~Enhancing Water Supply Reliability~

An Interdisciplinary Research Project to Enhance Predictive Capacity on the Colorado River

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Special Issue

Review: Water Supply Impacts of Climate Variability and Change in the Colorado River Basin

This edition examines a collection of recent reports and research on the regional water supply impacts of climate variability and change in the Colorado River Basin. This review includes reports generated in 2007 by the National Research Council, Intergovernmental Panel on Climate Change, and researchers at the University of Washington. The next edition of the newsletter will be released in **Summer 2007** and will provide a **mid-term progress report** of the University of Arizona research efforts for the second phase of the project.

Please visit http://ag.arizona.edu/azwater/ewsr for project details, updates, reports, and contact information.

In this Issue:

The Colorado River's Hydroclimatic Variability: 2007 National Research Council report

By Kiyomi Morino

According to the most recent report by the NRC (National Research Council, a branch of the National Academies) on water management in the Colorado River basin (NRC 2007), the gaged record of streamflow data represents a "chronologically-limited sliver of information" when evaluating hydroclimatic variability. Tree-ring reconstructions of streamflow are one of the best ways to address this shortcoming, extending the hydrological record back in time by several centuries. The longer time frame enables a more complete characterization of drought events, including recurrence intervals, durations, and, to some extent, magnitudes. From a managerial standpoint, this information can be invaluable for putting current conditions into context, given that uncertainties in the tree-ring reconstructions are understood (see Box 1).

Box 1. Sources of uncertainty in tree-ring based reconstructions.

1. Trees do not account for 100% of the variance in streamflow data; although they do explain a significant portion of historic flow variability,
2. The availability of tree ring data decreases back in time (older trees are more rare), thereby reducing the strength of the common signal in older portions of the reconstruction.
3. The amount of low frequency information is limited by the ages of the individual trees: younger trees cannot adequately reflect conditions that occur over long time periods.
4. The quality of the gage record used in calibration may vary over time.
5. Reconstruction values exceeding calibration period values, in either a positive or negative direction, tend to be less reliable.

Paleohydrological data resources for the Colorado River Basin are indeed rich. To date, there are four tree-ring based reconstruction studies of streamflow at Lees Ferry: Stockton and Jacoby (1976), Michaelson and colleagues (1990), Hidalgo and colleagues (2000), and Woodhouse and colleagues (2006). The generation of these multi-century streamflow records differs in the data—both tree-ring and gage—used in their development and the statistical methods and treatments applied to these data. Nevertheless, they all illustrate the following important points:

- Long-term, i.e., multi-centennial, averages of Colorado River flows are lower than both the Lees Ferry gage record upon which the Colorado Compact was based and the full twentieth century record;
- Flow conditions at the beginning of the twentieth century were, in fact, the wettest in the last 500 years;
- And, compared to the twentieth century, longer droughts have occurred in the past.

In side-by-side comparisons, notable differences amongst the reconstructions emerge. First, the long-term mean flows vary between 13.0 and 14.7 MAF (Million Acre Feet). And second, while the reconstructions are relatively synchronous in the timing and duration of high and low flow periods, the intensity of these events varies noticeably amongst the different studies. Some of these differences have tentatively been attributed to the amount of persistence, or level of year-to-year similarity, in the tree-ring data, originating from varying data processing and modeling approaches. Qualitatively speaking, the more recent reconstructions are considered to be more reliable because they are based on longer calibration periods. Amongst these recent reconstructions, however, there is no clearly superior, or most accurate, reconstruction.

In light of the historical context provided by tree-rings, two questions emerge: How does the five-year drought of the early 2000s (2000-2004) compare? And, what can we expect in the future? To answer the first question, there was only one other five-year period over the last 500 years with a lower mean value: 1844-1848 (Woodhouse et al 2006). However, several others had a high probability of exceeding the magnitude of the latest drought with respect to their deviations from average conditions. In response to the second question, the information provided by the tree-ring record, including the range of hydrologic variability and predisposition towards extended drought episodes in the Colorado River Basin, in conjunction with current temperature trends and projections due to global warming, have lead NRC to recommend that water managers consider the distinct future possibility of a drought more severe than any that has been experienced thus far.

While these tree-ring contributions are important, particularly because they represent a more complete characterization of hydrologic variability than the gaged record, there is still much information yet to be provided. For example, recent tree-ring investigations of Colorado River sub-basins have pointed out the spatial variability of streamflow over time. A comparison of tributary reconstructions showed that major droughts occur at varying levels of intensity throughout the basin (Woodhouse et al. 2006). Furthermore, there is also the potential for using tree-ring reconstructions to better understand linkages between ocean/atmospheric circulation, uncovering, perhaps, underlying mechanisms driving hydrologic variability at multidecadal timescales in the Colorado River Basin.

A Review: Colorado River Water Supply Impacts of Climate Change Scenarios

By Matthew Switanek

The Intergovernmental Panel on Climate Change (IPCC) Working Group I Fourth Assessment Report was released in February 2007. The IPCC has a Special Report on Emission Scenarios (SRES) which assesses climate change projections with a large number of simulations available from a broad range of models. The two most commonly used scenarios in model simulations are A2 and B1; the likely upper and lower bounds for projected CO_2 levels. As of January 2007, the earth's atmospheric CO_2 concentration was about 383 parts per million (ppm). If CO_2 emissions continue unabated throughout this century, as depicted by the A2 scenario, then global average CO_2 concentrations will be approximately 850 ppm by 2100. In contrast, scenario B1 portrays a future in which CO_2 concentrations initially increase, then level off around mid-century and end at 550 ppm by 2100.

A recent paper by Christensen and Lettenmaier (2006) used scenarios A2 and B1 from the SRES to observe their effects on the Colorado River basin. In this study, 11 General Circulation Models (GCMs) were chosen to predict temperature and precipitation data over three periods; period 1: 2010-2039, period 2: 2040-2069, period 3: 2070-

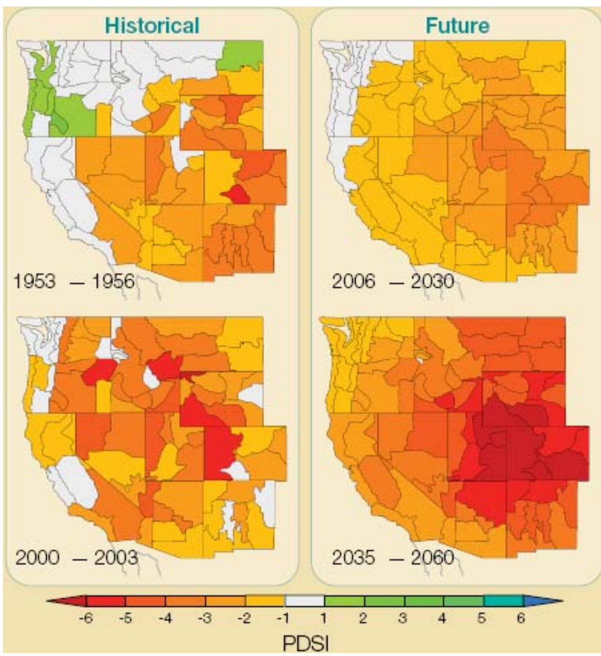
Scenario, Period	Precipitation (percent change relative to 1950-1999)	Evaporation (percent change relative to 1950-1999)	Runoff (percent change relative to 1950-1999)	Runoff Ratio – Precipitation/Runoff (percent change relative to 1950-1999)	Temperature (°C relative to 1950-1999)
HISTORIC	354 mm/yr.	309 mm/yr.	45.2 mm/yr.	12.8 %	10.5 °C
B1 / PERIOD 1	360 (+1%)	315 (+2%)	45.0 (0%)	12.5 (-2%)	11.8 (+1.3°C)
B1 / PERIOD 2	351 (-1%)	310 (0%)	41.8 (-7%)	11.9 (-7%)	12.6 (+2.1°C)
B1 / PERIOD 3	351 (-1%)	309 (0%)	41.6 (-8%)	11.8 (-8%)	13.2 (+2.7°C)
A2 / PER 1	351 (-1%)	307 (-1%)	44.6 (-1%)	12.7 (-1%)	11.8 (+1.2°C)
A2 / PER 2	348 (-2%)	305 (-1%)	42.7 (-6%)	12.2 (-5%)	13.1 (+2.6°C)
A2 / PER 3	347 (-2%)	306 (-1%)	40.3 (-11%)	11.6 (-10%)	14.9 (+4.4°C)

Table 1: Historic values are averaged over the time 1950-1999

2099. The results of the GCMs were then averaged and used in the macroscale hydrological model Variable Infiltration Capacity (VIC) (developed by the University of Washington). Forcing[1] the VIC model with the precipitation and temperature data in Table 1, runoff can be seen to decrease over time for scenarios A2 and B1.

Christensen et al created the Colorado River Reservoir Model (CRRM) as a simplified version of the CRSS long term planning model. VIC derived runoff values were used in the CRRM to observe the effects on reservoir storage. Average reservoir storage was seen to decrease 13 percent for A2 and 10 percent for B1 by 2100.

Another study by Hoerling and Eischeid (2006) uses the Palmer Drought Severity Index (PDSI) to project Colorado River basin conditions. The PDSI calculates the cumulative effects of precipitation and temperature on surface moisture balance. A regression equation, which includes natural flow at Lees Ferry and PDSI averaged over the upper Colorado Basin, found that the annual PDSI explains 63 percent of the annual river flow variations at Lees Ferry over the 95-year reference period. The monthly PDSI was calculated, for simulations using the A2 scenario, out to the year 2060. Based on this analysis, due to the effect of increased evapotranspiration associated with warmer temperatures, the predicted PDSI places the Colorado River basin in a near perpetual state of drought in the coming decades.



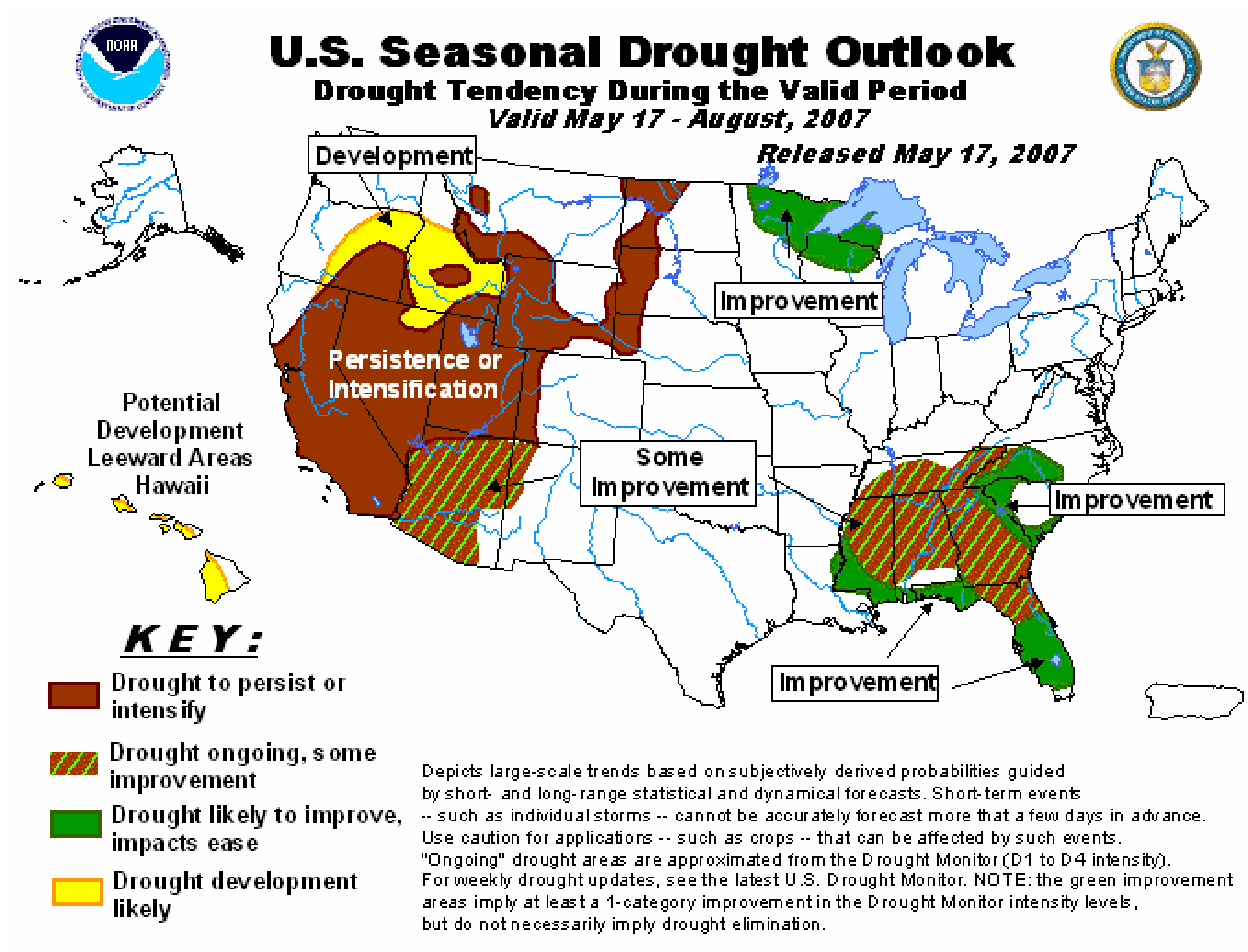
These findings bring additional focus to the concerns created by recent drought conditions, and emphasize the importance of developing interim guidelines for Lower Basin shortages and coordinated operations of Lakes Powell and Mead.

[1] GCM's averaged projected precipitation and temperature values are downscaled and used in the VIC model to observe how these conditions could potentially affect runoff.

Drought and Water Supply Report

By Dustin Garrick

The El Nino event during Winter 2006-07 failed to provide anticipated increases in winter precipitation in Arizona according to the Climate Assessment for the Southwest (CLIMAS). The NOAA seasonal drought outlook depicts intensified drought conditions throughout portions of the Colorado River Basin and anticipates the development of drought conditions throughout portions of the Upper Basin during summer 2007 (see below).



Water supply in the Colorado River Basin continues to decline due to dry conditions in water year 2007, marking the seventh year of below average runoff into Lake Powell within the last eight water years. The June 24-month study report projects April-July runoff into Lake Powell at 50% of average, and Lake Mead is expected to continue to decline. Under the *most probable*[2] water inflow scenario of the Bureau of Reclamation's June 2007 24-month study outlook, Lake Mead would decline to an elevation of 1100 ft above sea level in July 2008 – the first decline to 1100 ft since 1957. Under several of the proposed alternatives of the Shortage/Coordinated Operations Draft EIS, the first tier of shortages would be triggered at an elevation of 1075 feet, meaning that the first shortage is plausible in water year 2009 or 2010 under inflow conditions less than the most probable inflow.

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[2] based on forecasts by Colorado Basin River Forecasting Center

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Literature Cited

Christensen N. and D.P. Lettenmaier, 2006: A multimodel ensemble approach to assessment of climate change impacts on the hydrology and water resources of the Colorado River basin. *Hydrology and Earth System Sciences*.(in review).

Hidalgo, HG, TC Piechota, and JA Dracup. 2000. Alternative principle components regression procedures for dendrochronologic reconstructions. Water Resources Research 36(11): 3241-9.

Michaelson, J, HA Loaiciga, L Haston, and S Garver. 1990. Estimating drought probabilities in California using tree-rings. California Department of Water Resources Report B-57105. Santa Barbara, CA: University of California.

National Research Council (NRC). 2007. Colorado River Basin Water Management. Washington DC: National Academy Press.

Stockton, CW and GC Jacoby. 1976. Long-term surface water supply and streamflow trends in the Upper Colorado River basin based on tree-ring analyses. Lake Powell Project Research Bulletin 18: 1-70.

Woodhouse, CA, ST Gray and DM Meko. 2006. Updated streamflow reconstructions for the Upper Colorado River basin. Water Resources Research 42 W05415, doi: 10.1029/2005WR004455.