal dry periods in the late 1300s and 1400s AD.

A single dry year is not insurmountable from a water management standpoint, but responding to extended dry periods like those identified in the Sacramento River Basin would be challenging at today's level of development. Greater communication among paleoclimate researchers and the water supply industry would be useful in raising awareness of natural climatic variability and of potential implications of climate shift. Credence in the possibility of sustained drought could, for example, be an impetus for technological innovations such as improvement of seawater desalting affordability. On a more mundane level, fostering consciousness of past climate extremes could help spur development of management tools such as hydrologic/climatic indices or drought response plans.

This article reflects the views only of the author; nothing in the article is intended to express a policy or position of CDWR.

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Construction of Metropolitan Water District's 800 thousand acre-foot Diamond Valley Lake near Hemet, California exposed the remains of this mastodon. Mastodons and other now-extinct species occupied the area during the Pleistocene Epoch (the time of the last Ice Age), when the local climate was much cooler and wetter than the present. Photos courtesy of MWD.