

=Enhancing Water Supply Reliability=

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

Quarterly Newsletter

Spring 2005

Issue #3

UA Research Team Begins Addressing Stakeholder Questions

By Dustin Garrick

Having completed the first round of visits with water managers and user groups, the UA research team has begun to address the stakeholder questions summarized in the last newsletter (Issue #2, Winter 04-05). Continued dialogue with water managers and users will strengthen the UA research team's effort to improve predictive capacity, so readers are encouraged to contact the principal investigators listed on page 6 with additional information, feedback, and questions.

In addition to updates on drought conditions and shortage sharing discussions, this newsletter will feature a series of topical articles that address stakeholder questions and provide resources for water managers and policymakers.

Water Policy and Economics:

'Dry Year Water Transfer Options' (page 3) – An article on dry year options will outline common strategies for transferring water resources through voluntary and temporary agreements in times of drought. This article elaborates the purpose of dry year options and details the experiences of other states that have implemented such drought-coping mechanisms.

Paleoclimatology and Tree Ring Records:

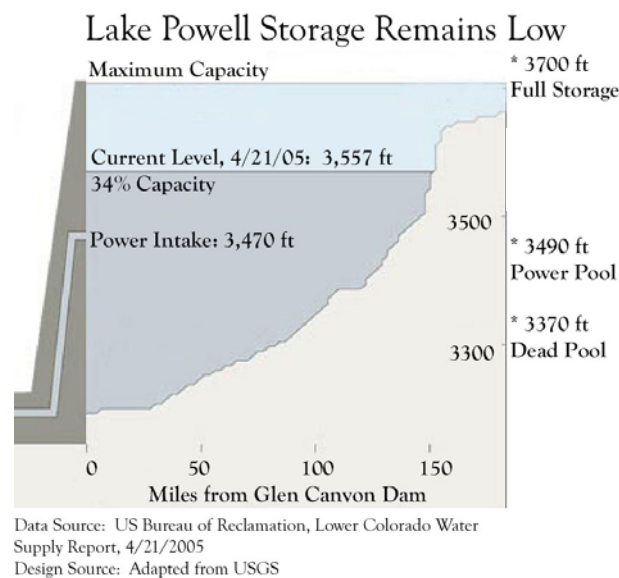
'Connecting Tree rings and River Flows' (page 4)– Water managers have increasingly referred to tree-ring records

for information about historical river flow conditions, particularly for the time period prior to the instrumental collection of runoff data during the past 100 years. This article explains the connection between tree ring growth and river flow.

'Tree Rings Capture the Low and High Flows (Page 5) – Stakeholder groups frequently posed the question whether tree rings can accurately record river flow during high flow periods. This article attempts to dispel the common misconception that tree rings are insensitive to high flow events, while also discussing the key limitations of tree rings as a gauge for high flows.

Climate and Hydrologic Modeling:

'Validating Hydrologic Models' (Page 5)– The previous newsletter (Issue #2, Winter 04-05) contained two articles that explain how climate information can be integrated into water supply forecasting. This article picks up where those previous articles leave off by describing the way such models are validated.



Drought Status Update

By Dustin Garrick

Short-term drought eases; long-term outlook is uncertain and large reservoirs remain depleted

Numerous sources have reported the easing of short-term drought conditions in the Colorado River basin, notably the National Drought Mitigation Center, National Oceanic and Atmospheric

Association, and Climate Assessment for the Southwest. This consensus on short-term conditions does not resolve longer term uncertainty regarding

water supply reliability in the Colorado River basin. The diagram (on page 1) represents the current status of Lake Powell – one of the two primary reservoirs in the Colorado River system – in relation to critical storage elevations.

The runoff generated by spring snowmelt is expected to raise Lake Powell by 45-50 feet and provide over 8 million acre feet (maf) of water; however, deliveries to Lake Mead under the terms of the 1922 Compact and the Minimum Objective Release (MOR)* requirement of 8.23 maf per year from Lake Powell will ultimately yield only a minimal net gain in the cumulative amount of water stored in Lakes Powell and Mead beyond the summer. Powell and Mead are currently at 34% and 62% of full capacity (as of April 28, 2005), respectively, and the two reservoirs are expected to partially equalize† by summer's end, reaching 48% in Powell and 58% in Mead. This outcome would, therefore, constitute a net gain of approximately 4.5% capacity or 2.3 maf of water stored in both reservoirs combined (see table above). Overall, the Colorado reservoir storage system contains about 31.5 maf or 53% of full system storage capacity, which represents a decrease of about 0.3 maf from a year ago at this time.

Complying with Compact terms, the MOR, and international treaty obligations of 1.5 maf to

* The Minimum Objective Release (MOR) is a reservoir operating criteria devised to ensure compliance with the terms of the 1922 Colorado River Compact and 1968 Colorado River Basin Project Act (CRBPA). The 8.23 maf per year released from Lake Powell represents the 7.5 maf allocation to the Lower Basin plus half of the 1.5 maf annual obligation to Mexico (.75 maf) minus .2 maf from tributary inflows from the Paria River which reaches the main stem Colorado prior to the gauging station at Lees Ferry.

† Section 602 (a) of the 1968 CRBPA identified criteria to maintain active storage in Lakes Powell and Mead at roughly equal levels if Powell is projected to be higher than Mead and the Upper Basin storage criterion is met.

Mexico means it could take many years to replenish system storage under average inflow conditions. Though this year's snowpack and runoff conditions provide a temporary reprieve, renewed drought conditions in the coming years could severely strain the capacity of the Colorado River system and potentially lead to water supply shortfalls (see 'Shortage Sharing Update' article below). In 1999, at the beginning of the recent 5-year drought, system storage was nearly full at approximately 95% capacity. If drought conditions in the basin resemble those of previous droughts, which contained sporadic average and above-average inflow years sandwiched within

periods of dry years, water supplies may still be at a high risk of shortage. This risk has led to a shortage sharing negotiation process among the seven US basin states receiving water from the Colorado River.

Storage in Colorado River System Major Reservoirs						
	Powell		Mead		Mead + Powell	
	% Full	MAF	% Full	MAF	% Full	MAF
Current (4/05)	34%	8.38	62%	15.9	48.28%	24.28
Projected (9/05)	48%	11.83	58%	14.75	52.84%	26.58
Change	+14%	+3.45	-4%	-1.15	+4.57%	+2.3

Data Source: Bureau of Reclamation, Lower Colorado River Water Supply Report, 4/28/2005

Shortage Sharing Update

Basin state plan forthcoming despite renewed conflict over 1922 Compact terms; Mid-year review preserves 8.23 maf release from Lake Powell

By Dustin Garrick

An April 1 deadline set by the Department of Interior for a shortage sharing plan from the seven Basin States has passed without a plan being submitted. The shortage sharing process is still proceeding, however, and the loose contours of a shortage sharing plan have begun to emerge. According to a presentation made at the Arizona Department of Water Resources (ADWR) on March 17, 2005, a series of issues have been defined through the shortage sharing process. The parameters for designating shortage have been clarified, although 'extraordinary drought,'‡ a term which causes various Compact responses, is not yet defined. A combination of a) reservoir elevations and

‡ The 1944 water treaty with Mexico stipulates restrictions of Colorado River water deliveries to Mexico in the event of 'extraordinary drought,' although terms for such a drought have not been defined.

b) intake levels would serve as parameters for triggering shortages, although the specific levels for those parameters have not been identified. The states have also have evaluated options for conjunctively managing Lakes Powell and Mead in order to balance the two reservoirs and preserve power generation at Lake Powell.

Despite progress toward the establishment of shortage sharing guidelines, a handful of potentially divisive issues have surfaced, raising the specter of renewed conflict and litigation over the interpretation of the 1922 Colorado River Compact and the Minimum Object Release (MOR) requirement of 8.23 maf from Lake Powell. The Upper and Lower Basin disagree on Compact language that calls for the Upper Basin states to share responsibility for redressing any runoff ‘deficiency’ to meet the delivery obligation to Mexico. The Upper Basin has also requested a reduction to the 8.23 maf MOR because of the tributary inflows in the lower basin, which the Upper Basin claims should count toward the Mexico obligation. Secretary Norton, the river master for the lower Colorado River system, issued a mid-year review of the Annual Operating Plan on May 2 in which she maintained the MOR at 8.23 maf from Lake Powell for 2005.

The shortage discussions have focused extensively on which water users would lose water if the reservoir system experiences a declared shortage. The next article on dry-year water transfers summarizes one mechanism that has been adopted in western states to proactively address water supply variability.

Dry Year Water Transfer Options

By Katie Pittenger

What are Dry-Year Options?

Dry-year options are contractual agreements that provide for **voluntary and temporary** drought-triggered water transfers. Dry-year options involve a transfer from agricultural water use to municipal or environmental restoration use. Typically, buyers pay an up-front fee to secure the option to use water during dry conditions, water that is normally used to irrigate crops. Then, if the option is exercised, buyers pay a price (specified in the contract) to exercise the option.

Agriculture represents over 80% of consumptive water use in the southwestern U.S., some of which yields relatively low economic returns. In addition, the costs associated with developing new water supplies for improved reliability are generally higher than the cost of temporary transfers of water out of agriculture. Dry-year options can be a more economically-attractive arrangement to ensure water supply protection during drought, as compared to the outright purchase of senior agricultural water rights. Though not without controversy, dry-year options create less concern about third-party impacts in communities dependent on irrigated agriculture because irrigators maintain their water rights. That is, under normal hydrologic conditions, irrigators’ access to the water supply is preserved and farming in the area continues.

When are Dry-Year Options Practical and Appropriate?

The following factors must be considered in structuring dry-year options:

1. The water supply must be adequate for irrigation use in normal years and sufficient for option use in dry years.
2. The relevant state and federal legal framework for water use and transfers must be conducive to dry-year options. Well defined and transferable rights to use water must exist.
3. Option contracts are generally limited to annual crop operations that can be temporarily suspended. Perennial crop production, vineyards and orchards are generally not well suited.
4. Buyers and sellers both need realistic information regarding use values and the cost of alternative water supplies.
5. Estimation of the probability and severity of drought is essential. Estimates of how often the option will be exercised must be within acceptable limits of risk for both parties.
6. The overall costs of negotiating and implementing a dry-year option contract, including transaction and transportation costs, must be lower than the buyer’s next most costly water supply alternative for dry years.

Where have Dry-Year Options Been Implemented?

California Dry Year Water Purchase Program- In 2001 the California Dry Year Water Purchase Program was established to help secure water supplies for public water agencies and other entities throughout California in the event of drought. Enduring dry conditions in the state have meant the dry-year program has been initiated almost every year since its induction.

Metropolitan Water District Dry-Year Transfer Options- Facing cutbacks in Colorado River supply and drought conditions, a number of times in recent years MWD of Southern California has authorized one-year transfer options from Central Valley water agencies.

Oregon Water Trust- With the aim of streamflow restoration for fishery conservation, the Oregon Water Trust employs split season leasing whereby irrigators use their water in the first half of the season, and then in the second, drier half of the season the Trust leases water from irrigators for instream flow augmentation.

Edwards Aquifer Authority- In anticipation of summer drought conditions, the Edwards Aquifer Authority in central Texas initiated an "Irrigation Suspension Program" in late 1996. Options were exercised, and farmers were paid to forgo crop irrigation during the summer of 1997. Here, dry-year options were used in an effort to temporarily reduce irrigation water use and maintain springflow levels to support federally listed endangered species.

The Connection between River Flow and Tree Growth

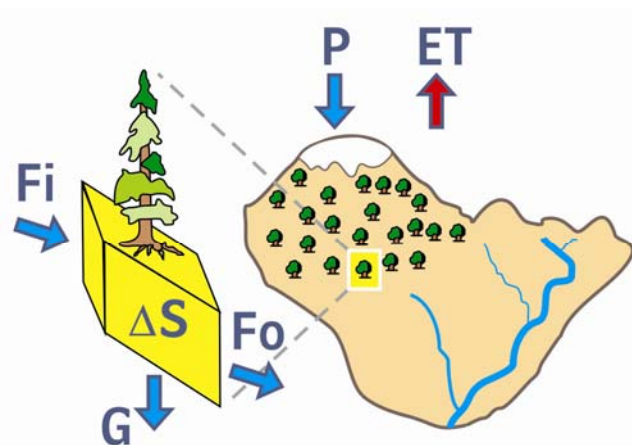
By Scott St. George

For several decades, scientists have used tree-ring records to understand how river flows in the American west behaved during the past several centuries. Usually the trees studied by dendrochronologists are far away from river banks, and are not directly affected by stream water. What makes these remote trees good predictors of river flow?

The answer is that both tree growth and river flow are similarly influenced by changes in precipitation and evapotranspiration. Streamflow is

essentially the sum of net precipitation (precipitation minus evapotranspiration) over the watershed upstream from the gauging point. Low precipitation and high evapotranspiration combine to produce reduced flow.

Low precipitation and high evapotranspiration also lead to reduced growth in trees located in or near the watershed. Water is absolutely critical for tree growth, mainly because it is required for the enlargement of cells within the cambium (the layer of living cells between the wood and the bark). When water is abundant, the tree is able to form large cells and wide tree rings. If the tree's water supply is limited, small cells are formed, creating a narrow ring. Water stress also reduces the amount of CO₂ available for photosynthesis and slows down the synthesis of proteins and other growth processes in the tree.



A conceptual model (see above) based on the water balance of a volume of soil beneath a sampled tree in the watershed can be used to illustrate the connections between river flow and tree growth. During a drought, low precipitation (P) and high evapotranspiration (ET) combine to limit the amount of water available to both trees and river systems. Dry conditions diminish the flow of water going to runoff (F_i and F_o) and into groundwater recharge (G). Reduced amounts of surface water deplete soil moisture (ΔS) and cause trees to experience moisture stress. Hot, dry conditions also cause trees to lose more water through transpiration. The net result is a water deficit within the tree that affects growth processes as described above. At the same time,

runoff components (F_o and G) contributing to streamflow (F_o) will also decrease; under extremely dry conditions, little or no water will make its way to the river.

These physical processes associated with the water balance and tree growth therefore provide a strong, though indirect, link between river flow and the trees growing across the watershed. This shared 'fingerprint' of past moisture conditions allow dendrochronologists to use tree-ring records to develop estimates of discharge levels that go back several hundred years.

Trees Capture the Low and High Flows

By Scott St. George

A common misconception is that tree rings provide accurate estimates of past droughts, but cannot record the occurrence of wetter periods. In watersheds where annual total streamflow is produced mainly by a few, short, intense rainstorms, runoff may occur so rapidly that very little moisture finds its way into the root zone of the tree. Consequently, tree rings are not good recorders of high annual flow for many smaller basins at lower elevation, where the climate is semi-arid and precipitation is episodic.

Fortunately, tree rings provide better estimates of high flows for larger watersheds (like the Upper Colorado River basin and its major tributaries). In large basins, high annual streamflow is generally caused by rain and snow storms that last for several days and affect the entire catchment. These extensive and persistent storms are more likely to leave their imprint in the soil moisture available to the trees, leading to the formation of wider rings. The large spatial scale of these storms also improves the chances that the events can be sampled by a sparse network of tree-ring sites across the basin.

Tree-ring records are particularly good recorders of streamflow when most runoff within a basin is derived from snowmelt. Because snow can persist on the landscape for several months, it is likely to provide moisture that continues to recharge the root zone well after the storms have passed. A heavy snowpack can lead to above-normal tree growth by releasing its stored water to the roots throughout the

relatively dry spring months when much of the cambial growth is occurring. Because high flow years in larger watersheds are almost always caused by a heavy winter snowpack, tree rings are ideally suited to provide estimates of both low and high flows for most of the major basins in the West.

Validating Hydrologic Models

By Laura Lindenmayer

Reservoir operations rely heavily on streamflow forecasts. The quality of these forecasts depends on the meteorological data that drives or "forces" the model simulation, the computer code that is used to make them, and the model parameters that turn the generic computer code into a site-specific model. This brief article focuses on the latter two.

Which computer code to use largely depends on the type of application, the available information, and the computational resources. Many of these computer codes exist, all with their own strengths and weaknesses. Some codes only simulate the streamflow at selected locations along a river, while others also predict processes such as evaporation, transpiration, and storage changes in the basin.

Model parameters turn the generic computer code into a site-specific model by defining the properties of individual model elements. For example, land use types and soil information would be included by specifying appropriate model parameters. Because these model parameters are typically not directly measurable in the field, their values are often determined through a process called calibration. In this process, parameters are adjusted manually or automatically to achieve the best possible model simulation. Different definitions of the "best possible model simulation" can be used depending on the application. For example, for flood control purposes, the magnitude and timing of the maximum flow would be of most interest. Consequently, the best possible model simulation would be the one that matches the observed peak flow most closely both in magnitude and timing. In other cases the flow volume during a certain period or the minimum flow might be of primary interest. It is important that the time period used in the calibration process includes a wide range of flow conditions, that is, both high and low flows must have occurred during the calibration period.

Following calibration, the model is often tested by assessing how well it performs during a time period which was not used during the calibration process. Again, it is important to use a period that covers a wide range of flow conditions. In some cases the term “model validation” is used for this process, although many object to the use of this term and prefer the term model testing. The main objection is that the term “validation” implies a greater level of certainty than is warranted in many cases.

During this process, simulated and observed

flows are again compared to quantify the ability of the model to simulate the dynamic behavior of the real system. If performed diligently, the model testing process will highlight both the strengths and weaknesses of the calibrated model. If the performance of the calibrated model is deemed satisfactory, it can then be used to make streamflow forecasts. These forecasts can provide a valuable tool for reservoir operations, as long as the user remains aware of the strengths and weaknesses as revealed during the testing or validation process.

Project Contacts

University of Arizona	Bureau of Reclamation
<p>Bonnie Colby, Economics bcolby@ag.arizona.edu 520-621-4775 Graduate Assistant: Katie Pittenger (kap@email.arizona.edu)</p> <p>Kathy Jacobs, Project Management and Water Policy kjacobs@ag.arizona.edu 520-792-9591 ext. 15 Graduate Assistant: Dustin Garrick (dustingarrick@gmail.com)</p> <p>David Meko, Tree Ring Research dmeko@lrr.arizona.edu 520-621-3457 Graduate Assistant: Scott St. George (sstgeorg@nrca.gc.ca)</p> <p>Bart Nijssen, Hydrological Modeling nijssen@u.arizona.edu 520-626-1277 Graduate Assistant: Laura Lindenmayer (laural@email.arizona.edu)</p>	<p>Carol Erwin, Area Manager Phoenix Office cerwin@lc.usbr.gov 602-216-3801</p> <p>Terry Fulp, Area Manager Boulder City Office tfulp@lc.usbr.gov 702-293-8190</p> <p>Leslie Meyers, Civil Engineer, Phoenix Office lmeyers@lc.usbr.gov 602-216-3835</p> <p>Lorraine Siano, Modeling, Boulder City Office lsiano@lc.usbr.gov 702-293-8539</p> <p>Darlene Tuel, Project Management, Phoenix Office dtuel@lc.usbr.gov 602-216-3918</p>

We would greatly appreciate additional feedback on this project.

Please contact the appropriate PI or you can contact Dustin Garrick (dustingarrick@gmail.com 520.400.4333) with any general comments or questions.