Introduction to Tree-Ring - Based Streamflow Reconstructions

Connie Woodhouse, Ph.D. *– NOAA Paleoclimatology Program, and* ***David Meko, Ph.D.****, Laboratory of Tree-Ring Research, University of Arizona*

Today's methods for water resource planning are based primarily on 20th century instrumental records of climate and streamflow. Unfortunately, these records are typically less than 100 years in length and may capture only a limited portion of the range of possible natural hydroclimatic variability. Tree-ring reconstructions of streamflow (dendrohydrological reconstructions) have been used to augment existing instrumental streamflow records. In their often-cited reconstruction of the Colorado River at Lee's Ferry, Stockton and Jacoby (1976) used tree rings to show that the compacts governing the allotment of water were based on the wettest period in the past 400 years. Besides the Colorado River, tree-ring reconstructions of streamflow have also been made for other Southwest river basins, including the Gila, Salt and Verde Rivers in Arizona (Smith and Stockton, 1981; Meko and Graybill, 1995).

> *Correlations between tree growth and seasonal precipitation indicate that trees in the Southwest are most sensitive to cool-season precipitation prior to the growing season*

Streamflow from Tree Rings

Tree growth can be used as proxy for streamflow because many of the same climatic factors that influence tree growth also influence annual streamflow, particularly precipitation and evapotranspiration (Meko et al. 1995). Correlations between tree growth and seasonal precipitation indicate that trees in the Southwest are most sensitive to cool-season precipitation prior to the growing season, most likely because this precipitation recharges soil moisture for the growing season, but also because some physiological processes continue even during winter (Fritts 1976). Providentially, the most important seasonal component to annual streamflow in the Southwest is also cool-season precipitation, which is controlled by regional- to continental-scale climate patterns (as opposed to local climate). As a consequence, trees from a broad region surrounding a watershed can be useful for reconstructions of streamflow in the watershed.

Generating a Tree-Ring Chronology

Long, thin cores obtained from trees are mounted and sanded to a fine polish. Cores from one sampling location are then cross-dated, a process of matching the ring patterns from tree to tree to insure exact calendar year dates. Growth trends and other non-climatic, biological effects are removed from the measured and dated series. The resulting data are averaged into a site-wide tree-ring chronology. Much like an annual stream discharge measurement, the tree-ring record is an integrated regional signal that represents cumulative climate conditions over a period of time.

Calibration and Reconstruction

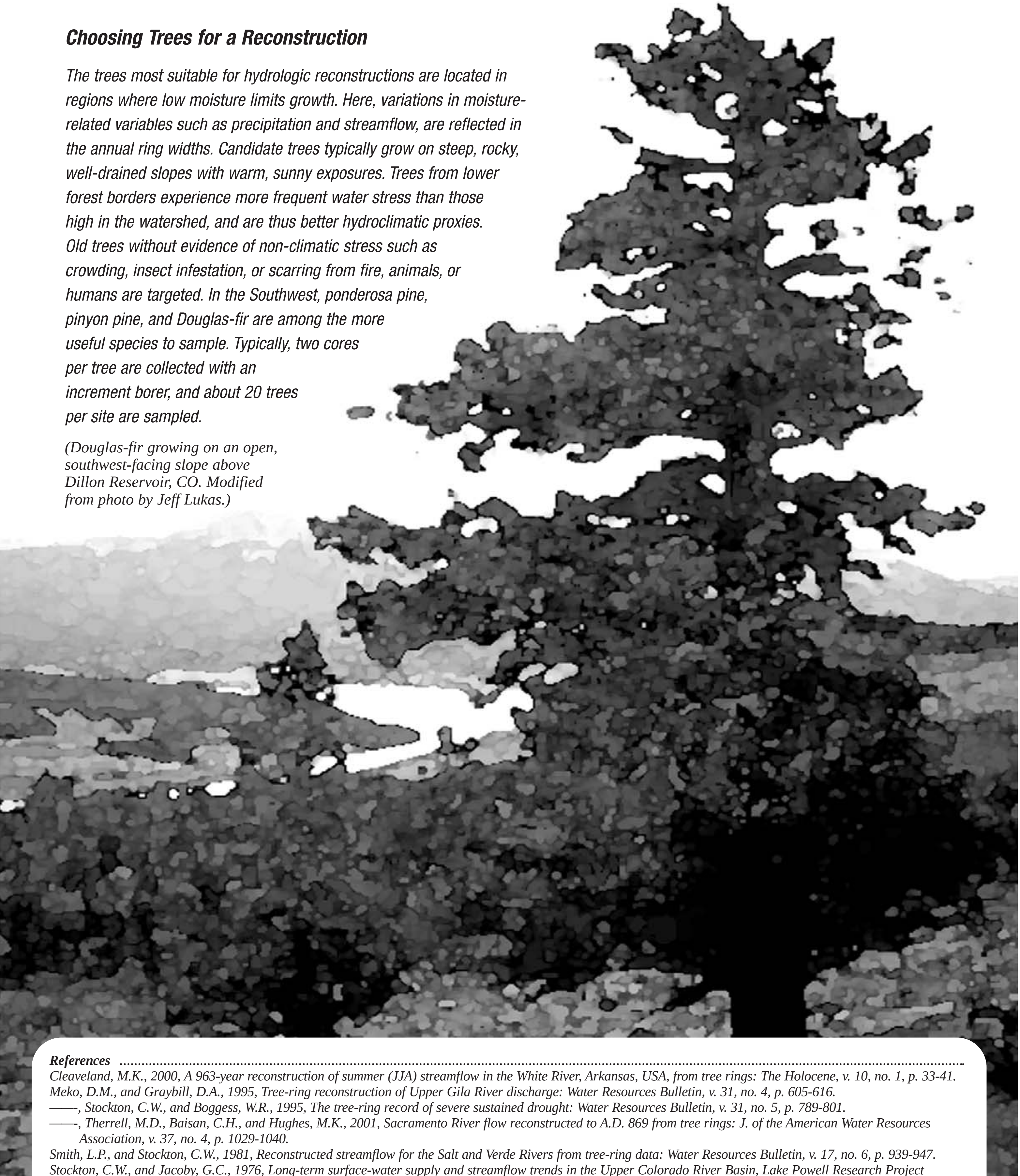
Hydroclimatic reconstructions are generated by calibrating tree-ring data with an instrumental time series, such as a gage record, typically using a linear regression model with tree-ring chronologies as the predictor variables and the instrumental record as the variable to be estimated (see Cleaveland 2000, Meko et al. 2001). The resulting regression model is usually tested against independent flow data withheld from the model. The skill of the model is quantified on the basis of a suite of statistics for both the calibration period and independent verification period reconstructed values. The explained variance or squared correlation is the most commonly reported statistic. A "good" reconstruction can be expected to explain about 50 to 70 percent of the variance in the gage record. The model is applied to the full length of the tree ring data to generate the reconstruction.

The quality of the reconstruction should be assessed in several other ways. Reconstructions tend to express a narrower range of variability than do the instrumental data, a function of the statistical processing. Most often, but not always, dry extremes are more accurately expressed than wet extremes, so that the reconstruction is more reliable for dry extremes. A visual inspection of the observed and reconstructed series will allow an evaluation of this. In addition, since the reconstruction model is based on the range of tree-ring values contained within the calibration period, values outside that range will produce predictions that should be considered extrapolations and less reliable. The sample size that makes up the reconstruction decreases over time and should be evaluated because a small sample size can lead to an increase in variance in the reconstruction, especially in the early part of the record, that is not due to climate. A final note: trees are not streamflow gages and cannot be expected to duplicate a gage record, but they do provide a long-term context for evaluating gage record characteristics.

For more information, contact Connie Woodhouse at Connie.Woodhouse@noaa.gov. *For more tree-ring information and data, see www.ngdc.noaa.gov/paleo/treering.html. For tree-ring and other reconstructions, see www.ngdc.noaa.gov/paleo/recons.html*

Choosing Trees for a Reconstruction

The trees most suitable for hydrologic reconstructions are located in regions where low moisture limits growth. Here, variations in moisture-related variables such as precipitation and streamflow, are reflected in the annual ring widths. Candidate trees typically grow on steep, rocky, well-drained slopes with warm, sunny exposures. Trees from lower forest borders experience more frequent water stress than those high in the watershed, and are thus better hydroclimatic proxies. Old trees without evidence of non-climatic stress such as crowding, insect infestation, or scarring from fire, animals, or humans are targeted. In the Southwest, ponderosa pine, pinyon pine, and Douglas-fir are among the more useful species to sample. Typically, two cores per tree are collected with an increment borer, and about 20 trees per site are sampled.



(Douglas-fir growing on an open, southwest-facing slope above Dillon Reservoir, CO. Modified from photo by Jeff Lukas.)

References

Cleaveland, M.K., 2000, A 963-year reconstruction of summer (JJA) streamflow in the White River, Arkansas, USA, from tree rings: The Holocene, v. 10, no. 1, p. 33-41.

Meko, D.M., and Graybill, D.A., 1995, Tree-ring reconstruction of Upper Gila River discharge: Water Resources Bulletin, v. 31, no. 4, p. 605-616.

——, Stockton, C.W., and Boggess, W.R., 1995, The tree-ring record of severe sustained drought: Water Resources Bulletin, v. 31, no. 5, p. 789-801.

——, Therrell, M.D., Baisan, C.H., and Hughes, M.K., 2001, Sacramento River flow reconstructed to A.D. 869 from tree rings: J. of the American Water Resources Association, v. 37, no. 4, p. 1029-1040.

Smith, L.P., and Stockton, C.W., 1981, Reconstructed streamflow for the Salt and Verde Rivers from tree-ring data: Water Resources Bulletin, v. 17, no. 6, p. 939-947.

Stockton, C.W., and Jacoby, G.C., 1976, Long-term surface-water supply and streamflow trends in the Upper Colorado River Basin, Lake Powell Research Project Bulletin No. 18: National Science Foundation, 70 pp.