Persistent Drought In The Colorado River Basin

Compiled by John Weisheit
See Stephen L. Gray, et. al, 2003

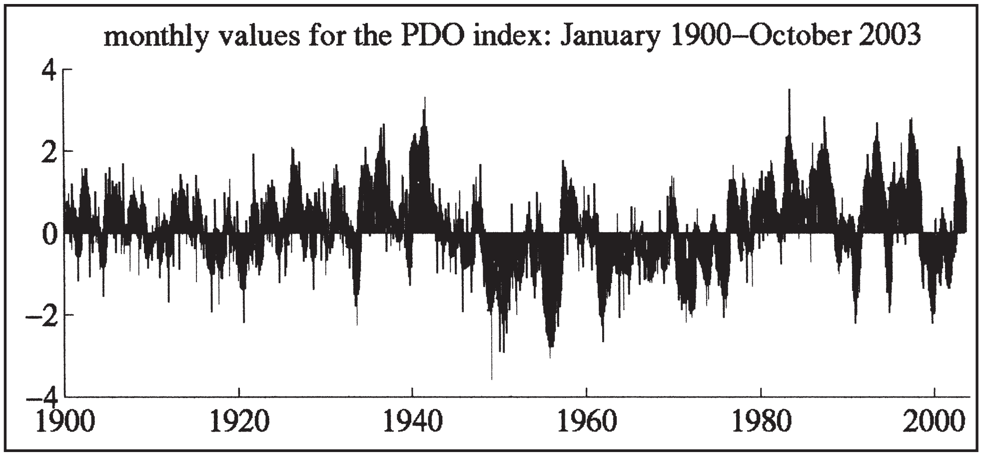
Introduction

Scientists have studied tree-ring records that span the last seven centuries for five regions of the United States, including the Colorado River basin. These records have been used to examine both wet and dry cycles of climate that can sometimes last for many decades, or multi-decadal. For example, droughts of 30–70 years persisted from the late 1500s until the mid-1800s in two of the five regions, and wet/dry cycles were synchronous at some sites until the drought of the 1950s. The pattern of severe drought in the late 1500s, followed by unusually wet conditions of the early 1600s, resembled the drought of 1942–1977 and the subsequent wet period from 1978–1998.

The mega-drought of the late 1500s may have resulted from a cooling phase in the tropical Pacific Ocean with a warming phase in the subtropical North Atlantic Ocean, and marked a substantial shift for the climate of the Rocky Mountain region. In 1998, scientists recognized similar sea surface temperatures and forecasted the present drought situation we now find ourselves in, and the present indicators offer little hope for improvement in the next few years. It is unknown if the current drought will become multi-decadal, but such a situation seems likely at some point in time, as do other extremes that include massive flooding, and higher sediment transport regimes.

Tree-Ring Chronologies

The identification of ocean oscillations from past centuries has been accomplished by scientists who have sampled tree-rings from, for example, logs from archeology sites (dwellings), and then comparing them with modern-day precipitation records. By modeling the climate records of the past by this method, there is a high degree of confidence within the science community that significant ocean oscillations in the future can be identified in order for communities to better prepare and manage the impacts of drought and floods.



1) PDO means Pacific Decadal Oscillation. Note the dominate negative PDO (dry conditions) from 1942 to 1977 and the dominate positive PDO (wet conditions) from 1978–1997.

2) The alternating varibles as noted from 1900–1941 were decades of increased sediment transport in the Colorado River (see article about sediment inventory in this issue).

Scientists have also refined the data for greater accuracy by examining more closely the chronologies from different tree species and geographic areas back to 1400 A.D.such as the central and southern Rocky Mountains. Although these two regions have different precipitation variables, historically they have suffered prolonged catastrophic droughts at similar times, such as the drought of the 1950s.

The results of refining the measurements from other tree-ring chronologies and from different regional areas mark both dry and wet periods that alternate for many successive decades, sometimes even four decades and more. However, the frequency and strength of these periods do vary in time spans and among the various regions. In other words, climate cycles do not necessarily impact all regions at the same time. For example, chronologies from Yellowstone and the southwest Rocky Mountains have a strong moisture signal in a band from 30–70 years around 1250–1400 A.D., but these signals are absent from other regions. Additionally, the Bighorn Basin (northern Wyoming) chronology shows significant energy for an even longer wet period that lasted 128 years around 1300–1400 AD.

A significant oscillation was observed during a severe and prolonged drought throughout much of North America from roughly 1575–1595 AD, which was followed by an unusually wet period in the central and southern Rockies from 1600–1625 AD.

Multi-decadal precipitation modes at 30–60 years do not persist after 1650 AD in either Yellowstone or the Colorado Plateau and remains so until the drought of the 1950s. However, the drought of the 1950s, though significant, did not resemble the severity of the drought that occurred in the late 1500s.

Discussion of Sea Surface Temperatures

In the North Pacific, much of the sea surface temperature variance occurs within a time scale of 15–25 years, and is accompanied by the strength and position of the Aleutian Low in winter. These variations have been defined as the North Pacific Oscillation (NPO) when referring to anomalies of the North Pacific, or Pacific Decadal Oscillation (PDO) if they extend into the tropics. The positive, warm phase of the PDO is associated with greater precipitation in all seasons throughout the central and southern Rockies (El Niño or wet). The 1900s were marked by two full +PDO cycles. The warm or positive +PDO regime prevailed from 1925–1946 and from 1977–1998. The cool or negative -PDO (La Niña or dry) regime prevailed from 1890–1924 and 1947–1976.

In 1998, scientists noted the tropical Pacific Ocean was cooling (-PDO).

Warmer sea temperatures in the North Atlantic exhibit a 65–80 year cycle termed the Atlantic Multidecadal Oscillation (+AMO). Warm phases occurred during 1860–1880 and 1930–1960 and cold phases during 1905–1925 and 1970–1990. The AMO shifted to its warm phase around 1995, coincident with the apparent recent shift to the negative, cool phase of the PDO. During the warm phase of the AMO, the central U.S., including the central and southern Rockies, receives less than normal rainfall, particularly in summer.

By 1998 scientists were confident that having a warm North Atlantic and a cool tropical Pacific would spell out a persistent drought for the United States. They were right, for the last five years have substantiated the prediction with water year 2002 being the driest ever in the history of documentation by modern instruments.

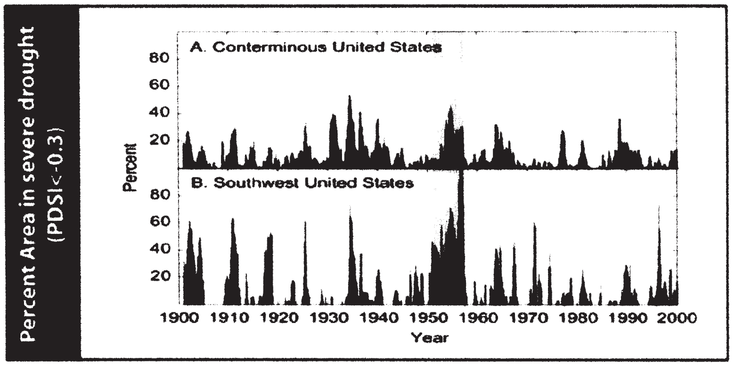
This phenomenon is also identified by dry springs (February–April) over most of the western states and were succeeded in the central and southern Rockies by failures in both the early summer (May–June) and late summer (July–August) monsoon moisture that originates in the Gulf of Mexico.

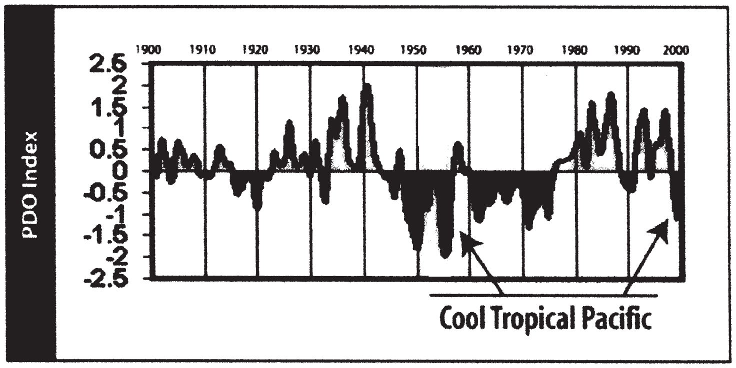
What the scientists envision is a similar pattern of intra-seasonal drought for the mega-drought of the late 1500s, which affected most of North America from northwestern Canada to the Valley of Mexico and the Atlantic Coast. Like the 1950s drought, the mega-drought of the late 1500s was followed by an unusual wet period in the early 1600s, and both events were associated with intense and prolonged La Niña episodes typical of southwestern U.S. and Great Plains droughts. Such continental-scale droughts may be symptomatic of major reorganizations in both Pacific and Atlantic climate.

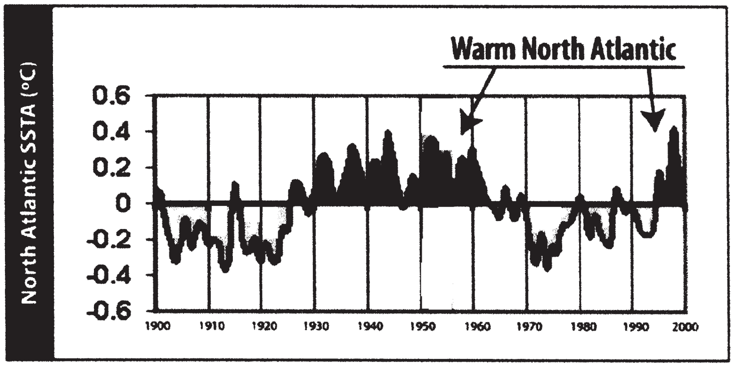
Long-term forecasting remains limited

There is considerable discussion about the steady state vs. chaotic behavior of multi-decadal variables in climate, and thus about its predictability. An optimistic view is that knowledge about the present phase of the long-term -PDO or +AMO modes can be used to forecast climate more than a year in advance. Some recent forecasts are already taking into account the possible regime shift in both the Pacific and Atlantic sea surface temperatures during 1995–1998, which could signal prolonged drought in the central and southern Rockies.

Opposing shifts in Tropical Pacific and North Atlantic Ocean temperatures may foretell persistence of disastrous, multiyear droughts across the North American continent.







Although there is plenty of multi-decadal persistence in western North America climate, the instabilities argue against extending the forecasting window much beyond 2–3 years. At the very least, however, recent shifts to the cool phase of the -PDO and the warm phase of the +AMO provide little reason for optimism about ongoing drought in the Rockies.

It is probable that multi-decadal variations in North American climate, specifically the occurrence of prolonged, continental-scale drought, involve complex interactions between the Atlantic and Pacific Oceans. Unraveling these relationships will require further development of multi-century, annually-resolved sea surface temperature analyses from the Atlantic and Pacific basins.

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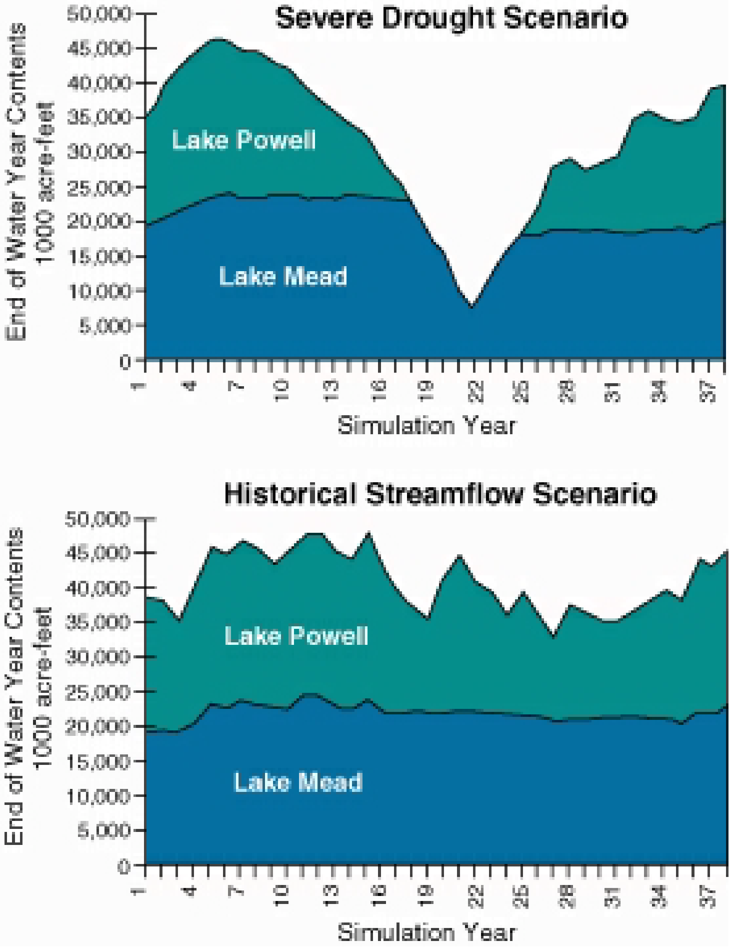
The Future Hydrology of the Colorado River

by John Weisheit

The purpose of this article is to demonstrate that the Colorado River can supply the water required by humans and the enviroment, and is available right now and at little cost. This can be done by reducing consumption through management policies to increase efficiency. Otherwise the eventuality for all residents in these arid lands, as dictated by its present course in history, is to become another failed hydrosociety. If we simply reduced our water consumption to the national average, Lake Powell would not be needed and the ecosystems of the Grand Canyon and the Colorado River delta in Mexico can be restored.

The other alternative is invasive and economically burdensome, which is to finance and construct: 1) massive powerplants to provide energy; 2) large-scale wastewater and desalinization plants; 3) pipelines to deliver water to the users. These alternatives will increase our dependence on finite natural resources, such as petroleum and nuclear fuels. These fuels are very inappropriate considering: 1) our degraded atmosphere; 2) the expense and dangers associated with nuclear technology and waste; 3) our penchant as a country to generate unproductive relationships with other countries to support our rampant consumptive life style.



If the mega-drought of the late 1500s were to repeat itself, Lake Powell reservoir would empty for eight years

Another consideration includes the potential for water to become a commodity controlled by corporations, rather than managed as a public trust.

According to law, the water allocations of the seven states and Mexico is 16.5 million acre-feet. The real-time average supply of the Colorado River is, at best, 14 million acre-feet. The total loss due to evaporation and leakage throughout the whole system is currently 3 million acre-feet, which is nearly the complete allocation for the state of Arizona (2.8 million acre-feet). Any objective financial analyst would be shocked at the poor performance of this business venture. Congress is fully aware of this poor performance because they continue to approve Band-Aid fixes and subsidies every year to maintain it.

When the persistent drought appeared in the middle 1900s, nobody really noticed the shortfall because the supply still exceeded the demand—leaks, evaporation and all. Afterwards, when the metropolitan building booms began, nobody noticed either, because the Colorado River overproduced and filled the reservoirs despite the development. Building so-called metropolitan dreams on luck is called greed, not business.

Things are different now that the swimming pools are dug and the golf courses seeded. The demand has almost peaked and the supply continues to wax and wane at the whim of climate. The drought situation at present is very similar to the 35 years of reduced supply that occurred between 1942 and 1977 when El Niños took a long nap and a negative Pacific Decadal Oscillation locked in for an extended stay (see previous article).

The total storage of the Colorado River system right now is below 50%. It took four years to get there. If the drought persisits for another four more years, the trend will instead become a long reality and will completely drain Lake Powell reservoir. Obviously the drought will break—they always do. But what is the next climate regime going to bring our way? Will extreme flooding occur and bring the associated shuddering at Glen Canyon Dam—as occurred in 1983 when the the spillways choked at only 20% of capacity? Will the four-hundred fold sediment loads of the early 20th century return? The answer to these questions are—yes.

Models have been generated by hydrologists and resource economists with results posted on the web. Visit: <http://geochange.er.usgs.gov/sw/changes/natural/codrought/impacts.shtml>. The model presented at the left is based on 400 years of tree-ring data and simulates a drought of the late 16th century (1570-1598). That severe and sustained drought had a 30 percent reduction in stream flow on average in a 19 year period.

How will a drained reservoir effect river running? Our Colorado River river trips will have to take out at the old ferry roads at Hall's Crossing.

Clay Hills Crossing on the San Juan River will continue to be impacted by sediment. The river incising into the sediment may leave the boat ramp perched above a downcutting river. Channel meandering may place the river on the opposite shore. Trips on the San Juan River may have to locate alternate sites to exit the river as well.

Author	Years of record	Location	Unregulated flow in millions of acre-feet
E.C. LaRue USGS; 1925	1895-1922	Lee's Ferry	16.8
L. B. Leopold USGS; 1959	1896-1956	Lee's Ferry	13.85
Bureau of Reclamation	1906-1983	Lee's Ferry	14.35
D. R. Dawdy 1990		Lee's Ferry	14.0
Tree ring record Meko et. al. 1995 Tarboton 1995	400 years before present	Lee's Ferry	13.5
Bureau of Reclamation	1922-1983	Lee's Ferry	15.0

For the Law of the River to function, Nature must supply 16.5 million acre-feet (unregulated flow) annually at Lee's Ferry. The upper and lower basins each receive 7.5 million acre-feet and Mexico receives 1.5 million acre-feet. As you can see from this chart, statistics very widely according to the data sets used. The fiqure stated by Dawdy, on behalf of the National Academy of Sciences, is probably the best estimate. Regardless, the system is flawed and will fail as demand increases. Presently there is no leadership in government agencies to correct the problem. The environmental issues at risk are decreasing instream flows above Lake Powell reservoir and for the Colorado River delta in Mexico. Litigation will dominate the next decade of Colorado River management due to non-compliance.

Source	Year (s)	Upper Basin depletions in million acre-feet
E. C. LaRue 1925	1985 - 1922	1.80
D. R. Dawdy 1990	1968 - 1974	4.28
Bureau of Reclamation	2000	4.72
Bureau of Reclamation	2010	5.20

This chart explains the consumption of the upper basin above Lee's Ferry, which is allocated 7.5 million acre-feet and includes evaporation and leakage. The lower basin completely consumes their allocation of 7.5 million acre-feet, as does Mexico with their allocation of 1.5 million acre-feet.

Source	Full reservoir calculation	Lake Powell evaporation in acre-feet	Lake Mead evaporation in acre-feet
E.C. LaRue USGS 1925	Evaporation formula	750,000	1,000,000
W.O. Smith et. al. USGS 1960	Water year 1942		1,045,000
US Weather Bureau 1959	Evaporation formula	730,000	
Bureau of Reclamation	Water year 1983	633,000	

This chart explains the evaporation rates for the reservoirs known as Lake Mead and Lake Powell. The combined evaporation of the two reservoirs is equilavent to the complete allocation of Utah (1.7 million acre-feet).