Upper Chattooga River Visitor Capacity Analysis
Data Collection Reports

The Forest Service is conducting a Visitor Capacity Analysis and is employing a modified "Limits of Acceptable Change" (LAC) planning framework for evaluating visitor use and potential impacts on the environment. Several types of information and analyses were needed as part of this analysis, as described in *Upper Chattooga River Visitor Capacity Analysis Implementation Plan for Data Collection Methods* (USFS, 2006). This document describes one element of those efforts ***Hydrology Issues on the Upper Chattooga River*** is a report that summarizes recreation-relevant hydrology information for the upper river.

A summary and integration of key findings from these collective efforts is provided in *Assessing Capacity and Conflict on the Upper Chattooga River* (CRC, 2007). Information from these efforts will be incorporated into the LAC effort to assess visitor capacity decisions on the Upper Chattooga. At the conclusion of the LAC effort, the Forest Service plans to develop a proposed action and alternatives for review through a National Environmental Policy Act (NEPA) process prior to implementation.

This document is one of several describing methods and findings from the data collection efforts. It serves as one of several "supporting reports" to the *Capacity and Conflict Report*. The complete list of reports includes:

- ***Chattooga River History Project, Literature Review and Interview Summary*** *(Tetra Tech, 2006)* – a history of Chattooga recreation decision-making that documents the basis for the 1976 boating ban and similar issues in order to help frame issues in the current analysis.

- ***Capacities on other Wild and Scenic Rivers: seven case studies*** *(Diedrich, 2007)* - a review of capacity issues on seven W&S with similarities to issues on the Upper Chattooga. This report provides examples of how other planners have interpreted laws and mandates, conducted analyses, or arrived at capacity decisions on other rivers.

- ***Use Estimation Workshop Summary*** *(Berger and CRC, 2007)*– summary of workshop conducted with resource agency personnel to help consolidate and summarize use information by capitalizing on extensive agency knowledge as well as some existing user surveys and creel surveys.

- ***Limited Use Monitoring Summary*** *(Berger, 2007)* – summary of data collected through the use monitoring conducted by the public, Forest Service and contractor of vehicle counts within selected access locations along the Chattooga River Corridor.

- ***Literature Review Report*** *(Louis Berger, 2007)* – Literature review and summary of information from existing studies on the Chattooga or studies /planning from other similar settings; includes the following components:

    - <u>Recreation-Related Social Impacts and Standards</u> - information related to the relationships between use and impacts and the "evaluative side" of the social impacts issue, including which impacts are most important, tolerances for those impacts, and which management actions tend to be used and supported to address them.

- *Recreation Related Trail/Site Impacts* - information about relationships between use and biophysical impacts, potential standards for those impacts, and the acceptability of management actions to address them.

- *Recreation-Related Wildlife Impacts* - information about relationships between recreation use and wildlife impacts, potential standards for those impacts, and the acceptability of management actions to address them.

- *Recreation Related Flow Preferences* **-** information about opportunities and flow preferences, particularly related to other rivers similar to the Chattooga.

- ***Proxy River Information*** *(USFS 2007)* – summary of management and flow related information for "similar-type" rivers to the Chattooga River as identified through public input.

- ***Biophysical Monitoring Information on the Chattooga River*** *(USFS 2007)* **-** information about current conditions in the corridor, including maps of existing trails, and a summary of other biophysical-related information that is relevant to Chattooga River capacity issues.

- ***Hydrology Issues on the Upper Chattooga River*** *(USFS 2007)* **-** This report summarizes recreation-relevant hydrology information for the upper river, including (1) rating curves and basin areas for staff gages at all bridges; (2) relationships between the Burrells Ford gage and the USGS Highway 76 gage; (3) summary hydrology for the period of record at the Highway 76 gage; and (4) extensions to the Burrells Ford gage.

- ***Expert Panel Field Assessment Report*** *(Louis Berger, 2007)* – report for the expert panel field assessment conducted to gather information about boating and angling opportunities on the upper Chattooga River, with particular attention to boater and angler flow preferences for these flow-dependent activities.

NORTH FORK CHATTOOGA RIVER

STREAMFLOW CHARACTER
BASED ON GAGED SITES

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NORTH FORK CHATTOOGA RIVER
STREAMFLOW CHARACTER BASED ON GAGED SITES[1]

BACKGROUND

This report is an interim report of the flow data compiled, collected, and analyzed for the North Fork (Upper) Chattooga River analyses that are addressing recreation capacity and conflict issues through a Limits of Acceptable Change planning process. These analyses will help in the reevaluation of the decision in the Revised Sumter National Forest Land and Resource Management Plan of the boating closure above the Highway 28 Bridge. Some of the data compiled and collected was not specifically developed for the capacity analyses, but to help characterize and present what information on the flow character of the Upper Chattooga. This recently collected flow data in this report are provisional and have had limited checking for mistakes and the stage discharge relationships presented will continue to be adjusted as higher flow data are collected. However, the flow data appear to be adequate for addressing major flow-recreation issues (particularly the expert panel component conducted in January, 2007.

To a large degree, this interim report was specifically prepared to present information on the hydrology and flow in the North Fork Chattooga River for use in the expert panel and integrated reports. The content is not intended to argue for or against specific uses, or to validate the estimates made by the expert users, panels, or associated analyses. Those issues are covered more specifically in those reports.

From the early stages of the reevaluation of river uses above Highway 28, understanding river flows and their impact on the river conditions appeared an important factor in determining potential use levels for different recreation opportunities, or the potential for conflict between those opportunities.

Although there are several types of river uses being considered and evaluated in the capacity analysis, conflicts between fishing and boating are considered important, and may vary depending upon flow conditions. Fishing is normally conducted when flows are not so high that flow velocity, depth, turbidity, water temperature or other extreme conditions hinder or prevent the use, while boating generally occurs when flows are higher and provide better boatability and whitewater challenge (Whittaker et al., 2006). .

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Probably over 90 percent of the time, flow and water quality are suitable to fish the North Fork Chattooga River. The Upper Chattooga stays low in suspended sediments and clears faster after storm events than many other streams within the Chattooga River Watershed. These observations were substantiated in a sediment study where the North Fork Chattooga River at Bull Pen Bridge and twelve other subwatershed and drainage locations within the Chattooga Watershed were compared for suspended sediment (Van Lear et. al., 1995). Even though the Bull Pen site was one of the largest streams sampled, it was among the lowest in total suspended sediment concentrations during storms, mean of storm maximums, individual storm maximum and after storm baseflow at 71 mg/l, 93 mg/l, 142 mg/l, and 11 mg/l, respectively.

The North Fork Chattooga River flow data in this report to a large extent are based on the short term flow data collected at Burrells Ford and how this data interacts with other stations with longer records. Stations with longer records are used to help define the frequency and duration of optimal, acceptable, marginal and non-acceptable conditions for river uses estimated from the expert panels. The flow information also helps to quantify the frequency of flows in different ranges.

HYDROLOGY ON THE NORTH FORK

The North Fork Chattooga River is one of several major tributaries in the Chattooga River watershed. This 64 square mile, 6^{th} level HUC subwatershed joins the West Fork of the Chattooga River below the Highway 28 Bridge. One real time stream gaging station exists in the Chattooga River at the Highway 76 Bridge (USGS site 0217000), about 20 miles downstream. This station has over 60 years of record. The other USGS stream gaging stations in the vicinity that have been referenced for this study include stations 02178400 Tallulah River near Clayton, GA; 03441000 Davis Creek near Brevard, NC; 03439000 French Broad River at Rosman, NC; and 0350056050 Cullasaja River near Highlands, NC. These sites were periodically used and compared with the flows in the Upper Chattooga.

Other stream points of interest within the North Fork Chattooga River include the Highway 28 Bridge, Burrells Ford Bridge (drainage area 47 square miles), Bull Pen Bridge (drainage area 23 square miles) and Grimshawes Bridge (drainage area 8 square miles). As part of this study, all these locations had staff gages repaired or installed to reference river levels when needed.

Although not part of the interim report, some flow data for the West Fork Chattooga River at Warwoman Road is being collected. The West Fork subwatershed is of similar size to the North Fork and is used by fishing, boating and other river uses.

Early in the planning effort, the Forest Service recognized that flow data from the Highway 76 Bridge may be difficult to extrapolate upstream 20 plus miles to the Upper Chattooga, so a temporary gage was installed to record water levels at the Burrells Ford Bridge. This location was selected because it was between Highway 28 and Bull Pen Bridge locations, and it offered some potential flexibility for use in predictions upstream and downstream. The water level measurements are being accomplished with a relatively inexpensive Global WL16 transducer that measures stage by the weight of water compensated automatically for barometric pressure. The water level data are compiled with an internal data logger that was programmed to collect water levels on a regular frequency beginning in June, 2006. For most of the record, measurements were taken at 15 minute intervals to coincide with the USGS gaging station data at the other USGS sites. The data have to be periodically downloaded to a laptop for analysis. Adjustments to standard time and staff gage readings on the bridge are made when needed to compensate for daylight savings time and/or water level probe and staff gage settings. For most of the record, data collection either coincides with the standard USGS streamgage timing or has been adjusted to that timing. Flow measurements needed to help define the stage discharge relationship are conducted under wadeable conditions by the US Forest Service and higher flow by the US Geological Survey under agreement (USGS, 2006).

A substantial amount of available background flow analysis existed within the Chattooga River watershed, but most of it was dated and not specifically directed at answering questions of interest relative to the Upper Chattooga. The available flow information was primarily based on the extensive flow records from the USGS stations on the Chattooga River at Highway 76 and adjacent Tallulah River (Hansen, 1992). In addition, strong similarities in normalized (area weighted) flow duration response from numerous North Georgia rivers in the Blue Ridge Province indicated the likelihood that there some degree of response predictability was likely. The shapes of the long term flow duration curves were similar, but their extent varied with estimated rainfall amounts.

The information collected at the Burrells Ford Bridge was also designed to help define how well the Highway 76 gage estimates the flows in the Upper Chattooga. A strong link would help support continued reliance on this gage for river uses and also help support contractual work associated with expert panels and additional analysis of river uses. Expert panels of boaters and fishing interests needed flow estimates to help define and categorize the types and conditions of river uses, the level of effects and the conflicts that could be expected to occur under different locations and flow regimes.

In addition, river flow, season and other criteria are already important in river management below Highway 28 for both commercial and non-commercial boating uses. Flow, daily use level, types of allowable equipment and other limitations have been set by the FS to improve safety and recreational experience, as well as reduce user conflicts. Most Chattooga users probably consider flow, rainfall, weather, season and/or other criteria in their decision to spend time on the National Forest in fishing, boating, sightseeing, trail hiking, swimming, camping, equestrian and other uses.

Installing the temporary stream gage at Burrells Ford avoided some issues that could arise if some of the flow data were not specific to the Upper Chattooga. With the temporary flow data, at least reasonable preliminary correlations to the Chattooga River gage at Highway 76 can be made. Installing the water level transducer at Burrells Ford has provided enough information to determine to how these sites normally interact.

The correlation of Upper Chattooga flow data to the Chattooga River at 76 was desired for several reasons. Flow information has been recorded on the lower part of the Chattooga River for over 67 years. Currently, the U.S. Geological Survey (USGS) maintains a web site for real time, average and historic stream data for individual sites including the Chattooga River near Clayton, GA. at highway 76 (station 02177000, drainage area 207 square miles). The real time access to present as well as recent flow data is very helpful to river users and information was included as part of expert panel discussion and information collection. Historically, some river users have used this gage as their reference to flows elsewhere in the river.

The use of other stream gages in the vicinity may occur among some boaters. Another nearby real time station and point of reference is the Tallulah River near Clayton (station 02178400, drainage area 57 square miles). It has been measured for about 40 years (http://water.usgs.gov) and is similar in size to the North Fork Chattooga River (64 square miles). The Chattooga at Highway 76 and Tallulah River data were normalized by area and compared used flow duration curves for each site with very close agreement (Hansen, 1992, 1998) using the USGS 1988 data (Figure 1). Currently stream data for both stations are beamed to satellites, analyzed and returned for use by users of the website with hourly updates. Annual USGS Water Resources Data reports from Georgia compile daily flow, monthly water quality and other records for both sites. The Tallulah site also includes a recording real-time raingage that is useful. After the bridge work is completed at Highway 76, the USGS probably will be installing a real-time raingage at this installation also. The magnitude of response of the Tallulah River to rainfall events was not evaluated in this or the other reports.

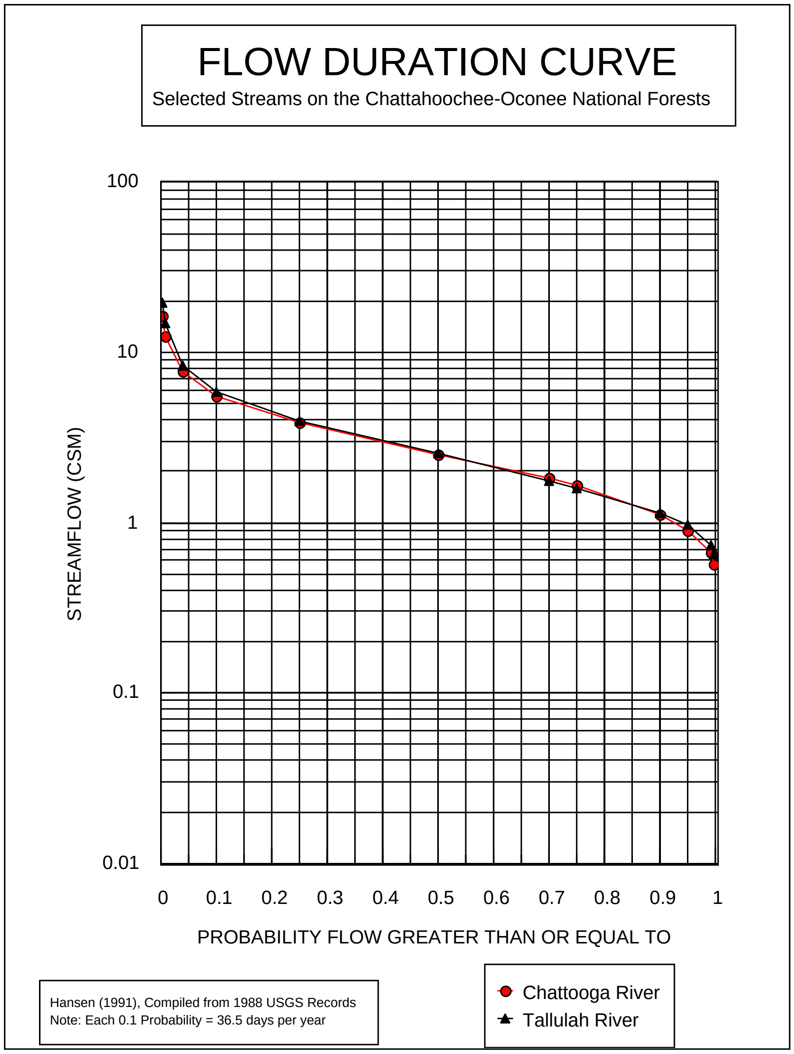
The USGS real-time station network and Water Resources Data Reports include many types of data for stations within the vicinity that are potentially useful to flow questions in the Upper Chattooga. Some of the most used hydrologic reports have been developed to evaluate flood flow responses across states to help extrapolate and predict flood frequency and other hydrologic phenomena in ungaged streams. The USGS normally divides hydrologic response by physiographic area and typically develop equations dependent on drainage size in order to predict floods of various return intervals (Whetstone 1982, Guimaraes and Bohman 1992, Stamey and Hess, 1993). Others have used the stream record to addressed low flow issues relative to drought and minimum flow needs (Hansen et al, 1990). No analysis was found on how streams of different sizes within the same general area interact and respond, and how extrapolating flows from the Lower Chattooga to the Upper Chattooga could be accomplished. No attempts were made to correlate rainfall and flow data, or develop unit hydrographs for various locations based on available estimates of flow regime. A report by Gordon Howard (1972) showed promise with remarkably high correlations of river stages taken during stable flow conditions, but in personal communications, he indicated that these correlations could not be verified, were probably erroneous and the data lost. In addition, Howard used the Randy Carter system to adjust stage data and display boatable waters. Some of these marks may be painted on bridge piers. Unfortunately, it is also uncertain to what degree the existing or reinstalled staff gages correlate with those used in Howard's report. All the existing or new staff gages have been surveyed with channel cross sections and standard surveying benchmarks installed except for the Highway 76 gage, which is probably already surveyed.

Flow Duration

Flow duration is a concept used to present the annual average frequency of flows based on long-term records. In 1988, the Chattooga and Tallulah Rivers' had 48 and 24 years of record for the data in Figure 1 (USGS data, 1988, Hansen, 1992). Daily streamflow measures in cubic feet per second (cfs) were normalized (divided by drainage area) to give the unit area response in cubic feet per second per square mile (CSM). The normalized values make it easier to compare different stream responses. Hansen found close agreement in normalized flow duration curves for these two adjacent stations with common physiography, vicinity and climactic conditions. Recognizably, there can be substantial timing differences on how two adjacent rivers respond as individual storms contribute varied rainfall intensity, duration and amount across a mountainous landscape, with complex elevation and aspect differences.

Flow duration curves for individual stream gaging stations utilize a probability plot with the percentage of time flows are equaled or exceeded on the x-axis and a multiple log plot of streamflow in cubic feet per second (cfs) on the Y-axis to handle the range of flows. Although somewhat easy to conduct with normal office software today, two decades ago much of this work was manually calculated and plotted. Flow duration curves remove the actual storm and non-storm timing fluctuations that occur over many years, and display the average flow regime of a river. Information regardless of whether it is a wet or dry water year for a specific use have been compiled and are available if needed for further analysis. The curves can be very helpful in estimating the average amount of time each year in a flow category, whether it is minimum, fishable or boatable flows. If flow duration data are used for river uses, the daily flow data is probably preferable over the 15 minute data collected from the gaging stations.

Figure 1. Comparison of Flow Duration Curve between Chattooga River (207 square miles, 48 years of record) and Tallulah River (57 square miles, 24 years of record) using area normalized flow (CSM=cubic feet per second per square mile) (1988 USGS records compiled by Hansen, 1992).

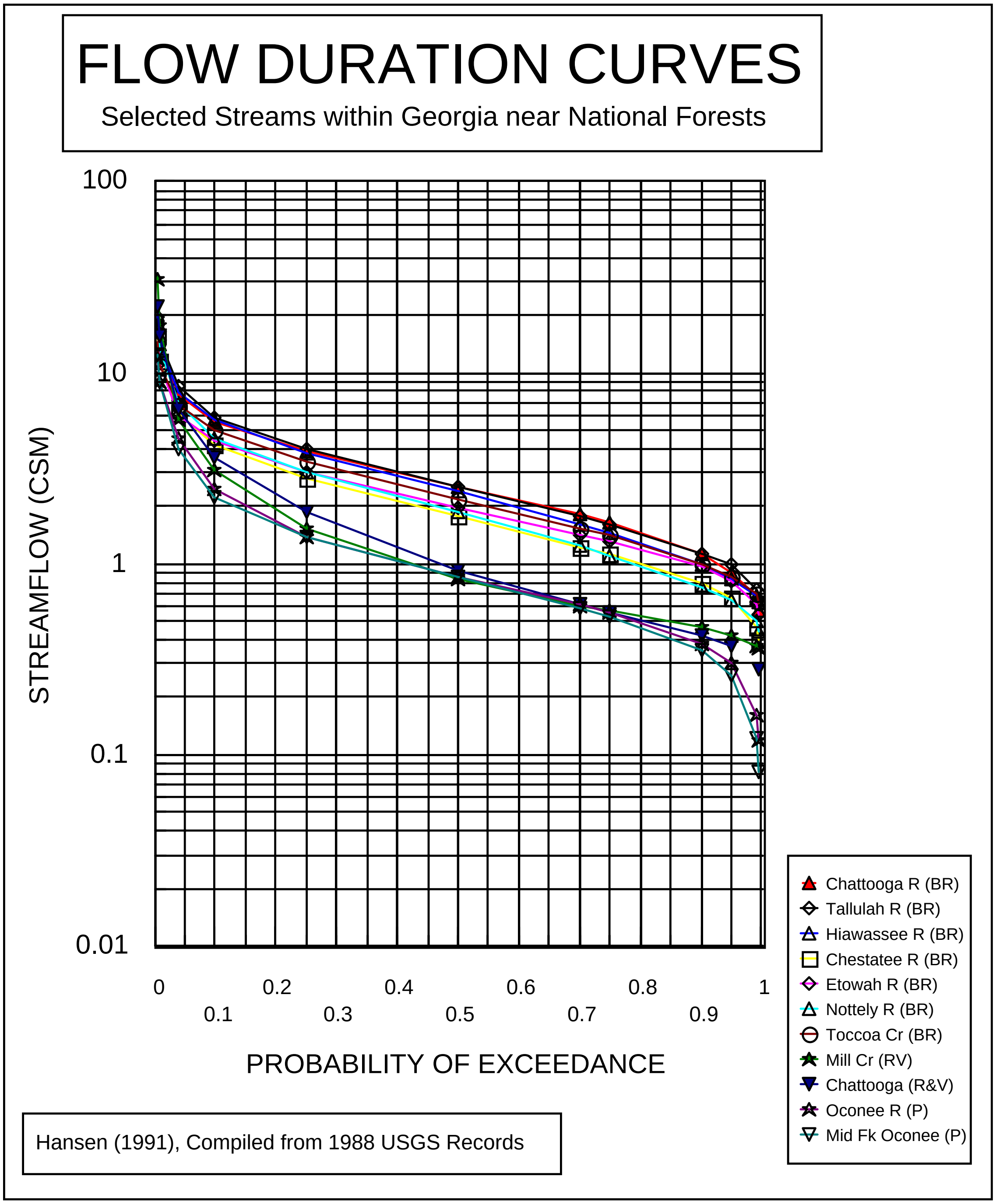


Normalized or area weighted flow duration curves can help estimate the frequency and magnitude of flows for other hydrologic units in the immediate vicinity. Each 0.1 probability across the X axis is 10 percent of time (i.e., 36.5 days over a year). The 5 percent subunits equate to 18.25 days a year. Extrapolating Figure 1 normalized flows at a 25% probability of exceedance occurs about 91 days a year. At 4 CSM, the estimated Chattooga flow at 76 (207 square miles) is 828 cfs and the Tallulah River (56.5 square miles) is 226 cfs. About 75% of each year or 274 days, flows would be less. If a specific reach has limiting range of flow criteria, you can develop the flow duration curve for that location and approximate the duration when flows would occur (on average).

Flow duration curves near the Chattahoochee-Oconee National Forests were developed from the 1988 Georgia streamflow data provided by the US Geological Survey to compare stream responses from various gages (Hansen, 1992) (Figure 2). These data helped to support the concept that river responses were similar within each physiographic area, but the levels changes with rainfall. River response as evidenced in the shape of the flow duration curve changed somewhat by physiographic areas.

Although the high correlation in flow response was expected based on these flow duration curve similarities for other streams, how well the North Fork Chattooga correlates to the Highway 76 stream gage was not specifically known before the North Fork was gaged at Burrells Ford. With the Burrells Ford temporary recording gage data, individual storm responses were compared with the Chattooga River at 76. This is not enough data to verify the exact long term flow correlations; however, it does provide a good initial estimate suitable for the level of precision in the capacity analysis. Information on the other gaged stations in the vicinity was collected so comparisons would be possible if desired. The short term flow detail from Burrells Ford provides ample data to begin this characterization of how the adjacent rivers of various sizes within the vicinity of the Upper Chattooga respond to storm and non-storm conditions. It is believed for the purposes of the river studies, these basic characterizations and correlations will probably be sufficient for the level of accuracy that the river use study would need (particularly with regard to the correlations between the Upper Chattooga with Lower Chattooga River).

Figure 2. Comparison of Normalized Flood Flow Duration Curves from several Blue Ridge (BR) streams with a few Ridge and Valley (R&V) and Piedmont (P) streams. The Blue Ridge streams respond consistently. Mill Creek (RV) was the only stream with under 20 years of record and Hiwassee Creek (BR) was the smallest drainage at 45.5 square miles.



The updated flow duration curve for the Chattooga River at Highway 76 is not much different from the one made almost 20 years ago (Figure 3). The curve is based on daily flows from about 68 years of flow data. These data can be used to estimate the frequency of flows equaling or exceeding a certain amount. If the range of boatable flows is 225 to 800 cfs in the North Fork (the equivalent of 700 to 2,500 cfs in the Chattooga River) as estimated in Whittaker & Shelby (2007), the flow duration data can help determine how many days each year on average fall into the category. For example, from Figure 3, a flow of 700 cfs is equaled or exceeded 32% of the time while 2,500 cfs is equaled or exceeded 2% of the time, so a flow range between 700 and 2,500 cfs would occur about 30% of the time. Monthly flow duration curves may also help evaluate the timing of the desired flows to help evaluate the seasonal opportunity (Figure 4). The long term daily data is useful for planning, but not an indicator of real-time boatable flows. Just as there is variation by season and year in river response, a storm on a given day can produce differences in flow outside the desired range that are probably not detectable with the daily average flow data.

The rate of flow change during a day can vary with season or watershed condition. For example, assume 225 cfs at Burrells Ford is required to provide boating. In the summer period, a boater might require a starting flow of closer to 450 cfs to assure at least 225 cfs remains in the channel as the hydrograph descends with no additional rain. In the winter, when groundwater levels are higher and trees do not remove as much water, the hydrograph will descend much less steeply and starting with 250 cfs might suffice. This discussion becomes more complicated when boaters put in and take out if different points, and what flows at which gage should be referenced.

The daily flow data would be used for planning level analysis, but the actual flow gages, storm forecast and information based on the real time or 15 minute data would be applied for real-time trip decisions. Either criteria has to be set, or the user must be familiar enough with the river data to make an informed decision on whether the variances in flow for the season and conditions likely to be maintained within the desired range.

As one would expect, the 15 minute data lack the duration of flow for long term planning for boating or fishing suitable flows. With 15 minute data, short duration suitable flows are accumulated that would not have enough duration to provide or be connected to a boatable experience. The 15 minute data are needed to help understand river response during storms, storm recession, base flow and seasonal conditions. The response curves change with rainfall, soil moisture and season (growing or dormant). Flow response is different when vegetation are actively growing and transpiring, from conditions where the vegetation is dormant and the soils and ground water levels within the watershed have replenished.

Figure 3. Flow Duration Curve for Chattooga River near Clayton at Highway 76 from 1939-2007 for available data. Comparing to Figure 1, streamflow of 1000 cfs or more still occurs approximately 15% of the time.

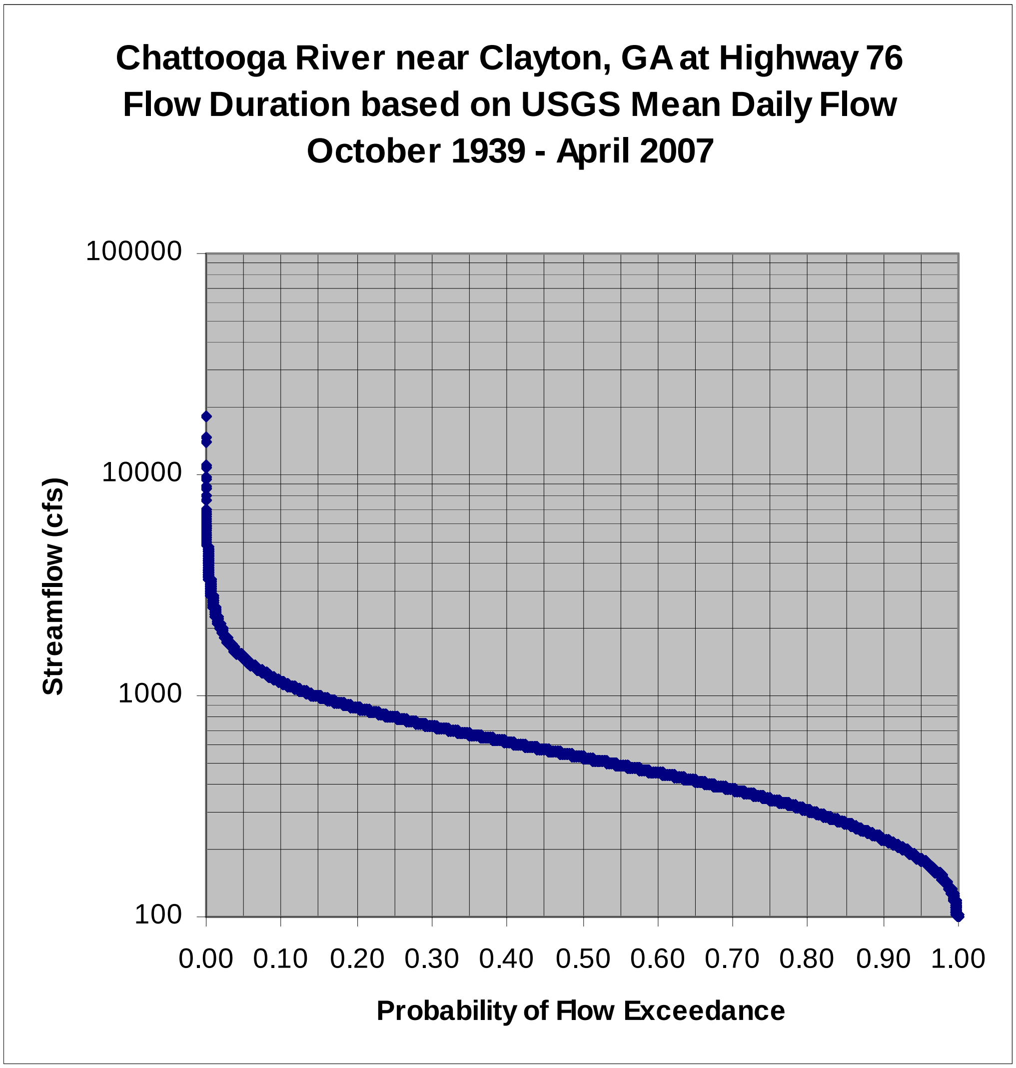
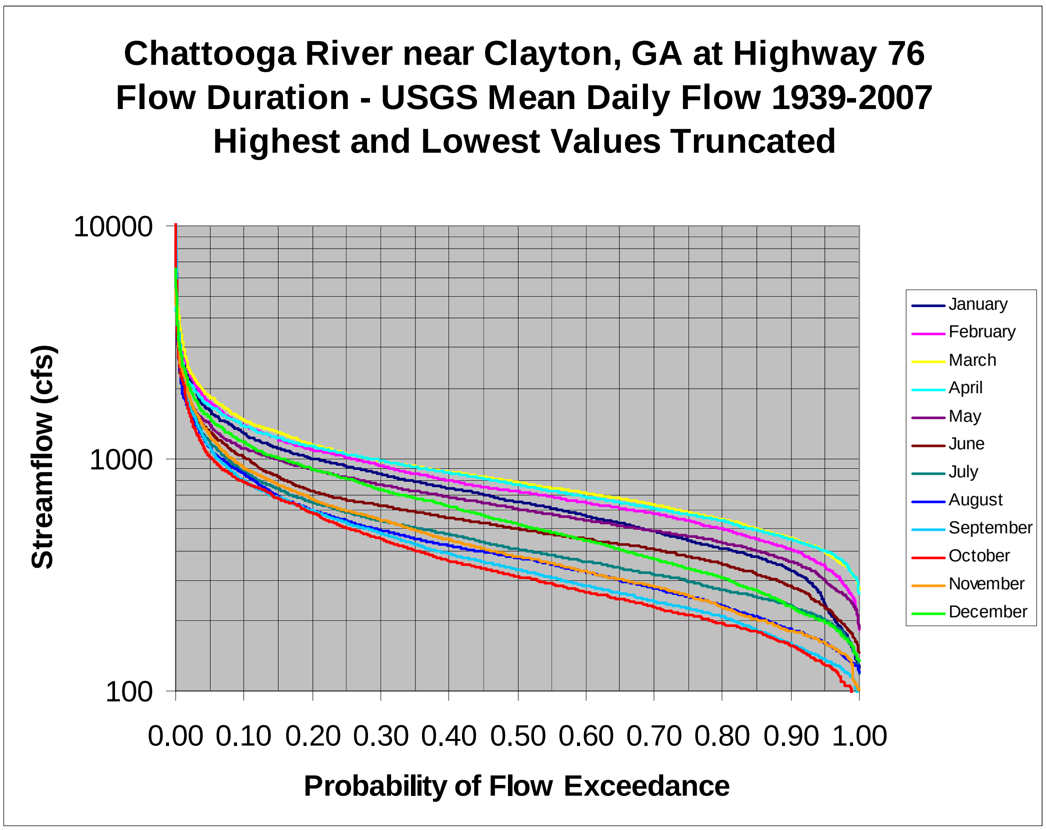


Figure 4. Monthly flow duration curves for Chattooga River at Highway 76 from 1939 to 2007 with the highest and lowest flow data truncated from plot. Each month is based on mean daily flows that occurred over 67 or 68 years, depending on the month. Review of the individual monthly plots also show some curve shape differences in the early winter months (November through January) might be a result of yearly variable conditions where the watershed has not fully recharged from the summer low flow period. This recovery delay apparently happens frequently enough that the curve shapes are different and cross other curves. Seasonal storm differences may explain the season change in the shape of the curves.



Comparison of Flow Data of Wet, Dry and Average Year

The 15 minute data for Chattooga River at 76 from 1990 to 2005 were used to display flow variation from wet, dry and average years. Although several years could be chosen to fit the categories, the wet, dry and average water years selected were 2004, 2000 and 1991, respectively (Figure 5). The data were also plotted for the specific calendar years requested for the integrated report (Whittaker & Shelby, 2007). The flow data are also available with log scale that shows more flow detail (Figure 6).

Figure 5. Comparison of Chattooga River at 76 flow data of wet, dry and average calendar year using regular scale.

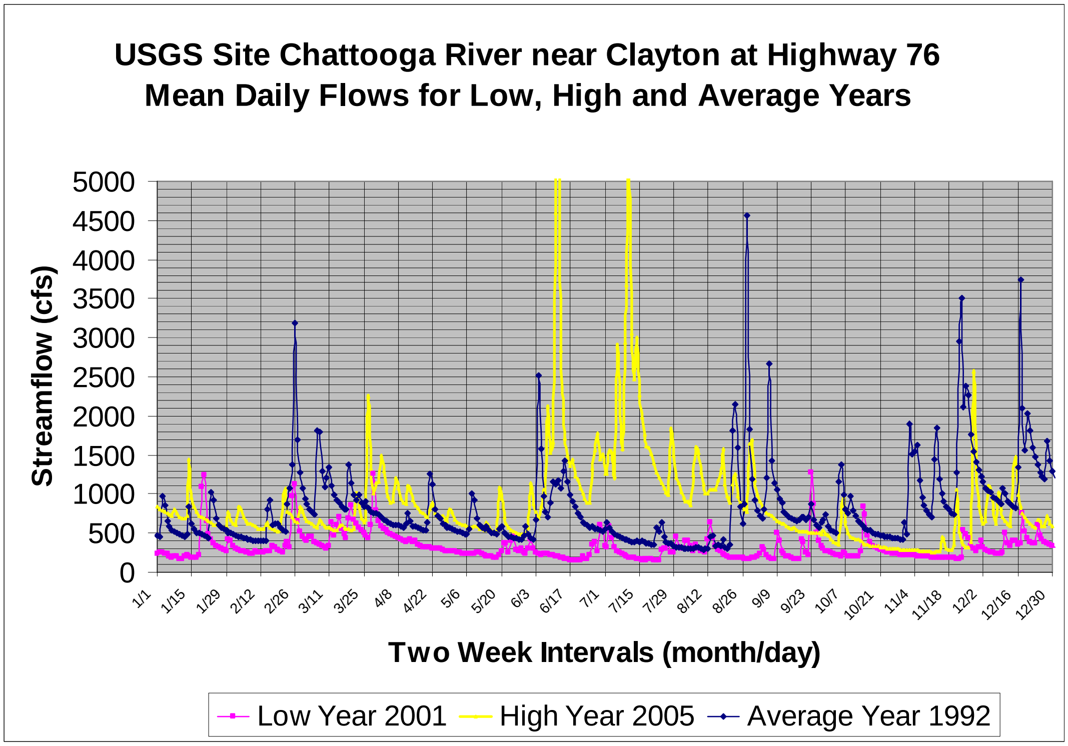
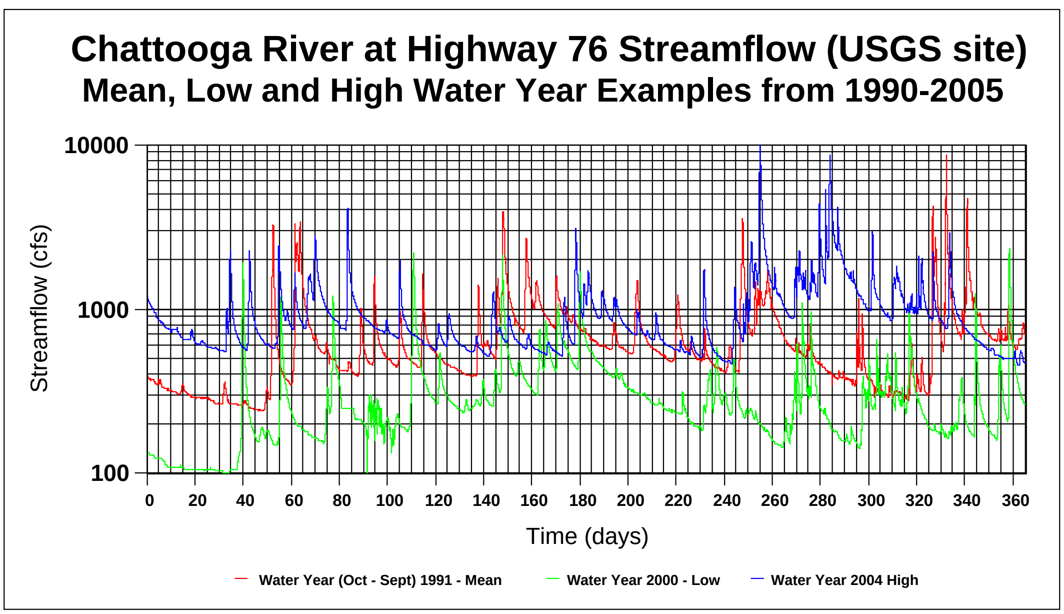
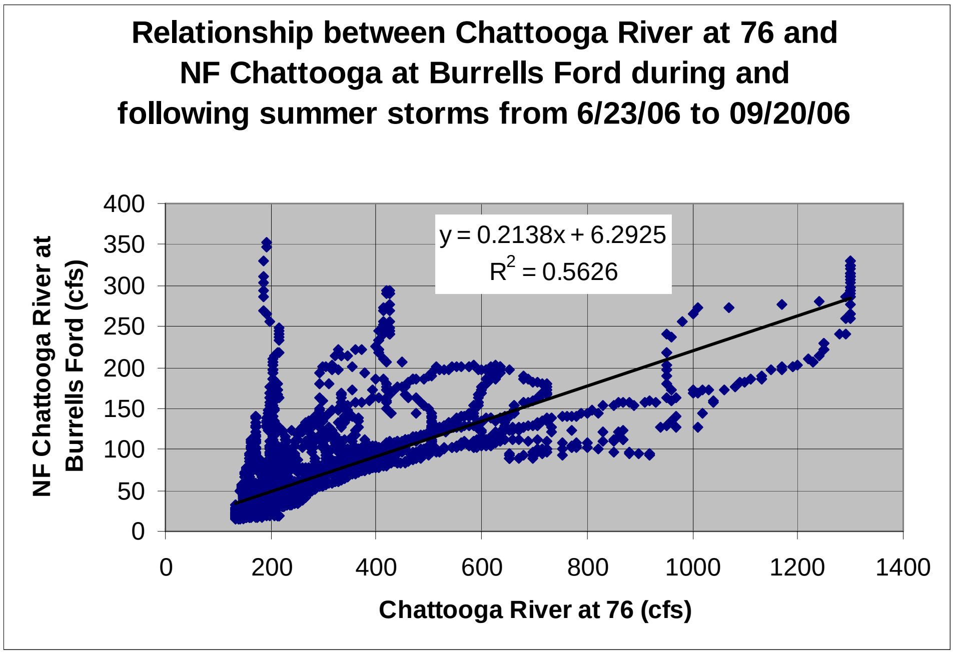
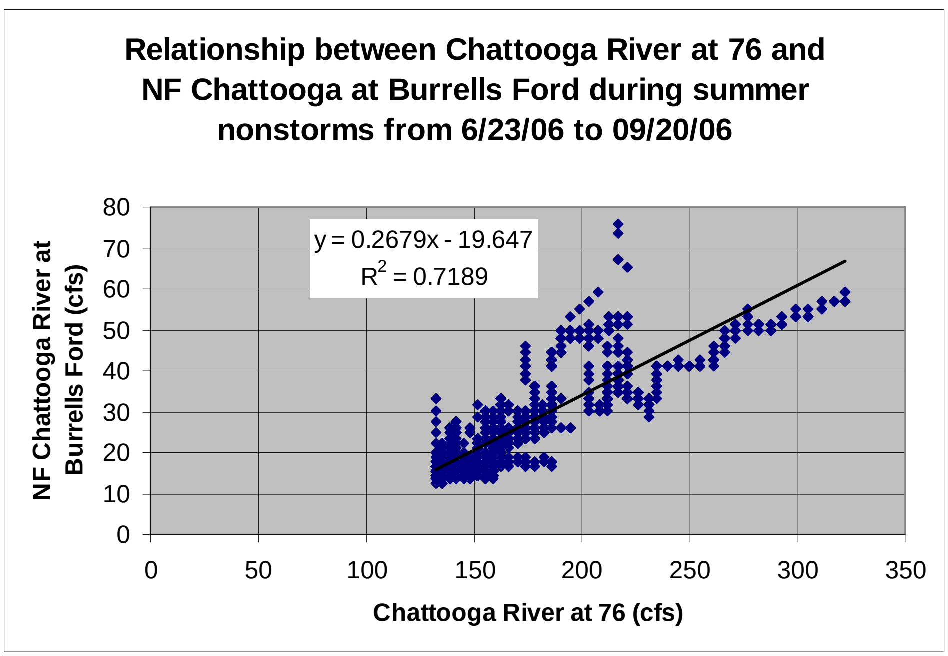


Figure 6. Comparison of Chattooga River at 76 flow data of wet, dry and average calendar year using log scale. Day 92 coincides with January 1 in Figure 4.

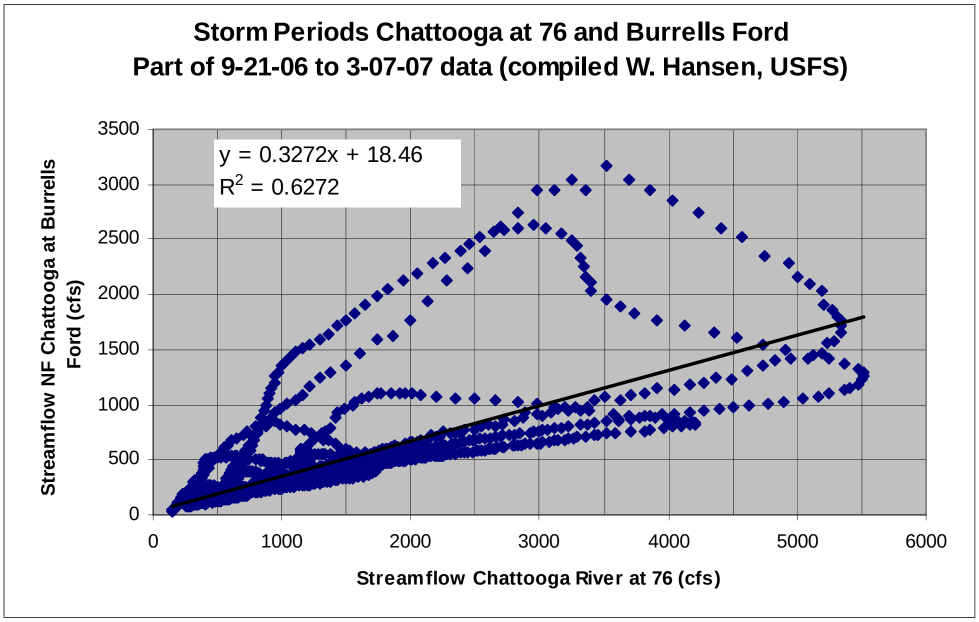


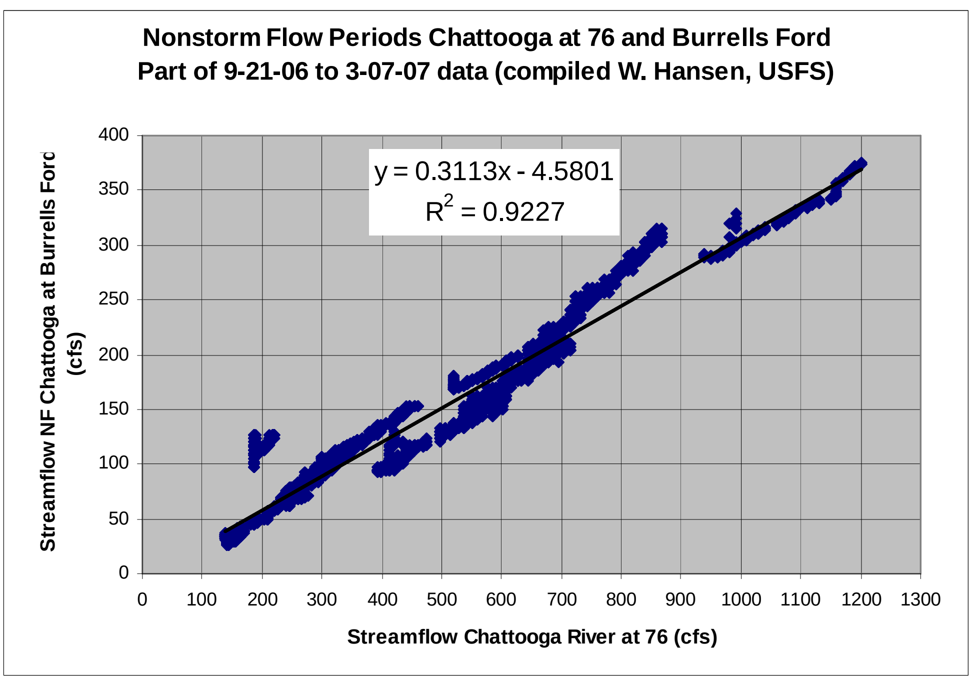
Figures 7 and 8 highlight the response differences between storm and non-storms periods during the summer between Chattooga River at Highway 76 and Burrells Ford. The timing of storm response made direct real time plotting difficult. These relations might be improved with adjustments for timing differences of flow from the two locations.



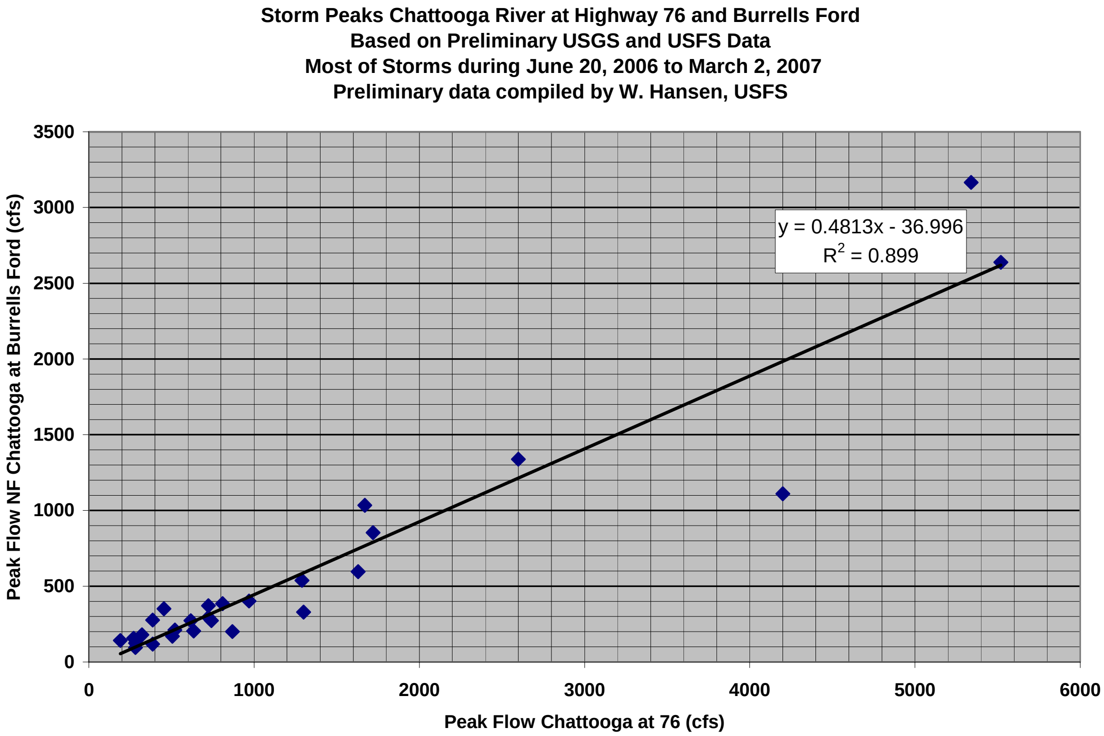


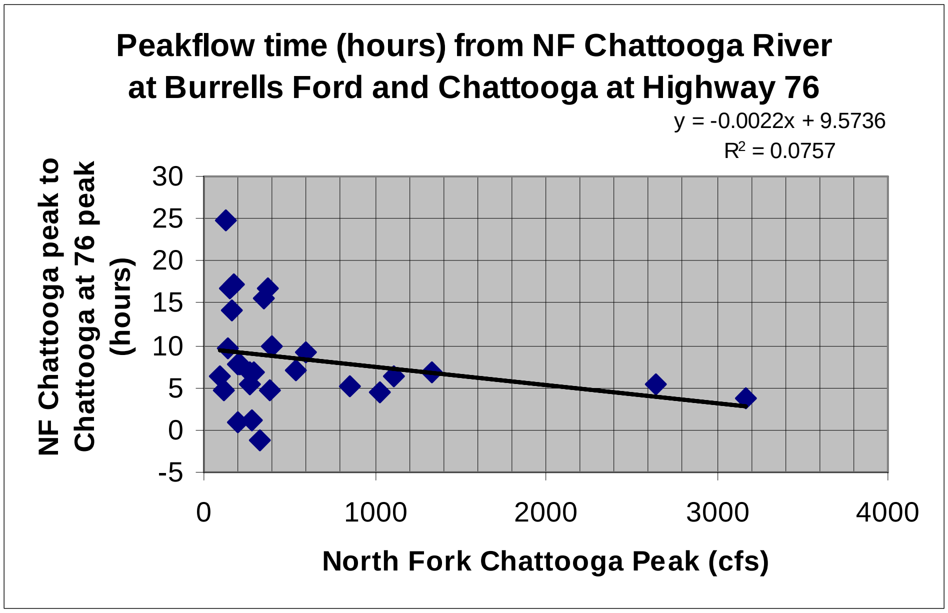
Figures 9 and 10 indicate the response differences between storm and non-storms periods during the fall/winter dormant period between Chattooga River at Highway 76 and Burrells Ford. The timing of storm response made direct plotting difficult. These relations might be improved with adjustments for timing of flows between the stations.





Figures 11 and 12 compare storm peaks between Chattooga River at Highway 76 and Burrells Ford from June 2006 to March 2007, and the hours delay from the peak at Burrells Ford to the peak flow at Highway 76 for different storm peak flow rates.





Peakflow time (hours) from NF Chattooga River
at Burrells Ford and Chattooga at Highway 76
y = -0.0022x + 9.5736
R2 = 0.0757
NF Chattooga peak to Chattooga at 76 peak (hours)
30
25
20
15
10
5
0
-5
0
1000
2000
3000
4000
North Fork Chattooga Peak (cfs)

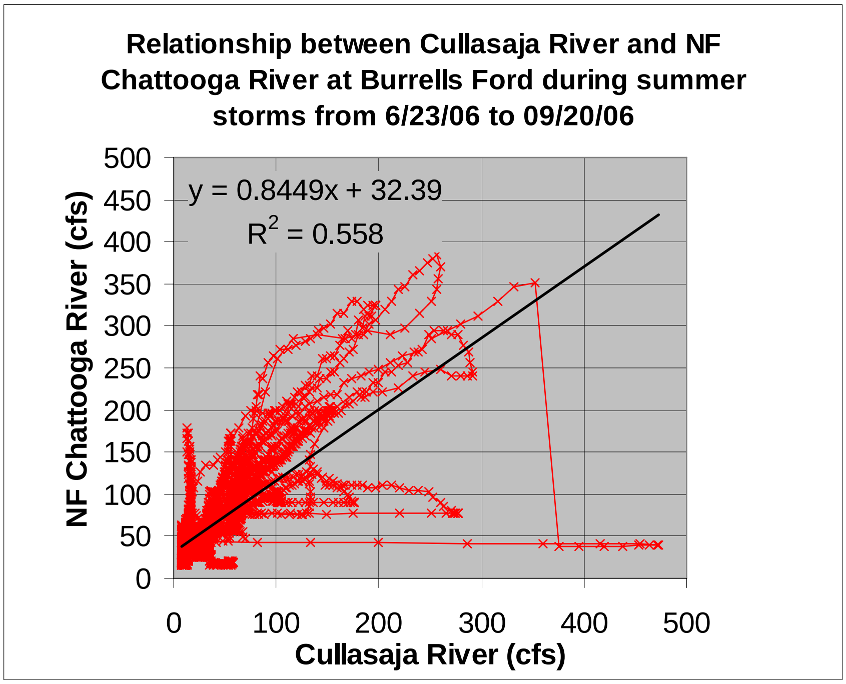
The Figures 7-12 highlight that there are some consistencies and inconsistencies in how Chattooga River at 76 and North Fork Chattooga at Burrells Ford respond to each other. From the plots, it is obvious that variances are magnified during storm response (Figures 7 and 9 in comparison to Figures 8 and 10). Compounded with their drainage size differences, they respond with a variable time delay (Figure 12). The summer period is the more unpredictable, possibly due to thunderstorms. The time delay difference is demonstrated in the plot scrolls of storm data (Figures 7 and 9). The lag time during flow peaks from Upper to Lower Chattooga stream gaging stations averages about 9.5 hours during relatively low flows, perhaps 5 hours lag at 2,000 cfs, and about 3 hours lag at 3,000 cfs (Figure 11). This decline in lag time between flow peaks with increasing flows is expected due to the increase in flow velocities that would shorten the lag time response between the stations. The varied differences in the lag times for the peaks at the low flow rates (varies from –2 to 25 hours) are probably due to individual storm differences, their size, location, and how they approach the watershed.

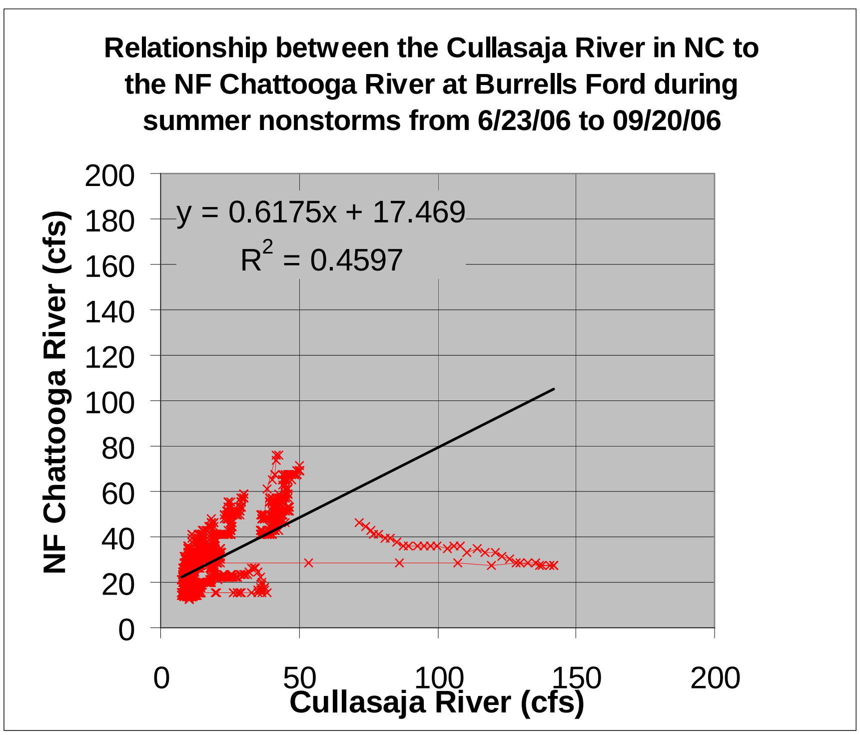
Figures 7 and 9 point out the difficulty of using the Highway 76 station to predict flow during storm events in the North Fork. The data plots or storm scrolls above the trend line are a result of the North Fork responding first, peaking and then declining before the points return to the trend line when Highway 76 peaks.

Comparison of North Fork Chattooga with other Rivers

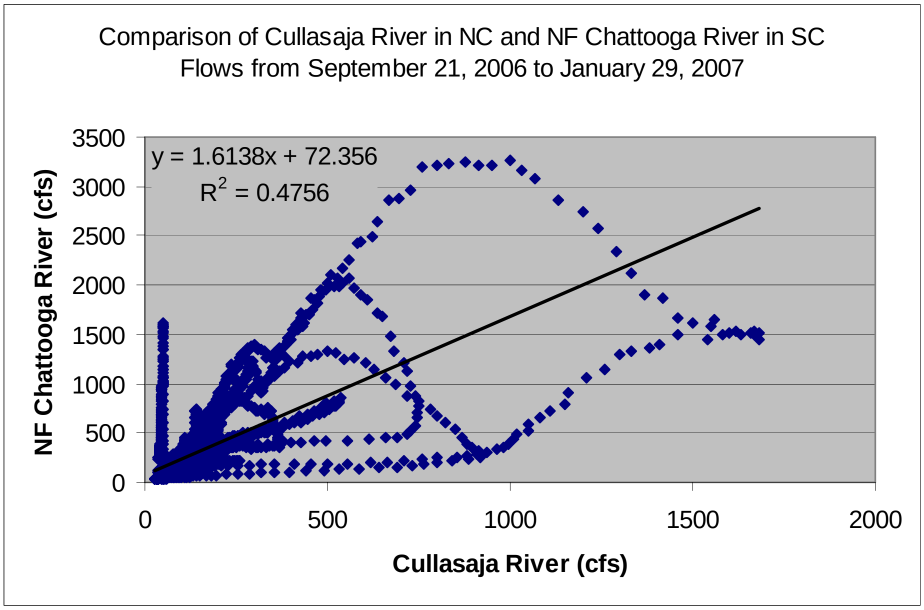
The Cullasaja River in NC is a smaller drainage that responds and often peaks about the same time as the NF Chattooga River, but there is also a lot of storm and other variation that could not be explained in their comparisons in Figures 13-15. Response time to peak probably varies with the storm system due to location and drainage size differences as was found with the Highway 76 gage. The comparison with the Tallulah River gage during the dormant season in Figure 16 shows a somewhat better correlation with a river of similar size, but still not as good as the Chattooga River at Highway 76 (Figure 17).

Figures 13 and 14. Relationship of summer storm and non-storm periods between NF Chattooga River and Cullasaja River from June 23-September 20, 2006.

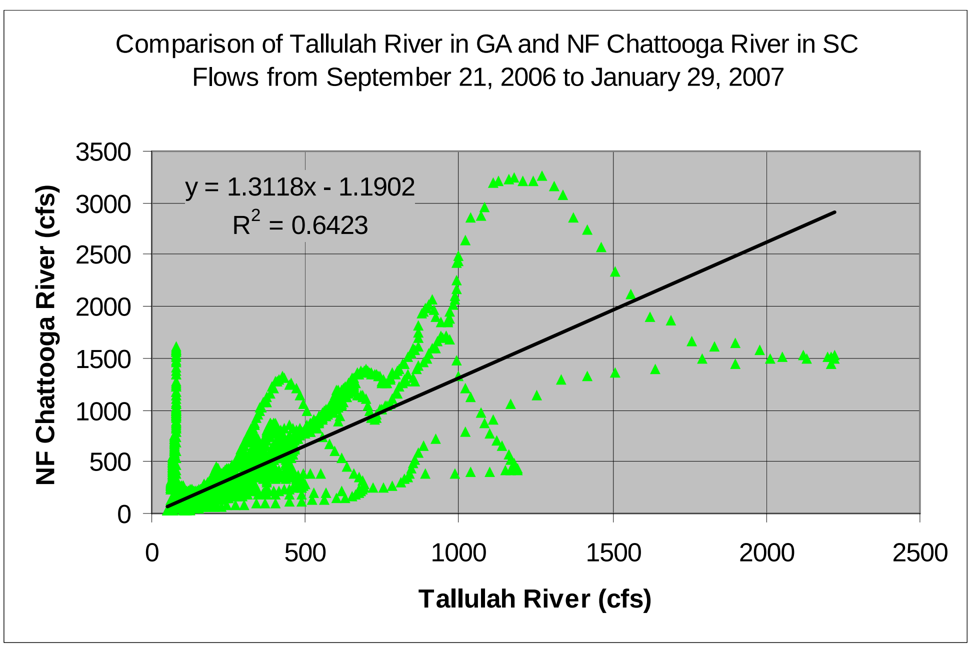




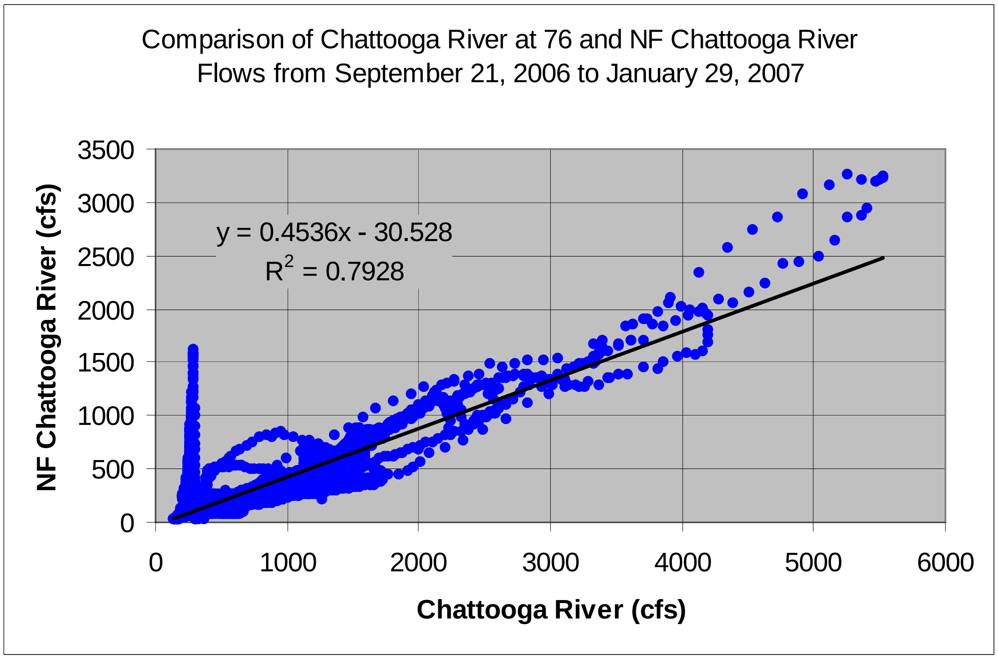
Figures 15. Relationship of dormant season storm and non-storm periods between NF Chattooga River and Cullasaja River from September 21, 2006 to January 29, 2007.



Figures 16. Relationship of dormant season storm and non-storm periods between NF Chattooga River and Tallulah River from September 21, 2006 to January 29, 2007.



Figures 17. Relationship of dormant season storm and non-storm periods between Chattooga River at Highway 76 and NF Chattooga River at Burrells Ford from September 21, 2006 to January 29, 2007.



The Chattooga River at Highway 76 is a very good predictor of the North Fork Chattooga River flow conditions in the dormant season, especially during a period that does not have frequent storm events where variability is would be increased. This figure includes both storm and non-storm data.

Changes in Scale and Location

Normalized flow duration curves for small drainages or catchments are typically going to have more variability in flow (flashy) than large watersheds. Small drainage areas with pronounced hillslope components have steeper gradients and may lack channel and floodplain storage components in comparison to large hydrologic units. Headwater drainage areas respond more rapidly in severe stormflow events and hillslope channels often become ephemeral after the event. Small areas can be subjected to or fully engulfed by localized rainfall extremes for extended periods, producing flows that can momentarily equal or exceed those in substantially larger drainage areas. For large watersheds, extreme sections of storms seldom affect the entire drainage area at one time, let alone for extended periods, so their response character is muted in comparison. Larger hydrologic units are slower to respond as their full channel network is much larger in extent with time and space differences, which tend to smooth and extend flow duration. At any given instant within a large watershed, smaller hydrologic units might have unit flow differences that might seem inconsistent with the flows at the watershed scale or even other small hydrologic units. These differences in timing and response at any given instant do not mean that the average responses over extended period of time are not similar as suggested in Figure 3. Flow durations within a physiographic area at the watershed and subwatershed scales are likely to have similar responses, but some adjustments for precipitation, land use or period of record may be needed. From the equations that compare flow during seasons, storms and non-storm periods, there is obviously more flow per unit area coming from the North Fork Chattooga than the Chattooga at Highway 76. This is expected as rainfall frequency analysis indicates that the Upper Chattooga generally has the highest rainfall rates for longer duration storms within the states of Georgia, South Carolina and North Carolina that is shared with rates along coastal areas for shorter duration storms (US Weather Bureau, 1961).

For ephemeral streams, the flow duration curves would show marked flow declines between 0-10% probability of flow exceedance, because they flow for only short periods of time each year. Some hillslope ephemeral streams may only flow for a few days each year in response to intense rainfall, so their flow duration response may be confined between 0 and 1% of the time flows are equaled or exceeded. Intermittent streams are able to maintain flow for significant periods beyond rainfall events, but lack perennial flow through the year (Hansen, 1998b). On the flow duration curve, their intermittent channel flows decline and fall off the chart between the 10-90% duration. Perennial channels maintain flow through most years, however could stop flowing in exceptionally dry conditions, so the borderline perennial streams may have some limited dry periods. In the Chattooga River area, most months average 4 or more inches of rainfall, so the frequency and amount of rainfall supports and extends a perennial stream network much further than would be found in many other areas of the United States (Hansen, 2001).

The Upper Chattooga is at higher elevations, receives more rainfall and has a more rapid response to its headwater channel system than the Lower Chattooga at Highway 76. The Upper Chattooga at Burrells Ford is 23% of the drainage area of the Highway 76 watershed (i.e., 47.2 square miles divided by 207 square miles). The flow data collected at Burrells Ford and compared to Highway 26 supports that except during summer storm periods, Burrells Ford produces more than 23% of the Highway 76 flow, based on the slopes of the lines for the equations where NF Chattooga is 21% of Chattooga at 76 during summer storms, 27% summer non-storm periods, 33% winter storms, 31% winter non-storm periods, and 48% in comparing peaks (Table 1).

Table 1 Storm, non-storm and peak comparison equations and correlation coefficients for Chattooga River at Highway 76 and North Fork Chattooga River at Burrells Ford

Period	Flow Comparison Equation	R^2
Summer during storms	QBF = 0.21 x (Q76) + 6	.56
Summer during non-storm periods	QBF = 0.27 x (Q76) - 20	.72
Winter/fall during storms	QBF = 0.33 x (Q76) + 18	.63
Winter/fall during non-storms	QBF = 0.31 x (Q76) - 5	.92
Comparing peaks	QBF = 0.48 x (Q76) - 37	.90

QBF = flow (cfs) NF Chattooga River at Burrells Ford
Q76 = flow (cfs) Chattooga River at Highway 76

Although area based stream flow and water yield conditions are somewhat higher in the North Fork Chattooga River than those measured downstream in the Chattooga River at Highway 76 based on rainfall in the headwaters and flow data collected in this study. However, the unit weighted flows are likely to be similar enough to draw careful inferences within neighboring drainages as long as they have similar land uses and are within the same physiographic area. Flow timing for different size and shape drainages can vary in real time and even within storm events, but disregarding that, their hydrologic response for any given unit flow appears to be similar as expressed in flow duration curves.

Comparison of Vicinity Gaged Sites with NF Chattooga River at Burrells Ford

The comparison between the Chattooga River at 76 and NF Chattooga at Burrells Ford became the primary emphasis for much of the reporting and river use capacity study. However, we also generated information on other stream gaging stations, and these offered useful comparisons.

Besides the Chattooga River at 76, several other real time stream gaging stations exist in the vicinity of the North Fork Chattooga River. These rivers are gaged by the US Geological Survey and are accessible most of the year from their website, including USGS site 02178400 Tallulah River near Clayton, GA (56.5 square miles); 03441000 Davis Creek near Brevard, NC (40.4 square miles); 03439000 French Broad River at Rosman, NC (67.9 square miles); and 0350056050 Cullasaja River near Highlands, NC (18.8 square miles). The data from these sites were periodically used and compared with the flows in the Upper Chattooga. Although there are timing differences due to station location, the drainage sizes are closer to NF Chattooga River and flows are generally similar, but can be erratic during the summer months (Figure 13). Although some irrigation and other water uses can occur in the summer to increase fluctuation in flow, the diurnal variation is due to the transpiration rate changes during the day by vegetation, and its effect on the riparian groundwater levels and connections to streamflow. Figures 14 and 15 indicate a much closer and reliable response as thunderstorms and transpiration by vegetation are reduced, and rainfall has replenished the soil and groundwater reserves to support a slower decline in baseflow.

Figure 13

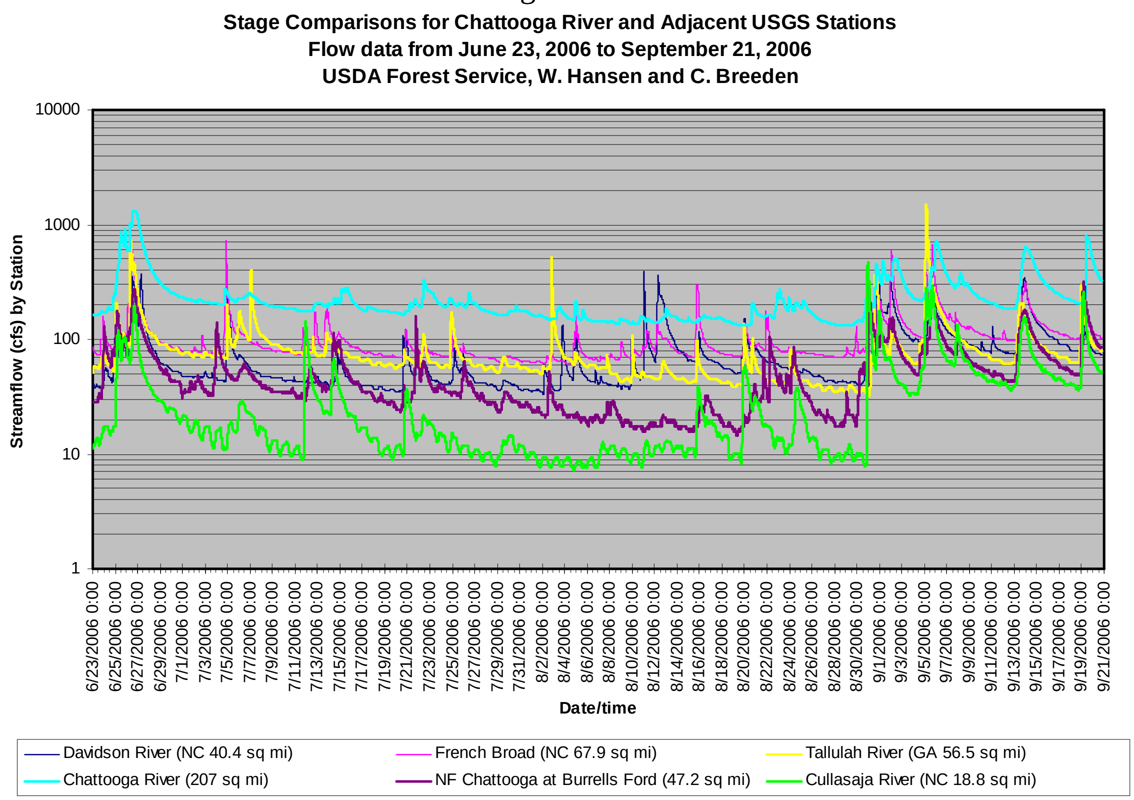


Figure 14

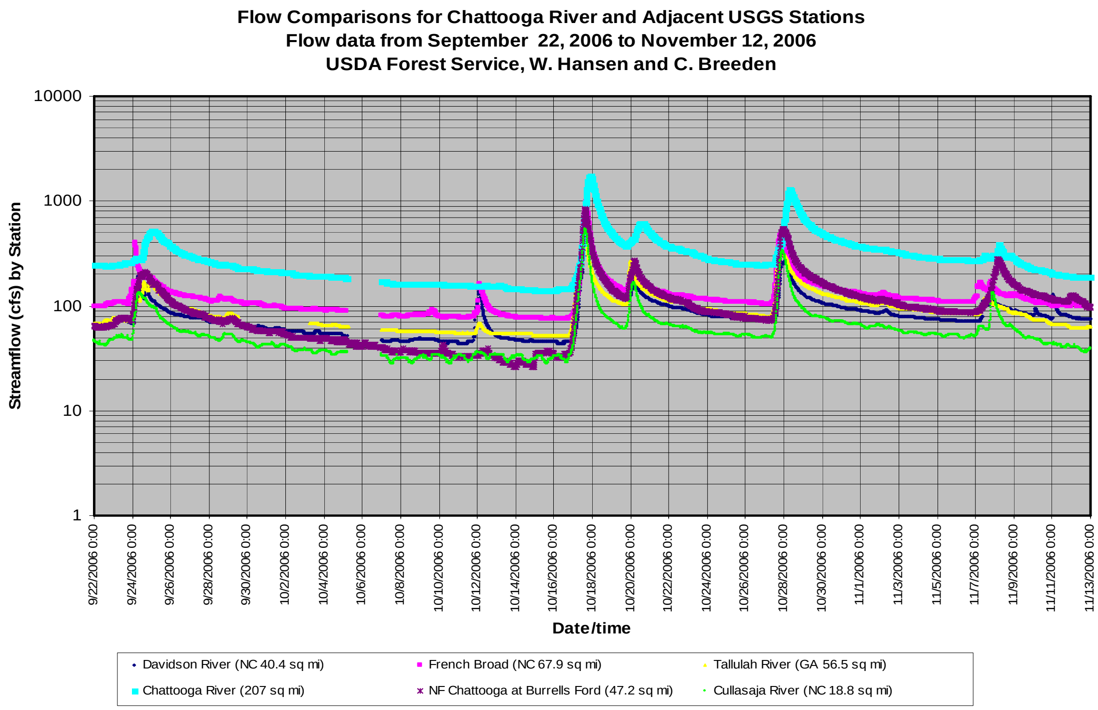
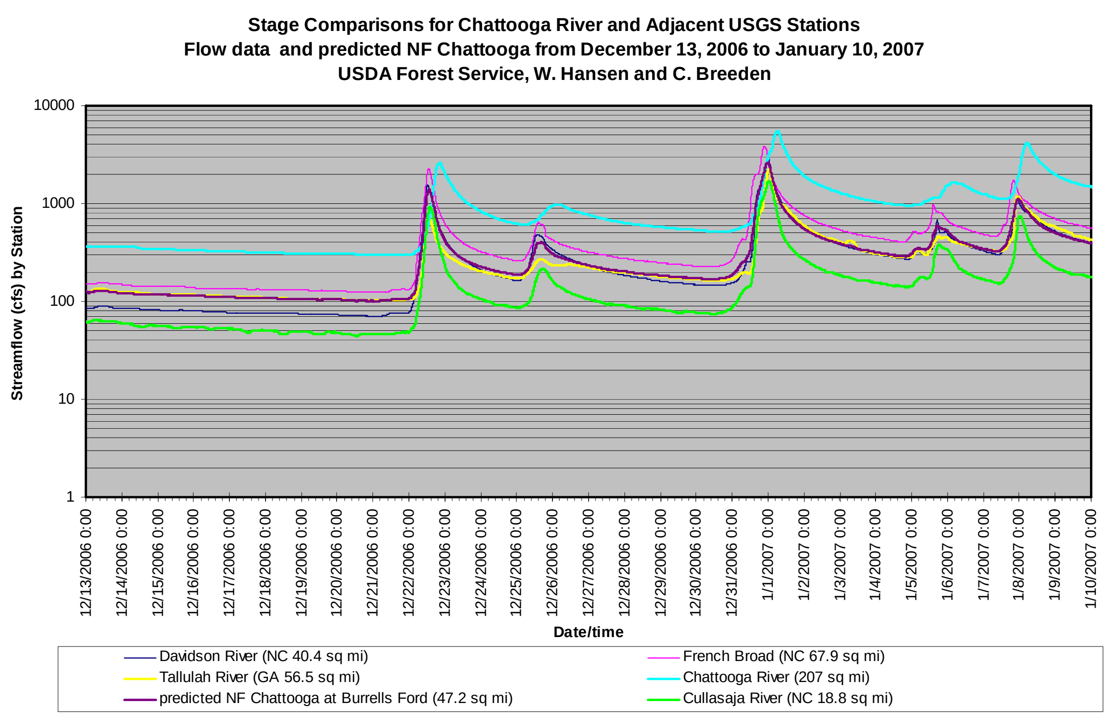


Figure 15



Figures 16-18 show comparisons in storm beginning, peak and ending flows for all the stations during three selected storm events.

Figure 16

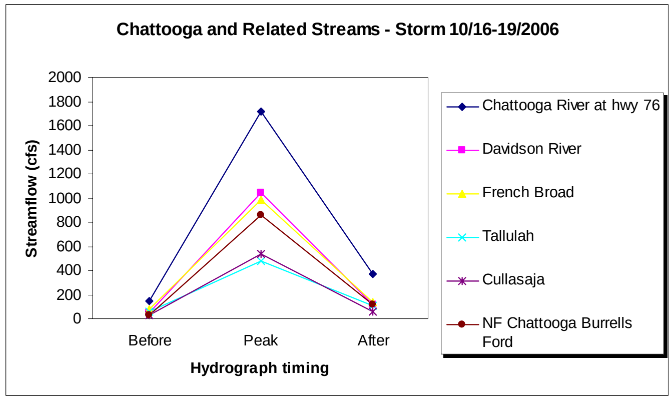


Figure 17

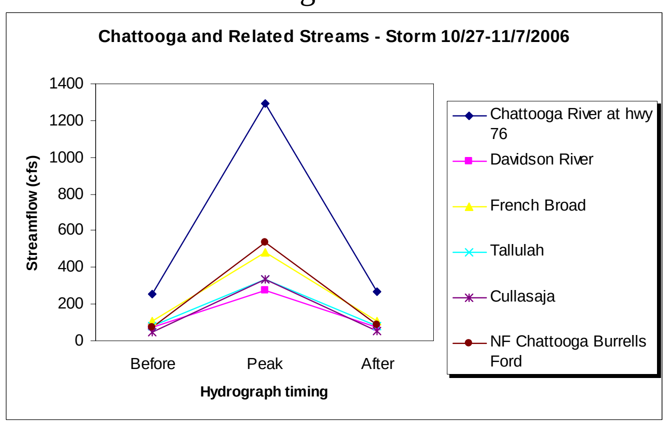
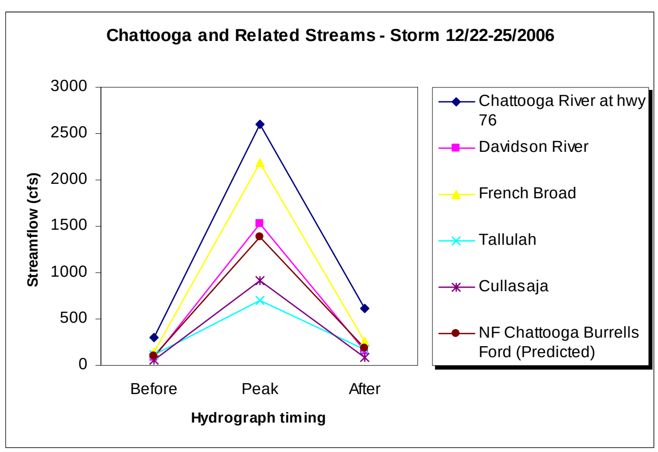


Figure 18



Figures 13 through 18 are examples of compiling flow and storm data and making it available for evaluation. There is much detail not presented at this time, and until we have some higher flows measured at the Burrells Ford and some of the other sites, compiling and presenting all the information is not appropriate. Although the user capacity analysis honed in on the relationship between the North Fork Chattooga River and the Chattooga River at Highway 76, the other stations in the vicinity also offer some potential for correlation and interpretation. The comparison of the Upper Chattooga and Lower Chattooga has definite timing issues that are especially noticeable during storm periods. Response to summer thunderstorms is another variable that causes uncertainty for all stations. Nonetheless, many of the river users have learned or chosen to rely on the Chattooga gage at 76 and perhaps augment this with the Weather Channel in assessing Upper Chattooga river levels, flows and conditions. The correlations between these two stations are about as good as we can expect under the circumstances.

The other nearby gages comparisons are not as well known by users. Plots and equations comparing the North Fork at Burrells Ford with all of the individual stream gages could be accomplished, but in looking at the figures, these comparisons are unlikely to produce anything significantly better.

And some of the river users are more keyed into river stages based on staff gages or the marks painted by boaters onto bridge piers. There are variances in stream channels at different locations, and the staff gage or other markings are unique to that station. Comparing river levels does not work without some type of forecasting table such as developed by Gordon Howard (1972). Individual site characteristics such as channel width, depth, cross section, slope, velocity, etc. alter the stage discharge relationship. The conversion of river stage to flow helps to improve and provide a communication tool. And the normalizing of flow data by area can have some benefits, but may also add to confusion, so this was avoided to a large extent for this report, except for the flow duration curves.

Available Reference Stream Channel Geomorphic Data

Stream reference curve data for bankfull flow are available from North Carolina streams (Harman et. al., 1999). These estimates are useful indicators of bankfull channel morphology and are helpful indicators of channel capacity differences by drainage size within the Chattooga River (Table 2). These data may be discussed in more detail in the final report.

Table 2. North Carolina Reference Curves

North Carolina Reference Curves

Equation

a Bankfull Cross-Sectional Area vs. Drainage Area: $y = 21.61x^{0.68}$

b Bankfull Discharge vs. Drainage Area: $y = 100.64x^{0.76}$

c Bankfull Width vs. Drainage Area: $y = 19.05x^{0.37}$

d Bankfull Mean Depth vs. Drainage Area: $y = 1.11x^{0.31}$

e Discharge/cross section = velocity (ft/sec) estimated from equations b/a

Chattooga Sites	Area (sq mi)	BFXS	BFD	BFW	BFMD	V
		a	b	c	d	e
	1	22	101	19	1.1	4.7
	2	35	170	25	1.4	4.9
	3	46	232	29	1.6	5.1
	4	55	289	32	1.7	5.2
	5	65	342	35	1.8	5.3
	6	73	393	37	1.9	5.4
	7	81	442	39	2.0	5.4
Grimshaws	8	89	489	41	2.1	5.5
	9	96	535	43	2.2	5.6
	10	103	579	45	2.3	5.6
	20	166	981	58	2.8	5.9
Bull Pen	23.4	184	1105	61	2.9	6.0
	30	218	1335	67	3.2	6.1
	40	265	1661	75	3.5	6.3
Burrells Ford	47.2	297	1884	79	3.7	6.3
	50	309	1968	81	3.7	6.4
	60	350	2260	87	3.9	6.5
Highway 28	64.4	367	2385	89	4.0	6.5
	70	388	2541	92	4.1	6.5
	80	425	2813	96	4.3	6.6
	90	461	3076	101	4.5	6.7
	100	495	3333	105	4.6	6.7
	200	793	5644	135	5.7	7.1
Highway 76	207	812	5793	137	5.8	7.1
	300	1045	7680	157	6.5	7.3

The above equations from NC stream geomorphic curves (Harman et. al., 1999)
The values presented do not necessarily suggest level of significance.

In Table 2, extrapolating the NC reference stream data for Chattooga at Highway 76 (207 square miles), estimated measures at bankfull flow would have a cross section of 812 square feet, discharge of 5,793 cfs, width of 137 feet, mean depth of 5.8 feet and calculated velocity of 7.1 ft/sec. For the NF Chattooga at Burrells Ford, bankfull flow would have a cross section of 297 square feet, discharge of 1,884 cfs, width of 79 feet, mean depth of 3.7 feet and calculated velocity of 6.3 ft/sec. However, recognizing that the Upper and Lower Chattooga stations are within the highest rainfall area of North Carolina, these estimates in bankfull flow and channel dimensions may be low.

Regardless, bankfull flows are substantially higher than those considered boatable or fishable, and they occur less than 1% of the time each year. However, they are the flows that form the primary channel shape that boatable and fishable flows are contained in. So totally disregarding this information as a tool for estimation of channel change could be limiting. Many of the stream sections exhibit a Rosgen F channel shape. This is an entrenched channel with a high width to depth ratio, and limited floodplain. At lower flows, the F type channels tend to be relatively broad and shallow. At high flows, floods are typically contained within the channel or may expand to narrow floodprone areas adjacent to the channel. The NC reference curves for the mountains provide useful information for a "typical" riffle at bankfull flow including width, mean depth, velocity and cross section area.

One potential opportunity to be explored is the potential availability LiDAR ground surface data for most counties in North Carolina. Even though LiDAR includes detailed topographic data, open water conditions are not included. However, this data could help characterize channel widths, sinuosity, bankfull or floodprone elevations, gradients, etc. These data would also help locate specific channel features like falls, cascades, etc.

Analysis of the channel morphology is not contemplated for the different sites. At the Burrells Ford site, topographic channel forms and channel cross section data were collected and benchmark references install. The other sites with staff gages have some basic benchmark and reference data collected. The data insure that the staff gages can be reset if damaged, may provide benchmark channel form data at the measured sites for time comparisons, and provide reference when adjustments are warranted due to changed conditions, such as from a flood or landslide. The data were not relevant to this specific report, and were not included.

NF Chattooga River at Burrells Ford and Highway 28

The provisional stage discharge relationship was developed for the North Fork at Burrells Ford and Highway 28 by wading measurements on several occasions and a couple of high flow measurements taken by the USGS under agreement for this study. Some old measurements of stage and discharges from individual storms were also available for these sites. The provisional stage discharge relationships for this analysis as of January 2007 was described (Figures 19 and 20). Additional storm peaks are going to be collected by the USGS under agreement, and these will refine the flows at the stages above 2 feet or over 700 cfs from the power function at Burrells Ford and above 5.4 feet (new gage) and 1,400 cfs at the Highway 28 gage. As these new data come in, the flow readings will be adjusted according to the new equations developed.

Figure 19. Provisional stage discharge relationship for North Fork Chattooga at Burrells Ford as of January 11, 2007.

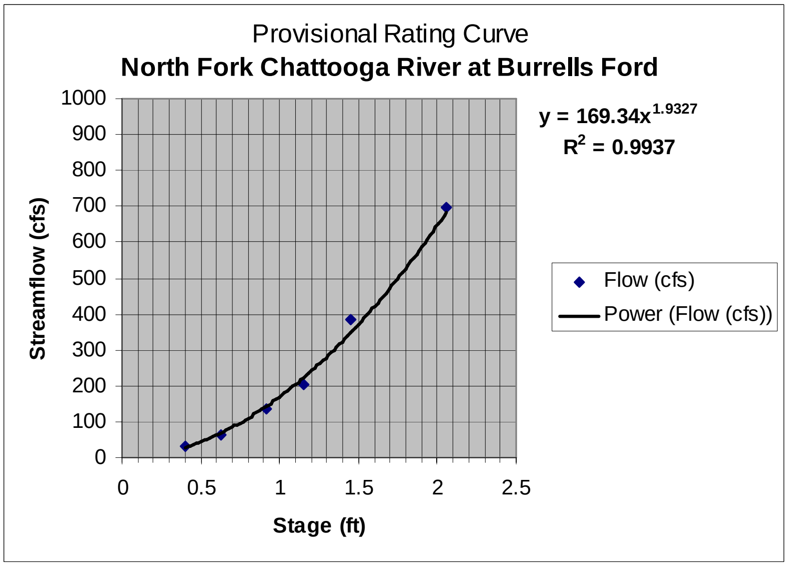
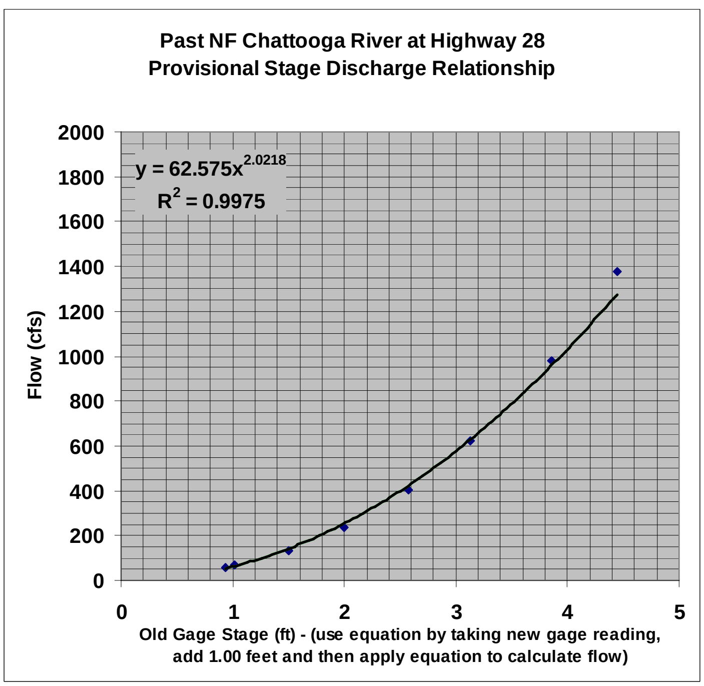


Figure 20. Provisional stage discharge relationship for North Fork Chattooga at Highway 28 Bridge as of January 18, 2007. Note equation is for old gage, need to add 1 foot to existing gage readings, then apply this equation. This will be adjusted at some point.

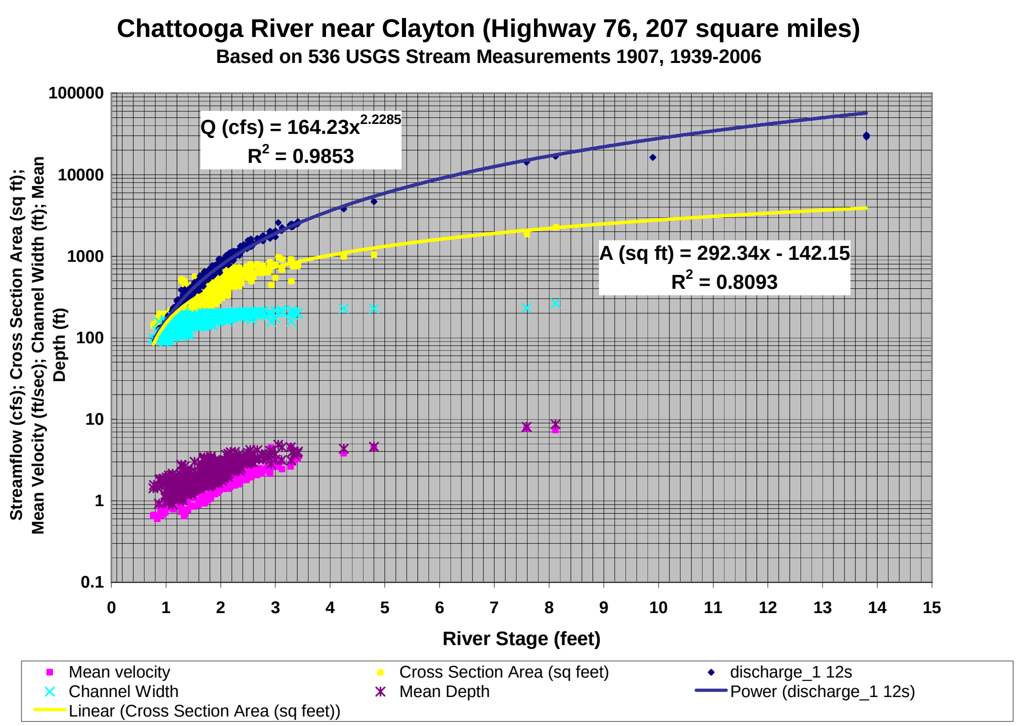


Chattooga River at Highway 76 Streamgage Stage Discharge Relationship

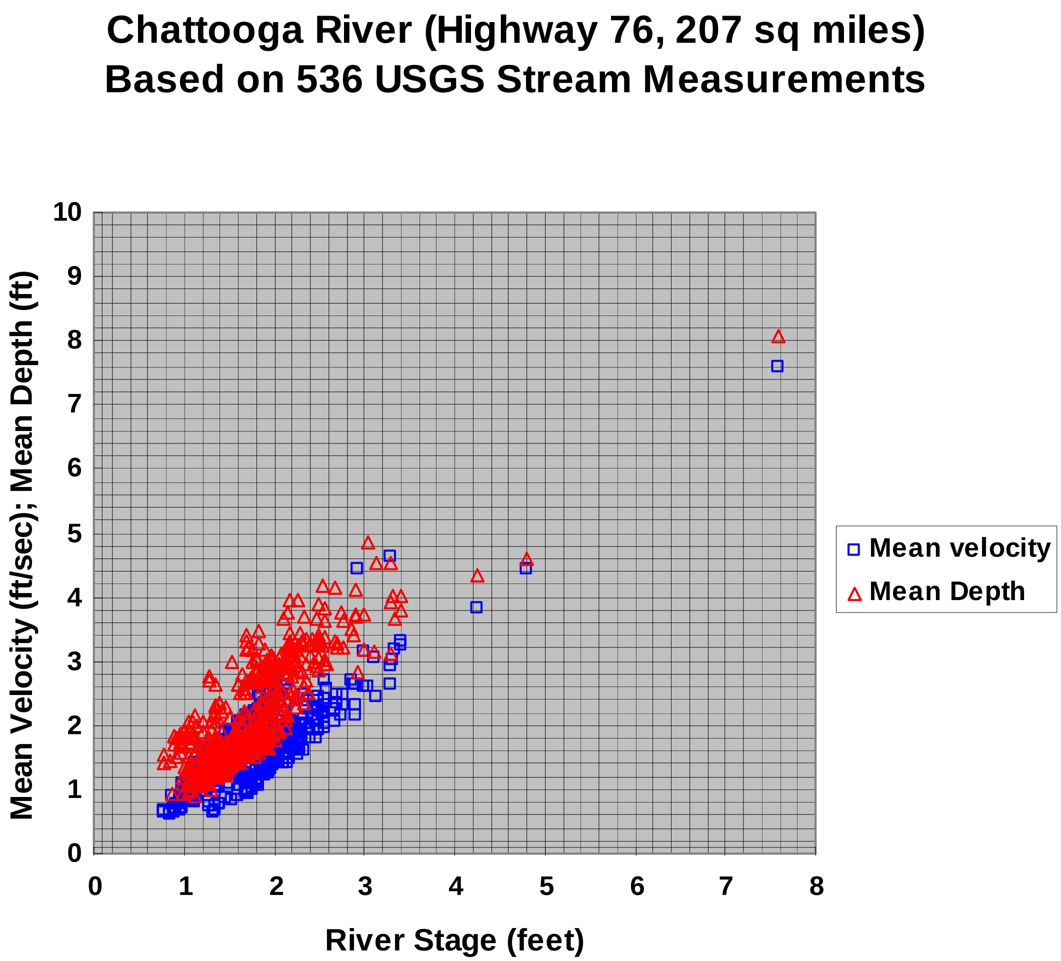
The long term stage - discharge data and associated measurements were plotted from the field measurements during the last 68 years (Figure 21). These data, especially the lower flow data that was based on wading measurements were not always collected at the same site. Higher flows were typically collected from the bridge, however the most recent measures typically use a Doppler System that is more accurate. The trend line and equation for mean velocity were not impressive or included. Since the measurement cross section is sometimes shifted upstream or downstream for a specific measurement, the mean velocity, width, depth and cross section readings can also vary with these changes. However, the discharge is the composite of all these minor adjustments as they interact with the staff gage. The various channel data collected with the flow measures were included for reference.

The data show mean velocities of 4.4 feet per second at a flow rate of 950 cfs and 7.6 feet/second at a flow rate of 1,870 cfs. Mean velocities across the cross section may be useful for estimating differences in storm peak lag times. The channel entrenchment of the Rosgen F shape is also evident in the data, even though there may be some adjustments in measurement location near the bridge. From stage 2.5 to 3.4, most of the channel widths are around 200 feet, the width increases to 228 feet to stage 7.6 feet. These indicate near vertical containment of the channel.

Figure 21



The near vertical entrenchment prevents the expansion onto floodplain, resulting in the changes in stream depth and velocity to be more severe than a stream that access to a well developed floodplain (Figure 22). The entrenchment at the higher river stages on this figure indicate that for every foot rise in river stage, mean depth also rises a foot and mean velocity rises about 1 foot/second.



The USGS typically has more accurate data that explains how each gaged river has adjusted in form due to time and major floods. The refined equations respond to the natural as well as induced channel shifts that have occurred at that location.

Stage discharge relationships have been developed for all the other real-time gages mentioned in this report. The field records for these sites are available on the USGS website. There is no reason to expect that those data will be needed in this analysis.

FINDINGS

Although little was initially known about the comparison of the flow characteristics within the North Fork Chattooga River, gaging the North Fork at Burrells Ford and compiling the data from several gages within the vicinity including the Chattooga River at Highway 76 has added substantially to what we know about the response of the Upper Chattooga. However, the data collected are still relatively short term and adjustments will be made in the flows as improved storm data becomes available.

The data collected so far suggest that:

1. Rainfall frequency maps that the Upper Chattooga has more rainfall per unit area than the Lower Chattooga, which should produce more flow per unit area. The flows estimated at Burrells Ford support more unit flow except for the summer storm periods. For significant periods each year, the North Fork is producing more than the 23% of the expected flow in relation to the Chattooga River at Highway 76. Summer non-storm, and dormant season storm and non-storm data suggest the North Fork at Burrells Ford is producing about 27, 32 and 31 percent of the flow, respectively. These data were not compensated for the time lag between the stations, but that should not affect these types of comparisons. Storm peaks were compared and these do account for the time lag. Peak flow data show that the North Fork at Burrells Ford has peaks that are almost half the peaks in the Chattooga River at Hwy 76. Six of the storms used in this comparison were extrapolated beyond the current stage discharge rating curve of 700 cfs for the North Fork, so some adjustments in these data may occur for the final report.
2. Without a permanent gage in the Upper Chattooga, predictions using the Lower Chattooga gage are challenging. A correlation does exist between these sites, but it is based in part on what has already happened in the Upper Chattooga contributing area that is contained within the Lower Chattooga Watershed. These two sites are not independent variables and there is generally no capability for prediction except after the fact (some call that hindsight). It is useful for characterizing what has happened rather than what is or could happen.
3. Flow correlations between the North Fork at Burrells Ford and the Lower Chattooga at Highway 76 are still fair to very good, depending on the storms and seasonal flow regime, with summer and storm periods more erratic, and non-storm dormant with groundwater recharged, stable.
4. Referencing adjacent real-time stations and weather channel information can provide added means for estimating North Fork flows. Although this approach is viable, it is not as user friendly as a real-time stream or rainfall gages.
5. The time lag in the Chattooga at 76 flow response are the results of individual storm, rainfall and associated differences in timing that affect the timing of how streams within the vicinity respond to these events.

6. A general trend in time lag was found. The erratic time lag for flows less than 500 cfs that varies from -2 to 25 hours suggests that individual storms are in control, and estimations to what is going on in the Upper Chattooga are weak. Although the peak storm data comparisons beyond 500 cfs in the North Fork are limited to 8 storms, the trend suggests that lag times in storm peaks between the two sites with increasing flows appear less erratic at 500 cfs with 8-9 hours lag, declining to about 5 hours at 2,000 cfs and 3 hours for flows at 3,100 cfs in the North Fork. These lag times correspond to approximate flows of 1,100 cfs, 4,200 cfs and 5,400 cfs in the Lower Chattooga based on the storm peak timing and flow data collected (Figure 12).

At this stage, there are no final conclusions. The information collected and analyzed in this report suggest that we do have enough reason to use the correlated data with other stations as needed, as long as we recognize the storm and other conditions that contribute to uncertainty. Much information has been compiled for possible future uses. Measurements in the North Fork Chattooga will continue in the near future to provide added information that may be needed for this analysis.

ACKNOWLEDGEMENTS

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