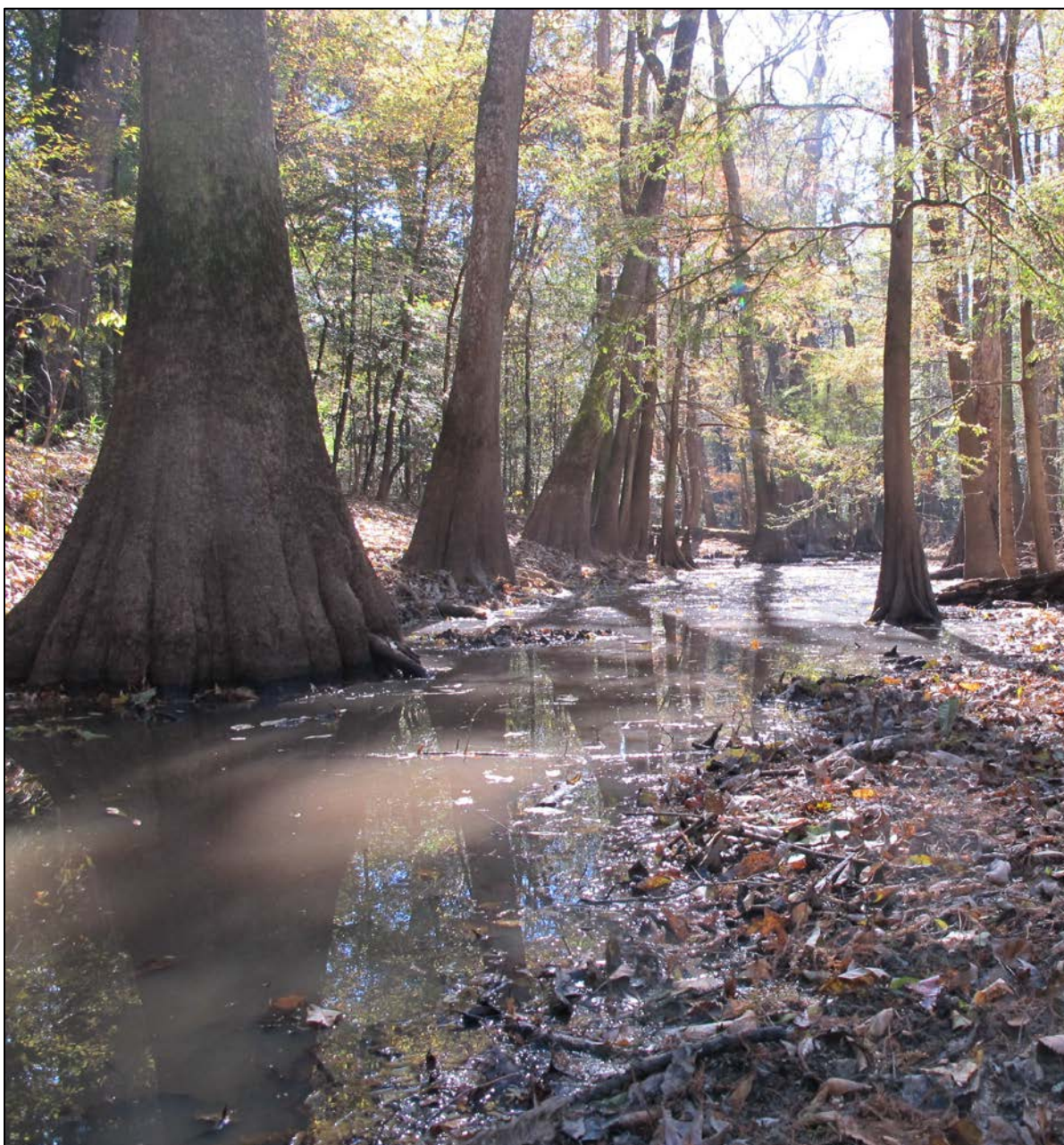




Summary of Stream Flow Conditions at Five Riverine Parks in the Southeast Coast Network, 2013

Natural Resource Data Series NPS/SECN/NRDS—2014/700



ON THE COVER

Chute channel flowing on the Congaree River floodplain due to high water in the Congaree River. December 2013. Photo by M.B. Gregory

Summary of Stream Flow Conditions at Five Riverine Parks in the Southeast Coast Network, 2013

Natural Resource Data Series NPS/SECN/NRDS—2014/700

M. Brian Gregory
National Park Service
Southeast Coast Network
Athens, GA 30602

Jeffery Kao
Warnell School of Forest Resources
University of Georgia
Athens, GA 30602

September 2014

U.S. Department of the Interior
National Park Service
Natural Resource Stewardship and Science
Fort Collins, Colorado

The National Park Service, Natural Resource Stewardship and Science office in Fort Collins, Colorado, publishes a range of reports that address natural resource topics. These reports are of interest and applicability to a broad audience in the National Park Service and others in natural resource management, including scientists, conservation and environmental constituencies, and the public.

The Natural Resource Data Series is intended for the timely release of basic data sets and data summaries. Care has been taken to assure accuracy of raw data values, but a thorough analysis and interpretation of the data has not been completed. Consequently, the initial analyses of data in this report are provisional and subject to change.

All manuscripts in the series receive the appropriate level of peer review to ensure that the information is scientifically credible, technically accurate, appropriately written for the intended audience, and designed and published in a professional manner. Data in this report were collected and analyzed using methods based on established, peer-reviewed protocols and were analyzed and interpreted within the guidelines of the protocols.

Views, statements, findings, conclusions, recommendations, and data in this report do not necessarily reflect views and policies of the National Park Service, U.S. Department of the Interior. Mention of trade names or commercial products does not constitute endorsement or recommendation for use by the U.S. Government.

This report is available in the Reports and Publications section of the Southeast Coast Inventory and Monitoring Network webpage (<http://science.nature.nps.gov/im/units/secn/>) and the Natural Resource Publications Management website (<http://www.nature.nps.gov/publications/nrpm>). To receive this report in a format optimized for screen readers, please email irma@nps.gov.

Please cite this publication as:

Gregory, M. B. and J. Koa. 2014. Summary of stream flow conditions at five riverine parks in the Southeast Coast Network, 2013. Natural Resource Data Series NPS/SECN/NRDS—2014/700. National Park Service, Fort Collins, Colorado.

Contents

	Page
Figures.....	v
Tables.....	vi
Summary and Key Findings.....	vii
Chattahoochee River National Recreation Area.....	vii
Congaree National Park.....	viii
Horseshoe Bend National Military Park.....	viii
Kennesaw Mountain National Battlefield Park.....	viii
Ocmulgee National Monument	ix
Introduction.....	1
Purpose and Scope.....	1
Parks Included in this Summary.....	1
<i>Chattahoochee River National Recreation Area</i>	2
<i>Congaree National Park</i>	3
<i>Horseshoe Bend National Military Park</i>	4
<i>Kennesaw Mountain National Battlefield Park</i>	4
<i>Ocmulgee National Monument</i>	4
Methods.....	6
Data Acquisition and Analysis	6
Assessment Criteria	7
Results.....	10
Summary of Flow Conditions in SECN Riverine Parks.....	10
Chattahoochee River National Recreation Area.....	10
Congaree National Park.....	10
Horseshoe Bend National Military Park.....	11

Contents (continued)

	Page
Kennesaw Mountain National Battlefield Park	11
Ocmulgee National Monument	11
Literature Cited	29
Appendix A. Station Metadata Information.....	31
Chattahoochee River at Buford Dam in Georgia (02334430).....	31
Chattahoochee River near Norcross, Georgia (02335000).....	31
Chattahoochee River above Roswell, Georgia (02335450)	31
Chattahoochee River at Atlanta, Georgia (02336000)	31
Wateree River below Eastover, South Carolina (02148315)	31
Gageing at this site was discontinued July 15, 2014	31
Congaree River at Columbia, South Carolina (02169500).....	32
Tallapoosa River at Wadley, Alabama (02414500)	32
Tallapoosa River at New Site, Alabama (Horseshoe Bend) (02414715)	32
Ocmulgee River near Jackson, Georgia (02210500).....	32
Ocmulgee River at Macon, Georgia (02213000)	32
Noses Creek at Powder Springs Road at Powder Springs, Georgia (02336968)	33

Figures

	Page
Figure 1. Map showing locations of inland riverine parks in the Southeast Coast Network. Individual park maps show locations of U.S. Geological Survey gages near and within park boundaries.	2
Figure 2. Park units and management sections along Chattahoochee River National Recreation Area in Atlanta, Georgia.	3
Figure 3. Daily flow (blue line), historical median monthly flow since the construction of Buford Dam (dots), and interquartile range (error bars) for the Chattahoochee River near Buford, Georgia in 2013.	16
Figure 4. Daily flow (blue line), historical median monthly flow since the construction of Buford Dam (dots), and interquartile range (error bars) for the Chattahoochee River near Norcross, Georgia in 2013.	17
Figure 5. Daily flow (blue line), historical median monthly flow since the construction of Buford Dam (dots), and interquartile range (error bars) for the Chattahoochee River above Roswell, Georgia in 2013.	18
Figure 6. Daily flow (blue line), historical median monthly flow since the construction of Buford Dam (dots), and interquartile range (error bars) for the Chattahoochee River at Atlanta, Georgia in 2013.	19
Figure 7. Daily flow (blue line), historical median monthly flow (dots), and interquartile range (error bars) for Noses Creek at Powder Springs Road, Powder Springs, Georgia in 2013.	20
Figure 8. Daily flow (blue line), historical median monthly flow (dots), and interquartile range (error bars) for the Wateree River below Eastover, South Carolina in 2013.	21
Figure 9. Daily flow (blue line), historical median monthly flow (dots), and interquartile range (error bars) for the Congaree River at Columbia, South Carolina in 2013.	22
Figure 10. Daily flow (blue line), historical median monthly flow (dots), and interquartile range (error bars) for the Tallapoosa River at Wadley, Alabama in 2013.	23
Figure 11. Daily flow (blue line), historical median monthly flow (dots), and interquartile range (error bars) for the Tallapoosa River near New Site, Alabama (Horseshoe Bend) in 2013.	24
Figure 12. Daily flow (blue line), historical median monthly flow (dots), and interquartile range (error bars) for the Ocmulgee River near Jackson, Georgia in 2013.	25
Figure 13. Daily flow (blue line), historical median monthly flow (dots), and interquartile range (error bars) for the Ocmulgee River at Macon, Georgia in 2013.	26

Tables

	Page
Table 1. U.S. Geological Survey station names, drainage areas, and periods of record used to calculate flow metrics for Southeast Coast Network riverine parks during 2013.....	5
Table 2. Indicators of Hydrologic Alteration metrics and Environmental Flow Components calculated and used in this report.....	7
Table 3. Assessment criteria for evaluating status of flow conditions at Chattahoochee River National Recreation Area from NPS Resource Stewardship Strategy (NPS 2010) and Nestler et al. (1986).....	9
Table 4. Assessment criteria for evaluating status of flow conditions on the Congaree River and in Congaree National Park using a two-dimensional flow model (Kupfer and Meitzen 2012) and flows at Columbia, South Carolina.....	9
Table 5. Monthly median flow magnitudes for Southeast Coast Network riverine parks during 2013.....	13
Table 6. One- to 90-day extreme flow magnitudes at Southeast Coast Network riverine parks during 2013.....	14
Table 7. Environmental Flow Components (TNC 2009) for flows in Southeast Coast Network riverine parks during 2013.....	14
Table 8. Number of days flow criteria and activity thresholds were met or exceeded in four sections of the Chattahoochee River National Recreation Area in Atlanta, Georgia during 2013.....	27
Table 9. Percentage and duration of inundation at Congaree National Park due to high flows on the Congaree River during 2013 as predicted by a two-dimensional flood model (Kupfer and Meitzen 2012).....	28

Summary and Key Findings

- The National Park Service Southeast Coast Network (SECN) evaluated stream flow variability and the magnitude and timing of specific flow events at five Network parks in 2013. The streams and rivers of these parks range in size from small creeks to small- and medium-sized rivers that encompass significant park acreage along the Chattahoochee, Congaree, Ocmulgee, Wateree, and Tallapoosa Rivers.
- Flow patterns were characterized and put in historical context using U.S. Geological Survey stream flow data, The Nature Conservancy's Indicators of Hydrologic Alteration software, and Flow software (Dowd 2011), which generates graphical representations of annual stream flow data.
- Flows across SECN parks were highly variable in 2013 and exhibited both extremely high and low flow conditions over the periods of record (PORs) used for the analysis. Median monthly flows were typically lower than normal to normal in most SECN parks in the winter months; however, flows in Kennesaw Mountain National Battlefield Park (KEMO) and Horseshoe Bend National Military Park (HOBE) were slightly higher than normal in January. Flows across the region quickly reached record high levels between May and August. Flows in the Congaree and Wateree Rivers approached near-record median monthly levels in July and August, and median monthly flows in the Congaree River in July were the highest observed in the last 75 years.

Chattahoochee River National Recreation Area

- For the purpose of this report, the Chattahoochee River was divided into four segments (referred to as Sections 1- 4) between Buford Dam and the park unit farthest downstream (near river mile 305.5) so that flow characteristics could be more accurately described by a corresponding USGS gage located within each segment (NPS 2013).
- Mean monthly flows in the Chattahoochee River were highest from May to July and lowest from January to March. Median monthly low flows from January to March approached record levels, and median monthly low flows in the river section near Buford Dam during this period were the lowest observed in the last 54 years.
- One-day low flows were above normal in Sections 2 and 3 of the Chattahoochee River but slightly below normal in Section 4. Three-day to 90-day low flows were near normal to slightly below normal in all river sections during 2013. One-day maximum flows were well above normal in Sections 1-3 of the Chattahoochee River.
- The number of low flow pulses was below the normal expected range. The number of high flow pulses was in the normal range in all river sections except Section 4, where high flow pulses were more common than normal. Small flood events occurred eight times in Section 1 and four times in Sections 2 and 3 in 2013, which exceeded normal in each section.
- Flows in the Chattahoochee River in 2013 favored recreational activities better suited for higher flow conditions. Flows greater than 2,000 cubic feet per second (cfs) were recorded on

the majority of days in all sections of the river. No flows in Section 4 were below the state-mandated minimum flow of 750 cfs.

Congaree National Park

- Mean monthly flows in the Congaree and Wateree Rivers were generally highest in the summer months. Near-record median monthly flows were observed in the Wateree River in July and August, and the highest median monthly flow recorded in 75 years was observed in July in the Congaree River.
- One- to 90-day low flows were normal to above-normal in the Congaree and Wateree Rivers. One- to 90-day high flows were in the normal range in the Wateree River. One-day and three-day high flows were above average for the Congaree River near Congaree National Park (CONG).
- Low flow pulses were rare in both the Congaree River and the Wateree River and occurred only a single time in the Congaree River in January. High flow pulses were common in 2013 and occurred eight times in the Wateree River and 26 times in the Congaree River.
- A two-dimensional flow model (Kupfer and Meitzen 2012) predicted that based on flows in the Congaree River at Columbia, 60-80% of CONG was inundated for approximately 20 days in 2013. Forty to 60% of the Park was predicted to have been inundated for approximately 67 days. Low-lying eastern areas of the Park may have been inundated for up to 131 days.

Horseshoe Bend National Military Park

- A record mean monthly flow was recorded in January in the Tallapoosa River near Wadley, and near-record flows were observed again in May and July at both stations in the Tallapoosa near HOBE. Flows were above normal in January and February.
- One- to 90-day low flows were all above normal at the Wadley site upstream of HOBE but near normal at the New Site downstream of the Park. One- to three-day high flows were above average upstream of HOBE, as were one-day high flows downstream of the Park.
- Low flow pulses were rare in the Tallapoosa River in 2013, with zero recorded at the Wadley gage and four recorded downstream of HOBE at the New Site gage. High flow pulses were more common than normal both upstream and downstream of HOBE, with 33 high flow pulses observed at Wadley and 27 observed downstream of the Park. A single small flood was recorded in the Tallapoosa in July.

Kennesaw Mountain National Battlefield Park

- Median monthly flows in Noses Creek were generally highest in February, March, and December. Above-average flows were common for the entire year, and only flows in September to November approached the normal range.
- One- to 90-day low flows and were in the average range over the POR for the year.

- No low flow pulses were observed along Noses Creek at KEMO; however, the greatest number of high flow pulses recorded over the POR (33) was observed in 2013. A single small flood was recorded in May.

Ocmulgee National Monument

- Mean monthly flows in the Ocmulgee River near Ocmulgee National Monument (OCMU) were generally high from February to August, although flows in the Ocmulgee River near Macon in January were well below the range of average flows for the POR.
- One- to 90-day low and high flows were all in the average range for the POR in the Ocmulgee River.
- The number of low flow pulses was somewhat below average in the Ocmulgee River in 2013, with three low flow pulses recorded upstream of OCMU near Jackson and eight recorded near OCMU at Macon. High flow pulses were more common and occurred at a rate much higher than normally expected, with 24 events occurring upstream of OCMU and 19 occurring at the Macon gage near the Monument.

Introduction

Evaluation of the flow characteristics of a river or stream offers some of the most appropriate and useful indicators for assessing the aquatic ecosystem's integrity and for monitoring environmental changes over time. It also provides key supporting data for other vital signs including water quality, threatened and endangered aquatic species, wetlands, and riparian habitats. A stream's flow regime can be thought of as a primary governing factor that is largely responsible for determining the type and magnitude of various physical and ecological processes that occur in a stream system (Puckridge et al. 1998). Although other environmental factors and characteristics of a stream influence the overall condition of a stream and its biological communities, a stream's flow is thought of as the master variable (Power et al. 1995). Stream flow has been shown to provide important conceptual and empirical linkages between watershed conditions, in-stream habitats, and the biotic integrity of stream biological communities. The large amount of uncertainty associated with many projections for changes in water availability due to climate change (Brekke et al. 2009; Miller and Yates 2006) means that more data are likely needed before the direction and magnitude of the influence can be inferred. This large amount of uncertainty has led to a federal recommendation to increase the tracking of water resources so that changes can be monitored more closely and water availability can be anticipated (Brekke et al. 2009).

Purpose and Scope

In an effort to evaluate the significance of changes in flow regimes due to both naturally-occurring and regulated conditions, the National Park Service (NPS) Southeast Coast Network (SECN) began harvesting relevant stream flow data sets collected at selected sites and disseminating this data to Network parks in the context of historical flow characteristics and/or park-specific flow thresholds. This report provides a summary of the previous calendar year's flow conditions in the context of recent historical flows (table 1) and provides information on overall flow variability as well as the seasonality and timing of ecologically relevant flow events in rivers near or adjacent to SECN parks. Data from the Chattahoochee River in Atlanta, Georgia are put in the context of river flow thresholds that have management or visitor use implications (Nestler et al. 1986), whereas data collected from the Congaree River in Columbia, South Carolina are presented in the context of a recently published flood inundation model (Kupfer and Meitzen 2012) that estimates the amount of inundation that occurred throughout the park during the previous year.

The NPS makes use of publically available data sets from stations monitored by the U.S. Geological Survey (USGS) Water Science Centers in Alabama, Georgia, and South Carolina as part of various ongoing national, state, and locally funded projects. Links to stream flow data sets, as well as additional ancillary water quality data sets collected during the previous water year (October to September) for stations included in this analysis, are provided in appendices. This effort is part of the SECN Surface Water Quantity monitoring effort described by DeVivo et al. (2008).

Parks Included in this Summary

SECN parks include a diversity of stream sizes and types, and many (if not all) have been altered by human activities, including impoundments, channelization, lowering of water tables, increased runoff due to urbanization, pollution, sedimentation, recreation, and introduced species (including mussels, fishes, and aquatic plants). Stream flows have a large influence on stream biota (Hackney and Adams 1992), and nearly all major stream systems in the southeastern United States have been channelized or dammed (Adams and Hackney 1992). Many major reservoirs have been constructed, and all large rivers flowing in or adjacent to SECN parks have managed flows. Five parks within the Network

were selected for evaluations—those characterized by significant non-tidal, flowing water resources within or adjacent to park boundaries (figure 1). In some cases, data from stations outside and upstream of these parks was included in the evaluation if such data could help characterize flow conditions within the park. The USGS gage on Cedar Creek, located in Congaree National Park, was not included in this analysis because only stage data have been recorded at that site. The lotic resources of the five parks range in size from small streams to small- and medium-sized rivers, encompassing significant park acreage along the Chattahoochee, Congaree, and Tallapoosa Rivers.

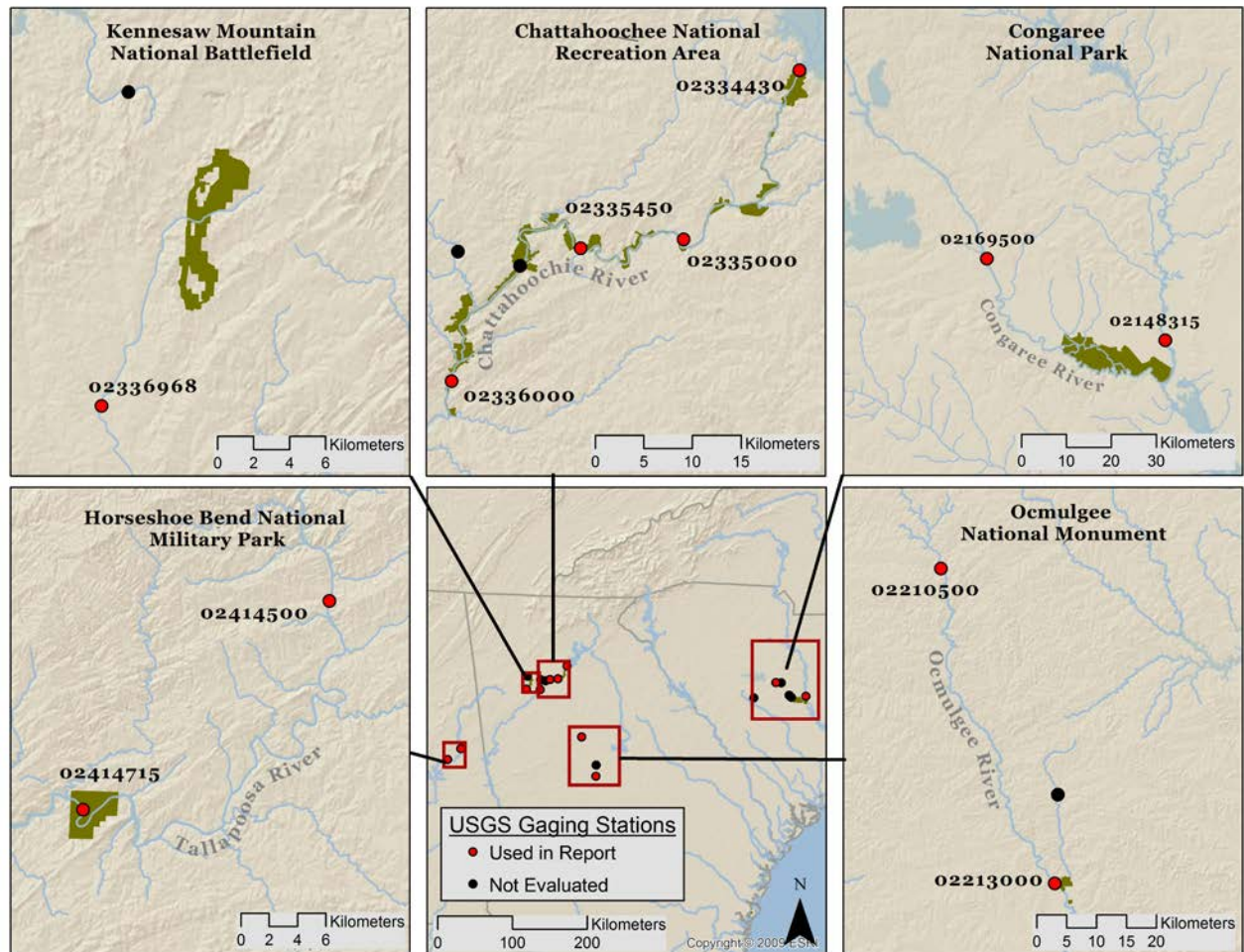


Figure 1. Map showing locations of inland riverine parks in the Southeast Coast Network. Individual park maps show locations of U.S. Geological Survey gages near and within park boundaries.

Chattahoochee River National Recreation Area

The Chattahoochee River National Recreation Area (CHAT) is made up of 6,800 acres of mixed pine/hardwood forests and wetlands that buffer 48 miles of the Chattahoochee River (figure 1) in the greater Atlanta, Georgia metropolitan area. Surface water bodies within CHAT include: the Chattahoochee River and associated tributaries; Bull Sluice Lake; Sibley Pond (in the Cochran Shoals unit); and Island Ford Pond. Flows upstream of the Park are regulated by Buford Dam, which has impounded Lake Lanier since its completion in 1956. Current regulations require that the flow be 750 cubic feet per second (cfs) at the confluence of the Chattahoochee River and Peachtree Creek; however beginning in 2008, the Georgia Environmental Protection Division allowed this standard to be lowered by 100 cfs during droughts to preserve storage in Lake Lanier (GAEPD 2008). Although

flooding is now rare, the river attracts large numbers of visitors that engage in fishing, boating, and rafting activities, all of which depend on adequate flows.

For the purpose of this report, the Chattahoochee River was divided into four segments (referred to as Sections 1-4) between Buford Dam and the park unit farthest downstream (near river mile 305.5) so that flow characteristics could be more accurately described by a corresponding USGS gage located within each segment (figure 2; NPS 2013).

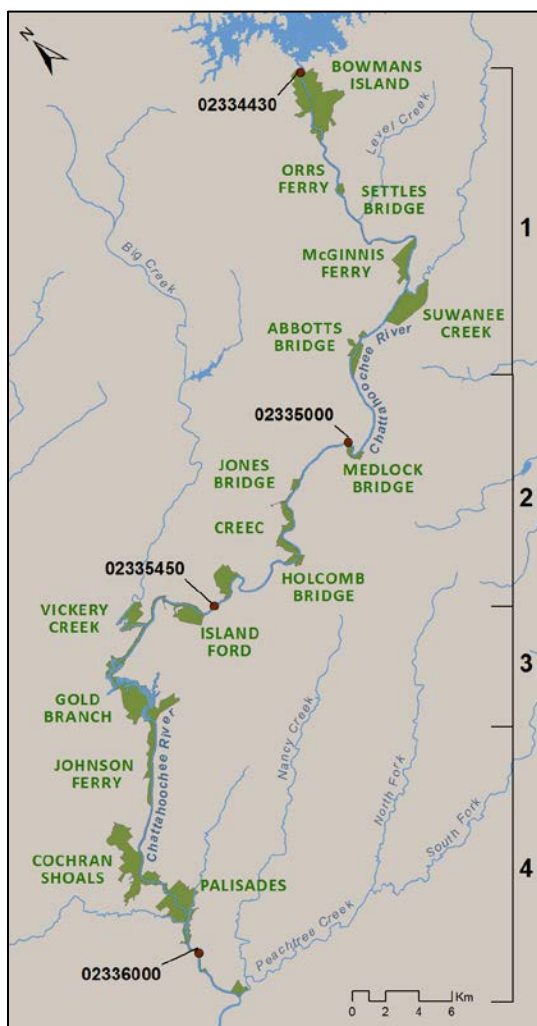


Figure 2. Park units and management sections along Chattahoochee River National Recreation Area in Atlanta, Georgia.

Congaree National Park

Congaree National Park (CONG) lies in the floodplain of the Congaree River in the Coastal Plain physiographic province of South Carolina (figure 1). CONG is made up of 24,180 acres of currently-owned land and 26,776 acres of authorized area. The upstream watershed includes over five million acres (Knowles et al. 1996), and major flooding events along the Congaree River, driven primarily by flows from the Broad River, may occur an average of 10 times per year. The Park consists of old-growth bottomland forests along the Congaree and Wateree Rivers, and it comprises an extensive floodplain ecosystem which depends on periodic inundation by the overflowing Congaree River. Natural flows in the Congaree River have been altered since the late 1920s by the construction of

Dreher Shoals Dam, which impounds Lake Murray. River flows from the Broad River, a major Wateree River tributary which intersects with the Wateree River approximately 23 river miles upstream of the CONG boundary, are also impacted by upstream dams and can further alter river flow patterns in the Park.

Horseshoe Bend National Military Park

Horseshoe Bend National Military Park (HOBE) is made up of 2,040 acres of mixed hardwood forest along the Tallapoosa River in eastern Alabama (figure 1). Most of HOBE is upland, with approximately 10% of the area composed of wetlands. There are many open fields that commemorate historic battlefronts, and the Park averages 100,000 visitors per year. Surface water bodies at HOBE include the Tallapoosa River and Whale Creek. Surface water resources in the HOBE study area include the Tallapoosa River and numerous creeks, including Emuckfaw, Timbergut, Hillabee, and Dobbs Creek (NPS 1997). Flows through HOBE have been significantly affected since 1983 by the construction of the Harris Dam and Lake hydropower project.

Kennesaw Mountain National Battlefield Park

Kennesaw Mountain National Battlefield Park (KEMO) is located in the northern suburbs of the sprawling Atlanta metropolitan area in the Allatoona Mountain Range (figure 1). KEMO consists of approximately 3,000 acres of mixed hardwood pine forest and open fields. Less than 10% of KEMO is composed of wetlands and only a few small streams flow within its borders. Although the Park commemorates a famous Civil War battle fought during the Atlanta Campaign, KEMO has become a popular outdoor recreational area, receiving approximately 1.5 million visitors per year (including passing traffic). Creeks are located within KEMO, including John Ward Creek, Noses Creek, and Allatoona Creek, all of which originate outside park boundaries and drain urban and suburban areas.

Ocmulgee National Monument

Ocmulgee National Monument (OCMU) is located just above the Fall Line in Macon, Georgia (figure 1). OCMU preserves an area of Native American habitation that includes temple and ceremonial burial mounds. The 702-acre monument is surrounded by urban and suburban development and contains approximately 300 acres of wetlands. Surface water resources in the area include: the Ocmulgee River and Walnut Creek; other minor creeks including Swift Creek and Town Creek; Edwards, Club, Nelsons, and other impounded lakes and ponds; and swamps and wetlands (NPS 2002). Flows in the Ocmulgee River near OCMU have been impacted for over 100 years by the construction of Lloyd Shoals Dam (Lake Jackson) in 1911. Flows in Walnut Creek have been impacted by upstream development as well as recent beaver activity inside the Monument.

Table 1. U.S. Geological Survey station names, drainage areas, and periods of record used to calculate flow metrics for Southeast Coast Network riverine parks during 2013. [sq. mi., square miles]

Park name	Station name	USGS station ID	Drainage area (sq. mi.)	Period of record
CHAT	Chattahoochee River at Buford Dam, GA	02334430	1,040	1960-2013
	Chattahoochee River near Norcross, GA	02335000	1,170	1960-2013
	Chattahoochee River near Roswell, GA	02335450	1,230	1976-2013
	Chattahoochee River at Atlanta, GA	02336000	1,450	1960-2013
KEMO	Noses Creek near Powder Springs, GA	02336968	44.5	1999-2013
CONG	Wateree River below Eastover, SC	02148315	5,590	1969-2013
	Congaree River at Columbia, SC	02169500	7,850	1939-2013
HOBE	Tallapoosa River at Wadley, AL	02414500	1,675	1984-2013
	Tallapoosa River at New Site, AL	02414715	2,058	1984-2013
OCMU	Ocmulgee River near Jackson, GA	02210500	1,420	1988-2013
	Ocmulgee River at Macon, GA	02213000	2,240	1960-2013

Methods

Data Acquisition and Analysis

Daily value flow data spanning the recent periods of record (PORs) were downloaded from relevant USGS stations and evaluated for inclusion in this analysis. Gages were considered relevant if the station was situated on a major river or large stream located upstream of or within a park boundary. Stations with only stage data available were not used. Although 20 years of data or more is considered an ideal POR for hydrologic analyses on natural systems (Richter et al. 1997), we used stations with a minimum of 12 years of data for this analysis. Flow periods prior to the construction and filling of new reservoirs were ignored. This resulted in a more relevant historic evaluation, since the analysis incorporated more recently collected data and evaluated flow under a river's managed or more developed conditions (table 1). All USGS gages located near or within SECN parks (including PORs and data types) can be found in the SECN Surface Water Monitoring Protocol (Jones et al. 2010).

Indicators of Hydrologic Alteration (IHA) software (TNC 2009a) was used to characterize general flow conditions and significant ecological events by processing the edited POR at each station. This program used single-period daily values in cubic feet per second to calculate nonparametric statistical metrics, including median monthly flow values and extreme event characterization and timing (table 2). IHA also was used to calculate Environmental Flow Components (EFCs) which are typically used to characterize natural flow and departures from natural conditions (table 2). EFCs are flow events defined by river ecologists and delineated based on reoccurring flow patterns observed at a site over many years. In this context, EFCs are meant to characterize flow events that have become typical since diversions or development occurred. The EFC procedure set initial high flows as 75% of daily flows for the POR used. We defined small floods as those events with a two-year return interval. We defined large floods as those events with a 10-year return interval. Extreme low flows were defined as comprising less than 10% of all flows for the period. More detailed information regarding the algorithm can be found in the IHA user's manual (TNC 2009b).

Annual river flow characteristics were also described and put into a historical flow context using a program that produces daily flow graphs that depict median monthly flow, interquartile range, and daily flow (Flow software; Dowd 2011). This graphical representation allows for quick comparison of basic flow characteristics with historical patterns at each gaging station within or near SECN parks. Similar to the IHA analysis, flow periods prior to long periods of missing data and prior to the construction and filling of reservoirs were ignored.

Assessment Criteria

Where defined, these data sets are also interpreted in the context of existing resource criteria relevant to individual parks within the SECN. These criteria may be found in the published scientific literature or in a park Resource Stewardship Strategy (RSS), which is a plan that includes strategies for managing natural and cultural resources. An RSS is based on science and scholarship and is designed to help park staff achieve and maintain desired conditions for resources as detailed in a park unit's General Management Plan. Wherever possible, Vital Signs (such as stream flow) are selected as RSS indicators of resource condition. This facilitates the use of Vital Signs monitoring data when tracking and reporting park progress toward attaining target values as defined in the RSS. To date within the SECN, only CHAT has completed its RSS (NPS 2010).

Minimum water flows in the Chattahoochee River were selected by CHAT as an indicator of conditions in the CHAT RSS (NPS 2010). In the RSS, five management targets are identified based on their relevance to state standards and on recommended flows for rafting, canoeing, and trout fishing or fishery condition (table 3; Nestler et al. 1986).

Table 2. Indicators of Hydrologic Alteration metrics and Environmental Flow Components calculated and used in this report. Potential Ecosystem Influences modified from IHA user's manual (TNC 2009b). Table number in parentheses refers to the table in this report where information is presented.

Parameter Type	Definition	Potential Ecosystem Influences
Indicators of Hydrologic Alteration Metrics		
Median Monthly Flow Conditions (Table 5)	Median daily value for each calendar month	• Habitat availability for aquatic organisms • Soil moisture availability for plants • Availability of water for terrestrial animals • Availability of food/cover for furbearing mammals • Reliability of water supplies for terrestrial animals • Access by predators to nesting sites • Water temperature, oxygen levels, photosynthesis in water column
Extreme Flow Conditions (Table 6)	1 to 90 day minimum and maximum flows	• Balance of competitive, ruderal, and stress-tolerant organisms • Creation of sites for plant colonization • Structuring of aquatic ecosystems by abiotic vs. biotic factors • Structuring of river channel morphology and physical habitat conditions • Soil moisture stress in plants • Dehydration in animals • Anaerobic stress in plants • Volume of nutrient exchanges between rivers and floodplains • Duration of stressful conditions such as low oxygen and concentrated chemicals in aquatic environments • Distribution of plant communities in lakes, ponds, floodplains • Duration of high flows for waste disposal, aeration of spawning beds in channel sediments

Table 2. Continued.

Parameter Type	Definition	Potential Ecosystem Influences
Indicators of Hydrologic Alteration Metrics		
Magnitude of Extreme Flow Conditions (Table 6)	Magnitude of 1 to 90 day high and low	• Compatibility with life cycles of organisms • Predictability or avoidance of stress for organisms • Access to special habitats during reproduction or to avoid predation • Spawning cues for migratory fish • Evolution of life history strategies, behavioral mechanisms
Environmental Flow Components		
Monthly Low Flows (Table 5)	Median low flow daily value for each calendar month	• Provide adequate habitat for aquatic organisms • Maintain suitable water temperatures, dissolved oxygen, and water chemistry • Maintain water table levels in floodplain, soil moisture for plants • Provide drinking water for terrestrial animals • Keep fish and amphibian eggs suspended • Enable fish to move to feeding and spawning areas • Support hyporheic organisms (living in saturated sediments)
Indicators of Hydrologic Alteration Metrics		
Extreme Low Flow and Low Flow Pulses (Table 6)	Frequency, duration, and timing of low flows and low flow pulses	• Enable recruitment of certain floodplain plant species • Purge invasive, introduced species from aquatic and riparian communities • Concentrate prey into limited areas to benefit predators
High Flow Pulses (Table 6)	Frequency, duration and timing of high flow pulses	• Shape and physical character of river channel, including pools and riffles • Determine size of streambed substrates (sand, gravel, cobble) • Prevent riparian vegetation from encroaching into channel • Restore normal water quality conditions after prolonged low flows, flushing away waste products and pollutants • Aerate eggs in spawning gravels, prevent siltation • Maintain suitable salinity conditions in estuaries • Influences bedload transport, channel sediment textures, and duration of substrate disturbance high pulses
Small Floods (Table 6)	Frequency, duration and timing of small floods	• Provide migration and spawning cues for fish • Trigger new phase in life cycle (i.e., insects) • Enable fish to spawn in floodplain, provide nursery area for juvenile fish • Provide new feeding opportunities for fish, waterfowl • Recharge floodplain water table • Maintain diversity in floodplain forest types through prolonged inundation (i.e., different plant species have different tolerances) • Control distribution and abundance of plants on floodplain • Deposit nutrients on floodplains

Table 3. Assessment criteria for evaluating status of flow conditions at Chattahoochee River National Recreation Area from NPS Resource Stewardship Strategy (NPS 2010) and Nestler et al. (1986).

Flow Criteria Threshold (in cfs)	Justification
Days less than 750	State standards for minimum flow at Peachtree Creek (River Mile 300.5).
750-1,000	Life history requirements for juvenile brown trout, adult brook trout. Possible wade and tube fishing, rafting.
1,000-1,500	Optimal conditions for wade and tube fishing, novice rafting and canoeing, and hanging out; boat fishing possible.
1,500-2,000	Possible conditions for wade and tube fishing, novice rafting and canoeing, and hanging out; optimal conditions for boat fishing.
Greater than 2,000	Powerboat fishing, mid-level rafting, and canoeing.

Table 4. Assessment criteria for evaluating flow conditions on the Congaree River and in Congaree National Park using a two-dimensional flow model (Kupfer and Meitzen 2012) and flows at Columbia, South Carolina.

Flow Thresholds (in cfs)	Percentage of Park Inundated	Justification
<5,300	Very little or no inundation	--
5,300 to 8,300	35	Meander channel inundation; flooding mostly in eastern park areas.
8,300 to 11,300	35 to 40	Meander channel inundation; flooding in eastern park areas; back flooding on Cedar Creek and Old Dead River.
11,300 to 26,000	40 to 60	Bank flooding into channels; activation of levee breaches; flood transport through floodplain channels.
>26,000	60 to 80	Entire floodplain inundated; all floodplain water bodies connected by cross-floodplain flows.

Results

Summary of Flow Conditions in SECN Riverine Parks

Riverine systems in and around SECN parks encompass drainage areas ranging from 44 square miles at Noses Creek in KEMO to 7,850 square miles at the Columbia gage upstream of CONG.

Regardless of drainage size, all large river flows through and adjacent to parks included in this report have been altered by placement of upstream impoundments.

Flows across SECN parks were highly variable in 2013 and exhibited both extremely high and low flow conditions over the PORs used for the analysis. Median monthly flows were typically lower than normal to normal in most SECN parks during the winter months; however, flows in KEMO and HOBE were slightly higher than normal during January. Flows quickly reached record high levels between May and August. Higher than normal flows were also observed again during December at CHAT, KEMO, and HOBE. Median monthly flows in May and July in the Chattahoochee River in Atlanta reached the second highest level in 54 years. Flows in the Congaree and Wateree Rivers approached near-record median monthly levels in July and August, and median monthly flows in the Congaree River in July were the highest observed during the last 75 years. Figures 2–12 depict daily flows compared to the historical variability observed at each gage.

Chattahoochee River National Recreation Area

Mean monthly flows in the Chattahoochee River were highest from May to July and lowest from January to March. Median monthly low flows from January to March approached record levels, and median monthly low flows in the river section near Buford Dam were the lowest observed during the last 54 years. One-day low flows were above normal in Sections 2 and 3 of the Chattahoochee River but slightly below normal in Section 4. Three-day to 90-day low flows were near normal to slightly below normal in all river sections in 2013. One-day maximum flows were well above normal in Sections 1-3 of the Chattahoochee River. Three-to 90-day high flows were in the normal range for the year over the POR.

Low flow pulses occurred between 10 and 32 times across the four sections of the Chattahoochee River and lasted between one and four days. Low flow pulses were more common in Sections 2-4 than in Section 1 near Buford Dam. During 2013, the number of low flow pulses was below the normal expected range. High flow pulses occurred between 22 and 36 times along the Chattahoochee River during 2013 and were most common in Section 4. The number of high flow pulses was within the normal range in all river sections except Section 4, where they were more common than normal. Small flood events occurred between eight and four times on Sections 2 and 3 during 2013, which exceeded normal in each section. No small floods occurred in Section 4 in 2013.

Flows in the Chattahoochee River during 2013 favored activities that are better suited for higher flow conditions. Flows greater than 2,000 cfs were recorded in the majority of days in all sections of the river (Table 3). No flows in Section 4 were below the state-mandated minimum flow of 750 cfs.

Congaree National Park

Mean monthly flows in the Congaree and Wateree Rivers were generally highest during the summer months. Near-record median monthly flows were observed in the Wateree River in July and August, and the highest median monthly flow recorded in 75 years was observed in July in the Congaree River. One- to 90-day low flows were normal to above-normal in the Congaree and Wateree Rivers. One- to 90-day high flows were within the normal range in the Wateree River. One-day and three-day high flows were above average for the Congaree River near CONG. Low flow pulses were rare

in the Congaree River and the Wateree River and occurred only a single time in the Congaree River in January. Low flow pulses normally occur between eight and 19 times on the Wateree River and between 13 and 25 times on the Congaree River. High flow pulses were common in 2013 and occurred eight times in the Wateree River and 26 times in the Congaree River. The number of high flow pulses recorded in the Wateree River was within the normal range for the POR, while the number recorded in the Congaree River was well above the normal range. Only a single small flood was recorded near CONG in the Congaree River in May.

A two-dimensional flow model (Kupfer and Meitzen 2012) predicted that based on flows in the Congaree River at Columbia, 60-80% of CONG was inundated for approximately 20 days during 2013. Forty to 60% of the Park was predicted to have been inundated for approximately 67 days. Low-lying eastern areas of CONG may have been inundated for up to 131 days.

Horseshoe Bend National Military Park

Mean monthly flows in the Tallapoosa River near HOBE were generally highest between January and May, with increasing flow observed again in December. A record mean monthly flow was recorded in January in the Tallapoosa River near Wadley, and near-record flows were observed again in May and July at both stations in the Tallapoosa River near HOBE. Flows were above normal in January and February. One- to 90-day low flows were above normal at the Wadley site upstream of HOBE but near normal at the New Site downstream of the Park. One- to three-day high flows were above average upstream of HOBE, as were one-day high flows downstream of the Park. Other high flow metrics were within the normal range over the POR for the year at both sites in the Tallapoosa River.

Low flow pulses were rare in the Tallapoosa River in 2013, with zero recorded at the Wadley gage and four recorded downstream of HOBE at the New Site gage. Normally between 24 and 37 low flow pulses are recorded upstream of HOBE and between 15 and 32 are recorded downstream. High flow pulses were more common than normal both upstream and downstream of HOBE, with 33 high flow pulses observed at Wadley and 27 observed downstream of the HOBE. A single small flood was recorded in the Tallapoosa in July.

Kennesaw Mountain National Battlefield Park

Median monthly flows in Noses Creek were generally highest in February, March, and December. Above-average flows were common for the entire year, and only flows during September to November approached the normal range. One- to 90-day low flows were within the average range over the POR for the year.

No low flow pulses were observed along Noses Creek at KEMO; however, the greatest number of high flow pulses recorded over the POR (33) was observed in 2013. A single small flood was recorded in May.

Ocmulgee National Monument

Mean monthly flows in the Ocmulgee River near OCMU were generally high from February to August, although flows in the Ocmulgee River near Macon in January were well below the range of average flows for the POR. Median monthly flows were well above average in May to August near Jackson and well above normal in the month of July near OCMU in Macon. One- to 90-day low and high flows were all in the average range for the POR in the Ocmulgee River.

The number of low flow pulses was somewhat below average in the Ocmulgee River in 2013, with three low flow pulses recorded upstream of OCMU near Jackson and eight recorded near OCMU at Macon. Normally, between eight and 16 and seven and 19 low flow pulses occur annually at the respective gage locations. High flow pulses were more common and occurred at a rate much higher than normally expected, with 24 events occurring upstream of OCMU and 19 occurring at the Macon gage near the Park. No small floods were recorded in the Ocmulgee River in 2013.

Table 5. Monthly median flow magnitudes for Southeast Coast Network riverine parks during 2013. Median flow calculated with Indicators of Hydrologic Alteration software (TNC 2009a) using daily data values collected by U.S. Geological Survey. Values in cubic feet per second (cfs). Color scale indicates flow magnitude across year at a site with darker blue indicating higher flow magnitude.

Park Name	USGS ID	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Median Flow 2013													
CHAT	02334430	553	533	539	613	5,150	2,625	3,510	2,860	1,890	1,810	1,525	3,500
	02335000	911	817	830	952.5	5,090	2,920	3,610	3,280	1,805	1,610	1,435	3,450
	02335450	848	764	763	1,012	5,450	2,995	4,140	3,810	1,940	1,840	1,570	4,210
	02336000	1,070	1,125	1,000	1,415	5,750	3,315	4,760	3,590	2,195	1,900	1,835	5,070
KEMO	02336968	42	84	72	65	63	38	45	36	19	24	27.5	100
CONG	02148315	3,910	7,585	6,500	5,255	8,407	8,390	8,885	8,696	2,940	2,190	2,900	6,200
	02169500	5,640	8,330	7,470	6,790	8,050	6,655	16,600	9,960	6,050	4,480	9,205	9,070
HOBE	02414500	6,971	4,605	3,180	2,175	3,650	2,465	3,640	2,380	1,071	1,990	2,175	5,830
	02414715	2,600	5,055	3,480	2,970	4,140	2,475	3,060	1,750	831	1,270	2,255	3,277
OCMU	02210500	958	2,185	1,670	2,135	1,910	2,260	3,060	1,360	606	395	410	1,360
	02213000	873	3,700	2,590	2,680	2,680	2,625	3,930	1,950	712.5	478	503	1,510

Table 6. One- to 90-day extreme flow magnitudes at Southeast Coast Network riverine parks during 2013. Metrics calculated using Indicators of Hydrologic Alteration software (TNC 2009a). Data from U.S. Geological Survey in cubic feet per second (cfs).

Park Name	USGS ID	1-day	3-day	7-day	30-day	90-day
Minimum						
CHAT	02334430	528	529.3	530	536.2	556.7
	02335000	691	722.3	736.7	863.1	934.3
	02335450	612	622.3	644.3	837.5	951.1
	02336000	802	822.3	872.3	1273	1,456
KEMO	02336968	12	13	13.43	23.3	30.49
CONG	02148315	1,810	1,843	1,857	2,210	2,737
	02169500	2,320	2,893	3,529	4,682	6,164
HOBE	02414500	375	538.3	792.9	1,285	1,776
	02414715	274	310.7	470.3	811.5	1,400
OCMU	02210500	369	371.7	376.4	477.4	626.9
	02213000	390	440.3	442.6	567.2	689.2
Maximum						
CHAT	02334430	7,820	7,403	5,235	3,980	3,351
	02335000	7,710	7,340	5,751	4,582	3,718
	02335450	8,780	8,093	6,423	5,185	4,129
	02336000	9,040	7,280	6,280	5,335	4,383
KEMO	02336968	1,290	688.3	393.9	185.2	148.5
CONG	02148315	9,870	9,642	9525	9,183	8,075
	02169500	98,200	75,630	45,330	19,630	14,910
HOBE	02414500	32,400	21,000	13,980	7,233	5,210
	02414715	44,800	26,600	14,900	7,363	5,792
OCMU	02210500	14,900	11,930	7,669	3,734	3,182
	02213000	26,300	20,470	14,020	6,810	5,375

Table 7. Environmental Flow Components (TNC 2009a) for flows in Southeast Coast Network riverine parks during 2013. [cfs, cubic feet per second; NC, metric not calculated]

		Extreme Low Flow			High Flow Pulses			Small Flood		
USGS ID		Frequency	Peak (cfs)	Duration (days)	Frequency	Peak (cfs)	Duration (days)	Frequency	Peak (cfs)	Duration (days)
CHAT	2334430	10	549.5	4	22	4,595	3	8	7,120	4
	2335000	24	736.5	1	27	5,210	3	4	7,525	4.5
	2335450	21	657	1	26	5,005	4	4	8,540	6.5
	2336000	32	954	2	36	5,315	3	0	NC	NC
KEMO	2336968	0	NC	NC	31	105	2	1	1,290	16
CONG	2148315	0	NC	NC	8	9,430	12.5	0	NC	NC
	2169500	1	2,320	1	26	13,250	2	1	98,200	13
HOBE	2414500	0	NC	NC	33	4,770	2	1	16,900	14
	2414715	4	292.5	1	27	5,200	2	1	22,200	10
OCMU	2210500	3	376	7	24	4,245	3.5	0	NC	NC
	2213000	8	436.5	5.5	19	6,060	5	0	NC	NC

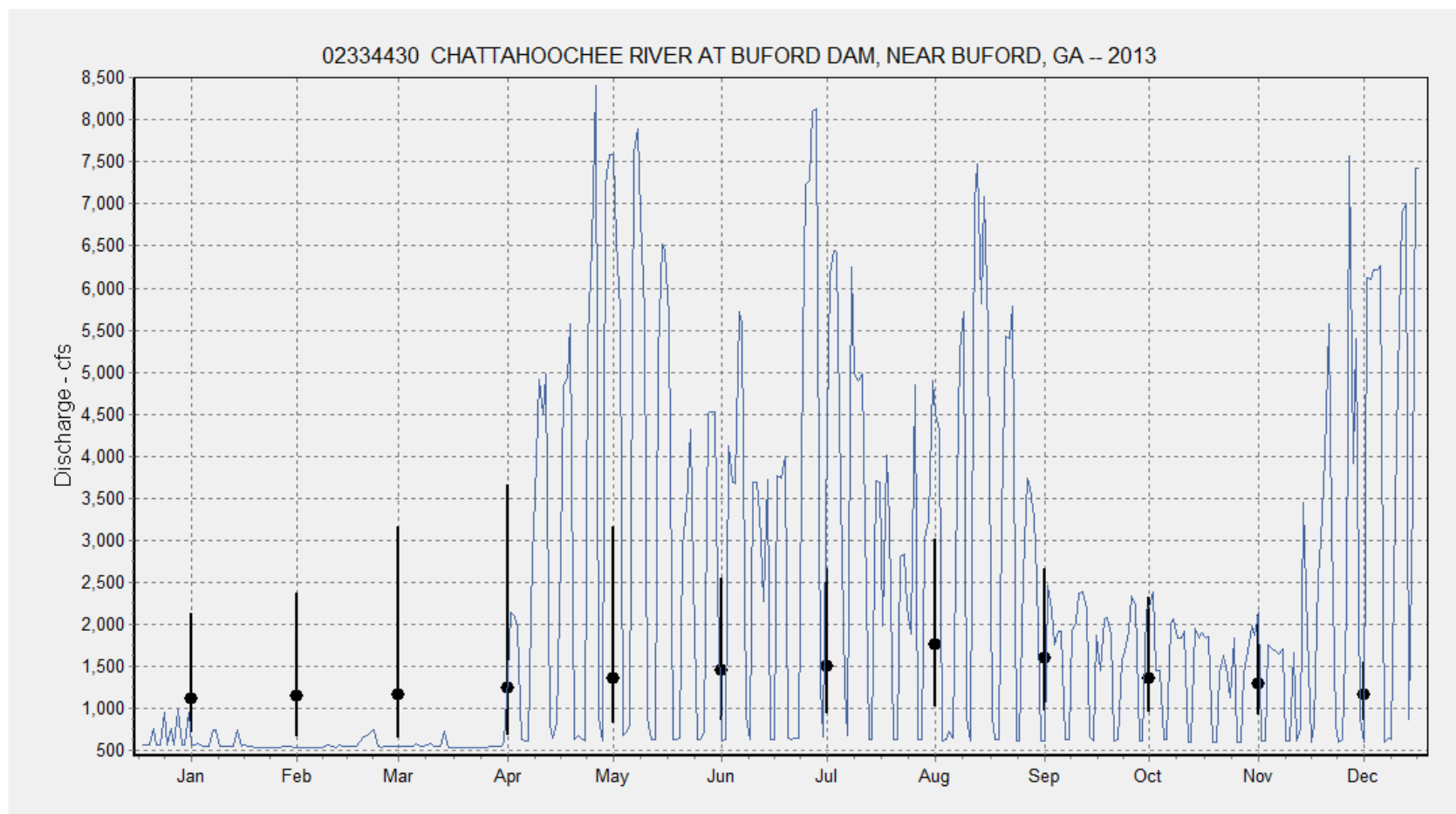


Figure 3. Daily flow (blue line), historical median monthly flow since the construction of Buford Dam (dots), and interquartile range (error bars) for the Chattahoochee River near Buford, Georgia in 2013.

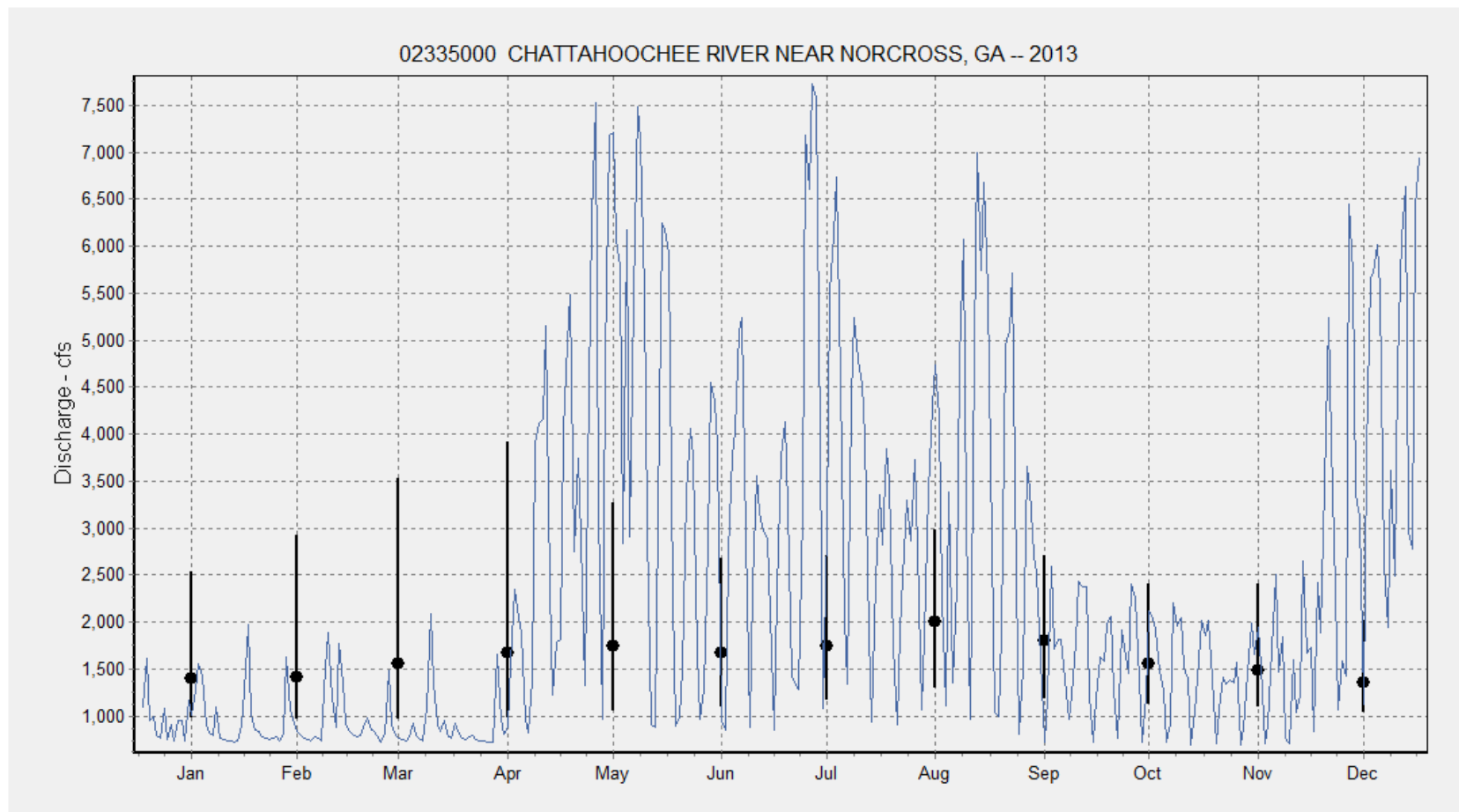


Figure 4. Daily flow (blue line), historical median monthly flow since the construction of Buford Dam (dots), and interquartile range (error bars) for the Chattahoochee River near Norcross, Georgia in 2013.

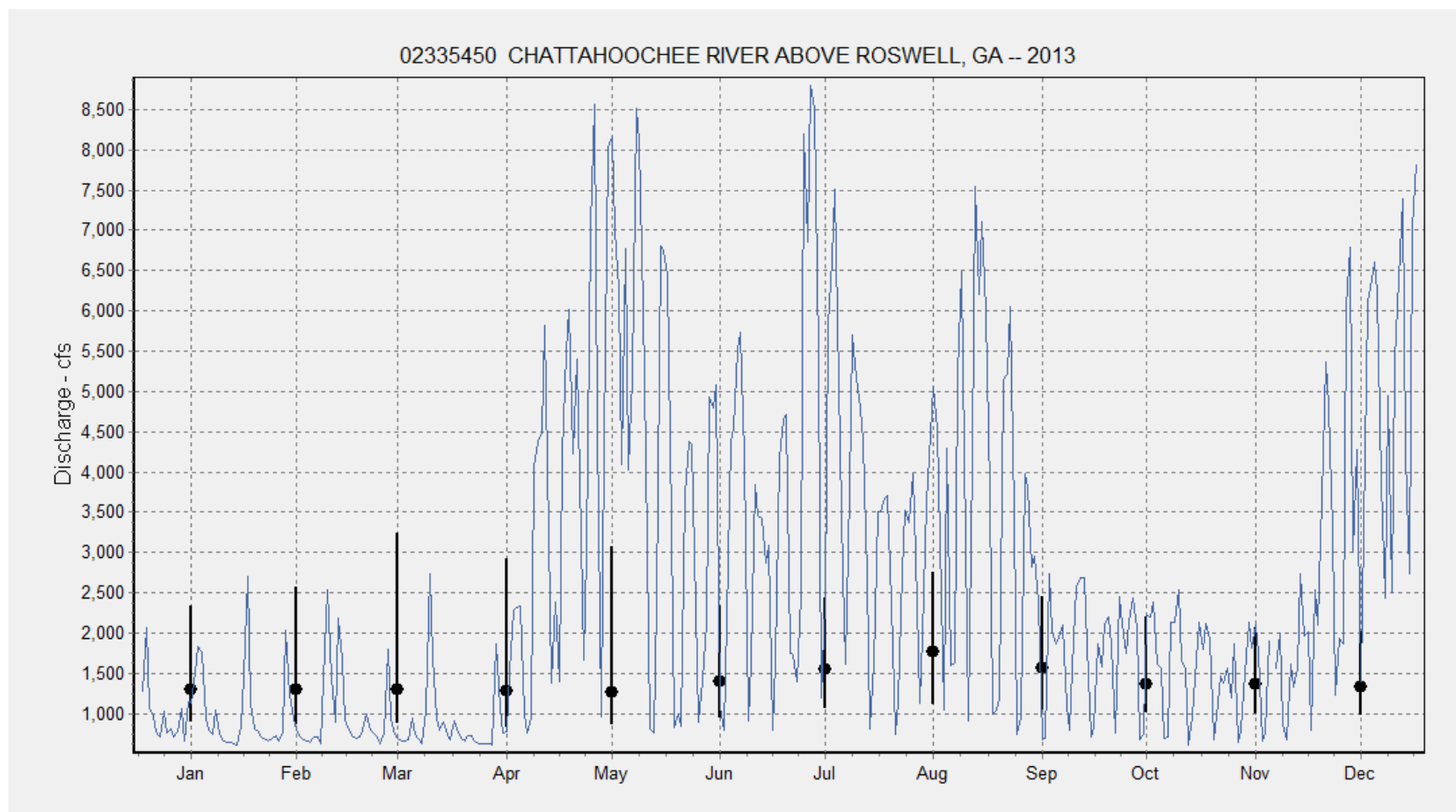


Figure 5. Daily flow (blue line), historical median monthly flow since the construction of Buford Dam (dots), and interquartile range (error bars) for the Chattahoochee River above Roswell, Georgia in 2013.

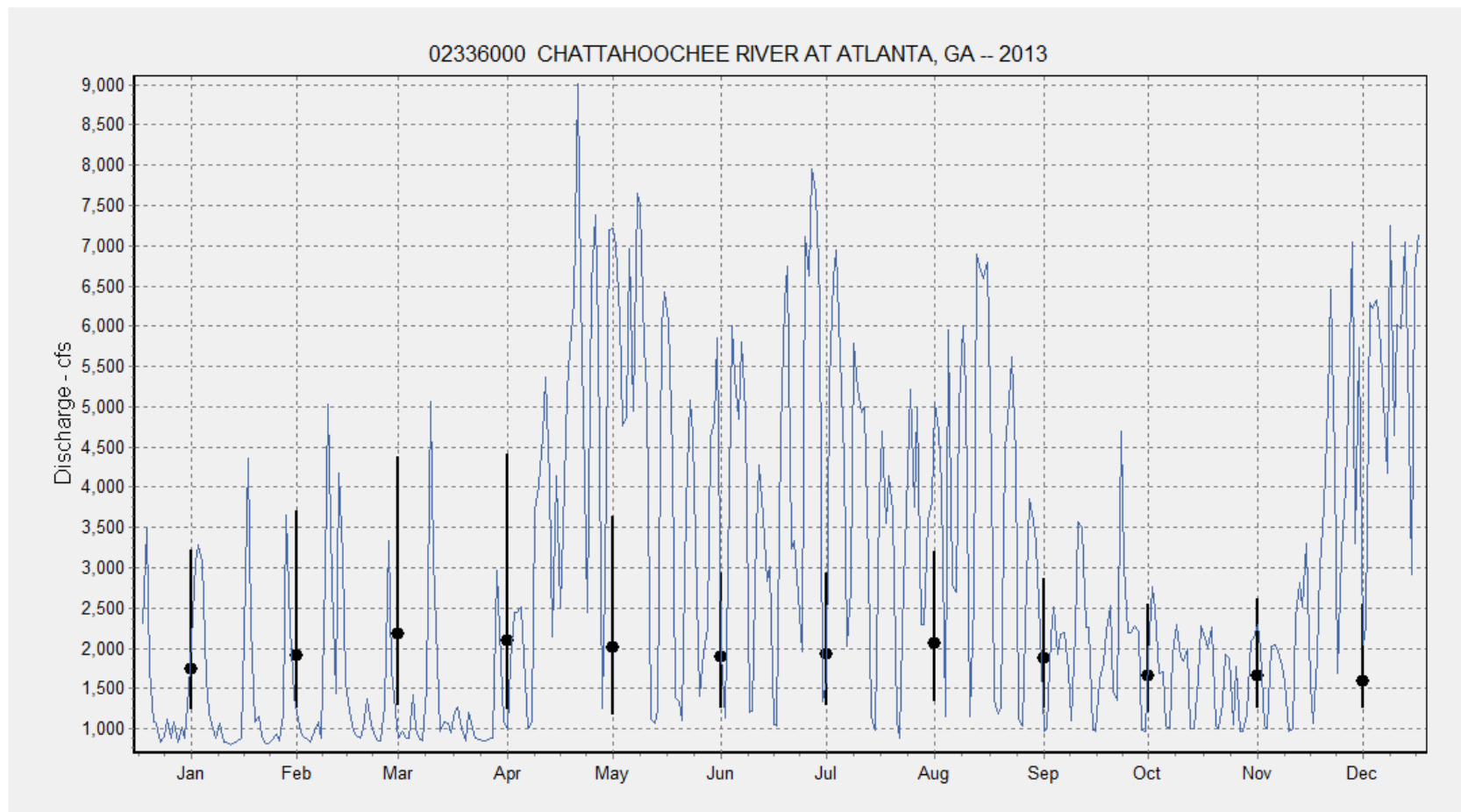


Figure 6. Daily flow (blue line), historical median monthly flow since the construction of Buford Dam (dots), and interquartile range (error bars) for the Chattahoochee River at Atlanta, Georgia in 2013.

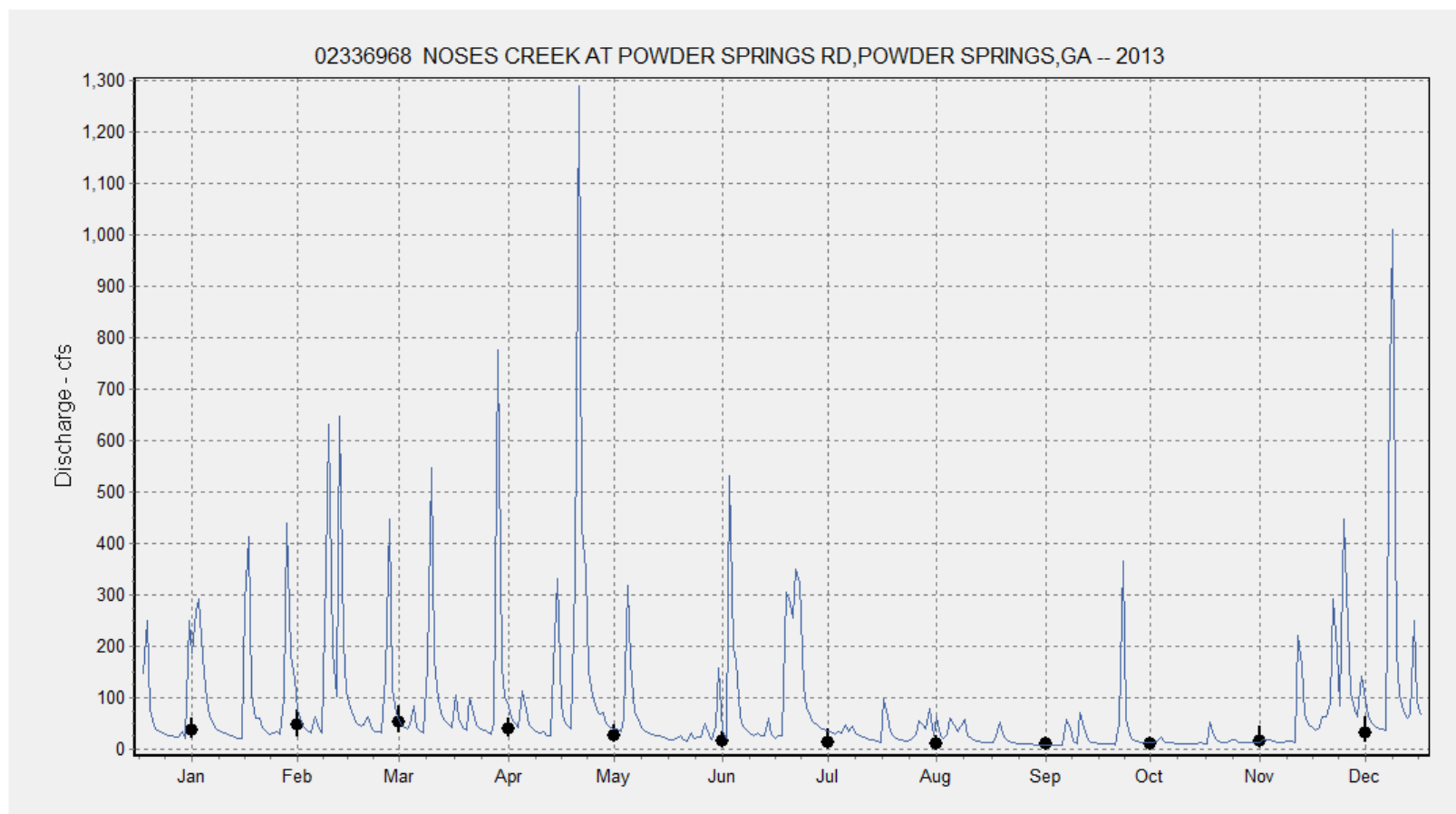


Figure 7. Daily flow (blue line), historical median monthly flow (dots), and interquartile range (error bars) for Noses Creek at Powder Springs Road, Powder Springs, Georgia in 2013.

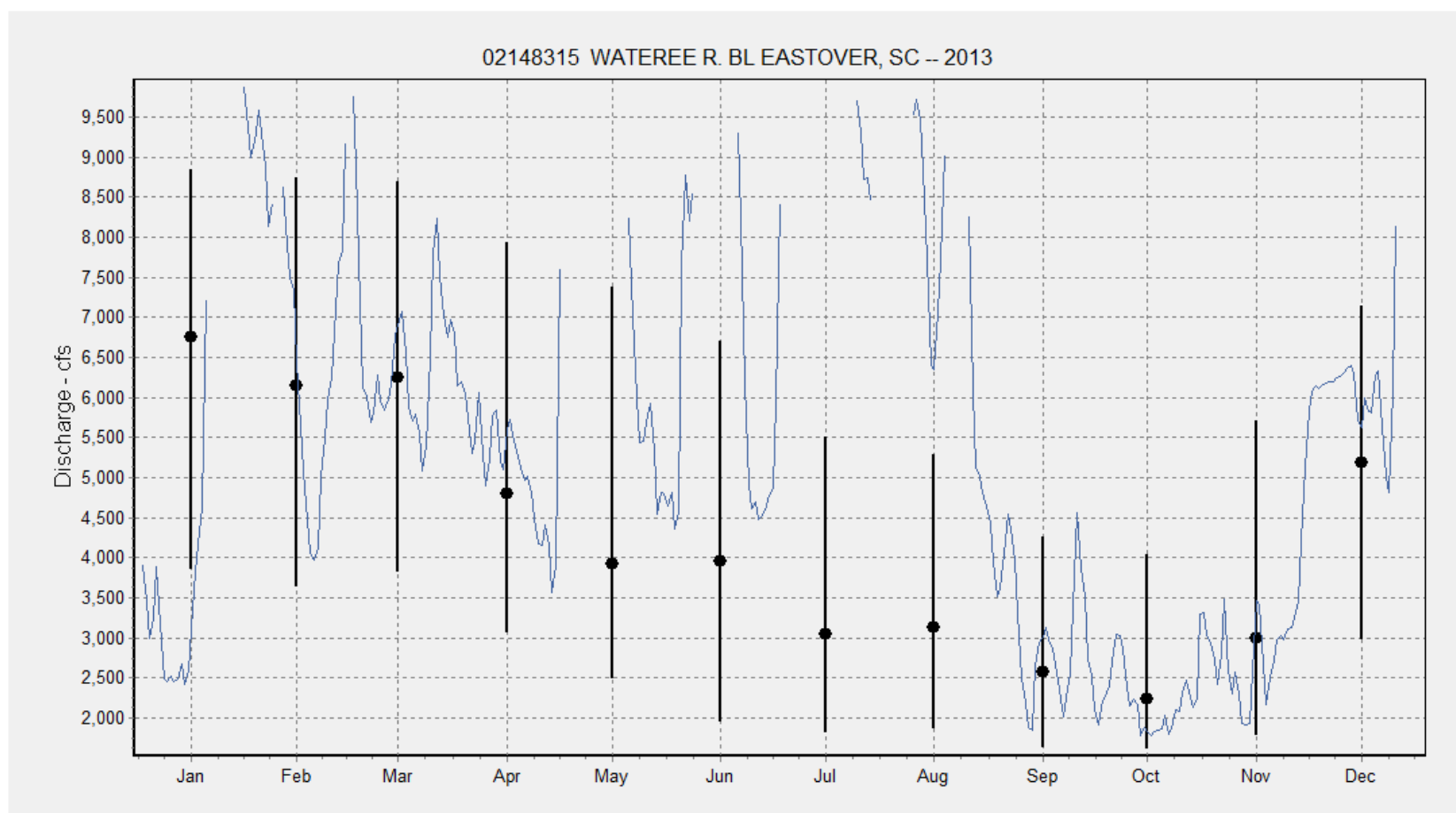


Figure 8. Daily flow (blue line), historical median monthly flow (dots), and interquartile range (error bars) for the Wateree River below Eastover, South Carolina in 2013. Broken blue line indicates missing data.

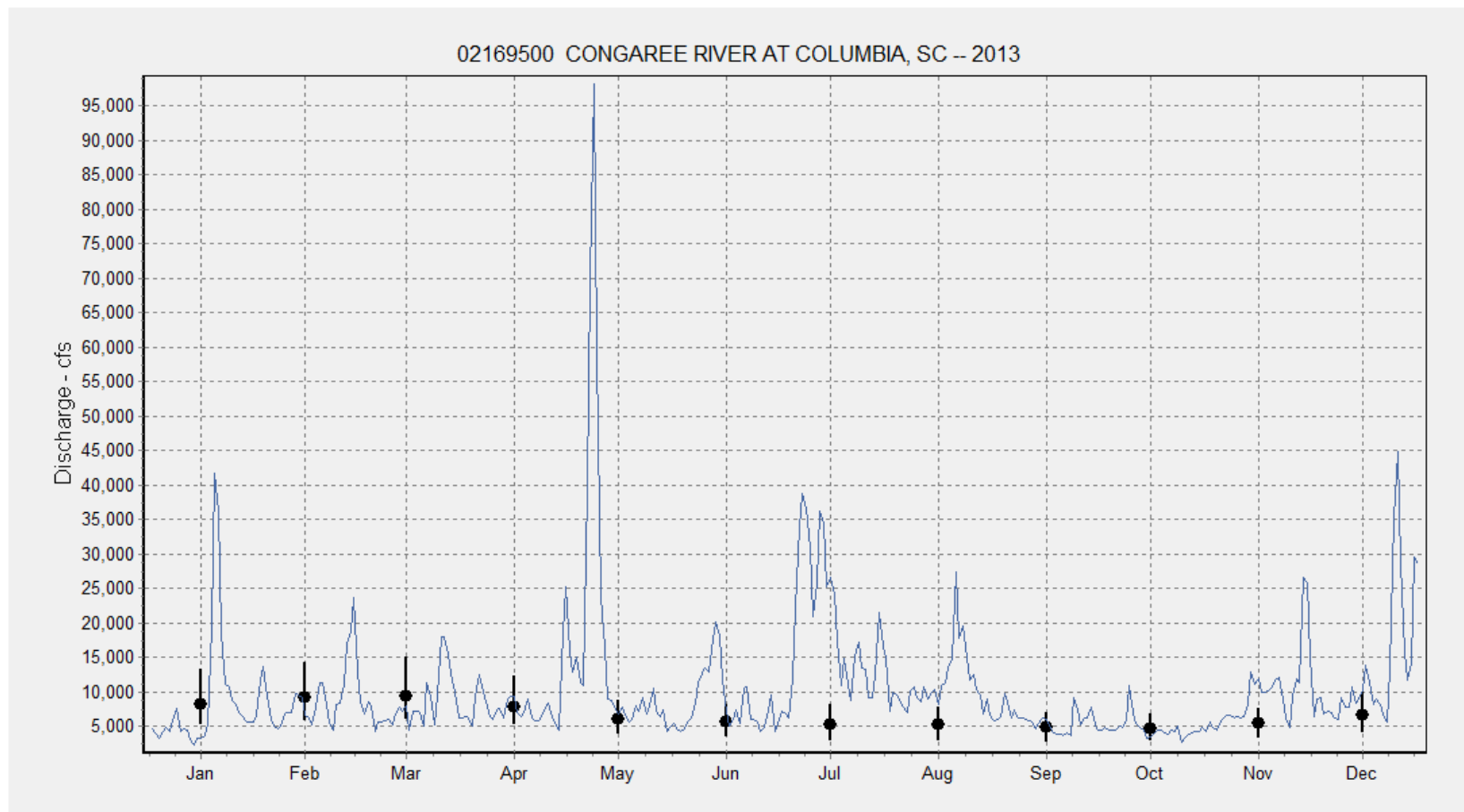


Figure 9. Daily flow (blue line), historical median monthly flow (dots), and interquartile range (error bars) for the Congaree River at Columbia, South Carolina in 2013.

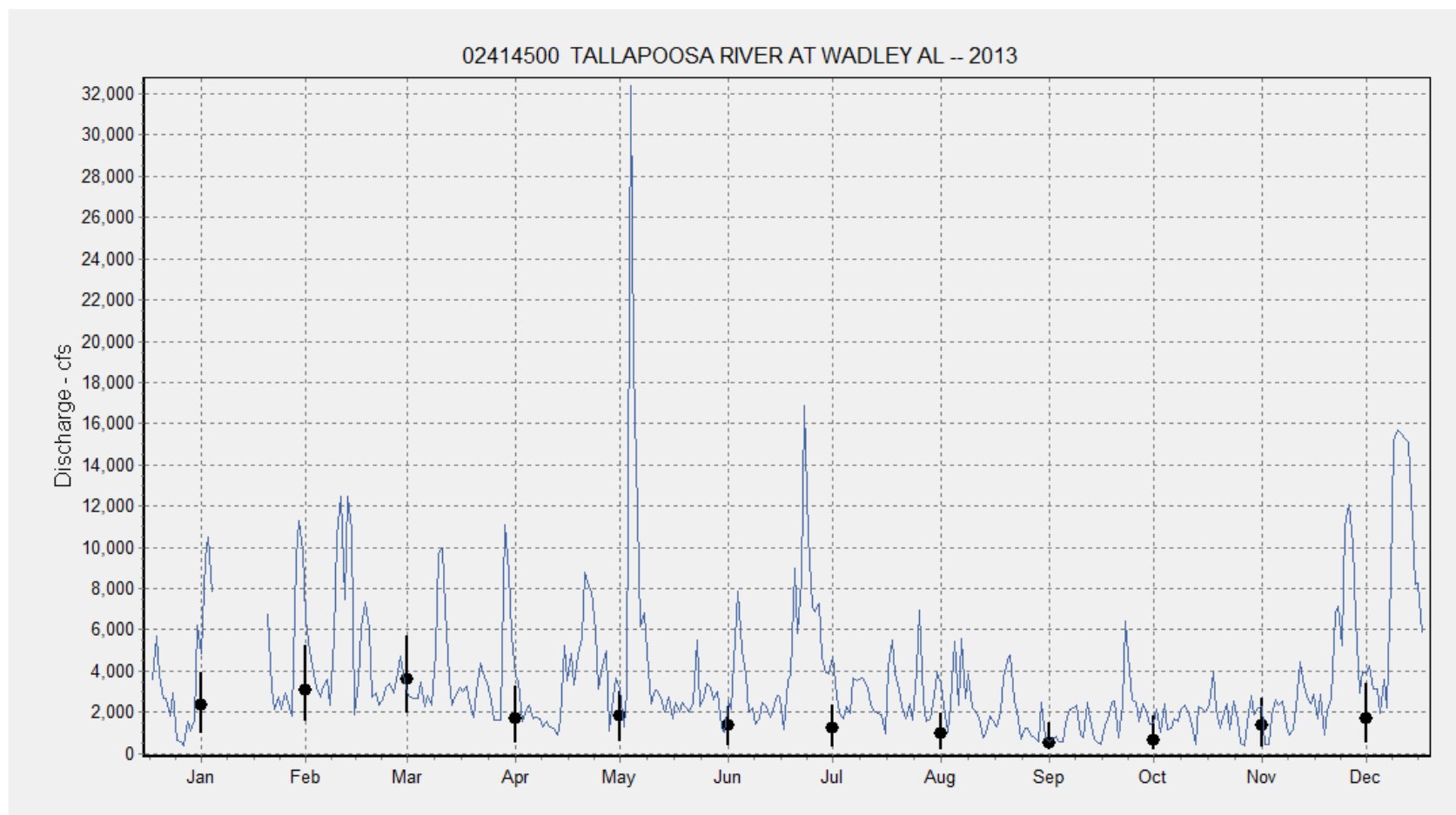


Figure 10. Daily flow (blue line), historical median monthly flow (dots), and interquartile range (error bars) for the Tallapoosa River at Wadley, Alabama in 2013.

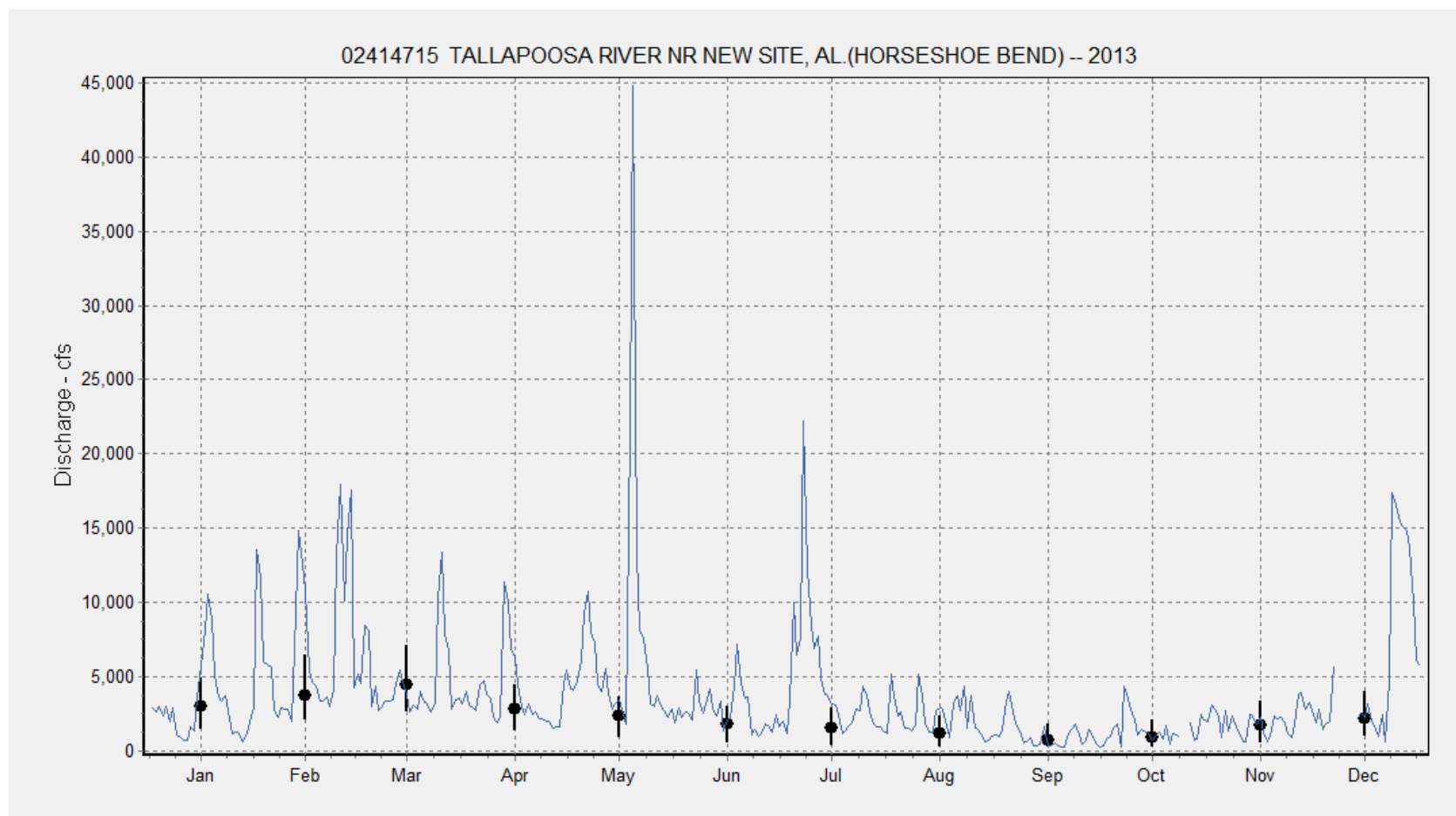


Figure 11. Daily flow (blue line), historical median monthly flow (dots), and interquartile range (error bars) for the Tallapoosa River near New Site, Alabama (Horseshoe Bend) in 2013.

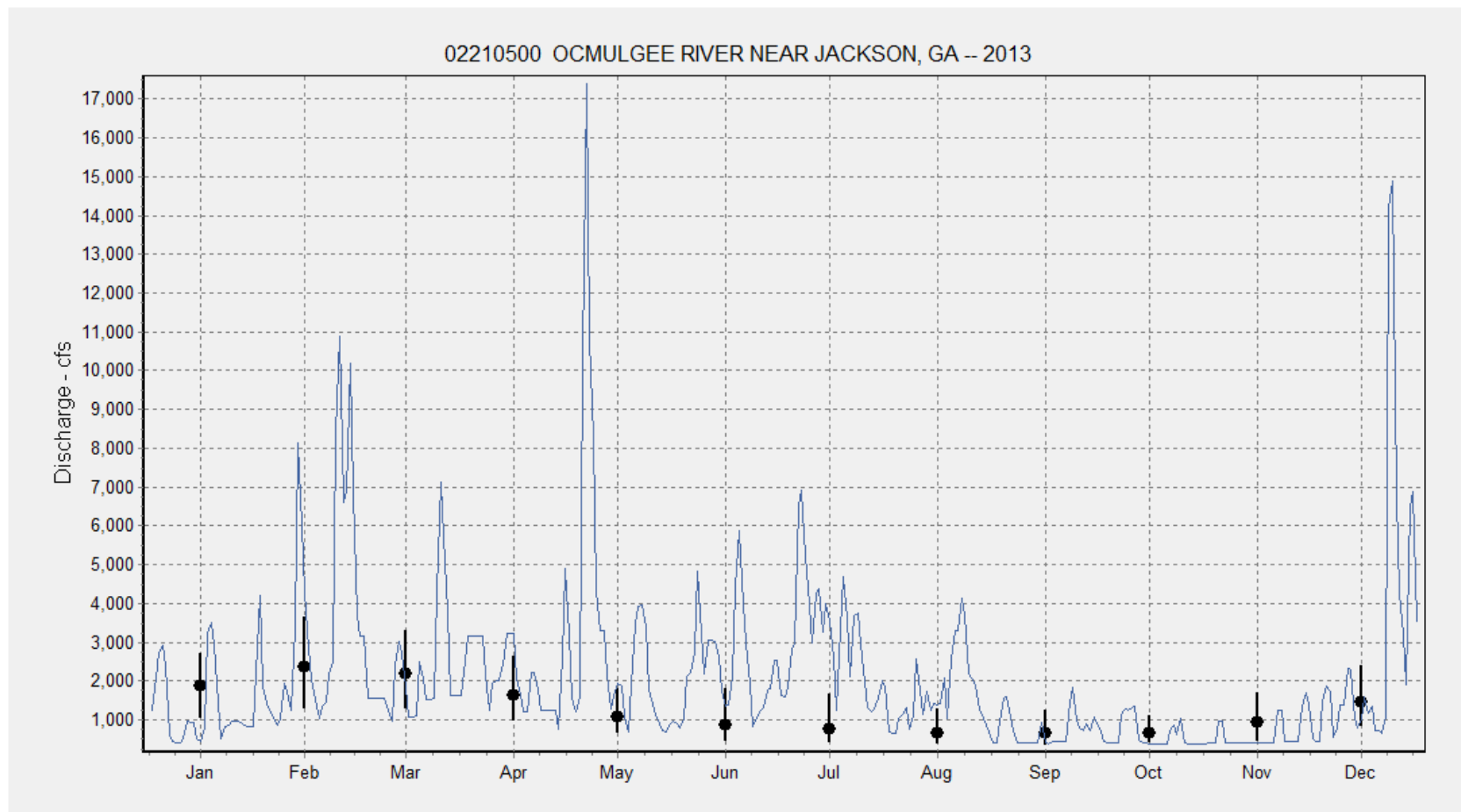


Figure 12. Daily flow (blue line), historical median monthly flow (dots), and interquartile range (error bars) for the Ocmulgee River near Jackson, Georgia in 2013. Broken blue line indicates missing data.

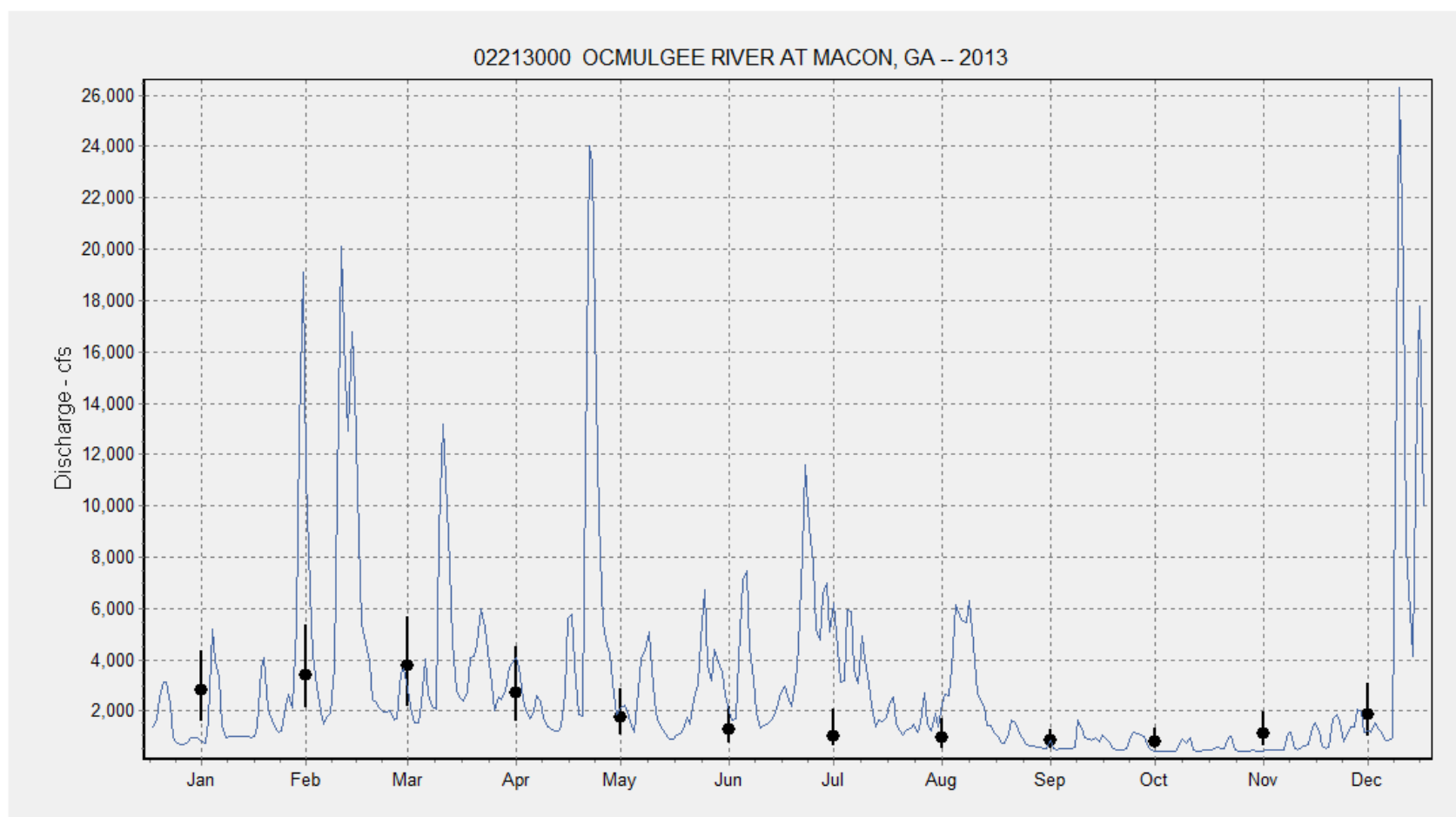


Figure 13. Daily flow (blue line), historical median monthly flow (dots), and interquartile range (error bars) for the Ocmulgee River at Macon, Georgia in 2013. Broken blue line indicates missing data.

Table 8. Number of days flow criteria and activity thresholds were met or exceeded in four sections of the Chattahoochee River National Recreation Area in Atlanta, Georgia during 2013. Flow criteria and activities (modified from Nestler et al. [1986]); low flow standard (<750 cfs) on River Segment 4 from GAEPD. River segments are based on proximity to nearest relevant gaging station and are shown in Figure 2. [NA, not applicable to segment; cfs, cubic feet per second]

Flow Criteria Threshold (in cfs)	Justification	River Segment			
		1	2	3	4
Streamflow less than 750 (Segment 4 only)	State standards for minimum flow at Peachtree Creek (River Mile 300.5).	NA	NA	NA	0
750-1000	Life history requirements for juvenile brown trout, adult brook, possible wade and tube fishing, rafting.	10	84	56	64
1,000-1,500	Optimal conditions for wade and tube fishing, novice rafting and canoeing, and hanging out; boat fishing possible.	10	55	32	65
1,500-2,000	Possible conditions for wade and tube fishing, novice rafting and canoeing, and hanging out; optimal conditions for boat fishing.	33	48	48	35
Greater than 2,000	Powerboat fishing, mid-level rafting, and canoeing.	129	149	163	193

Table 9. Percentage and duration of inundation at Congaree National Park due to high flows on the Congaree River during 2013 as predicted by a two-dimensional flood model (Kupfer and Meitzen 2012). Flows from U.S. Geological Survey gage at Columbia, South Carolina (USGS 02169500). [cfs, cubic feet per second]

Congaree River Discharge (cfs)	Percentage of Park Inundated	Duration (days)	Modeled Flood Description
<5,300	Very little or no flooding	72	
5,300 to 8,300	~ 35	131	Meander channel inundation; flooding in eastern park areas.
8,300 to 11,300	35 to 40	72	Meander channel inundation; flooding in eastern park areas; back flooding on Cedar Creek and Old Dead River.
11,300 to 26,000	40 to 60	67	Bank flooding into channels; activation of levee breaches; flood transport through floodplain channels.
>26,000	60 to 80	20	Entire floodplain inundated; all floodplain waterbodies connected by cross-floodplain flows.

Literature Cited

- Adams, S. M. and C. T. Hackney. 1992. Ecological processes in southeastern United States aquatic ecosystems. Pages 3-17 in C. T. Hackney, S. M. Adams, and W. H. Martin, editors. *Biodiversity of the southeastern United States: aquatic communities*. John Wiley & Sons, New York, New York.
- Brekke, L. D., J. E. Kiang, J. R. Olsen, R. S. Pulwarty, D. A. Raff, D. P. Turnipseed, R. S. Webb, and K. D. White. 2009. *Climate change and water resources management: A federal perspective*. U.S. Geological Survey Circular 1331. U.S. Geological Survey, Reston, Virginia.
- DeVivo J. C., C. J. Wright, M. W. Byrne, E. DiDonato and T. Curtis. 2008. Vital signs monitoring in the Southeast Coast Inventory & Monitoring Network. NPS/SECN/NRR—2008/061. National Park Service, Fort Collins, Colorado.
- Dowd, J. F. 2011. Program Flow. The University of Georgia. Athens, Georgia, USA.
- Georgia Environmental Protection Division (GAEPD). 2008. Letter from Carol Couch, Director GAEPD, to Byron G. Jorns, District Commander requesting temporary flow reduction in response to drought conditions (letter dated 2/11/2008).
- Hackney, C. T. and S. M. Adams. 1992. Aquatic communities of the southeastern United States: past, present, and future. Pages 747-760 in C. T. Hackney, S. M. Adams, and W. H. Martin, editors. *Biodiversity of the southeastern United States: aquatic communities*. John Wiley & Sons, New York, New York.
- Jones, C. D., A. M. Couch, R. D. Sherrell, T. C. Rasmussen, and J. F. Dowd. 2010. Southeast Coast Network surface water discharge monitoring: Analysis of existing data and data acquisition applications. Natural Resource Report NPS/HTLN/NRR—2010/264. National Park Service, Fort Collins, Colorado.
- Knowles, D. B., M. M. Brinson, R. A. Clark, and M. D. Flora. 1996. Water Resources Management Plan: Congaree Swamp National Monument. National Park Service. Cooperative agreement number CA-5240-3-9002/1.
- Kupfer, John A. and M. Meitzen. 2012. Modeling Flood Inundation & Hydrological Connectivity Across the Congaree River Floodplain, Congaree National Park. Proceedings of the 2012 South Carolina Water Resources Conference, held October 10-11. Columbia, South Carolina.
- Miller, K., and D. Yates. 2006. *Climate change and water resources: A primer for municipal water providers*. American Water Works Association, Denver, Colorado.
- National Park Service (NPS). 1997. Baseline water quality data inventory and analysis, Horseshoe Bend National Military Park. Technical Report NPS/NRWRD/NRTR-97/142. National Park Service, Fort Collins, Colorado.
- National Park Service (NPS). 2002. Baseline water quality data inventory and analysis, Ocmulgee National Monument. Technical Report NPS/ NRWRD/NRTR-2001/288. National Park Service, Fort Collins, Colorado.

- National Park Service (NPS). 2010. Chattahoochee River National Recreation Area Resource Stewardship Strategy: team review draft, September 2010. National Park Service, Atlanta, Georgia.
- National Park Service (NPS). 2013. Chattahoochee River National Recreation Area: values of special significance workshop report. National Park Service, Denver, Colorado.
- Nestler, J. M., J. Fritschen, R. T. Milhous, and J. Troxel. 1986. Effects of flow alterations on trout, angling, and recreation in the Chattahoochee River between Buford Dam and Peachtree Creek. Technical Report E-86-10. US Army Corps of Engineers Waterways Experiment Station, Vicksburg, Mississippi.
- Power M. E., A. Sun, M. Parker, W. E. Dietrich, J. T. Wootton. 1995. Hydraulic food-chain models: an approach to the study of food-web dynamics in large rivers. *Bioscience* 45(3): 159-167.
- Puckridge, J. T., F. Sheldon, K. F. Walker, and A. J. Boulton. 1998. Flow variability and the ecology of large rivers. *Marine & Freshwater Research* 49(1): 55-72.
- Richter, B. D, J. V. Baumgartner, R. Wigington, and D. P. Braun. 1997. How much water does a river need? *Freshwater Biology* 37(1): 231-249.
- The Nature Conservancy (TNC). 2009a. Indicators of Hydrologic Alteration, software version 7.1.0.10.
- The Nature Conservancy (TNC). 2009b. Indicators of Hydrologic Alteration Version 7.1 User's Manual.

Appendix A. Station Metadata Information

Chattahoochee River at Buford Dam in Georgia (02334430)

Latitude: 34°09'25"/Longitude: 84°04'44"/Datum: NAD83
Gwinnett County, Georgia
Hydrologic Unit 03130001
Drainage area: 1,040.00 square miles
Datum of gage: 912.04 feet above NGVD29
URL to access data:
http://waterdata.usgs.gov/ga/nwis/uv/?site_no=02334430&PARAMeter_cd=00065,00060,00062

Chattahoochee River near Norcross, Georgia (02335000)

Latitude: 33°59'50"/Longitude: 84°12'07"/Datum: NAD83
Gwinnett County, Georgia
Hydrologic Unit 03130001
Drainage area: 1,170 square miles
Datum of gage: 878.14 feet above NGVD29
URL to access data:
http://waterdata.usgs.gov/ga/nwis/uv/?site_no=02335000&PARAMeter_cd=00065,00060,00062

Chattahoochee River above Roswell, Georgia (02335450)

Latitude: 33°59'09"/Longitude: 84°18'58"/Datum: NAD27
Fulton County, Georgia
Hydrologic Unit 03130001
Drainage area: 1,220 square miles
Datum of gage: 858.01 feet above NGVD29
URL to access data:
http://waterdata.usgs.gov/ga/nwis/uv/?site_no=02335450&PARAMeter_cd=00065,00060,00062

Chattahoochee River at Atlanta, Georgia (02336000)

Latitude: 33°51'33"/Longitude: 84°27'16"/Datum: NAD83
Fulton County, Georgia
Hydrologic Unit 03130001
Drainage area: 1,450 square miles
Datum of gage: 750.10 feet above NGVD29
URL to access data:
http://waterdata.usgs.gov/ga/nwis/uv/?site_no=02336000&PARAMeter_cd=00065,00060,00062

Wateree River below Eastover, South Carolina (02148315)

Gageing at this site was discontinued July 15, 2014

Latitude: 33°49'42"/Longitude: 80°37'14"/Datum: NAD27
Richland County, South Carolina
Hydrologic Unit 03050104
Drainage area: 5,590 square miles
Datum of gage: 77.43 feet above NGVD29.
URL to access data no longer active

Congaree River at Columbia, South Carolina (02169500)

Latitude: 33°59'35"/ Longitude: 81°03'00"/Datum: NAD27

Lexington County, South Carolina

Hydrologic Unit 03050110

Drainage area: 7,850 square miles

Datum of gage: 113.02 feet above NGVD29

URL to access data:

http://waterdata.usgs.gov/sc/nwis/uv/?site_no=02169500&PARAMeter_cd=00065,00060,00062

Tallapoosa River at Wadley, Alabama (02414500)

Latitude: 33°07'00"/ Longitude: 85°33'39"/Datum: NAD27

Randolph County, Alabama, Hydrologic Unit 03150109

Drainage area: 1,675.00 square miles

Datum of gage: 599.87 feet above NGVD29

URL to access data:

http://waterdata.usgs.gov/al/nwis/uv/?site_no=02414500&PARAMeter_cd=00065,00060

Tallapoosa River at New Site, Alabama (Horseshoe Bend) (02414715)

Latitude: 32°58'38"/ Longitude: 85°44'23"/Datum: NAD27

Tallapoosa County, Alabama

Hydrologic Unit 03150109

Drainage area: 2,058.00 square miles

Datum of gage: 528.62 feet above NGVD29

URL to access data:

http://waterdata.usgs.gov/al/nwis/uv/?site_no=02414715&PARAMeter_cd=00065,00060

Ocmulgee River near Jackson, Georgia (02210500)

Latitude: 33°18'28"/Longitude: 83°50'18"/Datum: NAD27

Butts County, Georgia

Hydrologic Unit 03070103

Drainage area: 1,420 square miles

Datum of gage: 419.29 feet above NGVD29

URL to access data:

http://waterdata.usgs.gov/ga/nwis/uv/?site_no=02210500&PARAMeter_cd=00065,00060,00062

Ocmulgee River at Macon, Georgia (02213000)

Latitude: 32°50'19"/ Longitude: 83°37'14"/Datum: NAD83

Bibb County, Georgia

Hydrologic Unit 03070103

Drainage area: 2,240 square miles

Datum of gage: 269.80 feet above NGVD29.

URL to access data:

http://waterdata.usgs.gov/ga/nwis/uv/?site_no=02213000&PARAMeter_cd=00065,00060,00062

Noses Creek at Powder Springs Road at Powder Springs, Georgia (02336968)

Latitude: 33°51'33"/Longitude: 84°39'10"/Datum: NAD27

Cobb County, Georgia

Hydrologic Unit 03130002

Drainage area: 44.5 square miles

Datum of gage: 882.8 feet above NGVD29

URL to access data:

http://waterdata.usgs.gov/ga/nwis/uv/?site_no=02336968&PARAMeter_cd=00065,00060,00062

The Department of the Interior protects and manages the nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities.

NPS 910/126514, September 2014

National Park Service
U.S. Department of the Interior



Natural Resource Stewardship and Science

1201 Oakridge Drive, Suite 150
Fort Collins, CO 80525

www.nature.nps.gov

EXPERIENCE YOUR AMERICA™