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Streamflow Reconstructions of Southern Appalachian (North Carolina) Headwater Gages Using Tree Rings

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ABSTRACT

Tree rings have been used as a proxy in reconstructing streamflow in the western U.S. for many years, but few reconstructions have been attempted in the eastern United States. Clear limitations exist for streamflow reconstructions in the eastern U.S. compared to the western U.S., but value can be established as demonstrated in this research. The primary goal of this research was to reconstruct streamflow using data from five headwater gages in the Appalachian Mountains of North Carolina. These gages are located on the Valley River, the Oconaluftee River, the Nantahala River, the Little Tennessee River, and the Watauga River. Tree-ring chronologies were used to reconstruct streamflow. Tree-ring chronology predictors were selected using a seasonal correlation analysis. Seasonal correlation analysis revealed May-June-July (MJJ) streamflow variability being highly correlated with tree-ring chronologies in the study region and vicinity. Stepwise linear regression methods were used to reconstruct MJJ streamflow. The reconstructions for the Valley, Oconaluftee, and Nantahala Rivers were considered acceptable reconstructions because the models explained approximately 50% of the total variance in historic period MJJ streamflow records. These three streamflow reconstruction models have predictive skill indicated by a positive reduction of error (RE) values. The root mean square error (RMSE) statistic was 11.5 million cubic meters (MCM) for the Valley River (26% of the mean reconstructed MJJ flow), 15.9 MCM for the Oconaluftee River (16% of the mean reconstructed MJJ flow), and 8.2 MCM for the Nantahala River (20% of the mean reconstructed MJJ flow). Analysis of the reconstructed streamflow data for these three rivers revealed low flow periods from 1710 to 1712 at all three sites. The research presented here shows the potential benefit of using tree-ring chronologies to reconstruct streamflow in the Tennessee Valley region by demonstrating the ability of proxy-based reconstructions to provide

useful data beyond the instrumental record. These useful data include identification of extreme wet or dry periods and oscillations in the historical reconstructions that are not visible in the instrumental data.

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Introduction

Research Background

Instrumental data and information about the nation's water resources became available to water managers and planners across the country with the creation of the United States Geological Survey's (USGS) streamflow-gaging program in 1887 (Mason Jr., R.R. and T.H. Yorke, 1997). Proxy indicators such as tree rings are the only reliable source of information on climate occurring before the late 19th century (Meko *et al.*, 1995). Throughout the western U. S., proxies to the instrumental data were constructed using tree-ring chronologies because they were strong annual indicators of climate. Precipitation and evapotranspiration control the climate of the western U.S., and also control the growth of moisture sensitive trees used in tree-ring reconstructions (Meko *et al.*, 1995). The landscapes of the western U.S. are also an ideal for sampling moisture sensitive tree species because the preferred sites are typically those that are dry, high in elevation, and extreme in slope (Fritts, 1976).

In the western U.S., tree rings were the most reliable and preferred method of obtaining multi-century reconstructions of streamflow variability (Meko *et al.*, 2007; Watson *et al.*, 2009; Woodhouse *et al.*, 2006). Tree-ring reconstructions have been used to reconstruct drought (Meko *et al.*, 1995; Cook *et al.*, 2007; Girardin *et al.*, 2006), precipitation (Dettinger *et al.*, 1998; Blasing *et al.*, 1981; Stahle and Cleaveland, 1994; Stahle and Cleaveland, 1992; Grissino-Mayer, 1995), El Niño-Southern Oscillation climate index (Braganza *et al.*, 2009), Atlantic Multidecadal Oscillation climate index (Gray *et al.*, 2004), North Atlantic Oscillation climate index (Cook *et al.*, 2002), and temperature (Wiles *et al.*, 1998).

While the practice of reconstructing streamflow is prevalent in the western U.S. and abroad, few tree-ring reconstruction studies have been performed in the southeastern United States. Many misconceptions linger among scientists that tree-ring research simply is not

possible in the southeastern U.S. because of high decomposition and decay rates and a lack of trees that are long lived or have sensitive patterns of tree rings to facilitate crossdating (Grissino-Mayer, 2009). These misconceptions are likely the reason that more streamflow reconstruction studies have not been performed in the southeastern United States.

One study demonstrated the possibility of creating successful streamflow reconstructions in the south central U.S. involved the White River in Arkansas (Cleaveland, 2000). He reconstructed the June-July-August (JJA) average streamflow using tree-ring chronologies as a proxy to the instrumental record. Baldcypress (*Taxodium distichum*), a lowland forest species, was used in the reconstruction. The reconstruction of April through August monthly streamflow for the Occoquan River basin in Virginia was a study performed in the eastern U.S. (Phipps, 1983). Tree species used in the reconstructions of the Occoquan River basin were hemlock (*Tsuga canadensis*), post oak (*Quercus stellata*), hickory (*Carya glabra*), beech (*Fagus grandifolia*), chestnut oak (*Quercus montana*), and white oak (*Quercus alba*). Many of the tree species used by Phipps (1983) and Cleaveland (2000) are also used in this research.

The reconstruction of the White River in Arkansas was able to obtain results with the use of the three-month summer seasonal average June-July-August (JJA) (Cleaveland, 2000). Precipitation reconstructions have been performed for the southeastern U.S. in which the season to reconstruct precipitation was different for each statewide precipitation reconstruction (Stahle and Cleaveland, 1994; Stahle and Cleaveland, 1992). Statewide spring rainfall reconstructions were performed for North Carolina, South Carolina, and Georgia. The reconstructed precipitation seasons were: North Carolina (April-June), South Carolina (March-June), and Georgia (March-June) (Stahle and Cleaveland, 1994; Stahle and Cleaveland, 1992).

The primary goal of this research was to reconstruct streamflow records from five gages in the Appalachian Mountains of North Carolina using tree-ring chronologies. Many of the methods used in previous western U.S. streamflow reconstructions were applied in this research to demonstrate the value and need for additional climate reconstructions in the southeastern United States. Another goal of this research was to examine the reconstructions that were able to explain approximately 50% of the variance to determine if historical drought periods exist for these reconstructions. Wet periods were examined to determine if these periods were more extreme or more prolonged than the instrumental streamflow records indicate.

Site Description

The headwaters of many rivers within the Appalachian Mountains of North Carolina are a vital water downstream supply and are used to generate power by the Tennessee Valley Authority (TVA), one of largest utility corporations in the United States. Although the reconstruction gages are located in mountainous regions, the topography of the region contains many large valleys. The western border of North Carolina has a unique geology in that this mountainous region contains metamorphic, igneous, and sedimentary rocks that have little or no primary porosity due to intense heat and pressure related to mountain building (Bales *et al.*, 2009). The Soils of this region are shallow due to the underlying geology (Bales *et al.*, 2009). The climate in the Appalachian Mountains is very diverse as pockets of this region are temperate rain forests due to the large amount of rainfall. Parts of the region mirror the climate of the northeastern U.S. with very cold winters and mild summers while others mirror the climate in the southeastern U.S. with mild winters and hot, humid summers. The effects of these climate variations are evident in the tree-ring widths. Western U.S. tree-ring widths do not experience the same extreme variations in climate that the eastern U.S. tree rings do, and the effect of these

variations in climate in the eastern U.S. on streamflow reconstructions is unknown. Land cover change in the Blue Ridge Mountains of the southern Appalachian Mountains is unlike much of the eastern United States. The percentage of land area where land cover changed at least once between 1973 and 2000 was the lowest with only a 2.0% change (Taylor and Kurtz, 2010). This small change in land cover is important in this study because it can be hypothesized that the less land cover change in the study region, the more likely the reconstructed data will represent consistently accurate historical streamflow over the entire period.

Tree species used in this study are located in the Tennessee Valley, the Appalachian Mountains, and within a 640 kilometer radius of each of the gages studied (Figure 1 in Appendix 1). Tree-ring chronologies used in this research included, but were not limited to, the following species: tulip-poplar (*Liriodendron tulipifera*), red spruce (*Picea rubens*), white oak (*Quercus alba*), baldcypress (*Taxodium distichum*), eastern hemlock (*Tsuga canadensis*), and Carolina hemlock (*Tsuga caroliniana*).

Data

Streamflow Data

One of the most important components in a streamflow reconstruction is the accuracy and length of existing streamflow gage records. Although the USGS streamflow-gaging program began collecting streamflow data as early as 1887, not all of the USGS gage stations have the same period of record. Many USGS gage stations have gaps in the records due to a number of different technical, mechanical, or otherwise unknown reasons. The USGS gage stations that were selected for reconstruction in the current research contain no gaps in the data and have an acceptable overlapping period to calibrate with regional tree-ring chronologies (<http://waterdata.usgs.gov/nwis/sw>, 2009). The five USGS streamflow gages (Figure 1 and

Table 1 in Appendix 1) selected for reconstruction were: Watauga River near Sugar Grove, North Carolina; Little Tennessee River near Prentiss, North Carolina; Nantahala River near Rainbow Springs, North Carolina; Oconaluftee River at Birdtown, North Carolina; and Valley River at Tomotla, North Carolina. The elevations of these gages vary from 474 m to 937 m. The drainage areas of these rivers vary from 134 km² to 477 km². Although these rivers are located in close proximity, each are unique in location and elevation.

Tree-Ring Chronologies

The tree-ring chronology data used in this study came from the International Tree-Ring Data Bank (<http://www.ncdc.noaa.gov/paleo/treering.html>, 2009) which is maintained by the National Oceanic and Atmospheric Administration (NOAA) Paleoclimatology Program. Available data include raw ring widths, wood types, site chronologies, and wood density measurements. Each of the tree-ring chronologies used were uniformly processed using the ARSTAN program (Cook, 1985). Methods for detrending the multiple series into a single chronology were either the negative exponential/straight line fit or a cubic spline two-thirds the length of each individual series (Cook *et al.*, 1990). Residual chronologies were used because the low-order autocorrelation was removed from these chronologies. Low-order autocorrelations are often due to a number of different changes in growth factors including age, alteration in forest community, geological changes, or variations in climate (Fritts, 1976).

The 64 tree-ring chronologies selected were from ten states: Tennessee, Alabama, Georgia, Mississippi, Florida, Virginia, North Carolina, Kentucky, Ohio, and West Virginia (Table 2). To ensure a reconstruction of significant length, only residual chronologies extending beyond 1790 were investigated in the current research.

Methods

Pre-Screening Methods

Correlation is a process by which the degree of association between data sets of two variables is defined (Riggs, 1977). The two samples for which a degree of association was required were the tree-ring chronologies and averaged monthly values of streamflow. The degree of association between the two samples can be described by the correlation coefficient (r-value), and the significance (p-value) depends on the sample size (number of years the samples collectively span). An increase in sample size decreases the r-value required for significance. The opposite was true for a decrease in sample size.

Correlation analysis can yield positive or negative significance depending on the sign of the r-value. In this study, positive r-values of 95% significance or greater are used. A positive r-value indicates an increase in both, the seasonal streamflow and the annual tree-ring width. A negative r-value indicates an increase (decrease) in streamflow and a decrease (increase) in tree-ring width, and was not desired because a decrease (increase) in tree-ring width should not indicate an increase (decrease) in streamflow for the MJJ season.

The correlation analysis performed in this research helped determine which trees to use as predictors during the reconstruction process and helped determine the streamflow season to use as the most significant predictand. A similar correlation process was used in a study by Blasing *et al.* (1981) in the Knoxville, Tennessee area of the Tennessee Valley. This study used a correlation analysis to determine which seasonal precipitation period to reconstruct and which tree-ring chronologies to use as reconstruction predictors. Blasing *et al.* (1981) determined that that May-June precipitation was most highly correlated to the tree-ring growth in the region. The absence of streamflow reconstructions in the Tennessee Valley and the use of different tree-ring chronologies may cause the season for which streamflow and tree-ring widths were most highly

correlated in this research to differ from the work done by Blasing *et al.* (1981). This study investigated many different seasonally averaged streamflow periods including: three-month, four-month, six-month, and an annual average, in order to be exhaustive. For example, the three-month periods began at January-February-March (JFM) and shift by one month for each analysis i.e. February-March-April (FMA). A similar approach was done for four-month periods and six-month periods beginning at January-February-March-April (JFMA) and January-February-March-April-May-June (JFMAMJ), respectively. This analysis assured that the most highly correlated season was evaluated.

Temporal stability between the tree-ring chronologies and streamflow was analyzed using DendroClim2002 from Biondi and Waikul (2004). This analysis resulted in significant correlation of May, June, July streamflow with May and June showing the strongest moisture signal with the tree-ring chronologies. DendroClim2002 was used to identify climate signals and confirm that no significant changes over time were imbedded in the tree-ring records. These changes could be attributed to a number of different things including: wildfires, insects, and lightning.

Reconstruction Methods

After the prescreening process, positively significant tree-ring chronologies and seasonal streamflow data sets were used to reconstruct each of the five USGS streamflow gages. Stepwise linear regression is a proven method of statistical streamflow reconstruction in the western U.S. (Woodhouse *et al.*, 2006; Woodhouse, 2001) and was used for this research. In the simplest case, a linear regression equation is used to reconstruct past values of a single climatic variable from ring-width indices of a single tree-ring chronology, or from a mean of two or more chronologies which have been merged to form a single chronology (Blasing *et al.*, 1981).

Forward and backward stepwise regression was used to determine which tree-ring chronologies entered into the regression model. The alpha level for the entry of a predictor was set to allow a maximum p-value of 0.05 and 0.10 for removal in the regression model.

The five reconstructed streamflow stations were validated over the gage-specific calibration periods. For each gage, the strength of the regression model was measured by the adjusted R^2 value, which quantifies the explanatory power of the regression and accounts for lost degrees of freedom (Axelson *et al.*, 2009). Along with the adjusted R^2 value, the squared correlation coefficient (R^2) and the reduction of error (RE) statistic evaluated the strength of the reconstruction models. The overall variance explained within the calibration period was given by the R^2 value. The RE statistic tests the skill of the model over the verification period, compared to estimates based on the mean of the observed calibration data (Woodhouse, 2001). The RE statistic ranges from minus infinity to +1. A positive value for the RE demonstrates predictive skill in the model (Fritts, 1976). The root mean square error (RMSE) further validated model strength. A single validation series was produced using a leave-one-out cross validation scheme (Woodhouse *et al.*, 2006). The fit of the regression models was evaluated by the predicted R^2 value, and the predicted R^2 value was calculated from the prediction sum of squares test (PRESS) statistic. The Durbin-Watson statistic was used to confirm that no autocorrelation existed within the residuals (Watson *et al.*, 2009; Axelson *et al.*, 2009). The Durbin-Watson statistic ranges from 0 to 4. Generally, Durbin-Watson values near 2 indicate no autocorrelation between predictor variables. A value near 4 indicates negative autocorrelation, and a value near 0 indicates positive autocorrelation which was of the most concern in this research because the residual tree-ring widths were used in which autocorrelation was thought to be removed. The variance inflation factor (VIF) examines multicollinearity of the predictors (Watson *et al.*, 2009;

Axelsson *et al.*, 2009). A VIF near 1 was desired because, as the VIF increases towards infinity, multicollinearity arises between predictors. This is a problem because it indicates that one or more of the tree-ring chronologies may be highly correlated with one or more of the other tree-ring chronologies, causing an exaggerated R^2 value.

Streamflow Reconstruction Analysis Methods

Due to the proximity of the streamflow gages, the extreme periods of wet or dry years were hypothesized to be consistent for all the reconstructions. Water managers and planners are concerned with the severity and longevity of these periods. In a study done by Woodhouse (2001), the distribution of extreme low flows over the streamflow reconstruction were ranked for periods of lowest flow. The single year, three-year, and five-year average values that fell within the lowest 10th percentile were then plotted by rank over time (Woodhouse, 2001). The five-year seasonal streamflow was ranked for all of the gages reconstructed according to the lowest 10th percentile flows.

The instrumental and reconstructed extreme wet and dry periods were examined for each of the gages using a 5-year, 10-year, and 25-year moving-average approach. Streamflow percent departure from the mean of the instrumental and reconstruction periods was used to examine 5-year, 10-year, and 25-year extreme wet and dry periods. These moving averages allow for comparison of the reconstruction streamflow and the instrumental record. These examinations helped determine if the majority of prolonged wet or dry periods occurred in the reconstruction period or the instrumental period. The percent departures were compared to determine the severity of the wet and dry periods. Similarities in the percent departures for the reconstructed and instrumental records may indicate that the streamflow variance is likely comparable for the reconstructed and instrumental periods.

Results

Seasonal Correlations

One of the most important aspects of the seasonal correlation analysis was to determine a consistent streamflow season to reconstruct for all five of the USGS streamflow gages. A seasonal correlation analysis was performed to examine the number of significant tree-ring chronologies over three-month, four-month, and six-month/annual periods for each season and river to determine the most consistent season (Figures 2–5). The three-month period May-June-July (MJJ) was the season containing the largest number of significant tree-ring chronologies for the majority of the five gages subsequent to the seasonal correlation analysis (Figure 2). In a few cases, the number of significant tree-ring chronologies increased for the three-month period (JJA) for the Watauga River and the four-month period (May-June-July-August) for the Valley River. The number of significant trees was higher for the three-month period May-June-July (MJJ) than the three-month period April-May-June (AMJ). At no time during the seasonal correlation analysis did the winter months yield a large number of highly correlated tree-ring chronologies. Therefore, MJJ was used in this research because this seasonal period was the most consistent for all the gages. This seasonal consistency was critical for comparison of the individual reconstructions. A seasonal correlation plot showed the number of significant tree-ring chronologies retained against seasonal streamflow for each river (Figure 2). Regional tree-growth contained the highest signal with May-June-July streamflow in the Valley River (29 significant tree-ring chronologies).

The stability of the climate/tree-growth relationship was analyzed over time for each of the tree-ring chronologies retained for each river. This relationship is represented using correlation between tree-ring chronologies and MJJ streamflow over the calibration period (Figure 6). The retained tree-ring chronologies demonstrate a positive relationship with MJJ

streamflow over the entire calibration period for all of the stations indicating stability. This relationship was also found to be significant for the majority of the calibration periods for all of the streamflow gage stations.

Calibration and Verification of Reconstructions

Three of the five MJJ streamflow reconstructions were determined to be acceptable based on an R^2 value greater than or equal to 0.48. The longest reconstruction model (Valley River at Tomotla, North Carolina) dates back to 1652, and retained four tree-ring chronologies: Piney Creek Pocket Wilderness (white oak), Ramsey's Draft Recollection (eastern hemlock), Black River, and Grandfather Mountain (red spruce). The Piney Creek Pocket Wilderness chronology was also retained in the reconstruction models of the Oconaluftee River at Birdtown, North Carolina and the Nantahala River near Rainbow Springs, North Carolina.

The Oconaluftee River calibration model retained two tree-ring chronologies: Kelsey Tract II and Piney Creek Pocket Wilderness. Along with the Piney Creek Pocket Wilderness chronology, the Pearl River (baldcypress) and the Kelsey Tract II (Carolina hemlock) chronologies were also retained in the Nantahala calibration model. The retained tree-ring chronologies are located in four different states: North Carolina, Mississippi, Tennessee, and Virginia (Table 3).

The Valley River was the easternmost reconstructed streamflow stations (Figure 7). The Valley River calibration period was from 1919–1980, and the model explains 51% of the total variance (Figure 8). The Valley River reconstruction dates back to 1652. The resulting reconstruction for the Valley River was smoothed using a 10-year end-year filter (Figure 9) in which the reconstructed data (1661–1918) were combined with the instrumental record (1919–2008). A 20-year filter for the streamflow reconstruction was also performed for the Valley

River (Figure 10) where the reconstructed data (1671–1918) were combined with the instrumental record (1919–2008). The average seasonal streamflow volume for the entire period of reconstructed and instrumental streamflow for the Valley River was also plotted on both reconstructions. Statistical parameters for the instrumental and reconstructed streamflow data including the mean, median, standard deviation, minimum streamflow, and maximum streamflow are provided (Table 4). These statistics were calculated to compare the reconstructed and instrumental streamflow and determine if any major variations existed between the two datasets. The mean for the reconstructed period and the instrumental period was 44.8 MCM and 45.6 MCM respectively. One major difference in the reconstructed and instrumental statistics was the minimum MJJ flow. The minimum MJJ streamflow for the reconstructed period and the instrumental period was 1.3 MCM and is 13.5 MCM, respectively. The reconstruction of the Valley River was verified by the R^2 statistic, RE statistic, and the RMSE statistic (Table 5). The RE statistic for the Valley River was +0.51, indicating the model has predictive skill. The RMSE statistic for the Valley River was 11.5 MCM, which was approximately 26% of the average seasonal flow for the reconstructed period. The Durbin-Watson statistic for the Valley River was 1.7, indicating autocorrelation in the residuals was not a concern. The VIF was 1.1, which suggests that the predictors contain minimal multicollinearity (Table 5).

Located northeast of the Valley River, the Oconaluftee River reconstruction explains 48% of the total variance in the streamflow. The reconstruction model retained two tree-ring chronologies (Figure 11). The calibration period for the Oconaluftee River covers 1949 to 1980 (Figure 12), while the reconstruction spans 1679 to 1980. Reconstructed streamflow was smoothed using a 10-year end-year filter (Figure 13) in which the combined reconstruction (1688–1948) and instrumental period (1949–2008) was shorter than the previous Valley

Reconstruction. A 20-year end-year filter average streamflow reconstruction was performed for the Oconaluftee River (Figure 14) where the reconstructed data (1698–1948) was combined with the instrumental record (1948–2008). The mean, median, standard deviation, minimum streamflow, and maximum streamflow were calculated for the reconstructed and instrumental period for the Oconaluftee River (Table 6). The Oconaluftee River had a mean streamflow of 97.7 MCM and 99.9 MCM for the reconstructed and the instrumental period, respectively. The minimum flow was lower for the reconstructed period, and the maximum flow was higher for the instrumental period. The value of the Oconaluftee River reconstruction was demonstrated by the RE statistic and the RMSE which were respectively 0.48 and 15.9 MCM (Table 5). A RMSE of 15.9 MCM was approximately 16% of the mean flow of the reconstructed period. For the Oconaluftee River reconstruction, the Durbin-Watson statistic was 2.1, suggesting that autocorrelation between the model residuals was minimal, and insignificant multicollinearity exists between predictors (Table 5).

The final streamflow reconstruction was the Nantahala River, located east of the Valley River and south of the Oconaluftee River (Figure 15). The Nantahala River streamflow reconstruction retained three tree-ring chronologies. The variance explained by the Nantahala calibration model was 48%. The period from 1941 to 1980 was used for the model calibration (Figure 16). The Nantahala streamflow was reconstructed from 1679 to 1980. A 10-year end-year filter (Figure 17) was used to smooth the Nantahala average streamflow reconstruction with a combined reconstruction period (1688–1940) and instrumental period (1941–2008). Further smoothing was performed using a 20-year end-year filter (Figure 18) for the Nantahala average streamflow with a combined reconstruction period (1698–1940) and instrumental period (1941–2008). The mean, median, and standard deviation statistics were calculated for the reconstructed

period and the instrumental period for the Nantahala River along with the minimum and maximum streamflow values (Table 7). The mean for the reconstructed and the instrumental periods were 40.0 MCM and 39.5 MCM, respectively. The differences in the maximum and minimum flow values were not as extreme as those for the Valley and Oconaluftee River. The maximum flow was greater for the instrumental period (83.5 MCM) than the reconstructed period (63.1 MCM), and the minimum flow was lower for the reconstructed period (12.2 MCM) than for the instrumental period (16.7 MCM). Reconstruction statistics R^2 , RE, and RMSE were 0.48, 0.48, and 8.2 MCM respectively for the Nantahala River (Table 5). A RMSE of 8.2 MCM was approximately 20% of the mean for the reconstructed flow. The Durbin-Watson and VIF statistic were also calculated for the Nantahala and were 2.3 and 1.1 respectively (Table 5).

The Little Tennessee River (Figure 19) and the Watauga River (Figure 20) were also reconstructed. The calibration period for the Little Tennessee River was from 1945 to 1980 (Figure 21). A 10-year filter was used to smooth the streamflow reconstruction of the Little Tennessee River for the combined reconstructed period (1688–1944) and the instrumental period (1945–2008) (Figure 22). Further smoothing was applied using a 20-year filter of the streamflow reconstruction of the Little Tennessee River for the combined reconstructed period (1698–1944) and the instrumental period (1945–2008) (Figure 23). The calibration period for the Watauga River was from 1941 to 2008 (Figure 24). A 10-year filter was used to smooth the streamflow reconstruction of the Watauga River for the combined reconstructed period (1695–1940) and the instrumental period (1941–2008) (Figure 25). A 20-year filter was performed for the Watauga River reconstructed period (1705–1940) and instrumental period (1941–2008) (Figure 26). However, these reconstructions did not perform as well as the previously discussed reconstructions as demonstrated by the R^2 value (Table 5). The Little Tennessee River was able

to explain 42% of the total variance in streamflow, and the Watauga River explained 27% of the total variance in streamflow. For this reason, these rivers were considered not reliable even though some of the statistics appear consistent. For example, the Little Tennessee River had a positive RE of +0.42 indicating some predictive skill, but the RMSE was 19.1 MCM, the largest of all the reconstructed gages, which was approximately 24% of the reconstructed mean (Table 5). No large differences in the mean or median exist between the reconstructed or instrumental periods for the Little Tennessee River and the Watauga River (Tables 8 and 9). Because the streamflow reconstructions for the Little Tennessee River and the Watauga River were considered not accurate, a drought analysis was not performed for these rivers.

Leave-one-out cross validation resulted in predicted R^2 values ranging from 21% to 41% (Table 5). These predicted R^2 values suggested that minimal overfitting existed in these models. The most extreme case was the Watauga River that had a predicted R^2 value of 21%. The predicted R^2 value differed by 12% or less than the R^2 value for the Valley River, Oconaluftee River, and the Nantahala River.

Discussion

Importance of Climate Reconstructions Eastern U.S.

This research demonstrated that eastern U.S. streamflow reconstructions using tree-ring chronologies as proxies can be performed using similar techniques to those in the western United States. Three of the five streamflow reconstructions in the Appalachian Mountains were comparable in the amount of variance explained to previous studies in the south central and the eastern United States. Although the study performed by Cleaveland (2000) on the White River in Arkansas was able to explain 68% of the variance of the reconstruction model, the presented research was able to explain approximately 50% of the variance for three of the five rivers. A

possible explanation for this difference is likely due to the differences in location. The geology of the White River watershed is very different from the southern Appalachian Mountains. The White River watershed demonstrates consistent areas of karst topography in which the fractured limestone bedrock allows surface water to easily escape to the groundwater (<http://extra.mdc.mo.gov/fish/watershed/whriver/geology/>, 2010). The White River also contains sedimentary rocks other than limestone including sandstone and dolomite which differ greatly from the metamorphic and igneous bedrock of the Appalachian Mountains (<http://extra.mdc.mo.gov/fish/watershed/whriver/geology/>, 2010 and Bales *et al.*, 2009). The metamorphic and igneous rock have little to no porosity and allow very little surface water to enter the groundwater (Bales *et al.*, 2009). This drastic contrast in geology between the White River watershed and the Appalachian Mountains was likely mirrored by drastic differences in streamflow reactions after precipitation and drought events. Another difference between the present research and the work done by Cleaveland (2000) was the season used to create the streamflow reconstructions. Because a different season was chosen over which to reconstruct streamflow, it is likely that different tree-ring chronologies correlate with different seasons due to variations in environmental and climatic factors occurring in the southeastern and south central United States. A number of different moisture sensitive tree species were used in this research. It is possible that factors other than precipitation and evapotranspiration which control the majority of growth in trees in the western U.S. (Meko *et al.*, 1995) were recorded by tree-ring chronologies in the eastern U.S because of location and climate.

The results of the present research yielded comparable R^2 values to that of the research done by Phipps (1983). The reconstructions performed by Phipps (1983) were able to explain 39% to 53% of the variability of monthly streamflow for rivers in the Occoquan River basin.

These results were thought to be similar to the present research due to the similarities in location and tree species used to perform the reconstructions. The Occoquan River basin is located in northern Virginia. The tree species utilized in the Phipps (1983) study were hemlock, post oak, hickory, beech, chestnut oak, and white oak. Many of the tree species used by Phipps (1983) were also retained in the streamflow reconstruction models.

In a study conducted by Blasing *et al.* (1981), tree-ring chronologies were used as a proxy to reconstruct precipitation in Knoxville, Tennessee using similar regression techniques for reconstructing May-June precipitation. Another precipitation reconstruction was performed for the southeastern region of the U.S. in which March through June average statewide precipitation was reconstructed for North Carolina, South Carolina, and Georgia (Stahle and Cleaveland, 1994). The success of the present research in conjunction with Cleaveland (2000) and Phipps (1983) demonstrated the possibility of many more successful reconstruction studies in the eastern U.S. These studies should serve as a base for reconstructing a number of different climate variables in the eastern U.S., including streamflow, precipitation, drought, and temperature.

Limitations of Eastern U.S. Reconstructions

One of the main restrictions of this study and future climate reconstruction work in this region was the limited calibration period. When attempting to calibrate two data sets, a maximum number of years for the calibration period is optimal to capture the long-term variability in regional climate records. The calibration period can be limited by two factors. The first factor is the availability of the instrumental gage data. Streamflow gage data are a limiting factor because they begin in the early to mid-1900s, and the data were collected through 2008. Only streamflow gages that have complete data sets can be calibrated with tree-ring

chronologies. The second factor limiting the calibration period was the ending year of usable tree-ring chronologies. For example, the majority of the tree-ring chronologies in this research end in 1980. Both factors affected the length of the calibration periods in the present research. The majority of the tree-ring chronologies extend only to 1980, and the majority of streamflow gage data begins in early to mid 1900's. The only solution to eliminate this issue for future research in this region is to extend the tree-ring chronologies because most streamflow gages have data available through the present year. Unfortunately, updating the tree-ring chronology datasets has not been performed in this region on a large number of tree-ring chronology datasets.

Utilizing Larger Tree-Ring Chronology Search Radius

Initially, tree-ring chronologies within a 240 kilometer radius of each USGS streamflow gages were collected for testing. No baldcypress tree species were collected for use in the model with the 240 kilometer radius. Next, the radius was expanded to 640 kilometers primarily to include baldcypress species. This process was used in order to use the baldcypress species found to contain a high moisture signal in the Cleaveland (2000) study. After expanding the radius, three out of the five reconstructions retained a baldcypress chronology. The reconstructions that retained the baldcypress were able to explain more of the total variance in the models than the reconstructions that were performed without a baldcypress chronology. An expanded search radius should be used in any study in which tree-ring chronologies are being used as a proxy because certain moisture sensitive tree species are often only found in very specific regions that may not be within the original scope of study.

Streamflow Reconstruction Analysis

The reconstruction plots demonstrated several oscillating periods of wet and dry streamflow. Common dry periods of streamflow were 1708 to 1734, 1795 to 1803, and 1843 to 1851 for the reconstructions of the Valley River, the Oconaluftee River, and the Nantahala River. Consistent wet periods shown in the three reconstructions were 1738 to 1759, 1809 to 1833, and 1869 to 1873. Water managers and planners can use streamflow reconstructions in a number of different ways. One way is by performing drought analysis on the reconstruction. The rank of the 5-year average streamflow values that fall within the lowest 10th percentile were plotted for each of the three reconstructed rivers (Figures 27–29). The three streamflow reconstructions the Valley River, Nantahala River, and Oconaluftee River were analyzed to determine low flow periods over the reconstructed and instrumental periods. A period of 5-year average low flow events for the three reconstructed rivers was the period from 1710 to 1712. For two of the reconstructions (Valley River and Oconaluftee River) the 5-year average low flow events were extended out to 1718. This period was the most prolonged and extreme drought period over the reconstructed and instrumental record for the Valley River and Oconaluftee River. Another low flow period consistent for all three rivers occurred from 1954 to 1955. The Valley River and the Nantahala River consistently demonstrated low flow years during the early 1700s as discussed, and the late 19th (1895, 1897, and 1898) into the 20th century (1914, 1915) also have short periods of extreme dry. The Valley River and the Nantahala River demonstrated multiple periods of low flows around the middle of the 1900s, but the results were spaced over a period of time instead of a consistent period of prolonged low flow. The Oconaluftee River was unique over one prolonged period from 1788 to 1792 during which the 5-year low flow analysis revealed an extended drought period for this river only.

The 5-year, 10-year, and 25-year extreme dry and wet events for each of the three rivers were determined according to the percent departure from the mean of the instrumental and reconstructed periods separately (Tables 10–12). For each of the three rivers, the wettest 5-year average period was at least 25% wetter than the average for the reconstruction periods compared to what was shown in instrumental records. The Valley River was the only river in which the extreme dry periods for the 5-year, 10-year, and 25-year percent departure from the mean was greater than the wet percent departure over the reconstructed period only. This demonstrated the fact that the driest periods were more extreme than the wettest periods for the Valley River over the reconstructed period. Without the reconstruction of the Valley River streamflow, this distinction between historical wet and dry periods would not be known. With the exception of the 5-year average for the Nantahala River, the low percent departure from the mean over the reconstructed period was higher than that of the instrumental period for the each of the three rivers for the 5-year, 10-year, and 25-year averages. This conclusion was mirrored by the fact that the minimum flow value was lower for the reconstruction period than the instrumental period for all three rivers (Tables 4, 6, and 7).

Many other techniques have been published for use in drought analysis, and one such technique was used by Zhang *et al.* (2004) in which tree-ring data were calibrated against the instrumental record of summer drought (June-August Palmer Drought Severity Index) based on application of the ‘Regularized Expectation Maximization’ algorithm to relate large-scale patterns of variation in proxy and instrumental data over a common (20th century) interval. This type of regionalized study of drought in the Tennessee Valley would help confirm the results of the present research. A study of “worst case” drought scenario for the Upper Colorado River Basin has also been performed using tree rings (Meko *et al.*, 1995). Another way to examine the

reconstructions is to graph the percent normal flow over the reconstructed period and the calibration period. The percent normal reconstruction graphs with 20-year end-year filters were created for each of the three rivers (Figures 30–32). These figures demonstrated the percent departure of the streamflow value from the average streamflow over the reconstructed and instrumental periods. Many of the previously mentioned periods of extreme wet and dry were visible graphically in these reconstruction plots.

Conclusions

Although few studies exist that provide a solid method of reconstructing streamflow in the eastern U.S., this research reconstructed streamflow gages for three rivers in this region with predictive skill using techniques similar to western U.S. studies. The results of this work provided a valuable group of tree-ring based streamflow estimates that can be used along with the instrumental records by water managers and planners in the Tennessee Valley region.

Another important conclusion from this study was that the last century has not experienced a prolonged period of drought like that of the early 18th century for the reconstructions of the Valley River, the Oconaluftee River, and the Nantahala River. This conclusion presents a serious concern for the Tennessee Valley and especially the Appalachian Mountains of North Carolina in that the recurrence of more extreme low flow periods than that seen over the last century may be a real possibility in the future given past occurrences. The current research also established a method of climate reconstruction for use in other studies in this region. Valuable information about the variability of streamflow in the Appalachian Mountains was uncovered in this study, and future studies in the eastern U.S. may help further explain the natural variations in streamflow and the climate of this region.

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Appendices

Appendix 1: Tables and Figures

Tables

Table 1: USGS streamflow gage information.

Station #	Description	Drainage Area (km ²)	Elevation (m)	Start	End
03479000	Watauga River	239	795	1941	2008
03500000	Little Tennessee River	363	612	1945	2008
03504000	Nantahala River	134	937	1941	2008
03512000	Oconaluftee River	477	562	1949	2008
03550000	Valley River	269	474	1919	2008

Table 2: Tree-ring chronologies used in the research along with latitude, longitude, period of record, and species.

Station	Lat.	Lon.	Period	Species
Altamaha River	31.6	-81.8	933–1985	TADI BALDCYRPRESS
Andrew Johnson Woods	40.9	-81.8	1626–1985	QUAL WHITE OAK
Balsam Gap Mount Mitchell	35.7	-82.3	1610–1983	PCRU RED SPRUCE
Black River	34.3	-78.2	385–1985	TADI BALDCYPRESS
Blackwater River	36.8	-76.9	937–1985	TADI BALDCYPRESS
Blue Ridge Parkway Bluff Mountain, Nature Conservancy	37.6	-79.5	1594–1982	QUPR CHESTNUT OAK
	36.4	-81.6	1713–1993	TSCR HEMLOCK
Boogerman Trail Tennessee	35.6	-83.1	1738–1995	LITU TULIPTREE
Buffalo Beats Prairie	39.5	-82.2	1681–1995	QUAL WHITE OAK
Chickahominy River	37.4	-76.9	1665–1984	TADI BALDCYPRESS
Clingman's Dome	35.6	-83.4	1560–1983	PCRU RED SPRUCE
Davis Purdue	39.9	-84.4	1662–1985	QUAL WHITE OAK
Dragon Run	37.6	-76.7	1377–1984	TADI BALDCYPRESS
Dysart Woods	40.0	-81.0	1625–1998	QUAL WHITE OAK
Ebenezer Creek	32.4	-81.2	995–1985	TADI BALDCYPRESS
Grandfather Mountain	36.1	-82.8	1561–1983	PCRU RED SPRUCE
Greenbrier II	35.7	-83.4	1737–1995	QUPR CHESTNUT OAK
Hampton Hills	35.8	-78.7	1770–1992	QUAL WHITE OAK
Hemlock Cove - Sunset Field	37.5	-79.5	1533–1982	TSCA EASTERN HEMLOCK
Hen Wallow Falls	35.8	-83.2	1768–1995	TSCA EASTERN HEMLOCK
Joyce Kilmer Memorial Forest II	35.4	-83.9	1672–1997	LITU TULIPTREE
Joyce Kilmer Wilderness	35.2	-84.0	1643–1983	QUAL WHITE OAK
Kelsey Tract I	35.1	-83.2	1561–1983	TSCA EASTERN HEMLOCK
Kelsey Tract II	35.1	-83.2	1679–1983	TSCR CAROLINA HEMLOCK
Kit Springs Ranch, Nantahala	35.3	-83.9	1660–1993	TSCA HEMLOCK
Knob Job	38.9	-79.4	1476–1981	JUVI EASTERN RED CEDAR
Land Between The Lakes Lassiter Swamp (Merchants Millpond State Park)	36.8	-88.1	1689–2005	QUST POST OAK
	36.5	-76.6	1528–1984	TADI BALDCYPRESS
Lilley Cornett Tract	37.1	-83.0	1665–1982	QUAL WHITE OAK
Linville Gorge	35.9	-81.9	1620–1977	QUAL WHITE OAK
Lower Withlacoochee River	29.0	-82.7	1618–2005	TADI BALDCYPRESS
Lynn Hollow and Look Rock Trail	35.6	-85.9	1685–1996	PIEC SHORTLEAF PINE
Lynn Hollow I	35.6	-85.4	1755–1997	QUPR CHESTNUT OAK
Lynn Hollow II	35.6	-85.4	1745–1997	QUVE BLACK OAK
Mammoth Cave (Recollect)	37.2	-86.1	1651–1985	QUAL WHITE OAK

Middle Withlacoochee River	28.9	-82.3	1516–2003	TADI BALDCYPRESS
Montpelier National Landmark Forest	38.2	-78.2	1713–2001	QUAL WHITE OAK
Mount Rogers	36.7	-81.7	1647–1982	TSCA EASTERN HEMLOCK
Mountain Lake Virginia I	37.4	-80.5	1695–1982	QUAL WHITE OAK
Mountain Lake Virginia II	37.4	-80.5	1554–1980	QUAL WHITE OAK
Mt. Collins	35.5	-83.5	1654–1986	PCRU RED SPRUCE
Norris Dam State Park	36.2	-84.1	1633–1981	QUAL WHITE OAK
Nottoway River	36.8	-77.1	1175–1984	TADI BALDCYPRESS
Ocmulgee River	32.1	-83.3	1206–1984	TADI BALDCYPRESS
Pascagoula River	30.6	-88.6	1470–1992	TADI BALDCYPRESS
Patty's Oaks, Blue Ridge Pkwy	37.9	-79.8	1572–1982	QUAL WHITE OAK
Pearl River	32.9	-89.1	1550–1983	TADI BALDCYPRESS
Piney Creek Pocket Wilderness	35.7	-84.9	1651–1982	QUAL WHITE OAK
Pinnacle Point/Hawksbill Gap	38.5	-78.4	1615–1981	QUAL WHITE OAK
Porter's Creek II	35.7	-82.4	1700–1997	LITU TULIPTREE
Pulaski Woods	41.1	-86.7	1692–1985	QUAL WHITE OAK
Rainbow Falls Trail II	35.7	-83.5	1689–1995	TSCA EASTERN HEMLOCK
Ramseys Draft Recollection	38.3	-79.3	1600–1981	TSCA EASTERN HEMLOCK
Reelfoot Lake (Quake Effects After 1811)	36.4	-89.4	1677–1990	TADI BALDCYPRESS
Savage Gulf	35.5	-85.6	1616–1985	TSCA EASTERN HEMLOCK
Scotts Gap	35.6	-83.9	1684–1981	LITU TULIP POPLAR
Shenandoah National Park	38.5	-78.5	1757–1997	TSCA EASTERN HEMLOCK
Shot Beech Ridge	35.6	-83.4	1772–1997	QURU RED OAK
Sipsey Wilderness	34.3	-87.5	1682–1985	QUAL WHITE OAK
Stebbin's Gulch	41.6	-81.3	1612–1983	QUPR CHESTNUT OAK
Suwannee River	29.7	-83.0	1725–1993	QULY OVERCUP OAK
Sweet Briar College Old-Growth White Oak	37.6	-79.1	1754–1998	QUAL WHITE OAK
Upper Withlacoochee River	28.3	-82.1	1622–2005	TADI BALDCYPRESS
Watch Dog, Massenhutten Mtn	38.5	-78.4	1645–1981	QUPR CHESTNUT OAK

Table 3: Tree-ring chronologies that are retained in the regression model and the state, period, species, and model(s) the chronology entered.

Station	State	Period	Species	Model
Kelsey Tract II	NC	1679–1983	CAROLINA HEMLOCK	Little TN, Nantahala, Oconaluftee
Pearl River	MS	1550–1983	BALDCYPRESS	Little TN, Nantahala
Piney Creek Pocket Wilderness	TN	1651–1982	WHITE OAK	Nantahala, Oconaluftee, Valley
Ramseys Draft Recollection	VA	1600–1981	EASTERN HEMLOCK	Valley
Black River	NC	385–1985	BALDCYPRESS	Valley
Grandfather Mountain	NC	1561–1983	RED SPRUCE	Valley
Scotts Gap	TN	1684–1981	TULIP POPLAR	Watauga

Table 4: Valley River basic statistics: mean, median, standard deviation, minimum MJJ streamflow, and maximum MJJ streamflow.

Units = MCM	Reconstructed	Instrumental
Period	1652-1918	1919-2008
Mean	44.8	45.6
Median	45.1	40.9
Standard Deviation	12.9	19.2
Min MJJ (Year)	1.3 (1911)	13.5 (1988)
Max MJJ (Year)	82.5 (1680)	104.1 (2003)

Table 5: Reconstruction statistics for each river including the R-squared, R-squared adjusted, R-squared predicted, Durbin-Watson, VIF, RE, and RMSE.

River	R²	R² (adj)	R² (pred)	Durbin- Watson	VIF	RE	RMSE (MCM)
Little TN	42.0	38.4	31.3	2.1	1.0	0.42	19.1
Nantahala	48.2	43.9	35.7	2.3	1.1	0.48	8.2
Oconaluftee	48.4	44.8	38.8	2.1	1.0	0.48	15.9
Valley	51.1	47.7	41.4	1.7	1.1	0.51	11.5
Watauga	27.7	25.8	21.3	1.4	1.0	0.28	11.6

Table 6: Oconaluftee River basic statistics: mean, median, standard deviation, minimum MJJ streamflow, and maximum MJJ streamflow.

Units = MCM	Reconstructed	Instrumental
Period	1679-1948	1949-2008
Mean	97.7	99.9
Median	97.8	92.5
Standard Deviation	22.0	33.4
Min MJJ (Year)	29.9 (1708)	46.2 (2007)
Max MJJ (Year)	170.8 (1739)	227.4 (1989)

Table 7: Nantahala River basic statistics: mean, median, standard deviation, minimum MJJ streamflow, and maximum MJJ streamflow.

Units = MCM	Reconstructed	Instrumental
Period	1679-1940	1941-2008
Mean	40.0	39.5
Median	40.3	38.2
Standard Deviation	9.4	13.8
Min MJJ (Year)	12.2 (1936)	16.7 (1986)
Max MJJ (Year)	63.1 (1679)	83.5 (1989)

Table 8: Little Tennessee River basic statistics: mean, median, standard deviation, minimum MJJ streamflow, and maximum MJJ streamflow.

Units = MCM	Reconstructed	Instrumental
Period	1679-1944	1945-2008
Mean	78.7	76.1
Median	78.1	70.5
Standard Deviation	17.9	29.2
Min MJJ (Year)	30.5 (1926)	29.2 (1986)
Max MJJ (Year)	131.0 (1679)	152.3 (1976)

Table 9: Watauga River basic statistics: mean, median, standard deviation, minimum MJJ streamflow, and maximum MJJ streamflow.

Units = MCM	Reconstructed	Instrumental
Period	1686-1940	1941-2008
Mean	32.3	32.3
Median	32.0	29.8
Standard Deviation	10.6	14.1
Min MJJ (Year)	.5 (1854)	11.9 (1988)
Max MJJ (Year)	61.4 (1916)	74.2 (1976)

Table 10: Valley River 5, 10, and 25-year extreme wet and dry events for both the instrumental and reconstructed period. The values in the table are the percent departures from the mean.

# of Years	Instrumental (1919-2008)		Reconstruction (1652-1918)	
	Dry	Wet	Dry	Wet
5	-32.4	35.2	-37.5	29.6
10	-18.7	24.2	-30.1	19.1
25	-11.9	8.4	-13.6	7.5

Table 11: Oconaluftee River 5, 10, and 25-year extreme wet and dry events for both the instrumental and reconstructed period. The values in the table are the percent departures from the mean.

# of Years	Instrumental (1949-2008)		Reconstruction (1679-1948)	
	Dry	Wet	Dry	Wet
5	-19.0	19.5	-26.3	28.5
10	-13.3	18.4	-23.9	18.4
25	-6.0	8.0	-16.6	6.1

Table 12: Nantahala River 5, 10, and 25-year extreme wet and dry events for both the instrumental and reconstructed period. The values in the table are the percent departures from the mean.

# of Years	Instrumental (1941-2008)		Reconstruction (1679-1940)	
	Dry	Wet	Dry	Wet
5	-27.5	31.5	-21.6	26.4
10	-11.7	21.5	-17.8	19.8
25	-5.8	6.6	-9.3	8.6

Figures

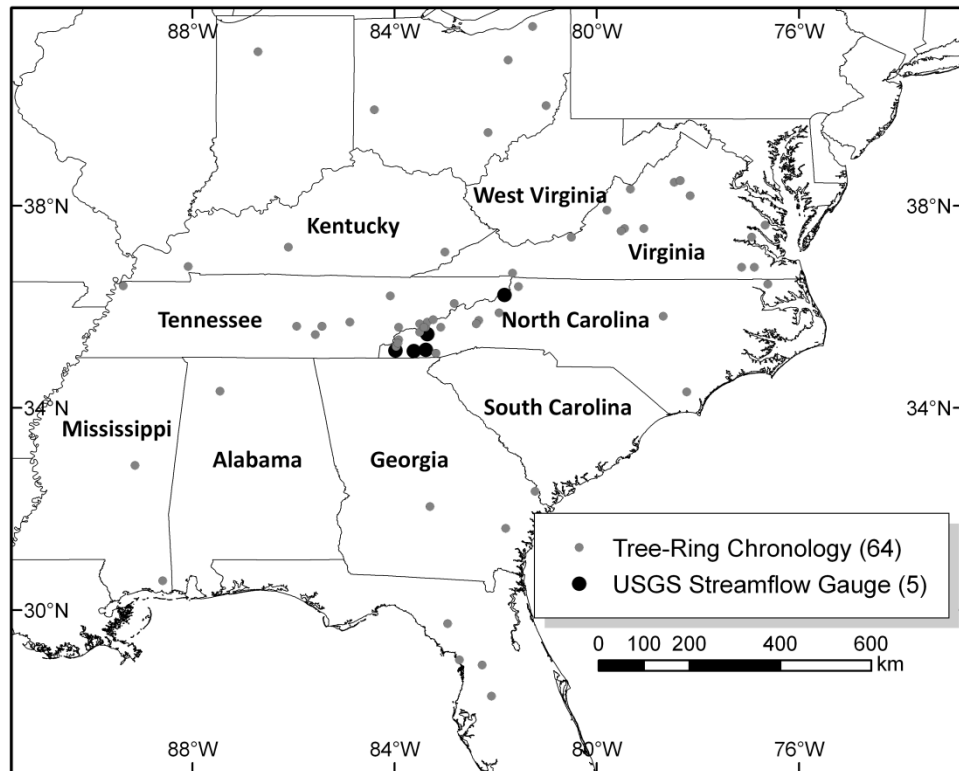


Figure 1: Map of the USGS streamflow gages and tree-ring chronologies used.

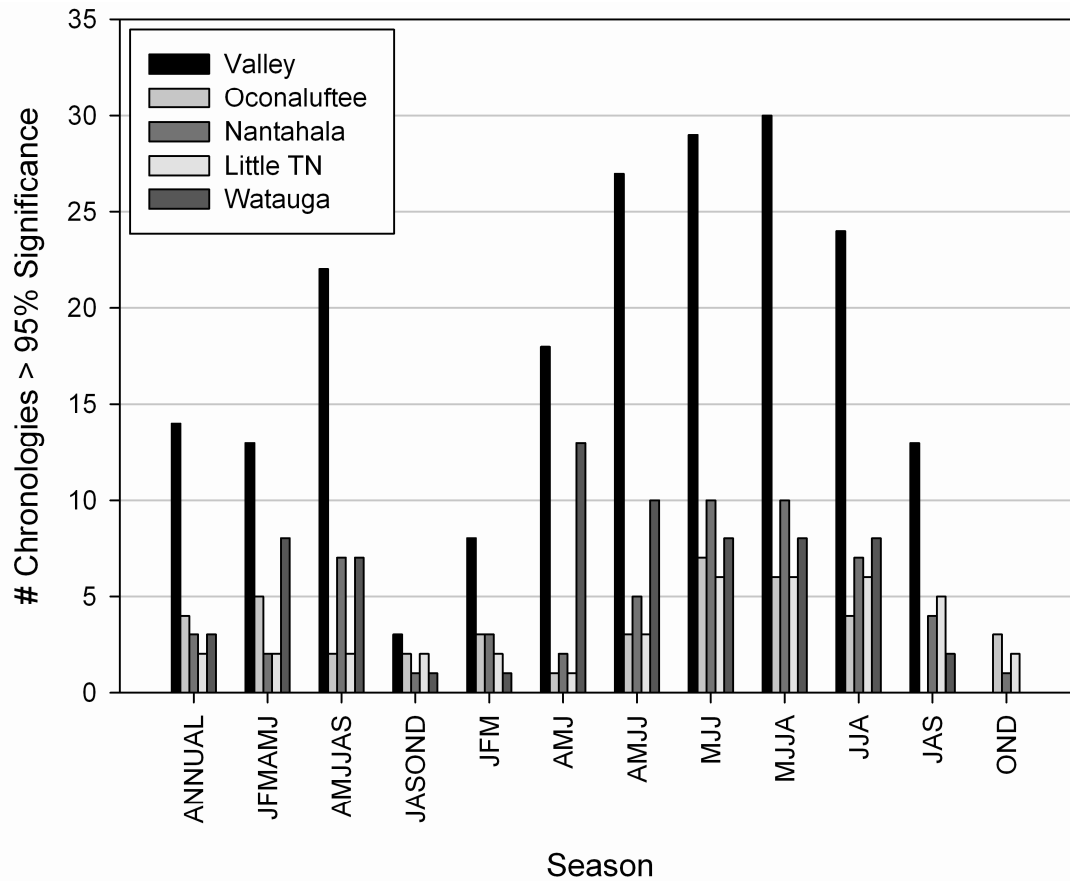


Figure 2: Seasonal correlation plot.

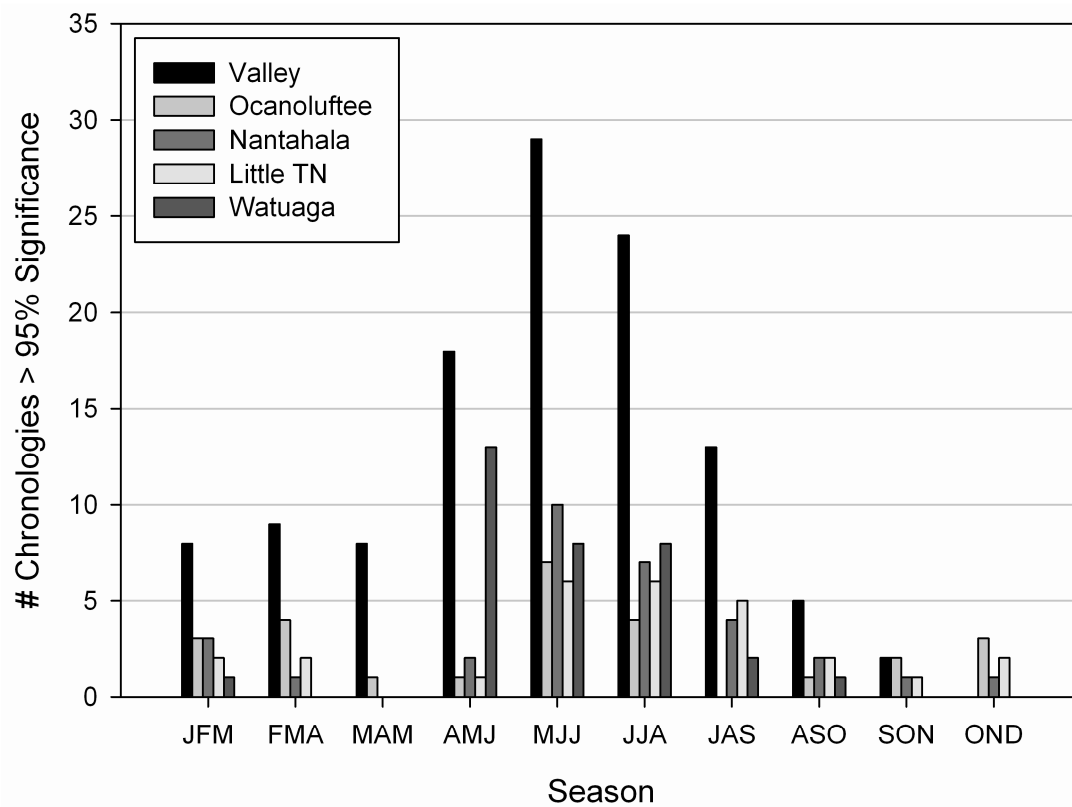


Figure 3: Three month seasonal correlation plot.

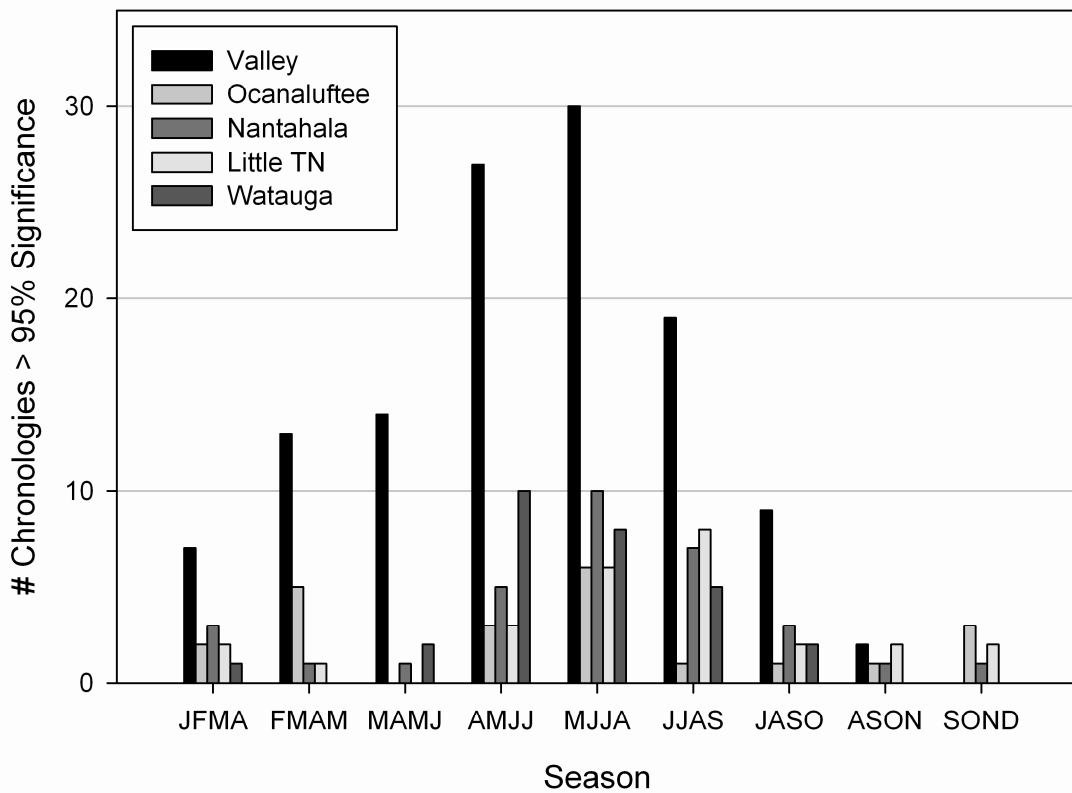


Figure 4: Four month seasonal correlation plot.

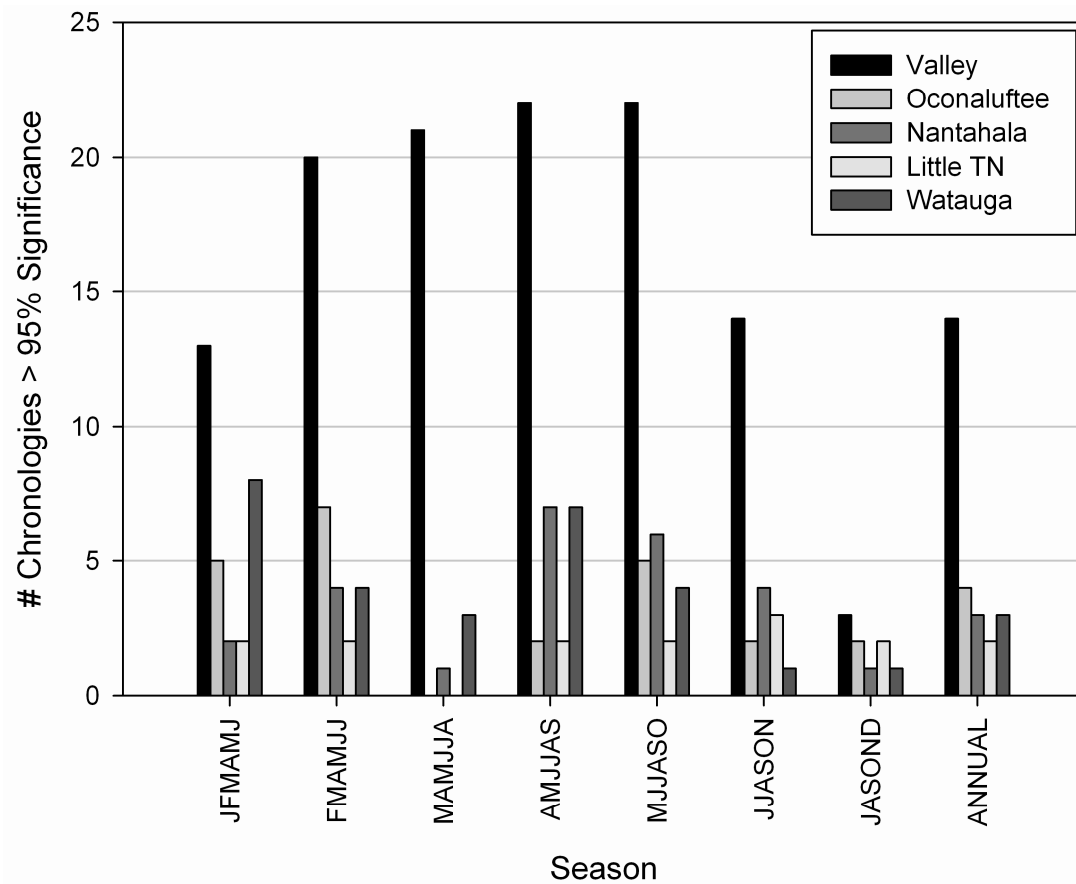


Figure 5: Six month and annual seasonal correlation plot.

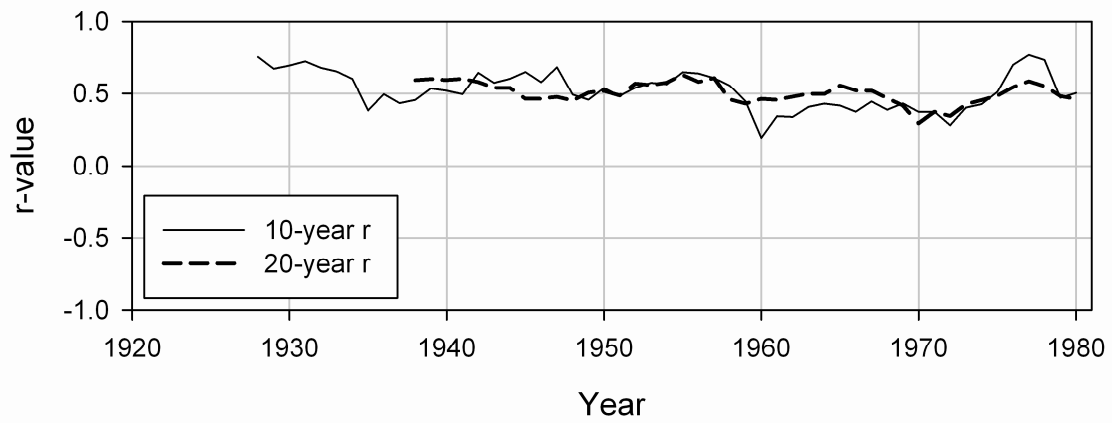


Figure 6: Climate/tree growth relationship for the Valley River MJJ streamflow/Piney Creek Tree-Ring Chronology using a 10-year filter and the 20-year filter over the periods (1928–1980) and (1938–1980) respectively.

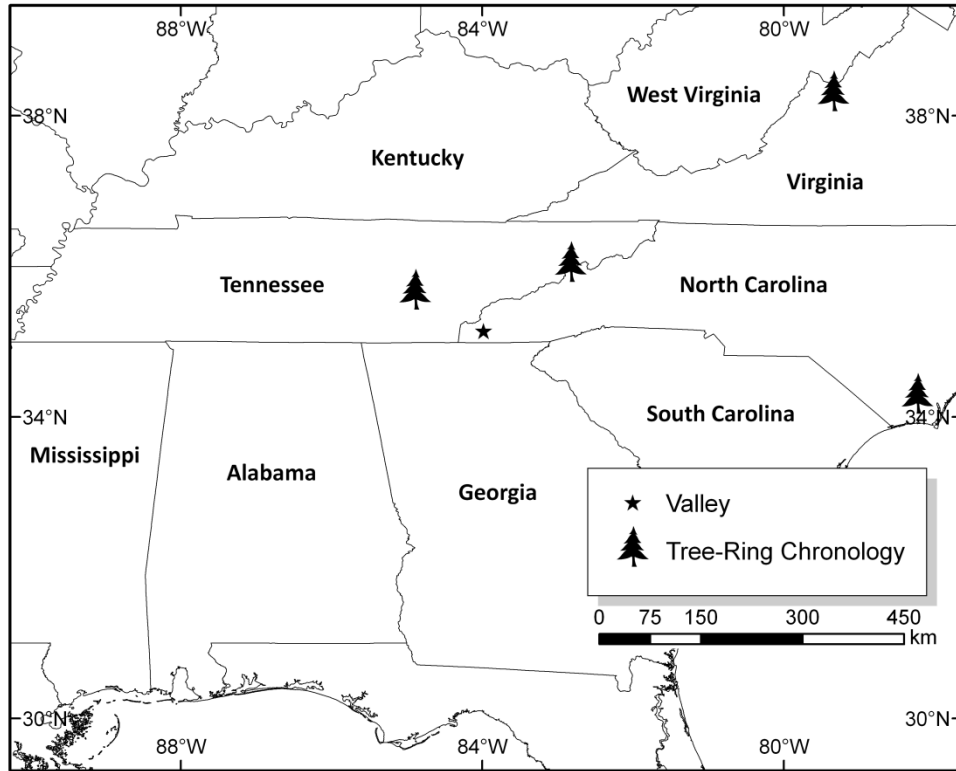


Figure 7: Map of the Valley River streamflow gage and retained tree-ring chronologies.

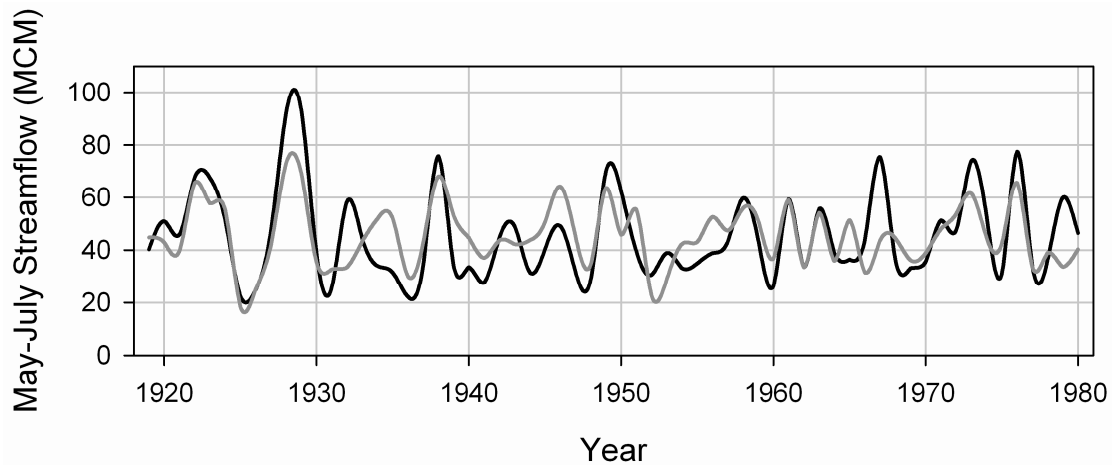


Figure 8: Valley River calibration plot of MJJ average streamflow from 1919 to 1980. The black line represents the instrumental streamflow, and the gray line represents the reconstructed streamflow.

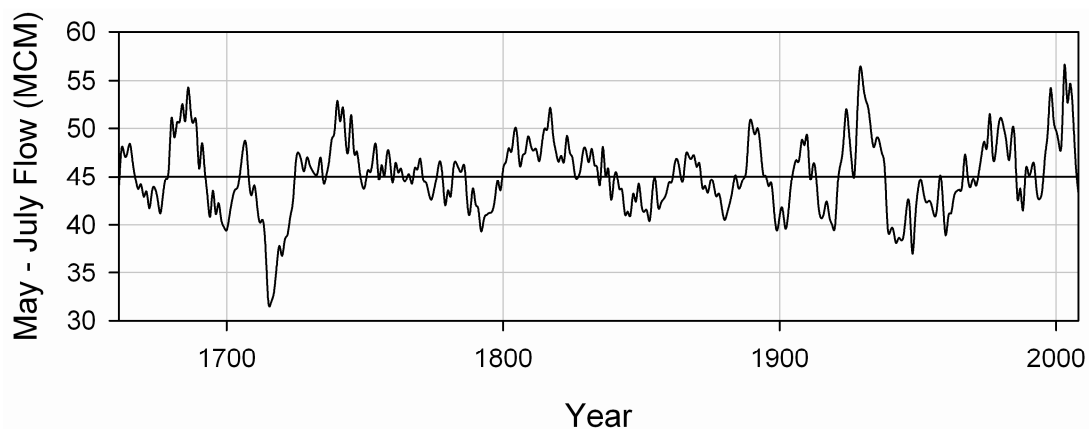


Figure 9: Valley River plot of combined reconstructed (1661–1918) and instrumental (1919–2008) MJJ streamflow using a 10-year end-year filter.

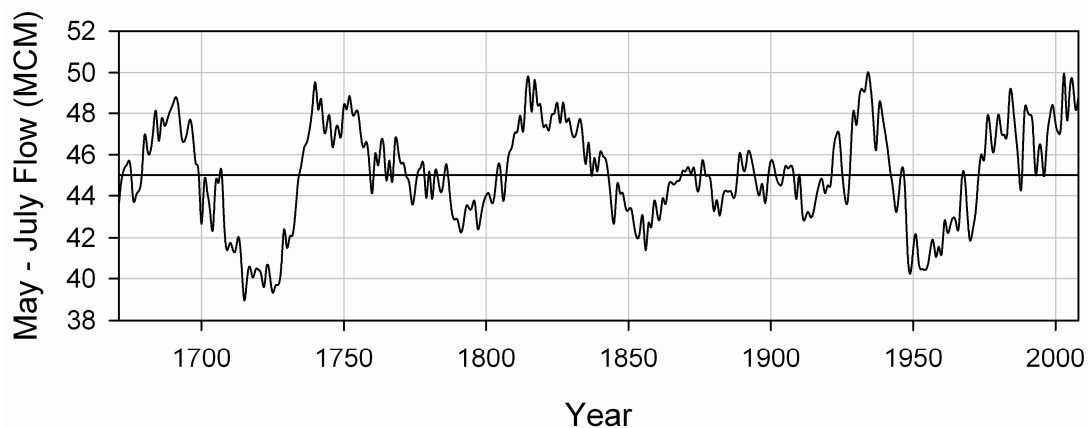


Figure 10: Valley River plot of combined reconstructed (1671–1918) and instrumental (1919–2008) MJJ streamflow using a 20-year end-year filter.

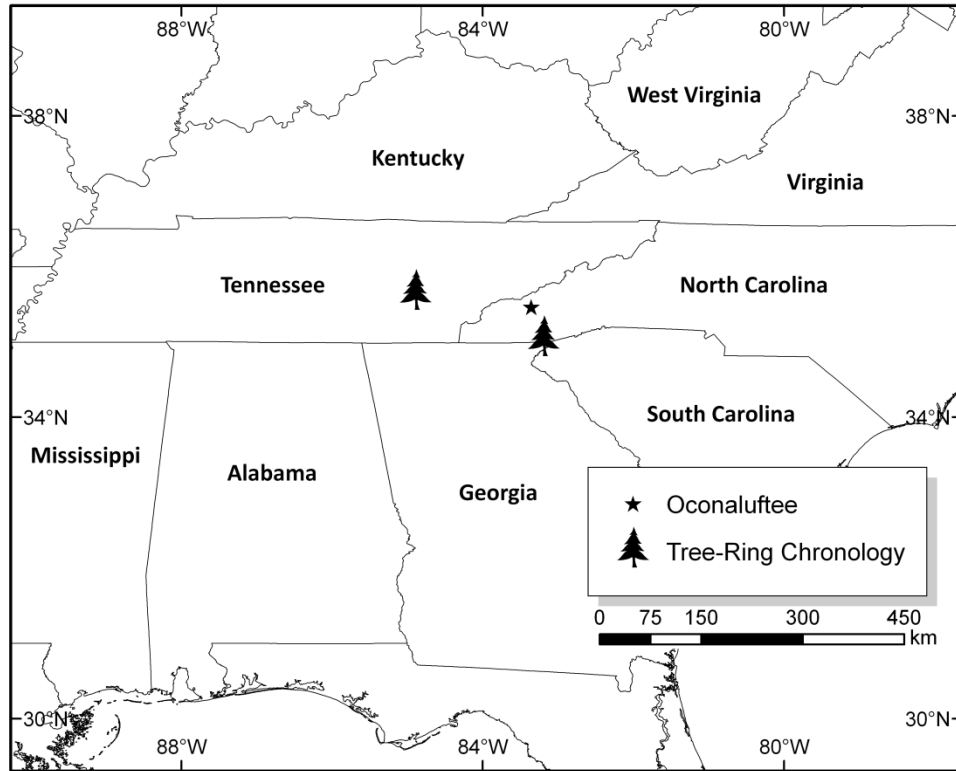


Figure 11: Map of Oconaluftee River streamflow gage and retained tree-ring chronologies.

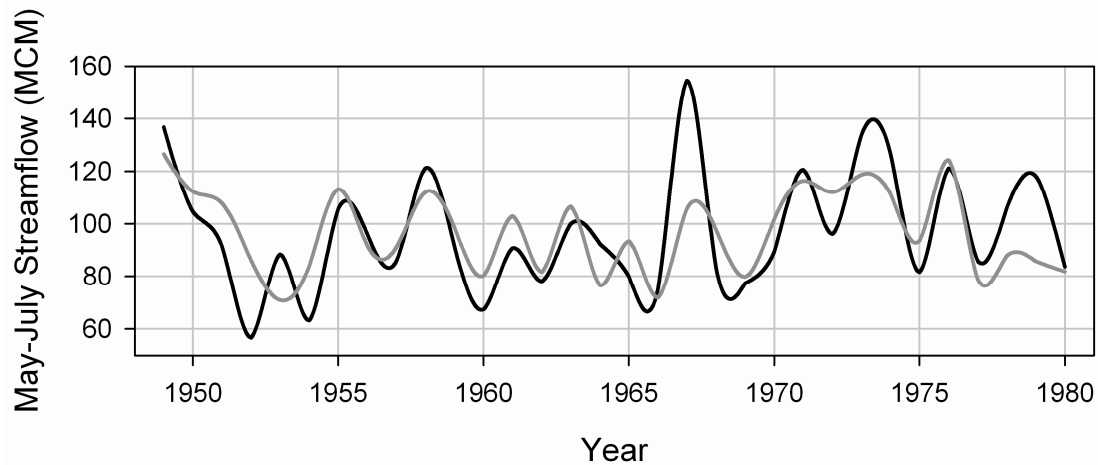


Figure 12: Oconaluftee River calibration plot of MJJ average streamflow from 1949 to 1980. The black line represents the instrumental streamflow, and the gray line represents the reconstructed streamflow.

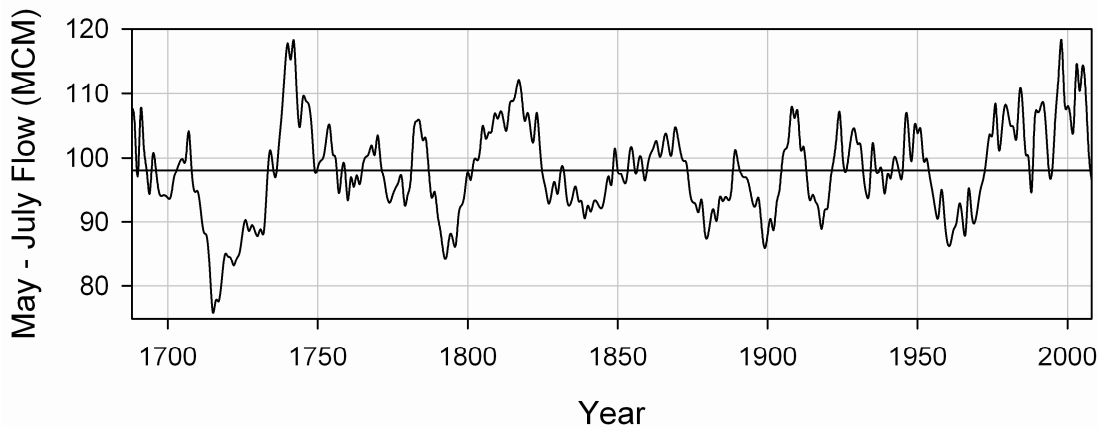


Figure 13: Oconaluftee River plot of combined reconstructed (1688–1948) and instrumental (1949–2008) MJJ streamflow using a 10-year end-year filter.

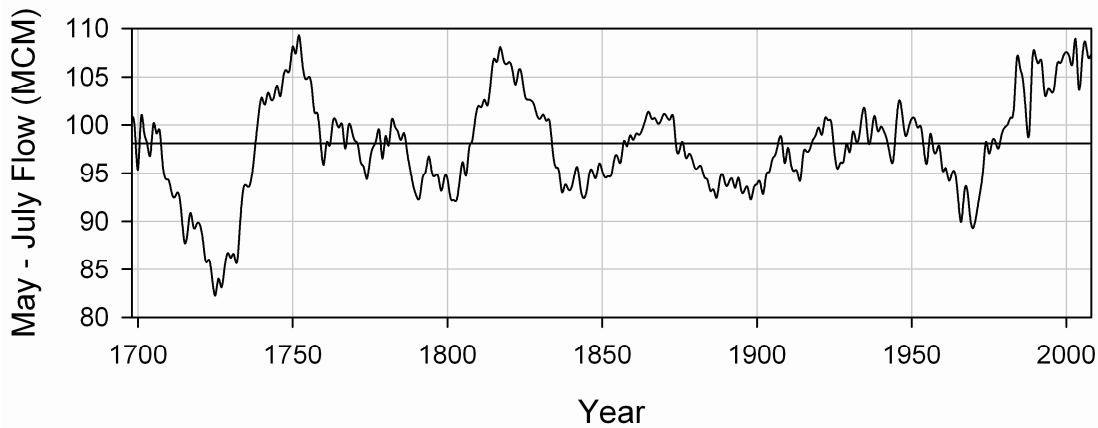


Figure 14: Oconaluftee River plot of combined reconstructed (1698–1948) and instrumental (1949–2008) MJJ streamflow using a 20-year end-year filter.

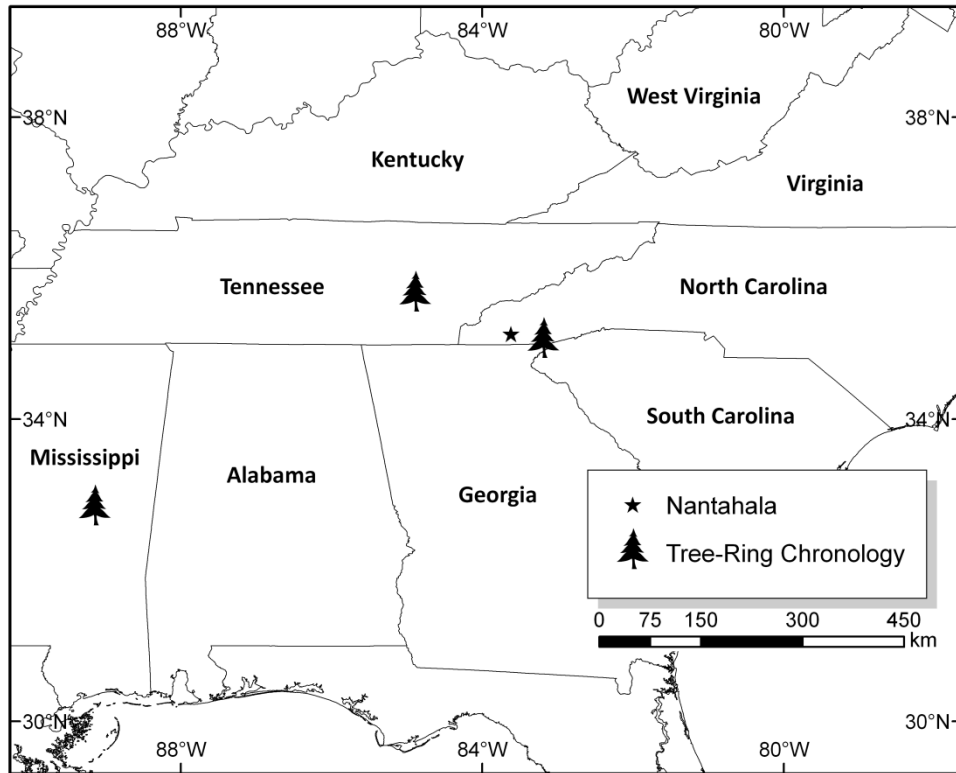


Figure 15: Map of Nantahala River streamflow gage and retained tree-ring chronologies.

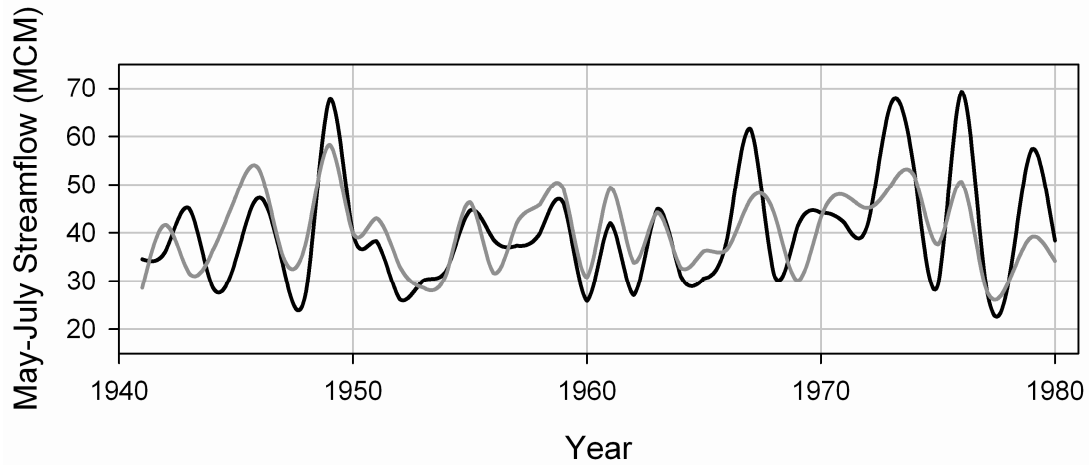


Figure 16: Nantahala River calibration plot of MJJ average streamflow from 1941 to 1980. The black line represents the instrumental streamflow, and the gray line represents the reconstructed streamflow.

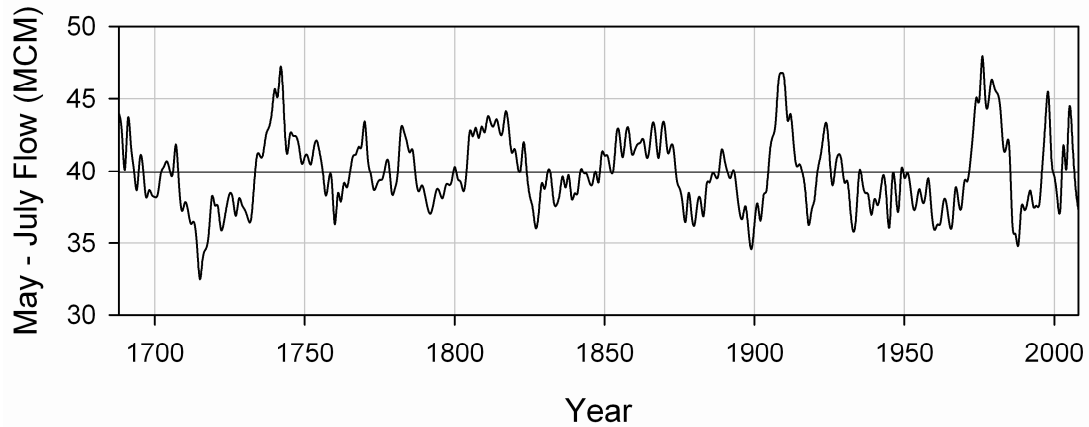


Figure 17: Nantahala River plot of combined reconstructed (1688–1940) and instrumental (1941–2008) MJJ streamflow using a 10-year end-year filter.

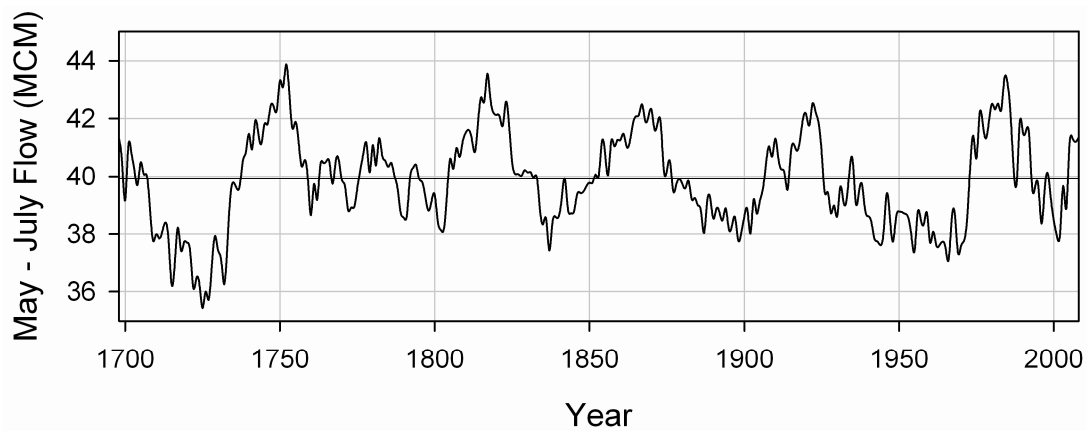


Figure 18: Nantahala River plot of combined reconstructed (1698–1940) and instrumental (1941–2008) MJJ streamflow using a 20-year end-year filter.

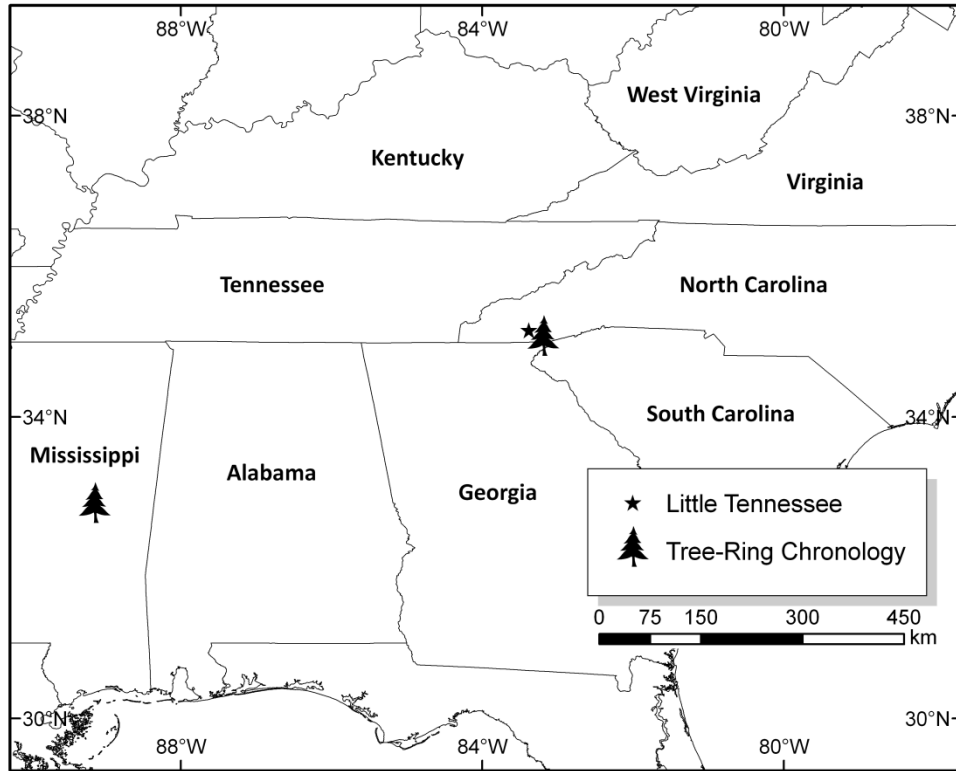


Figure 19: Map of Little Tennessee River streamflow gage and retained tree-ring chronologies.

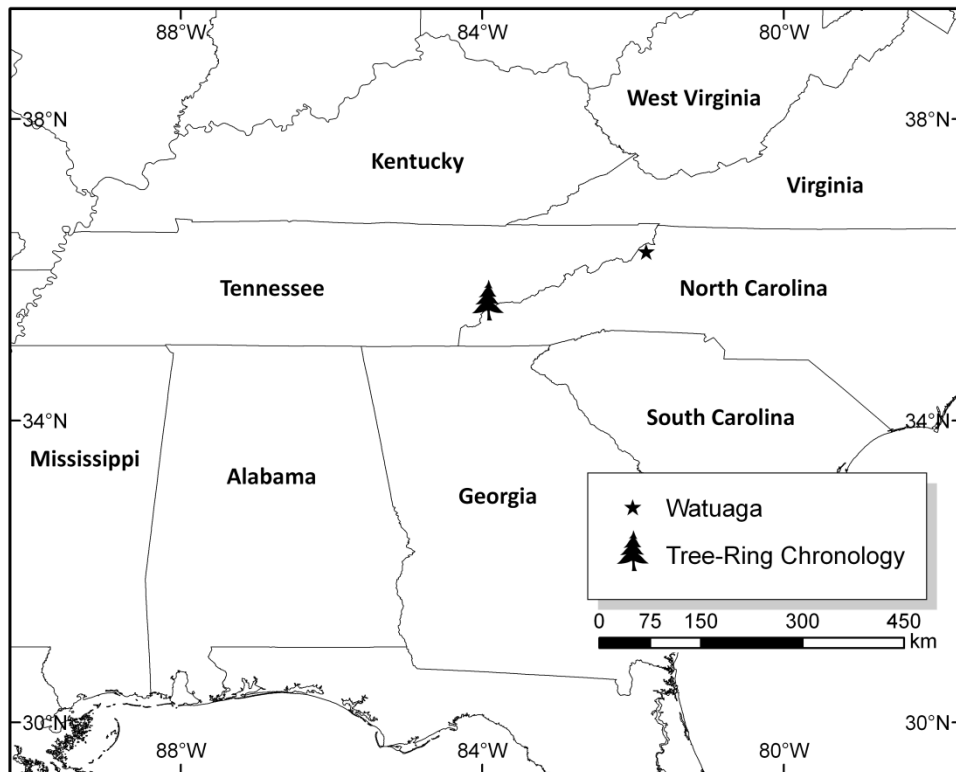


Figure 20: Map of Watauga River streamflow gage and retained tree-ring chronologies.

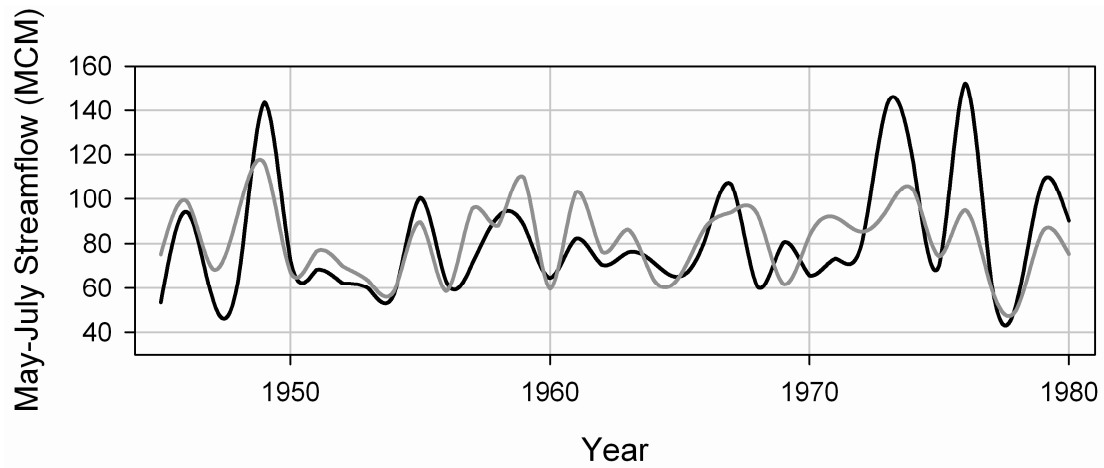


Figure 21: Little Tennessee River calibration plot of MJJ average streamflow from 1945 to 1980. The black line represents the instrumental streamflow, and the gray line represents the reconstructed streamflow.

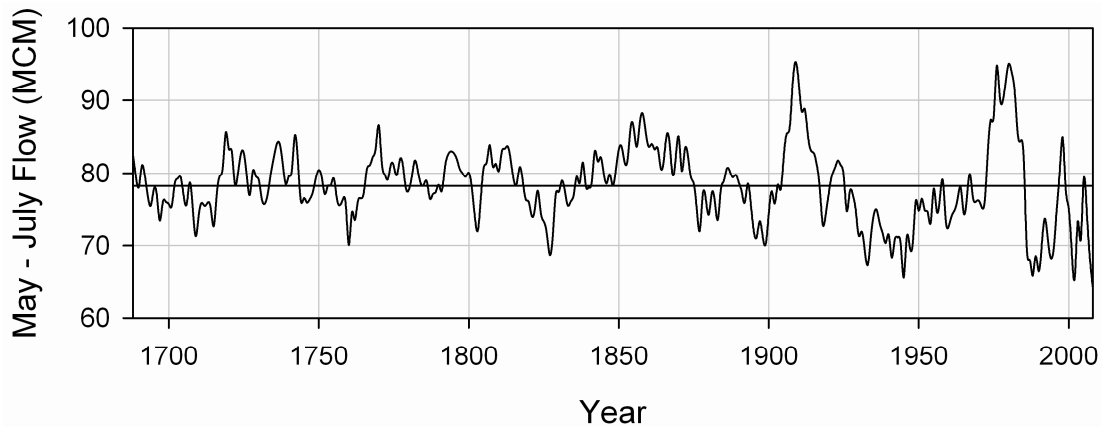


Figure 22: Little Tennessee River plot of combined reconstructed (1688–1944) and instrumental (1945–2008) MJJ streamflow using a 10-year end-year filter.

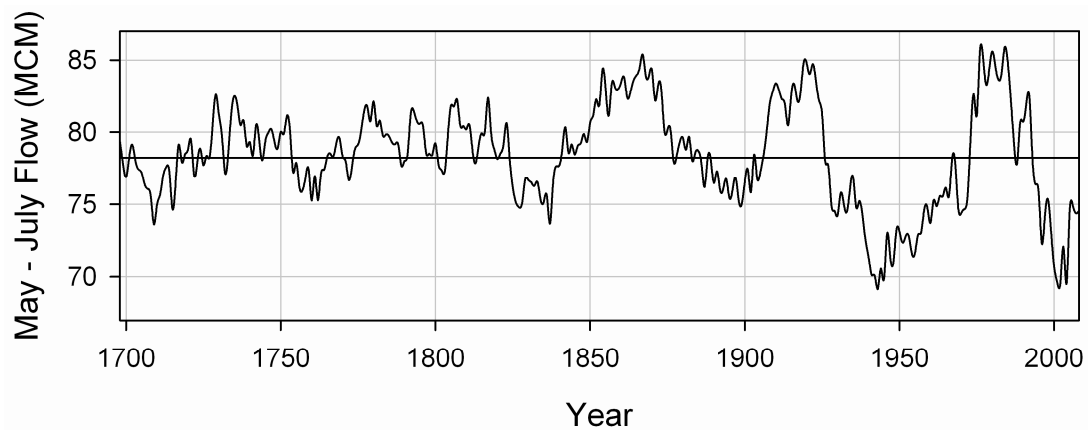


Figure 23: Little Tennessee River plot of combined reconstructed (1698–1944) and instrumental (1945–2008) MJJ streamflow using a 20-year end-year filter.

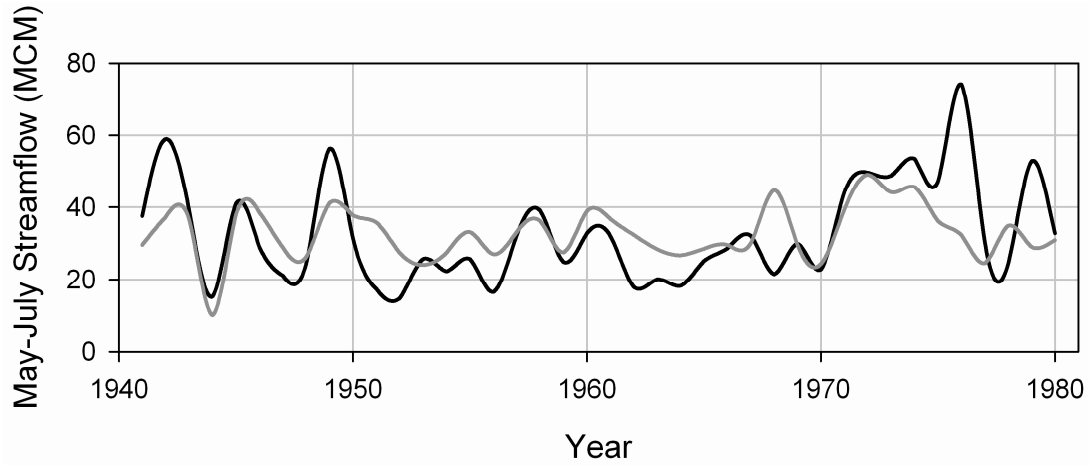


Figure 24: Watauga River calibration plot of MJJ average streamflow from 1941 to 1980. The black line represents the instrumental streamflow, and the gray line represents the reconstructed streamflow.

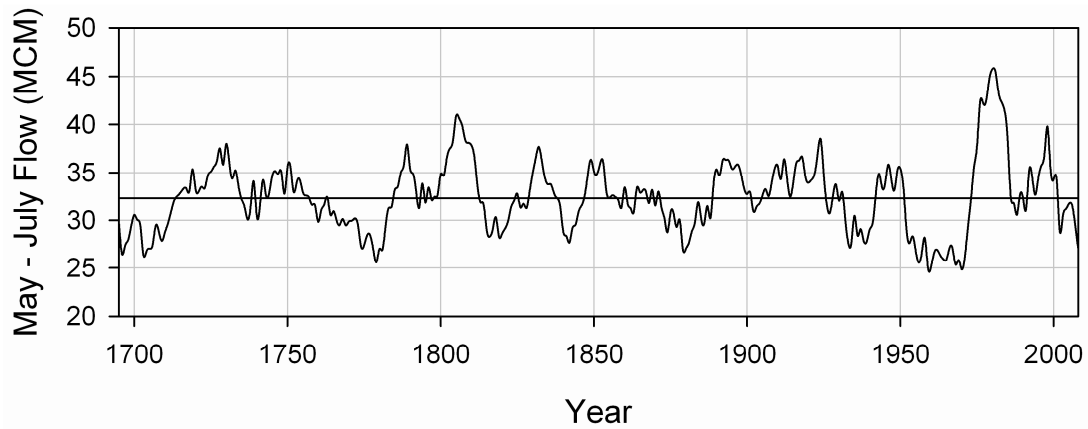


Figure 25: Watauga River plot of combined reconstructed (1695–1940) and instrumental (1941–2008) MJJ streamflow using a 10-year end-year filter.

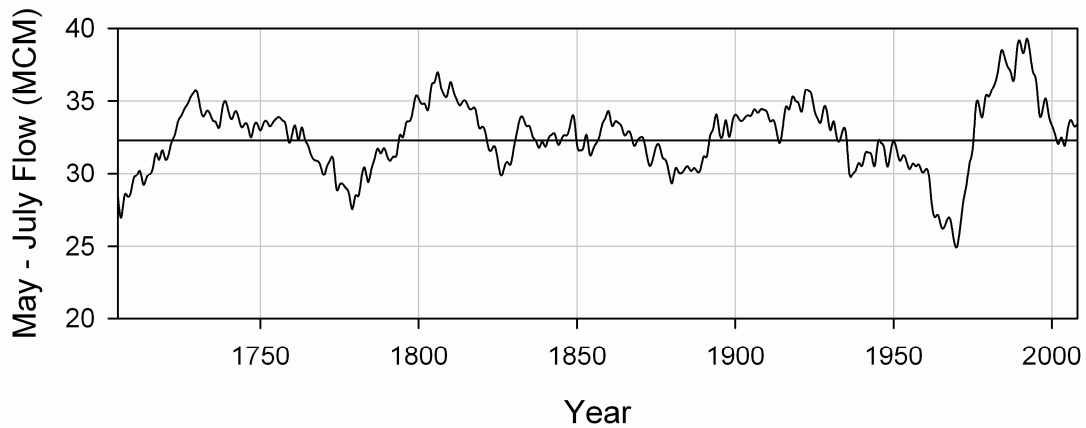


Figure 26: Watauga River plot of combined reconstructed (1705–1940) and instrumental (1941–2008) MJJ streamflow using a 20-year end-year filter.



Figure 27: Valley River 5-year averages distribution of reconstructed values within the lowest 10th percentile. The y-axis represents the rank for the period of low flow, and the x-axis represents the end year for the 5-year average period of the reconstructed (1656–1918) and instrumental (1919–2008) record.

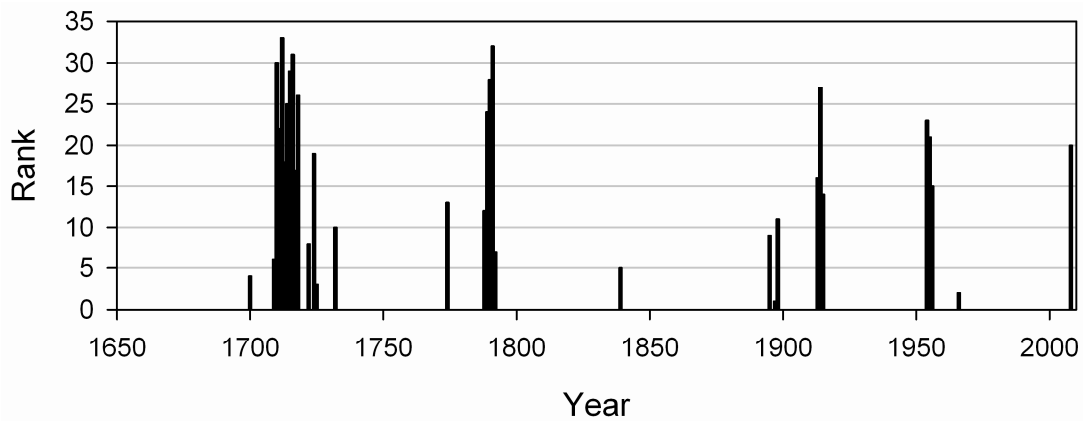


Figure 28: Oconaluftee River 5-year averages distribution of reconstructed values within the lowest 10th percentile. The y-axis represents the rank for the period of low flow, and the x-axis represents the end year for the 5-year average period of the reconstructed (1683–1948) and instrumental (1949–2008) record.

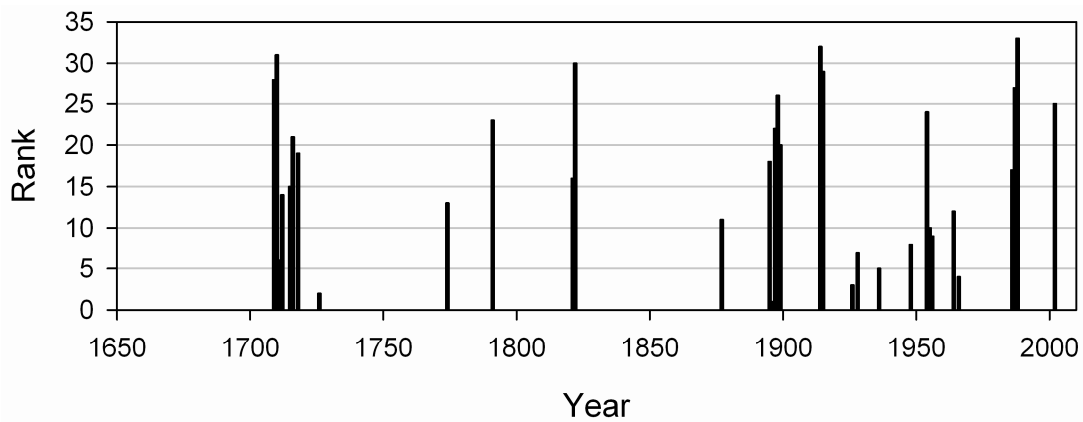


Figure 29: Nantahala River 5-year averages distribution of reconstructed values within the lowest 10th percentile. The y-axis represents the rank for the period of low flow, and the x-axis represents the end year for the 5-year average period of the reconstructed (1683–1940) and instrumental (1941–2008) record.

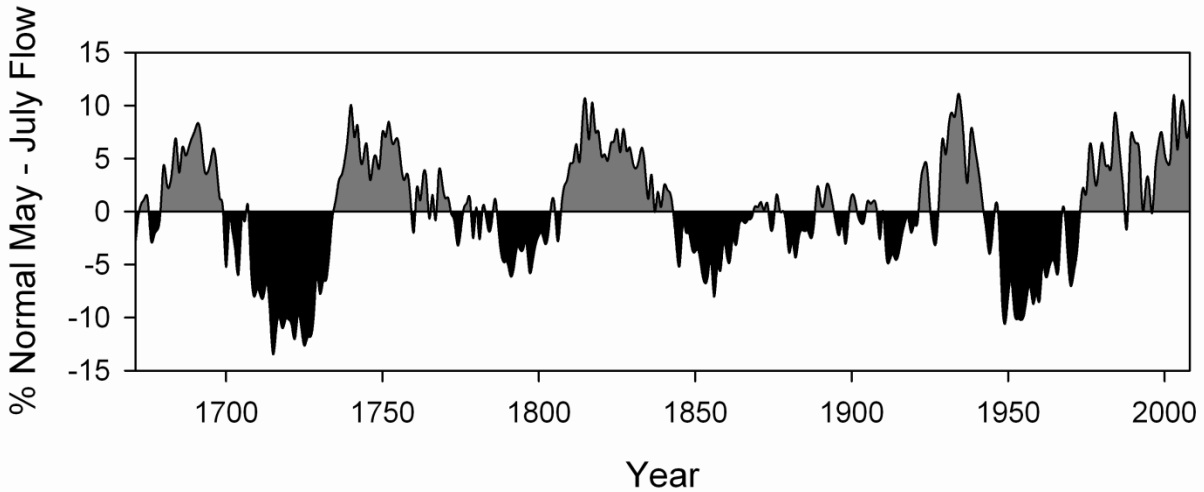


Figure 30: Valley River percent normal plot of combined reconstructed (1671–1918) and instrumental (1919–2008) MJJ streamflow using a 20-year end-year filter. Gray areas represent wet periods and black areas represent dry periods.

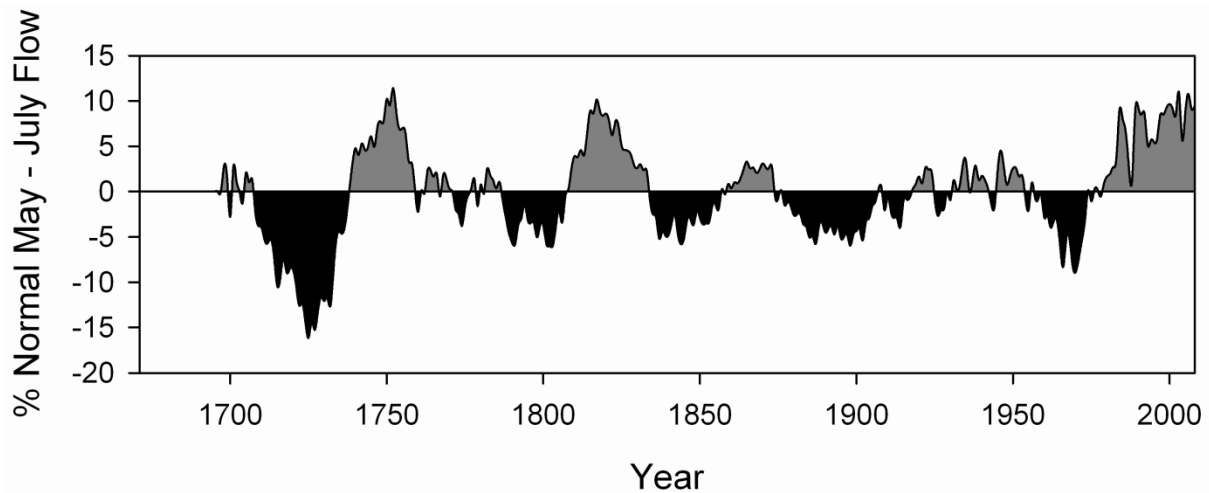


Figure 31: Oconaluftee River percent normal plot of combined reconstructed (1698–1948) and instrumental (1949–2008) MJJ streamflow using a 20-year end-year filter. Gray areas represent wet periods and black areas represent dry periods.

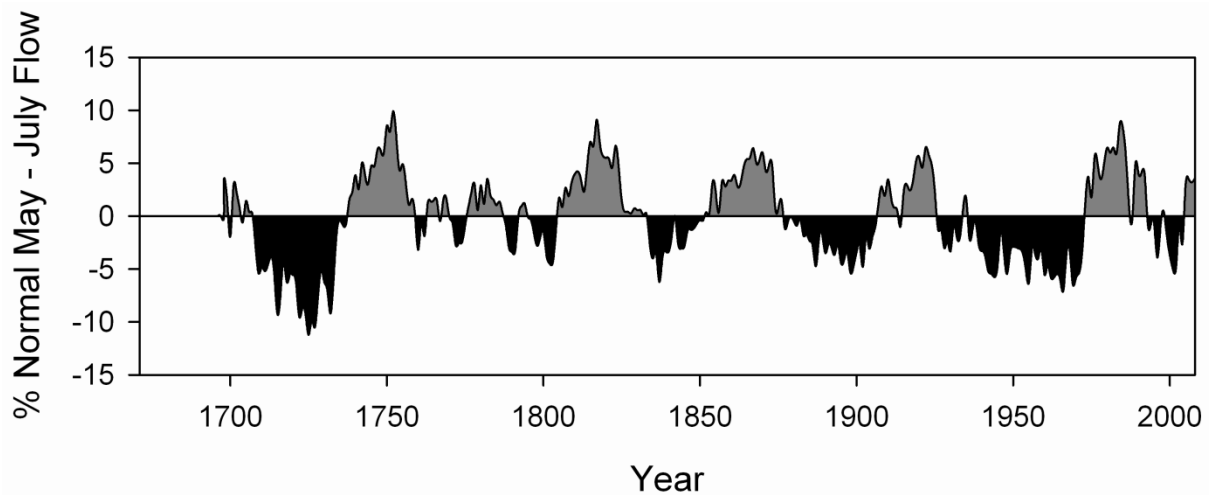


Figure 32: Nantahala River percent normal plot of combined reconstructed (1698–1940) and instrumental (1941–2008) MJJ streamflow using a 20-year end-year filter. Gray areas represent wet periods and black areas represent dry periods.

Appendix 2: Reconstruction Data

Tree Based

Note: Residual tree-ring chronology index values are unitless. A value of 1000 represents the long term mean. Higher or lower values for a given year represent proportionally higher or lower tree growth for that year

Kelsey Tract II Residuals

Year	Kelsey Tract II Residual				
1679	1376	1714	885	1749	1148
1680	1050	1715	669	1750	972
1681	763	1716	1277	1751	970
1682	1122	1717	1174	1752	1031
1683	1126	1718	866	1753	1024
1684	1043	1719	1267	1754	786
1685	874	1720	983	1755	964
1686	1097	1721	1063	1756	983
1687	895	1722	914	1757	875
1688	733	1723	1067	1758	991
1689	904	1724	976	1759	1156
1690	828	1725	771	1760	635
1691	1172	1726	1072	1761	1360
1692	915	1727	945	1762	842
1693	806	1728	1083	1763	1124
1694	990	1729	1197	1764	845
1695	1052	1730	945	1765	1085
1696	932	1731	992	1766	1273
1697	742	1732	704	1767	1058
1698	980	1733	1228	1768	1211
1699	1249	1734	1271	1769	1078
1700	761	1735	902	1770	895
1701	901	1736	1158	1771	940
1702	1305	1737	939	1772	756
1703	980	1738	940	1773	1214
1704	999	1739	1014	1774	919
1705	890	1740	902	1775	1016
1706	792	1741	1070	1776	1009
1707	949	1742	1082	1777	1073
1708	719	1743	881	1778	1103
1709	975	1744	850	1779	852
1710	1205	1745	952	1780	966
1711	1177	1746	899	1781	1065
1712	1219	1747	992	1782	681
1713	824	1748	886	1783	1206

1784	959	1819	719	1854	1406
1785	961	1820	841	1855	911
1786	1099	1821	753	1856	869
1787	824	1822	1068	1857	1237
1788	1064	1823	1220	1858	977
1789	796	1824	949	1859	963
1790	914	1825	1061	1860	972
1791	1028	1826	852	1861	1204
1792	1190	1827	995	1862	982
1793	1038	1828	957	1863	1166
1794	1095	1829	1083	1864	1011
1795	948	1830	830	1865	1039
1796	941	1831	1073	1866	996
1797	801	1832	853	1867	987
1798	1154	1833	1171	1868	805
1799	856	1834	1054	1869	1016
1800	1047	1835	1018	1870	1239
1801	807	1836	936	1871	728
1802	883	1837	831	1872	1311
1803	1023	1838	1064	1873	932
1804	1340	1839	891	1874	886
1805	1045	1840	913	1875	886
1806	990	1841	1031	1876	716
1807	1252	1842	1157	1877	918
1808	908	1843	908	1878	1055
1809	949	1844	1115	1879	990
1810	856	1845	882	1880	949
1811	989	1846	1164	1881	961
1812	999	1847	989	1882	1146
1813	997	1848	994	1883	685
1814	1285	1849	1125	1884	1144
1815	1095	1850	1113	1885	987
1816	1153	1851	1021	1886	865
1817	1259	1852	1094	1887	903
1818	623	1853	1046	1888	1100

1889	964	1924	803	1959	1179
1890	888	1925	962	1960	780
1891	825	1926	600	1961	1042
1892	872	1927	1085	1962	1087
1893	963	1928	989	1963	1075
1894	1127	1929	1148	1964	616
1895	656	1930	988	1965	795
1896	877	1931	1102	1966	924
1897	1128	1932	766	1967	1051
1898	861	1933	733	1968	1078
1899	981	1934	1007	1969	911
1900	1091	1935	1129	1970	954
1901	1208	1936	707	1971	1166
1902	991	1937	937	1972	1099
1903	1263	1938	840	1973	1148
1904	1115	1939	942	1974	1079
1905	1157	1940	1131	1975	967
1906	1072	1941	853	1976	1217
1907	966	1942	1014	1977	922
1908	1369	1943	924	1978	784
1909	948	1944	949	1979	997
1910	947	1945	1048	1980	1020
1911	932	1946	1118		
1912	795	1947	1004		
1913	919	1948	1248		
1914	790	1949	1246		
1915	1126	1950	998		
1916	881	1951	893		
1917	867	1952	1067		
1918	1023	1953	869		
1919	1233	1954	768		
1920	1267	1955	1160		
1921	1028	1956	954		
1922	928	1957	1188		
1923	872	1958	1114		

Pearl River Residuals

Year	Pearl River Residual				
1549	639	1584	1344	1619	857
1550	942	1585	1271	1620	1541
1551	1096	1586	2072	1621	668
1552	1021	1587	556	1622	943
1553	898	1588	882	1623	729
1554	1014	1589	1906	1624	653
1555	1125	1590	1176	1625	746
1556	938	1591	1180	1626	1867
1557	1250	1592	1375	1627	842
1558	898	1593	927	1628	679
1559	1519	1594	601	1629	1231
1560	1368	1595	1003	1630	1215
1561	1173	1596	884	1631	1095
1562	863	1597	804	1632	872
1563	1519	1598	639	1633	805
1564	1840	1599	554	1634	752
1565	267	1600	1273	1635	882
1566	493	1601	1067	1636	1067
1567	823	1602	903	1637	569
1568	1343	1603	1179	1638	879
1569	438	1604	1009	1639	1287
1570	635	1605	1237	1640	1187
1571	700	1606	1063	1641	906
1572	885	1607	1158	1642	790
1573	1027	1608	550	1643	766
1574	1284	1609	944	1644	797
1575	1227	1610	759	1645	1356
1576	606	1611	773	1646	718
1577	1061	1612	719	1647	1111
1578	1239	1613	981	1648	1266
1579	829	1614	780	1649	1109
1580	985	1615	849	1650	1026
1581	1079	1616	1003	1651	661
1582	817	1617	982	1652	1067
1583	989	1618	714	1653	968

1654	775	1689	1871	1724	1347
1655	806	1690	1110	1725	391
1656	1193	1691	840	1726	829
1657	878	1692	1108	1727	854
1658	1535	1693	1017	1728	1216
1659	912	1694	645	1729	1138
1660	771	1695	1150	1730	727
1661	1153	1696	1119	1731	855
1662	786	1697	568	1732	937
1663	804	1698	1197	1733	1010
1664	889	1699	902	1734	1398
1665	1452	1700	1210	1735	730
1666	838	1701	1528	1736	1168
1667	1086	1702	981	1737	864
1668	1028	1703	740	1738	755
1669	734	1704	659	1739	771
1670	844	1705	768	1740	1207
1671	614	1706	1221	1741	876
1672	1087	1707	900	1742	1380
1673	1200	1708	802	1743	969
1674	1316	1709	476	1744	782
1675	758	1710	873	1745	694
1676	632	1711	1263	1746	1715
1677	777	1712	1097	1747	862
1678	780	1713	1333	1748	1217
1679	1537	1714	725	1749	1009
1680	980	1715	623	1750	1371
1681	1057	1716	1240	1751	830
1682	943	1717	1053	1752	785
1683	1000	1718	773	1753	927
1684	932	1719	1165	1754	987
1685	956	1720	787	1755	971
1686	874	1721	1494	1756	609
1687	1263	1722	541	1757	884
1688	1095	1723	1038	1758	1153

1759	773	1794	471	1829	1435
1760	577	1795	1103	1830	1055
1761	1125	1796	1227	1831	689
1762	998	1797	781	1832	922
1763	1449	1798	830	1833	858
1764	964	1799	944	1834	596
1765	869	1800	781	1835	1326
1766	806	1801	703	1836	1625
1767	553	1802	866	1837	926
1768	896	1803	1009	1838	1268
1769	1390	1804	1154	1839	937
1770	801	1805	2233	1840	756
1771	691	1806	1314	1841	1025
1772	739	1807	230	1842	1432
1773	967	1808	615	1843	1162
1774	1401	1809	792	1844	610
1775	1024	1810	994	1845	986
1776	1148	1811	1035	1846	539
1777	1183	1812	658	1847	881
1778	998	1813	1187	1848	949
1779	1006	1814	706	1849	964
1780	507	1815	1215	1850	1088
1781	899	1816	709	1851	1157
1782	1685	1817	938	1852	942
1783	558	1818	801	1853	967
1784	693	1819	640	1854	1157
1785	1137	1820	926	1855	806
1786	1033	1821	1098	1856	598
1787	1148	1822	733	1857	1193
1788	1289	1823	1382	1858	1382
1789	1263	1824	720	1859	632
1790	972	1825	917	1860	875
1791	730	1826	1046	1861	757
1792	1244	1827	759	1862	1025
1793	1609	1828	648	1863	668

1864	1422	1899	984	1934	1005
1865	784	1900	1667	1935	1275
1866	1341	1901	797	1936	494
1867	1469	1902	563	1937	793
1868	562	1903	1013	1938	845
1869	1256	1904	407	1939	1319
1870	987	1905	777	1940	810
1871	653	1906	1287	1941	517
1872	1011	1907	1478	1942	907
1873	1115	1908	1504	1943	658
1874	814	1909	1958	1944	884
1875	897	1910	1175	1945	708
1876	1029	1911	318	1946	1258
1877	728	1912	1221	1947	629
1878	1427	1913	920	1948	748
1879	1145	1914	640	1949	1435
1880	1119	1915	741	1950	599
1881	933	1916	1325	1951	1190
1882	1122	1917	729	1952	489
1883	1006	1918	891	1953	844
1884	1387	1919	1584	1954	985
1885	993	1920	1167	1955	845
1886	1173	1921	832	1956	450
1887	666	1922	1184	1957	951
1888	1014	1923	1394	1958	924
1889	1331	1924	398	1959	1421
1890	946	1925	738	1960	982
1891	907	1926	573	1961	1605
1892	1436	1927	960	1962	637
1893	1040	1928	849	1963	983
1894	581	1929	1153	1964	1576
1895	742	1930	854	1965	1122
1896	869	1931	802	1966	1448
1897	709	1932	834	1967	1294
1898	1010	1933	1113	1968	1185

1969	675
1970	1238
1971	889
1972	884
1973	1058
1974	1535
1975	912
1976	851
1977	598
1978	687
1979	1185
1980	794

Piney Creek Pocket Wilderness Residuals

Year	Piney Creek Residual				
1652	687	1687	1097	1722	712
1653	738	1688	1151	1723	809
1654	936	1689	1097	1724	826
1655	960	1690	959	1725	1094
1656	1020	1691	1249	1726	1096
1657	979	1692	871	1727	971
1658	882	1693	777	1728	703
1659	908	1694	1066	1729	940
1660	1013	1695	1211	1730	775
1661	879	1696	861	1731	1170
1662	913	1697	860	1732	782
1663	1001	1698	950	1733	1322
1664	1224	1699	916	1734	1189
1665	1087	1700	963	1735	835
1666	803	1701	1412	1736	877
1667	919	1702	902	1737	1397
1668	981	1703	815	1738	1227
1669	1177	1704	1171	1739	1623
1670	649	1705	1336	1740	1182
1671	946	1706	939	1741	908
1672	692	1707	1127	1742	837
1673	1006	1708	540	1743	791
1674	1114	1709	782	1744	948
1675	1113	1710	721	1745	1200
1676	660	1711	1004	1746	988
1677	1100	1712	657	1747	1316
1678	1262	1713	838	1748	925
1679	1066	1714	784	1749	975
1680	1552	1715	869	1750	1185
1681	536	1716	829	1751	1057
1682	1274	1717	994	1752	934
1683	933	1718	745	1753	992
1684	1361	1719	974	1754	1115
1685	772	1720	828	1755	812
1686	953	1721	1041	1756	867

1757	907	1792	886	1827	1024
1758	1160	1793	1017	1828	1023
1759	1043	1794	999	1829	854
1760	902	1795	888	1830	1064
1761	1155	1796	1051	1831	955
1762	910	1797	1067	1832	1089
1763	1096	1798	978	1833	838
1764	960	1799	932	1834	929
1765	1010	1800	1069	1835	961
1766	831	1801	927	1836	937
1767	851	1802	1321	1837	915
1768	1153	1803	1045	1838	958
1769	959	1804	961	1839	730
1770	1026	1805	1203	1840	1192
1771	1006	1806	855	1841	897
1772	750	1807	902	1842	1056
1773	799	1808	1130	1843	983
1774	821	1809	1122	1844	823
1775	1151	1810	1102	1845	1049
1776	1076	1811	929	1846	1029
1777	929	1812	1124	1847	1019
1778	1272	1813	938	1848	897
1779	696	1814	1334	1849	1092
1780	1131	1815	1226	1850	784
1781	1141	1816	882	1851	854
1782	1464	1817	1082	1852	983
1783	941	1818	1063	1853	936
1784	798	1819	903	1854	1043
1785	926	1820	1217	1855	1040
1786	1050	1821	814	1856	881
1787	632	1822	951	1857	1074
1788	905	1823	1197	1858	912
1789	805	1824	1092	1859	889
1790	838	1825	817	1860	1078
1791	927	1826	850	1861	915

1862	1132	1897	908	1932	908
1863	948	1898	815	1933	1038
1864	1055	1899	1020	1934	1108
1865	1101	1900	901	1935	1197
1866	993	1901	967	1936	616
1867	1033	1902	916	1937	1186
1868	900	1903	1051	1938	1327
1869	1208	1904	1008	1939	873
1870	834	1905	1063	1940	1085
1871	948	1906	1066	1941	954
1872	837	1907	1132	1942	1041
1873	1029	1908	974	1943	919
1874	755	1909	884	1944	956
1875	1027	1910	1079	1945	1260
1876	1111	1911	599	1946	1159
1877	970	1912	1053	1947	949
1878	930	1913	864	1948	698
1879	798	1914	823	1949	1106
1880	914	1915	1146	1950	1115
1881	1057	1916	1074	1951	1133
1882	1058	1917	1082	1952	847
1883	1011	1918	896	1953	821
1884	932	1919	981	1954	990
1885	923	1920	942	1955	1035
1886	1090	1921	936	1956	958
1887	932	1922	1251	1957	825
1888	1075	1923	1223	1958	1050
1889	1316	1924	1142	1959	896
1890	832	1925	649	1960	952
1891	959	1926	997	1961	1009
1892	1135	1927	1178	1962	797
1893	848	1928	1207	1963	1023
1894	809	1929	1102	1964	1008
1895	900	1930	895	1965	1059
1896	1044	1931	877	1966	799

1967	1029
1968	942
1969	877
1970	1046
1971	1060
1972	1058
1973	1090
1974	1063
1975	967
1976	1102
1977	863
1978	1016
1979	882
1980	835

Ramsey's Draft Recollection Residuals

Year	Ramseys Draft Recollection Residual				
1598	661	1633	994	1668	1208
1599	731	1634	930	1669	670
1600	988	1635	1182	1670	1102
1601	913	1636	718	1671	1002
1602	888	1637	937	1672	1241
1603	1415	1638	1206	1673	1100
1604	1287	1639	1109	1674	1129
1605	1498	1640	1048	1675	1059
1606	1081	1641	1030	1676	737
1607	768	1642	1098	1677	1241
1608	786	1643	588	1678	1139
1609	828	1644	945	1679	1037
1610	1207	1645	1011	1680	896
1611	1536	1646	783	1681	908
1612	1256	1647	796	1682	823
1613	1177	1648	917	1683	974
1614	1338	1649	846	1684	1138
1615	503	1650	937	1685	1049
1616	916	1651	783	1686	1165
1617	974	1652	888	1687	619
1618	1152	1653	1014	1688	1180
1619	1178	1654	1224	1689	1025
1620	1143	1655	1077	1690	1105
1621	567	1656	1028	1691	897
1622	1271	1657	1121	1692	730
1623	1281	1658	1097	1693	1039
1624	844	1659	1147	1694	890
1625	884	1660	1139	1695	982
1626	1077	1661	891	1696	839
1627	1165	1662	1159	1697	877
1628	1071	1663	1119	1698	773
1629	933	1664	914	1699	885
1630	881	1665	1096	1700	892
1631	1132	1666	925	1701	1024
1632	892	1667	1097	1702	1082

1703	924	1738	968	1773	1108
1704	988	1739	975	1774	1048
1705	1004	1740	957	1775	941
1706	1138	1741	825	1776	1331
1707	1037	1742	1034	1777	1091
1708	757	1743	1014	1778	953
1709	868	1744	973	1779	923
1710	1184	1745	1148	1780	914
1711	979	1746	798	1781	1013
1712	903	1747	1077	1782	817
1713	921	1748	789	1783	914
1714	1015	1749	1182	1784	1028
1715	783	1750	1059	1785	997
1716	944	1751	1015	1786	1219
1717	969	1752	1031	1787	785
1718	918	1753	889	1788	1042
1719	851	1754	976	1789	1124
1720	946	1755	869	1790	895
1721	939	1756	1169	1791	912
1722	1201	1757	1089	1792	737
1723	1052	1758	975	1793	1073
1724	924	1759	1021	1794	811
1725	1388	1760	1028	1795	988
1726	1237	1761	1209	1796	1054
1727	1029	1762	887	1797	872
1728	888	1763	989	1798	928
1729	1088	1764	926	1799	961
1730	1050	1765	897	1800	1088
1731	1093	1766	1069	1801	1144
1732	1021	1767	1078	1802	859
1733	1068	1768	938	1803	909
1734	890	1769	1156	1804	905
1735	894	1770	884	1805	938
1736	1117	1771	1071	1806	1043
1737	913	1772	959	1807	1110

1808	1237	1843	944	1878	1125
1809	920	1844	756	1879	857
1810	996	1845	869	1880	770
1811	917	1846	993	1881	1019
1812	935	1847	1025	1882	964
1813	1059	1848	1058	1883	1195
1814	975	1849	924	1884	1051
1815	1068	1850	1002	1885	867
1816	1052	1851	854	1886	998
1817	1072	1852	1001	1887	1212
1818	922	1853	974	1888	862
1819	760	1854	952	1889	1175
1820	819	1855	872	1890	1091
1821	991	1856	928	1891	805
1822	1066	1857	1093	1892	1032
1823	1125	1858	1174	1893	1060
1824	1116	1859	1017	1894	824
1825	1030	1860	1029	1895	764
1826	814	1861	1039	1896	962
1827	1272	1862	1017	1897	1218
1828	1067	1863	939	1898	843
1829	953	1864	1078	1899	971
1830	989	1865	767	1900	940
1831	1004	1866	957	1901	951
1832	1270	1867	1074	1902	1070
1833	1122	1868	985	1903	1145
1834	1255	1869	853	1904	1255
1835	884	1870	879	1905	1010
1836	1105	1871	1048	1906	941
1837	952	1872	902	1907	745
1838	1056	1873	927	1908	1031
1839	663	1874	1044	1909	982
1840	1116	1875	872	1910	944
1841	1232	1876	1134	1911	742
1842	880	1877	986	1912	898

1913	1234	1948	1073
1914	737	1949	1132
1915	841	1950	1100
1916	1228	1951	1253
1917	1177	1952	720
1918	946	1953	918
1919	1002	1954	1079
1920	918	1955	1072
1921	884	1956	1145
1922	921	1957	983
1923	1022	1958	1055
1924	933	1959	1125
1925	1031	1960	754
1926	756	1961	1219
1927	800	1962	937
1928	1211	1963	1017
1929	1060	1964	754
1930	819	1965	883
1931	683	1966	971
1932	1089	1967	969
1933	1054	1968	1072
1934	1107	1969	769
1935	1092	1970	861
1936	1080	1971	1036
1937	795	1972	941
1938	1096	1973	1185
1939	1394	1974	913
1940	928	1975	1016
1941	928	1976	1127
1942	952	1977	935
1943	1207	1978	745
1944	970	1979	986
1945	946	1980	1073
1946	980		
1947	1010		

Black River Residuals

Year	Black River Residual				
367	1235	402	565	437	355
368	832	403	1363	438	775
369	929	404	989	439	852
370	717	405	581	440	665
371	752	406	641	441	1770
372	1427	407	509	442	803
373	1600	408	685	443	1177
374	2462	409	1113	444	582
375	2000	410	1372	445	527
376	840	411	893	446	1120
377	535	412	1236	447	573
378	710	413	603	448	1015
379	625	414	725	449	903
380	899	415	1095	450	1307
381	1486	416	426	451	835
382	1748	417	1129	452	2396
383	1393	418	631	453	1016
384	354	419	1212	454	1542
385	746	420	278	455	770
386	606	421	234	456	786
387	805	422	957	457	1023
388	850	423	1273	458	503
389	735	424	1852	459	480
390	728	425	976	460	1150
391	267	426	637	461	781
392	637	427	1056	462	857
393	1323	428	1356	463	1233
394	1874	429	1000	464	1440
395	1872	430	1000	465	1042
396	1459	431	379	466	1756
397	802	432	564	467	52
398	441	433	1138	468	966
399	339	434	1632	469	2976
400	1157	435	1186	470	725
401	1207	436	352	471	913

472	1852	507	1006	542	241
473	922	508	395	543	398
474	347	509	720	544	941
475	1070	510	433	545	1912
476	717	511	623	546	1280
477	946	512	1099	547	1357
478	826	513	1322	548	520
479	423	514	1572	549	1023
480	2262	515	910	550	421
481	1387	516	981	551	1738
482	1661	517	1593	552	347
483	755	518	1259	553	966
484	1043	519	48	554	1309
485	670	520	197	555	1414
486	795	521	780	556	71
487	401	522	956	557	451
488	531	523	967	558	1474
489	670	524	1879	559	394
490	1601	525	2091	560	668
491	341	526	732	561	796
492	610	527	310	562	599
493	592	528	438	563	475
494	1584	529	1525	564	722
495	1125	530	1144	565	2719
496	1825	531	1441	566	396
497	463	532	888	567	1705
498	1850	533	1184	568	820
499	1940	534	412	569	68
500	570	535	1803	570	1114
501	448	536	2641	571	620
502	1844	537	1197	572	1559
503	639	538	1237	573	847
504	85	539	215	574	183
505	662	540	877	575	942
506	492	541	818	576	1303

577	1060	612	829	647	1023
578	1364	613	574	648	601
579	1006	614	655	649	574
580	1786	615	1691	650	1016
581	1024	616	1495	651	397
582	366	617	1077	652	1232
583	1387	618	1128	653	928
584	1037	619	552	654	2196
585	286	620	796	655	448
586	1601	621	1794	656	1802
587	534	622	1043	657	378
588	329	623	874	658	618
589	624	624	1599	659	746
590	523	625	1070	660	1991
591	1148	626	1206	661	2372
592	1389	627	1610	662	675
593	1700	628	161	663	2101
594	913	629	390	664	540
595	467	630	664	665	196
596	2315	631	2165	666	526
597	1419	632	672	667	354
598	1713	633	137	668	2628
599	957	634	607	669	1499
600	1172	635	631	670	977
601	900	636	1234	671	621
602	496	637	832	672	548
603	1254	638	1515	673	1083
604	409	639	1338	674	1191
605	398	640	1931	675	1134
606	853	641	866	676	1544
607	853	642	700	677	818
608	737	643	1230	678	472
609	1049	644	482	679	760
610	818	645	1098	680	881
611	1057	646	470	681	584

682	558	717	299	752	1146
683	972	718	683	753	1862
684	594	719	642	754	893
685	968	720	723	755	-101
686	548	721	960	756	426
687	577	722	1023	757	598
688	436	723	1059	758	946
689	564	724	1386	759	1244
690	728	725	3031	760	605
691	1721	726	1259	761	1058
692	1835	727	2346	762	892
693	723	728	1573	763	1085
694	728	729	442	764	1378
695	2046	730	1356	765	534
696	621	731	1043	766	1530
697	287	732	1148	767	1599
698	292	733	788	768	848
699	930	734	916	769	1644
700	1778	735	395	770	966
701	490	736	1767	771	938
702	911	737	660	772	1002
703	416	738	1164	773	891
704	459	739	1797	774	466
705	683	740	1440	775	883
706	711	741	1132	776	1070
707	1100	742	844	777	1030
708	1423	743	1172	778	950
709	871	744	900	779	232
710	697	745	1178	780	802
711	481	746	966	781	1109
712	872	747	474	782	787
713	469	748	597	783	1806
714	665	749	585	784	361
715	1032	750	1110	785	1951
716	444	751	1023	786	1722

787	459	822	1724	857	442
788	2739	823	474	858	326
789	398	824	253	859	521
790	1256	825	476	860	1582
791	865	826	976	861	697
792	270	827	754	862	691
793	926	828	617	863	2734
794	1104	829	1002	864	1495
795	645	830	538	865	398
796	1269	831	1041	866	1605
797	716	832	1156	867	659
798	1087	833	805	868	1483
799	1165	834	1176	869	818
800	638	835	2077	870	458
801	700	836	1026	871	864
802	1378	837	1759	872	428
803	772	838	945	873	534
804	1992	839	637	874	1771
805	396	840	1399	875	584
806	352	841	1180	876	813
807	873	842	1291	877	419
808	1156	843	588	878	808
809	224	844	2560	879	824
810	442	845	1220	880	1174
811	645	846	1327	881	453
812	916	847	413	882	594
813	721	848	1318	883	1339
814	503	849	240	884	816
815	763	850	834	885	1021
816	769	851	915	886	2155
817	2191	852	768	887	1292
818	1234	853	799	888	103
819	1612	854	1061	889	1730
820	111	855	669	890	1394
821	991	856	940	891	1740

892	437	927	1577	962	1075
893	1109	928	328	963	1151
894	727	929	459	964	1379
895	768	930	584	965	1206
896	1134	931	1091	966	1769
897	422	932	1188	967	1502
898	756	933	1297	968	1689
899	750	934	290	969	656
900	548	935	2149	970	801
901	1174	936	496	971	1204
902	803	937	903	972	1019
903	1491	938	1138	973	726
904	966	939	911	974	2039
905	2353	940	1744	975	698
906	877	941	281	976	513
907	685	942	757	977	1044
908	661	943	977	978	620
909	1575	944	1311	979	1203
910	506	945	1105	980	943
911	913	946	687	981	593
912	1114	947	925	982	512
913	739	948	884	983	635
914	1349	949	1209	984	1476
915	575	950	389	985	355
916	1514	951	354	986	682
917	715	952	662	987	807
918	551	953	811	988	868
919	1289	954	1212	989	798
920	1466	955	1351	990	309
921	616	956	366	991	570
922	1225	957	1981	992	1857
923	1075	958	426	993	1460
924	839	959	894	994	789
925	814	960	506	995	1018
926	1310	961	988	996	1545

997	999	1032	1447	1067	876
998	1909	1033	695	1068	1060
999	1057	1034	923	1069	1147
1000	295	1035	1028	1070	2155
1001	1231	1036	1075	1071	489
1002	1628	1037	834	1072	517
1003	780	1038	780	1073	707
1004	1477	1039	1118	1074	1067
1005	945	1040	1982	1075	1887
1006	762	1041	546	1076	870
1007	843	1042	1777	1077	1418
1008	1291	1043	792	1078	527
1009	992	1044	651	1079	347
1010	1035	1045	243	1080	895
1011	680	1046	1349	1081	2105
1012	975	1047	562	1082	600
1013	1102	1048	144	1083	1094
1014	617	1049	1204	1084	610
1015	766	1050	630	1085	932
1016	1449	1051	914	1086	260
1017	512	1052	574	1087	1912
1018	903	1053	2149	1088	220
1019	605	1054	553	1089	406
1020	818	1055	812	1090	385
1021	1266	1056	950	1091	1156
1022	1426	1057	696	1092	721
1023	689	1058	1261	1093	317
1024	1830	1059	1061	1094	552
1025	742	1060	999	1095	1088
1026	768	1061	668	1096	1182
1027	720	1062	718	1097	877
1028	498	1063	463	1098	421
1029	1129	1064	1399	1099	1038
1030	689	1065	1282	1100	1943
1031	1813	1066	1752	1101	1154

1102	926	1137	1101	1172	1377
1103	1067	1138	1152	1173	1202
1104	880	1139	565	1174	2056
1105	945	1140	1302	1175	542
1106	1103	1141	1245	1176	1375
1107	950	1142	416	1177	543
1108	1452	1143	804	1178	2342
1109	628	1144	610	1179	291
1110	495	1145	1286	1180	675
1111	869	1146	582	1181	851
1112	1291	1147	779	1182	567
1113	1013	1148	1106	1183	1620
1114	798	1149	340	1184	1260
1115	1539	1150	1996	1185	528
1116	1172	1151	457	1186	1432
1117	989	1152	775	1187	1532
1118	1098	1153	1297	1188	879
1119	1378	1154	405	1189	1075
1120	1274	1155	1038	1190	1113
1121	1478	1156	1303	1191	659
1122	1455	1157	636	1192	1100
1123	533	1158	515	1193	1020
1124	171	1159	1090	1194	1082
1125	764	1160	782	1195	923
1126	895	1161	710	1196	1781
1127	1134	1162	1144	1197	436
1128	1998	1163	471	1198	547
1129	519	1164	719	1199	691
1130	660	1165	446	1200	1249
1131	1052	1166	937	1201	584
1132	846	1167	1470	1202	561
1133	1400	1168	1488	1203	852
1134	2904	1169	298	1204	666
1135	632	1170	1567	1205	798
1136	331	1171	1288	1206	1052

1207	211	1242	613	1277	1509
1208	834	1243	689	1278	670
1209	1019	1244	1472	1279	502
1210	1141	1245	1394	1280	940
1211	518	1246	555	1281	972
1212	1240	1247	732	1282	652
1213	1253	1248	564	1283	771
1214	731	1249	1683	1284	504
1215	414	1250	620	1285	789
1216	720	1251	492	1286	1345
1217	541	1252	882	1287	720
1218	1274	1253	1248	1288	709
1219	1437	1254	671	1289	756
1220	1286	1255	1093	1290	2055
1221	938	1256	1180	1291	1567
1222	1178	1257	418	1292	1202
1223	164	1258	854	1293	1135
1224	1938	1259	678	1294	462
1225	1414	1260	757	1295	2181
1226	1441	1261	1245	1296	455
1227	221	1262	613	1297	658
1228	1144	1263	510	1298	1397
1229	728	1264	776	1299	1398
1230	1418	1265	1332	1300	920
1231	521	1266	806	1301	1346
1232	1245	1267	802	1302	1034
1233	931	1268	445	1303	470
1234	986	1269	960	1304	625
1235	1354	1270	730	1305	511
1236	721	1271	581	1306	1913
1237	1171	1272	1021	1307	1257
1238	1038	1273	1678	1308	1444
1239	1670	1274	1289	1309	1457
1240	1396	1275	1153	1310	1363
1241	2100	1276	803	1311	232

1312	548	1347	440	1382	443
1313	1038	1348	565	1383	1037
1314	1218	1349	830	1384	933
1315	419	1350	1131	1385	401
1316	853	1351	762	1386	1090
1317	1135	1352	683	1387	2420
1318	563	1353	1186	1388	755
1319	1286	1354	576	1389	358
1320	1284	1355	1299	1390	1019
1321	1215	1356	502	1391	1147
1322	697	1357	833	1392	693
1323	909	1358	1199	1393	1160
1324	463	1359	449	1394	1698
1325	1025	1360	803	1395	168
1326	562	1361	914	1396	1122
1327	1546	1362	1136	1397	1363
1328	2066	1363	1850	1398	929
1329	902	1364	526	1399	1120
1330	915	1365	1192	1400	1634
1331	1024	1366	1129	1401	513
1332	1141	1367	1300	1402	381
1333	854	1368	1505	1403	1426
1334	1002	1369	841	1404	1103
1335	762	1370	1246	1405	998
1336	440	1371	2278	1406	1529
1337	654	1372	277	1407	325
1338	805	1373	612	1408	1517
1339	964	1374	726	1409	553
1340	1158	1375	978	1410	816
1341	1440	1376	1005	1411	979
1342	444	1377	945	1412	168
1343	1765	1378	886	1413	1178
1344	1132	1379	546	1414	912
1345	1656	1380	1025	1415	873
1346	1336	1381	1182	1416	1115

1417	1432	1452	1165	1487	1114
1418	1693	1453	613	1488	1143
1419	970	1454	345	1489	560
1420	835	1455	507	1490	711
1421	392	1456	895	1491	494
1422	1464	1457	1850	1492	946
1423	976	1458	1120	1493	1988
1424	969	1459	904	1494	774
1425	1283	1460	1051	1495	1250
1426	580	1461	921	1496	795
1427	490	1462	1721	1497	1428
1428	1564	1463	637	1498	1543
1429	2022	1464	809	1499	794
1430	557	1465	672	1500	676
1431	311	1466	1221	1501	690
1432	763	1467	1860	1502	856
1433	548	1468	1052	1503	1144
1434	932	1469	688	1504	1585
1435	1084	1470	1142	1505	688
1436	780	1471	576	1506	666
1437	1116	1472	732	1507	1272
1438	779	1473	726	1508	1640
1439	1646	1474	615	1509	378
1440	342	1475	616	1510	826
1441	1492	1476	1553	1511	1264
1442	513	1477	1678	1512	1331
1443	1085	1478	757	1513	1228
1444	1082	1479	1021	1514	628
1445	461	1480	1335	1515	684
1446	1410	1481	1113	1516	1140
1447	485	1482	890	1517	1154
1448	1175	1483	823	1518	285
1449	856	1484	888	1519	1147
1450	1270	1485	2267	1520	1254
1451	411	1486	447	1521	528

1522	644	1557	193	1592	1008
1523	470	1558	1462	1593	590
1524	1075	1559	1040	1594	1011
1525	1102	1560	772	1595	618
1526	1121	1561	1329	1596	1252
1527	764	1562	1183	1597	452
1528	563	1563	794	1598	600
1529	2163	1564	761	1599	655
1530	1137	1565	1223	1600	2007
1531	1009	1566	491	1601	914
1532	1783	1567	821	1602	1469
1533	656	1568	1356	1603	1748
1534	1001	1569	489	1604	581
1535	726	1570	708	1605	1622
1536	763	1571	921	1606	1787
1537	1077	1572	1216	1607	624
1538	816	1573	857	1608	750
1539	972	1574	492	1609	1346
1540	1005	1575	760	1610	444
1541	1655	1576	1120	1611	635
1542	458	1577	1224	1612	433
1543	1061	1578	1204	1613	2246
1544	616	1579	1871	1614	521
1545	1132	1580	1362	1615	1694
1546	514	1581	691	1616	890
1547	888	1582	1542	1617	1199
1548	929	1583	816	1618	963
1549	699	1584	1273	1619	653
1550	981	1585	807	1620	583
1551	1019	1586	980	1621	480
1552	514	1587	299	1622	597
1553	1845	1588	821	1623	1017
1554	1540	1589	1018	1624	1251
1555	859	1590	1324	1625	939
1556	995	1591	1065	1626	1391

1627	1164	1662	1463	1697	1268
1628	883	1663	620	1698	1276
1629	916	1664	524	1699	1254
1630	821	1665	1767	1700	512
1631	911	1666	478	1701	1006
1632	553	1667	633	1702	1018
1633	524	1668	807	1703	826
1634	1043	1669	894	1704	732
1635	2063	1670	470	1705	1589
1636	1412	1671	1409	1706	1009
1637	637	1672	958	1707	852
1638	385	1673	1025	1708	391
1639	1064	1674	838	1709	651
1640	840	1675	774	1710	1249
1641	807	1676	578	1711	809
1642	961	1677	1014	1712	1283
1643	344	1678	1465	1713	1251
1644	865	1679	973	1714	302
1645	752	1680	1698	1715	454
1646	1426	1681	1103	1716	1682
1647	1159	1682	1065	1717	1379
1648	1038	1683	1445	1718	600
1649	2057	1684	1170	1719	1328
1650	1520	1685	1165	1720	1049
1651	1383	1686	929	1721	2131
1652	256	1687	830	1722	348
1653	1467	1688	961	1723	2292
1654	674	1689	405	1724	1397
1655	1800	1690	555	1725	792
1656	716	1691	863	1726	1016
1657	920	1692	1254	1727	736
1658	935	1693	406	1728	243
1659	274	1694	1072	1729	1659
1660	463	1695	1272	1730	486
1661	1273	1696	824	1731	1050

1732	740	1767	732	1802	537
1733	492	1768	1297	1803	1563
1734	889	1769	1026	1804	1495
1735	1008	1770	976	1805	479
1736	2493	1771	1311	1806	844
1737	756	1772	819	1807	887
1738	119	1773	1002	1808	1016
1739	485	1774	764	1809	890
1740	1340	1775	1061	1810	1031
1741	1067	1776	1121	1811	840
1742	1199	1777	902	1812	1145
1743	797	1778	291	1813	715
1744	960	1779	735	1814	1208
1745	1474	1780	1548	1815	704
1746	571	1781	421	1816	475
1747	853	1782	721	1817	1408
1748	545	1783	1092	1818	504
1749	885	1784	544	1819	710
1750	961	1785	1202	1820	669
1751	1101	1786	1651	1821	2008
1752	830	1787	843	1822	994
1753	1226	1788	866	1823	827
1754	1011	1789	798	1824	710
1755	960	1790	1314	1825	1825
1756	918	1791	895	1826	358
1757	1506	1792	1118	1827	812
1758	641	1793	1512	1828	625
1759	563	1794	399	1829	1670
1760	628	1795	1704	1830	549
1761	1987	1796	1899	1831	585
1762	756	1797	414	1832	1132
1763	723	1798	1876	1833	1574
1764	744	1799	435	1834	1076
1765	553	1800	1608	1835	702
1766	1446	1801	730	1836	1852

1837	323	1872	913	1907	1527
1838	1215	1873	1245	1908	815
1839	660	1874	945	1909	1510
1840	1247	1875	1466	1910	954
1841	944	1876	661	1911	390
1842	789	1877	792	1912	1266
1843	1047	1878	758	1913	922
1844	734	1879	926	1914	424
1845	501	1880	477	1915	1185
1846	1742	1881	773	1916	884
1847	1195	1882	891	1917	1301
1848	755	1883	1481	1918	930
1849	107	1884	1388	1919	970
1850	1112	1885	1204	1920	824
1851	776	1886	1166	1921	1316
1852	809	1887	572	1922	1510
1853	895	1888	1695	1923	869
1854	1791	1889	1094	1924	1408
1855	1496	1890	329	1925	535
1856	352	1891	1357	1926	475
1857	912	1892	774	1927	498
1858	1174	1893	942	1928	1395
1859	950	1894	363	1929	1573
1860	1341	1895	1450	1930	877
1861	746	1896	992	1931	691
1862	1520	1897	643	1932	782
1863	855	1898	817	1933	599
1864	537	1899	1484	1934	977
1865	786	1900	1173	1935	610
1866	1640	1901	1444	1936	1034
1867	949	1902	339	1937	782
1868	1335	1903	844	1938	1194
1869	579	1904	700	1939	970
1870	1435	1905	1370	1940	869
1871	800	1906	927	1941	719

1942	837	1977	741
1943	834	1978	1288
1944	956	1979	604
1945	735	1980	678
1946	1929		
1947	784		
1948	1109		
1949	1468		
1950	806		
1951	726		
1952	922		
1953	830		
1954	681		
1955	402		
1956	1263		
1957	1584		
1958	1340		
1959	1149		
1960	920		
1961	1273		
1962	1249		
1963	923		
1964	932		
1965	1504		
1966	668		
1967	880		
1968	879		
1969	1339		
1970	585		
1971	796		
1972	1291		
1973	1293		
1974	1040		
1975	928		
1976	1235		

Grandfather Mountain Residuals

Year	Grandfather Mountain Residual				
1563	948	1598	802	1633	1098
1564	296	1599	843	1634	984
1565	1308	1600	1108	1635	712
1566	747	1601	864	1636	980
1567	1273	1602	875	1637	1150
1568	1286	1603	1314	1638	640
1569	649	1604	1297	1639	1422
1570	1358	1605	1250	1640	892
1571	594	1606	838	1641	1283
1572	1226	1607	1141	1642	887
1573	1608	1608	496	1643	723
1574	519	1609	859	1644	1056
1575	810	1610	1083	1645	958
1576	1022	1611	1028	1646	1253
1577	855	1612	824	1647	973
1578	981	1613	769	1648	755
1579	682	1614	1074	1649	775
1580	652	1615	750	1650	1048
1581	871	1616	851	1651	908
1582	982	1617	978	1652	1008
1583	903	1618	945	1653	1063
1584	796	1619	1169	1654	987
1585	946	1620	1252	1655	686
1586	767	1621	988	1656	1307
1587	831	1622	874	1657	1255
1588	937	1623	1177	1658	1645
1589	1012	1624	1147	1659	975
1590	1500	1625	1063	1660	976
1591	1263	1626	1172	1661	914
1592	1444	1627	1003	1662	1157
1593	1539	1628	1200	1663	678
1594	435	1629	941	1664	991
1595	717	1630	1155	1665	808
1596	878	1631	1402	1666	1222
1597	894	1632	938	1667	931

1668	1010	1703	1163	1738	942
1669	886	1704	940	1739	1079
1670	1185	1705	1219	1740	935
1671	785	1706	1159	1741	866
1672	1104	1707	775	1742	1086
1673	1131	1708	773	1743	795
1674	845	1709	928	1744	977
1675	948	1710	1022	1745	1089
1676	1103	1711	1058	1746	881
1677	987	1712	934	1747	953
1678	808	1713	984	1748	749
1679	968	1714	818	1749	1134
1680	1095	1715	836	1750	987
1681	1074	1716	1133	1751	995
1682	1054	1717	1137	1752	1071
1683	1214	1718	1097	1753	966
1684	874	1719	1101	1754	1035
1685	699	1720	848	1755	1070
1686	1205	1721	913	1756	1039
1687	824	1722	1206	1757	882
1688	878	1723	999	1758	947
1689	1194	1724	869	1759	1151
1690	829	1725	1029	1760	773
1691	915	1726	1012	1761	878
1692	789	1727	1156	1762	968
1693	967	1728	1029	1763	1095
1694	931	1729	1206	1764	1050
1695	922	1730	866	1765	966
1696	927	1731	884	1766	1104
1697	1107	1732	923	1767	1045
1698	903	1733	1202	1768	1261
1699	929	1734	1054	1769	844
1700	979	1735	970	1770	931
1701	957	1736	1021	1771	900
1702	1063	1737	1049	1772	985

1773	936	1808	1037	1843	1162
1774	868	1809	892	1844	951
1775	780	1810	1120	1845	1042
1776	1080	1811	1137	1846	846
1777	1349	1812	1000	1847	997
1778	1065	1813	971	1848	1118
1779	578	1814	1154	1849	956
1780	954	1815	1176	1850	1087
1781	1002	1816	1126	1851	1221
1782	1071	1817	1051	1852	1034
1783	1031	1818	799	1853	934
1784	820	1819	944	1854	884
1785	979	1820	907	1855	956
1786	1099	1821	833	1856	893
1787	861	1822	1015	1857	1092
1788	921	1823	1348	1858	894
1789	1039	1824	1105	1859	961
1790	1031	1825	1091	1860	831
1791	1045	1826	818	1861	945
1792	1124	1827	1200	1862	1053
1793	932	1828	971	1863	1129
1794	960	1829	994	1864	902
1795	858	1830	987	1865	1054
1796	1213	1831	952	1866	933
1797	706	1832	953	1867	1168
1798	1064	1833	963	1868	920
1799	825	1834	909	1869	920
1800	1104	1835	973	1870	951
1801	1117	1836	960	1871	972
1802	1054	1837	921	1872	1101
1803	918	1838	1060	1873	849
1804	1077	1839	908	1874	987
1805	904	1840	962	1875	1149
1806	977	1841	878	1876	960
1807	841	1842	1032	1877	973

1878	1125	1913	1045	1948	951
1879	936	1914	813	1949	1043
1880	979	1915	750	1950	773
1881	1090	1916	1024	1951	958
1882	1050	1917	1072	1952	764
1883	969	1918	803	1953	867
1884	948	1919	994	1954	957
1885	990	1920	1172	1955	1068
1886	976	1921	830	1956	995
1887	1174	1922	1076	1957	1047
1888	1072	1923	1078	1958	1014
1889	1155	1924	936	1959	1140
1890	905	1925	816	1960	1067
1891	781	1926	795	1961	1047
1892	1125	1927	1024	1962	824
1893	1022	1928	1154	1963	1272
1894	960	1929	1281	1964	927
1895	928	1930	1063	1965	940
1896	780	1931	1254	1966	1030
1897	1280	1932	708	1967	957
1898	955	1933	983	1968	1019
1899	996	1934	904	1969	927
1900	1047	1935	974	1970	1040
1901	820	1936	971	1971	1031
1902	969	1937	899	1972	1079
1903	1093	1938	1006	1973	1026
1904	1031	1939	1038	1974	909
1905	1079	1940	948	1975	944
1906	1155	1941	979	1976	1254
1907	928	1942	976	1977	990
1908	1235	1943	847	1978	839
1909	1015	1944	1045	1979	978
1910	1178	1945	911	1980	1164
1911	687	1946	890		
1912	909	1947	1164		

Scotts Gap Residuals

Year	Scotts Gap Residual				
1686	1578	1721	1031	1756	919
1687	616	1722	972	1757	1061
1688	509	1723	863	1758	958
1689	636	1724	1588	1759	968
1690	930	1725	1054	1760	786
1691	989	1726	1075	1761	1112
1692	685	1727	1502	1762	742
1693	1389	1728	762	1763	1120
1694	1028	1729	908	1764	851
1695	799	1730	1443	1765	923
1696	740	1731	559	1766	683
1697	826	1732	536	1767	931
1698	663	1733	1088	1768	1121
1699	998	1734	1174	1769	800
1700	1226	1735	706	1770	886
1701	859	1736	868	1771	1134
1702	532	1737	1181	1772	801
1703	620	1738	1108	1773	946
1704	1129	1739	1559	1774	298
1705	868	1740	527	1775	948
1706	837	1741	810	1776	946
1707	1330	1742	1233	1777	924
1708	518	1743	680	1778	757
1709	747	1744	1234	1779	454
1710	1439	1745	1153	1780	1245
1711	1100	1746	1011	1781	1110
1712	837	1747	1111	1782	1419
1713	905	1748	1156	1783	1419
1714	1249	1749	975	1784	337
1715	954	1750	1218	1785	1380
1716	940	1751	813	1786	1033
1717	1346	1752	592	1787	1311
1718	446	1753	924	1788	954
1719	1328	1754	1312	1789	979
1720	907	1755	829	1790	621

1791	968	1826	845	1861	551
1792	947	1827	1094	1862	1119
1793	998	1828	859	1863	1141
1794	970	1829	874	1864	819
1795	881	1830	1676	1865	866
1796	1428	1831	1147	1866	1124
1797	987	1832	1156	1867	1029
1798	1039	1833	802	1868	898
1799	1024	1834	850	1869	1218
1800	1175	1835	835	1870	821
1801	923	1836	842	1871	916
1802	1414	1837	860	1872	712
1803	1239	1838	729	1873	854
1804	1174	1839	664	1874	450
1805	1508	1840	1010	1875	1387
1806	1375	1841	1043	1876	1092
1807	801	1842	983	1877	677
1808	665	1843	1186	1878	1086
1809	955	1844	933	1879	449
1810	1112	1845	1177	1880	834
1811	612	1846	1007	1881	1073
1812	663	1847	1120	1882	1024
1813	802	1848	1281	1883	1096
1814	1120	1849	1051	1884	955
1815	845	1850	706	1885	957
1816	1202	1851	978	1886	969
1817	996	1852	1243	1887	1131
1818	974	1853	1240	1888	765
1819	451	1854	183	1889	1313
1820	1182	1855	981	1890	1255
1821	750	1856	1067	1891	921
1822	866	1857	1075	1892	1413
1823	1169	1858	1191	1893	1102
1824	1288	1859	871	1894	944
1825	1015	1860	1232	1895	744

1896	1017	1931	917	1966	910
1897	1187	1932	895	1967	920
1898	521	1933	626	1968	1288
1899	930	1934	914	1969	910
1900	1108	1935	1096	1970	779
1901	953	1936	397	1971	1150
1902	931	1937	1061	1972	1394
1903	1209	1938	1093	1973	1273
1904	1038	1939	1051	1974	1309
1905	952	1940	912	1975	1074
1906	1183	1941	910	1976	977
1907	1007	1942	1102	1977	783
1908	882	1943	1086	1978	1041
1909	1298	1944	421	1979	896
1910	1171	1945	1115	1980	943
1911	609	1946	1133		
1912	1451	1947	894		
1913	715	1948	826		
1914	552	1949	1197		
1915	1307	1950	1114		
1916	1704	1951	1064		
1917	1089	1952	855		
1918	955	1953	772		
1919	788	1954	856		
1920	1014	1955	998		
1921	685	1956	845		
1922	1613	1957	998		
1923	1244	1958	1073		
1924	915	1959	858		
1925	381	1960	1142		
1926	912	1961	1088		
1927	891	1962	979		
1928	1401	1963	880		
1929	1074	1964	838		
1930	594	1965	882		

Instrumental Based

Valley River

Monthly mean in cfs (Calculation Period: 1904-07-01 -> 2009-09-30)												
YEAR	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1919	441.4	355.4	416.9	247.3	230.9	162.5	142.8	90.5	57.3	135.5	104.1	307.5
1920	486.5	354.1	557.2	831.9	287.6	163.4	226.2	563	321.7	119.2	139	470
1921	373.5	634.6	256	331.3	302.8	146.3	160.5	228.4	119.8	94.1	350.6	405.7
1922	785.7	523.1	806.4	509.9	442.3	275.4	183.5	92.1	82.3	69.4	67.3	466.6
1923	435.4	687.7	591	417.3	395.6	312.3	192.1	149.7	84	56.2	71	174.6
1924	451.4	281	353	357.1	333.8	189.3	161	82.3	109	63.4	51.6	207.2
1925	497	236.3	226.2	166.2	156	90.9	51.3	24.6	21.3	67.8	155.7	139.6
1926	338	296.4	313.8	270.9	141.7	116.4	72.8	182.7	74	67.8	208.9	654.5
1927	266.4	471.4	540.7	288.2	175.6	294.4	159.4	229.7	101.9	82.1	120.9	542.8
1928	308.1	295.9	512.1	440.6	412.8	444.9	369.5	241.7	434.3	156.2	165.1	157.6
1929	481.6	447	740.8	493.5	755	306	176.5	105.4	228.2	137.6	684.6	263.6
1930	291.9	287.8	462.1	243	302.7	122.3	91	37.5	56.6	46.3	80.5	121.8
1931	160.1	202.3	170.6	419.1	180.2	82.5	78.5	59.2	44.5	33.3	44.6	439.1
1932	418.4	711.4	310.1	312.3	284	173.9	317.7	98.5	64.9	139.3	270.7	1,045
1933	466.7	716	375.4	278.8	378.9	117.7	92.1	81.7	61.1	43.2	38.6	57.4
1934	198.3	136.6	554.4	228.7	153.5	182.5	118.7	196.9	97.6	111.7	96.8	143.2
1935	248.7	290.6	480.3	493.8	226.5	109.8	81.3	70	39	37.5	102.1	76.7
1936	753.6	669.4	524	834.8	157.7	78.9	59.1	54	48	70.7	72.9	221.5
1937	704.4	483.6	262.3	284.7	250.3	112.8	88.1	112.1	72.9	87.7	69.5	125.4
1938	222.9	174.5	382.4	556.5	272.1	322	415.2	391.8	132.4	71.2	95.2	106.5
1939	267.4	720.6	529.1	349.5	194.7	142.7	117.1	79	45.6	36.3	39.4	63.7
1940	93	221.1	287.4	325.8	165	174.2	108.4	89.1	52.2	44.2	74	88.4
1941	157.6	92.7	218.7	176	88.9	61.3	215.3	99.9	61.8	43.7	80.6	131.1
1942	181.4	373.1	458.5	168.4	214.6	181.3	197.5	220.7	134.4	119.5	111	624.1
1943	488.9	477.4	465	309.9	223	127.1	301.5	147.1	93.8	66	74.1	100.7
1944	189.2	661.9	645	458.2	232.6	115.1	73.1	69.9	77	73.5	82.5	237.1
1945	268.2	489	313.5	301.4	300.2	126.8	108.8	83.3	72.7	83.8	145.2	276.6
1946	579	696.4	396.5	333.1	360.8	162.1	129.4	64.6	61.7	64.7	83.6	144
1947	882.8	271.4	308.3	257.3	190.6	129.7	104.7	76.3	48.1	45.6	79.3	115.7
1948	133.1	529.9	427.6	444.6	154.3	105.5	121.6	144.2	53.9	42.7	400.7	460.3
1949	658.9	588.5	361.3	404.6	279	207.3	442.9	177.3	182.5	232.4	237.4	339.8
1950	593.6	556.5	684.5	300.3	225.8	285.4	320.3	151.4	132.1	81.7	87.7	149.8
1951	194	266	578.4	428.2	180.4	196.7	151	78.2	74.7	56.9	142.8	451.3
1952	499.8	304.8	556.8	217.6	157.5	180.9	70.7	142	86.6	52.5	80.9	174.5
1953	395.3	615	334.8	238.8	332	104.7	79.5	46.6	52.9	36.5	46.1	162.9
1954	732.7	205.7	470.2	308.7	192.5	180.5	69.5	59.8	29.5	25.2	44.4	140.7
1955	121.4	447.6	379.4	405.4	185.6	119.2	159.6	143.7	60.6	97.3	127.8	193.7

1956	133	732.5	530	428.7	262.5	124	129.9	60.5	48.9	49.5	55.2	294.6
1957	474.8	1,022	343.7	492	184	263.1	130.9	83.5	69.9	116.9	374	452.1
1958	270.2	510.6	330.7	380.9	428.1	128.7	234.8	111.5	67.7	71	79.3	97.7
1959	270.7	306.5	269.7	408	205.5	257.7	124.5	73.9	69.8	118.4	281.8	305.9
1960	344.4	406.4	430.3	324.3	153.5	116.6	81.1	126.2	79.6	89.4	105.2	168.5
1961	211.9	636.5	527.9	351.4	227.6	284.7	278.8	131.2	89.7	67.1	85.2	679.4
1962	663.4	687.4	553.2	576.3	195.9	147.7	103.3	82.7	88.5	82.9	202.4	161.5
1963	299	381.6	948.2	300	285.6	198	256.8	142.3	88.4	60.5	93.2	171.8
1964	455.9	402.2	807.2	668.4	268.6	118	129	214.9	84.1	223.5	218.5	322.9
1965	377.8	487.9	649.7	430.7	217.3	160.2	107.9	82.4	94.5	109.9	97.2	81.3
1966	147.2	559.5	387.3	302.7	334.5	133.3	113.9	127.3	89.2	204.6	275.7	251.4
1967	355.1	451.9	334.2	205.9	405	236.6	360.7	276.7	169.2	103.9	247.1	580
1968	561.1	219.7	269.6	321.7	243.1	132	108.9	119.8	68.9	79	112	224.1
1969	256.6	688.4	288.1	355.2	178.2	162.1	101.6	116.1	89.8	67.4	114.1	169.4
1970	227.5	266.5	233.1	306.7	157.9	214	104	95.6	60.4	80.5	109.9	188.9
1971	463	595.6	476.5	324.1	199	148.8	333.2	358.4	106	78.5	83.1	232.3
1972	636.3	370.4	395.3	430	262.8	145	223.5	203.8	105.7	214.4	270.6	646.8
1973	337.2	437.6	518.6	453.3	474.7	296.6	214.4	176.4	114.5	84.1	158.8	391.7
1974	936.4	771.1	342.7	609.9	298.6	256.6	147.7	130.2	90.8	71.3	125	304.7
1975	526.2	837	869.7	406.1	195.9	132.4	85.5	93.5	69.1	96.9	147.2	212.6
1976	462.4	268.4	459.8	321.4	451.5	298.9	281.1	108.4	80.3	146.7	150.8	328.5
1977	320.3	211.4	452.3	649.2	203.9	156.2	91.5	128	168.6	209	333.1	351.5
1978	542.1	251.4	384	209.9	233.1	162	88.8	121.4	53.8	38.3	57.2	228.4
1979	633.7	418.6	660.2	633.5	238.6	236.8	322.4	217.8	208.7	163.1	373.9	221.5
1980	442.8	336.4	1,071	552.3	308.9	202.7	107.7	63.2	67.4	67.5	90	92.5
1981	69.9	316.5	190	272.9	201.4	271.2	82.1	54.5	60.5	53.8	78.3	228.6
1982	550.1	681.3	430.5	303.9	186.3	133.3	108.8	193.5	286.8	152.3	231.7	548.9
1983	243	327.2	232.3	472.9	440.8	204.7	102.2	69.1	64.4	60.9	138.5	420.3
1984	256.9	362.1	420.1	400.4	699.5	147.1	231.9	157.3	72.6	71.4	101.6	168.1
1985	169.2	481	193.2	166.1	111.5	89.6	101.5	184.1	73.6	72.2	129.3	178.3
1986	118.7	233.6	267.4	135.3	95.2	65.7	52	55.4	49	105.5	309.1	323.7
1987	303.6	407.4	365.8	290.3	191.7	234.6	169.3	54.7	53.9	49.1	55.1	91.3
1988	285.6	186.6	154.9	220.1	92.9	44.8	42.4	48.6	63.1	63.3	158.8	131.5
1989	404.1	518.6	588.9	401	402.8	607.2	367.2	153.9	261.8	338.1	411.9	355.6
1990	671.8	1,008	745	263.7	270	157	126.4	86.7	68.6	139.8	100.5	460.4
1991	369.2	560.6	506.7	428.6	291.5	185	139	298.9	177.1	85.9	157.7	440.8
1992	356.2	400.7	445.7	324	204.7	168.4	133	139.3	142.7	123.4	340.1	651.2
1993	518.5	291.5	511.5	336.7	174.7	111.2	63.2	67.6	72.5	50.3	160.3	290.3
1994	452.9	494.2	872	736.5	238.4	394.5	364.3	319	181.1	154.6	168.8	259.3
1995	469.9	853.2	494.2	204.2	207.4	153.2	76.2	96.6	76.2	174.6	343.2	216.6
1996	625	532.3	565.1	421.1	344	226.9	119.8	152.9	149.6	143.7	245.2	463
1997	460	439.2	698.3	399.7	375	381.6	181.7	86.3	99.4	121.5	144.2	196.3
1998	525.2	368	365.2	547.8	317.5	336.7	120.8	69.9	45.8	43.7	71.7	155.8

1999	367.5	432	367.5	210.7	366.4	288.3	288.4	82.7	50.4	64.2	81.7	95.9
2000	224.4	219	223.5	401.5	174	130.4	78.7	75.9	65.3	36.1	100.5	109.9
2001	218	327.9	267.4	182.2	128.9	178.7	129.8	149.7	126.5	71.4	70.9	164.5
2002	383.6	230.1	289.6	280.2	314.6	124.7	121	76.9	256.9	195.8	453.1	461
2003	289.1	566.2	389.5	326.6	721.2	249.2	409.8	202.5	142.5	96.4	202.5	296.7
2004	283.3	362.2	303.4	228.9	184.9	132.4	159.4	107.2	205.9	88.6	383.8	553.4
2005	237.1	367.3	391.7	381.5	242.8	222.3	230.6	173	95.1	64.8	85.6	216.6
2006	413.2	275.7	177.7	201.4	144	111.8	68.5	48.9	79	133.1	198.7	146.1
2007	320.6	152.4	229.8	148.8	93.7	60.8	70.8	39.5	42.2	31.4	52.2	98.5
2008	140.9	244.2	374.5	234.3	187.1	83.2	57.8	50.8	31.2	33.9	45.6	326.2

Oconaluftee River

Monthly mean in cfs (Calculation Period: 1945-08-01 -> 2009-09-30)												
Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1948							284.9	389.9	190.8	139.4	771.5	824.1
1949	1,042	963.8	662.5	701	583.7	521.7	714.2	484.3	394.1	412.5	492.2	747
1950	1,068	1,086	1,014	516.8	431.4	506.8	457.1	282.8	291.3	192.1	214.7	448.4
1951	423	573.9	933.3	775.8	385.2	437.5	398.4	212	252.3	163.5	416.4	867.9
1952	941.6	552.7	992.2	464.8	312.2	274.8	168.6	172.3	148	100.4	203.5	298.9
1953	649.5	1,058	666.1	429.8	547.9	298.4	329	217.6	141.8	101.7	127.2	429.3
1954	1,161	425.2	805.4	633.3	369.1	270.2	202.5	199.5	121	94.5	145.5	410.7
1955	275.4	879.3	977.2	695.8	493.3	357	552.2	381.2	166.2	258.1	227.6	320.8
1956	233.4	1,166	947.6	940.6	504.8	311.4	460	202.7	203.1	173.4	207.9	593
1957	856.1	1,679	544.6	932.4	439.8	447.1	258.6	198.9	235.3	355.8	777.5	865
1958	414.3	659.1	628.9	737.5	775	314.8	517.9	290.3	184.2	172.5	189	244.1
1959	651.2	568.8	634.5	843.4	430.6	483	307.8	311.5	271.7	474.4	626.2	801.6
1960	676.4	744.3	679.4	895.1	346	291	261.4	535.4	260.8	252.1	234.7	319.1
1961	380.6	1,106	1,034	730.6	451.6	389.8	367.8	313.9	190.7	194.6	366.9	1,266
1962	976.9	1,253	1,136	935.6	343.2	338.4	358.7	323.9	236.4	203.6	382.9	307.9
1963	463.5	529	1,714	494.1	468.5	398.6	463.1	272.2	169.1	125.8	211	228.2
1964	743	504.1	1,611	1,265	603.9	281.6	340.9	438	244.3	507.8	425.1	617.8
1965	677.5	649.4	1,128	727.8	465.8	338.2	262.1	221.6	177.9	266	196.9	162.1
1966	210.8	1,044	610.8	412.9	487.7	216.4	294.2	486.8	309.7	521.7	686.3	606.5
1967	626.9	787.7	691.5	366	600.7	784.7	677.1	627.8	387.8	276.1	457.1	1,003
1968	833.9	405.9	612.5	625.1	413.6	411.8	283.3	295.8	175.5	244.5	319.8	475.2
1969	476.6	996.4	623.3	743.2	364.5	369	297.8	364	240.8	169.2	293	479.8
1970	434.8	455.4	504.1	742.1	400.5	538	257.1	253.6	178	239.9	287	413.1
1971	696.8	943.9	808.2	536.4	445.1	414.8	743.5	693.7	237.5	231.9	299.9	632.1
1972	1,057	658.4	773.9	742.4	571.1	344.1	363.3	304.8	270.4	591.2	614.3	1,249
1973	618.4	797.5	1,257	806.1	871.1	564.3	345.1	322.4	245.7	180.3	394.5	826.3
1974	1,428	1,070	697.7	1,124	816.8	493.8	374.7	402	275.1	225.5	382.4	558.4
1975	797	1,112	1,597	766.3	489.8	336.8	261.2	245.4	437.6	268.8	420.2	454.8
1976	908.6	665.4	753.8	583.3	758.9	503.9	350.1	197.1	187.2	450.2	307.2	516.3
1977	291.6	419	1,113	1,156	389	460.8	299	342.8	439.1	402.1	487.6	763.2
1978	977.4	392.4	902.9	462.2	692.9	458.5	260.6	455.1	181.6	132.5	200.1	629.6
1979	1,247	790.6	1,089	1,032	495.6	403.7	671.2	386.3	542.1	351.8	714	433
1980	760.7	460.6	1,386	890.4	555.1	336.1	223.3	161.9	174.3	212.8	294.9	232.7
1981	169.9	667.3	466.5	701	461.8	503.5	330.9	206.1	271.4	213.2	241.9	566.5
1982	1,202	1,183	790.9	512.6	461.8	440.5	333.1	351.1	343.8	305.1	568.3	932.8
1983	421.7	607.1	553.1	1,101	847.7	412.4	310.8	191.3	178.2	240.3	395	812.6
1984	485.1	808.2	935.6	821	1,202	523.3	902.2	475.7	200.6	183.2	279.9	335.9
1985	358.1	964.4	432.3	388.6	355.2	235.6	225.3	354	162.5	138.8	365.2	368.9

1986	187.3	440.9	531.3	277.1	239	189.9	188	173.4	199.2	248.5	535.5	595.2
1987	478.9	678.5	763.1	828.8	362	375.1	304.4	161.5	157.9	100.7	125	247
1988	591	422.7	329.8	514.4	314.7	175.1	206.9	220.9	249.2	176.7	405.3	307.8
1989	839.9	792.5	1,043	777	961.2	1,136	937.8	500.4	584.5	644.7	606.4	529.7
1990	1,001	1,700	1,397	476	613	359.4	349.7	215.5	199.6	410.7	222.3	824
1991	704.1	882	1,046	847.7	543.1	493.5	363.9	509.4	335.7	190.7	352.3	812.8
1992	516.9	619.1	736.8	478.8	504.4	535	274	415.7	383.3	298.9	684.3	998.8
1993	879.1	512.9	968.7	696.8	421.4	272.8	174.3	198.7	266.9	168.7	364.5	750.6
1994	1,050	1,245	1,456	1,315	462.3	661.5	701.7	733.2	380.4	288.3	265.1	407.5
1995	737.8	999.8	847.1	371.8	426	355.5	259.1	306.6	253.1	499	773.5	441.5
1996	1,239	1,025	839.7	672.8	689.1	618.8	384.9	494	388.1	299	543.3	986.9
1997	747.4	874.6	1,459	819	725.5	769.4	347.3	192	266	292.6	332.3	487.3
1998	1,180	802	866.5	1,234	662.8	512.7	261.4	176.2	123	116	172.9	435.1
1999	752.3	648.9	718	539.5	667.4	436.5	663.4	235.5	146.5	203.9	243.8	292.9
2000	417.3	611.7	500.5	791.7	539.6	359.9	315.9	300	219.6	160.9	278.9	323.3
2001	426.7	616.1	573.5	507.9	361.1	386.9	412.4	415.8	315.3	183.4	142.4	337.1
2002	646	398.8	577.2	523.2	567.4	258.8	238.4	151.9	283.3	292.3	613.2	722.7
2003	446.8	1,045	704.5	810.5	1,157	516.7	542.5	321.8	291.1	183.5	521.4	579.6
2004	553.4	629.8	637.5	556	433.2	433.8	402.7	322.1	967.7	327.4	689.5	959.7
2005	567.9	615.4	686.3	755.5	504.8	475	581.6	406.6	272.5	165.5	181.1	381.5
2006	913.7	573.3	443.7	573.9	501.7	329.7	354.1	264.8	392.5	440.2	546.6	399.3
2007	656.8	333.5	559.7	446.2	261.3	177.3	176.4	125.3	97.9	103.7	142.9	363.5
2008	420.8	680.7	827	464.2	382	195.6	198.5	181.7	102.1	93.5	137.8	727.3

Nantahala River

Monthly mean in cfs (Calculation Period: 1940-10-01 -> 2009-09-30)												
YEAR	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1940										86.4	120.8	149.2
1941	180.5	115.3	159.6	159.5	102.5	77.2	278.2	132.2	86.6	73.9	92.4	159.1
1942	176.7	265.5	346.5	173.1	200	154.8	128.2	166.5	137.5	113.1	109.1	355.9
1943	369.5	366.5	333	255.2	203.9	135.1	259	160.8	110.4	81.6	88	97.5
1944	163.5	376.4	432.6	338.8	191.2	110.2	81	80.7	75	69.8	88.4	169.9
1945	230.3	275.8	247.7	269	243.1	127.7	88.6	83	120.7	107.5	126.2	200.9
1946	431.6	443.2	384.7	253	314.1	162	151.7	80.3	75.3	98.2	113.2	125
1947	499.1	217.6	214.4	237.5	175.9	149.5	121.5	90.5	62.2	125.7	194	177.5
1948	166	418.7	357.8	299.1	139.3	93.5	136.3	206.3	95.8	66.1	355.5	360.2
1949	427.4	373.8	235.8	268.6	245	362.3	296.2	179	201.7	175.5	192.6	220.6
1950	318.6	367.4	388.7	212.1	151.7	188	191.6	144.8	374.4	151.9	127.2	201.4
1951	168.6	204	288.5	306.1	175	190.6	145.2	81.7	83.4	67.5	145.5	353.1
1952	339.1	299.3	484.5	229.3	155.3	123	70.4	73.8	65.8	45.6	79.7	154
1953	274	438.5	303.8	184.9	200.1	106.1	93.8	73.5	61.1	44.2	57.2	202.7
1954	502.2	240.7	341.5	297.8	180.6	150.5	98.4	83.9	46.8	42.2	56.6	129.5
1955	114.5	298.9	300	322.6	257.3	175.7	160.1	130.5	73.3	98.8	101.3	143
1956	96.5	377.2	360.2	321.3	221.7	118.9	172.5	87.5	71.6	67.6	74.4	231.9
1957	311.3	657.4	238.2	453.9	173.6	183.6	140.8	79.1	94.2	163.8	289.8	342.8
1958	219.1	306	212.6	263	265.9	107.7	156.8	102.9	63.2	64.7	67	77.2
1959	191.9	248.6	218.2	286.5	269.2	233.3	112.2	89.9	103	198.5	178.9	219.1
1960	260	316.7	263.7	307.3	142.4	112.2	89.6	150.6	103.8	143.2	118.2	129.7
1961	169.1	382.5	367.9	271.8	177	202.9	179.9	172.9	125.1	81.5	104.6	451.5
1962	391.2	347.5	321	367.3	147.5	130	82.9	63.5	54.9	71.8	137.2	116.7
1963	172.5	199.8	426.3	212.9	208.1	167.7	220.9	133	90.6	65	85.8	135.4
1964	302.4	267.2	554.2	487.3	228.1	102.3	83.7	112	121.6	414.5	183.9	254.7
1965	267.1	303.4	334.4	279.5	178.5	135.8	92.6	79.9	102.8	188.1	110.4	92.6
1966	109.5	508.9	298.5	224.9	283.2	147.7	86.7	85.1	96.1	157.3	244	228.8
1967	273.1	347.5	292.6	169	240.7	322.3	258	259.1	224.2	118.2	158.6	291
1968	343.8	154.8	230.5	260.7	170.9	137.5	108.4	104.8	86.8	86.6	125.6	212.1
1969	255.6	494.6	223.1	275.4	216	218.9	116.2	269.9	150.3	126.6	185.7	174.5
1970	193.8	222.4	215.6	220.8	150.7	313.2	127.2	103.3	74.9	122.2	155.7	150.5
1971	328.3	450.3	328.4	236.8	210.6	149	199.7	198.6	102.1	95.6	129.1	346.9
1972	455.5	250.6	273	250.7	211.6	164.4	179.6	170.6	90.8	123.2	229	370.6
1973	287.5	346.8	414.2	336.5	433.3	301.7	155.3	142	102.3	75.9	142.9	343.8
1974	568.5	481	247.4	425.4	303.8	266.9	131.5	180.5	93.9	76	131.5	214
1975	360	571	566.2	309.5	186.3	121.1	80.3	78.8	111.3	198	212.5	181.4
1976	376.3	267.2	315.8	285.6	491.4	271	159.9	96.2	81.6	190.7	146.4	263.1
1977	231.5	182	448.1	475.4	191.5	139.4	81.5	89.7	151.2	165.5	376.3	310.2

1978	399.8	206.1	258.3	159.2	187.3	124.6	79	154.9	65.2	48.4	71.8	187.8
1979	412	329.4	572.1	493	307.5	221.4	233	147.6	199.8	175.6	333.1	208.1
1980	259.5	207.7	551.3	390.2	254.4	166.9	90	66.5	71.4	75	105.4	107.9
1981	84.4	216.1	162.6	186.1	194.1	218.7	96.9	61.4	69.5	63	74.9	166.2
1982	341	413.4	229.1	187.7	165.7	122.9	124.7	121.9	141.6	125	184.9	452.7
1983	238.1	359.6	274.6	479.3	278.8	164.4	95.6	75.5	94.4	101.2	171.8	404.5
1984	217.1	335.5	333.8	320.9	395.3	134.8	176.6	157.9	75.5	82.3	125.4	189.6
1985	162.9	342.1	178.1	158.8	131	105.6	130.9	193.2	108.4	79.5	164.6	169.6
1986	110.5	162.2	187.8	118.5	96.8	67.1	59	49.5	41.8	83.1	219.6	325.1
1987	233.9	285.1	288.9	225.9	134	102.9	84.9	50.1	71.2	46.7	89.8	124.1
1988	258.5	191.7	137.6	209.4	125.1	78.6	79.2	71.7	98.1	86.6	139.4	128.3
1989	292.4	304.9	372.3	277.5	296.6	485.3	334.6	155.8	223.5	282.3	250.7	252.4
1990	375.6	612.1	503.9	201	232.6	116.7	139.4	90.5	75.1	152.5	101.3	303
1991	278.7	302.1	356.4	318.3	266.4	174.1	133.2	171.2	124.6	70.2	124.6	278
1992	226.2	224.9	319.1	237.4	187.2	227.1	111.5	161.6	166.4	154.5	372.1	474.5
1993	380.1	242	375.1	302.5	198.4	124.6	67.1	62.1	64.2	45.4	103.6	180.9
1994	242.7	298.1	392.8	481.9	168.7	296.2	256.2	327.5	143.5	191.9	144.9	216.8
1995	315.2	484.4	370.9	160.9	141.9	149.6	93.4	117.4	87.1	283.1	288.7	179.7
1996	409.3	398.9	311.1	260.3	237.9	203.6	142.9	196.2	240.5	184.1	224.8	345.5
1997	319.1	315.8	490.3	349.6	283.1	268.8	164.4	109	99.2	108.7	143.1	142.5
1998	441.3	473.2	327.5	350.5	239.1	220.1	98	61.6	45.8	38.4	73.5	116
1999	254.4	325.7	259.5	192.3	231.6	148.1	150	70.7	44	61.7	97	109.3
2000	146.9	165.1	202.7	303.4	135	98.5	66.1	58	49.4	35.6	84	93.9
2001	178.5	208.3	252.6	191.3	114.3	134	119.3	88	113.5	115.7	87.9	142.1
2002	237.3	198.3	202.8	210.8	233.1	112.6	85.9	62	162.3	148.6	261.1	269.7
2003	237.7	332.4	293.7	241.1	426.7	267.6	285.7	160.8	152.4	114	234	246.5
2004	197.5	242.4	210	188	183.5	165.4	149.4	104.2	594.4	190.3	321.1	409.9
2005	239	257.6	289.2	318.8	221.1	349.9	378.1	275	185.2	112.5	132.7	242.1
2006	316.8	238.2	163.6	163.7	121.8	95	82.5	62.5	104.3	114.8	181.9	183.8
2007	299.2	147.7	181.6	162.7	113.2	86.7	90.1	60.5	51.8	59.4	76.4	116.4
2008	157.5	202.9	317	179.9	165	95.3	61.2	88.5	59.4	50.6	62.2	254.9

Little Tennessee River

Monthly mean in cfs (Calculation Period: 1944-04-01 -> 2009-09-30)												
YEAR	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1944				700	370	235.1	162.5	153.4	147.1	132.2	161.2	223.3
1945	279.5	376	401.5	443	351.2	203.7	156	152.2	287.9	207.8	243.5	432.2
1946	1,008	907.6	892.7	593.5	664.7	342.6	244.4	159.4	156.2	182	188.6	206.5
1947	679.4	366.4	366.2	469.6	333.5	242.2	159.2	138.2	101.5	216.7	351.5	285.4
1948	285.3	683	716.9	591.7	300	208.6	352	372.3	202	135.3	751.4	632.9
1949	788.3	711.4	513.5	633.1	594.3	694.1	626.6	462.3	530.9	436.4	447.7	438
1950	541.9	566.5	716.7	428	309.9	373.4	285	249.7	671.3	333.8	246.5	411.1
1951	291.8	350.6	455.8	505.9	338.6	346	226.5	144.5	144.2	128	244	623.7
1952	493	553	1,199	599.3	364.9	313.1	152.7	152.4	131.1	105.6	160.3	227
1953	513.1	726.6	598.6	365.2	387.4	213.9	194.6	140.5	119.9	103.7	140.8	387.8
1954	734.9	442.5	570.1	563.9	351	245.4	168	131	80.2	70.5	100.6	238.9
1955	200.3	464.3	399.7	581.5	665.1	356.7	313.7	269.1	145.1	154.9	146.1	158.9
1956	131.5	598.2	499.7	694.3	370.4	214.2	252.5	149.9	132.5	135.7	140.7	360.9
1957	365.7	783	481.1	814.5	323.2	391.7	234.2	139.2	184.1	307.6	641	607.5
1958	493.7	564.7	511	636.6	556.5	257.1	406.8	243.8	156.5	138.2	128.4	155.5
1959	347.9	343.3	366.5	471.8	462.3	475	237.8	153.2	240.2	462.4	296.9	358.6
1960	439.5	779.2	621.2	711.3	336.2	284.4	240.9	376	256.2	333.4	229.5	236.1
1961	279.7	633.2	641.7	576.5	370.5	371.6	353.9	368.5	292.2	190	224.6	841
1962	665.6	654.1	642.8	785.1	371.3	367.9	202.8	157.5	151.3	181	207.1	202.5
1963	284.9	310.3	736.6	361.5	362.1	293.3	356.9	205.6	163.2	131.8	174.7	244.7
1964	549.5	490.5	950.2	1,014	500.2	259.5	191	214	316.5	1,078	369.4	549.5
1965	501.6	592.1	598	522.4	367.2	303	201.8	176	172.4	363.7	191	157.8
1966	243.7	843.1	587.7	406	568.3	318.3	210.5	189.6	227	275.9	450.6	357.7
1967	472.7	459.8	494.3	309	352.5	644	427.1	607.2	477.7	293	379.1	653.5
1968	664.8	348.5	544.5	496.2	355.8	260.3	190.2	173	154.6	152.6	218.1	308.8
1969	405.7	661.2	422.6	528.2	415.3	426.7	232.6	372.3	306.5	276.8	417.9	405
1970	405.8	405.6	401.2	422.1	273.1	415	192.5	196	139.7	232	305	230.4
1971	438.2	690.2	602.3	445.8	377.3	278.5	320.5	361.5	203.5	210.9	264.3	629.9
1972	693.1	437.3	414.7	361.2	423.2	342.8	291.5	287.8	180.2	254.5	431.9	635.9
1973	619.5	761.5	917.7	756.8	883.1	668.5	354.4	290.8	199.8	170.5	278.2	633.3
1974	928.8	829.3	507.1	889	648.6	534.7	369.5	695.1	324.8	229.9	266.7	381.6
1975	556.9	849.6	1,019	636	429.9	315.4	193.2	153.8	337.5	469.8	475.3	391.7
1976	688.1	507.6	576.1	639.1	999.4	668.8	361.2	222.9	181.9	360.7	265.8	426.6
1977	384.5	299.8	863.1	906.6	405.1	285.2	156.2	157.7	330	280.1	640.3	579.8
1978	810	481.3	496.1	311.8	348.3	229.9	144.1	419.8	163.6	121.4	120.9	287
1979	624	534	1,119	969.4	618.5	412.9	406.4	306.8	514.9	454.1	814.7	498.2
1980	518.2	411.4	983.4	926.9	602.5	386.1	212.6	155.8	156.8	162.1	181.8	153.6
1981	119.7	364.5	253.3	265.2	294.6	364.5	162.5	106.5	121.9	110.4	113.9	238.3

1982	517.9	767.2	458.2	381.4	296.6	211.2	189.7	177.5	165.2	182.8	233	679.2
1983	430.6	823.6	581.7	900.7	567.5	359.3	204.5	135.3	165.9	230.1	313	741.1
1984	451.5	664.1	640.7	718.2	759.8	349.8	313.4	291.2	142.8	164.9	221.6	255.5
1985	217.4	550.2	267.3	296.4	241.3	170	194	267.9	141.2	124.4	296.2	259.5
1986	177.4	221.7	282	172	156.8	138.2	94.8	78.3	81.8	138.8	318.5	501.7
1987	414.8	449.4	548.7	460.6	259	210.6	158.4	148.5	153.7	107	212.8	274.1
1988	489.9	310.3	243.9	372.3	188.5	109.6	120.2	112.5	122.3	131.1	172.6	154.3
1989	324.8	339.2	563.7	410.7	416.1	626.8	772.5	367.5	367.2	567.9	413.7	435.6
1990	598.2	1,252	1,079	508.5	428	233.4	242.6	166.8	178.3	325.3	228.7	432.9
1991	515.3	470.1	696.7	703.3	610.3	392.3	306.7	322.9	247.9	162.4	232.4	385.9
1992	354.5	419.1	553.4	395.8	333.9	573.3	287.9	399.6	439.8	383.9	811.2	777.4
1993	768.8	528.5	778.1	705.4	419.3	212.9	128.5	110.5	137.3	94.6	238.8	313.2
1994	409.5	512.1	741.9	833.4	362.2	342.4	368.2	609.2	322.8	463.1	334.1	427.6
1995	646.5	769.1	767.7	368.7	278.4	299.4	211.6	310.5	222.3	557.7	532.4	345.1
1996	800.9	707.3	590.8	457.6	394.5	491.2	225.5	224.1	306	269.6	281.8	552.1
1997	527.3	582.9	865	649.2	520.9	489.7	322.4	207.7	213.5	252.5	235.8	276.7
1998	825	939.5	754.3	722.2	518.6	340.2	176.7	136.3	92	103.9	147.1	193.9
1999	355.2	519.6	396.9	423.8	397.7	251.8	216.2	112.7	85.2	181.7	273.7	281.3
2000	275.4	293.9	379.8	494.5	267.1	166.4	105.5	80.5	88	70.7	155.3	152.8
2001	228.5	265.4	354.4	242	160.1	203.5	166.3	146.4	168.8	170.3	144.4	204.8
2002	336.2	282.1	347	348.6	336.9	195.5	142.9	107	299	268.9	378.8	475.5
2003	371.6	466.6	508.9	505.7	781.3	521.3	516.8	380.7	400.8	271.7	511.3	503.5
2004	363.9	509.2	319.5	296.1	256	244.7	228.2	180	1,030	357	497.9	695.8
2005	457.1	435.8	483.7	572.1	402.2	716.6	809.6	589.3	385.8	270.2	297.6	468.7
2006	506.6	414.5	291.5	275.9	198.2	184.6	134.2	105.4	183.4	201.3	309.5	326.7
2007	567.6	278.6	377.8	260.1	176.2	148	162.3	105.4	97.5	98.7	109	174
2008	249.7	360.3	584.7	304.5	222.4	137.4	99.1	127.2	84.4	81.5	97.1	303.2

Watauga River

Monthly mean in cfs (Calculation Period: 1940-04-01 -> 2009-09-30)												
YEAR	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1940				300	122.8	169	134.2	1,169	184.8	72.3	78.1	152.8
1941	115.9	67.5	140.4	168	67.5	52.2	376.8	74	36.5	29.4	45.2	111.2
1942	101.1	152.2	297.5	106.2	334.8	329.4	123.1	151.5	282.8	99.7	85.8	276.2
1943	271.1	264.3	204.9	255.8	202.8	132.3	186.3	59.5	39.7	28.5	48.6	51.1
1944	108.2	295.4	305.8	198	115.8	52	35	30	51.5	109.9	96	143.5
1945	181.7	227.9	202.5	249.8	314.3	120.4	108.4	64.2	343.1	111.9	118.3	224.6
1946	428.8	261.2	279.8	165.8	185.2	91	109.4	55.4	40.2	67.1	57.9	53.3
1947	239.4	122.9	195.4	192.3	81.5	119.5	81.6	96	98.9	300	386.4	117.1
1948	98.3	310.7	237.5	260.8	76.3	94	153.3	156.7	209.2	75.6	349.9	275.9
1949	216.4	232.3	223.1	329.5	229.8	218.5	300.3	416.2	150.1	145.7	239.6	171.7
1950	179.4	285.2	239	132.7	178.9	124	115.3	122.8	301.5	88.2	89.1	433.8
1951	145.9	193.9	286.8	241.5	105.3	77.3	49.3	38.5	27.5	24.3	61.4	186.2
1952	164.4	230.2	312	155.2	98	63	36.3	53.9	36.5	32.6	86.7	100.3
1953	273.5	297.3	359.4	141.4	170.5	106	65.5	32.5	29.5	23.4	41.9	92.2
1954	225.2	195.3	276	185.7	193.6	65.7	36.5	28.2	18.1	19.2	51.9	113.2
1955	70	225	378.6	359.9	117.1	76.8	146.9	111.6	45.6	40.9	46	52.7
1956	55.5	269.7	211.5	286.8	107	46.7	65.7	25.6	41.7	92.2	109.6	106.5
1957	214	452.6	191.5	556.6	106.8	230.6	94.5	39.2	102.1	110.3	333.8	363.5
1958	225	300.6	252.1	383.5	322.9	100.7	93.1	69.2	37.4	37	40.9	123.4
1959	184.3	119.2	177.2	300	129	124.3	78.9	91.5	256.4	232.9	113.7	224.4
1960	205.7	399.5	438	428.3	153.4	122.9	159.5	156.5	92.4	78.7	58.3	73.9
1961	122.7	324.2	243.9	327.4	216.2	132.9	77.8	287.6	95.8	67.8	167.6	343.9
1962	303.1	297.8	312.5	281.1	89.9	91.6	58.5	41.1	50.7	69	155.8	144.6
1963	127.9	90.9	557.2	104.6	126.6	83.2	57.4	36.2	28.9	21.8	53	45.6
1964	184.5	180.3	362.5	232.8	111	56.2	75.2	79.3	94.5	379.7	181.5	179
1965	186.7	278.9	380.9	306.4	149.4	108.1	77.2	55.9	60.2	155.4	65.9	50.2
1966	65.5	598.6	177.4	132.9	227.5	80.4	71.6	174.4	260.3	144.8	256.6	288.8
1967	186.8	190.4	267.9	94.5	148.8	147.3	132	173.7	111.9	128.1	131.9	220.6
1968	280.3	164.9	237.9	213.9	103.3	123.4	60.6	51.1	37.4	130.3	106.7	107.4
1969	136.1	243.5	299.9	228.2	139.1	155.3	105	82.8	98.3	138.2	237.5	255.2
1970	199.7	284.8	186.1	229.4	141.4	94.5	67.7	216.6	55.4	157.2	225.5	104.4
1971	184.7	403.1	244.2	149.8	254.6	142.4	188.4	183.6	79.8	205.8	197.8	183.7
1972	204.4	327	205.5	246.4	243	300.6	119.9	72.8	52.3	70.1	115.9	204.6
1973	207.3	314	512.7	297.9	411.4	152	83.5	76.9	62.6	67.8	106.7	332.7
1974	313.5	324.6	289.5	418	194.9	358.4	162.7	151.1	292.1	106.1	111.9	326.3
1975	274.8	382.9	557.9	180.2	263	261.1	104.8	94	262.6	299.8	178.5	149
1976	323.2	250.1	163.4	167.3	348.8	519.1	126.8	55.5	65.1	277	104.1	238.8
1977	117.6	168	499.2	371.5	163.4	147.9	95.7	72.3	173.8	205.2	661.7	216.8

1978	402.4	139.9	344.4	164.4	201.7	75.6	47.1	144.1	47.3	35.3	46.8	112.5
1979	285.6	360	857.6	368.2	252.7	192.4	256.4	116.6	690.6	223.1	579.5	177.6
1980	216.5	163.1	399.2	535.6	213.6	119.1	103	65.5	48	62.1	71	67
1981	56.1	286.6	180.2	190.8	278.4	212	67.6	32.3	35	35.2	34.6	72.5
1982	252.1	328.6	252.3	163.6	161.9	112.3	95.9	84	80.5	74	147.8	329.6
1983	224.3	551	570.3	567.4	249.2	168.4	94.5	46.9	44.1	118.8	154.8	403.4
1984	142.5	425	356.3	303.2	339.4	130.8	117.7	89.9	42	44.5	96.1	84.6
1985	103.9	333.8	124.2	136.7	86.9	74.5	60.6	129.1	48.2	49.2	367	168.2
1986	166.5	191.8	167.8	82.1	97	58.1	43.6	38.6	79.9	42.6	88.1	243
1987	164.3	211.3	389.5	688.6	145.6	111.8	64.9	31.1	68	29.6	105.6	117.4
1988	152.9	118	77	178.8	76.9	41.4	39.5	30.5	52.3	36.7	116	68.8
1989	130.9	154.7	229.2	155.8	287	227.9	461.2	141	359.5	273.5	197.6	199.2
1990	263.9	402.7	453.3	165.9	225	88.3	83	77.2	48.5	361.4	134.5	195.1
1991	230.1	242.2	467.4	354.7	172.9	127.5	95.6	66.7	55.6	32.5	107.4	150.6
1992	203.2	140.7	207.9	417.7	240.8	582.7	104.3	145.2	127.2	197.2	521	288.3
1993	270.8	241.8	552.8	338	291.2	80.6	43.1	34	33.6	26.9	50.8	121.5
1994	181.3	256.2	363	315	113.3	101.4	125.5	467.4	93.3	81	66.1	128.5
1995	816.8	273	372.3	97	142.3	211.3	109.2	98.5	65.7	355.4	169.6	102.1
1996	468.9	313.1	213	169	154.5	148	72.7	230.8	115.6	83.4	221.8	265.7
1997	177.5	211.9	414.7	211.4	158.4	198.4	120.1	58.7	64.4	51.8	54	70.5
1998	496.9	642.8	395.2	403.5	285.2	175.2	80.6	60	28.5	39.5	34.7	70.5
1999	228	170.7	214.6	143.3	163.1	105.3	117.5	41.6	34.4	40.8	187.3	109.6
2000	97.6	198.9	218.4	302.1	116.8	72.8	67.3	117	45.4	28	49.6	50.3
2001	70.8	84	208.3	139.1	68.3	104.2	212.2	146.1	69.9	59.1	56.1	92.1
2002	181.5	114.2	200	134.7	82.3	62.4	59.3	23.9	94.6	89.4	176.1	229.5
2003	170.6	332.1	284.5	427.8	187.6	254	191.1	213.1	112.5	71.2	385.1	255.3
2004	140	237.6	178.9	227.2	130.6	201.1	106.9	62.6	1,049	208.1	242.7	261.3
2005	238	175.6	280.7	302.4	155.3	194.9	186.9	116.7	65.2	89.1	197.9	176
2006	256.5	189	117.5	202.2	140.5	139.4	78.5	57.1	130.8	75.7	266.3	195
2007	255	104.8	192.2	119.9	68.1	59.1	80.6	38.7	31	71.1	42.9	72
2008	82.3	131.5	316.2	109	67	62.3	71.5	73.5	67.7	52.9	61	141.1

Appendix 3: Minitab Output

Valley River

Stepwise Regression: Valley MJJ versus Altamaha Riv, Black River , ...

Alpha-to-Enter: 0.05 Alpha-to-Remove: 0.1

Response is Valley MJJ on 30 predictors, with N = 62

Step	1	2	3	4
Constant	-4.523	-16.451	-18.399	-25.117
Piney Creek Residual	0.0197	0.0188	0.0168	0.0160
T-Value	4.71	4.84	4.56	4.43
P-Value	0.000	0.000	0.000	0.000
Ramseys Draft Recollection Resi		0.0129	0.0117	0.0105
T-Value		3.26	3.16	2.89
P-Value		0.002	0.003	0.006
Black River Residual			0.0052	0.0050
T-Value			3.15	3.09
P-Value			0.003	0.003
Grandfather Mountain Residual				0.0091
T-Value				2.14
P-Value				0.037
S	4.76	4.41	4.11	3.99
R-Sq	26.98	38.14	47.19	51.10
R-Sq(adj)	25.76	36.04	44.46	47.67
Mallows Cp	22.8	12.5	4.4	2.1
PRESS	1443.91	1269.92	1129.71	1089.94
R-Sq(pred)	22.31	31.67	39.21	41.36

Regression Analysis: Valley MJJ versus Piney Creek , Ramseys Draf, ...

The regression equation is

Valley MJJ = - 25.1 + 0.0160 Piney Creek Residual
+ 0.0105 Ramseys Draft Recollection Resi
+ 0.00501 Black River Residual
+ 0.00906 Grandfather Mountain Residual

Predictor	Coef	SE Coef	T	P	VIF
Constant	-25.117	5.810	-4.32	0.000	
Piney Creek Residual	0.015953	0.003599	4.43	0.000	1.049
Ramseys Draft Recollection Resi	0.010509	0.003642	2.89	0.006	1.040
Black River Residual	0.005010	0.001619	3.09	0.003	1.049
Grandfather Mountain Residual	0.009064	0.004243	2.14	0.037	1.051

S = 3.99285 R-Sq = 51.1% R-Sq(adj) = 47.7%

PRESS = 1089.94 R-Sq(pred) = 41.36%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	4	949.79	237.45	14.89	0.000
Residual Error	57	908.74	15.94		
Total	61	1858.53			

Durbin-Watson statistic = 1.65878

Autocorrelation Function: RESI1

Lag	ACF	T	LBQ
1	0.167012	1.32	1.81
2	-0.069569	-0.53	2.13
3	0.145373	1.11	3.56
4	0.057998	0.43	3.79
5	0.107097	0.80	4.58
6	0.069020	0.51	4.92
7	-0.054875	-0.40	5.14
8	-0.097563	-0.72	5.84
9	0.120260	0.87	6.92
10	0.063087	0.45	7.23
11	-0.085157	-0.61	7.79
12	0.064517	0.46	8.12
13	-0.037980	-0.27	8.24
14	-0.027922	-0.20	8.30
15	-0.037327	-0.26	8.42
16	-0.113129	-0.80	9.52

Autocorrelation for RESI1

Oconaluftee River

Stepwise Regression: Oconaluftee versus Chickahominy, Hampton Hill, ...

Alpha-to-Enter: 0.05 Alpha-to-Remove: 0.1

Response is Oconaluftee MJJ on 7 predictors, with N = 32

Step	1	2
Constant	-7.921	-25.212
Piney Creek Residual	0.0412	0.0378
T-Value	3.74	3.85
P-Value	0.001	0.001
Kelsey Tract II Residual		0.0205
T-Value		3.06
P-Value		0.005
S	6.31	5.58
R-Sq	31.75	48.39
R-Sq(adj)	29.47	44.83
Mallows Cp	9.9	2.7
PRESS	1336.95	1072.07
R-Sq(pred)	23.63	38.76

Regression Analysis: Oconaluftee versus Piney Creek , Kelsey Tract

The regression equation is

Oconaluftee MJJ = - 25.2 + 0.0378 Piney Creek Residual
+ 0.0205 Kelsey Tract II Residual

Predictor	Coef	SE Coef	T	P	VIF
Constant	-25.21	11.12	-2.27	0.031	
Piney Creek Residual	0.037768	0.009820	3.85	0.001	1.013
Kelsey Tract II Residual	0.020549	0.006721	3.06	0.005	1.013

S = 5.58207 R-Sq = 48.4% R-Sq(adj) = 44.8%

PRESS = 1072.07 R-Sq(pred) = 38.76%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	2	847.10	423.55	13.59	0.000
Residual Error	29	903.63	31.16		
Total	31	1750.73			

Durbin-Watson statistic = 2.08473

Autocorrelation Function: RESI1

Lag	ACF	T	LBQ
1	-0.0490227	-0.28	0.08
2	-0.0351592	-0.20	0.13
3	0.0329315	0.19	0.17
4	-0.0343890	-0.19	0.22
5	0.0070939	0.04	0.22
6	0.0203551	0.11	0.24
7	0.0417493	0.23	0.31
8	-0.0892418	-0.50	0.67

Autocorrelation for RESI1

Nantahala River

Stepwise Regression: Nantahala MJ versus Grandfather , Hampton Hill, ...

Alpha-to-Enter: 0.05 Alpha-to-Remove: 0.1

Response is Nantahala MJJ on 10 predictors, with N = 40

Step	1	2	3
Constant	-0.002453	-11.852179	-13.085839
Kelsey Tract II Residual	0.0133	0.0128	0.0127
T-Value	3.55	3.76	3.96
P-Value	0.001	0.001	0.000
Piney Creek Residual		0.0126	0.0104
T-Value		2.98	2.56
P-Value		0.005	0.015
Pearl River Residual			0.0037
T-Value			2.46
P-Value			0.019
S	3.36	3.05	2.87
R-Sq	24.87	39.45	48.17
R-Sq(adj)	22.89	36.17	43.85
Mallows Cp	17.2	8.9	4.7
PRESS	481.587	415.668	366.551
R-Sq(pred)	15.52	27.09	35.70

Regression Analysis: Nantahala MJ versus Kelsey Tract, Piney Creek , ...

The regression equation is

Nantahala MJJ = - 13.1 + 0.0127 Kelsey Tract II Residual
+ 0.0104 Piney Creek Residual + 0.00368 Pearl River Residual

Predictor	Coef	SE Coef	T	P	VIF
Constant	-13.086	4.967	-2.63	0.012	
Kelsey Tract II Residual	0.012665	0.003196	3.96	0.000	1.002
Piney Creek Residual	0.010354	0.004050	2.56	0.015	1.054
Pearl River Residual	0.003677	0.001494	2.46	0.019	1.053

S = 2.86502 R-Sq = 48.2% R-Sq(adj) = 43.8%

PRESS = 366.551 R-Sq(pred) = 35.70%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	3	274.581	91.527	11.15	0.000
Residual Error	36	295.500	8.208		
Total	39	570.081			

Durbin-Watson statistic = 2.25023

Autocorrelation Function: RESI1

Lag	ACF	T	LBQ
1	-0.135274	-0.86	0.79
2	-0.064525	-0.40	0.97
3	0.373239	2.31	7.30
4	0.024883	0.14	7.33
5	-0.284483	-1.56	11.21
6	0.280716	1.46	15.10
7	0.198597	0.98	17.11
8	-0.255469	-1.23	20.54
9	0.012982	0.06	20.55
10	0.197439	0.92	22.73

Autocorrelation for RESI1

Little Tennessee River

Stepwise Regression: Little TN MJ versus Ebenezer Cre, Kelsey Tract, ...

Alpha-to-Enter: 0.05 Alpha-to-Remove: 0.1

Response is Little TN MJJ on 6 predictors, with N = 36

Step	1	2
Constant	-2.671	-13.894
Kelsey Tract II Residual	0.0293	0.0300
T-Value	3.48	3.97
P-Value	0.001	0.000
Pearl River Residual		0.0105
T-Value		2.99
P-Value		0.005
S	7.37	6.64
R-Sq	26.27	41.96
R-Sq(adj)	24.10	38.44
Mallows Cp	13.4	5.7
PRESS	2132.17	1721.59
R-Sq(pred)	14.93	31.31

Regression Analysis: Little TN MJ versus Kelsey Tract, Pearl River

The regression equation is

Little TN MJJ = - 13.9 + 0.0300 Kelsey Tract II Residual
+ 0.0105 Pearl River Residual

Predictor	Coef	SE Coef	T	P	VIF
Constant	-13.894	8.632	-1.61	0.117	
Kelsey Tract II Residual	0.030048	0.007578	3.97	0.000	1.001
Pearl River Residual	0.010543	0.003529	2.99	0.005	1.001

S = 6.63927 R-Sq = 42.0% R-Sq(adj) = 38.4%

PRESS = 1721.59 R-Sq(pred) = 31.31%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	2	1051.70	525.85	11.93	0.000
Residual Error	33	1454.64	44.08		
Total	35	2506.34			

Durbin-Watson statistic = 2.06196

Autocorrelation Function: RESI1

Lag	ACF	T	LBQ
1	-0.057414	-0.34	0.13
2	0.084715	0.51	0.42
3	0.261060	1.55	3.24
4	0.088982	0.50	3.58
5	-0.090073	-0.50	3.94
6	0.059486	0.33	4.10
7	0.157190	0.86	5.27
8	-0.287765	-1.55	9.31
9	0.212106	1.07	11.59

Autocorrelation for RESI1

Watauga River

Stepwise Regression: Watauga MJJ versus Bluff Mounta, Boogerman Tr, ...

Alpha-to-Enter: 0.05 Alpha-to-Remove: 0.1

Response is Watauga MJJ on 8 predictors, with N = 40

Step	1
Constant	-2.269
Scotts Gap Residual	0.0133
T-Value	3.81
P-Value	0.000
S	3.96
R-Sq	27.68
R-Sq(adj)	25.77
Mallows Cp	2.3
PRESS	648.654
R-Sq(pred)	21.25

Regression Analysis: Watauga MJJ versus Scotts Gap Residual

The regression equation is

Watauga MJJ = - 2.27 + 0.0133 Scotts Gap Residual

Predictor	Coef	SE Coef	T	P	VIF
Constant	-2.269	3.516	-0.65	0.523	
Scotts Gap Residual	0.013335	0.003497	3.81	0.000	1.000

S = 3.95934 R-Sq = 27.7% R-Sq(adj) = 25.8%

PRESS = 648.654 R-Sq(pred) = 21.25%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	227.98	227.98	14.54	0.000
Residual Error	38	595.70	15.68		
Total	39	823.68			

Durbin-Watson statistic = 1.44154

Autocorrelation Function: RESI1

Lag	ACF	T	LBQ
1	0.273046	1.73	3.21
2	0.061700	0.36	3.38
3	0.232834	1.37	5.84
4	0.195730	1.10	7.63
5	0.151070	0.82	8.72
6	0.062843	0.34	8.92
7	0.006541	0.04	8.92
8	-0.077154	-0.41	9.23
9	-0.026882	-0.14	9.27
10	-0.008539	-0.05	9.28

Autocorrelation for RESI1

Vita

Tate Geren was born in Knoxville, Tennessee. He currently resides in Knoxville with his wife Kristin. He has four younger brothers: Wesley Geren, Cole Geren, Zac Geren, and Seth Bales.

Tate graduated from a local Knoxville high school, South-Doyle, and after graduation he attended Maryville College in Maryville, TN. He has a Bachelor of Arts in Civil Engineering from Maryville College, and a Bachelor of Science in Civil Engineering from the University of Tennessee, Knoxville where he graduated *Summa Cum Laude*.

Currently, Tate is pursuing a Master of Science in Environmental Engineering with a concentration in Water Resources. He is on track to graduate in December of 2010.