National Park Service
U.S. Department of the Interior
Natural Resource Stewardship and Science

# Natural Resource Condition Assessment

## *Congaree National Park*

Natural Resource Report NPS/SECN/NRR—2018/1665

**ON THE COVER**
A quiet gut off Weston Lake Trail, Congaree National Park
Photograph by Stacie Flood.

# Natural Resource Condition Assessment

*Congaree National Park*

Natural Resource Report NPS/SECN/NRR—2018/1665

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# Executive Summary

The two major goals of this report were to (i) inventory the natural resources of Congaree National Park (CONG, or the park) within the Columbia Metropolitan Area of South Carolina, including a synthesis of available information and collection of geospatial data layers and maps; and (ii) to develop a set of indicators, quantitative insofar as possible, for natural resource conditions that can be tracked over time. The natural resources that were evaluated included air quality, geology and soils, groundwater, surface water, terrestrial and wetland biota, and species of special concern. Climate was also evaluated.

Congaree National Park is a large park (10,845 hectares or 26,800 acres [ac]) located within the Coastal Plain of South Carolina about 32 kilometers (km; or 20 miles [mi]) southeast of the City of Columbia. The park protects over 105 square kilometers (40.6 $mi^2$) of forested floodplains. Most of the park is forested wetland that is flooded periodically each year. Within the park both the sixth-order Congaree River and the Wateree River meander through densely forested wetlands. These wetlands and other major water features such as creeks, oxbow lakes, and sloughs support numerous fish, birds, herpetofauna, mammals, and other aquatic life. Congaree National Park is home to a highly diverse flora and fauna population, with 22 plant communities and dozens of species of trees in this unique old-growth bottomland forest. The major goals of park staff are to promote the natural function of the floodplain through preserving the wilderness areas and wetlands and minimize the disturbance to natural features such as landforms, vegetation and wildlife habitat.

Congaree National Park is a popular park with 113,000 visitors per year, averaging seven visitors/kilometer of trail (11 visitors/mile of trail) per day. The park is located in Richland County and lies within the Columbia Metropolitan Area (population 399,000), only 32 kilometers (20 mi) from the City of Columbia (population 131,700). Both the county and the metropolitaion area are growing in human population, with rates increasing 2% per year. The park is down-airshed and downstream from this urbanized population center, and its pollution represents a major threat to the park's natural resources.

Congaree National Park still has a fair soundscape condition from a natural resource perspective, but its lightscape condition is poor. A state highway transects the park; a federal highway and two interstate highways are 2.4 kilometers (1.5 mi) north and 17.7 kilometers (11 mi), respectively, to the north/northwest; and some flight paths pass over the park en route to the Columbia Metropolitan Airport or two area military bases. The airshed has moderate ozone levels that could adversely affect both human health and the park vascular plant communities. Visibility is poor because of compromised air quality, and the park also lies in an area that is prone to acid deposition by nitrogen and sulfur species.

Most of the dominant soils in Congaree National Park are erodible, acidic, and flood frequently. The groundwater level of the deep aquifer in the area is not monitored even though groundwater use is projected to increase significantly with the demands of the rapidly growing human population in the area. The groundwater level in an adjacent aquifer in Columbia has significantly decreased over the five year period from 2007–2011. Surface-water quality in Congaree National Park is characterized

by good pH and dissolved oxygen. However, high fecal bacteria levels were detected in the Cedar Creek sub-watershed; turbidity is also sometimes high; and phosphorus and nitrogen levels are excessive in comparison to EPA recommendations, so that overall the surface water-quality condition of this park is poor.

The terrestrial and wetland/aquatic biota of Congaree National Park are diverse, based on surveys completed within the last 15 years. The park contains rich vascular plant floras, with 325 and 513 taxa in terrestrial and wetland/aquatic habitats, respectively. However, the natural floras are being compromised by exotic/invasive species especially in terrestrial habitats, which include 29 highly invasive species. Herpetofauna are evaluated to be in good condition in the park; Congaree National park has high species richness, but only two sensitive species of concern (SoCs) still occur there. Bird fauna includes 191 species including over half of the bird SoCs known from the general region, suggesting that this park is an important refuge for sensitive species. In contrast, mammalian fauna in the park were assessed to be in poor condition, considering that 11% of the species are exotic/invasive (feral/domestic dogs, feral cats, and feral pigs).

Three special management issues (SMIs) identified for Congaree National Park are interrelated and include fire management, re-establishment of longleaf pine habitat, and feral pig management. The park is making progress in all three issues toward the goal of restoring habitats to more natural historic conditions.

This in-depth analysis of the natural resources of Congaree National Park considered available information for all natural resource categories ranging from climate and surrounding land use to SMIs, especially emphasizing park conditions in the most recent 15 years through 2011. In selecting the suite of indicators that we developed for natural resource status at Congaree National Park, a foremost consideration was to ensure insofar as possible that the indicators are scientifically sound, clear to the general citizenry, and logistically assessable by park personnel with minimal time and additional resources required. We also strove to ensure that the indicators meet the specific needs of this park as described by park staff.

Fifty-seven indicators were used to evaluate the sixteen categories of natural resources (Table E-1) for which sufficient information was available to allow some level of quantitative or semi-quantitative assessment. The overall condition of four categories was rated as good; four were evaluated to be in fair condition and eight were in poor condition. Nearly all of the natural resources in fair and poor condition were strongly influenced by external forces, not possible for the National Park Service to control.

**Table E-1.** Natural resource condition report card for Congaree National Park.

| Natural Resource Category | Indicator(s) | Congaree NP |
|---|---|---|
| Human Population Surrounding the Park | 4 | poor |
| Visitation–Human Population in the Park | 3 | good |
| Surrounding Land Use/Land Cover | 4 | poor |
| Air Quality | 8 | fair |
| Soundscape | 3 | fair |
| Lightscape | 2 | fair |
| Soil and Streambank Erosion | 4 | poor |
| Groundwater Supply | 2 | poor |
| Surface-water quality | 8 | poor |
| Vascular Flora | 4 | poor |
| Aquatic Benthic Macroinvertebrates | 1 | good |
| Fish | 2 | good |
| Herpetofauna | 2 | good |
| Birds | 5 | good |
| Mammals | 2 | poor |
| Special Management Issues | 3 | fair |

Major knowledge gaps that restricted evaluation of the present condition for resource categories and efforts needed to fill them include:

*Erosion/Weathering Processes Active in the Park*—Geologic hazards such as slope creep, streambank erosion, and slumps would be especially expected to affect areas with weaker rock units such as the semi-consolidated sandstone, silts, and claystone underlying the Congaree River, and uncosolidated alluvium. Park staff identified this issue, and there is a need for a comprehensive study of erosion/weathering processes, including data on rates of sediment accumulation and erosion in the Congaree River.

*Stream Sediment Quality*—Information is needed to enable assessment of the quality of stream sediments in Congaree National Park, with suggested focus on toxic substances such as mercury, arsenic, copper, and polychlorinated biphenyls (PCBs).

*Sewage overflows, septic effluent leachate, and agricultural pollution near the park*—The effects of urbanization, stormwater runoff, municipal and industrial wastewater discharges, septic effluent leachate, and agriculture and industrialized confined poultry feed operations threaten both surface and groundwater resources. Adequate protection of park ecosystems will require accurate knowledge about the chemicals (fertilizers, pesticides, additives to feed such as heavy metals) used in regional agriculture, together with an understanding of the airshed and hydrogeologic system within and surrounding the park.

*Combined Studies on Surface Water Hydrology and Surface-water quality*—Data from the Congaree River gaging station 02169325 near the park are needed to track long-term changes in discharge and stream depth in the Congaree River. These data should be collected concomitantly with data on pollutants, salinity, conductivity, and chloride. Data for the parameters selected as water-quality indicators should be collected at least monthly every other year to enable reliable assessment of water-quality conditions over time at water-quality stations, one coinciding with the flow gaging station as Congaree River enters the park (C-074), and another station as the stream exits the park.

*Groundwater Quantity*—Currently there is no monitoring of the Southeastern Coastal Plain Aquifer system in the park vicinity. One monitoring well should be installed in the park for deep aquifer characterization and monitoring.

*Groundwater Quality*—Groundwater-quality data presently are not available for the park. Monthly sampling at least every other year is needed to characterize pH, salinity, conductivity, chloride, and concentrations of potential contaminants known to impact groundwater from industrialized poultry operations, such as nitrate+nitrite, ammonia, sulfide, fecal bacteria, and metals (e.g., arsenic, copper).

*Stream Macroinvertebrate Communities*—Stream macroinvertebrates are commonly used to evaluate habitat conditions because they provide integrative information about wetland/aquatic habitats and water quality. The stream macroinvertebrate community should be re-evaluated/updated at three-year intervals using established protocols. Metrics for these important biotas should be added to natural resource monitoring in the park once recent data are in hand, so that a macroinvertebrate index of biological integrity (M-IBI) can be calculated and tracked over time.

*Fish Community*—Fish are widely understood by the general public and generally accepted as beneficial organisms. The fish community of the park in 2004 was in relatively good condition, (56 native species), but the most recent survey was done in 2001. Fish communities should be sampled using established protocols at three-year intervals to enable calculation of a fish index of biological integrity (F-IBI), used to track stream biological condition over time.

*Additional Surface-Water-Quality Monitoring*—Data were sparse for total suspended solids; in addition, chlorophyll *a* data are needed at sites monitored by the South Carolina Department of Health and Environmental Control near the park. Fecal coliform monitoring is consistent throughout the three sub-watersheds, but enterococcus and *E. coli* monitoring should be increased at sites C-077, C-076, and CW-222 to accurately characterize incoming stream water quality.

*Population Studies of Selected Desirable and Undesirable Biota*—Species of special management concern, such as sensitive species, should be quantitatively assessed over time to inform park staff in efforts to strengthen protective measures. Selected highly invasive taxa should be quantitatively tracked as well, to inform park staff as they work to develop and/or modify management plans to reduce these species and mitigate their impacts on park ecosystems.

*Updated Biota Surveys*—Rigorous efforts on a decadal basis are suggested to update the NPS Certified Species List for Congaree National Park, including vouchered specimens for verification of vascular plant species.

*Analysis Over Time of the Cumulative and Synergistic Effects of Pressures from Climatic, Land Use, and Exotic/Invasive Species Changes*—The rate of climate warming in this century is projected to be from 2.5 to 5.8 times higher than the rate measured during the 1900s (Hansen et al. 2014, and references therein). Temperatures are expected to increase by 2.58°C to 4.58°C. Watershed development is expected to accelerate; for example, an average 255% increase in housing density is projected by 2100 in lands surrounding national parks throughout the nation. Exotic/invasive species generally are favored by disturbances such as these (Ferriter et al. 2007).

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# List of Terms

Alluvial — materials such as silt, clay, sand or gravel that are deposited by water of rivers, floods, etc.
AQI — Air-quality Index (of the U.S. EPA)
BMP — best-management practice
Brl — below reporting limit
BOD5 — biochemical oxygen demand (five-day testing duration)
CAAE — Center for Applied Aquatic Ecology (of North Carolina State University)
CAFO — confined (or concentrated) animal feed operation, a form of industrialized animal agriculture
Cd — cadmium
Cfs — cubic feet per second
Cfu — colony forming units
CCC — criterion continuous concentration (of the U.S. EPA)
CERCLA — Comprehensive Environmental Response, Compensation, and Liability Act commonly known as Superfund
CMC — criterion maximum concentration (of the U.S. EPA)
$CO_2$ — carbon dioxide, a major greenhouse gas contributing to global warming
COD — chemical oxygen demand
Cr — chromium
Cu — copper
DIP — dissolved inorganic phosphorus
DO — dissolved oxygen
DOC — dissolved organic carbon
DON — dissolved organic nitrogen
DOP — dissolved organic phosphorus
DP — dissolved organic phosphorus
EC — type of culture medium used to assess fecal coliform densities with a multiple-tube procedure
ECHO ICIS — Enforcement and Compliance History Online Integrated Compliance Information System (of the U.S. EPA)
EIS — environmental impact statement
FC — fecal coliforms
FEMA — Federal Emergency Management Agency
Fluvial — sediment deposited or erosion by a river
FS — fecal streptococci
Ft — foot or feet
Gap — bottom land, marsh, or mire; sometimes used interchangeably with slough
GIS — Geographic Information System
G — gram
gm (gms) — geometric mean(s)

gpd — gallons per day
gpm — gallons per minute
Gut — a narrow water passage
Ha — hectare(s)
Hg — mercury
HUC — Hydrologic Unit Code
IPCC — United Nations Intergovernmental Panel on Climate Change
lat. — latitude
long. — longitude
m — meter
$m^3/s$ — cubic meters per second
MF — membrane filter (refers to a technique for analysis of fecal coliform densities, also using M-FC medium)
M-FC — type of culture medium for assessment of fecal coliform densities (see above)
Mgd — million gallons per day
mg/L — milligrams per liter (= parts per million, ppm; 10–3 gram/L, or 1/1 thousandth of a gram/L)
MPN — most probable number (pertaining to fecal bacteria)
µg/L — micrograms per liter (= parts per billion, ppb; 10–6 gram/L, or 1/1 millionth of a gram/L)
MPN — most probable number
MS4 — municipal separate storm sewer system
N — nitrogen (nutrient; excessive enrichment can degrade water quality)
NAAQS — National Ambient Air-quality Standards
NARSAL — Natural Resources Spatial Analysis Laboratory
Ng — nanograms (10–9 gram, or 1/1 billionth of a gram)
$NH_3$ — ammonia (gaseous form; can be an air or water pollutant)
$NH_4$+N — ammonium (inorganic form of nitrogen, ionized from ammonia; excessive enrichment can degrade water quality
NO3- + NO2- — nitrate + nitrite (inorganic forms of nitrogen; excessive enrichment can degrade water quality)
NOx — in waters, refers to nitrate + nitrite
NOx or NOy — in the atmosphere, a “catch-all” term for all reactive oxides of nitrogen
NP — nonpoint
NPC — not possible to control (by the NPS)
NPCA — National Parks Conservation Association
NPDES — National Pollutant Discharge Elimination System
NPS — National Park Service
NTU — Nephelometric turbidity units
NWIS — National Water Information System (of the USGS)
ONRW — Outstanding National Resource Waters
ORW — Outstanding Resource Waters

Oxbow lake — a natural lake along a pronounced winding bend of a river that is "intermittently flushed and refilled during high-water flood events" (Bradley et al. 2009).

P — phosphorus (nutrient; excessive enrichment can degrade water quality)

PAMS — Photochemical Assessment Monitoring Stations (for air quality)

Park — Congaree National Park

Pb — lead

PCB — polychlorinated biphenyl (refers to a group of various forms of these toxic substances, called congeners)

PCS — Permit Compliance System (of the U.S. EPA)

$PM_{2.5}$ — particulate matter, diameter < 2.5 µm (air pollutant)

$PM_{10}$ — particulate matter, diameter < 10 µm (air pollutant)

QA/QC — quality assurance/quality control (refers to standardized procedures for ensuring acceptable quality of data)

SAV — submersed aquatic vegetation (sometimes erroneously referred to as submerged aquatic vegetation—see Wetzel 2001)

S.C. — South Carolina

SC DHEC — South Carolina Department of Health and Environmental Control

SC DNR — South Carolina Department of Natural Resources

SECN — Southeast Coast Network of the National Park Service

Slough (pron. slew) — a depression or hollow, usually filled with deep mud or mire; a stagnant swamp, marsh, bog, or pond; an area of soft, muddy ground; swamp or swamp-like area. In CONG, sloughs are considered as shallow channels that transport river water into the park during intermediate and high flow events; sloughs usually contain standing water when flow in the rivers is low

$SO_2$ — sulfur dioxide (air pollutant)

spec. cond. — specific conductivity

SoC — species of concern

sq. mi. — square mile(s)

SRP — soluble reactive phosphorus

STORET — STOrage and RETrieval Environmental Data System (of the U.S. EPA)

Strep — streptococci (type of fecal bacteria)

sv — single value

SVOC — semi-volatile organic compounds, also called polycyclic aromatic hydrocarbons (air pollutants)

TDP — total dissolved phosphorus

TDS — total dissolved solids

TKN — total Kjeldahl nitrogen

TM — trace metal

TMDL — total maximum daily load

TP — total phosphorus

TSS — total suspended solids
USACE — United States Army Corps of Engineers
USDA — United States Department of Agriculture
U.S. EPA — United States Environmental Protection Agency
U.S. FWS — United States Fish and Wildlife Service
USGS — United States Geological Survey
USGS NAWQA — United States Geological Survey National Water Quality Assessment Program
VOC — volatile organic compound
WBD — Watershed Boundary Dataset
WC — water column
WPCP — water pollution control plant (wastewater treatment plants)
WQ — water quality
WTP — water treatment plant (drinking water)
WUI — Wildland-Urban Interface

# 1. NRCA Background Information

Natural Resource Condition Assessments (NRCAs) evaluate current conditions for a subset of natural resources and resource indicators in national park units, hereafter "parks." NRCAs also report on trends in resource condition (when possible), identify critical data gaps, and characterize a general level of confidence for study findings. The resources and indicators emphasized in a given project depend on the park's resource setting, status of resource stewardship planning and science in identifying high-priority indicators, and availability of data and expertise to assess current conditions for a variety of potential study resources and indicators.

**_NRCAs Strive to Provide…_**

- *Credible condition reporting for a subset of important park natural resources and indicators*
- *Useful condition summaries by broader resource categories or topics, and by park areas*

NRCAs represent a relatively new approach to assessing and reporting on park resource conditions. They are meant to complement—not replace—traditional issue-and threat-based resource assessments. As distinguishing characteristics, all NRCAs:

- Are multi-disciplinary in scope;[1]
- Employ hierarchical indicator frameworks;[2]
- Identify or develop reference conditions/values for comparison against current conditions;[3]
- Emphasize spatial evaluation of conditions and GIS (map) products; [4]
- Summarize key findings by park areas; and [5]
- Follow national NRCA guidelines and standards for study design and reporting products.

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[1] The breadth of natural resources and number/type of indicators evaluated will vary by park.

[2] Frameworks help guide a multi-disciplinary selection of indicators and subsequent "roll up" and reporting of data for measures ⇨ conditions for indicators ⇨ condition summaries by broader topics and park areas

[3] NRCAs must consider ecologically-based reference conditions, must also consider applicable legal and regulatory standards, and can consider other management-specified condition objectives or targets; each study indicator can be evaluated against one or more types of logical reference conditions. Reference values can be expressed in qualitative to quantitative terms, as a single value or range of values; they represent desirable resource conditions or, alternatively, condition states that we wish to avoid or that require a follow-up response (e.g., ecological thresholds or management "triggers").

[4] As possible and appropriate, NRCAs describe condition gradients or differences across a park for important natural resources and study indicators through a set of GIS coverages and map products.

[5] In addition to reporting on indicator-level conditions, investigators are asked to take a bigger picture (more holistic) view and summarize overall findings and provide suggestions to managers on an area-by-area basis: 1) by park ecosystem/habitat types or watersheds, and 2) for other park areas as requested.

Although the primary objective of NRCAs is to report on current conditions relative to logical forms of reference conditions and values, NRCAs also report on trends, when appropriate (i.e., when the underlying data and methods support such reporting), as well as influences on resource conditions. These influences may include past activities or conditions that provide a helpful context for understanding current conditions, and/or present-day threats and stressors that are best interpreted at park, watershed, or landscape scales (though NRCAs do not report on condition status for land areas and natural resources beyond park boundaries). Intensive cause-and-effect analyses of threats and stressors, and development of detailed treatment options, are outside the scope of NRCAs.

Due to their modest funding, relatively quick timeframe for completion, and reliance on existing data and information, NRCAs are not intended to be exhaustive. Their methodology typically involves an informal synthesis of scientific data and information from multiple and diverse sources. Level of rigor and statistical repeatability will vary by resource or indicator, reflecting differences in existing data and knowledge bases across the varied study components.

The credibility of NRCA results is derived from the data, methods, and reference values used in the project work, which are designed to be appropriate for the stated purpose of the project, as well as adequately documented. For each study indicator for which current condition or trend is reported, we will identify critical data gaps and describe the level of confidence in at least qualitative terms. Involvement of park staff and National Park Service (NPS) subject-matter experts at critical points during the project timeline is also important. These staff will be asked to assist with the selection of study indicators; recommend data sets, methods, and reference conditions and values; and help provide a multi-disciplinary review of draft study findings and products.

NRCAs can yield new insights about current park resource conditions, but, in many cases, their greatest value may be the development of useful documentation regarding known or suspected resource conditions within parks. Reporting products can help park managers as they think about near-term workload priorities, frame data and study needs for important park resources, and communicate messages about current park resource conditions to various audiences. A successful NRCA delivers science-based information that is both credible and has practical uses for a variety of park decision making, planning, and partnership activities.

***Important NRCA Success Factors***

- *Obtaining good input from park staff and other NPS subject-matter experts at critical points in the project timeline*
- *Using study frameworks that accommodate meaningful condition reporting at multiple levels (measures ⇨ indicators ⇨ broader resource topics and park areas)*
- *Building credibility by clearly documenting the data and methods used, critical data gaps, and level of confidence for indicator-level condition findings*

However, it is important to note that NRCAs do not establish management targets for study indicators. That process must occur through park planning and management activities. What an

NRCA can do is deliver science-based information that will assist park managers in their ongoing, long-term efforts to describe and quantify a park's desired resource conditions and management targets. In the near term, NRCA findings assist strategic park resource planning[6] and help parks to report on government accountability measures.[7] In addition, although in-depth analysis of the effects of climate change on park natural resources is outside the scope of NRCAs, the condition analyses and data sets developed for NRCAs will be useful for park-level climate-change studies and planning efforts.

NRCAs also provide a useful complement to rigorous NPS science support programs, such as the NPS Natural Resources Inventory & Monitoring (I&M) Program.[8] For example, NRCAs can provide current condition estimates and help establish reference conditions, or baseline values, for some of a park's vital signs monitoring indicators. They can also draw upon non-NPS data to help evaluate current conditions for those same vital signs. In some cases, I&M data sets are incorporated into NRCA analyses and reporting products.

***NRCA Reporting Products…***

***Provide a credible, snapshot-in-time evaluation for a subset of important park natural resources and indicators, to help park managers:***

- *Direct limited staff and funding resources to park areas and natural resources that represent high need and/or high opportunity situations*
  ***(near-term operational planning and management)***
- *Improve understanding and quantification for desired conditions for the park's "fundamental" and "other important" natural resources and values*
  ***(longer-term strategic planning)***
- *Communicate succinct messages regarding current resource conditions to government program managers, to Congress, and to the general public*
  ***("resource condition status" reporting)***

Over the next several years, the NPS plans to fund a NRCA project for each of the approximately 270 parks served by the NPS I&M Program. For more information visit the NRCA Program website.

[6] A NRCA can be useful during the development of a park's Resource Stewardship Strategy (RSS) and can also be tailored to act as a post-RSS project.

[7] While accountability reporting measures are subject to change, the spatial and reference-based condition data provided by NRCAs will be useful for most forms of "resource condition status" reporting as may be required by the NPS, the Department of the Interior, or the Office of Management and Budget.

[8] The I&M program consists of 32 networks nationwide that are implementing "vital signs" monitoring in order to assess the condition of park ecosystems and develop a stronger scientific basis for stewardship and management of natural resources across the National Park System. "Vital signs" are a subset of physical, chemical, and biological elements and processes of park ecosystems that are selected to represent the overall health or condition of park resources, known or hypothesized effects of stressors, or elements that have important human values.

# 2. Introduction and Resource Setting

## 2.1. Introduction

Congaree National Park (CONG or Congaree NP or the park) is an old-growth bottomland forest comprising a floodplain ecosystem in the Upper Coastal Plain within Richland County located 32 kilometers (20 mi) southeast of Columbia, South Carolina (Figure 1). The park lies in the floodplain of the Congaree River, bordering its north bank and extends to the recently acquired Riverstone Tract and Bates Fork Tract now completing a contiguous corridor of 16,997 hectares (42,000 ac) along the Congaree, Wateree and upper Santee Rivers.

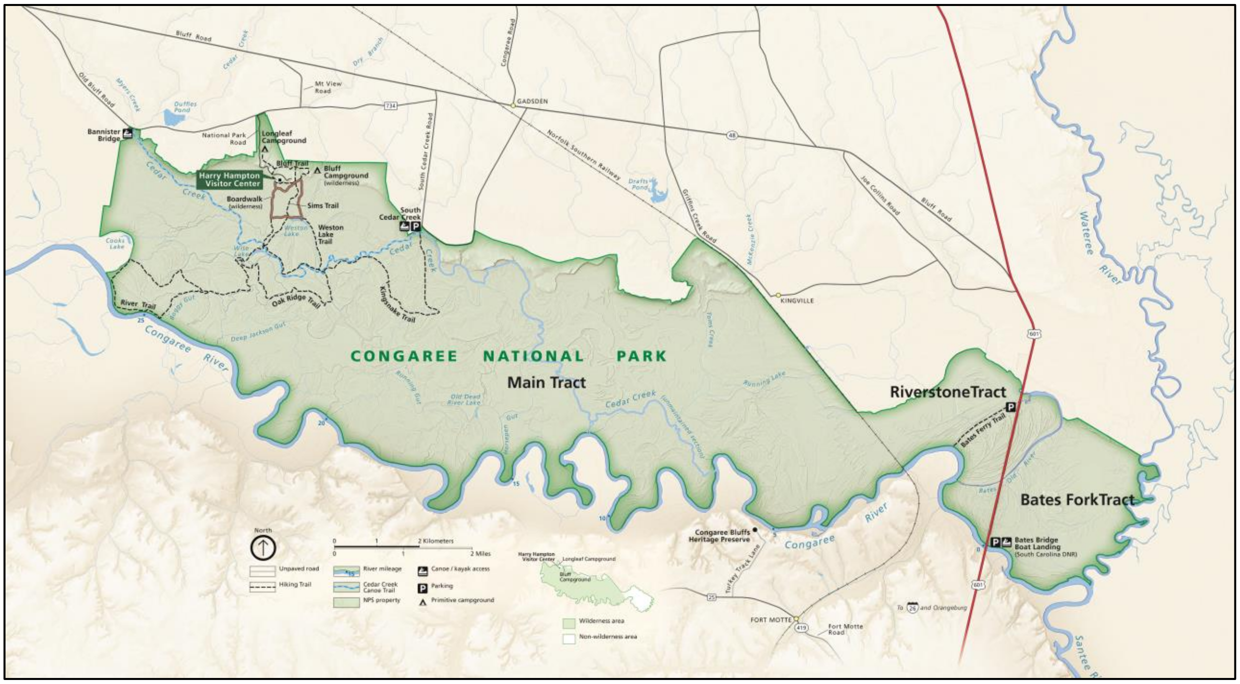


**Figure 1.** Map of Congaree NP showing the park and surrounding areas. Note the Riverstone and Bates Fork tracts in the eastern area of the park. Modified from NPS Harper’s Ferry Center map.

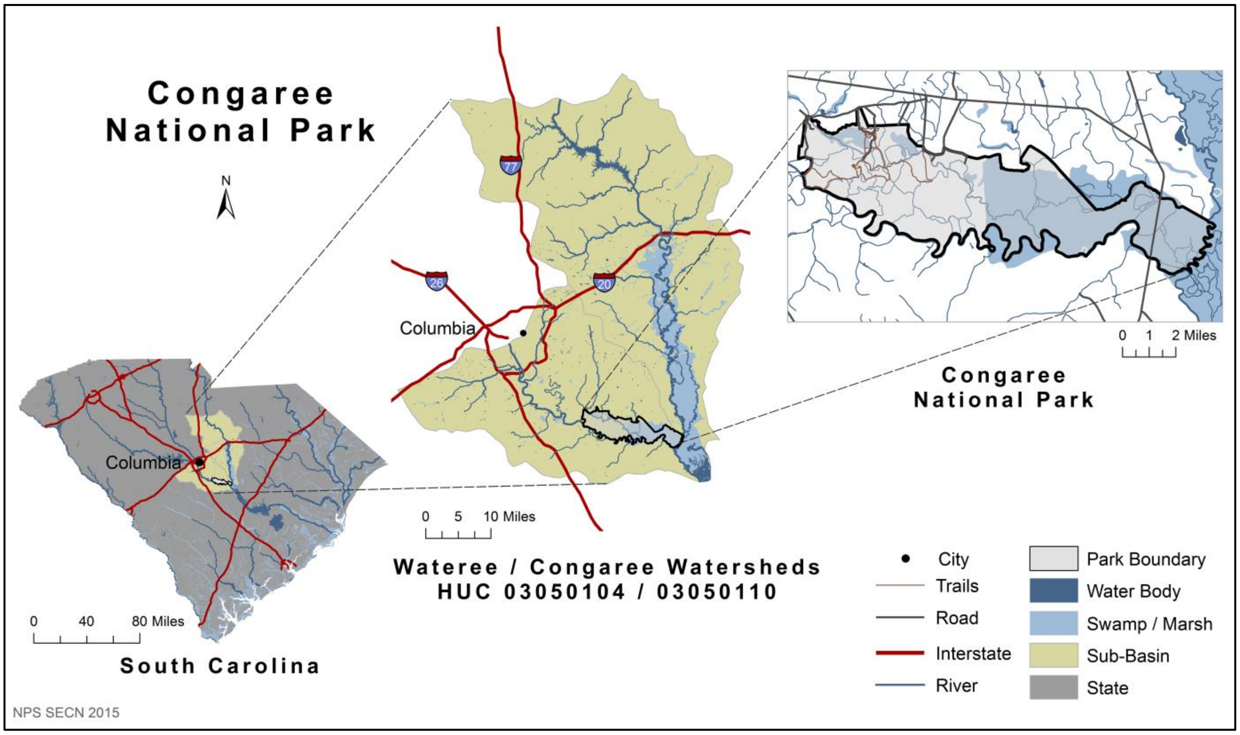


**Figure 2.** Map of general location of the park within South Carolina.

The park spans approximately 43.5 river kilometers (km; 27 river miles [mi]) along the Congaree River to its confluence with the Wateree River. The park is about 25 kilometers (15.5 mi) long and varies in width from between 3 to 6.4 kilometers (1.8 to 4 mi) inland from the Congaree River bank to 4 kilometers (2.5 mi) wide at the Bates Fork Tract. Most of the park is in the Congaree River floodplain, with meandering streams and oxbow lakes; in addition, upland habitat is along the northern park boundary. The National Park Service maintains the Harry Hampton Visitor's Center and Museum, the Old-Growth Bottomland Forest and Education Center (the Learning Center), a maintenance facility and fire building and a lower and upper boardwalk trail totaling 3.9 kilometers (2.4 mi; Figure 2), and five other trails in the wooded areas (NPS 2004a). Overall, there are approximately 32 kilometers (20 mi) of trails in the park (Mallin and McIver 2010). The substantial natural resources of this park include a diverse and unique flora and fauna among forested bottomland wetlands, champion trees, Cedar Creek, Dry Branch, Toms Creek, McKenzie Creek, Weston Lake, Wise Lake and numerous oxbow lakes, ponds, and other hydrological features. The Congaree River floods an average of ten times per year with varying degrees of severity (Rasmussen et al. 2009), and the park is predominantly wetland swamps; thus, land use within the park boundaries is primarily forested wetlands.

**Figure 3.** A boardwalk within Congaree NP, also showing the annual flooding high water mark on adjacent trees. From Mallin and McIver (2010).

#### *2.1.1. Enabling Legislation and Potential for Expansion*

During the 1950s, conservationist Harry Hampton began a campaign to protect the Congaree floodplain ecosystems and was somewhat successful. In 1969, however, with increases in timber prices, logging, re-established by Mr. Francis Beidler II, again threatened the area (Almlie 2011; NPS 2006).

Because of the logging threat to the area's giant trees in the early 1970s, a public campaign to save the trees led Congress (Public Law 94-545) to establish Congaree Swamp National Monument in 1976 (Lockhart 2006). With Public Law 108-108, Congress changed the park name in 2003 to Congaree National Park, and allowed the inclusion of an additional 4,576 acres (1851.8 ha) of land in the authorized boundary for a total area covering 8,768 hectares (ha; 21,666 ac). In 2005, the Bates Fork Tract was purchased for $6 million and added to the park. The present Harry Hampton Visitor's Center was completed in 2000, and the Old-Growth Bottomland Forest and Education Center was completed in 2004.

The Riverstone Tract acquisition was completed in June 2011 and connected the main park and the Bates Fork Tract (Figure 1; Janiskee 2009). This acquisition protects a 48.3-kilometer (30-mi) conservation corridor along the Congaree, Wateree, and upper Santee Rivers. The Riverstone Tract consists of 744.6 hectares (1,840 ac) of flood plain and river bottom forest land. In 2003 Congress authorized an 1861.6-hectare (4,600-ac) expansion covering both the Bates Fork (969.2 hectares or 2,395 ac) and the Riverstone tracts for inclusion with the park's designated boundaries. In late 2007 the private owner of the Riverstone Tract agreed to sell the land for $5.88 million, its federally appraised market value. The Trust for Public Land stepped in to assist, and had purchased all of the Riverstone Tract by April 2009 with intent to transfer the land to the National Park Service as funds can be secured to buy it. The National Park Service was able to purchase 63.2 hectares (156.25 ac) of the Riverstone Tract from the Trust for Public Land in 2008 for $500,000 and 330.1 hectares (838 ac) more for $2.69 million in FY 2009, including all 124.6 hectares (308 ac) of the Riverstone Tract east of Highway 601 and contiguous with the Bates Fork Tract. The National Park Service received another $1.32 million from Congress in FY 2011 to buy 166.9 hectares (412.5 ac) more. The final 175.6 hectares (433.9 ac) were acquired by the National Park Service on 23 June 2011 with $1.4 million in funds from a lump sum appropriated by Congress in April 2011.

This valuable park is nationally and internationally renowned for its outstanding natural resources and its ecological uniqueness, and has received a number of special designations attesting to its importance as a natural feature (Mallin and McIver 2010, Shelley et al. 2012):

- *Natural National Landmark*—U.S. Secretary of the Interior, 15 August 1974.
- *Congaree Swamp National Monument*—U.S. Congress, 21 September 1976.
- *International Biosphere Reserve*—United National, Educational, Scientific and Cultural Organization (UNESCO), 30 June 30 1983.
- *Wilderness*—U.S. Congress, 24 October 1988. As an especially important designation, nearly all of Congaree National Park is now officially designated as wilderness. The Congaree Swamp National Monument Expansion and Wilderness Act of 1988 (Public Law 88-577, 16 U.S.C. 1131-1136, National Wilderness Preservation System) designated approximately 6,074 hectares (15,010 acres) of Congaree Swamp National Monument, now Congaree National Park, as wilderness, and approximately 2,768 hectares (6,840 acres) as potential wilderness additions. On 29 May 2014, 2,707 hectares (6,690 acres) of potential wilderness were added to the wilderness lands (Federal Register 2014), to be managed in accordance with the Federal Wilderness Act of 1964. This action left only 36 hectares (90 acres) of private land remaining within the park's designated potential wilderness.

  The Wilderness Act set aside public lands where natural processes are supposed to dominate: "Wilderness areas…shall be administered for the use of the American people in such a manner as will leave them unimpaired for future use and enjoyment as wilderness…" (16 U.S.C. Sec. §1131). The Wilderness Act directs the National Park Service to protect and manage the wilderness area so that it generally appears to have been affected primarily by the forces of nature, with the imprint of man's work substantially unnoticeable, and so that it has outstanding opportunities for solitude, or a primitive and unconfined type of recreation. The Wilderness Act is founded on the absence of actively used human structures such as roads, and the presence of an undisturbed, healthy, naturally functioning ecology.

- *Congaree National Park*—U.S. Congress re-designated the name and expanded the monument by another 4,600 acres (1,861.5 ha), 10 November 2003.
- *Outstanding Resource Waters*—the waters within the park were so classified by the South Carolina General Assembly (State Register Document No. 3025, Amendment of R.61-69), 23 June 2006.
- *Outstanding National Resource Waters*—portions of Cedar Creek were so classified by the South Carolina General Assembly (same document as above). The Cedar Creek designation was the first of its kind for South Carolina waters.
- *Ramsar Wetland of International Importance*—2 February 2012

#### 2.1.2. Geographic Setting

Congaree National Park is located within the floodplain of the Congaree River in the lower section of the Congaree River Watershed in the Coastal Plain of South Carolina (SC DHEC 2011). The park is at a general elevation of 30.5 meters (100 ft) above mean sea level (MSL), with a maximum elevation of 42.7 meters (140 ft) at Old Bluff Road (Rasmussen 2009, Shelley et al. 2012). Congaree National Park lies within Richland County and flanks the northern bank of the Congaree River from approximately 32.2 kilometers (20 mi) southeast of Columbia to its confluence with the Wateree River. Congaree National Park is broadly in the Santee River watershed, within three sub-watersheds including the Congaree River-Cedar Creek, the Toms Creek and the Lower Wateree River sub-basins (Figure 4; SC DNR 2009; SC DHEC 2011,). Easiest access from Columbia is via South Carolina Highway 48 or from the east by exiting U.S. Highway 601 to South Carolina Highway 48, from which Old Bluff Road can be accessed either from the east or west. The NPS service road is entered from Old Bluff Road.

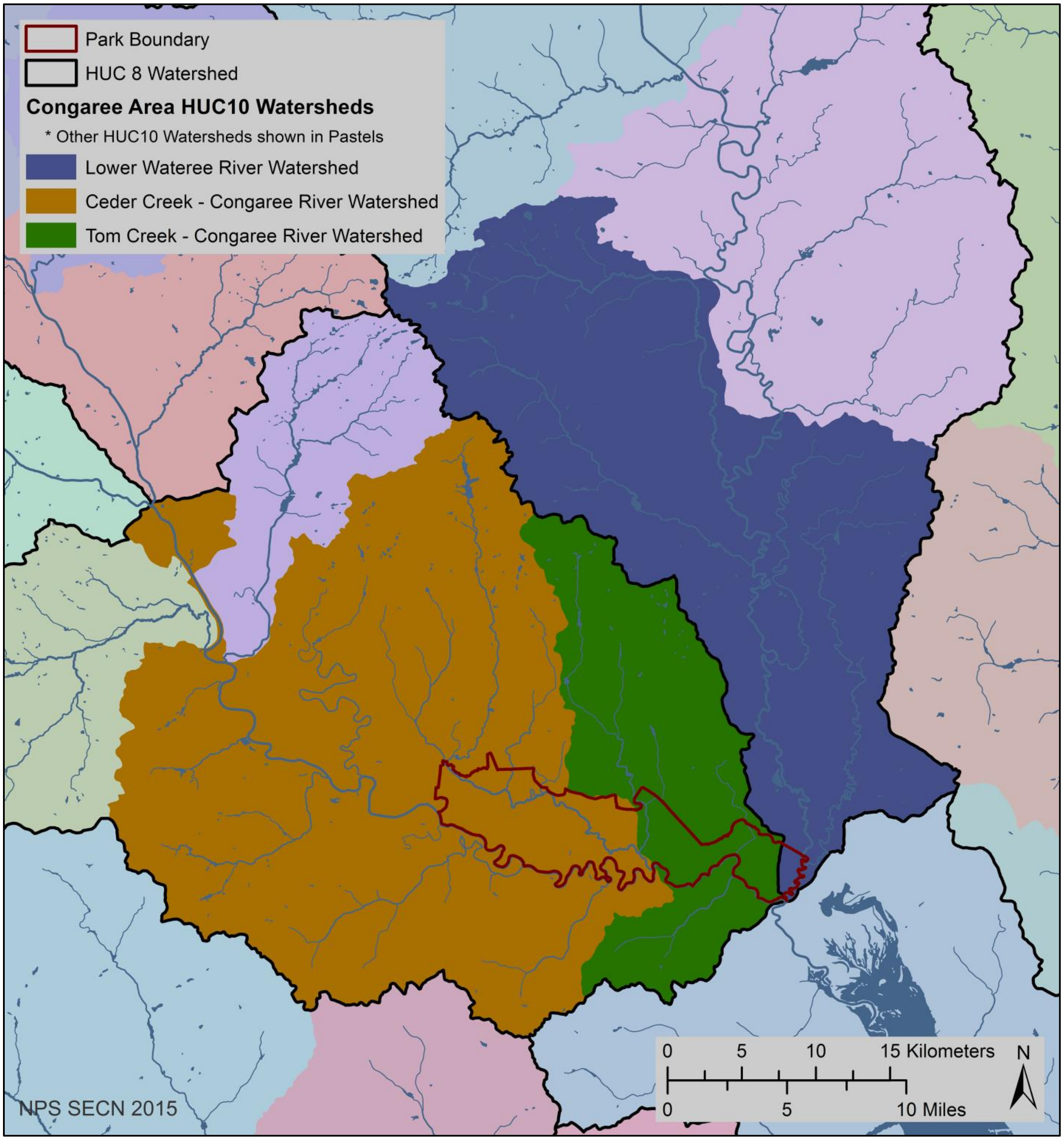


**Figure 4.** Map showing the three HUC 8 sub-watersheds (Cedar Creek, Toms Creek, and the Lower Wateree River) that are a part of Congaree NP.

The North Carolina State University Center for Applied Aquatic Ecology (NCSU CAAE) generated a land use-land cover map for the Congaree River Watershed using the following procedure. The sub-basin boundary (8-digit Hydrologic Unit Code [HUC]) Geographic Information System (GIS) data layer was provided by the U.S. Geological Survey (USGS), and National Land Cover Data (NLCD) for 2011 (Homer et al. 2015) were downloaded from the USGS Seamless Data Distribution System (USGS 2017). Using the Spatial Analyst extension of ArcGIS9.1, the land-use classification system was modified to include eight general categories: urban areas, row crop agriculture, animal agriculture, forests, grasslands, water, wetland, and barren/disturbed. Once the grid was reclassified, the spatial analyst "tabulate area" function was used to calculate the area of each land class. The land cover within the park is mostly woody wetland (Figure 5, Table 1). Within a five-kilometer (3.1 mi) buffer, woody wetlands also cover the bulk of the landcover while at the watershed level, deciduous forest and evergreen forests cover most of the area (Table 2; Jones et al. 2010).

Land use characteristics of the three sub-watersheds containing the park were assessed using data layers from 2011 provided by the National Land Cover Database (Homer et al. 2015; Figure 5). Data were also used from the South Carolina Multiple Resolution Land Coverage, which was produced from Landsat Thematic Mapper and from the Georgia Multiple Resolution Land Coverage (MRLC).

This analysis revealed that, as expected, the land cover within the park is mostly woody wetlands (Figure 5, Table 1). Within a five-kilometer (3.1 mi) buffer, woody wetlands predominate. At the watershed level, deciduous forest and evergreen forests cover most of the land area (Table 2; Jones et al. 2010). At the sub-watershed level, forest and forested wetlands are dominant (46.7–72.5%; mean 60.0%; Figure 5, Table 3). Agriculture is also important, averaging 25.9% of the land use/land cover (range, 18.2–32.4%; Table 3; and SC DHEC 2011, 2012a).

**Table 1.** Land use in the Cedar Creek, Toms Creek, and Lower Wateree River sub-watersheds. Data summarized from the 2011 NLCD (Homer et al. 2015).

| Land Cover | Area ($km^2$) | Area (acres) | Percentage |
|---|---:|---:|---:|
| Open Water | 28 | 6,979 | 1.45 |
| Developed Open Space | 93 | 22,922 | 4.75 |
| Urban | 89 | 21,931 | 4.55 |
| Barren/Rock | 7 | 1,833 | 0.38 |
| Forested | 537 | 132,727 | 27.53 |
| Scrub/Shrub/Grassland | 358 | 88,585 | 18.37 |
| Agricultural—Pasture (Animal Production) | 61 | 14,956 | 3.10 |
| Agricultural—Cropland | 113 | 27,957 | 5.80 |
| Woody Wetlands | 637 | 157,401 | 32.64 |
| Herbaceous Wetlands | 28 | 6,900 | 1.43 |
| TOTAL | 1,951 | 482,191 | 100 |

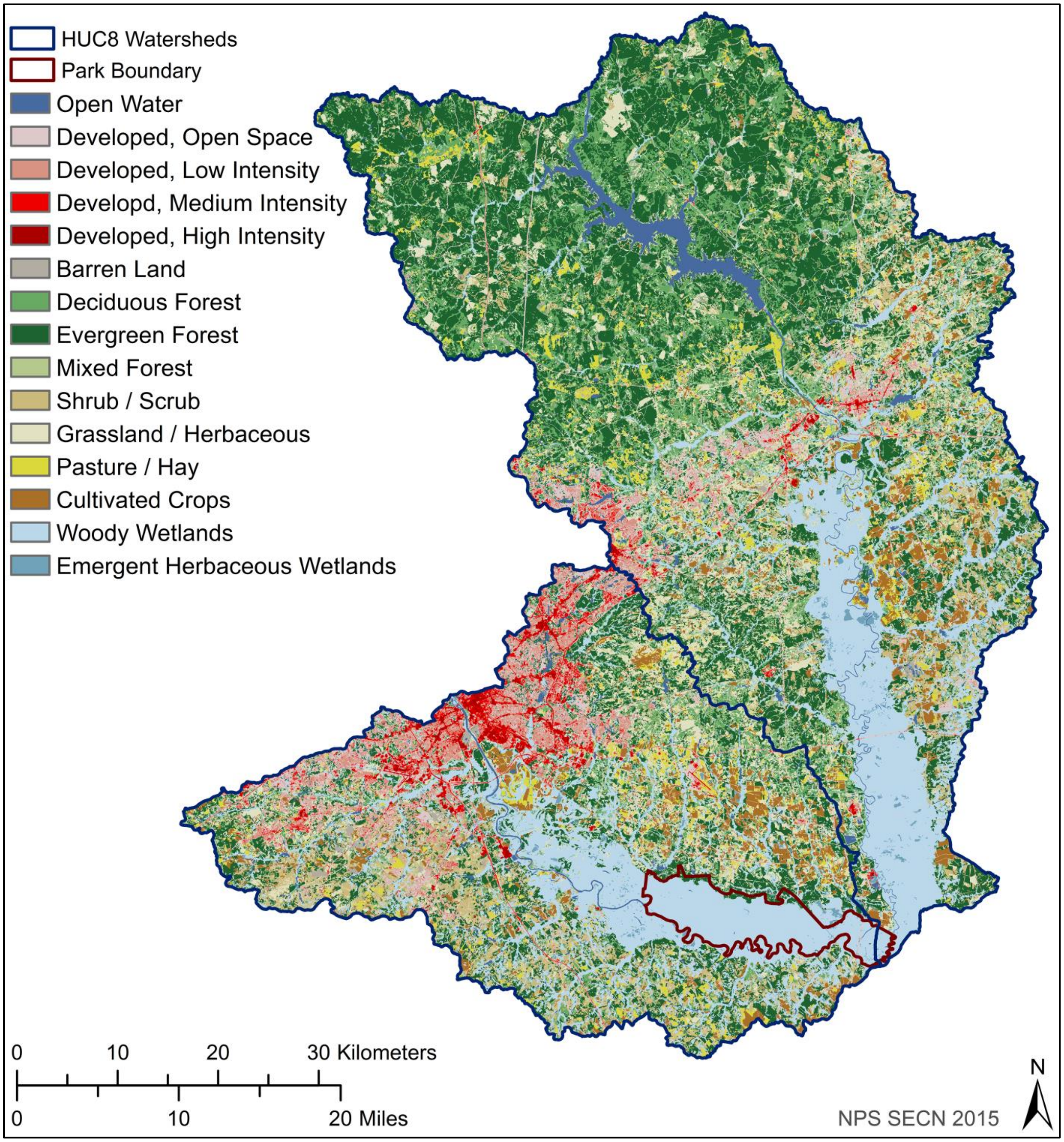


**Figure 5.** Map of land use/land cover in the watersheds affecting Congaree NP and Santee River basin. This map was created by the Southeast Coast Network from 2011 NLCD data (Homer et al. 2015).

**Table 2.** Land cover within CONG, within a 5-km buffer surrounding the park, and within the HUC 8 watershed. From Jones et al. (2010).

| Land cover | Within Park Acres | Percent | 5-km buffer Acres | Percent | HUC 8 Watershed Acres | Percent |
|---|---|---|---|---|---|---|
| Open Water | 142.56 | 0.59 | 1,892.14 | 1.61 | 24,486.34 | 1.98 |
| Developed Open Space | 40.03 | 0.17 | 3,061.04 | 2.60 | 69,362.06 | 5.60 |
| Developed Low Intensity | 4.45 | 0.02 | 607.58 | 0.52 | 41,935.22 | 3.38 |
| Developed Medium Intensity | 2.22 | 0.01 | 47.15 | 1.04 | 14,300.88 | 1.15 |
| Developed High Intensity | 0.22 | 0.00 | 2.22 | 0.00 | 5,253.86 | 0.42 |
| Barren Land | 0.00 | 0.00 | 0.00 | 0.00 | 7,723.55 | 0.62 |
| Deciduous Forest | 133.44 | 0.55 | 10,453.45 | 8.89 | 181,725.28 | 14.66 |
| Evergreen Forest | 1,226.95 | 5.06 | 19,062.80 | 16.21 | 340,332.83 | 27.46 |
| Mixed Forest | 137.88 | 0.57 | 1,133.32 | 0.96 | 41,905.42 | 3.38 |
| Shrub/Scrub | 10.01 | 0.04 | 620.48 | 0.53 | 8,499.04 | 0.69 |
| Grassland/Herbaceous | 8.45 | 0.03 | 12,299.32 | 10.46 | 180,231.45 | 14.54 |
| Pasture/Hay | 10.01 | 0.04 | 2,592.23 | 2.20 | 5,559.35 | 4.48 |
| Cultivated | 8.45 | 0.03 | 7310.12 | 6.22 | 63,310.25 | 5.11 |
| Woody Wetlands | 22,488.12 | 92.81 | 57,940.08 | 49.27 | 201,583.58 | 16.26 |
| Emergent Herbaceous Wetland | 30.25 | 0.12 | 576.67 | 0.49 | 3,351.27 | 0.27 |

**Table 3.** Land use by percent cover in the watersheds including or otherwise affecting Congaree NP. From SC DHEC (2011a, 2012a).

| Watershed | Hydrologic Unit | Forested | Forested Wetland | Nonforested Wetland | Agriculture | Urban | Barren |
|---|---|---|---|---|---|---|---|
| Congaree River—Cedar Creek | 03050110-03 | 35.8% | 10.9% | 0.4% | 27.0% | 10.9% | 0.2% |
| Congaree River—Toms Creek | 03050110-04 | 37.2% | 23.4% | 0.3% | 32.4% | 5.8% | 0.0% |
| Wateree River | 03050104-04 | 36.5% | 36.0% | 1.4% | 18.2% | 6.3% | 0.4% |

#### *2.1.3. Demographics and Visitation Statistics*

The Santee River basin is moderately populated with growth in the Congaree River watershed, which contains a portion of Columbia. Although the southeastern portion of the sub-basin is mainly rural, the central-western area is one of the most densely populated regions of the state (Figure 6). The estimated population of Richland County in 2013 was 399,256 people including the Columbia Metropolitan Area. The population consists of 48.1% Caucasians, 46.8% African Americans, 2.6% Asians, and 0.4% Native Americans (USCB 2017a). The median household income for 2011–2015 was $49,131 (USCB 2017b). The 2013 annual unemployment rate was 7.2% (this percentage was less than the national average reported for that year (South Carolina Department of Employment & Workforce 2014).

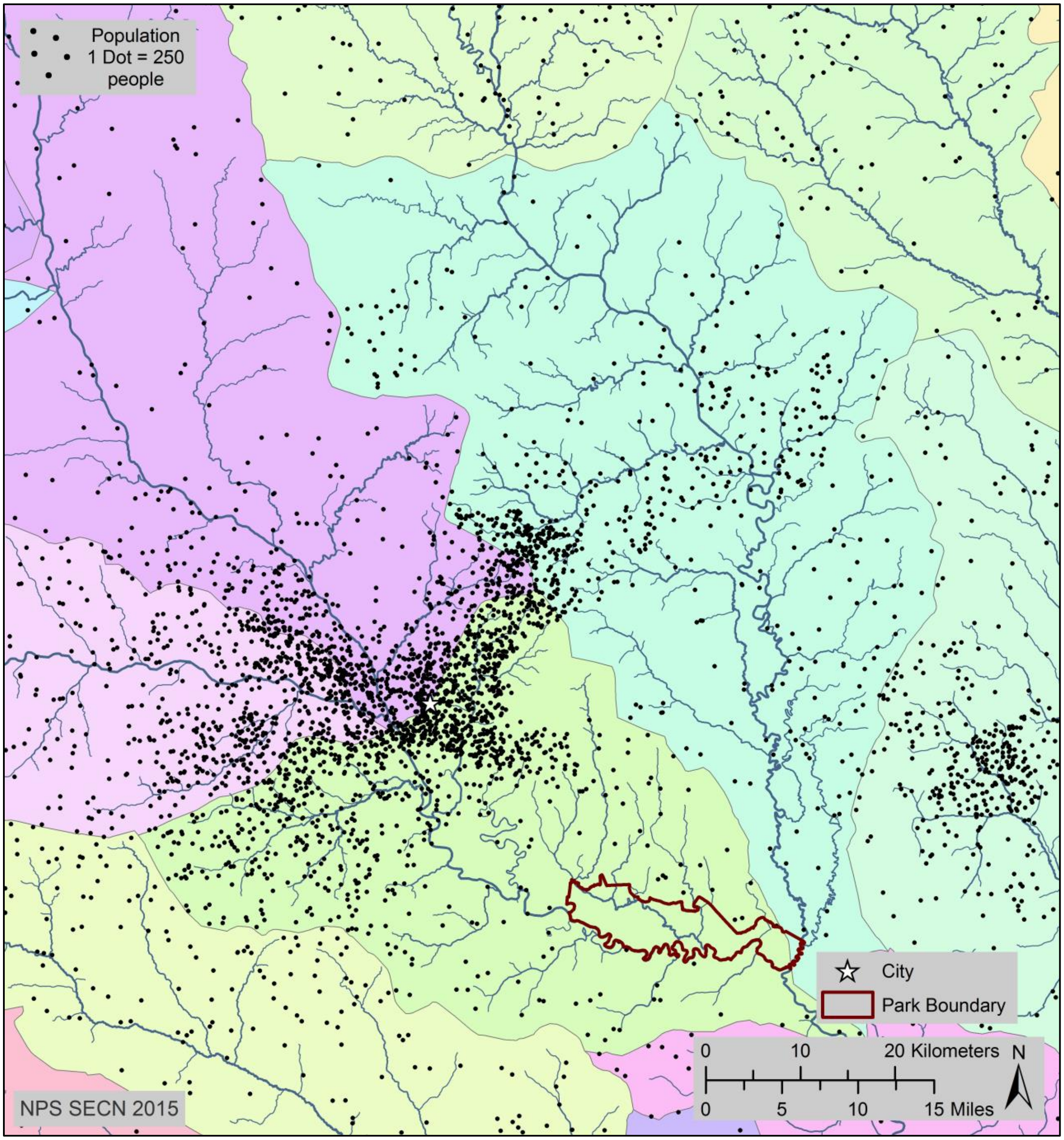


**Figure 6.** Map showing population density in the surrounding sub-watersheds. The star indicates the location of Columbia, South Carolina (data source UCB 2016).

Urban land use is highest (10.9%) in the Congaree River sub-watershed (hydrologic unit #03050110-03) which drains much of the Columbia Metropolitan Area (SCDHEC 2011a). The Congaree River upstream from the park receives nonpoint-source loads of suspended sediments, nutrients, fecal bacteria, metals and other toxic substances from this urban area. Other than Columbia, impervious surface coverage (roads, sidewalks, parking lots, rooftops), which concentrates pollutants and increases stormwater runoff pollution, is presently very low in the sub-watersheds influencing the park. In the park itself, impervious area includes only the parking areas near the Visitor's Center and the entrance road, along with roofs of the park buildings. All of these surfaces are well away from the surface waters, so that immediate runoff within the park is not a potential problem to park water quality.

Visitation Statistics

Visitation at Congaree National Park over the 15 year period prior to 2011 has been steady. In 2014, 120,122 people visited the park. The lowest visitation was in 2005 with 84,301 visitors, whereas the highest number of visitors annually was in 134,045 in 2006 (Figure 7). Visitation is usually heavier in the spring and fall with a slower period in the summer season, which is normally characterized by high temperatures and especially high mosquito densities. Access to the interior of the park is limited to a boardwalk and numerous trails that are often inundated with floodwater (Webster 2010).

A study of visitor activities in the park was conducted during 2–15 May 2011, in which 450 questionnaires were distributed to visitors from 40 states and Washington, D.C. A total of 54% of visitors were from South Carolina and 6% were international visitors from nine countries. Visitor activities included 81% walking/hiking, 71% frequented the visitor's center, and 24% were engaged in birdwatching (Kulesza et al. 2012).

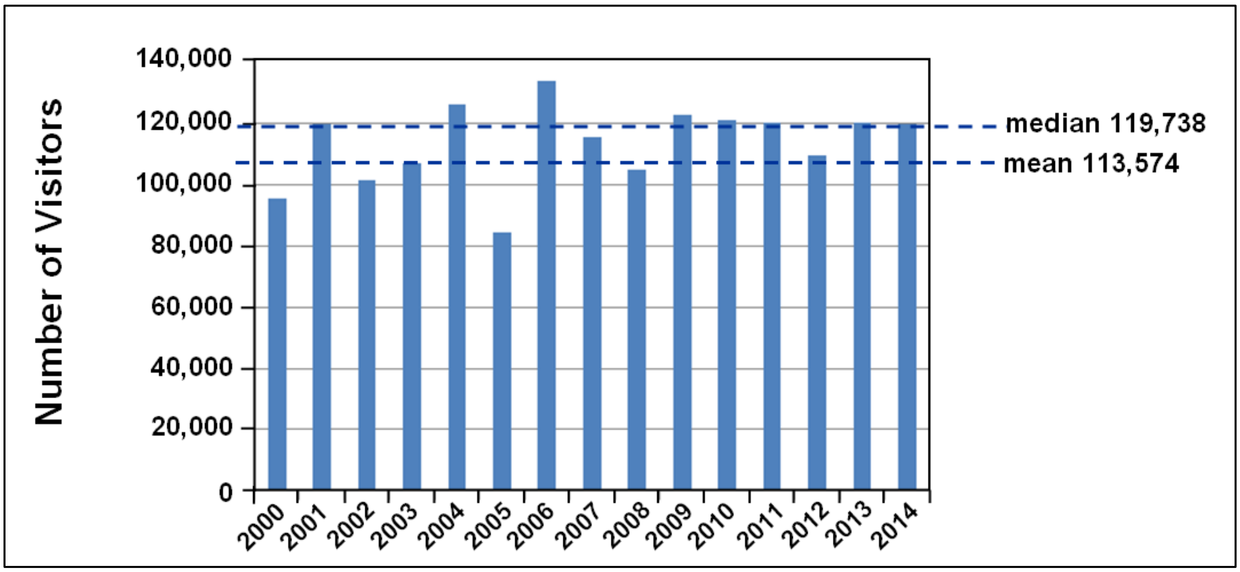


**Figure 7.** The annual number of visitors per year at Congaree NP during 2000–2014 (NPS 2016).

## 2.2. Natural Resources

### *2.2.1. Watersheds*

Congaree National Park is located in the Santee River watershed, which is the largest river basin in South Carolina (Figure 8). The Santee watershed begins in North Carolina with the Catawba River, later becoming the Wateree River, while the Congaree River begins with the confluence of the Saluda and Broad Rivers at the fall line (Piedmont-Coastal Plain boundary) in Columbia.


**Figure 8.** Map showing the Santee River watershed in North and South Carolina. From https://upload.wikimedia.org/wikipedia/commons/9/9d/Santeerivermap.png (last accessed in June 2017).

The park is located within three sub-watersheds comprising four hydrologic units or hydrologic unit codes (HUCs), as designated by the U.S. Geological Survey (USGS), including the Congaree River (two hydrologic units) and the Lower Wateree River sub-watershed. The two Congaree River sub-basins drain 1,222 square kilometers (472 $mi^2$) (Figure 8). Although the Bates Fork Tract is within the lower Congaree River Watershed, it is also strongly influenced by flooding from the Wateree River (SC DHEC 2004). The USGS recently designated the Congaree River watersheds as the Cedar Creek watershed (Hydrologic Unit Code [HUC] 03050110-03) and the Toms Creek watershed (HUC 03050110-04). Most of Congaree National Park is located within the two Congaree River sub-watersheds, which drain 1,222 square kilometers (472 $mi^2$) of area (Figure 8). The Lower Wateree River watershed (HUC 03050104-04) comprises the lowest portion of the Wateree River from Swift Creek to the confluence of the Wateree and Congaree Rivers (Figure 8). The hydrologic units used by South Carolina DHEC are from the most recent delineation efforts by the USGS, and include the newest Hydrologic Unit Codes for the state (nationally available as the 2013 Watershed Boundary Dataset [WBD] (USGS 2017b).

#### *2.2.2. Natural Resources Inventory*

Air Quality

*Federal Criteria for Major Air Pollutants and a Federal Index Scale*

The EPA (2012a) maintains National Ambient Air-quality Standards (NAAQS) under the federal Clean Air Act. The Clean Air Act has set standards for six “criteria” pollutants (including two categories for one of these, particulate matter) that must meet a health-based regulatory standard (Table 4). The regulatory air-quality standards are health-based, and concentrations above the standards are considered unhealthy for sensitive groups. For example, the 8-hour (hr) ozone standard is attained when the average of the fourth highest concentration measured is equal to or below 0.08 parts per million (ppm; 0.085 ppm with the EPA rounding convention), averaged over three years. To be in compliance with the federal air $PM_{2.5}$ standard, an area must have an annual arithmetic mean concentration of less than or equal to 15 µg $PM_{2.5}/m^3$. An additional requirement imposed a stricter standard for fine particulate matter as of 2007, wherein the 98th percentile 24-hr concentration must be < 35 µg $PM_{2.5}/m^3$ to protect sensitive groups (Table 5).

Ozone is generally monitored from March to October, since that is the period when ozone production is highest (EPA 1994a). This pollutant is a serious health concern because it attacks the mammalian respiratory system, causing coughs, chest pain, throat irritation, increased susceptibility to respiratory infections, and impaired lung functioning. In fact, moderate ozone levels can interfere with performance of normal daily activities by people who have asthma or other respiratory diseases. Of more concern than acute affects are chronic effects of repeated exposure to ozone, which can lead to lung inflammation and permanent scarring of lung tissue, loss of lung function, and reduced lung elasticity.

Fine particulate matter ($PM_{2.5}$) is produced by various sources including industrial combustion, residential combustion, and vehicle exhaust, or when combustion gases are chemically transformed into particles. Recent research has indicated that $PM_{2.5}$ is a human health concern because it can penetrate into sensitive areas of the lungs and cause persistent coughs, phlegm, wheezing, more serious respiratory and cardiovascular disease, cancers, and premature death at particle levels well below the existing standards (Schwela 2000, EPA 2004). Mounting evidence indicates that $PM_{2.5}$ enhances delivery of other pollutants and allergens deep into lung tissue where the effects are exacerbated. Especially sensitive groups include children, the elderly, and people with cardiovascular or lung diseases such as asthma. $PM_{2.5}$ also impairs visibility and contributes to haze in the humid conditions that characterize South Carolina climate (EPA 1994a).

The EPA Air-quality Index (AQI; scale from 0 to 500 with lower values indicating less pollution) was designed to help inform the general citizenry about potential health impacts from air quality degradation (Tables 5 and 6). The goal is to provide accurate, timely, easily understandable information about daily levels of air pollution with a uniform system for the major air pollutants regulated under the Clean Air Act (AirNow 2015). The index allows the general citizenry to assess whether air pollution levels in the location of interest are good, moderate, unhealthy for sensitive groups, or worse. For example, an AQI value of 50 indicates good air quality with low potential for adverse public health effects, whereas an AQI of more than 300 indicates hazardous air quality. An AQI less than 100 generally is used as the acceptable level set by the EPA to protect public health (EPA 2017). Information is also provided about precautions that should be taken if air pollution levels are unhealthy or worse.

**Table 4.** National ambient air-quality (AQ) standards (NAAQS, 40 CFR part 50), set by the EPA (2014) for six principal ("criteria") pollutants considered harmful to public health and the environment. (P—primary; S—secondary).

| Pollutant [final rule cited] | Primary / Secondary[5] | Averaging Time | Level | Form |
|---|---|---|---|---|
| Carbon Monoxide [76 FR 54294, Aug 31, 2011] | P | • 8-hour<br>• 1-hour | • 9 ppm<br>• 35 ppm | Not to be exceeded more than once per year |
| Lead [73 FR 66964, Nov 12, 2008] | P and S | Rolling 3 month average | 0.15 µg/m$^3$ (1) | Not to be exceeded |
| Nitrogen Dioxide [75 FR 6474, Feb 9, 2010] [61 FR 52852, Oct 8, 1996] | P | 1-hour | 100 ppb | 98th percentile, average over 3 years |
| | P and S | Annual | 53 ppb (2) | Annual Mean |
| Ozone [73 FR 16436, Mar 27, 2008] | P and S | 8-hour | 0.075 ppm (3) | Annual fourth-highest daily maximum 8-hr concentration, averaged over 3 years |

[1] Final rule signed October 15, 2008. The 1978 lead standard (1.5 µg/m$^3$ as a quarterly average) remains in effect until 1 year after an area is designated for the 2008 standard, except that in areas designated nonattainment, the 1978 standard remains in effect until implementation plans to attain or maintain the 2008 standard are approved.

[2] The official level of the annual $NO_2$ standard is 0.053 ppm, equal to 53 ppb, which is shown here for the purpose of clearer comparison to the 1-hour standard.

[3] Final rule signed March 12, 2008. The 1997 ozone standard (0.08 ppm, annual fourth-highest daily maximum 8-hour concentration, averaged over 3 years) and related implementation rules remain in place. In 1997, the EPA revoked the 1-hour ozone standard (0.12 ppm, not to be exceeded more than once per year) in all areas, although some areas have continued obligations under that standard ("anti-backsliding"). The 1-hour ozone standard is attained when the expected number of days per calendar year with maximum hourly average concentrations higher than 0.12 ppm is 1 day or less.

[4] Final rule signed June 2, 2010. The 1971 annual and 24-hour $SO_2$ standards were revoked in that same rulemaking. However, these standards remain in effect until 1 year after an area is designated for the 2010 standard, except in areas designated non-attainment for the 1971 standards, wherein the 1971 standards remain in effect until implementation plans to attain or maintain the 2010 standard are approve

[5].The Clean Air Act identifies two types of national ambient AQ standards: Primary standards provide public health protection, including protecting the health of "sensitive" populations such as asthmatics, children, and the elderly. Secondary standards provide public welfare protection, including protection against decreased visibility and damage to animals, crops, vegetation, and buildings (EPA 2016).

**Table 4 (continued).** National ambient air-quality (AQ) standards (NAAQS, 40 CFR part 50), set by the EPA (2014) for six principal ("criteria") pollutants considered harmful to public health and the environment. (P—primary; S—secondary).

| Pollutant [final rule cited] | Primary / Secondary[5] | Averaging Time | Level | Form |
|---|---|---|---|---|
| Particle pollution Dec 14, 2012 | $PM_{2.5}$ P | Annual | 12 µg/$m^3$ | annual mean, averaged over 3 years |
| | $PM_{2.5}$ S | Annual | 15 µg/$m^3$ | annual mean, averaged over 3 years |
| | $PM_{2.5}$ P and S | 24-hour | 35 µg/$m^3$ | 98th percentile, average over 3 years |
| | $PM_{10}$ P and S | 24-hour | 150 µg/$m^3$ | Not to be exceeded more than once per year on average over 3 years |
| Sulfur Dioxide [75 FR 35520,June 22, 2010] [38 FR 25678, Sept 14, 1973] | P | 1-hour | 75 ppb [(4)] | 99th percentile of 1-hour daily maximum concentrations, averaged over 3 years |
| | S | 3-hour | 0.5 ppm | Not to be exceeded more than once per year |

[1] Final rule signed October 15, 2008. The 1978 lead standard (1.5 µg/$m^3$ as a quarterly average) remains in effect until 1 year after an area is designated for the 2008 standard, except that in areas designated nonattainment, the 1978 standard remains in effect until implementation plans to attain or maintain the 2008 standard are approved.

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Based on the AQI, air quality in Columbia was "good" 254 days and "moderate" 111 days out of 365 days reported in 2013. Daily AQI values are calculated for each air pollutant. The highest of those values become the "main pollutant" for that day. In 2013, the number of days each pollutant in Table 4 was the "main pollutant" was: $NO_2$: 2; $O_{3:}$ 101; $SO_2$: 8; $PM_{2.5}$: 254 (EPA 2013).

AQI primary pollutants in Columbia for 2012: $PM_{2.5}$ was 10µg/$m^3$ just below the 12 µg/$m^3$ standard and $PM_{10}$ was 71 µg/$m^3$ above the 35 µg/$m^3$ standard. Carbon monoxide was 1 ppm below the national standard of 8 ppb averaged over an 8-hour period. Nitrogen dioxide was 4 ppb, well below the 53 ppb standard. Sulfur dioxide was 33 ppb, below the 75 ppb standard (EPA 2012a).

Additionally, ozone in Richland County exceeded the standard 0.075 ppm 9 days in 2011. The $PM_{2.5}$ standard level of 15.0 µg/$m^3$ for the annual averaging time and 35 µg/$m^3$ for the 24-hour averaging time was not exceeded in 2011. The annual average $PM_{2.5}$ was 0.0 µg/L. (SC DHEC 2011b).

The Congaree Bluff site ID 45-079-0021 is located at latitude 33.81467 and longitude -80.78113 in Richland County within the park boundaries. Parameters monitored include ozone, sulfur dioxide, mercury vapor and precipitation. Congaree Bluff also has samplers for mercury deposition and precipitation chemistry. Congaree Bluff monitoring continues a data record begun in 1981 with the Congaree Swamp site (45-079-1006). The original site was established by the U.S. Department of the Interior and the South Carolina General Assembly to provide long-term monitoring in the park. The Congaree Swamp site was located in the floodplain, and was relocated to the current Congaree Bluff site in 2001. Mean annual ozone (8 hr) concentration from 2002 through 2013 was 69.1 ppb and mean annual sulfur dioxide (1 hr) concentration was 42.2 ppb. Nitrogen oxides were measured from 2002–2007; the mean annual concentration was 2.3 ppb (SC DHEC 2014; SC DHEC 2015).

**Table 5.** EPA Air-quality Index (AQI) criteria (modified from AirNow 2015a).

| **PM2.5 (24 hr) µg/m3** | **PM10 (24 hr) µg/m3** | **SO2 (1 hr) ppm** | **O3 (8 hr) ppm** | **CO (8 hr) ppm** | **NO2 (1 hr) ppm** | **ACI Value** | **Descriptor** | **EPA Health Advisory** |
|---|---|---|---|---|---|---|---|---|
| 0.00–15.4 | 0–54 | 0–0.035 | 0.00–0.059 | 0.0–4.4 | 0.0–0.053 | 0–50 | GOOD | Air quality satisfactory; little or no risk from air pollution |
| 15.5–40.4 | 55–154 | 0.036–0.075 | 0.060–0.075 | 4.5–9.4 | 0.054–0.100 | 51–100 | MODERATE | Air quality acceptable, but for some pollutants there may be a moderate health concern for a small number of unusually sensitive people |
| 40.5–65.4 | 155–254 | 0.0766–0.185 | 0.076–0.095 | 9.5–12.4 | 0.101–0.360 | 101–150 | UNHEALTHY for Sensitive Groups | Sensitive groups (people with greater risk from exposure to particulate pollution, ozone |
| 65.5–150.4 | 255–354 | 0.186–0.304 | 0.096–0.115 | 12.5–15.4 | 0.361–0.64 | 151–200 | UNHEALTHY | Everyone may begin to sustain health effects; members of sensitive groups may experience more serious health impacts |
| 150.5–250.4 | 355–424 | 0.305–0.604 | 0.116–0.374 | 15.5–30.4 | 0.65–1.24 | 201–300 | VERY UNHEALTHY | AQI values trigger a health alert; everyone sustains more serious health effects. If related to high ozone, outside activities should be restricted to morning or late evening to minimize exposure |
| 250.5–500.4 | 425–604 | 0.605–1.004 | None | 30.5–50.4 | 1.25–2.04 | 301–500 | HAZARDOUS | AQI values over 300 trigger health warnings of emergency conditions; the entire populace is more likely to be affected |

**Table 6.** The Air-quality Index (AQI) of the EPA, translated into actions that citizens can take to protect their health from potentially harmful levels of major air pollutants. From EPA (2009).

| AQI Value | Actions To Protect Your Health From Particle Pollution | Actions to Protect Your Health From Ozone | Actions To Protect Your Health From Carbon Monoxide | Actions to Protect Your Health From Sulfur Dioxide |
|---|---|---|---|---|
| Good<br>(0-50) | None | None | None | None |
| Moderate<br>(51-100) | Unusually sensitive people should consider reducing prolonged or heavy exertion. | Unusually sensitive people should consider reducing prolonged or heavy outdoor exertion. | None | None |
| Unhealthy for Sensitive Groups<br>(101-150) | The following groups should reduce prolonged or heavy outdoor exertion:<br>• People with heart or lung disease<br>• Children and older adults<br>• Everyone else should limit prolonged or heavy exertion | The following groups should reduce prolonged or heavy outdoor exertion:<br>• People with lung disease, such as asthma<br>• Children and older adults<br>• People who are active outdoors | People with heart disease, such as angina, should reduce heavy exertion and avoid sources of carbon monoxide such as heavy traffic. | People with asthma should consider reducing exertion outdoors. |
| Unhealthy<br>(151-200) | The following groups should avoid all physical activity outdoors:<br>• People with heart or lung disease<br>• Children and older adults<br>• Everyone else should avoid prolonged or heavy exertion | The following groups should avoid prolonged or heavy outdoor exertion:<br>• People with lung disease such as asthma<br>• Children and older adults<br>• People who are active outdoors<br>• Everyone else should limit prolonged outdoor exertion. | People with heart disease, such as angina, should reduce moderate exertion and avoid sources of carbon monoxide such as heavy traffic | Children, asthmatics, and people with heart disease should reduce exertion outdoors |
| Very Unhealthy<br>(201-300) | The following groups should remain indoors and keep activity levels low:<br>• People with heart or lung disease<br>• Children and older adults<br>• Everyone else should avoid all physical activity outdoors. | The following groups should avoid all outdoor exertion:<br>• People with lung disease, such as asthma<br>• Children and older adults<br>• People who are active outdoors<br>• Everyone else should limit outdoor exertion. | People with heart disease, such as angina, should avoid exertion and sources of carbon monoxide such as heavy traffic | Children, asthmatics, and people with heart or lung disease should avoid outdoor exertion. Everyone else should reduce exertion outdoors. |

*National Park Service Indices for Air Quality*

The National Park Service (2011a) has developed guidance for assessing AQ conditions within its parks, including information for evaluating ozone ($O_3$) as related to plant responses. The Air Resources Division of the National Park Service used all available monitoring data over the 2005–2009 five-year period to generate interpolations for the parks throughout the continental U.S., including parks such as Congaree National Park that do not have on-site monitoring. National Park Service then determined an index for each type of air-quality data considered, including ozone concentrations and exposures (mean annual 4$^{th}$ highest 8-hour [hr] ozone concentrations), nitrogen wet deposition, sulfur wet deposition, and visibility condition (Group 50 visibility minus estimated annual average natural conditions, where Group 50 is the mean of the 40$^{th}$ to 60$^{th}$ percentiles of observed measurements in deciview). Park AQ interpolated values are then assigned to one of three condition categories for each NPS AQ index:

- Air quality is in good condition
- Air quality is in moderate condition
- Air quality is a significant concern

The following procedures are taken from NPS (2011a):

*Ozone Condition*

The $O_3$ human health standard (EPA 2008) requires that the 3-year average of the 4$^{th}$ highest daily maximum 8-hour average ozone concentrations measured at each monitor within the area of interest over each year must not exceed 75 parts per billion (ppb). Accordingly, the NPS assigned 5-year average values as in Table 7:

**Table 7.** The NPS ranks for ozone concentrations to protect human health in air-quality condition assessment (NPS 2011a).

| Ozone Condition (Human Health) | Ozone concentration |
|---|---|
| Significant Concern | ≥ 76 ppb |
| Moderate | 61-75 ppb |
| Good | ≤ 60 ppb |

Note that the “moderate” and “good” conditions are assigned to parks with average 5-year 4$^{th}$-highest 8-hour ozone concentrations > 80% of the standard and ≤ 80% of the standard, respectively.

The National Park Service has incorporated vegetation sensitivity, as well as human health, into its park air-quality rating, in consideration of the fact that some plant species have been shown to be more sensitive to $O_3$ than humans so use of an $O_3$ standard for humans would not be sufficiently protective of those plant species. The National Park Service completed a risk assessment in 2004 that rated parks at low, moderate, or high risk for ozone injury to vegetation based on the presence of sensitive plant species, $O_3$ exposures, and environmental conditions (especially soil moisture). For $O_3$ condition assessment, parks that were evaluated as high risk are moved into the next worse condition category. For example, a park with an average $O_3$ concentration of 72 ppb, but evaluated at high risk for vegetation injury, would be moved from “moderate condition” to “significant concern.”

The National Park Service also developed a method for rating $O_3$ condition considering only on plant response, based on the EPA proposed approach—use of the metric W126 for a secondary $O_3$ standard designed to protect vegetation. The W126 measures cumulative $O_3$ exposure over the growing season and is considered a better predictor of plant response than the 8-hr human health standard metric. A similar metric, SUM06, also measures cumulative exposure. The thresholds below for both metrics are based on recommendations from an expert workgroup (Table 8): W126 in the range of 7–13 ppm-hour would protect growth effects to tree seedlings in natural forest stands, whereas W126 ranging from 5–9 ppm-hour would protect plants in natural ecosystems from foliar injury (Heck and Cowling 1997; EPA 2007).

**Table 8.** The NPS ranks for ozone concentrations to protect sensitive plant species in air-quality condition assessment (NPS 2011a).

| Ozone Concentration (Ecological) | Ozone Exposure—W126 | Ozone Exposure—SUM06 |
|---|---|---|
| Significant Concern | > 13 ppm-hr | > 15 ppm-hr |
| Moderate | 7–13 ppm-hr | 8–15 ppm-hr |
| Good | < 7 ppm-hr | < 8 ppm-hr |

Ozone concentrations in Columbia ranged from 0.07 to 0.1 ppm during 2000–2012. Ozone measured at ground level in 2012 was 0.066 ppm, below the national standard of 0.075 ppm (EPA 2012c).

*Nitrogen and Sulfur Conditions:*

Wet deposition is calculated by multiplying the N or S concentration in precipitation by a normalized precipitation amount (note: dry deposition data are not available). Factors considered in rating the deposition condition include natural background deposition estimates (0.25 kilograms per hectare per year [kg/ha/yr] for either N or S), and deposition effects on ecosystems. Certain sensitive ecosystems respond to levels of N or S deposition at 1.5 kg/ha/hr, whereas information is not available indicating that wet deposition of less than 1 kg/ha/yr causes ecosystem harm. Therefore, the National Park Service ranks parks with wet N or S deposition as in Table 9.

**Table 9.** The NPS ranks for wet deposition of nitrogen (N) or sulfur (S) in air-quality condition assessment, in order to protect park ecosystems (NPS 2011a).

| Deposition Condition | Wet Deposition of N or S (kg/ha/yr) |
|---|---|
| Significant Concern | > 3 |
| Moderate | 1–3 |
| Good | < 1 |

Note that the basis for the level of deposition ranked as "Significant Concern" was not given by National Park Service (2011a). Values for parks with ecosystems that are potentially more sensitive to N or S are adjusted up one category.

In Columbia, nitrogen dioxide was 4 ppb, well below the 53 ppb standard in 2012. For the same year, sulfur dioxide was 33 ppb, below the 75 ppb standard. (EPA 2012c).

*Visibility Condition*

This rating is based on the deviation of the current Group 50 visibility conditions from the estimated Group 50 natural visibility conditions, where Group 50 is the mean of the visibility observations within the range from the 40$^{th}$ through the 60$^{th}$ percentiles. Current visibility is estimated from interpolating the 5-yr averages of the Group 50 visibility. Visibility is expressed in terms of a Haze Index (derived from calculated light extinction—see report #EPA-454/B-03-005), in deciviews (dv), where visibility equals the present Group 50 condition visibility minus the estimated Group 50 visibility under natural conditions.

The dv ranges for these categories were described as somewhat subjective but were selected to reflect, insofar as possible, the variation in visibility conditions across the monitoring network. The NPS criteria for visibility were finalized as shown in Table 10:

**Table 10.** The NPS ranks for visibility in air-quality condition assessment (NPS 2011a).

| Visibility Condition | Current Group 50 minus- Estimated Group 50 Natural (dv) |
|---|---|
| Significant Concern | > 8 |
| Moderate | 2–8 |
| Good | < 2 |

*Air Quality in Congaree National Park and Vicinity*

Congaree National Park is within a Class II airshed under the Clean Air Act, wherein modest increases in air pollution are allowed beyond baseline levels for particulate matter, sulfur dioxide, nitrogen and nitrogen dioxide, provided that the EPA National Ambient Air-quality Standards are not exceeded (NPS 2004a).

Principal sources of air pollution in the park vicinity include vehicles, industries, and powerplants (DeVivo et al. 2008). A number of air quality issues were identified for Congaree National Park by DeVivo et al. (2008; Table 11). Among the more serious concerns is the increasing concentration and deposition of ammonia, likely from intensive livestock production. Acidification and the potential for aerial deposition of metals were other identified concerns. Acid precipitation can adversely affect or kill aquatic life and harm human health (Abelson 1987, Herlihy et al. 1991, Baker and Christensen 1992), and can act synergistically with ozone to harm human health as well (Abelson 1987).

In 2001–2003, Sullivan et al. (2011) assessed the threat of acid deposition to national parks across the U.S., including Congaree National Park. First, they compiled and mapped data for total sulfur (S) and total nitrogen (N) emissions from the EPA (2002a dataset—tons per mile$^2$ per year); from the

National Atmospheric Deposition Program (NADP) for wet deposition (2001–2003; kg/hectare/yr) and from the 12-kilometer Community Multiscale Air Quality (CMAQ) Model projections for dry deposition for 2002. The area of central South Carolina including the park was mapped for S and N emissions and S and N deposition (Figure 9a–d). Sullivan et al. (2011) then ranked the 32 NPS I&M networks and also the individual parks within each network considering four metrics: pollutant exposure, ecosystem sensitivity, park protection, and an overall metric, summary risk to acid deposition. This analysis indicated that the SECN ranked at the top of the second highest quintile in pollutant exposure among the NPS networks. Emissions and deposition of S and N within the SECN were evaluated as fairly high. The SECN ecosystem sensitivity ranking was very low, in the bottom quintile among the networks, and at the bottom of the second lowest quintile in park protection because it has only limited amounts of protected lands. The SECN's overall summary risk ranking was relatively low among the networks.

**Table 11.** Air quality issues identified in CONG (I—increasing; Y—Yes there is an issue, N—there is not an issue; IS—infrequently surpasses air quality thresholds; L—low; – no data). From DeVivo et al. (2008).

| Type | Contaminant | Type of contamination | Code |
|---|---|---|---|
| Wet deposition | Ammonium | Deposition | I |
| | Ammonium | Concentration | I |
| | Nitrate | Deposition | – |
| | Nitrate | Concentration | – |
| | Sulfate | Deposition | – |
| | Sulfate | Concentration | – |
| Dry deposition | Nitrogen | Overall dry deposition | – |
| | Nitrogen | Percentage of total N that is dry | – |
| | Sulfur | Overall dry deposition | – |
| | Sulfur | Percentage of total S that is dry | – |
| Surface water chemistry | Acidification | Concern for Park | Y |
| | Mercury | Potential aerial deposition | Y |
| | Nutrients | Potential aerial deposition | N |
| Ozone | Sum06 | Frequency standard surpassed | IS |
| | W126 | Frequency standard surpassed | IS |
| | Foliar injury | Risk based on conditions | L |

Sullivan et al.'s (2011) assessment ranked Congaree NP high (i.e., in the second highest quintile ranking) for pollutant exposure. Congaree NP was evaluated as low (the lowest quintile ranking) for ecosystem sensitivity, high in park protection, and overall as moderate in summary risk from acid deposition. As noted, the data used for this study were from 2001–2003, now more than fifteen years.

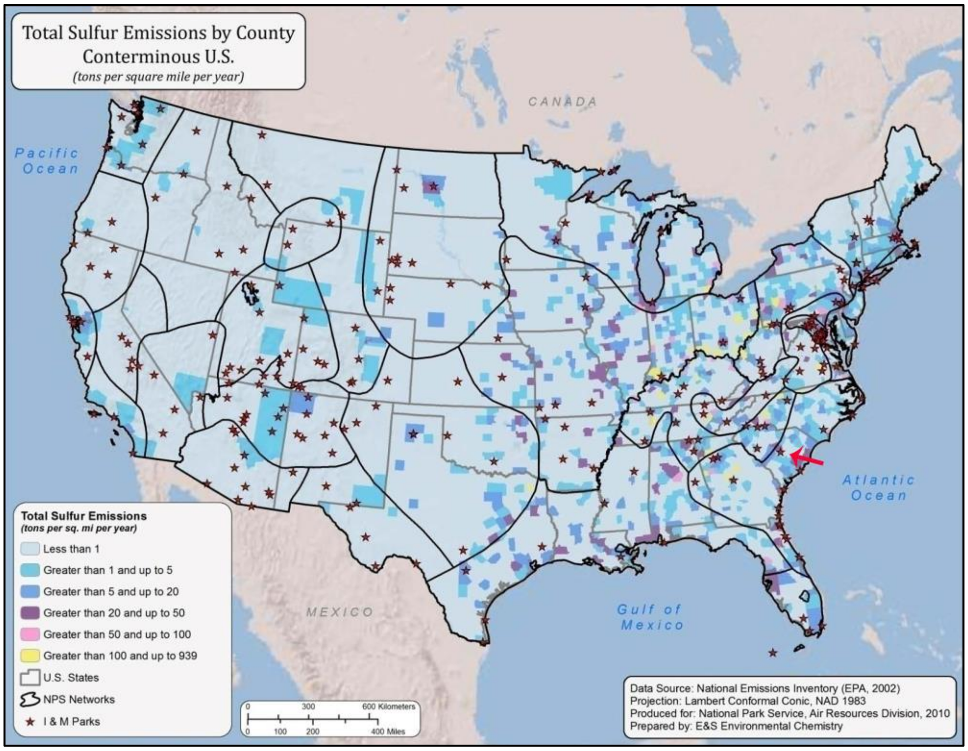


**Figure 9a.** Map of total sulfur (S) emissions (tons/mi$^2$/yr) by county as of 2002. (Congaree NP—red arrow). From Sullivan et al. (2011).

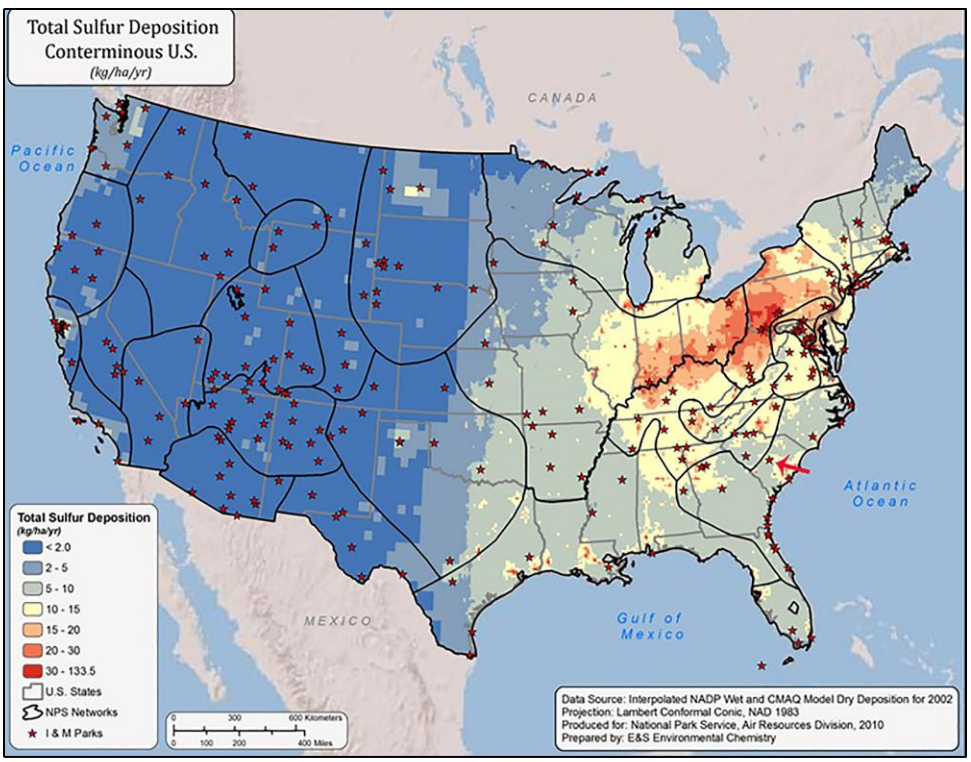


**Figure 9b.** Map of total sulfur (S) emissions (kg/ha/yr) by county as of 2002. (Congaree NP—red arrow). From Sullivan et al. (2011).

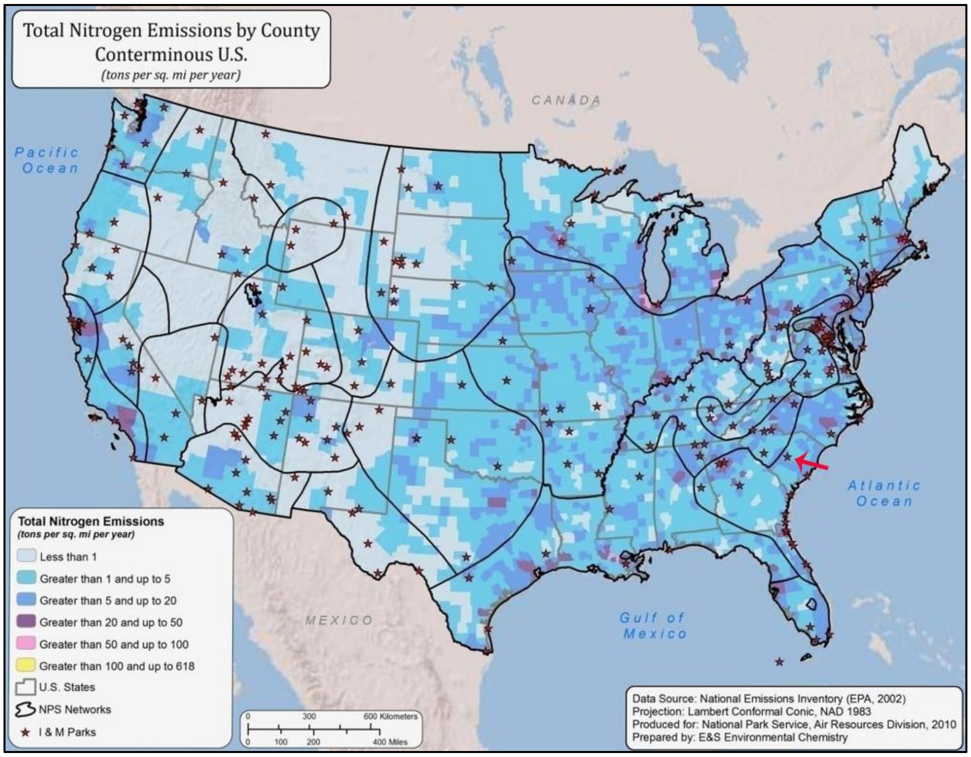


**Figure 9c.** Map of total nitrogen (N) emissions (tons/mi$^2$/yr) by county as of 2002. (Congaree NP—red arrow). From Sullivan et al. (2011).

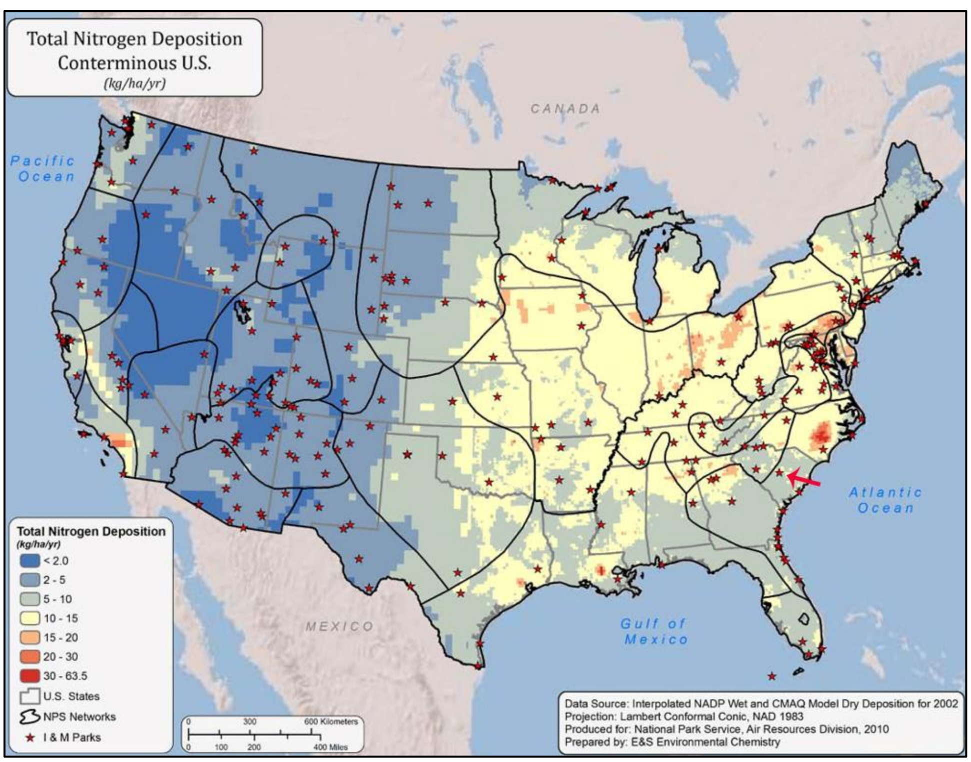


**Figure 9d.** Map of total nitrogen (N) emissions (kg/ha/yr) by county as of 2002. (Congaree NP—red arrow). From Sullivan et al. (2011).

More recently, the NPS Air Resources Division also evaluated the air quality of the park. The Congaree Bluff air quality monitoring site is within the park boundaries, and continues data gathering initiated in 1981 with establishment of the Congaree Swamp site (#45-079-1006). The original site was in the floodplain and had to be relocated to higher ground in 2001. The site, run the the SC DHEC, has monitors for ozone, sulfur dioxide, mercury deposition, precipitation, and precipitation chemistry (SC DHEC 2018). The National Park Service estimated several parameters from regional data by interpolating values at the location of the park center. The five-year average (2005–2009) air-quality conditions for the park were evaluated as moderate for ozone and significant concern for N deposition, S deposition, and visibility (Table 12).

**Table 12.** Evaluation of air-quality conditions in CONG, 2005–2009 (NPS 2009).

| Parameter | Condition |
|---|---|
| Ozone Condition[1] | Moderate concern |
| N Deposition Condition[2] | Significant concern |
| S Deposition Condition[3] | Significant concern |
| Visibility Condition[4] | Significant concern |

[1] Ozone condition assessments are derived from interpolated five-year (2005–2009) values of the mean annual 4th-highest 8-hour ozone concentrations.

[2] Nitrogen (N) deposition condition assessments are derived from interpolated 5-year (2005–2009) values of nitrogen wet deposition.

[3] Sulfur (S) deposition condition assessments are derived from interpolated 5-year (2005–2009) values of sulfur wet deposition.

[4] Visibility condition assessments are derived from interpolated 5-year (2005–2009) values of Group 50 visibility minus estimated annual average natural conditions, where Group 50 is the mean of the 40$^{th}$–60$^{th}$ percentiles of observed measurements in deciviews.

## Soundscape

*Definitions and Interpretations*

Sound is defined as an auditory sensation perceived by humans that is created by pressure variations that move in waves through a medium such as air or water (NPS 2017a). Sound is measured in terms of frequency and amplitude. Noise is defined as sound(s) that is unwanted or inappropriate in an environment. Frequency (sometimes referred to as pitch; units, hertz [Hz]) is the number of times per second that a sound pressure wave repeats itself. Humans with normal hearing can hear sounds ranging from 20 to 20,000 Hz; bats can hear up to 120,000 Hz. Amplitude is defined as the relative strength of sound waves (or transmitted vibrations), perceived as loudness or volume. Amplitude, or the sound pressure level (intensity), is measured in decibels (dB). The terms dB(A) or dB(C) designate two frequency-response functions (weighting characteristics) that filter sounds detected by a microphone in a sound-level meter. Each emphasizes or de-emphasizes sounds of certain pitches relative to others (Figure 10).

The “A” weighting, germane to Congaree National Park, filters out the low frequencies and slightly emphasizes upper-middle frequencies at 2–3 kilohertz (kHz). A-weighting, used to assess noise impacts on wildlife, measures hearing risk and compliance with Occupational Safety and Health

Administration and Mine Safety and Health Administration regulations that specify permissible noise exposures as a time-weighted average sound level or daily noise "dose" that can be tolerated without appreciable health risks. Thus, the World Health Organization (WHO 2009) has recommended that outdoor environmental noise should not exceed 55 dB(A) and 40 dB(A) for daytime and nighttime activity, respectively, to prevent potential adverse psychosocial and physiological effects. For perspective, the lower threshold of human hearing is 0 dB; moderate sound levels (e.g., normal speaking voice) are less than 60 db(A); a typical suburban area is 50–60 dB(A); thunder is 100 dB(A); and a military jet flying at 100 meters (328 ft) above ground level is 120 dB(A) (NPS 2017a; Crocker 1997). The noise of secluded woods is 30 dB(A) (decibels) in the absence of heavy machinery, which is relatively low background environmental noise (California State Board of Forestry and Fire Protection 2016).

Because dB are on a logarithmic scale, an increase of 10 dB causes a doubling of perceived loudness and represents a ten-fold increase in sound level. Sound levels adjusted for human hearing are expressed as dB(A). "Soundscape" is used here in accord with the NPS definition, that is, the human perception of these physical sound resources. The acoustical environment is the combination of all of the acoustic resources within a given area, including both natural and non-natural (human-caused) sounds. Thus, it is important to consider the entire acoustical environment in efforts to protect natural sounds.

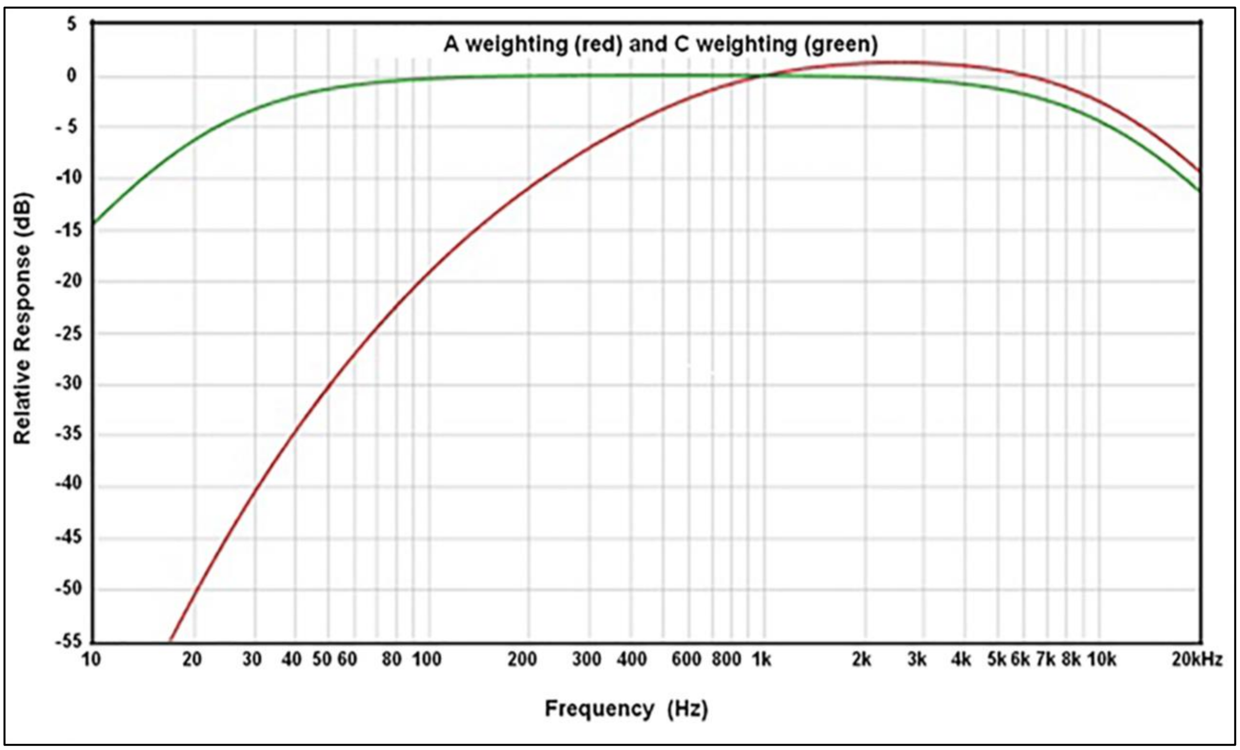


**Figure 10.** Influence of A- and C-weighting curves on the relationship between dB and frequency (pitch, Hz; Modified from Sengpiel (2017).

Sound is an important component of natural park ecosystems; the acoustical environment influences a wide array of animal behavior, such as finding desirable habitat and mates, avoiding predators, protecting young, and establishing territories (Monroe et al. 2007; Lynch et al. 2011, and references therein; and NPS 2017a). National parks in all regions of the U.S. are under increasing noise pressure from ground transportation, air transportation, and other human activities (Lynch et al. 2011). For example, noise levels in park transportation corridors are 1,000-fold higher than natural sound levels (Barber et al. 2009, 2011). Noise from airplanes can cause as much as a 70% reduction in the size of the hunting area where predatory animals are able to hear their prey (Barber et al. 2009). There is no question that parks are becoming noisier from human activities, even in remote areas. This conflicts with the fact that 70% of Americans indicated that one of the most important reasons for preserving national parks is to provide opportunities to experience natural peace and the sounds of nature (Haas and Wakefield 1998). The problem is growing to the extent that national parks are presently sustaining what has been described as "an ongoing acoustic assault" by human-related noise (NPS 2017a). Thus, the National Park Service has determined that "Increasingly, careful consideration of the impacts of human-generated noise on wildlife is a critical component of management for healthy ecosystems in our parks" (NPS 2017a).

Wildlife, like humans, is stressed by the increasing noise and must adapt. As examples, robins in suburban and urban environments are now singing at night in order to be heard by other members of their population (Fuller et al. 2007). Males of at least one frog species have adapted to traffic noise by calling at a higher pitch, although females have been shown to prefer lower-pitched calls which are indicative of larger, more "fit" males. Bats avoid hunting in areas with road noise (Barber et al. 2009; Parris et al. 2009). Noise stress can exacerbate the impacts of other stressors in national parks, with important ramifications for wildlife populations (Radle 1998).

*Congaree National Park Soundscape*

Congaree National Park is a predominantly rural area, with generally minor noise pollution. Data on the soundscape of the park are not available, but park staff described human-related environmental noise (e.g., from highway, and aircraft overflight) as minimal, and stated that the park is generally very quiet. Park management—including hazard fuels reduction, hazard tree removal, prescribed fires, and fire suppression—can involve use of noise-generating equipment such as chainsaws, trucks and helicopters (Reid and Olson 2013). Some of this equipment can be loud (in excess of 100 dB(A)), but the impacts generally occur over very short periods (hours to a few days per decade). Operation of motorized equipment or machinery that exceeds a noise level of 60 dB(A) at 15.2 meters (50 ft). The NPS (2014a) described the park soundscape as degraded by external intrusion of sounds from boat traffic, vehicular noise, artificial light, the railroad line though the park, and aircraft overflights. However, military aircraft overflight and powered aircraft take-offs and landings have concerned park management from two local military bases, McEntire Air National Guard Base and Shaw Air Force Base. Aircraft overflights not only cause disruption in visitor experience but also may disrupt roosting and nesting of certain bird species (NPS 2004a). As part of the 2010 Acoustic Monitoring Project for Congaree National Park, aircraft overflights were to be quantified, but the data apparently are not available.

Lightscape

Light pollution is considered here as the upward "spill" of light that is scattered and reflected by water vapor, dust, and other particles to create "sky glow" (Figure 11; NPS 2007; and NPS 2017b). The National Park Service uses the term "natural lightscape" to describe resources and values that exist in the absence of human-caused light at night.

**Figure 11.** The night sky above the Bluff Trail at CONG showing "sky glow" toward the far right above the canopy opening. Credit: NPS/jt-fineart.com. This image is not to be re-used without permission.

The 2006 NPS Management Policies direct the National Park Service to conserve natural lightscapes, in part because protection of natural darkness is important for ecological integrity and sustainability—that is, the natural lightscape is critical for maintaining nocturnal habitat. Light from cities can be visible from more than 322 kilometers (200 mi) away (NPS 2007, and references therein). Thus, to maintain a natural nocturnal lightscape, it is essential to minimize the sky glow from artificial light (Figure 12).

There is clear evidence that human health is adversely impacted by artificial light at night. Although research on light pollution versus wildlife is relatively sparse, the available studies suggest that artificial light also adversely affects the natural environment and the biological rhythms of flora and fauna. Nocturnal predators are especially affected, with "cascading" effects on prey species. Many bird species migrate at night and are prone to disorientation by artificial lights. Some biomes are more sensitive than others, such as wetlands, ponds, and shorelines.

The National Park Service is committed to minimizing light from park facilities at night, and to restricting the use of artificial light as much as possible. As with noise pollution, the problem of artificial light pollution at night is caused by sources beyond NPS control, such as highways and suburban areas immediately adjacent to the park boundaries.

Although various instruments are available for measuring light in the night sky (NPS 2017b) few such data have been collected as of yet for national parks in much of the network. Here we consider two forms of information about the night sky at Congaree National Park. First, the Bortle Dark-Sky Scale (BDSS, range 1–9; Bortle 2001a, b) was developed to assess light pollution using a numerical scale that is easily understood by the general public, policymakers, etc. (Table 13). Truly dark skies typically have a BDSS of 7.1 to 7.5. According to Dr. David Shelley and Paul Romanyszyn (Midlands Astronomy Club Inc, Columbia SC, personal communication, August 2014), the park is moderately impacted by light pollution from Columbia and there is a "light dome" from the city toward the northwest of the park (Figure 12). The habitat generally is equivalent to bright suburban skies to the northwest, and to rural suburban transition skies to the southeast.

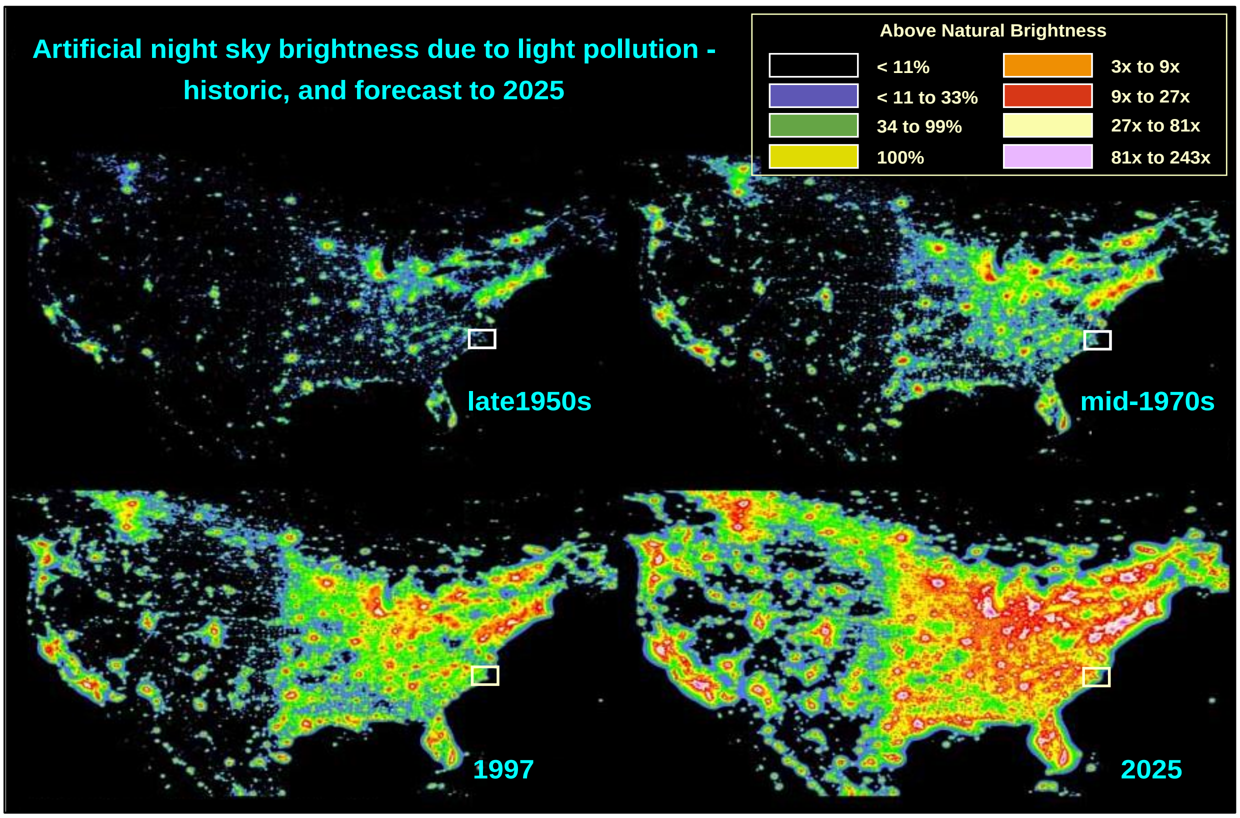


**Figure 12.** Artificial night sky brightness due to light pollution in the 1950s, 1970s, 1997, and projected to 2025. Modified from Cinzano et al. (2001).

**Table 13.** The Bortle Dark-Sky Scale for assessing artificial light pollution. The column labeled "naked-eye limiting magnitude" indicates the dimmest stars visible under each class of light pollution [NELM—Naked-eye limiting magnitude].

| Class | Color Key | NELM | Sky Description | Milky Way (MW) | Astronomical Objects | Zodiacal Light/Con-stellateing | Airglow and Clouds | Night Time Scene |
|---|---|---|---|---|---|---|---|---|
| 1 | | 7.6–8.0 | Excellent, truly dark skies | MW shows great detail and light from the Scorpio/Sagittarius region— casts obvious shadow on the ground | M33 (Pinwheel Galaxy) is an obvious object | Zodiacal light has an obvious color and can stretch across the entire sky | Bluish airglow is visible near the horizon and clouds appear as dark blobs against the backdrop of the stars | The brightness of Jupiter and Venus is annoying to night vision; ground objects are barely lit and trees and hills are dark |
| 2 | | 7.1–7.5 | Typical, truly dark skies | Summer MW shows great detail and has veined appearance | M33 is visible with direct vision, as are many globular clusters | Zodiacal light bright enough to cast weak shadows after dark and has an apparent color | Airglow may be weakly apparent and clouds still appear as dark blobs | Ground is mostly dark, but objects projecting into the sky are discernible |
| 3 | | 6.6–7.0 | Rural sky | MW still appears complex, dark voids and bright patches and meandering outline are all visible | Brightest Globular Clusters are distinct, but M33 only visible with averted vision; M31 (Andromeda Galaxy) obviously visible | Zodiacal light is striking in spring and autumn, extending 60 degrees above the horizon | Airglow is not visible and clouds are faintly illuminated, except at the zenith | Some light pollution evident along the horizon; ground objects are vaguely apparent |
| 4 | | 6.1–6.5 | Rural/ suburban transition | Only well above the horizon does the MW reveal any structure; fine details lost | M33 is difficult to see, even with averted vision; M31 still readily visible | Zodiacal light is clearly evident, but extends less than 45 degrees after dusk | Clouds faintly illuminated except at the zenith | Light pollution domes are obvious in several directions; sky is noticeably brighter than the terrain |
| 5 | | 5.6–6.0 | Suburban sky | MW appears washed out overhead and is lost completely near the horizon | The oval of M31 is detectable, as is the glow in the Orion Nebula | Only hints of zodiacal light in spring and autumn | Clouds are noticeably brighter than the sky, even at the zenith | Light pollution domes are obvious to casual observers; ground objects are partly lit |
| 6 | | 5.1–5.5 | Bright suburban sky | MW only apparent overhead and appears broken as fainter parts are lost to sky glow | M31 is detectable only as a faint smudge; Orion Nebula is seldom glimpsed | Zodiacal light is not visible; constellations are seen and not lost against a starry sky | Clouds anywhere in the sky appear faintly bright as they reflect back light | Sky from horizon to 35 degrees glows with grayish color; ground is well lit |
| 7 | | 4.6–5.0 | Suburban/ urban transition | MW is totally invisible or nearly so | M31 and the Beehive Cluster are rarely glimpsed | The brighter constellations are clearly recognizable | Clouds brilliantly lit | Entire sky background appears washed out, with a grayish or yellowish color |
| 8 | | 4.1–4.5 | City sky | MW is not visible at all | The Pleiades Cluster is visible, but very few other objects can be detected | Dimmer constellations lack key stars | Clouds brilliantly lit | Entire sky background has an orangish glow and it is bright enough to read at night |
| 9 | | 4.0 at best | Inner city sky | MW is not visible at all | Only the Pleiades Cluster is visible to all but the most experienced observers | Only the brightest constellations are discernible and they are missing stars | Clouds brilliantly lit | Entire sky background has a bright glow, even at the zenith |

The National Park Service has begun to use the Anthropogenic Light Ratio (ALR) to assess the lightscape of national parks (Moore et al. 2013). For its State of the Parks Program, the National Park Service recently developed a stoplight indicator system (green—good, amber—fair, red—poor) to evaluate the overall light regime condition using a single parameter, the amount of anthropogenic light averaged over the entire sky, measured in the green (human visual) spectral band. If the horizon is fairly unobstructed while the measurement is taken, the measure will not vary significantly because of the microenvironment where it was taken. The average anthropogenic light (anthropogenic quanta) is calculated as the total observed sky brightness minus the natural night sky environment where it was taken. The average anthropogenic light (anthropogenic quanta) is calculated as the total observed sky brightness minus the natural night sky component (average brightness, 78 nanolamberts [nL], a measure of luminance by starlight). A ratio of 0.0 would indicate pristine natural conditions (anthropogenic component, 0 nL; natural component, 78 nL). A ratio of 1.0 would indicate that anthropogenic light was 100% brighter than natural light from the night sky, equating to a situation wherein both the anthropogenic component and the natural component = 78 nL).

The average anthropogenic sky luminance is derived from ground-based empirical data if available or, alternatively from a GIS model (calibrated to other ground-based measures) derived from data in the 2001 World Atlas of Night Sky Brightness (Cinzano et al. 2001). The World Atlas depicts zenith sky brightness, that is, the brightness of the sky directly above the observer. A neighborhood analysis is applied to determine the anthropogenic sky brightness over the entire sky. The modeled anthropogenic light over the entire sky is presented as the ALR.

The ALR has two levels of sensitivity, based on NRSS I&M Program natural resource designations (Table 14): Level 1 parks, including Congaree National Park, have significant natural resources so that the nighttime photic environment has a greater potential influence on the natural resources and ecosystems (Moore et al. 2013). These areas tend to have higher-quality night sky conditions and lower levels of light pollution (anthropogenic light), and tend to be more sensitive to light pollution effects. The threshold separating green from amber conditions is set at an ALR of 0.33 (i.e., one-third brighter than natural conditions), corresponding to the point wherein portions of the sky become sufficiently bright that humans cannot fully adapt to the dark when looking toward them (condition known as scotopic vision, an attribute of human night vision). Above this threshold, humans lose visual sensitivity and require time under dark conditions to re-adapt their eyes. This threshold also corresponds to the transition between Bortle Class 3 (rural and dark) and Class 4 (suburban skies). The threshold separating amber from red conditions is set at an ALR of 2.0, corresponding to the point wherein portions of the sky cast shadows so that the entire Milky Way cannot be seen, the zodiacal light is seldom seen, and full dark adaptation is not possible regardless of which direction the observer looks (Table 15).

**Table 14.** Thresholds for the Anthropogenic Light Ratio (ALR)[1] for Level 1 and Level 2 national parks. From Moore et al. (2013, and references therein)[2].

| Threshold for Level 1 Parks | Additional Threshold for Areas Managed as Wilderness | Threshold for Level 2 Parks |
|---|---|---|
| ALR < 0.33 (< 26 nL avg. anthropogenic light in sky); ≥ 50% of the park area should meet this criterion | ALR < 0.33 (< 26 nL avg. anthropogenic light in sky); ≥ 90% of the wilderness area should meet this criterion | ALR < 2.00 (< 156 nL avg. anthropogenic light in sky); ≥ 50% of the park area should meet this criterion |
| ALR < 0.33 to 2.00 (26 to 156 nL avg. anthropogenic light in sky); 50% of the park area should meet this criterion | ALR < 0.33 to 2.00 (26 to 156 nL avg. anthropogenic light in sky); ≥ 90% of the wilderness area should meet this criterion | ALR 2.00 to 18.00 (< 156 to 1,404 nL avg. anthropogenic light in sky); ≥ 50% of the park area should meet this criterion |
| ALR > 2.00 (> 156 nL avg. anthropogenic light in sky); ≥ 50% of the park area should meet this criterion | ALR > 2.00 (> 156 nL avg. anthropogenic light in sky); ≥ 90% of the wilderness area should meet this criterion | ALR 2.00 to 18.00 (> 1,404 nL avg. anthropogenic light in sky); ≥ 50% of the park area should meet this criterion |

[1] ALR = average anthropogenic all-sky luminance average (natural all-sky luminance, wherein the average natural all-sky luminance = 78 nL). Light flux is totaled above the horizon (the terrain is omitted) and the anthropogenic and .natural components are expressed as a unit less ratio.

[2] note that the 90% confidence interval (CI) for the ground-based data = + 8 nL (+ 0.1 ALR); the 90% CI for modeled data = + 40%; and 1 nL = 0.0031831 millicandelas (mcd)/m$^2$.

**Table 15.** Functional impacts of light regime determinations. From Moore et al. (2013, and references therein).

| Qualitative Description | Sensitivity | Good Condition (Green) | Moderate Condition (Amber) | Poor Condition (Red) |
|---|---|---|---|---|
| Bortle Class | More Sensitive | Bortle Class 1-3 | Bortle Class 4 | Bortle Class 5–9 |
| | Less Sensitive | Bortle Class 1-4 | Bortle Class 5-6 | Bortle Class 7–9 |
| Typical Limiting Magnitude | More Sensitive | 6.8–7.6 | 6.3–6.7 | < 6.2 |
| | Less Sensitive | 6.3–7.6 | 5.6–6.2 | < 5.6 |
| Sky Quality Meter | More Sensitive | ≥ 21.60 | 21.20–21.59 | < 21.20 |
| | Less Sensitive | ≥ 21.20 | 19.70–21.19 | < 19.70 |

**Table 15 (continued).** Functional impacts of light regime determinations. From Moore et al. (2013, and references therein).

| Qualitative Description | Sensitivity | Good Condition (Green) | Moderate Condition (Amber) | Poor Condition (Red) |
|---|---|---|---|---|
| Celestial Feature Appearance | More Sensitive | Zodiacal light can be seen under favorable conditions; Milky Way shows detail and stretch from horizon to horizon | Milky Way has lost most detail and is not visible near the horizon; Zodiacal light is rarely seen | Milky Way may be visible when directly overhead—otherwise not apparent; Andromeda Galaxy may be barely visible |
| | Less Sensitive | Milky Way is frequently visible | Milky Way is only visible when it is directly overhead, and is not generally apparent | No extended celestial features are visible; only the brightest constellations are visible |
| Lightscape Appearance | More Sensitive | Most observers feel they are in a natural environment, with natural features of the night sky readily visible | Anthropogenic light dominates natural celestial features; some shadows from distant lights may be seen | Little sense of naturalness remains in the night sky; the landscape is clearly shadowed or illuminated and the horizon is aglow from light pollution |
| | Less Sensitive | From within a built environment, the sky appears largely intact | Discoloration of the sky is likely apparent; shadows are seldom noticed from within a built environment | The sky has lost all aspects of naturalness except for a few hundred (or less) visible stars |
| Human Vision | More Sensitive | Negligible impact to dark adaptation looking in any direction | Dark adaptation possible in at least some directions, although visible shadows likely are present | Full dark adaptation is not possible; substantial glare may be present; circadian rhythms may be disrupted |
| | Less Sensitive | Full dark adaptation possible in at least some directions, although visible shadows may be present | Full dark adaptation is not possible; shadows are obvious at night from light sources in the sky or along the horizon; circadian rhythms may be disrupted | Full dark adaptation is not possible; there is significant glare from the sky or sources near the horizon; and there is higher concern over impact to circadian rhythms |
| Sky Quality Index | More Sensitive | > 75 | 50–74 | < 50 |
| | Less Sensitive | > 50 | 25–49 | < 25 |

Level 2 parks, usually near urban or suburban areas, have fewer natural resources; thus, light pollution has less of an influence on biota and ecosystems. Although Level 2 parks themselves can be relatively dark, the night skies tend to be degraded from surrounding urban development contributing high levels of light pollution. The threshold separating green from amber conditions is set at an ALR of 2.0 (characteristics as described above). The threshold separating amber from red conditions is set at an ALR of 18.0, corresponding to the point wherein extended features of the night sky (e.g., the Milky Way and the Andromeda Galaxy) are invisible in nearly all situations, constellations are difficult to identify, and the sky is colored by light from numerous light pollution sources. At this level of light pollution, photographs at night easily capture the altered appearance of the night sky.

These ALR thresholds are applied spatially to NPS parks; the designated condition corresponds to the ALR level that exists in at least half of (as the median condition) the park landscape, except for wilderness/proposed wilderness areas such as Congaree National Park wherein the ALR level exists in more than 90% of the area. The ALR recently modeled for the Columbia/Congaree National Park area was indicated in red (Figure 13), suggesting unacceptably high light pollution in the park. This information is supported by recent satellite imagery of the lightfield at night in the area (Figure 14).

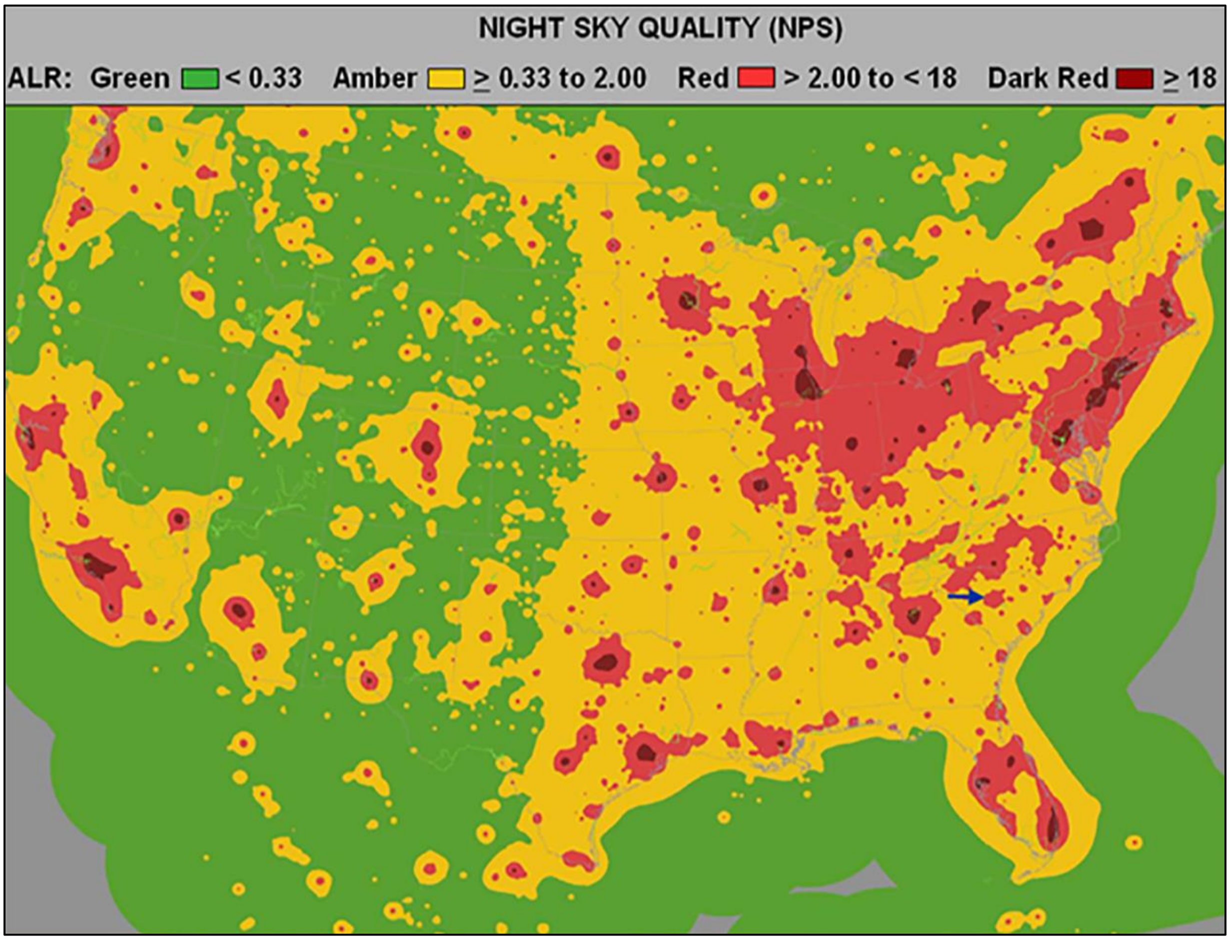


**Figure 13.** Map showing modeled data for the U.S. including Columbia, S.C. and surrounding area (arrow). Modified from Moore (2013).

**Figure 14.** NASA satellite image of the continental U.S. at night, representing a composite of data from April and October 2012 (left). Close-up of the same satellite image (right) showing Columbia and the surrounding area (arrow). Modified from the NASA Earth Observatory/NOAA National Geophysical Data Center (NGDC).

Geology and Soils

*Geology of Congaree National Park*

Congaree National Park lies in the Upper Coastal Plain and encompasses the Congaree River floodplain in central South Carolina. The deposits under the Coastal Plain form a wedge that dips and thickens in the subsurface to the southeast, where the major volume of the Coastal Plain deposits lie (Shelley et al. 2012). The Congaree River floodplain has been simplified into a single geologic map scale unit, but it should be noted that it contains a mosaic of fluvial features including infilled abandoned channels, floodplain streams, natural levee deposits, and back swamps. The features represent polymorphic landforms that are indicative of various environmental conditions from the late Pleistocene to the Holocene (Figure 15; Table 16; Meitzen 2011; NPS 2014b). The Congaree River floodplain alluvium in the confluence area includes fine- to very course-grained, light tan to dark-brown sand, silt, clay, and organic-rich peat deposits and may also contain additional flood plain terraces, meander belts, and a variety of other depositional landforms (Shelley et al. 2004, Meitzen and Shelley 2005).

Underlying the park, there are igneous and metamorphic crystalline basement rocks and unconsoliated sedimentary formations. Overlying this are about 152.4 meters (500 ft) of interbedded sands and clays of the late Cretceous and younger ages (Patterson et al. 1985). Late Cretaceous to Holocene age-unconsolidated sediments cover older rocks in eastern South Carolina, with valleys consisting of alluvial deposits of the Quaternary age (Overstreet and Bell 1965; Conrads et al. 2008). More specifically, the Middendorf Formation consists of fine to course-grained sand and sediment that is micaceous, glauconitic and calcareous in some areas. The late Cretaceous Black Creek Formation overlies the Middendorf Formation and consists of micaceous, phophatic, quartzose, calcareous, glauconitic sand. Overlying this is the Black Mingo, Congaree, McBean, and Barnwell

Formations of Tertiary age. The Congaree formation consists of fine to coarse-grained sand and sandstone; the McBean Formation consists of glauconitic sand and glauconitic marl and the Barnwell Formation consists of fine- to coarse-grained sand (Aucott et al. 1987; Conrads et al. 2008). The Congaree floodplain consists of alluvial and terrace deposits of the Pleistocene and Holocene age and overly the Black Mingo Formation of gravel, sand, silt and clay that accretes during flood events. Accumulation is greatest near the banks of the Congaree River where deposits are coarser than inland deposits (Patterson et al. 1985; Shelley 2007a; Conrads et al. 2008). See Shelley (2007a–f) for maps of the detailed complexity of the Congaree River Valley in central South Carolina and discussion of these terraces.

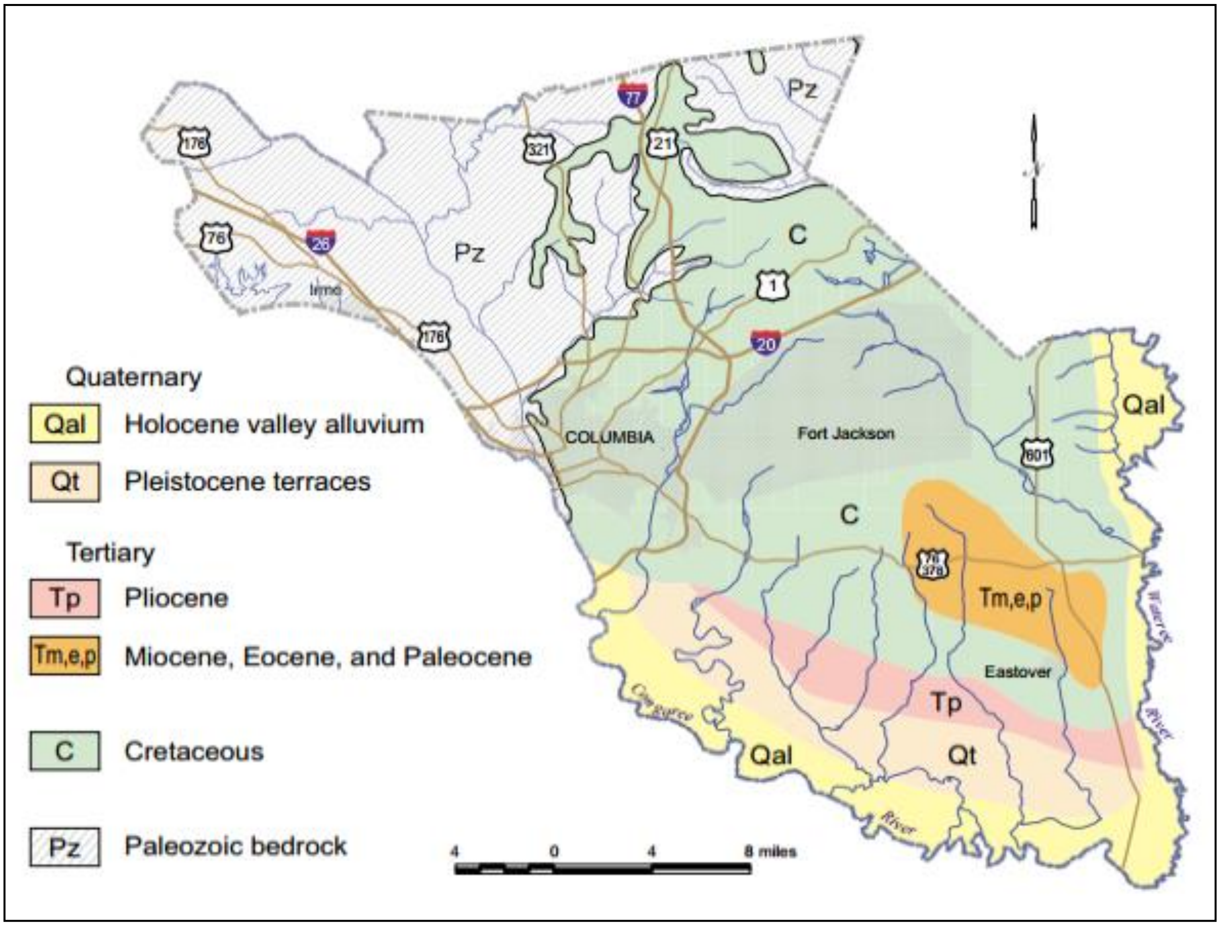


**Figure 15.** Generalized geology of Richland County. From Maybin and Nystrom (1995), Newcome (2003).

**Table 16.** Geologic Units for CONG and surrounding watersheds.

| Label | Unit age | Most common landform | Second most common landform |
|---|---|---|---|
| Cgcl | Carboniferous to Permian | granite | – |
| Kbcb | Cretaceous | sand | clay or mud |
| Kcfe | Cretaceous | sand | gravel |
| Kpb | Cretaceous | clay or mud | sand |
| Kpd | Cretaceous | sand | limestone |
| Qavs | Quaternary | sand | gravel |
| Qpd | Holocene | sand | – |
| Tbmc | Tertiary | sand | clay or mud |
| Td | Pliocene | sand | clay or mud |
| Thlb | Eocene | sand | clay or mud |
| Tnu | Neogene | sand | gravel |

*Soil Composition and Structure*

The Congaree River floodplain is a complex alluvial formation composed of organic-rich clay and silts deposited in the backswamps and abandoned channels of low-energy areas to the mineral-heavy fine to very coarse sands deposited in higher energy environments (Meitzen 2011). The floodplain region in Richland County, extending along the Congaree River, is 0.8 to 8.0 kilometers (0.5 to 5 mi) wide and is dominated by silt and clay alluvial sediments overlying marine sediments of coastal terraces. The floodplain is predominantly derived from soils washed from the Piedmont province (Lawrence 1978). The Congaree and Wateree Rivers move within the floodplain and are actively depositing new surfaces and eroding older deposits (Meitzen 2011). Depositional features include natural levees adjacent the channel of the Congaree River, pointbars, meander scroll ridge-and-swale complexes, backwater muck swamps, and partially infilled abandoned meanders (NPS 1996; Meitzen 2006). The soil composition within Congaree National Park is predominantly Tawcaw silty clay loam.(43.7%), Congaree loam (20.3%), Chastain silty clay loam (17.3%), and Chewcla loam, frequently flooded (6.6%; Figures 16 and 17; Tables 17 and 18). Persanti soils (3.3%) are in the northern-most portions of the park characterized by a moderately well-drained, fine sand surface underlain by deep sandy clay loam (Lawrence 1978; NPS 1996).

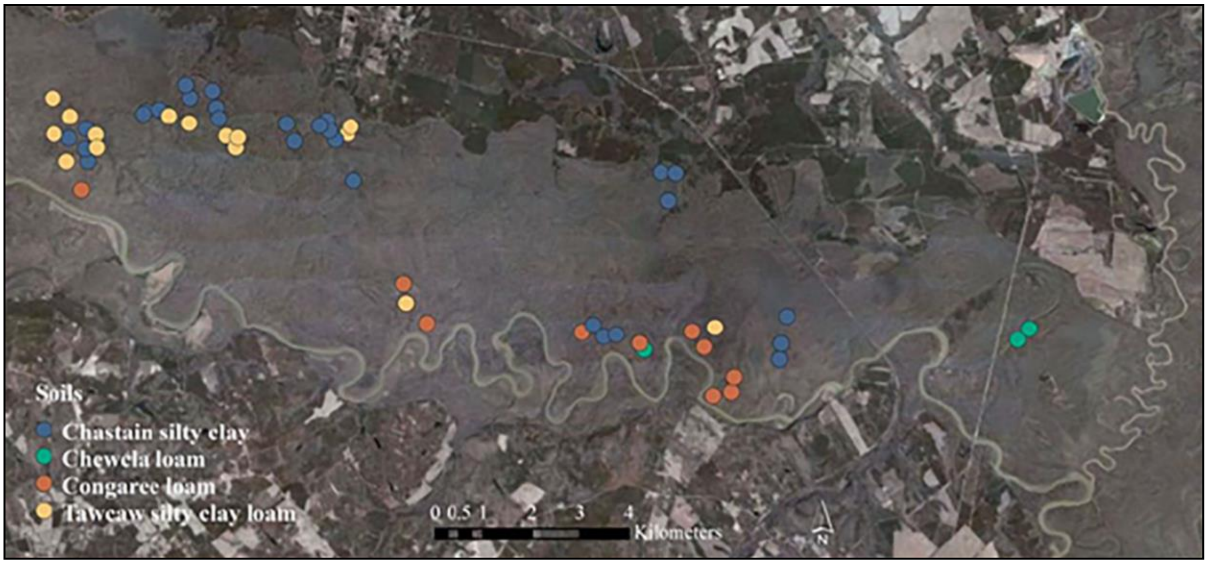


**Figure 16.** CONG soil classification and study sites from Meitzen (2011) as described in Table 17.

**Table 17.** Soil series classifications and taxonomic descriptions. From Meitzen (2011).

| Soil Classification | Description |
|---|---|
| Chastain silty clay loam | Poorly drained, frequently flooded (intermittent to permanent saturation, limited ponding), <25% fine to very fine sand, >50% silt, 25% clay, slope 0–2% |
| Tawcaw silty clay loam | Poorly drained, frequently flooded (intermittent to permanent flooding, shallow to deeply ponded), 25% very fine sand, >25% silt, 50% clay to kaolinitic clay, slope 0–2% |
| Chewcla loam | Moderate to poorly drained, frequently flooded (intermittent, brief duration, limited ponding), sandy-silty-clayey loam (% of each varies, but predominantly sandy loam), slope 0–2% |
| Congaree loam | Well to moderately well drained, sandy mix, frequent to occasional flooding (intermittent, brief furation flooding, limited ponding, permeable) even fine loamy mixed sand, slope 0–4% |

*Erosion Along Roads and Trails, and General Soil Erodibility*

General soil erodibility during the last 300 years in the South Carolina Piedmont area has been heavy, contributing a large volume of sediments to the Congaree River floodplain mostly in natural levee deposits; thus, the levee is the highest elevation on the floodplain. Constant landform migration in the floodplain valley is created from erosion and simultaneous deposition on accreting pointbars (Patterson et al. 1985; Meitzen 2011). The rate of soil loss transported by rainfall and runoff is defined as the soil erodibility factor or K-factor. The top four soil types in the park, comprising 87% of the total park surface area, have moderate erodibility based on soil content and texture. K-factors range from 0.02 to 0.69, values closer to 1.0 indicate higher soil erodibility (Stewart et al. 1975; Goldman et al. 1986; SC DHEC 2004). Typically, for a site with significant variations in soil erodibility the conservative approach is to use the highest value for all portions of the site (Goldman et al. 1986). K-factor values for the Congaree River Basin range from 0.06 to 0.20 (SC DHEC 2004).

Park staff have mentioned concern over erosion in the park and have documented visible evidence of erosion along roads and trails.

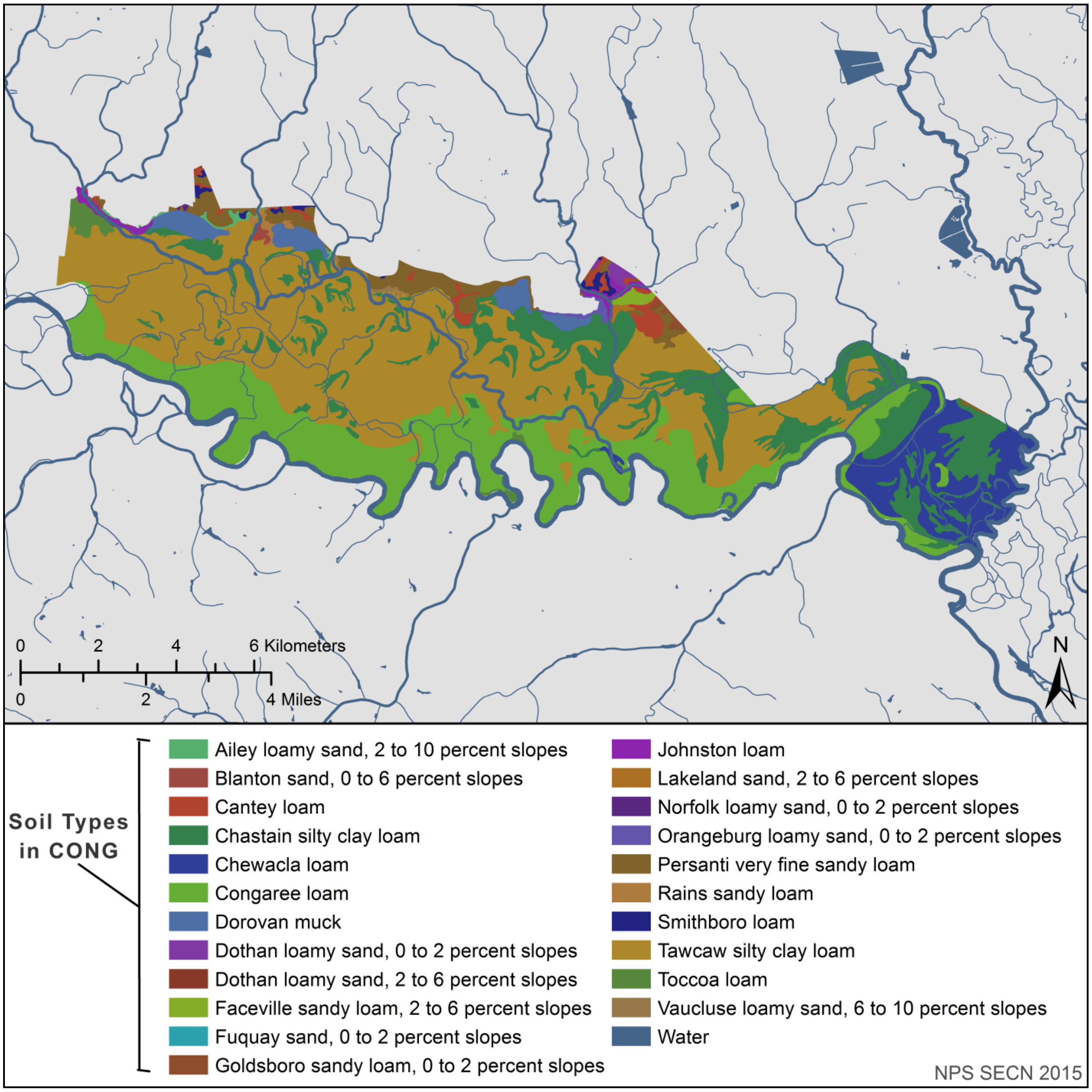


**Figure 17.** Soils in CONG. See Appendix A for soils data.

**Table 18.** The area and proportion of the 26 soil types within the park survey area version date, 16 July 2006, are highlighted in blue. Source USDA Soil Conservation Service (SCS).

| **Map Unit** | **Hectares** | **Area (acres)** | **% Total Surface Area** |
|---|---|---|---|
| Ailey-Vaucluse complex, 6 to 15 percent slopes | 0.04 | 0.09 | 0.00 |
| Ailey loamy sand, 2 to 10 percent slopes | 27.97 | 69.10 | 0.25 |
| Blanton sand, 0 to 6 percent slopes | 13.59 | 33.59 | 0.12 |
| Cantey loam | 265.41 | 655.85 | 2.39 |
| Chastain silty clay loam[a] | 1,920.16 | 4,744.81 | 17.27 |
| Chewacla loam, 0 to 2 percent slopes, frequently flooded | 739.72 | 1827.90 | 6.65 |
| Congaree loam[a] | 2,259.97 | 5,584.50 | 20.33 |
| Congaree loam, occasionally flooded | 0.89 | 2.21 | 0.01 |
| Dorovan muck | 244.26 | 603.58 | 2.20 |
| Dothan loamy sand, 0 to 2 percent slopes | 25.50 | 63.01 | 0.23 |
| Dothan loamy sand, 2 to 6 percent slopes | 0.58 | 1.43 | 0.01 |
| Faceville sandy loam, 2 to 6 percent slopes | 29.52 | 72.94 | 0.27 |
| Fuquay sand, 0 to 2 percent slopes | 0.05 | 0.12 | 0.00 |
| Goldsboro sandy loam, 0 to 2 percent slopes | 26.84 | 66.33 | 0.24 |
| Johnston loam | 83.37 | 206.02 | 0.75 |
| Lakeland sand, 2 to 6 percent slopes | 15.22 | 37.61 | 0.14 |
| Norfolk loamy sand, 0 to 2 percent slopes | 2.44 | 6.02 | 0.02 |
| Orangeburg loamy sand, 0 to 2 percent slopes | 50.39 | 124.51 | 0.45 |
| Persanti very fine sandy loam | 366.78 | 906.34 | 3.30 |
| Rains sandy loam | 25.99 | 64.22 | 0.23 |
| Smithboro loam | 60.92 | 150.55 | 0.55 |
| Tawcaw-Duckbottom-Mullers complex, 0 to 2 percent slopes, frequently flooded | 0.46 | 1.13 | 0.00 |
| Tawcaw silty clay loam[a] | 4,753.17 | 11,745.34 | 42.75 |
| Toccoa loam | 79.74 | 197.04 | 0.72 |
| Udorthents | 1.07 | 2.65 | 0.01 |
| Vaucluse loamy sand, 6 to 10 percent slopes | 12.25 | 30.28 | 0.11 |
| Water | 112.77 | 278.66 | 1.01 |
| Total | 11,119.08 | 27,475.82 | 100 |

[a] the three most abundant soil types

Water Resources

*Hydrology*

Hydrologic features such as stream flow characteristics provide what have been described as:

> "…some of the most appropriate and useful indicators for assessing aquatic ecosystem integrity, and for monitoring environmental changes over time.
>
> [They] also provide key support data for other vital signs indicators including water quality, threatened and endangered aquatic species, wetlands, and riparian habitat. The hydrologic output of a watershed is a function of land characteristics, human use, weather and climate conditions, urbanization, and soil characteristics. Hydrologic variation plays a key part in structuring the biotic diversity within river ecosystems by controlling critical habitat conditions within the river channel, the floodplain, and hyporheic zones…." (Gregory et al. 2012).

The dynamic hydrologic framework of the park includes extensive influence from creeks, rivers, wetlands, lakes and a shallow aquifer. Flooding severity within the park is controlled by the Congaree River and Wateree River discharge. Major flood events occur along the Congaree River an average of 10 times per year, flooding 90% of the park annually (Knowles et al. 1996). The primary driver for these flood events is the Broad River upstream from the park. As mentioned, the Congaree River is formed from the confluence of the Broad River and the Saluda River at the fall line in Columbia, South Carolina. The Dreher Shoals Dam, constructed in the 1920s to form the Lake Murray impoundment, affects natural flows of the Congaree River. Highest flow occurs in late winter to early spring, whereas lowest flow occurs late summer and early fall (Meitzen 2011). There is also a natural levee along the north bank of the Congaree River, which is pierced by floodwaters at guts (small floodp as the floodplain fills when river discharge increases. Water movement across the floodplain is eastward toward the Wateree River. Floodwaters from both the Congaree River and the Wateree River affect the Bates Fork Tract, an area in need of further study (Mallin and McIver 2010).

Toms Creek (fourth order) and Cedar Creek (fifth order) are the two perennial streams that transect the park. Other streams flowing into the park include Dry Branch, McKenzie Creek, Griffins Creek, and Singleton Creek. These blackwater creeks meander through the floodplain, and their slightly acidic, darkly stained waters contain elevated dissolved organic carbon from floodplain vegetation leachate (Meyer 1990; Figure 18). All streams within the 2006 boundary of the park were classified as outstanding resource waters (ORW) except the Cedar Creek reach from Wise Lake to the Congaree River, which is classified as outstanding national resource waters (ONRW). Since the park boundary has expanded with the more recent Riverstone Tract and Bates Fork Tract acquisitions, SCDHEC will be reevaluating these classifications (SCDHEC 2011).

There are numerous other water features dispersed throughout the park. In addition to the two oxbow lakes Wise and Weston Lakes, there are seven other named lakes, 25 named ponds and 14 named sloughs. There are also at least two oxbow lakes in the Bates Fork Tract, not accessible by vehicle (Mallin and McIver 2010). Guts and channels also transport water and sediment throughout

Congaree National Park. Several types of channels have been classified by Shelley and Meitzen (2005) as scroll complex channels, batture channels, backswamp channels, crevasse channels and artificial cuts. Wetlands cover approximately 61% or 122,169 acres of the park and surrounding watersheds based upon USFWS NWI of 2014 (Figure 18). Data from two USGS gaging stations were used for streamflow data, one on the Congaree River at Columbia USGS Station 02169500 and one on the Wateree River below Eastover USGS Station 02148315. Data from 17 additional stations were analyzed and included in this report (Figure 19, Tables 19a–c).

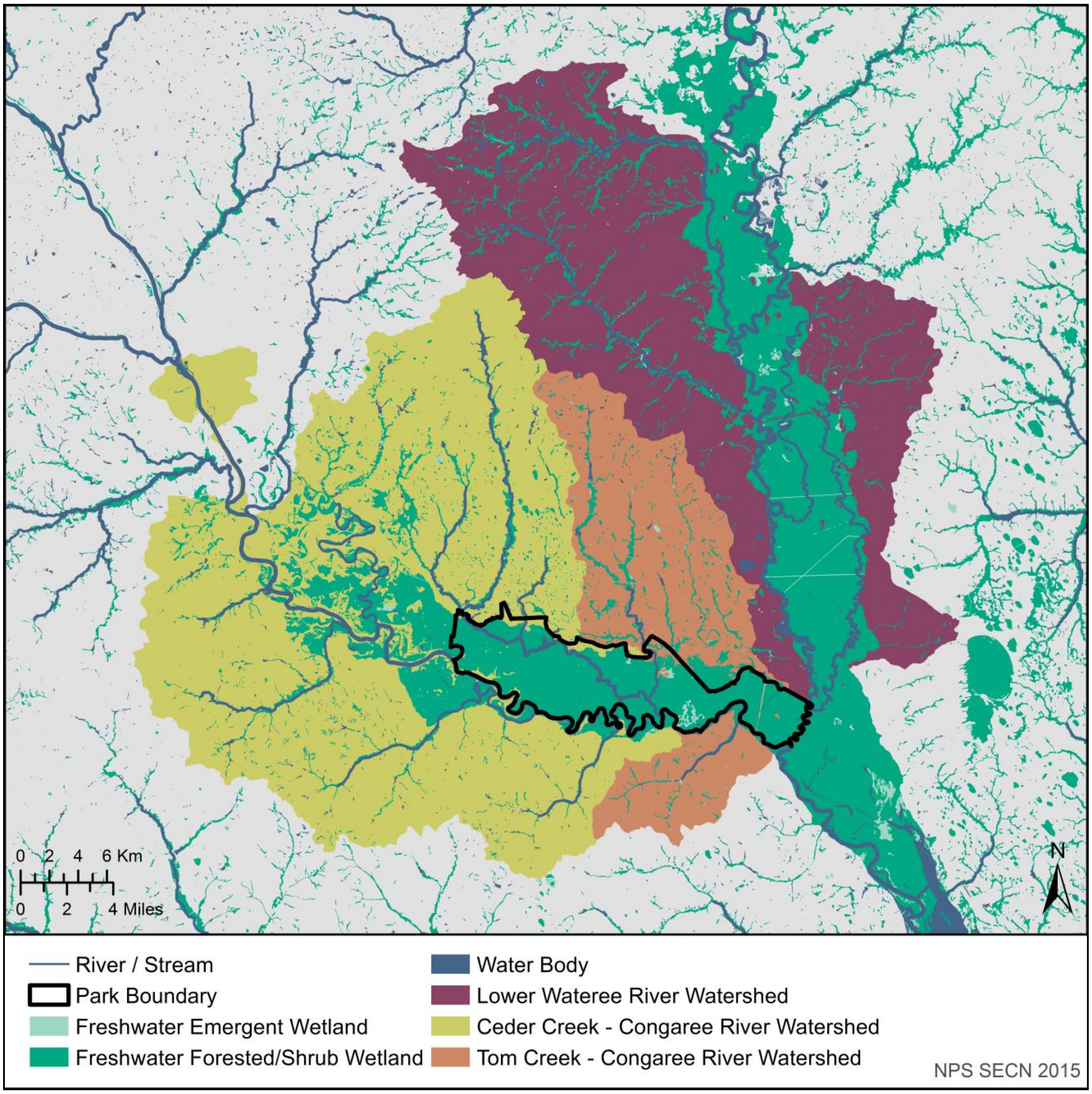


**Figure 18.** National Wetlands Inventory Map (USGS) of water features in and surrounding CONG. Modified by the NPS SECN.

Hydrology controls integration of the natural, physical and biological components of the park (NPS 2004a). As referred to earlier in this report, the Congaree River is formed by the confluence of the Saluda and Broad Rivers 38.6 kilometers (24 mi) upstream from the park at Columbia. The Broad River basin supplies about two-thirds of the drainage area of the Congaree River. The Saluda Dam, constructed in 1929 mainly for power generation, regulates streamflow in the Saluda River. The USGS and the National Park Service cooperatively studied the interaction between surface water in the Congaree River and groundwater in the floodplain to determine the effects the Saluda Dam has on Congaree National Park floodplain water levels. A total of eleven gaging stations (seven upstream, three in or near the park, and one in the Broad River basin in Georgia) were monitored for current and historical data to analyze streamflow and elevation. The overall finding was that the operation of the Saluda Dam has had more of an effect on water-surface elevations within the river than in the floodplain. An analysis after dam construction showed that a reduction in peak flows may have resulted more from an influence of climate variability together with a lack of large floods after 1930 than from the dam operation (Conrads et al. 2008). In the park, the frequency of flooding may also be more likely to be a result of the flows from the Broad River (Jones et al. 2010).

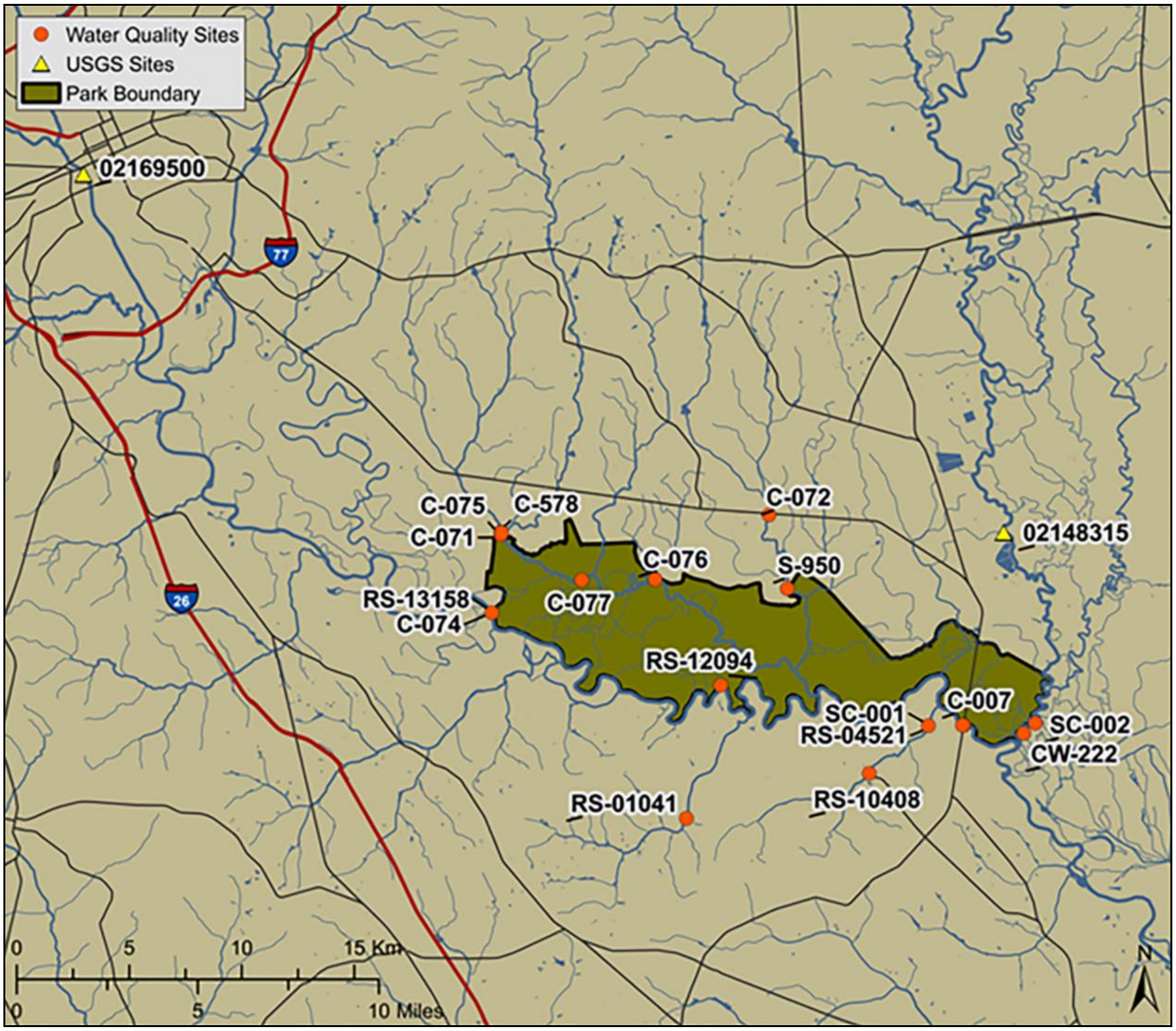


**Figure 19.** Map of sampling stations for aquatic data that were mentioned or included in this report. NCSU CAAE (S. Flood), modified by the NPS SECN. See Appendices 1 and 2 for data.

**Table 19a.** Stations at Cedar Creek sub watershed HUC-0305011030 with aquatic data mentioned or included in this report. Water-quality stations not supporting use classifications are listed according to the 2012 South Carolina 303(d) List. SCPSA– Santee Cooper-South Carolina Public Service Authority; SC DHEC– South Carolina Department of Health and Environmental Control

| Station | Agency | Location | Latitude | Longitude | Parameters | 303(d) List Use and Cause of Impairment |
|---|---|---|---|---|---|---|
| C-071 | SC DHEC | Cedar Creek at S-40-734, Richland Co. | 33.8410 | -80.8602 | Water quality | Aquatic Life; Macroinvertebrate |
| C-074 | SC DHEC | Congaree River, west boundary of CONG, Richland Co. | 33.8091 | -80.8670 | Environmental conditions, water quality, bacteria | Recreational use; Fecal coliform bacteria |
| C-075 | SC DHEC | Cedar Creek south of S-40-734 at old USGS gaging platform, Richland Co. | 33.8399 | -80.8604 | Environmental conditions, water quality, bacteria | – |
| C-076 | SC DHEC | Cedar Creek, Richland Co. | 33.8184 | -80.7880 | Bacteria | – |
| C-077 | SC DHEC | Cedar Creek, Richland Co. | 33.8199 | -80.8231 | Bacteria | – |
| C-578 | SC DHEC | Myers Creek at SR 734, Richland Co. | 33.8407 | -80.8600 | Water quality | – |
| RS-01041 | SC DHEC | Bates Mill Creek at County Rd 24, 4 mi N of St Mathews, Calhoun Co. | 33.7225 | -80.7800 | Water quality, bacteria | – |
| RS-12094 | SC DHEC | Congaree River between C-074 and C-007, Richland Co. | 33.7747 | -80.7598 | Water quality, bacteria | – |
| RS-13158 | SC DHEC | Congaree River same location as C-074, West boundary of CONG, Richland Co. | 33.8091 | -80.8670 | Water quality, bacteria | – |

**Table 19b.** Stations at Toms Creek Congaree River sub-watershed HUC 0305011004 with aquatic data mentioned or included in this report. Water-quality stations not supporting use classifications are listed according to the 2012 S.C. 303(d) List. SCPSA– Santee Cooper-South Carolina Public Service Authority; SC DHEC– South Carolina Department of Health and Environmental Control

| Station | Agency | Location | Latitude | Longitude | Parameters | 303(d) List Use and Cause of Impairment |
|---|---|---|---|---|---|---|
| C-007 | SC DHEC | Congaree River at US 601, Calhoun Co. | 33.7529 | -80.6450 | Environmental conditions, water quality, bacteria | Fish consumption; Mercury |
| C-072 | SC DHEC | Toms Creek at S.C. 48, Richland Co. | 33.8413 | -80.7318 | Environmental conditions, water quality, bacteria | Recreational use; Fecal coliform bacteria |
| RS-04521 | SC DHEC | Buckhead Creek at S-09-151, 2.1 mi NE of Fort Motte, Calhoun Co. | 33.7535 | -80.6619 | Environmental conditions, water quality, bacteria | Aquatic Life; Macroinvertebrate |
| RS-10408 | SC DHEC | Buckhead Creek at S.C.-419, Calhoun Co. | 33.7360 | -80.6915 | Environmental conditions, water quality, bacteria | – |
| S-950 | SC DHEC | at Red Bluff Road, private road running between SSR1288 and SSR489, Richland Co. | 33.8116 | -80.7252 | Environmental conditions, water quality, bacteria | Recreational use; Fecal coliform bacteria |
| S.C.-001 | SC SCPSA | Congaree River at U.S. 601 bridge, Richland Co. | 33.7528 | -80.6456 | Environmental conditions, water quality, bacteria | Fish consumption; Mercury |

**Table 19c.** Stations at Lower Wateree River sub-watershed HUC 0305010404 with aquatic data mentioned or included in this report. Water-quality stations not supporting use classifications are listed according to the 2012 S.C. 303(d) List. SCPSA– Santee Cooper-South Carolina Public Service Authority; SC DHEC– South Carolina Department of Health and Environmental Control

| Station | Agency | Location | Latitude | Longitude | Parameters | 303(d) List Use and Cause of Impairment |
|---|---|---|---|---|---|---|
| CW-222 | SCDHEC | Wateree River at junction with Congaree, Richland Co. | 33.7519 | -80.6108 | Environmental conditions, water quality, bacteria | – |
| S.C.-002 | S.C.-SCPSA | Wateree River at Little River, Sumter Co. | 33.7481 | -80.6167 | Environmental conditions, water quality, bacteria | – |

The Southeast Coast Network evaluated stream flow variation and the magnitude and timing of specific flow at USGS stations on the Wateree River below Eastover (USGS ID 02148315) and the Congaree River at Columbia (USGS ID 02169500) for surface water dynamics including discharge, magnitude and duration of flooding events during 2012 (Figure 20) (Jones and Gregory 2013; NPS 2013c). Flow patterns were characterized using USGS stream flow data, The Nature Conservancy

(2009) Indicators of Hydrologic Alteration (IHA) software, and program Flow (Dowd 2011; Table 20a). The IHA software used single-period daily values in cubic feet per second (cfs) to calculate nonparametric and parametric statistical metrics including mean monthly flow values and extreme event characterization and timing. IHA was also used to calculate environmental flow components (EFCs), used to characterize natural flow and departures from natural conditions. EFCs characterize flow events that have become typical (over a long period such as many years) since perturbations such as diversions or development occurred (Table 20b). The EFC procedure used by Gregory et al. (2012) set initial high flows as 75% of daily flows for the period of record used, and included the following definitions: small floods = events with a 2-year return interval; large floods = events with a 10-year return interval; and extreme low flows = less than 10% of all flows for the period.

**Table 20a.** Indicators of Hydrologic Alteration (IHA) Metrics and Environmental Flow Components, including potential ecosystem influences modified from the IHA User's manual (The Nature Conservancy 2009).

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

**Table 20a (continued).** Indicators of Hydrologic Alteration (IHA) Metrics and Environmental Flow Components, including potential ecosystem influences modified from the IHA User's manual (The Nature Conservancy 2009).

| Parameter Type | Definition | Potential Ecosystem Influences |
|---|---|---|
| Magnitude of Extreme Flow Conditions | Magnitude of 1- to 90-day high and low | • Compatibility with life cycles of organisms<br>• Predictability/avoidability of stress for organisms<br>• Access to special habitats during reproduction or to avoid predation<br>• Spawning cues for migratory fish<br>• Evolution of life history strategies, behavioral mechanisms |
| Extreme Low Flow and Low Flow Pulses | Frequency, duration and timing of low flows and low flow pulses | • Enable recruitment of certain floodplain plant species<br>• Purge invasive, introduced species from aquatic and riparian communities<br>• Concentrate prey into limited areas to benefit predators |
| High Flow Pulses | Frequency, duration and timing of high flow pulses | • Shape physical character of river channel, including pools,riffles<br>• Determine size of streambed substrates (sand, gravel, cobble)<br>• Prevent riparian vegetation from encroaching into channel<br>• Restore normal water-quality conditions after prolonged low flows, flushing away waste products and pollutants<br>• Aerate eggs in spawning gravels, prevent siltation<br>• Maintain suitable salinity conditions in estuaries<br>• Influences bedload transport, channel sediment textures, and duration of substrate disturbance high pulses |
| Small Floods | Frequency, duration and timing of small floods | • Provide migration and spawning cues for fish<br>• Trigger new phase in life cycle (i.e., insects)<br>• Enable fish to spawn in floodplain, provide nursery area for juvenile fish<br>• Provide new feeding opportunities for fish, waterfowl<br>• Recharge floodplain water table<br>• Maintain diversity in floodplain forest types through prolonged inundation (i.e., different plant species have different tolerances)<br>• Control distribution and abundance of plants on floodplain<br>• Deposit nutrients on floodplains |

**Table 20b.** Environmental Flow Components, including potential ecosystem influences modified from the IHA User's manual (The Nature Conservancy 2009).

| Parameter Type | Definition | Potential Ecosystem Influences |
|---|---|---|
| Monthly Low Flows | Median low flow daily value for each calendar month | • Provide adequate habitat for aquatic organisms<br>• Maintain suitable water temperatures, dissolved oxygen, and water chemistry<br>• Maintain water table levels in floodplain, soil moisture for plants<br>• Provide drinking water for terrestrial animals<br>• Keep fish and amphibian eggs suspended<br>• Enable fish to move to feeding and spawning areas<br>• Support hyporheic organisms (living in saturated sediments) |

*Historic Flow Conditions, 1998–2010*

From USGS data at Columbia (USGS Station 02169500; Figure 20), 2.2 kilometers (1.4 mi) downstream from the confluence of the Broad and Saluda Rivers, 35.4 river kilometers (22 river mi) upstream from the park, the mean annual discharge during the period from 1998 through 2010 ranged from 73.4 to 391.3 cubic meters per second ($m^3/s$) (2,592 to 13,820 cubic feet per second [cfs]; Table 21). Mean monthly discharge was 30.3 to 886 $m^3/s$ (1070 to 31,290 cfs; Table 22). In the Wateree River below Eastover (USGS Station 02148315; Figure 20), 16.5 kilometers (10.2 mi) upstream from the Park, the mean annual discharge from June 1998 through 2010 ranged from 58.5 to 159.8 $m^3/s$ (2,066 to 5,642 cfs; Table 23). Mean monthly discharge ranged from 24 to 219.5 $m^3/s$ (848 to 7,753 cfs; Table 24). USGS data generally have indicated maximal average monthly discharge in winter and minimal average monthly discharge in late summer-early fall. Minimum average monthly flow occurred in the Congaree River in winter in 2004 and 2007 and late summer in 2008. Maximum average monthly flow for Congaree River occurred in the winters of 1998 and 2003 (Table 21). In the Wateree River, minimum average monthly flow occurred in December 2004, fall of 2007, and late summer of 2008, whereas maximum average monthly flow occurred in the winters of 1998 and 2003 (Table 24).

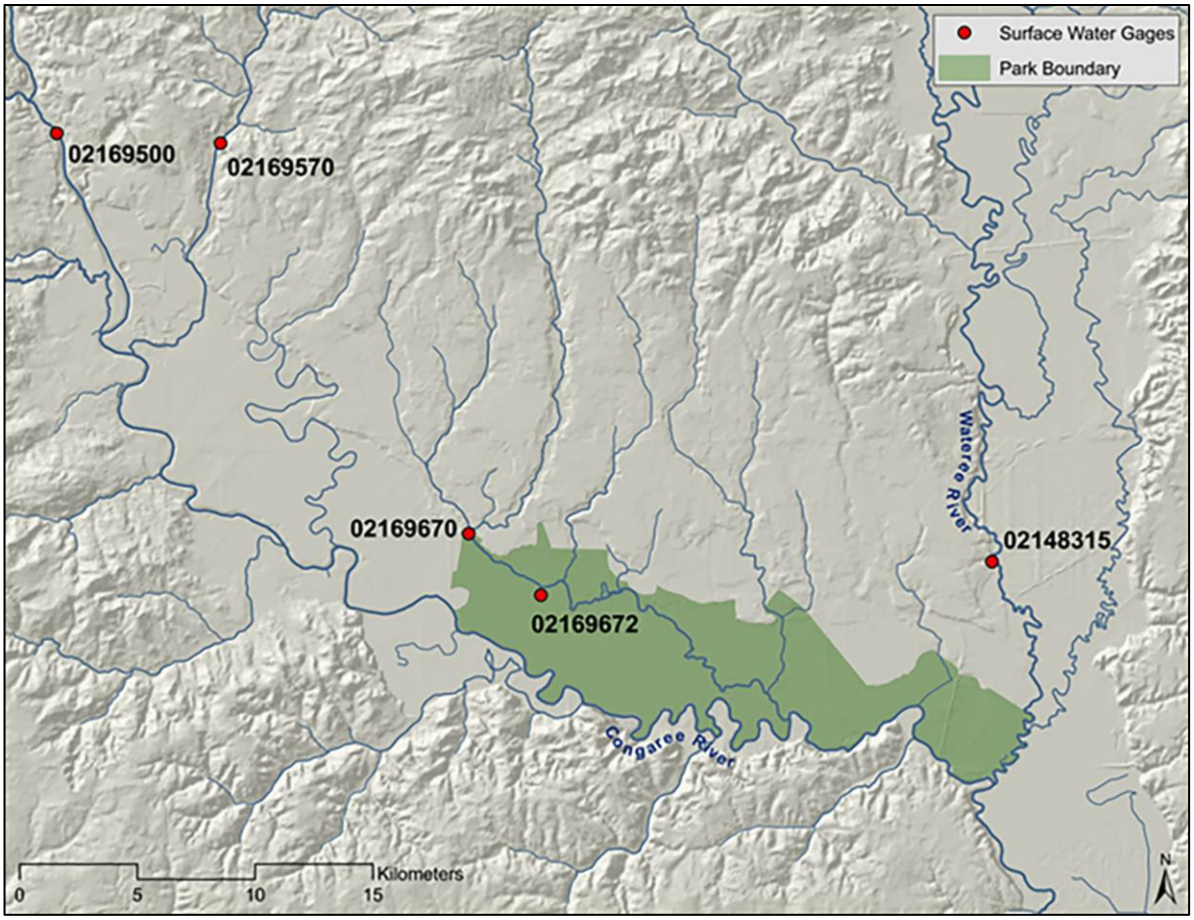


**Figure 20.** Location of USGS gages within park boundaries and upstream from the park. Modified from Gregory et al. 2012.

*Flow Conditions in 2010*

As part of ongoing flow monitoring by the Southeast Coast I&M staff, Gregory et al. (2012) reported that flow was highest in winter (January–February), and low during most of summer-early fall in the Congaree River at Columbia (Figure 21, upper panel). Flow for the Wateree River was highest in winter (January–March) and lowest during early fall (September–October; Figure 22 upper panel). Based on IHA analysis, flow metrics at the Congaree River USGS station 02169500 were as follows: Monthly median flow ranged from 39.9 $m^3/s$ (1,410 cfs; October) to 346.9 $m^3/s$ (12,250 cfs; February) and low flow ranged from 73.9 $m^3/s$ (2,610 cfs; November) to 223.7 $m^3/s$ (7,900 cfs; March; Table 25). Flow metrics at the Wateree River USGS station 02148315 were as follows: Monthly median flow ranged from 39.4 $m^3/s$ (1,390 cfs; October) to 277.6 $m^3/s$ (9,805 cfs; February) and low flow ranged from 52.2 $m^3/s$ (1,845 cfs; November) to 201.9 $m^3/s$ (7,130 cfs; January; February data missing; Table 25).

At the Congaree River station, minimum 1- to 90-day extreme flows in 2010 ranged from 26.1 $m^3/s$ (921 cfs; 1 day) to 55.0 $m^3/s$ (1,943 cfs; 90 days); and the maximum 1- to 90-day extreme flow ranged from 2149.2 $m^3/s$ (75,900 cfs; 1 day) to 446.6 $m^3/s$ (15,770 cfs; 90 days; Table 26). The peak extreme low flow conditions at the Congaree River station (53.4 $m^3/s$ or 1,885 cfs, 20 events) lasted

3 days; the peak in high flow pulses (339.8 $m^3$/s or 12,000 cfs, 9 events) lasted 2.5 days; and one small flood lasting 33 days occurred in February 2010, with peak flow at 2149.2 $m^3$/s (75,900 cfs; Table 27b).

At the Wateree River station 02148315 the minimum 1- to 90-day extreme flow ranged from 33.4 $m^3$/s (1,180 cfs; 1 day) to 49.4 $m^3$/s (1,744 cfs; 90-day); the maximum 1- to 90-day extreme flow ranged from 281.8 $m^3$/s (9,950 cfs; 1 day) to 243.1 $m^3$/s (8,584 cfs; 90 days; Table 26). The peak extreme low flow conditions (39.1 $m^3$/s or 1,380 cfs, 9 events) lasted 3 days; the peak in high flow pulses (276.8 $m^3$/s or 9,775 cfs, 4 events) lasted five days; and one small flood (defined as a flood event with an initial high flow having a maximum greater than a 2-year return interval event) lasting 41 days occurred in January 2010, with peak flow at 281.8 $m^3$/s (9,950 cfs; Table 27a).

**Table 21.** Mean annual discharge at the Congaree River USGS gaging station 02169500 in Columbia, 35.4 river kilometers (22 river mi) upstream from CONG, during 1998–2010.

| Year | 00065, Gage height (ft) | 00060, Discharge (cfs) |
|---|---|---|
| 1998 | – | 12,250 |
| 1999 | – | 4,975 |
| 2000 | – | 4,637 |
| 2001 | 3.308 | 3,601 |
| 2002 | 3.207 | 3,245 |
| 2003 | – | 13,820 |
| 2004 | – | 6,464 |
| 2005 | – | 8,405 |
| 2006 | – | 5,320 |
| 2007 | 3.880 | 5,680 |
| 2008 | – | 2,592 |
| 2009 | – | 5,486 |
| 2010 | 5.147 | 9,514 |

**Table 22.** Mean monthly discharge at the Congaree River USGS gaging station 02169500 in Columbia, South Carolina, 35.4 river kilometers (22 river mi) upstream from CONG, during the period of record from January 1998–2010 (available at http://waterdata.usgs.gov/nwis/, last accessed in September 2014). Units are in CFS ($ft^3/s$).

| Year | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1998[a] | 23,130 | 27,460[c] | 21,200 | 21,850 | 11,770 | 6,633 | 3,597 | 4,938 | 5,346 | 4,932 | 4,909 | 5,695 |
| 1999 | 8,660 | 8,414 | 6,207 | 5,050 | 4,756 | 3,155 | 4,615 | 1,832 | 1,642 | 4,069 | 2,702 | 3,969 |
| 2000 | 8,821 | 7,535 | 8,542 | 5,964 | 3,490 | 2,099 | 2,001 | 2,625 | 3,882 | 2,911 | 2,953 | 3,701 |
| 2001 | 3,281 | 3,211 | 7,926 | 4,977 | 2,283 | 2,934 | 3,322 | 3,082 | 2,560 | 2,849 | 2,602 | 2,617 |
| 2002 | 4,828 | 4,577 | 5,525 | 4,242 | 3,122 | 1,623 | 1,945 | 1,961 | 3,138 | 4,515 | 7,795 | 12,300 |
| 2003[a] | 6,636 | 12,590 | 31,290[c] | 26,160[c] | 20,460 | 12,240 | 12,810 | 13,200 | 5,666 | 4,268 | 4,747 | 6,751 |
| 2004[a] | 5,408 | 10,880 | 5,813 | 5,416 | 3,933 | 5,287 | 3,778 | 3,273 | 18,560 | 5,782 | 6,659 | 1,070[b] |
| 2005 | 7,484 | 7,909 | 13,850 | 12,550 | 5,567 | 10,010 | 11,300 | 6,072 | 3,533 | 7,034 | 3,764 | 9,738 |
| 2006 | 12,240 | 6,573 | 4,486 | 3,851 | 3,054 | 3,583 | 2,634 | 2,839 | 3,969 | 2,698 | 6,439 | 6,501 |
| 2007[a] | 14,260 | 7,433 | 14,940 | 4,644 | 3,816 | 2,653 | 2,027 | 1,342 | 1,328 | 1,085[b] | 1,191[b] | 1,804 |
| 2008[a] | 3,004 | 3,870 | 5,803 | 5,216 | 2,701 | 1,427 | 1,109[b] | 2,405 | 1,540 | 2,031 | 2,624 | 7,046 |
| 2009 | 7,114 | 3,730 | 13,010 | 9,683 | 7,292 | 6,570 | 2,245 | 1,790 | 2,512 | 4,306 | 12,990 | 24,450 |
| 2010 | 18,260 | 19,460 | 9,946 | 6,747 | 5,496 | 5,778 | 2,393 | 3,051 | 1,912 | 1,851 | 2,348 | 3,918 |
| Mean | 9,470 | 9,510 | 11,400 | 8,950 | 5,980 | 4,920 | 4,140 | 3,720 | 4,280 | 3,720 | 4,750 | 7,580 |
| Median | 7484 | 7535 | 8542 | 5416 | 3933 | 3583 | 2634 | 2839 | 3138 | 4069 | 3764 | 5695 |

[a] Months with greatest extremes in flow are highlighted (in bold) along with

[b] Minimum (red) values

[c] Maximum (blue) values.

**Table 23.** Mean annual discharge at the Wateree River USGS gaging station 02148315 below Eastover, 35.4 river kilometers (22 river mi) upstream from CONG, during 1998–2010.

| Year | 00065, Gage height (ft) | 00060, Discharge (cfs) |
|---|---|---|
| 1998 | 9.957 | 4,212 |
| 1999 | 6.580 | 3,092 |
| 2000 | 6.292 | 2,960 |
| 2001 | 4.465 | 2,066 |
| 2002 | 4.986 | 2,313 |
| 2003 | 11.842 | 5,642 |
| 2004 | 9.351 | 4,508 |
| 2005 | 9.660 | 5,018 |
| 2006 | 7.650 | 3,561 |
| 2007 | 6.111 | 2,676 |
| 2008 | 5.345 | 2,505 |
| 2009 | 8.708 | 3,929 |
| 2010 | 8.137 | 3,650 |

**Table 24.** Mean monthly discharge at the Wateree River USGS gaging station 02148315 below Eastover, 35.4 river kilometers (22 river mi) upstream from CONG, during the period of record from June 1998–2010 (USGS 2017c, na = not available). Units are in CFS ($ft^3/s$).

| Year | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1998 | na | na | na | na | na | 4,252 | 3,107 | 4,359 | na | 2,256 | 2,102 | 3,197 |
| 1999 | na | na | 3,859 | 2,647 | 3,767 | 2,086 | 2,811 | 1,769 | 1,506 | 2,150 | 1,954 | 3,404 |
| 2000 | na | na | na | 5,459 | 3,122 | 1,758 | 1,666 | 1,566 | 2,645 | 1,725 | 1,648 | 2,142 |
| **2001**[a] | 2,123 | 2,202 | 4,310 | na | 1,814 | 2,103 | 1,684 | 1,582 | 1,570 | 1,576 | 1,431 | 848.1[b] |
| 2002 | 2,195 | 2,254 | 2,825 | 2,753 | 1,564 | 1,484 | 1,486 | 1,456 | 1,413 | 1,464 | 3,654 | na |
| 2003 | na | na | na | na | na | na | na | na | 3,876 | 3,185 | 4,160 | 5,745 |
| **2004**[a] | 4,868 | 5,851 | 4,391 | 3,103 | 2,643 | 2,855 | 3,457 | 3,944 | na | na | 4,764 | 7,753[c] |
| **2005**[a] | 6,871[c] | 4,283 | na | na | 3,639 | 5,241 | 6,932[c] | 5,421 | 2,046 | 3,910 | 2,192 | na |
| 2006 | na | 5,060 | 2,785 | 2,502 | 1,853 | 3,295 | 2,090 | 2,150 | na | 2,611 | na | na |
| 2007 | na | 5,871 | na | 3,908 | 2,430 | 1,857 | 1,836 | 1,502 | 1,099 | 1,375 | 1,047 | 1,171 |
| 2008 | 1,911 | 2,523 | 4,324 | 4,571 | 2,122 | 1,191 | 1,335 | na | na | 1,410 | 1,961 | na |
| 2009 | na | 1,865 | na | na | na | na | 2,055 | 1,994 | 1,637 | 2,166 | na | na |
| 2010 | na | na | na | 5,361 | 3,357 | 4,018 | 2,753 | 3,355 | 1,940 | 1,675 | 1,649 | 2,911 |
| Mean | 3,590 | 3,740 | 3,750 | 3,790 | 2,630 | 2,740 | 2,600 | 2,650 | 1,970 | 2,130 | 2,410 | 3,270 |

[a] Months with greatest extremes in flow are highlighted (in bold)

[b] minimum (red)

[c] maximum (blue) values.

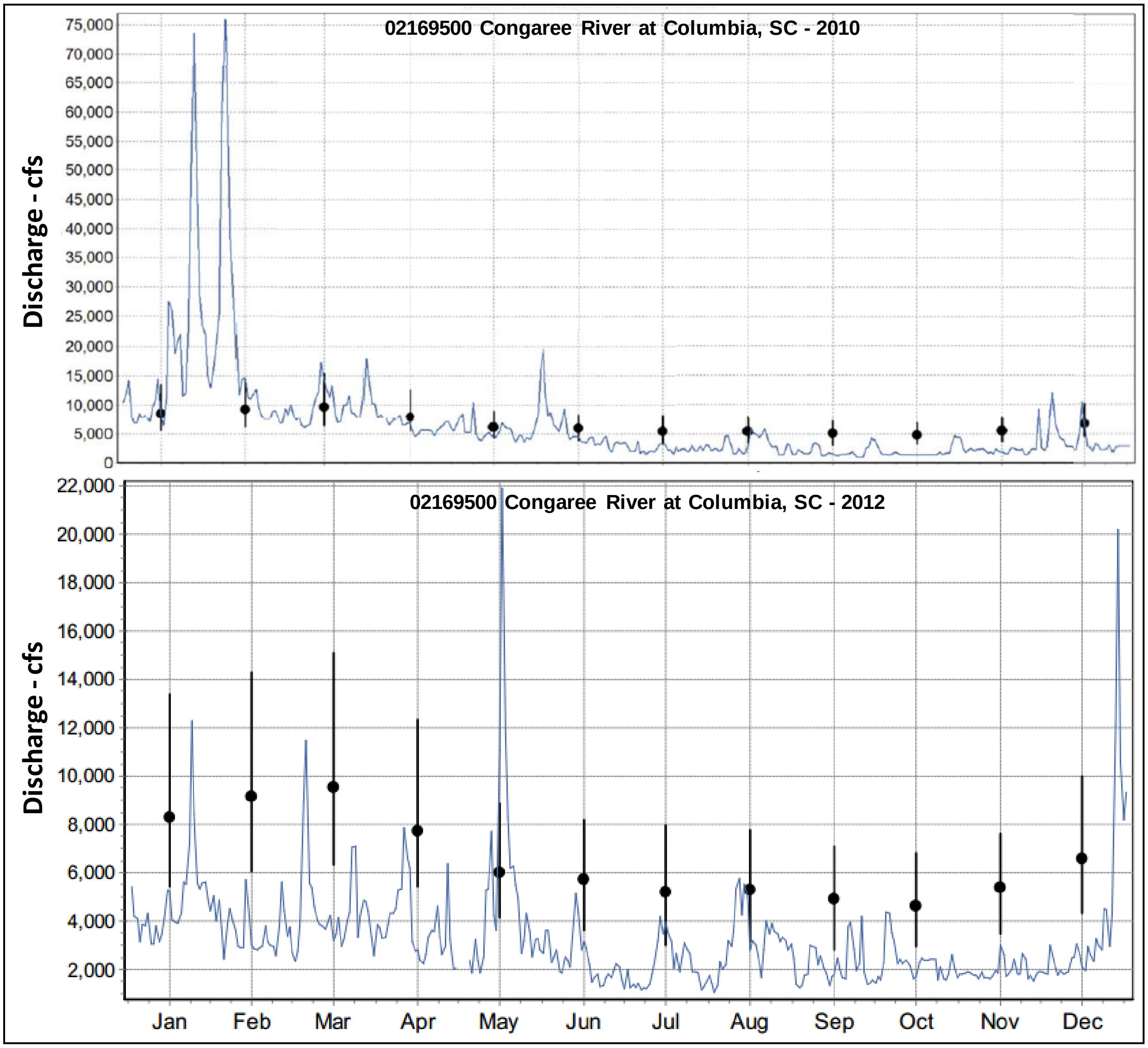


**Figure 21.** Flow characteristics of the Congaree River at Columbia, South Carolina. Shown are daily flow (discharge, cfs—blue line), historical median monthly flow (dots), and interquartile range (error bars) in baseline year 2010 (upper panel) and 2012 (lower panel) at the USGS station 02169500, 37 km (23 mi) upstream from CONG. From Gregory et al. (2012; the 2010 data) and Jones and Gregory (2013; the 2012 data).

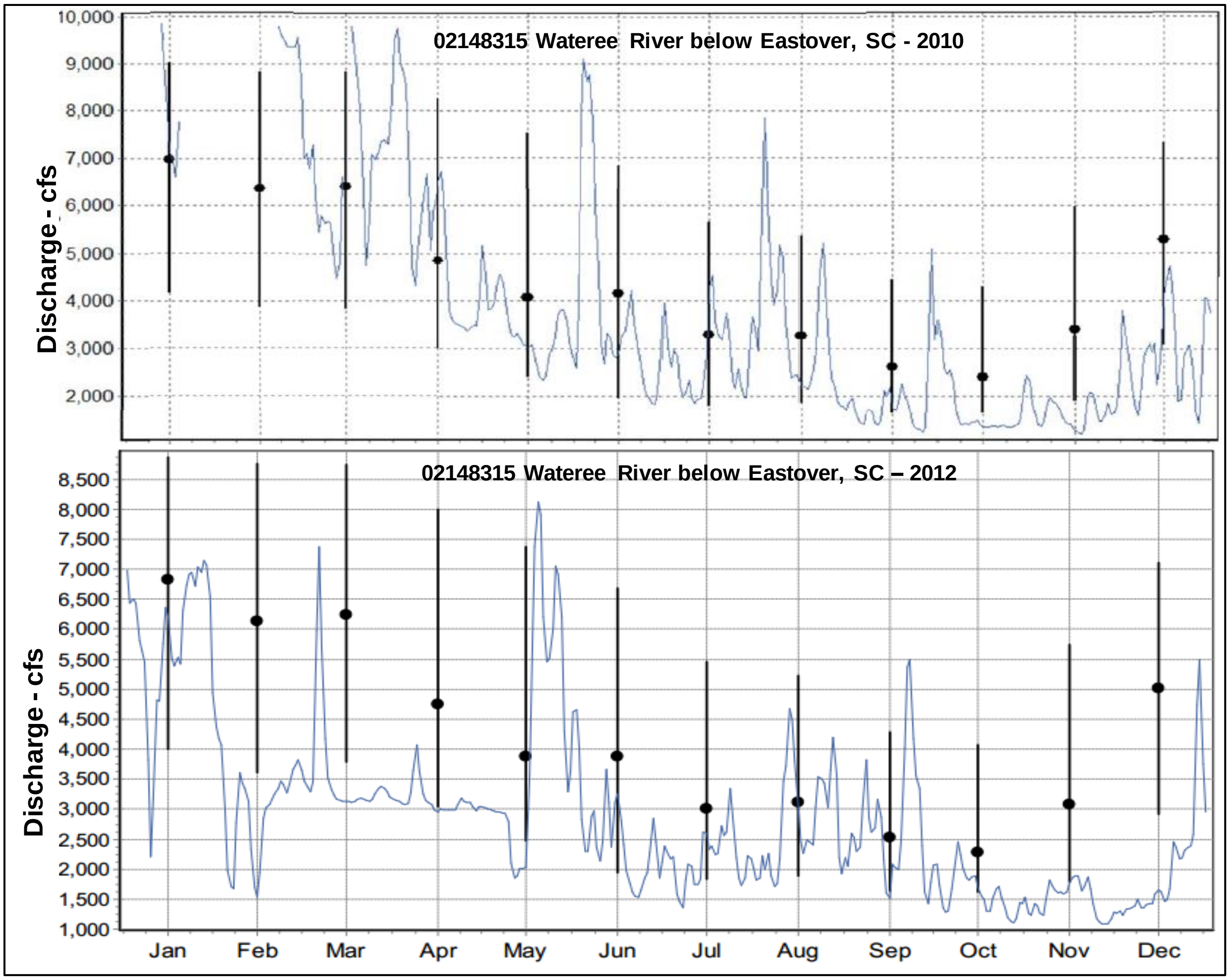


**Figure 22.** Flow characteristics on Wateree River below Eastover, South Carolina. Daily flow (discharge, cfs—blue line), historical median monthly flow (dots), and interquartile range (error bars) in baseline year 2010 (upper panel) and 2012 (lower panel) at the USGS station 02148315, 16.5 km (10.2 mi) upstream from CONG. From Gregory et al. (2012; the 2010 data) and Jones and Gregory (2013; the 2012 data).

**Table 25.** Monthly median flow magnitudes (in cfs) at USGS gaging stations near CONG during 2010. Median flows were calculated with IHA software (The Nature Conservancy 2009) using USGS daily data. From Gregory et al. (2012) [na–not available].

| Flow | Jan | Feb | March | April | May | June | July | Aug | Sept | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Median flow 2148315 Wateree | 9,778 | 9,805 | 7,010 | 5,070 | 3,230 | 3,245 | 2,600 | 2,860 | 1,695 | 1,390 | 1,605 | 2,920 |
| Median flow 2169500 Congaree | 12,000 | 12,250 | 9,190 | 6,635 | 5,120 | 4,485 | 2,190 | 2,860 | 1,590 | 1,410 | 2,215 | 2,910 |
| Low flow 2148315 -Wateree | 7,130 | na | 6,640 | 4,670 | 3,230 | 3,110 | 2,600 | 2,860 | 1,950 | 2,430 | 1,845 | 2,950 |
| Low flow 2169500 Congaree | 7,700 | 7,875 | 7,900 | 6,550 | 5,120 | 4,480 | 3,145 | 4,030 | 3,345 | 4,385 | 2,610 | 2,950 |

**Table 26.** 1 to 90-day extreme flows (in cfs) at two USGS gaging stations near CONG during 2010. Metrics were calculated from USGS daily data using IHA software (The Nature Conservancy 2009). From Gregory et al. (2012).

| USGS ID | Flow Magnitude | 1-day | 3-day | 7-day | 30-day | 90-day |
|---|---|---|---|---|---|---|
| 2148315–Wateree | Minimum | 1,180 | 1,213 | 1,303 | 1,494 | 1,744 |
| 2169500–Congaree | Minimum | 921 | 934 | 1,290 | 1,660 | 1,943 |
| 2148315–Wateree | Maximum | 9,950 | 9,944 | 9,931 | 9,851 | 8,584 |
| 2169500–Congaree | Maximum | 75,900 | 66,300 | 44,730 | 28,240 | 15,770 |

**Table 27a.** Environmental Flow Components for flows (in cfs) at Wateree USGS station 0214815 near CONG during 2010 (The Nature Conservancy 2009). Timing refers to the average date (average of Julian dates) of a peak event if more than one occurred. NC–metric not calculated. From Gregory et al. (2013).

| Component | Extreme low flow | High flow pulses | Small flood |
|---|---|---|---|
| Frequency | 9 | 4 | 1 |
| Peak (cfs) | 1,380 | 9,775 | 9,950 |
| Duration (days) | 3 | 5 | 41 |
| Timing | 5 Nov | 25 March | 23 January |

**Table 27b.** Environmental Flow Components for flows (in cfs) at Congaree USGS station 02169500 near CONG during 2010 (The Nature Conservancy 2009). Timing refers to the average date (average of Julian dates) of a peak event if more than one occurred.[1] From Gregory et al. (2013).

| Component | Extreme low flow | High flow pulses | Small flood |
|---|---|---|---|
| Frequency | 20 | 9 | 1 |
| Peak (cfs) | 1,885 | 12,000 | 75,900 |
| Duration (days) | 3 | 2.5 | 33 |
| Timing | 30 Aug | 15 March | 7 February |

[1] Average timing not calculated due to distribution of Julian dates

*Flow Conditions in 2012*

Data for these EFCs were collected again in 2012 at the Congaree River (USGS station 02169500) and the Wateree River (USGS station 02148315; Jones and Gregory 2013). The two years, 2010 and 2012, were quite different. Monthly median flow in the Congaree River was two- to three-fold higher in January through April 2010 compared to monthly median flow in 2012. Monthly median flow in the Wateree River was two-fold higher for the same months in 2010 in comparison to 2012 (Table 25 versus Table 28). The maximum 1- to 90-day extreme flow in 2010 was higher compared to 2012 for both rivers. The 90-day maximum extreme flow in 2010 was greater than 70% and 50% higher than in 2012 for the Congaree River and the Wateree River, respectively (Table 26 versus Table 29). There were 56% and 75% more high flow pulses in the Congaree River and the Wateree River, respectively, in 2010 compared to 2012 (9 and 4 in 2010 [Table 27a and 27b] vs. 4 and 1 in 2012 [Table 30a and 30b], respectively). In 2012 there were no small floods, versus one small flood in both the Congaree and Wateree Rivers.

**Table 28.** Monthly median flow magnitudes (in cfs) at USGS gaging stations near CONG during 2012. Median flows were calculated with IHA software (The Nature Conservancy 2009) using USGS daily data. From Gregory et al. (2012).na–not available.

| Flow | Jan | Feb | March | April | May | June | July | Aug | Sept | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Median flow 2148315 Wateree | 6,210 | 3,250 | 3,230 | 3,090 | 3,290 | 2,365 | 2,190 | 2,460 | 2,505 | 1,540 | 1,535 | 1,580 |
| Median flow 2169500 Congaree | 4330 | 3,520 | 4,140 | 3,350 | 3,240 | 2,135 | 1,910 | 3,160 | 1,910 | 2,280 | 2,280 | 2,630 |

**Table 29.** 1 to 90-day extreme flow magnitudes (in cfs) near CONG during 2012. Metrics were calculated from USGS daily data using IHA software (The Nature Conservancy 2009). From Jones and Gregory (2013).

| USGS ID | Flow Magnitude | 1-day | 3-day | 7-day | 30-day | 90-day |
|---|---|---|---|---|---|---|
| 2148315–Wateree | Minimum | 1,090 | 1090 | 1,146 | 1,394 | 1,581 |
| 2169500–Congaree | Minimum | 1,060 | 1,213, | 1,280 | 1,894 | 2,134 |
| 2148315–Wateree | Maximum | 8,120 | 7,800 | 6,970 | 5,853 | 4,170 |
| 2169500–Congaree | Maximum | 21,900 | 14,870 | 10,050 | 5,001 | 4,563 |

**Table 30a.** Environmental Flow Components for flows (in cfs) at Congaree USGS station 02169500 near CONG during 2012 (The Nature Conservancy 2009). Timing refers to the average date (average of Julian dates) of a peak event if more than one occurred.[1] NC–average timing was not calculated due to distribution of Julian dates. From Gregory et al. (2013).

| Component | Extreme low flow | High flow pulses | Small flood |
|---|---|---|---|
| Frequency | 29 | 4 | 0 |
| Peak (cfs) | 1,880 | 16,250 | NC |
| Duration (days) | 2 | 2 | NC |
| Timing | 14 Sept | NC | NC |

**Table 30b.** Environmental Flow Components for flows (in cfs) at Wateree USGS station 02148315 near CONG during 2012 (The Nature Conservancy 2009). Timing refers to the average date (average of Julian dates) of a peak event if more than one occurred.[1] NC–average timing was not calculated due to distribution of Julian dates. From Gregory et al. (2013).

| Component | Extreme low flow | High flow pulses | Small flood |
|---|---|---|---|
| Frequency | 10 | 1 | 0 |
| Peak (cfs) | 1,390 | 8,120 | NC |
| Duration (days) | 2 | 1 | NC |
| Timing | 12 Oct | NC | NC |

[1] Average timing not calculated due to distribution of Julian dates

*Surface-Water quality Criteria*

The General Assembly of South Carolina in the S.C. Pollution Control Act, Section 48-1-10 et seq., 1976 Code of Laws, states:

> "It is declared to be the public policy of the State to maintain reasonable standards of purity of the air and water resources of the State, consistent with the public health, safety and welfare of its citizens, maximum employment, the industrial development of the State, the propagation and protection of terrestrial and marine fauna and flora, and the protection of physical property and other resources. It is further declared that to secure these purposes and the enforcement of the provisions of this Act, the Department of Health and Environmental Control shall have authority to abate, control and prevent pollution."

The South Carolina Department of Health and Environmental Control (SCDHEC 2012c) developed surface-water-use classifications and ambient water-quality standards for common parameters. These parameters include: dissolved oxygen (DO; less than 5 mg/L), turbidity (≤ 50 nephelometric turbidity units [NTU] for freshwater rivers and streams, and 25 NTU for lakes and reservoirs), and fecal bacteria (≤ 126 colony forming units [CFU] per 100 mL as a geometric mean [gm] based on at least four samples collected within 30 days; Table 31). For the Middle Atlantic Coastal Plains ecoregion of the State, total phosphorus (TP) shall not exceed 0.09 mg/L, corrected chlorophyll *a* (chl *a*) shall not exceed 40 µg/L, and total nitrogen (TN) shall not exceed 1.50 mg/L applicable to all waters (SCDHEC 2012c).

**Table 31.** South Carolina surface water use classifications and water-quality standards, excluding trout waters (DO–dissolved oxygen; Chl*a*—corrected chlorophyll *a*; GM–geometric mean). From SCDHEC (2012c), updated in June 2012: R.61-68, Water Classification and Standards.

| USE CLASSIFICATION | TEMP. ºC (ºF) | pH | DO (mg/L) | Turbidity (NTU) | Chl*a* (µg/L)[a] | Fecal Bacteria (GM #/100 mL)* *E. coli* |
|---|---|---|---|---|---|---|
| Freshwater (aquatic life; primary and secondary recreation, and drinking water source) | ≤ 2.8 ºC (5.04ºF) above natural; never > 32ºC (89.6ºF) as a result of heated liquid discharge | 6.0–8.5 | ≥ 5.0 average ≥ 4.0 minimum instantaneous | 50 (streams); 25 (lakes, reservoirs) | 40 | ≤ 126; ≤ 349 single sample |

* geometric mean of at least four samples collected from a given sampling site over a 30-day period

Other recommended guidelines for acceptable water-quality parameters—including turbidity, nutrients (nitrate+nitrite, $NO_x$; total Kjeldahl nitrogen, TKN; and total phosphorus, TP), five-day biochemical oxygen demand ($BOD_5$), total suspended solids (TSS), polychlorinated biphenyls (PCBs), and a suite of toxic metals—in waters designated for use as fishing and general recreation, have been published by the EPA (2000, 2002b, 2003) and other sources (Table 32). The federal Clean Water Act requires the EPA to develop recommended criteria for water, which are designed in part to protect aquatic life. The criteria are supposed to reflect accurately the up-to-date scientific knowledge. Whereas the State of South Carolina has imposed regulations, a EPA water-quality criterion is not a regulation; it does not impose legally binding requirements on the EPA or the states. States have the discretion to adopt approaches that differ from the EPA water-quality criteria, but these criteria are meant to provide useful guidance.

Stream segments are placed on the South Carolina Impaired Waters (303(d) list based on water quality and biota sampling data. Seven water-quality sites evaluated for this report were listed on the 2012 303(d) List of Impaired Waters for South Carolina (Tables 19a–c; SCDHEC 2012b).

For the water use classification of aquatic life, impairment is listed as biota impacted—macroinvertebrate. For water use classification fish consumption, the pollutant in violation was mercury and the use classification of recreational use (swimming) violation was fecal coliform bacteria (see Appendix B). Potential causes are agricultural runoff, (other) nonpoint sources, and/or municipal and industrial facilities (point sources).

**Table 32.** EPA recommendations for reference (minimally impacted) stream conditions for nutrient, turbidity (NTU–Nephelometric turbidity unit; FNU–Formazin Nephelometric unit; JCU—Jackson turbidity unit), and suspended microalgal biomass as chlorophyll *a* concentrations in streams within Level III nutrient sub-ecoregion #65, which includes CONG (EPA 2000). These recommendations were based on the 25th percentile of all available streams data for the previous decade.

| Parameter | 25th Percentiles based on all seasons data for the past decade (P25-all seasons) |
|---|---|
| TKN (mg/L) | 0.300 |
| $NO_2$-+$NO_3$- (mg/L) = $NO_x$ | 0.095 |
| TN (mg/L) calculated | 0.395 |
| TN (mg/L) reported | 0.618 |
| TP (µg/L) | 22.500 |
| Turbidity (NTUs) | 6.200 |
| Turbidity (FNUs) | 4.338 |
| Turbidity (JTUs) | 6.55 |
| Chlorophyll *a* (µg/L)–fluorometric technique | 1.438 |
| Chlorophyll *a* (µg/L)–spectrophotometric technique | 0.049 |

*Surface-water quality in the Park*

This section provides a synopsis of surface water-quality conditions between 2000 and 2013. Locations for sampling stations near or within the park were obtained from SCDHEC and the EPA STOrage and RETrieval (STORET) Data Warehouse, a repository for water quality, biological, and physical data. We selected water-quality sites within a 5-kilometer (3-mi) radius of the park monitored by SCDHEC and Santee Cooper-South Carolina Public Service Authority. Figure 23 shows the various sampling station locations with respect to roads and the park boundary as well as point sources of water pollution including CERCLA sites (commonly known as Superfund sites), National Pollutant Discharge Elimination System (NPDES)-permitted sites and agricultural facilities. (SCDHEC 2016).

From 2000 to 2013, 17 stations (Cedar Creek sub-watershed [9]; Toms Creek sub-watershed [6]; Lower Wateree sub-watershed [2]) were monitored (Figure 19). Available data were inconsistently sampled (frequency) and vary in parameters monitored. Most of the water-quality sites are not located within the park but, rather, near the park boundary, and are unevenly distributed across the three sub-watersheds. Some stations are clustered together or co-located (Figure 19, Tables 19a–c).

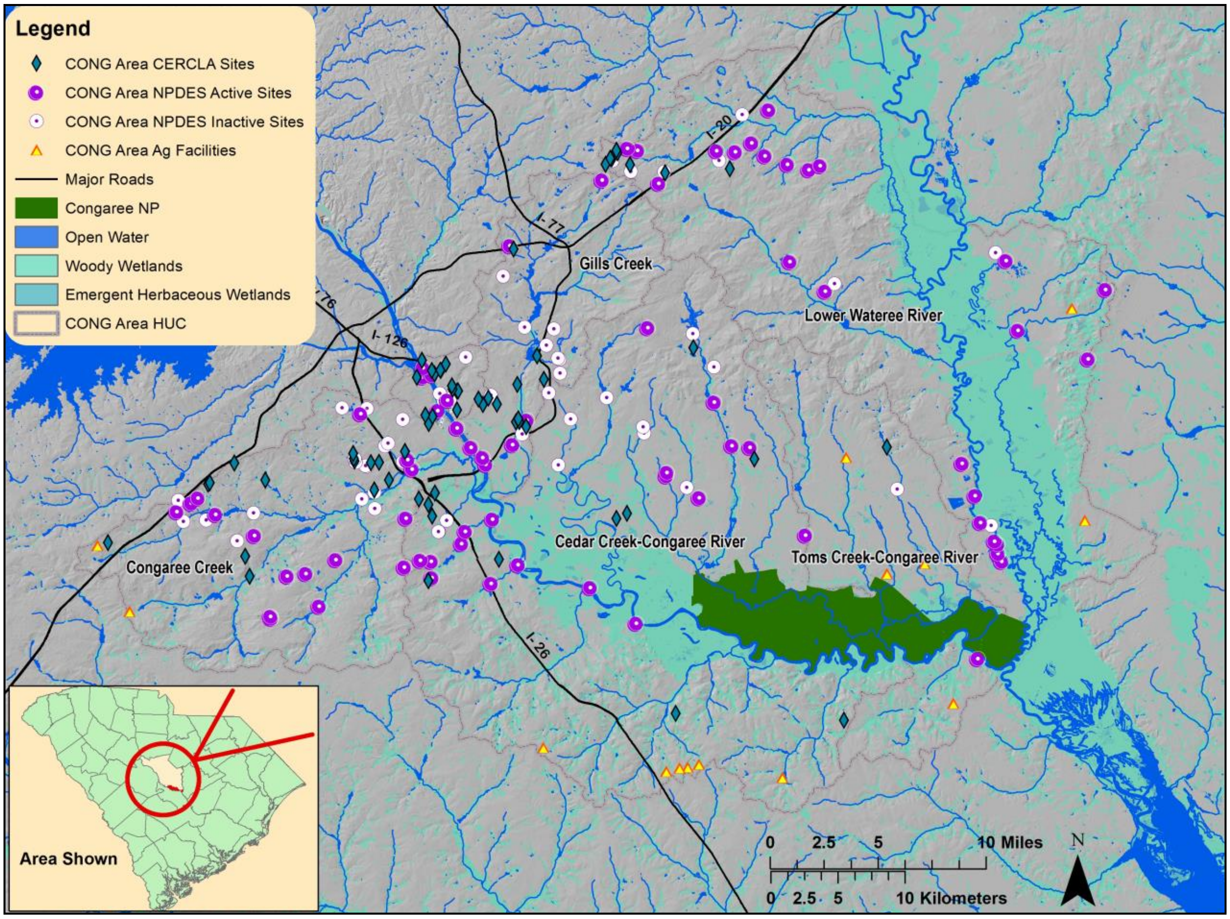


**Figure 23.** Map showing sources of pollution near CONG, including CERCLA (Superfund) sites, NPDES-permitted point sources, and agriculture facility within a 16-km (10-mi) radius of the park (SCDHEC 2016).

The available data indicate water-quality degradation in more than 50% of samples from high turbidity, and in more than 65–75% of samples for excessive TSS and nutrients (TP, NOx, TKN; Figure 24, exceedance of recommendations by parameter). $BOD_5$ and fecal coliform bacteria showed the least degradation of the parameters (< 10% exceedance of recommendations for both). Approximately 25% or more of the samples exceeded recommended values for *Enterococcus* and *Escherichia coli*.

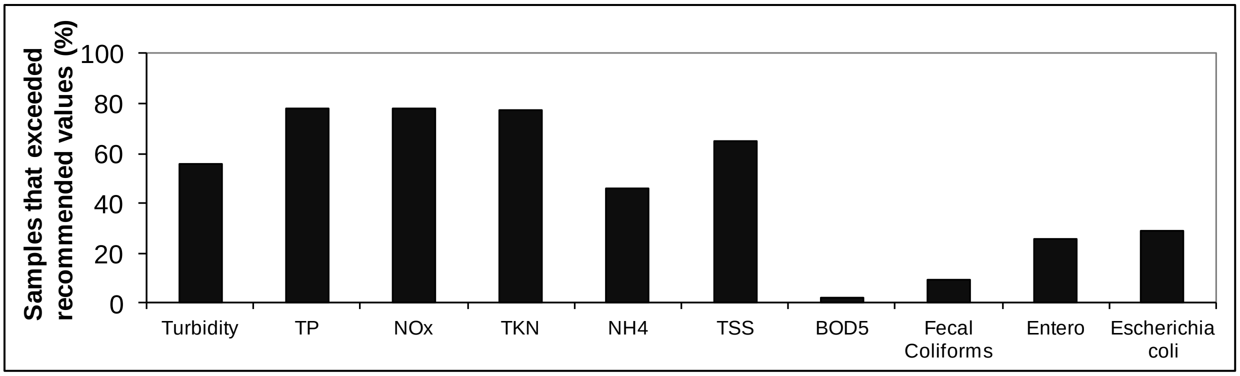


**Figure 24.** The percentage of samples that exceed criteria or recommended values for acceptable water quality for ten parameters in the overall area from 2000–2013. The ten parameters are turbidity, total phosphorus (TP), nitrate+nitrite-N (NOx), total Kjeldahl nitrogen (TKN), ammonium (NH4+N), total suspended solids (TSS), 5-day biochemical oxygen demand (BOD5), fecal coliform bacteria, *Enterococcus* bacteria (Entero), and the fecal bacterium *Escherichia coli*.

Of the three sub-watersheds, the Lower Wateree sub-watershed had the highest percentage of samples that exceeded water-quality standards, 76–99% (turbidity, TP, $NO_x$, TKN and TSS). Generally, water-quality conditions were better in the Cedar Creek sub-watershed than in the Toms Creek and Lower Wateree sub-watersheds for these nutrients, excluding TKN data (84% exceeded water-quality standards). However, the *Enterococcus* and *Escherichia coli* indicators had the highest percentage of exceedances in the Cedar Creek sub-watershed (> 30%). The Lower Wateree sub-watershed had the lowest percentage of samples that exceeded recommended water-quality criteria among the three indicators of fecal bacteria analyzed (Figure 25). Bacteria were evaluated collectively under the single sample maximum EPA guidelines (EPA 2000). Two sites, C-076 and C-077, had sufficient data for calculating geometric means as well (Figure 26, Table 33).

In 2009, these two sites (C-076 and C-077) were sampled for three different indicators for fecal bacteria (fecal coliform, *Enterococcus*, and *E. coli*). The samples were collected on the same dates at each location providing a direct comparison between indicators. Data for *Enterococcus* showed the highest percentage of violations in consideration of both sites C-076 and C-077; fecal coliform bacteria showed the lowest number of violations for the same sites (Figure 26). The number of violations using the single sample maximum value followed the same pattern as the geometric mean analysis. The fewest number of violations were for fecal coliform densities; there were an intermediate number of violations for *E. coli*; and the highest numbers of violations were for *Enterococcus* at each of these two sites (see Appendix B for further information).

Generally, median values for nitrogen species ($NO_x$, TKN, $NH_4$) were higher in the Cedar Creek sub-watershed and declined moving eastward across the park. Total suspended solids analysis shows the opposite pattern, although there are numerous sites where TSS was not monitored. Median values for TSS, turbidity and TP were highest for sites CW-222 and S.C.-002 in the Lower Wateree sub-watershed, with the exception of turbidity at site RS-13158 in the Cedar Creek sub-watershed (Figure 25).

Median TP values were relatively consistent across all sites. At 5 of 13 site for $NO_x$ and 7 of 13 for TP, nearly 100% of samples exceeded the recommended water-quality criteria across all three sub-watersheds (Figures 27–30).

Fecal indicator bacteria were analyzed at 13 sites using the single sample maximum criterion for each indicator because samples were collected at insufficient frequency to calculate geometric means. Fecal coliform bacteria were in violation in < 20% of samples across the three sub-watersheds. Less than 20% of fecal coliform data exceeded water-quality criteria (Figure 31). Violations for enterococcus ranged between 10–65% (Figure 32) and *E. coli* violations ranged from 0–57% (Figure 33). Although data were sporadic, Cedar Creek, Toms Creek and Congaree River each had sites showing degraded water-quality conditions for bacteria.

According to the 2012 South Carolina 303(d) List of Impaired Waters, the Toms Creek sub-watershed had the most sites not supporting classified uses. Congaree River site C-007, co-located with S.C.-001 was not supporting fish consumption due to mercury contamination. Toms Creek sites C-072 and S-950 were not supporting recreational use (swimming) due to elevated fecal coliform bacteria. Buckhead Creek site RS-04521 was not supporting aquatic life classification due to biota impacted macroinvertebrate community. In the Cedar Creek sub-watershed, two sites were listed as impaired on the 2012 303(d) list. Cedar Creek site C-071 was not supporting aquatic life due to a biota impacted violation for the macroinvertebrate community. Congaree River site C-074 was not supporting recreational use (swimming) due to fecal coliform bacteria violations. The Lower Wateree River sub-watershed sites in our study area were not impaired for their designated uses (Figure 19, Table 19c).

Recent chlorophyll *a* data are lacking for surface waters within Congaree National Park. Algal blooms have occurred in Wise Lake, indicating that shallow blackwater systems can host blooms if sufficient nutrients and light are available (Mallin et al. 2001; 2004; Mallin and McIver 2010). Consideration of oxbow lakes mean N/P ratios showed low values in Weston Lake (4.3), Wise Lake (6.2) and Bates Old River (6.8), suggestive of nitrogen limitation. Therefore, phytoplankton production in these systems may be nitrogen-limited. With nutrients supplied to the lakes from annual flooding and groundwater inputs, and sufficient light availability from the open canopy, algal blooms are a potential problem for some surface waters in this park (Mallin and McIver 2010).

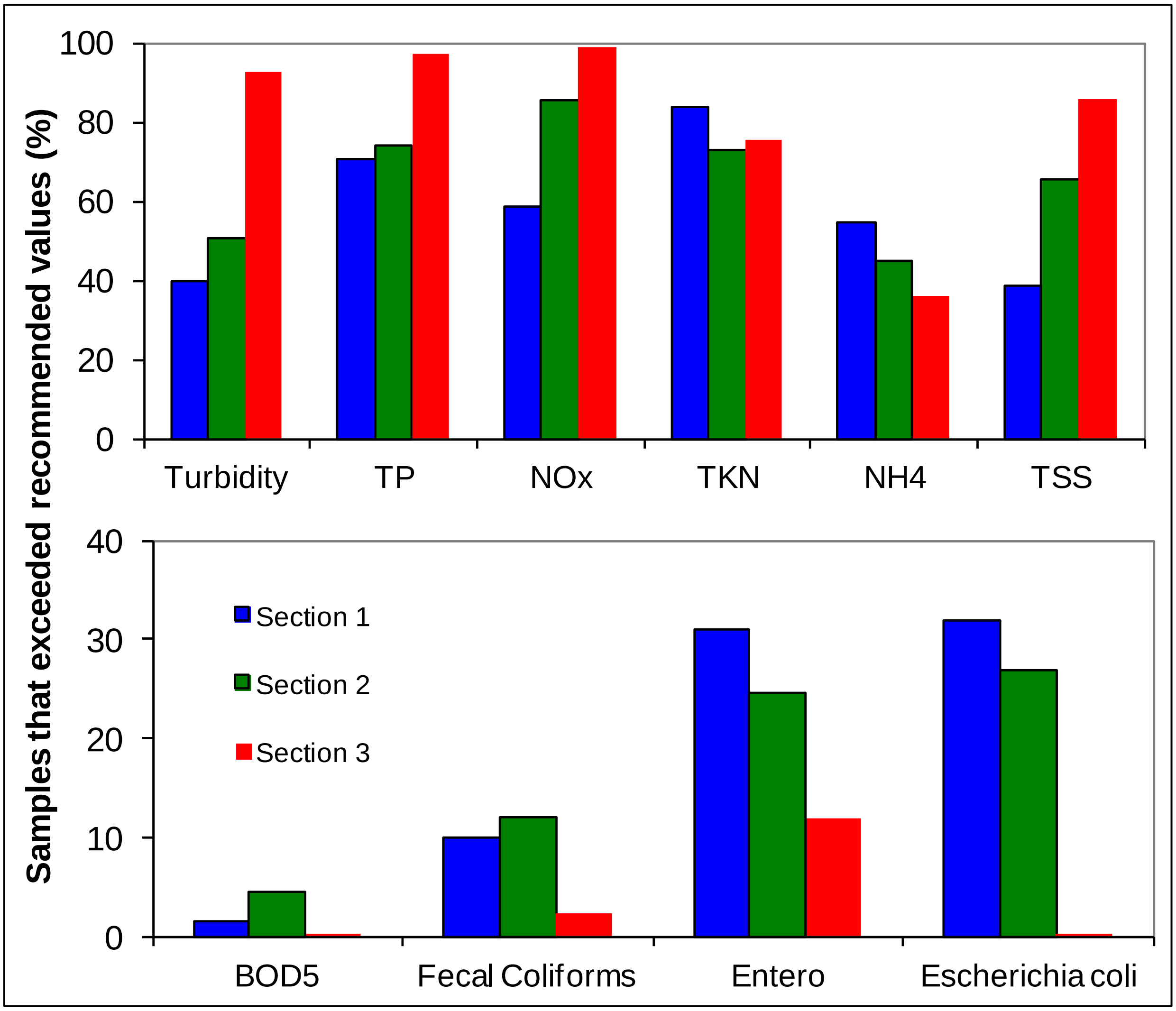


**Figure 25.** The percentage of samples for ten parameters that exceeded criteria or recommended values for acceptable water quality in 2000–2013, arranged by sub-watershed Section 1—Blue = Cedar Creek-Congaree River, Section 2—Green = Toms Creek-Congaree River, Section 3—Red = Lower Wateree River.

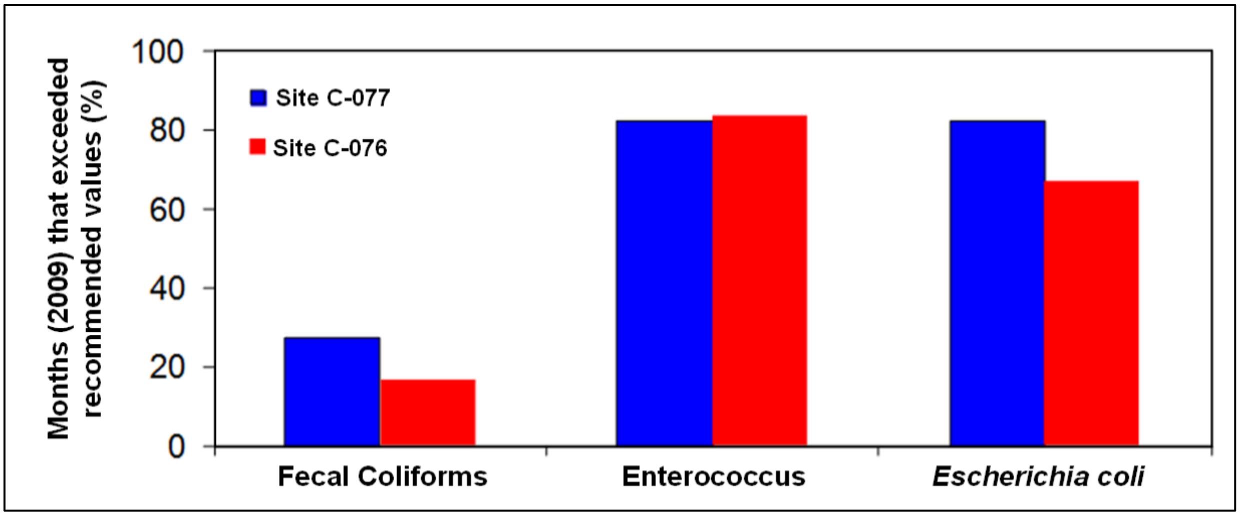


**Figure 26.** The percentage of months in 2009 that exceeded recommended values for acceptable water quality using geometric means for the two sites with sufficient data.

**Table 33.** Geometric mean values for each bacteria community by month[1] (Figure 26). C-076–March, June, August, November, n=5, all other months n=4. C-077–June, August, n=5, all other months n=4.

| Date | C-076 Fecal | C-076Entero | C-076E.coli | C-077 Fecal | C-077Entero | C-077E.coli |
|---|---|---|---|---|---|---|
| Jan 09 | 80 | 14 | 116 | 141 | 25 | 193[1] |
| Feb 09 | 29 | 3 | 51 | 41 | 10 | 72 |
| March 09 | 128 | 52[1] | 201[1] | 147 | 34[1] | 179[1] |
| April 09 | 103 | 38[1] | 148[1] | 103 | 42[1] | 124 |
| May 09 | 103 | 114[1] | 133[1] | 185 | 210[1] | 265[1] |
| June 09 | 72 | 293[1] | 85 | 148 | 753[1] | 205[1] |
| July 09 | 76 | 323[1] | 87 | 166 | 750[1] | 196[1] |
| Aug 09 | 118 | 519[1] | 142[1] | 336[1] | 727[1] | 360[1] |
| Sept 09 | 170 | 304[1] | 195[1] | 328[1] | 367[1] | 392[1] |
| Oct 09 | 347[1] | 388[1] | 482[1] | 392[1] | 297[1] | 487[1] |
| Nov 09 | 113 | 118[1] | 167[1] | 113 | 86[1] | 217[1] |
| Dec 09 | 286[1] | 300[1] | 366[1] | – | – | – |
| Percent in violation | 17 | 83 | 67 | 27 | 82 | 82 |

[1] Red indicates values above the EPA recommendation

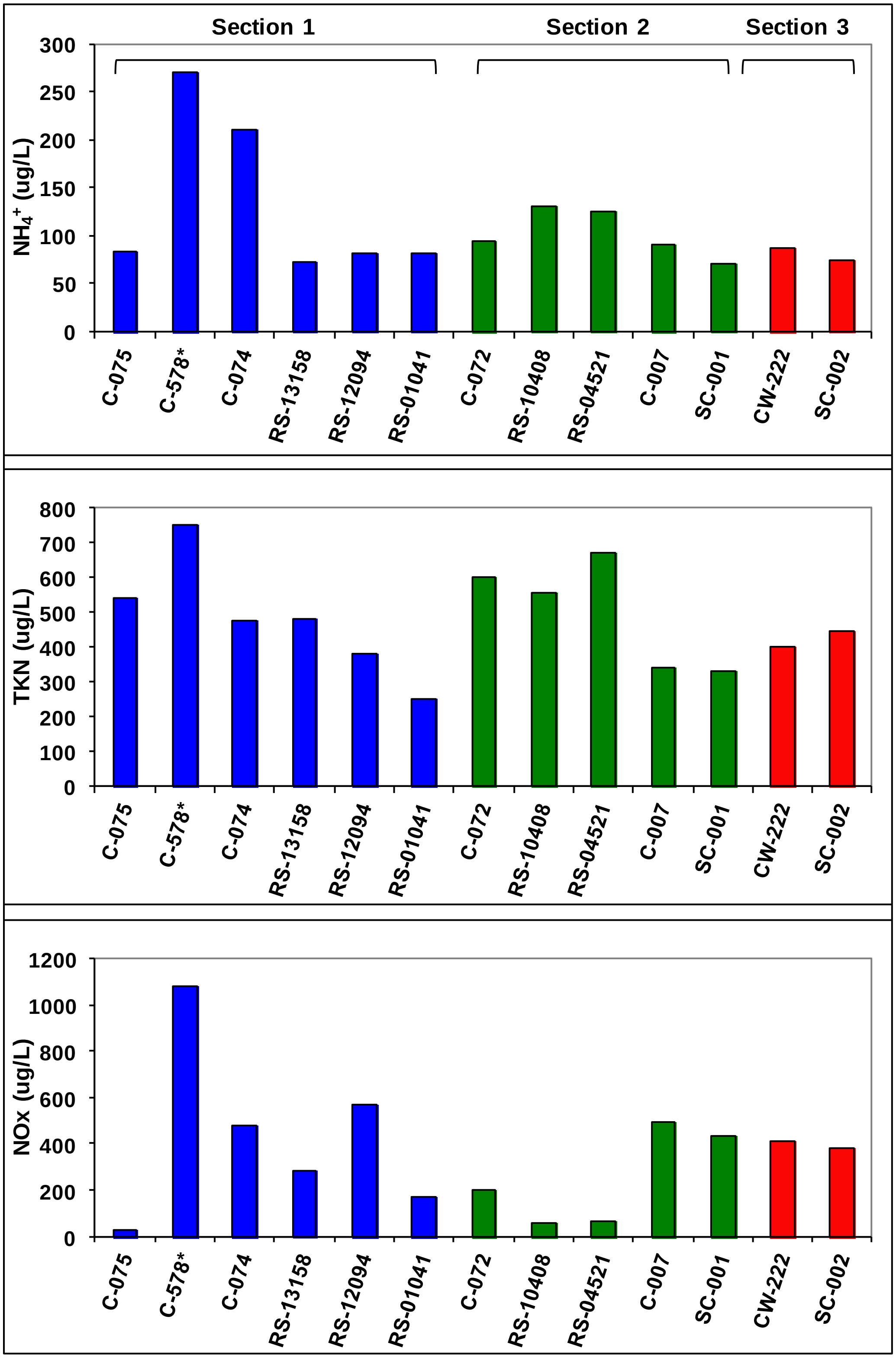


**Figure 27.** Median values by site for nutrient concentrations including ammonium (NH4+), total Kjeldahl nitrogen (TKN), and NOx (upper, middle and lower panels, respectively), arranged by watershed (section): Blue = Cedar Creek-Congaree River, Green = Toms Creek-Congaree River, Red = Lower Wateree River; * = samples = 2. For additional information see Appendix B.

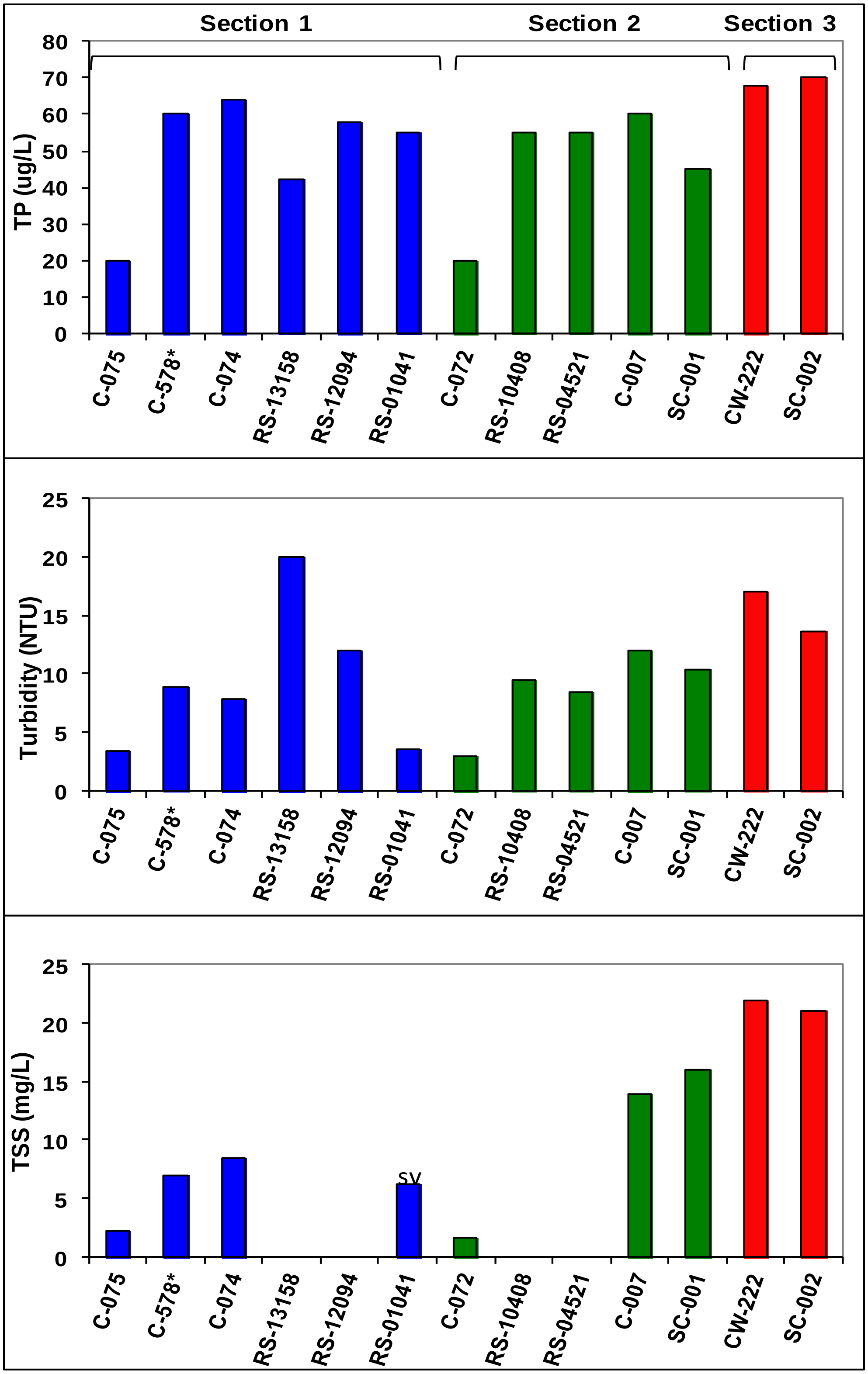


**Figure 28.** Median values for total phosphorus (TP), turbidity, and total suspended solids (TSS; upper, middle, and lower panels, respectively), arranged by watershed (section): Blue = Cedar Creek-Congaree River, Green = Toms Creek-Congaree River, Red = Lower Wateree River. For additional information, see Appendix B.

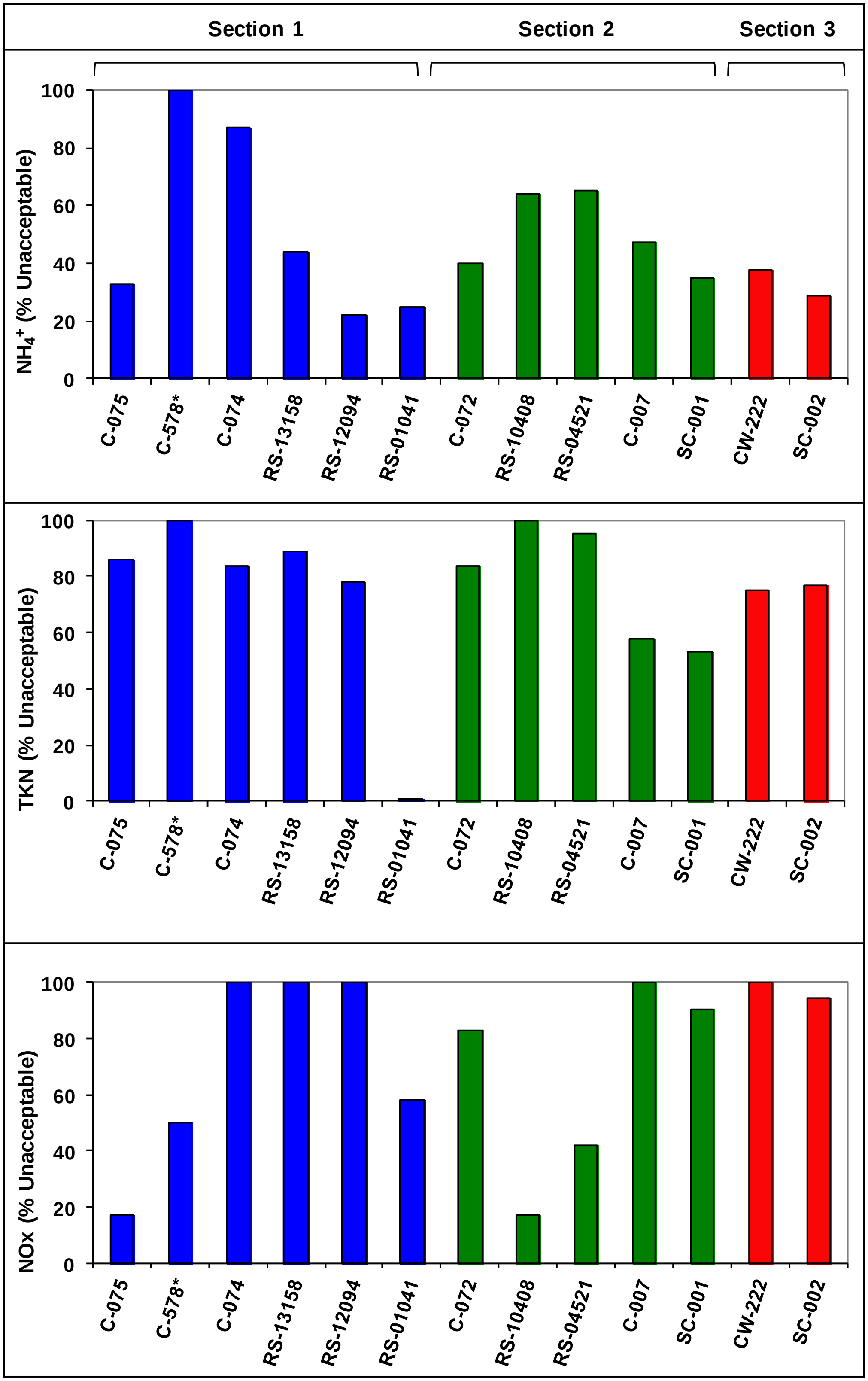


**Figure 29.** The percentage of unacceptable samples for TKN, $NH4^+$, and NOx, (upper, middle, and lower panel, respectively), arranged by watershed (section): Blue = Cedar Creek-Congaree River, Green = Toms Creek-Congaree River, Red = Lower Wateree River. For additional information see Appendix B.

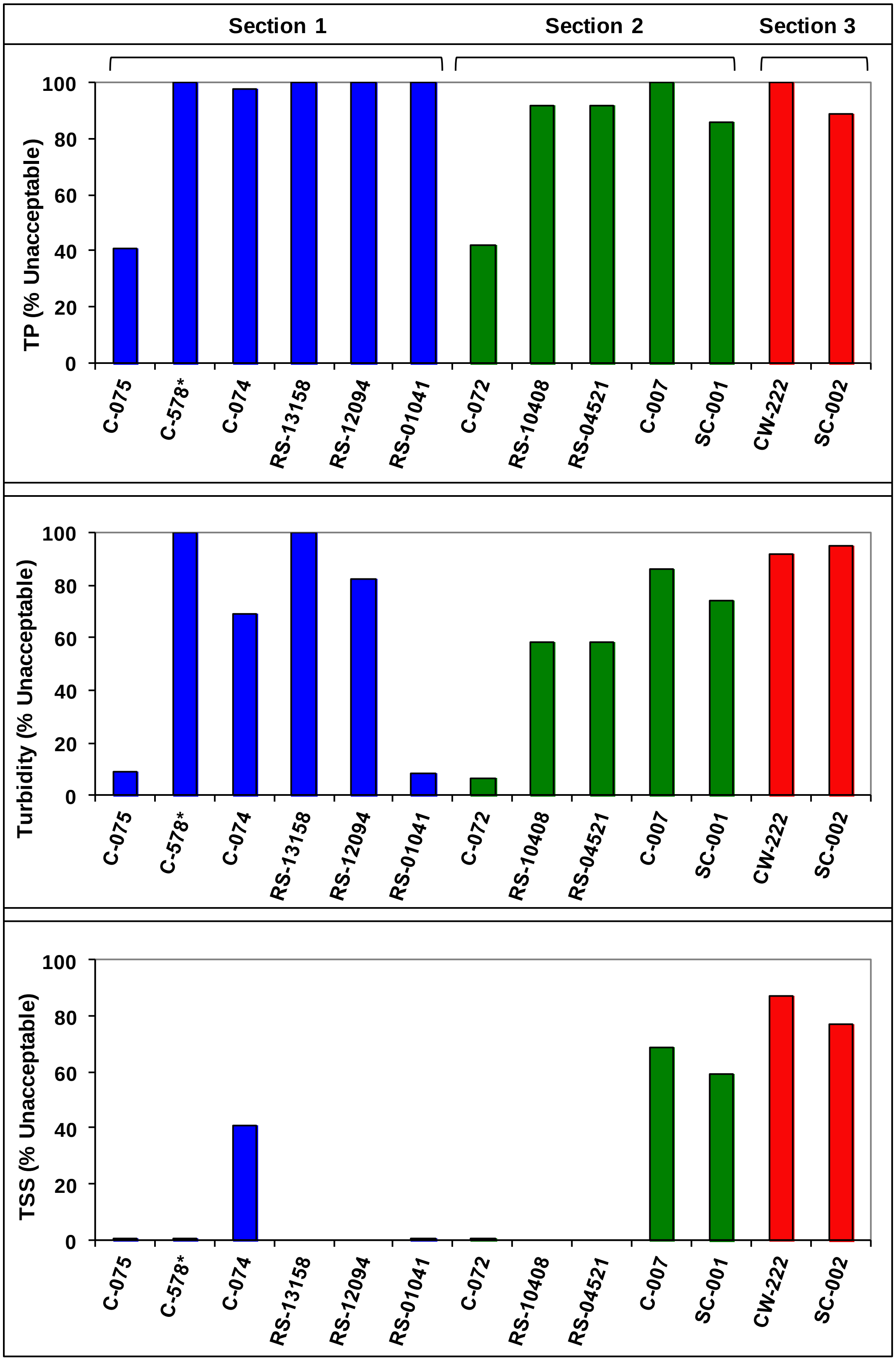


**Figure 30.** The percentage of unacceptable samples for TP, turbidity, and TSS (upper, middle and lower panel, respectively), arranged by watershed (section): Blue = Cedar Creek-Congaree River, Green = Toms Creek-Congaree River, Red = Lower Wateree River. For additional information see Appendix B.

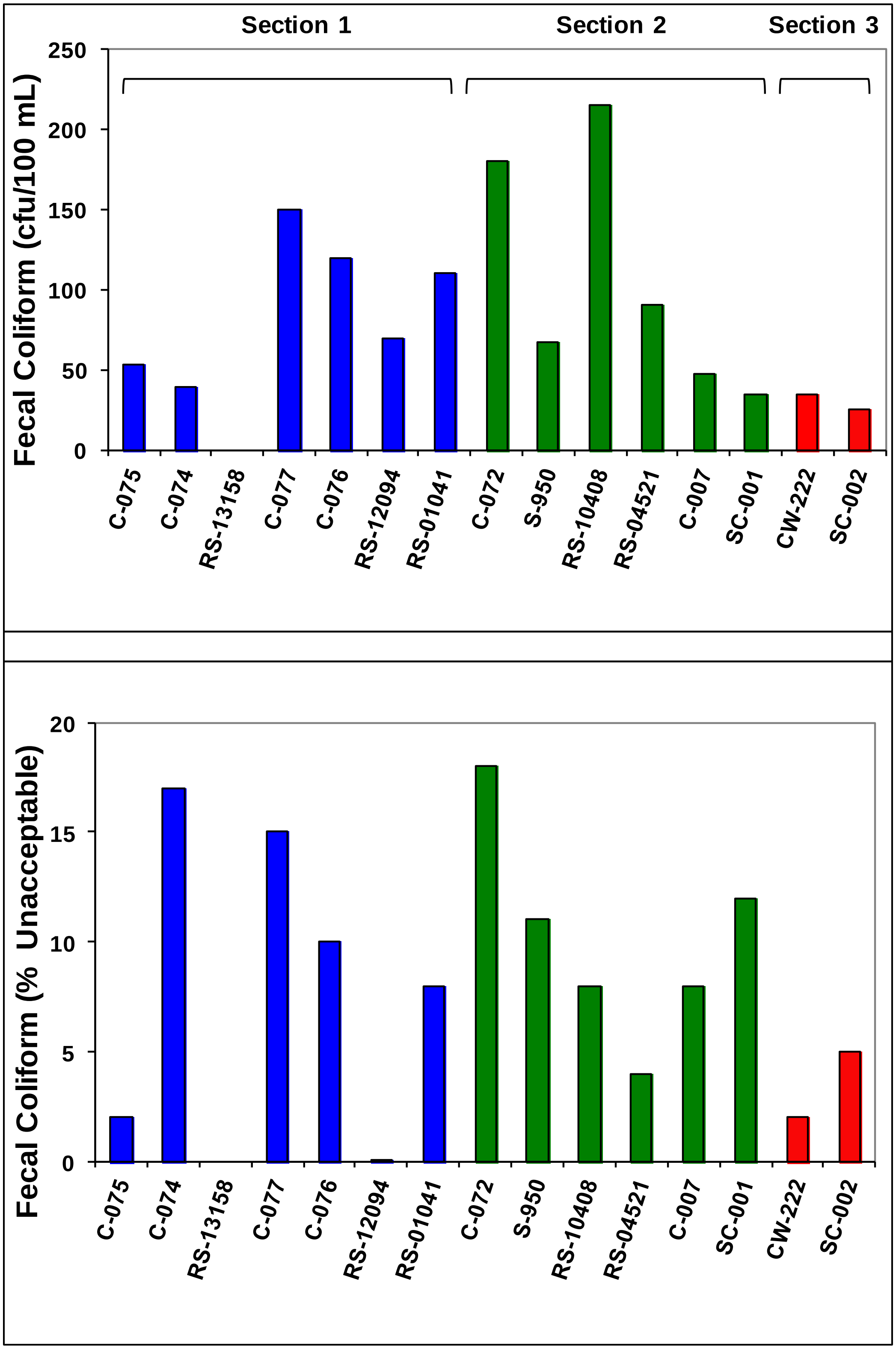


**Figure 31.** Median values and percentage of unacceptable samples for fecal coliform bacteria (median shown in upper panel and percentage unacceptable shown in lower panel) arranged by watershed (section) and site: Blue = Cedar Creek-Congaree River, Green = Toms Creek-Congaree River, Red = Lower Wateree River. For additional information see Appendix B.

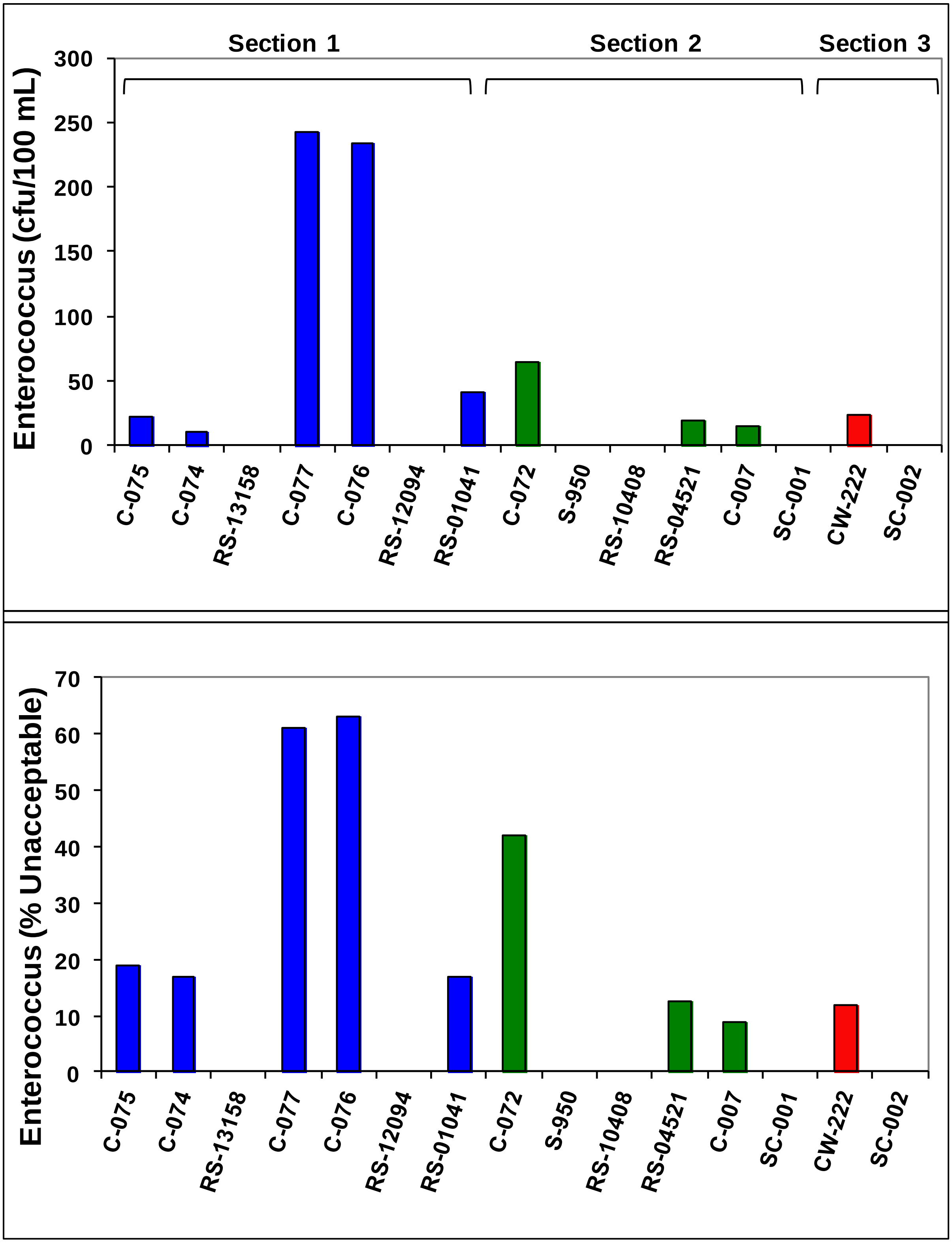


**Figure 32.** Median values and percentage of unacceptable samples for Enterococcus fecal bacteria, (median values shown in upper panel and percentage unacceptable shown in lower panel) arranged by watershed (section) and site: Blue = Cedar Creek-Congaree River, Green = Toms Creek-Congaree River, Red = Lower Wateree River. For additional information see Appendix B.

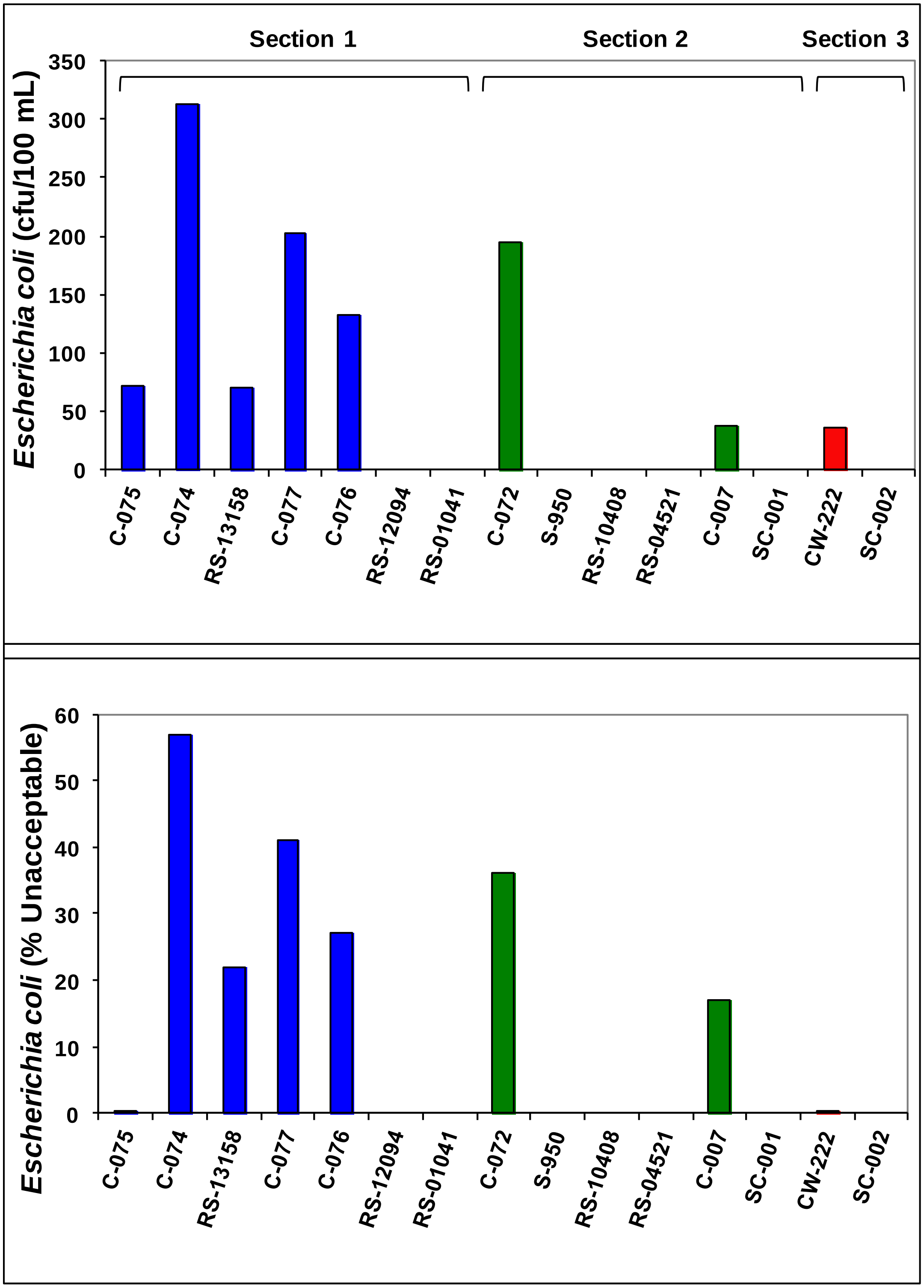


**Figure 33.** Median values and the percentage of unacceptable samples for *Escherichia coli* fecal bacteria, (median values shown in upper panel and percentage unacceptable shown in lower panel) arranged by watershed (section) and site: Blue = Cedar Creek-Congaree River, Green = Toms Creek-Congaree River, Red = Lower Wateree River. For additional information see Appendix B.

*Sources of Pollutants Linked to Water-quality Degradation*

Water quality is degraded by both point and nonpoint-source pollution. Urban development commonly causes undesirable habitat alteration, hydrologic modifications, erosion and sedimentation from land disturbance, stormwater runoff, combined sewer overflows, illegal discharges, improper storage and/or disposal of deleterious materials, and failure of sewerage systems (GA DNR 2008).

Regarding point sources, there are 19 active NPDES permits within 16 kilometers (10 mi) of Congaree National Park within the surrounding sub-watersheds (Table 34, Figure 23). Some of these permit holders have multiple pipes that discharge into receiving waters. There are also 12 CERCLA sites (Comprehensive Environmental Response, Compensation, and Liability Act, commonly known as Superfund) within 16 kilometers (10 mi) of the park within the surrounding sub-watersheds (Table 35, Figure 23).

Sewer overflows from municipalities and utilities are another pollution source. A query of SCDHEC Wastewater (Sewer) System Overflow database from October 2011 to October 2014 revealed 488 sewer overflows from 16 facilities in Richland County. The majority of overflows were from Columbia (421 of 488) were surcharge from either high water due to wet weather and broken lines or blockage from roots, grease, and other debris (SCDHEC 2017). The sewer systems have failed for years. Plans by Richland County to build a regional sewer system could resolve the problem but some Richland County residents have balked at the cost and tax increases, therefore the County Council has slowed the progress of the project. As development increases, pollutant loads to area streams are expected to become an increasing problem.

Regarding nonpoint sources of pollution, of concern are urban stormwater runoff, agricultural runoff, and effluent leachate from failing septic systems. The amount of impervious cover will increase with encroaching urbanization from the Columbia Metropolitan Area and represents a pervasive threat to water quality in the park. There are also ten industrialized agricultural livestock production facilities in the three sub-watersheds containing the park. Potential livestock waste runoff from dry litter poultry waste and manure from horse facilities negatively affect portions of the park with fecal microbial or nutrient pollution. Resulting threats to surface and groundwater quality include natural or anthropogenically caused hypoxia, excessive nutrient loading leading to eutrophic conditions, farm chemical runoff, pharmaceuticals flushed into the environment through sewer systems, and other toxic compounds (NPS 2004a; Mallin and McIver 2010).

**Table 34.** Active NPDES permits within 16 kilometer (10 mi) of CONG boundary. Note that some permitees have multiple pipes discharging wastes into streams (SCDHEC 2016).

| Name | NPDES ID | Facility Type | Hydrologic Unit Code 12 | Basin | Description |
|---|---|---|---|---|---|
| St. Matthews/South Plant | SC0028801 | municipal | 030501110103 | Santee | sewerage systems |
| Pinewood Site Custodial Trust | SC0042170 | industrial | 030501110109 | Santee | refuse systems |
| Town of Pinewood | SC0046868 | municipal | 030501110102 | Santee | sewerage systems |
| Cherokee, Inc./Belleville Mine | SCG731120 | industrial | 030501100403 | Saluda | miscellaneous non-metallic minerals |
| Devro, Inc./Coria Division | SC0033367 | industrial | 030501100310 | Saluda | sausages and other prepared meats |
| SCE&G/Wateree Station | SC0002038 | industrial | 030501040407 | Catawba | electric services |
| Westinghouse Elec., LLC/Columbia | SC0001848 | industrial | 030501100303 | Saluda | industrial inorganic chemicals, No exposure certification (NEC) |
| Richland Co./Eastover Reg. WWTP | SC0047911 | municipal | 030501040407 | Catawba | sewerage systems |
| Finnchem USA, Inc. | SC0047902 | industrial | 030501040407 | Catawba | industrial inorganic chemicals, NEC |
| Rich Dist 1/Gadsen Elementary | SC0031526 | domestic | 030501100310 | Saluda | elementary and secondary schools |
| S.C. Dept of Trans/I-26 Rest | SC0040339 | municipal | 030501100303 | Saluda | miscellaneous personal services, NEC |
| International Paper/Eastover | SC0038121 | industrial | 030501040407 | Catawba | paper mills |
| Eastman Chemical/S.C. Operations | SC0001333 | industrial | 030501100303 | Saluda | cyclic organic crudes and intermediates, and organic dyes and pigments |
| Rich Dist 1/ Hopkins Jr. High | SC0031500 | domestic | 030501100305 | Saluda | elementary and secondary schools |
| BIO Tech, Inc./Cayce Land Sludge | ND0069761 | domestic | 030501100303 | Saluda | combination utilities, NEC |
| Manchester Farms | ND0068969 | industrial | 030501100305 | Saluda | poultry and eggs, NEC |
| Rich Dist 1/Hopkins Elementary | SC0031496 | domestic | 030501100305 | Saluda | elementary and secondary schools |
| S.C. Air National Guard/McEntire | SC0000701 | industrial | 030501100306 | Saluda | national security |
| Cedar Creek MHP | SC0032018 | domestic | 030501100306 | Saluda | operators of residential mobile home sites |

**Table 35.** Superfund sites within 16 kilometer (10 mi) of CONG boundaries. Also known as Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) sites. RCRA—the federal Resource Conservation and Recovery Act of 1976.

| Site Name | EPA ID Number | Site Description |
|---|---|---|
| ESSEX Group, Inc–St. Matthews | SCD049122187 | Small quantity generator stored drums of solvents until shipment for recycling. |
| GSX Corp./SCA Chemical Services | SCD070375985 | Former RCRA permitted hazardous waste landfill. |
| Safety-Kleen | SCD987594165 | EPA Discovery– EPA cleanup. |
| Calhoun County Sanitary Landfill | SCD987566882 | A landfill receiving normal domestic and inert solid wastes and other waste with SCDHEC approval. |
| Millender Processing Co. | SCD052942091 | Meat packing plant with wastewater lagoon system. No hazardous materials handled by plant. |
| Carolina Eastman Co. | SCD069326007 | Inactive landfill with chemical process waste and large lagoons with toxic chemical wastes. |
| Westinghouse Electric/Columbia Plant | SCD047559331 | RCRA-permitted storage of drums. |
| USAF Shaw AFB Poinsett Range | SC9570090002 | Federal site currently being handled on federal level. (01/28/88). |
| SCR&D Bluff Road site | SCD000622787 | Drum storage facility where wastes were originally planned to be recycled. |
| Old Eastover Dump | SCS123456842 | Used as a municipal dump in the 1960s. Household & possible industrial waste deposited on-site. |
| Weeks Liquid Fertilizer, Inc. | SCD987580933 | Bankrupt facility used for blending fertilizer, herbicides, and pesticides. |
| Polymer Equipment site | SCD981030778 | Wastewater from a metal filter cleaning operation discharged into a septic system. |

*Groundwater*

Drinking water for the park is supplied by two on-site wells. The water is drawn at a depth of 36 meters (118 ft) and treated by chlorination. For waste treatment, the park uses septic systems (Mallin and McIver 2010); thus, septic leachate problems could be a factor in water quality in this watershed thus affecting the park.

Knowledge of groundwater supplies and quality is critically important to enable sound assessment of the status of water resources in most ecosystems:

> *Groundwater-level and groundwater-quality data are essential for water-observation wells and are the principal source of information about the hydrologic stresses on aquifers and how these stresses affect groundwater recharge, storage, and discharge. Long-term, systematic measurements of water levels provide essential data needed to evaluate changes in the resource over time; develop groundwater models and forecast trends; and design, implement, and monitor the effectiveness of groundwater management and protection programs (Taylor and Alley 2001). Groundwater-quality data are necessary to ensure that*

*public water supplies meet health standards; deterioration of groundwater quality may be virtually irreversible, and treatment of contaminated groundwater can be expensive (Alley, 1993 in USGS 2008).*

The regional geology controls the aquifer types present, and influences the natural quantity and quality of the groundwater. The Coastal Plain sediments in the southeastern portion of Richland County contain sand and clay formations of the Cretaceous and Tertiary ages overlying crystalline bedrock. The groundwater supply sources in this area are the Middendorf and Black Creek Formations. The park lies in the alluvial valleys of the Congaree and Wateree Rivers, specifically within the Tertiary Pliocene and the Quaternary Holocene valley alluvium and Pleistocene terraces. Generally, groundwater flows in the shallow Coastal Plain aquifers east toward the Wateree River and southwest to the Congaree River, and also southeast following the contour of the aquifer system (Newcome 2003). Crystalline bedrock lies 182.9–243.8 meters (600–800 ft) below the park (Mallin and McIver 2010). Well water in the Coastal Plain is acidic, low in mineral content, hardness and dissolved solids, and usually within the range of chemical quality of rainwater (Aucott 1996; Newcome 2003).

**Table 36.** USGS groundwater monitoring locations that have been monitored continuously. From Conrads et al. 2008, Rasmussen et al. (2009), and Wright (2012b).

| USGS well ID | Well name and characteristics (latitude, longitude, depth, elevation, beginning date, and number of observations) | Aquifer |
|---|---|---|
| 334930080514400 | RIC-341 (33.825278, -80.861944, 18.3 ft, 101.98 ft, 11/7/2003, continuous through 7/28/2005) | CONG floodplain-surficial |
| 334844080514200 | RIC-342 (33.8125, -80.861389, 28.0 ft, 105.09 ft, 11/8/2003, continuous through 9/28/2005) | CONG floodplain-surficial |
| 334950080491000 | RIC-345 (33.825278, -80.819167, 22.2 ft, 115.24 ft, 11/6/03, continuous through 9/2/2006) | CONG floodplain-surficial |
| 334859080493900 | RIC-346 (33.816639, -80.827222, 23.5 ft, 99.25, 10/29/2003, continuous through 10/4/2006) | CONG floodplain-surficial |
| 334613080470400 | RIC-699 (33.770556, -80.784722, 14.5 ft, 99.11 ft., 11/26/2003, continuous through 9/30/2005) | CONG floodplain-surficial |
| 334548080403100 | RIC-700 (33.763333, -80.675278, 13.0 ft, 86.37, 11/26/2003, continuous through 5/30/2005) | CONG floodplain-surficial |
| 334833080515800 | RIC-701 (33.809444, -80.866389, 14.8 ft, 107.65 ft, 10/29/2003, continuous through 10/15/2006) | CONG floodplain-surficial |
| 334852080471400 | RIC-702 (33.814722, -80.7875, 13.0 ft, 95.95 ft, 10/24/2003, continuous through 7/20/2005) | CONG floodplain-surficial |
| 334751080424200 | RIC-703 (33.797778, -80.711944, 12.0 ft, 88.65 ft, 12/10/2003, continuous through 7/25/2005) | CONG floodplain-surficial |

* observations that the USGS considers provisional

**Table 36 (continued).** USGS groundwater monitoring locations that have been monitored continuously. From Conrads et al. 2008, Rasmussen et al. (2009), and Wright (2012b).

| USGS well ID | Well name and characteristics (latitude, longitude, depth, elevation, beginning date, and number of observations) | Aquifer |
|---|---|---|
| 334616080470600 | RIC-704 (33.771111, -80.785, 14.0 ft, 99.63 ft, 11/26/2003, continuous through 8/25/2005) | CONG floodplain-surficial |
| 334741080465400 | RIC-705 (33.794722, -80.781667, 14.5 ft, 93.84 ft, 7/7/2003, continuous through 7/2/2007) | CONG floodplain-surficial |
| 340837081173800 | RIC-748 (34.124369, -81.29397, 250 ft, 367 ft, 1/17/2007, 57, 223*) | Piedmont and Blue Ridge |

* observations that the USGS considers provisional

The dynamics of Congaree River and floodplain inundation directly affect the groundwater in the park. Flooding replenishes sediments and nutrient maintaining the ecosystem (Conrads et al. 2008, Patterson et al. 1985). The sand, clay and peat sediments deposited in the Congaree National Park floodplain that form the shallow floodplain aquifers Black Creek and Middendorf within the park include intra-floodplain terraces, alluvial fans, rimswamps, dune fields, and meanderbelts of the post-late Pleistocene age (Shelley 2007a). The Black Creek aquifer underlies the shallow floodplain aquifer, and movement of groundwater between the two may be limited because of clay deposits within the shallow floodplain aquifer. The Middendorf aquifer underlies the entire Black Creek aquifer and the park floodplain (Figure 34; Aucott et al 1987).

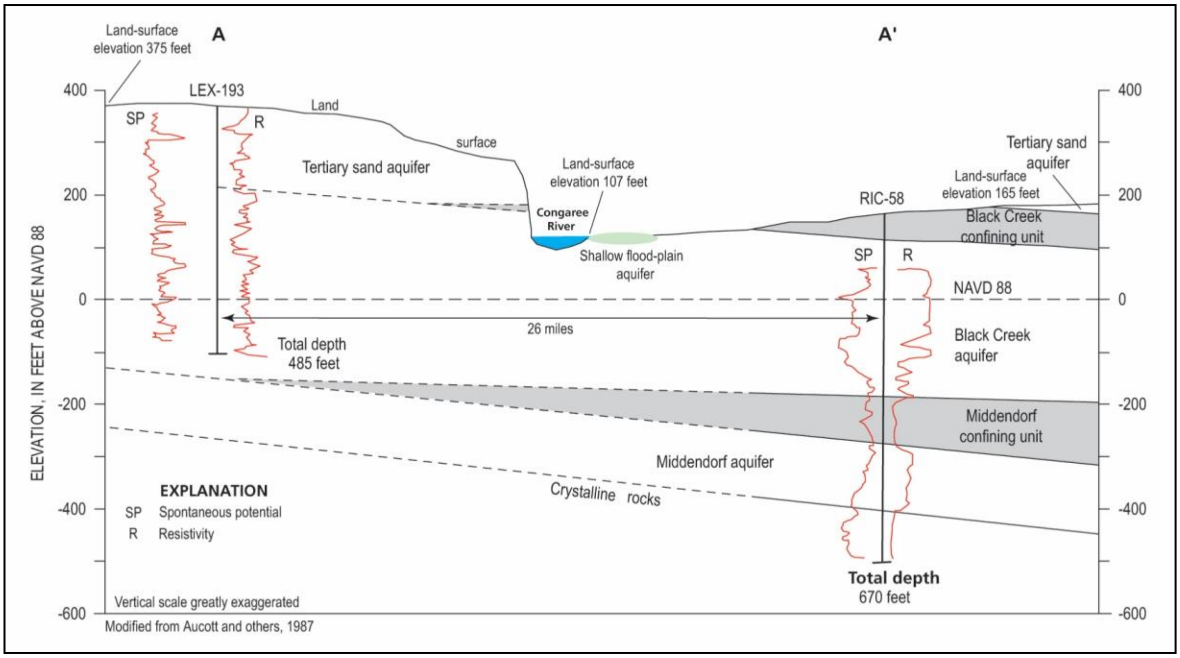


**Figure 34.** Cross-section diagram illustrating the hydrogeologic section through CONG from well LEX 193 to well RIC-58. From Conrads et al. (2008), modified from Aucott et al. (1987).

In swamps and floodplains adjacent to rivers, groundwater and surface waters are more closely interrelated. Surface waters dominate groundwater movement. The local flow system in the park floodplain is characterized by shallow, short flow paths from recharge to discharge areas and interaction with rivers and surface waters (Conrads et al. 2008 and references therein). Conrads et al. (2008) found that operation of the Saluda Dam had more influence on raising low and median groundwater elevations than lowering high groundwater elevation. They also noted that surficial groundwater elevations were higher and the interannual range in surficial groundwater elevations had decreased. Surficial groundwater elevations were lower especially in the first half of the year, and higher in the second half of the year. A decrease in the range of groundwater elevations may affect the root zone and vegetative community structure (Conrads et al. 2008). Minchin and Sharitz (2007) hypothesized that trends toward less flood-tolerant tree species in the park may be due to long-term climate change as evident in decreased annual rainfall.

Information and data are lacking relating to groundwater monitoring and characterization in the deep aquifers that underlie the park (Rasmussen et al. 2009). Conrads et al. 2008 conducted a U.S. Geological Survey groundwater network study consisting of eleven observation wells with continuous water-level recorders in efforts to determine the effects of the Saluda Dam on surface water and groundwater levels (Table 36). Wright (2012b) listed USGS well 340837081173800 (RIC 748) in the Piedmont and Blue Ridge crystalline-rock aquifer northwest of Columbia as a relevant well. Water level trend analysis indicates a significant declining trend in groundwater levels over the period of record 17 January 2008–24 December 2011, weekly sampling ($p < 0.01$; Wright 2012b). Groundwater quality is not monitored at this well or at any well in the park. Congaree National Park is underlain by the Southeastern Coastal Plain Aquifer System. In the Wateree River sub-basin groundwater use is limited; therefore, SCDNR has stated that there are no groundwater-level problems associated with withdrawal (Newcome 2003; SCDNR 2009).

<u>Biological Resources and Management</u>

Information regarding species richness and biodiversity, based on data gathered 15 years ago, was that the state ranked 14th in overall biological diversity (3,286 species) and 24th in the number of endemic species (eight species) (Stein et al. 2000). It also ranked 7th among the states in amphibian diversity (67 species), 24th in freshwater fish diversity (122 species), 11th in reptile diversity (73 species), 14th in vascular plant diversity (2,543 species), 22nd in bird diversity (312 species), and 16th in mammal diversity (96 species). In marked contrast, however, the state also ranked 15th in the number of imperiled species (293 species), and 18th in the number of known or suspected extinctions (five species), due in part to the spread of non-native species (Stein et al. 2000).

*Attributes Used in Assessment*

The NPS Omnibus Management Act of 1998, and other reinforcing policies and regulations, require park managers "to establish baseline information and to provide information on the long-term trends in the condition of National Park System resources" (Title II, Sec. 204). A first step toward meeting that mandate is to inventory the species diversity of park biota. Understanding changes in species distributions is integral to informed management of species and their habitats—changes in species distributions over time provide valuable insights at local and landscape scales about how species respond to influences such as changing land use, climate, hydrology, or habitat quality/availability. Climate change, for example, influences the distribution, phenology, population demographics, and abundance of individual species. In turn, the cascading effects through altered species interactions and altered food web structure can affect ecosystem processes (Montoya and Raffaelli 2010). It is also valuable to assess the number of species (species richness) and their relative abundance (species evenness or dominance) within a given community. These two components describe the species diversity, often communicated as various diversity indices.

Diversity, defined as “the variety and abundance of species in a defined unit of study” (Magurran 2004), is a community property that is broadly related to trophic structure, productivity, stability (McIntosh 1967; McNaughton 1977), immigration/emigration (Colwell and Lees 2000), and ecological condition (i.e., ecological integrity as defined by Karr and Chu 1995). Diversity indices respond differently to various mechanisms that influence community structure, so the National Park Service uses a suite of alpha diversity indices (the diversity of species within a defined area, community or ecosystem; Whittaker 1972) in order to fully characterize diversity in SECN parks (Haedrick 1975, Boyle et al. 1984 in Byrne et al. 2011b).

*Biota Assessment*

At present the biota at Congaree National Park are mostly known through species lists, and ecological studies available either historically or recently. The Southeast Coast Network has begun to characterize the amphibians and birds of the park. The NPS Inventory Project for Congaree National Park has data and information from 1996–2001 published online at https://science.nature.nps.gov/im/inventory/veg/project.cfm?ReferenceCode=1047700.

The species lists suggest a rich diversity of flora and birds at the park. A total of 1,220 taxa have been found in Congaree National Park (Appendix C), including 377 fauna (33 amphibians, 45 reptiles, 71 fish, 191 birds, and 37 mammals) and 843 taxa of vascular flora (328 terrestrial plants [325 species], 512 wetland plants [495 species] and three aquatic plants). In addition, 302 macroinvertebrate taxa have been found in the floodplain streams and two lakes in the park (Pescador et al. 2004). At least three mammalian species (red wolf [*Canus rufus*], American black bear [*Ursus americanus*], and mountain lion [*Puma concolor*]) have been extirpated from the region. At present, 38 taxa (one amphibian, one reptile, five mammals, eleven birds, seven terrestrial plants, and thirteen wetland/aquatic plants) occur as species of concern (SoCs) and an additional taxon (one fish species; the American eel) is an at-risk species in the park (Appendix C). A partial list of invertebrates is also available for the park, including at least twelve species of molluscs and crustaceans, 21 species of mosquitoes, and 154 species of beetles within the park (Appendix C).

The park is heavily impacted by exotic/invasive taxa, which represent 61 species (5%) of the total flora. They include 29 species (11.7%) of terrestrial plants and 18 (4.5%) of the wetland plants (Appendix C). Exotic fauna in the park also include one fish, two birds, and four mammals on the NPS Certified Species List (2013a), one mollusc species, and also of note, one exotic insect—the tiger mosquito (*Aedes albopictus*).

*Vascular Flora*

> *Vegetation communities provide many ecosystem services. Among their many functions, they are an important component of food webs and wildlife habitat for many species, and serve as a carbon sink, produce oxygen, cycle nutrients and energy through an ecosystem, influence the local climate, improve water quality, and moderate flooding and erosion. Plant communities also respond to multiple stressors such as changes in air quality, hydrology, disturbance regimes, and climate. Determining trends in vegetation communities is vital to understanding the ecological processes occurring at a site, and identifying stressors and their impacts.*

—*Byrne et al. (2012)*

The primary drivers to vegetation community changes in many southeastern national parks are fire, weather, and the anthropogenic influences on fire suppression, landscape fragmentation, altered hydrology, and nonnative species introduction.

*Historic Vascular Flora (1996 USGS-NPS Survey)*

Major plant communities in the park include bald cypress (*Taxodium distichum*) and water/swamp tupelo (*Nyssa aquatica/biflora*) dominated communities to loblolly pine and longleaf pine (*Pinus taeda* and *P. palustris*) communities and old pine plantations. Within these communities, sugarberry (*Celtis laevigata*), sweetgum (*Liquidambar styraciflua*) and laurel oak (*Quercus laurifolia*) frequently occur (Byrne et al. 2012, NPS 2013a).

Vegetation sampling and classification of 128 plots were conducted by the USGS-NPS Biological Resources Division Vegetation Mapping Program at the park during July through September 1996. The goal of the project was to classify and describe all plant communities in the park. The park was divided into six zones by drainage, and each vegetation type was sampled in each zone. As a result, 22 distinct assemblages were defined including 20 forests, one woodland, and one shrubland. Twelve plant associations were newly described, along with one upland successional forest. Classifications are listed below (Landaal et al. 1998).

- *Quercus michauxii* / *Carpinus caroliniana-Ilex opaca* / *Leucothoe racemosa* forest (swamp chestnut oak / American hornbean-American holly / swamp doghobble forest)
- *Taxodium distichum-Nyssa aquatica* / *Fraxinus caroliniana* forest (bald cypress-water tupelo forest)
- *Fraxinus pennsylvanica* / *Leersia lenticularis-Carex lupulina* forest (green ash / catchfly grass-hop sedge forest)
- *Celtis laevigata-Liquidambar styraciflua-Quercus laurifolia* / *Carpinus caroliniana* / *Arundinaria gigantea* / *Carex lupulina* forest (sugarberry-sweetgum-laurel oak / American hornbean / cane / hop sedge forest-sweetgum component)
- *Liquidambar styraciflua-Quercus nigra-Quercus laurifolia* / *Arundinaria gigantea* / *Carex abscondita* forest (sweetgum-water oak-laurel oak / cane / thicket sedge forest)

- *Taxodium distichum-Fraxinus pennsylvanica-Quercus laurifolia* / *Acer rubrum* / *Saururus cernuus* forest (bald cypress-green ash-laurel oak / red maple / lizard's tail forest)
- *Vitis rotundifolia-Ampelopsis arborea-Campsis radicans* vine-shrubland (muscadine grape-peppervine-trumpet creeper vine-shrubland)
- Successional pine-mixed hardwood upland forest
- *Nyssa biflora-Acer rubrum* / *Ilex opaca* / *Leucothoe axillaris* / *Carex atlantica* ssp. *capillacea* forest (swamp tupelo)-red maple / American holly / coastal doghobble / prickly bog sedge forest)
- *Celtis laevigata-Fraxinus pennsylvanica-Acer negundo*-(*Juglans nigra*) / *Asimina triloba* / *Carex grayi* forest (sugarberry-green ash-box elder-(black walnut) / pawpaw / Gray's sedge forest)
- *Taxodium distichum-Nyssa aquatica* / *Nyssa biflora* / *Fraxinus caroliniana* / *Itea virginica* forest (bald cypress-water tupelo / swamp tupelo / Carolina ash / Virginia sweetspire forest)
- *Fagus grandifolia-Quercus nigra* forest (American beech-water oak forest)
- *Pinus palustris-Pinus taeda* / *Schizachyrium scoparium* woodland (longleaf pine-loblolly pine / little bluestem woodland)
- *Liquidambar styraciflua-Quercus* (*nigra, phellos*)-*Pinus taeda* / *Vaccinium elliottii-Morella [Myrica] cerifera* forest (sweetgum–oak (water, willow)-loblolly pine / Elliott's blueberry-wax myrtle forest)
- *Quercus phellos* / *Carex* (*intumescens, joorii*)-*Chasmanthium sessiliflorum* / *Sphagnum lescurii* forest (willow oak / sedge (greater bladder, cypress swamp)-longleaf spikegrass / lescur's sphagnum [moss] forest)
- *Platanus occidentalis-Celtis laevigata-Fraxinus pennsylvanica* / *Lindera benzoin-Ilex decidua* / *Carex retroflexa* forest (American sycamore-sugar berry-green ash / northern spicebush-possumhaw / reflexed sedge forest)
- *Planera aquatica* forest (water elm forest)
- *Salix nigra-Fraxinus pennsylvanica* forest (black willow-green ash forest)
- *Populus deltoides* / *Acer negundo* / *Boehmeria cylindrica* forest (cottonwood / box elder / small-spike false nettle forest)
- *Liquidambar styraciflua-Quercus laurifolia* / *Magnolia virginiana* / *Carex folliculata* forest (sweetgum-laurel oak / sweetbay / northern long sedge [not in NPS Certified Species List 2013 for Congaree National Park] forest)
- *Acer saccharinum* / *Leersia lenticularis-Commelina virginica* forest (silver maple / catchfly grass-Virginia dayflower forest)
- *Quercus lyrata-Quercus laurifolia* / (*Arundinaria gigantean*) forest (silver maple / catchfly grass-Virginia dayflower forest)

The most detailed survey of terrestrial vascular plant species was taken 14 years ago by Gaddy et al. (2000). Over 500 species were found, including 80 native species of trees, 26 species of climbing woody vines, and 47 species of the sedge genus *Carex*. This inventory also identified ten basic types of vegetation cover: 1) upland pine; 2) upland pine-mixed hardwood; 3) upland mixed hardwood depressions; 4) bluff mixed hardwoods; 5) mixed bottomland hardwoods; 6) pine-mixed bottomland hardwoods; 7) swamp tupelo; 8) bald cypress-water tupelo; 9) open water/flowing water; and 10) open fields/disturbed areas. Gaddy et al. described the park vegetative communities as "extremely complex and diverse" and recognized Congaree National Park as having one of the most diverse forest communities in North America.

The Southeast Coast Network I&M Program continues to monitor vegetation. As mentioned, the NPS Certified Species List for the park (NPS 2013a, as modified in Appendix C) contains 843 vascular plant taxa, including 328 terrestrial and 515 wetland/aquatic taxa. Determination of terrestrial versus wetland status was made following Godfrey and Wooten (1981a,b), the PLANTS Database (also called the National Plants Database) of the USDA Natural Resources Conservation Service (USDA-NRCS 2017a) and The National Wetland Plant List (Lichvar 2013; USACE 2017).

Congaree National Park is also home to state champion big trees (Clemson 2017). Big trees provide insights about old-growth ecosystems and opportunities to further scientific understanding of these ecosystems. A survey of the distribution and status of champion trees was being conducted in 2013. The last survey was by Jones (1996, 1997) and established that five known National Champions and twenty-seven State Champion trees occur in the park. American Forests' National Register of Big Trees includes the loblolly pine (*Pinus taeda*), swamp tupelo (*Nyssa aquatica*), laurel oak (*Quercus laurifolia*), possumhaw (*Ilex decidua*), and sweetgum (*Liquidambar styraciflua*) (American Forests 2017). Jones (1997) noted that "Big trees serve as indicators of optimum ecological conditions for a species, and can help in discerning disturbance history and patterns of succession [and give] insights into the autecology of individual species and the history of the park's forests." Objectives of the in-progress survey are to confirm the status of already documented trees, to update and expand champion tree records, and to recover data and samples from recently downed champion-sized trees that preserved a unique record of climate and environmental changes.

*Vegetation Community Monitoring in 2010*

During 12 June to 3 July 2010, the Southeast Coast Network I&M Program initiated data collection on vegetation communities as part of its vital signs monitoring program. This survey marked the beginning of a long-term effort to track changes in the park vegetation communities over time. The long-term goal is to determine trends in plant species frequency, percent cover, diversity, and distribution in the canopy, shrub, and groundcover strata.

Within each of these strata, vegetation communities were sampled using a hybrid of techniques from the North Carolina Vegetation Survey nested-subplot design (Peet et al. 1998) within a circular plot similar to the Forest Inventory and Analysis Protocol of Bechtold and Patterson (2005). Data were collected at 30 spatially-balanced, random locations in the park (Figure 35). The areas of the park that were sampled within the park boundaries conformed with safety guidelines; in addition, sites could not be located in entirely non-natural areas, open water, or areas such as marshes where application of the methods would be inappropriate.

The initial monitoring effort detected six new taxa (species, subspecies, or varieties), of which five actually were newly reported for the park; the sixth, *Conyza canadensis* (var. *canadensis*), was already included in the NPS Certified Species List (NPS 2013a) as the synonym, *Erigeron canadensis* (see Appendix C). The five newly reported taxa included three from terrestrial habitats (Elliott's milkpea [*Galactia elliottii*]; bahiagrass [*Paspalum notatum*], which can be both native and exotic/invasive—Byrne et al. (2012) described it as native in Congaree National Park; American black nightshade [*Solanum americanum*]; and two wetland species (bushy bluestem [*Andropogon glomeratus*] and manyflower marshpennywort [*Hydrocotyle umbellata*]. We added the five species to the NPS Certified Species List detailed in Appendix C (NPS 2013a). Absolute canopy cover across the park was 83%. Water tupelo (*Nyssa aquatica*) had the largest average diameter at breast height of any canopy species, and box elder (*Acer negundo*) had the highest frequency of seedling occurrence. In the shrub stratum, pawpaw (*Asimina triloba*) was the most frequently occurring species and had the highest absolute and relative cover. In the groundcover stratum, *Smilax* spp. and poison ivy (*Toxicodendron radicans*) were the most frequently occurring species. Giant cane (*Arundinaria gigantea* ssp. *gigantea*) had the highest absolute and relative cover.

*Exotic plant management*

Park staff currently manage exotic plant infestations that threaten natural resources. The primary means of controlling invasive plants is through the Southeast Coast Exotic Plant Management Team (SEC-EPMT), based at Congaree National Park, which serves fifteen national park units across the Southeast region. Exotic plants are found throughout the floodplain as well as in the upland. Species being inventoried and treated include Chinese wisteria (*Wisteria sinensis*), Chinese privet (*Ligustrum sinense*), Japanese climbing fern (*Lygodium japonicum*), beefsteak (*Perilla frutescens*), shrub lespedeza (*Lespedeza bicolor*), Japanese stiltgrass (*Microstegium vimineum*), Chinaberry (*Melia azedarach*), Japanese honeysuckle (*Lonicera japonica*), and kudzu (*Pueraria montana*). In addition, there is an ongoing effort to remove the native invasive sweetgum (*Liquidambar styraciflua*) to restore longleaf pine habitat in the upland. More information on goals and objectives for invasive plant management is outlined in the Foundation Document (NPS 2014a) and Strategic Plan for the park. The major goal for the park regarding invasive plants is to continue to treat high-priority infestations until they are brought under control and reduced to maintenance level. More detailed mapping of invasive plant populations is a future goal. Early detection rapid response to new invasions is recognized as important (personal communication, L. Serra, SEC-EPMT Liaison, Congaree National Park).

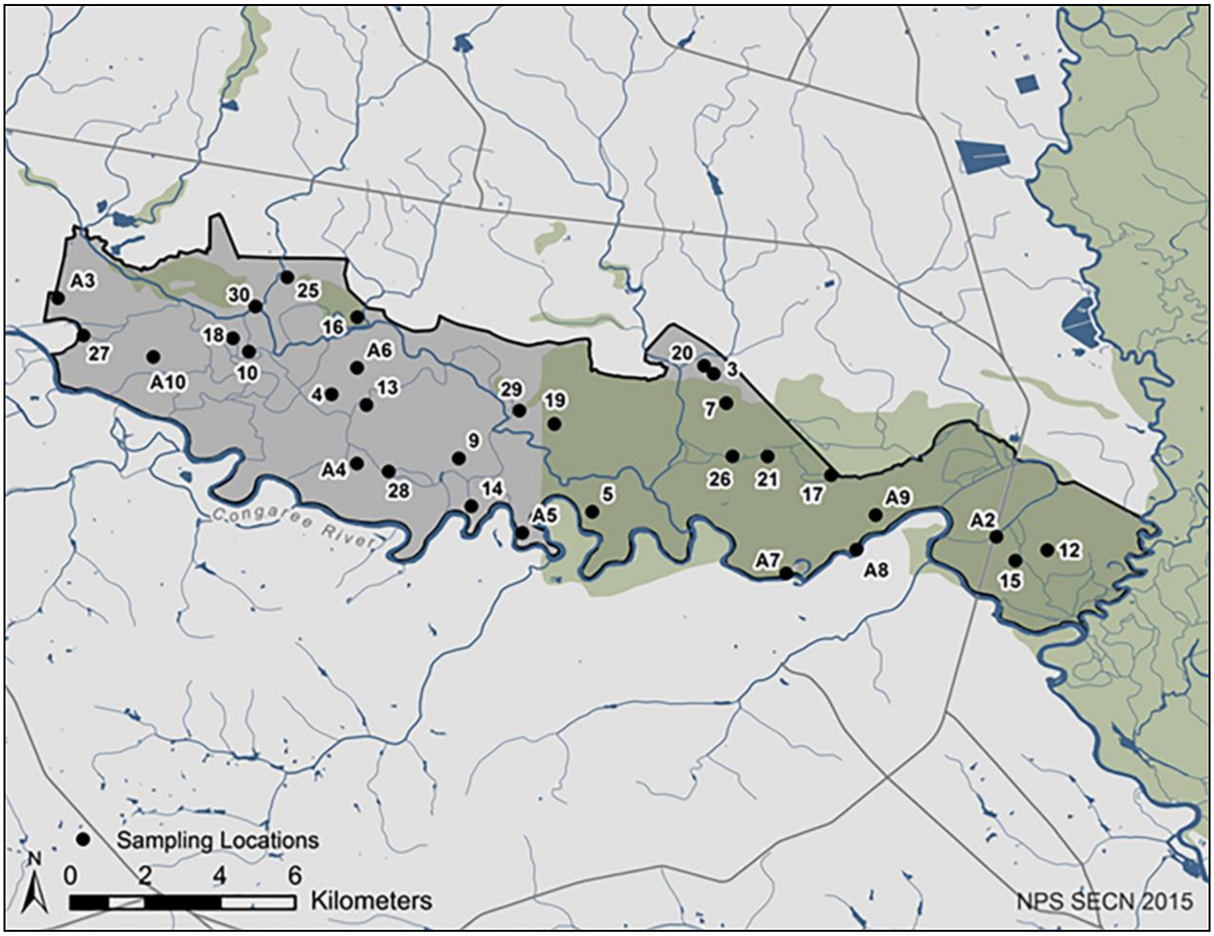


**Figure 35.** Map showing the spatially-balanced random sampling locations for vascular plant communities at CONG, in the NPS 2010 survey. From Byrne et al. (2012).

*Restoration of Upland Longleaf Pine Plantation*

The plantation pine forest type located on the low northern bluffs contains loblolly pines established by former landowners and acquired as part of the park boundary expansion in 1988. The southern pine forest type also located in low northern bluffs but extending into the floodplain consists of large loblolly and longleaf pine (*Pinus palustris*) with mixed hardwood and pine understory (NPS 2004b). Longleaf pine forests are highly diverse, valued ecosystems which sometimes contain more than 3,400 species per hectare (0.34 species per square meter, or 3.7 species per $ft^2$). These fire-dependent, open-canopy ecosystems once dominated much of the southeastern U.S. Coastal Plain, including Congaree National Park. Historically, lightning caused wildland fires creating wildlife dependence on the resulting habitat and vegetation structure (NPS 2004b). Fire suppression has since altered successional processes in the park, and forestry practices have led to species-poor pine plantations in some areas (DeVivo et al. 2008). Continued fire suppression also has resulted in takeover of these systems by woody broadleaf vegetation such as sweetgum, oaks (*Quercus* spp.), hickories (*Carya* spp.), common persimmon (*Diospyros virginiana*) and southern magnolia (*Magnolia grandiflora*; USDA 2002 and references therein). These hardwoods close the canopy and decrease light available for shade-intolerant longleaf pines to regenerate. In what becomes a “positive feedback loop,” this woody vegetation also decreases the system flammability, making fires less likely to occur (Ford et al. 2010).

Congaree NP has actively engaged in long-term efforts to restore the historic landscape and vegetation by planned fire treatments. A longleaf pine restoration plan is being created and this need has been identified in the upcoming strategic plan for the park. The park has received an impact grant for thinning around existing longleaf pines. Thinning is intended to restore the habitat to a more natural state and expand the longleaf pine distribution within the park. Selective thinning and prescribed fire are returning the pine stands to a more natural state of uneven age and appropriate spacing (personal communication, S. Kidd, Acting Chief, Integrated Resource Management, and T. Yednock, formerly of Congaree National Park, personal communication).

##### *Prescribed Fires and Wildfires*

Under the fire management plan (NPS 2004b), park staff combine management of wildfires, use of prescribed fire, mechanical, and/or chemical treatment toward the overall goal of restoring historic fire regimes and reducing hazardous fuels. Unplanned fire is a concern at the park because the vegetation is seasonally susceptible to fire, mainly during summer months due to lightning ignition (NPS 2004b).

Prescribed burns can be applied to the entire park site under the Congaree National Park Fire Management Plan (NPS 2004b), and fire is being used to help restore both upland pine communities and lowland longleaf pine savannah wetland habitat by maintaining an open habitat. Burning by hand, or prescribed fires, are applied to eradicate undesirable vegetation that competes with native longleaf pine communities. Fire also initiates nutrient recycling for healthy soil conditions and promotes control of exotic vegetation (NPS 2004b).

The Congaree NP fire management plan combines management of wildfires, use of prescribed fire, mechanical, and/or chemical treatment toward the overall goal of restoring historic fire regimes and reducing hazardous fuels. In the 2004 Fire Management Plan, the park was subdivided into four fire management units (FMUs). Once management objectives are attained for a given prescribed FMU, the park will implement a maintenance program for the FMU with a prescribed fire return interval of 3–5 years (NPS 2004b).

#### *Aquatic Macroinvertebrate Insects*

Several macroinvertebrate studies have been completed in Congaree National Park including Smock and Gilinsky (1982), Smock et al. (1985), Maluk and Abrahamsen (1999) and Pescador et al. (2004). The most recent study, Pescador et al. (2004), sampled ten sites; eight located in floodplain streams and two located in lakes. The study focused on five insect groups: Coleoptera (beetles), Odonata (dragonflies), Ephemeroptera (mayflies), Plecoptera (stoneflies) and Trichoptera (caddisflies). The surveys were conducted from 2002–2003. A total of 302 species representing 152 genera in 47 families were found (Table 37). The most diverse group was aquatic beetles, accounting for 50% of the species, while mayfly and stonefly taxa had a low diversity in the park. The total number of species by site is given in Table 38; the complete species list (from Pescador et al. 2004) is provided in Appendix C.

**Table 37.** Taxonomic richness by family, genus, and species for five insect orders found in CONG, 2002–2003. Modified from Pescador et al. (2004), as described in Mallin and McIver (2010).

| Order | Common names | Families | Genera | Species |
|---|---|---|---|---|
| Coleoptera | beetles | 16 | 65 | 153 |
| Trichoptera | caddisflies | 13 | 30 | 67 |
| Odonata | dragon & damselflies | 6 | 34 | 55 |
| Ephemeroptera | mayflies | 8 | 15 | 19 |
| Plecoptera | stoneflies | 4 | 7 | 8 |

Although Pescador et al. (2004) found relatively diverse macroinvertebrate species richness, in the 2012 303(d) list of impaired Streams (SCDHEC 2012b), site RS-04521 (Buckhead Creek, Calhoun County, outside the park) was listed as not supporting the aquatic life use classification, based on assessment of the macroinvertebrate community.

**Table 38.** Benthic macroinvertebrate species richness by location. From Pescador et al. (2004).

| Site | Total Species |
|---|---|
| Cedar Creek at Bluff Rd. below bridge | 141 |
| Weston Lake | 129 |
| Cedar Creek at Dawson Lodge | 123 |
| Toms Creek | 98 |
| Cedar Creek at Service Rd. | 83 |
| Cedar Creek at Bluff Rd. above bridge | 75 |
| McKenzie Creek | 73 |
| Cedar Creek at jeep trail | 67 |
| Wises Lake | 49 |

*Fish*

Historically, fish species were surveyed in the park by the U.S. Geological Survey in 1995–1998 and South Carolina Department of Natural Resources in cooperation with the National Park Service from 1999–2002 (Maluk and Abrahamsen 1999; Rose 2002; Rose and Bulak 2004 as referenced in Mallin and McIver 2010). The overall index of biotic integrity rated upper Cedar Creek as fair, and lower Cedar Creek, Myers Creek, Toms Creek, and the Congaree River as poor (Maluk and Abrahamsen 1999).

Alternatively, the South Carolina DNR study surveyed streams, guts, sloughs, ponds and Lakes Weston and Wise in the park, and cluster analysis grouped the data into four distinct fish communities based on habitat conditions. Group 1 sites, with relatively low flows and dissolved oxygen consisted of flier (*Centrarchus macropterus*), eastern mudminnow (*Umbra pygmaea*), golden shiner (*Notemigonus crysoleucas*), and banded pygmy sunfish (*Elassoma zonatum*). Group 2 sites consisting of faster flowing, deeper streams included the tessellated darter (*Etheostoma olmstedi*), largemouth bass (*Micropterus salmoides*), and redear sunfish (*Lepomis microlophus*). Group 3 sites were characterized by the high flow and firm, sandy bottoms, between bluff and swamp areas and included the sailfin shiner (*Pteronotropis hypselopterus*), dusky shiner (*Notropis cummingsae*), spotted sunfish (*Lepomis punctatus*), and the dollar sunfish (*Lepomis marginatus*). The only Group 4 site, McKenzie Creek, was suggested to be a degraded stream warranting further study included only four species: yellow bullhead (*Ameiurus natalis*), largemouth bass (*Micropterus salmoides*), pirate perch (*Aphredoderus sayanus*) and mosquitofish (*Gambusia holbrooki*; Mallin and McIver 2010).

A total of 71 fish species were reported in Congaree NP in the NPSpecies List (NPS 2013a; Appendix C). No exotic species were included. One SoC was reported to occur in the park (NPS 2013a)—the American eel (*Anguilla rostrata*), which is being considered for federal listing.

> *Herpetofauna*
> *Amphibian communities in the southeastern U.S. are widely considered to be among the most diverse in the world, and they are a valued resource in Southeast Coast Network parks….Several factors are attributable to [amphibian] population declines and localized extinctions…[including] disease and anthropogenic stressors such as habitat loss and degradation, non-native predators, acid precipitation, altered hydrology and hydroperiod, ultraviolet radiation, and chemical contaminants (Collins and Storfer 2003)….Given their habitat requirements, anatomy, and physiology, amphibians are considered good indicators of ecological condition...[and] amphibian communities are a priority for SECN monitoring efforts.*
>
> *—Byrne et al. (2011a)*

Amphibian communities in the southeastern U.S. are widely considered to be among the most diverse in the world, and they are a valued resource in SECN parks (Byrne and Moore 2011). South Carolina presently has 142 amphibian and reptilian taxa (SCDNR 2005). The high diversity is attributed to the extensive habitat diversity and the mild, moderate climate (Tuberville et al. 2005).

In 2001–2003, Tuberville et al. (2005) conducted a survey of herpetofauna for Congaree National Park and found 29 amphibian and 32 reptilian taxa in the park. That survey is the basis for the herpetofauna included in the NPS Certified Species List (2013a). Reptiles are represented by nineteen species of snakes (two venomous, the cottonmouth [*Agkistrodon piscivorus*], and the copperhead [*A. contortrix*]), seven species of turtles, and five species of lizards. Amphibians consist of twenty-one species of frogs and toads and eight species of salamanders. None of these species are introduced or exotic. Tuberville et al. (2005) noted that the park contains an unusually rich assemblage of amphibians and reptiles (Figure 36), due in part to the high diversity of freshwater habitat types.

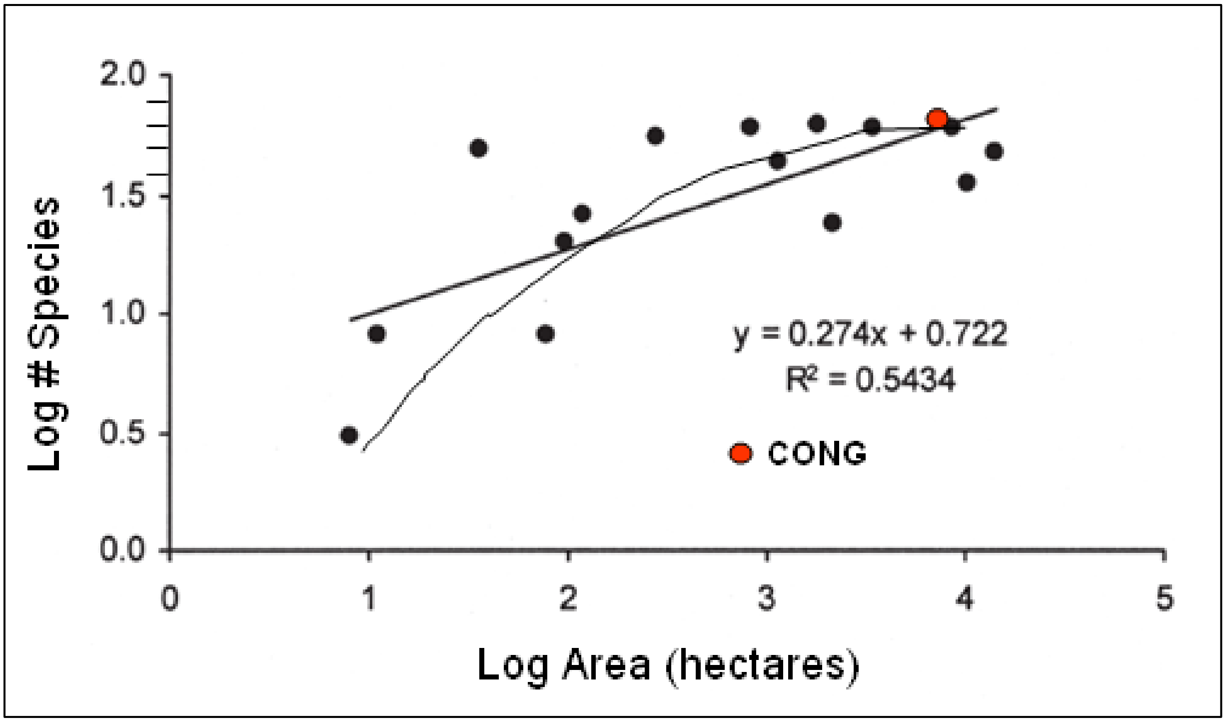


**Figure 36.** Relationship between land area and species richness, excluding exotic (introduced) species, among the 16 parks within the SECN, including CONG. Modified from Tuberville et al. (2005).

Byrne et al. (2011a) completed a preliminary study of amphibian communities in the park for the National Park Service during April and June of 2010. Data were collected at 31 spatially-balanced, random locations (Figure 37) using automated recording devices (ARDs) and visual encounter surveys. A total of 1,132 amphibians were detected in 24 species, genera, or order. Four species composed about 75% of the sample: Cope's gray tree frog (*Hyla chrysoscelis*) larval and poste-metamorphic, marbled salamander (*Ambystoma opacum*), dusky salamander (*Desmognathus* sp.), and southern leopard frog (*Rana sphenocephala*). Although Byrne et al. (2011a) primarily focused on amphibians; they additionally reported having detected 58 reptiles in 18 species, genera, order or sign. Four of these species were added to the NPS Certified Species List: *Elaphe obsoleta obsoleta* (black rat snake), *Elaphe alleghaniensis* (Eastern rat snake, yellow rat snake), red-bellied water snake (*Nerodia erythrogaster erythrogaster*), and *Trachemys scripta scripta* (yellow-bellied slider). As overall findings, only native species of amphibians and reptiles were detected. The most widely distributed amphibian and reptile was Cope's gray treefrog and the five-lined skink, respectively. The full dataset and associated metadata are available at http://science.nature.nps.gov/nrdata/.

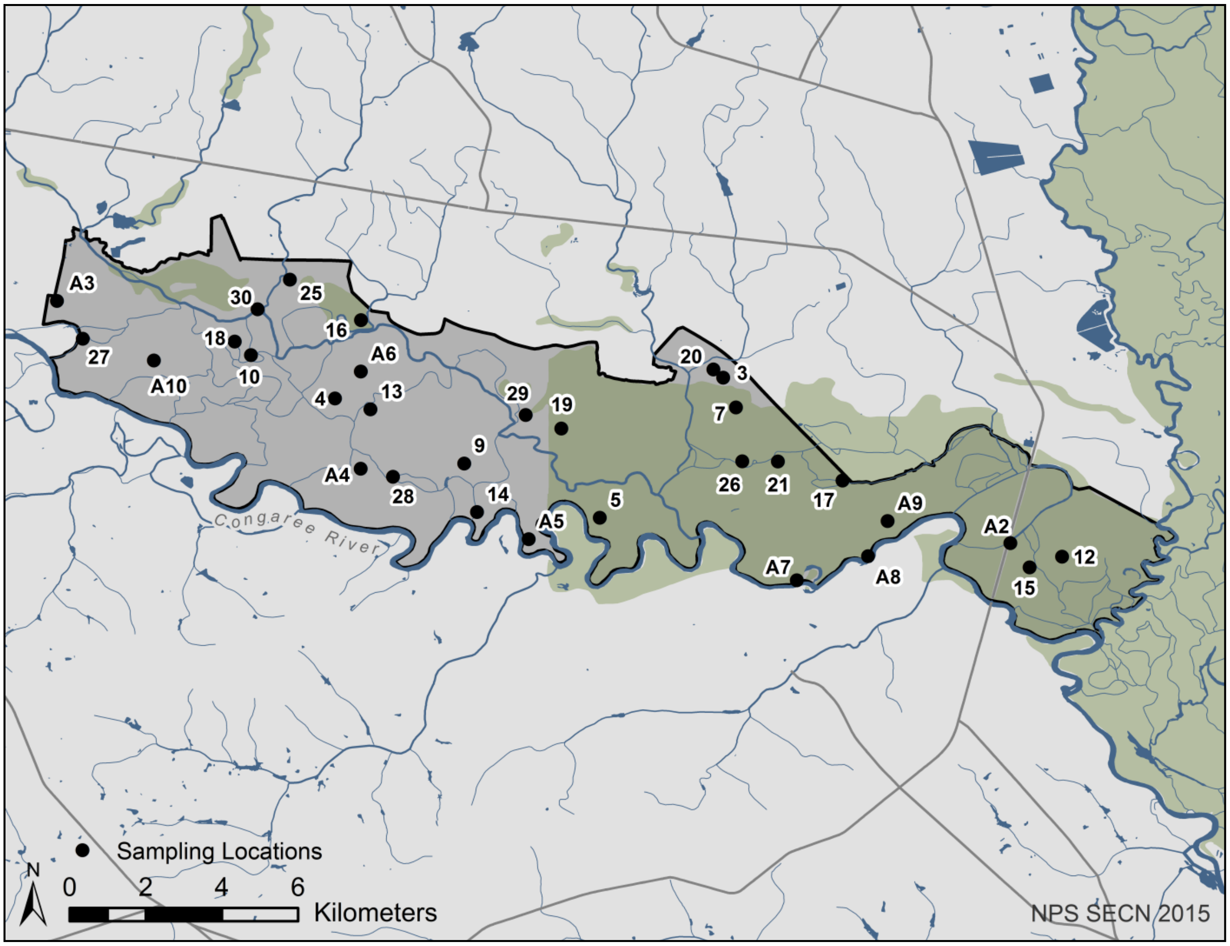


**Figure 37.** Map showing spatially-balanced random sampling locations for landbirds in 2009 and herpetofauna in 2010 at CONG. From Byrne et al. (2011a).

As a supplement to 2010 amphibian monitoring to ensure the amphibian community was adequately characterized, Southeast Coast Network I&M personnel deployed ARDs at 12 of the 31 sampling locations used in 2010 during March–May of 2011 (Figure 38). Species richness doubled compared to findings from ARD monitoring in 2010 (Byrne et al. 2011a). Twelve of twenty-three known vocal anuran species were detected with the most frequent occurrence and most widely distributed species being the spring peeper (*Pseudacris crucifer*) and the southern leopard frog (*Lithobates sphenocephalus*). The least frequent species occurrence was the southern chorus frog (*Pseudacris nigrita*) and the bullfrog (*Lithobates catesbeianus*). No non-native species were detected (Smrekar et al. 2013).

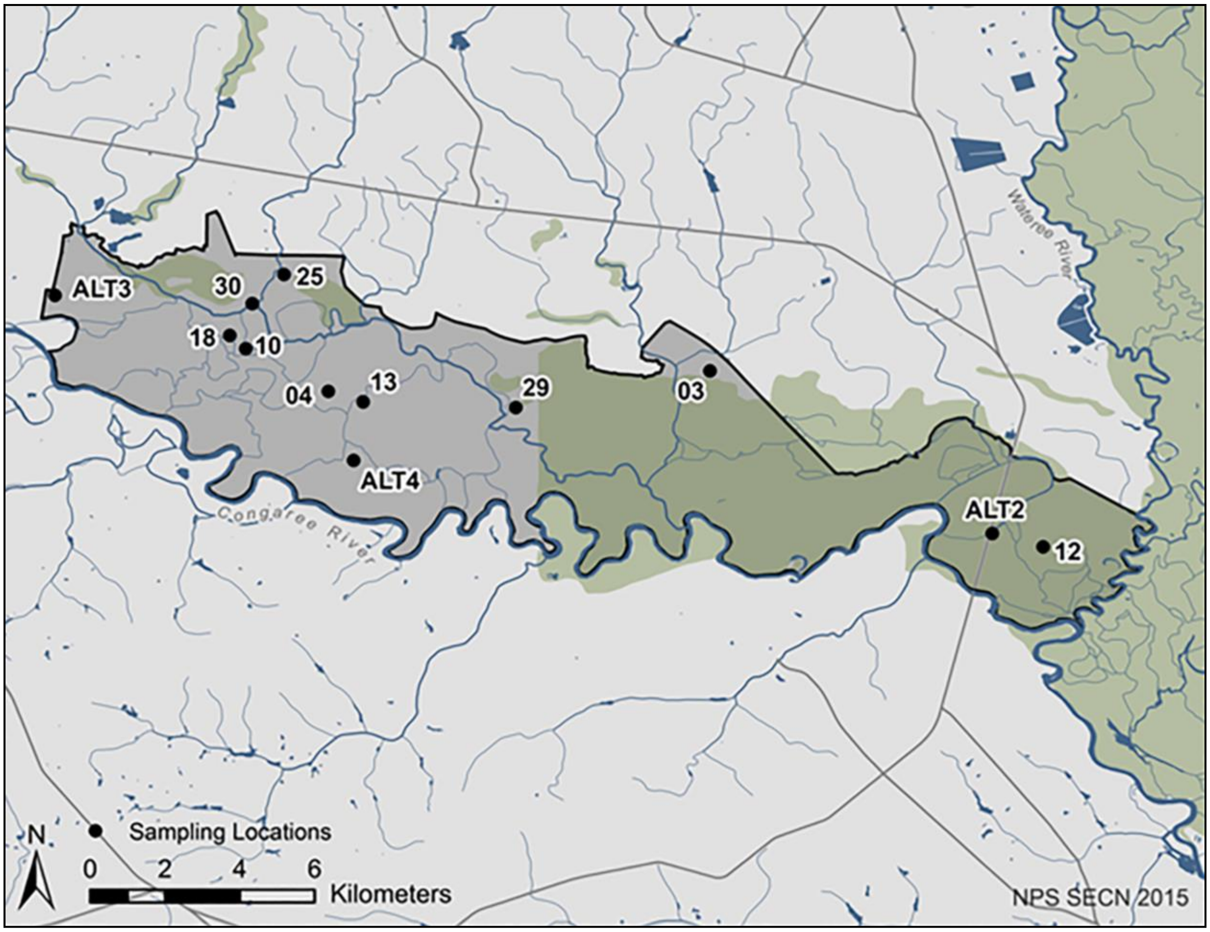


**Figure 38.** Map showing the sampling locations for vocal anurans based on ARD deployment at CONG during the 2011 NPS survey. From Smrekar et al. (2013).

*Birds*

> *Birds are an important component of park ecosystems, and their high body temperature, rapid metabolism, and high ecological position in most food webs make them a good indicator of the effects of local and regional changes in ecosystems. Long-term trends in the community composition, relative abundance, distribution, and occurrences of breeding bird populations provide a measure for assessing the ecological integrity and sustainability in southeastern systems. Further, long-term patterns of these attributes in relation to changes in the structural diversity of vegetation resulting from fire and other management practices will improve our understanding of the effects of various management actions.*
>
> *—Byrne et al. (2011b, p.ix)*

As mentioned, 191 species of birds have been reported from Congaree National Park (Appendix C). Of the 191 taxa, 37 species (19% of the total) are mostly associated with wetland/aquatic habitats). The park has three state-listed SoCs (Table 40c) bald eagle (*Haliaeetus leucocephalus*), American swallow-tailed kite (*Elanoides forficatus*), and wood stork (*Mycteria americana*), and one exotic/invasive species, the European starling (*Sturnus vulgaris*). A total of 30 priority species (as defined in Watson and Malloy 2008), were detected during this study, including Acadian flycatcher (*Empidonax virescens*), bald eagle, blackpoll warbler (*Dendroica striata*), chimney swift (*Chaetura pelagica*), eastern kingbird (*Tyrannus tyrannus*), eastern towhee (*Pipilo erythrophthalmus*), eastern wood-pewee (*Contopus virens*), great egret (*Ardea alba*), hooded warbler (*Wilsonia citrina*), indigo bunting (*Passerina cyanea*), Kentucky warbler (*Oporornis formosus*), Louisiana waterthrush (*Seiurus motacilla*), Mississippi kite (*Ictinia mississippiensis*), northern parula (*Parula americana*), orchard oriole (*Icterus spurius*), pine warbler (*Dendroica pinus*), prairie warbler (*Dendroica discolor*), prothonotary warbler (*Protonotaria citrea*), red-bellied woodpecker (*Melanerpes carolinus*), red-headed woodpecker (*Melanerpes erythrocephalus*), red-shouldered hawk (*Buteo lineatus*), solitary sandpiper (*Tringa solitaria*), summer tanager (*Piranga rubra*), Swainson's warbler (*Limnothlypis swainsonii*), white-eyed vireo (*Vireo griseus*), wood thrush (*Hylocichla mustelina*), worm-eating warbler (*Helmitheros vermivorum*), yellow-billed cuckoo (*Coccyzus americanus*), yellow-throated vireo (*Vireo flavifrons*), and yellow-throated warbler (*Setophaga dominica*).

Byrne et al. (2011b) used the Draft SECN landbird community monitoring protocol (See Byrne 2014 for final document) to conduct a survey of birds in the park in April –June 2009. Data were collected at spatially-balanced random locations (Figure 37). The study indicated high bird diversity at Congaree National Park: A total of 1,047 birds representing 68 species were detected. The barred owl (*Strix varia*) was a new report for the park. The most widely distributed species were the northern cardinal (*Cardinalis cardinalis*), the northern parula and the tufted titmouse (*Baeolophus bicolor*), which were found at 94–97% of the sampling locations. The second most widely distributed species group consisted of the blue-gray gnatcatcher (*Polioptila caerulea*), Acadian flycatcher, red-bellied woodpecker, red-eyed vireo (*Vireo olivaceus*), and yellow-billed cuckoo found at 80% of the sampling locations. The dispersion (i.e., the variance divided by the mean) also suggest that species are not aggregated and occur uniformly across the park.

Evaluation of the study sampling effort in comparison to the number of species detected (species accumulation curve) indicated that the sample sized adequately characterized bird diversity. The observed species richness was 68. Species richness estimators are consistent with one another, ranging from 74.70–91.15. Diversity indices suggest high bird species diversity at the park. The sample was relatively well distributed among species, with four species representing 30% of the species detected. The consistent performance of the evenness/dominance indices suggested varied relative abundances of the species and a diverse bird community at the park. The 2009 study described by Byrne et al. (2011b) is the first of its type for the park. The Southeast Coast Network plans to use the findings (e.g., the diversity index values) as a baseline for comparison with future monitoring efforts.

#### *Mammals*

About 37 mammalian species occur in Congaree National Park, including feral dogs and feral cats (Appendix C; NPS Certified Species List—NPS 2013a).

During 22 May 2003 through 7 April 2004, Webster (2010) surveyed mammalian species in the park. The survey included 22 man-days of sampling effort including two man-days on the Congaree River by boat at five major terrestrial habitats along the perimeter of the park—creek and river edges, bottomland forest, upland oak-hickory forest, upland managed pine plantation, and mechanically maintained camping areas and road edges (Figure 39). Thirty-four species of terrestrial mammals were documented as occurring or "probably occurring" in the park. Species listed as uncertain in the park were documented as commonly encountered in the region or widely distributed in the U.S. Southeast. Since the domestic dog and domestic horse are not permanent residents of the park, they were not included in this list. The survey did not extend to most recent land acquisition, the Riverstone Tract; in addition, bats were not included in the survey (but see discussion of the Loeb 2005 report).

As of 2013, the NPSpecies list (NPS 2013a) of mammals for the park includes 37 mammalian species. Of the thirty-four species reported by Webster (2010), twenty-seven species were confirmed present in the park while and nine more of were listed as uncertain ("probably occurring"). In addition, the feral horse (*Equus ferus*) was listed as "present" by Webster (2010) but was excluded from the NPS Certified Species List as described above (NPS 2013a). Seven species listed as "probably present" by Webster were also missing from the NPS Certified Species List (NPS 2013a) including the woodland vole (*Microtus pinetorum pinetorum*), golden mouse (*Ochrotomys nuttalli*), common muskrat (*Ondatra zibethicus*), black rat (*Rattus rattus*), Norway rat (*Rattus norvegicus*), house mouse (*Mus musculus*) and the long-tailed weasel (*Mustela frenata*). Also in the NPS Certified Species List (NPS 2013a), but not in Webster's list, were 7 species including the northern short-tailed shrew (*Blarina brevicauda*), domestic dog (*Canis familiaris*), southeastern myotis (*Myotis austroriparius*), red fox (*Vulpes vulpes*), cotton mouse (*Peromyscus gossypinus*), white-footed mouse (*Peromyscus leucopus*), and eastern pipistrelle (*Pipistrellus subflavus*).

While the NPS Certified Species List (NPS 2013a) included the domestic dog (*Canis lupus familiaris*) Webster (2010) felt that since this species is not a permanent resident of the park, it should not be included in the mammalian checklist for Congaree National Park. Similarly, the NPSpecies list contains several species of bats including the southeastern myotis (*Myotis austroriparius*), a federally listed species of concern. In contrast, Webster (2010) noted that various species of bats occur in the region surrounding Congaree NP, but he excluded them from the species checklist for the park based on the premise that the park lacks suitable habitat for them, so if seen within the park they would not be permanent residents.

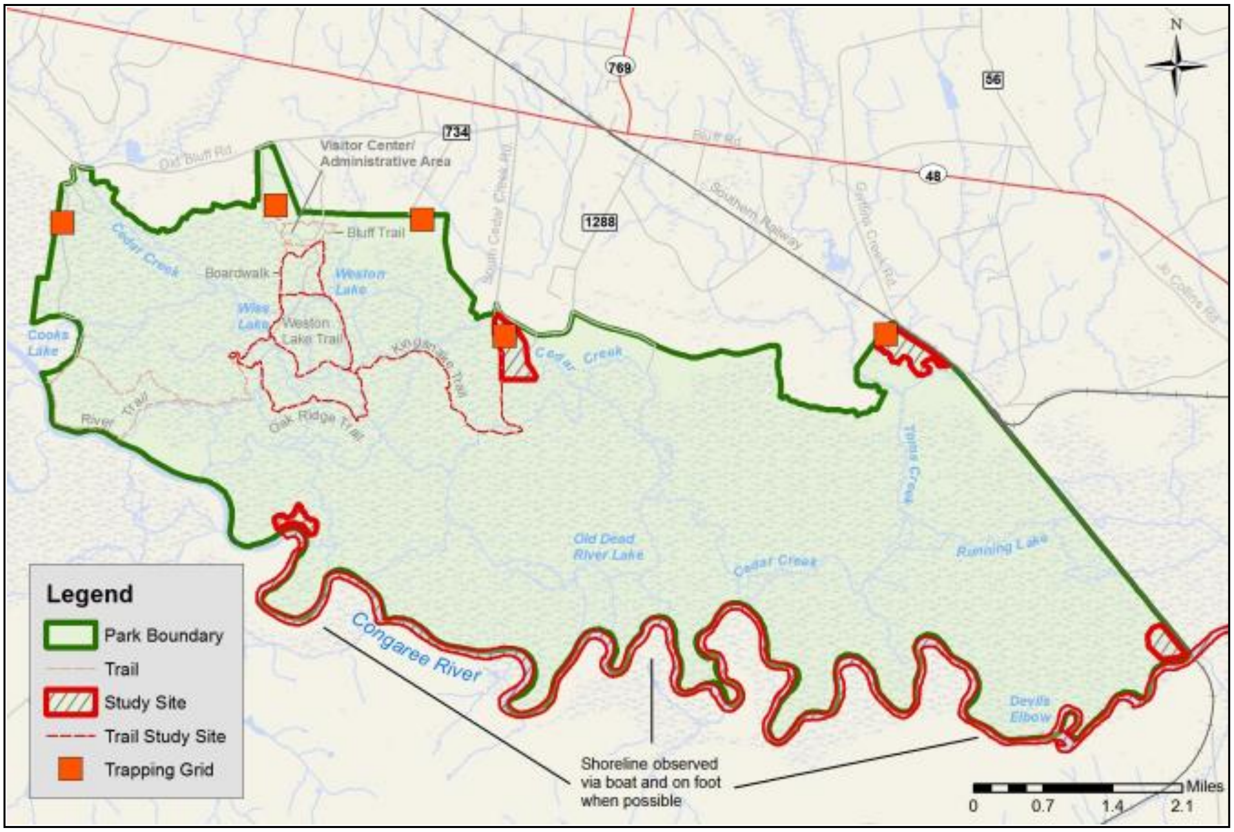


**Figure 39.** Map showing the five sampling locations for most mammals that were surveyed at CONG during 2003–2004. Orange squares indicate sampling locations. From Webster (2010).

In spring, summer, and fall of 2004–2005, Loeb (2005) surveyed for bats in five SECN parks, including Congaree NP. Mist-netting for bats was conducted at six sites and acoustic sampling at twenty sites. A total of 32 bats within six species were captured in the mist nets, including two SoCs, Rafinesque's big-eared bat (*Corynorhinus rafinesquii*) and the southeastern myotis (*Myotis austroriparius*; with evidence of breeding colonies for both in the park), and four other species—the fairly common red bat (*Lasiurus borealis*) and eastern pipistrelle (*Pipistrellus subflavus*), and the surprisingly rare big brown bat (*Eptesicus fuscus*) and evening bat (*Nycticeius humeralis*). Two other species were expected but were not detected in this survey: The Seminole bat (*Lasiurus seminolus*) may have been missed because it was not possible to access the most mature pine areas in the park, and it was also not possible to discern between the echolocation calls of Seminole bats and red bats. The Mexican free-tailed bat (*Tadarida brasiliensis*) may have been missed because individuals likely flew too high to be within range of the mist-nets. Four of the six species detected by mist-nets were also detected acoustically. Overall, Congaree NP was found to support a diverse bat community, including optimal habitat for two SoCs that are dependent on old-growth bottomwood hardwood forest in the Coastal Plain.

*Mammalian Species of Special Management Interest*

The feral hog population in the park is increasing with widespread distribution in the park. The activities of these animals threatens the bottomland hardwood ecosystem function, regeneration of vegetation and tree species, the health of rare and imperiled species, stream water quality and stream banks as well as other natural resources (discussed in more detail in Section 3.6.10). The park has drafted a nonnative pig environmental assessment and management plan to address this growing issue aggressively.

*Species of Concern*

At least twenty species of vascular plants, one fish and eighteen species of animals are presently reported as SoCs in the park (Table 39a–d). The federal Endangered Species Act of 1973 (ESA: 7 U.S.C. §136, 16 U.S.C. § 1531) includes a set of listing status levels. Two other ranking systems are also instructive in considering species of concern in the park; both are conservation status ranks that are assessed and determined by scientists at NatureServe, a nonprofit conservation organization allied with a network of natural heritage programs.

The Global Rank System (GRank) uses a numbered status rank from 1 to 5 to indicate a species' risk of extinction. The State Rank System (SRank) refers to a species' status within a specific state or province (Buchanan and Finnegan 2010). National Heritage Programs, Conservation Data Centers, NatureServe, and The Nature Conservancy have developed a consistent method for evaluating the status of both species and ecological communities, designated as a conservation rank from S1 to S5. The status assessments are based on best available information (abundance, distribution, population trends, threats, etc.). The South Carolina Natural Heritage Program maintains computerized data and GIS map files on Endangered, Threatened, Proposed, Special Concern, and Significantly Rare species. In addition, paper files are maintained on Watch List species.

**Table 39a.** Vascular plant species of concern (SoCs)* reported to occur in CONG (FSC–federal SoC, SCSC–South Carolina SoC). From NatureServe (2008), the SCDNR (2014) Rare, Threatened and Endangered Species List (SCDNR 2017a), the South Carolina Heritage Program, and NPS Certified Species List (NPS 2013a).

| Scientific Name | Common Name(s) | General Habitat | State Rare, Threatened, and Endangered Species Listing | State/Federal Status; State/Global Rank |
|---|---|---|---|---|
| *Aristolochia tomentosa* | Common dutchmanspipe, woolly dutchman's pipe | wetland | – | G5;S1 |
| *Botrychium lunarioides* | Winter grapefern | terrestrial | – | G4?;S1 |
| *Carex amphibola* | Amphibious sedge, eastern narrowleaf sedge | wetland | – | G5;SNR |
| *Carex cherokeensis* | Cherokee sedge | wetland | – | G4,G5;S2 |
| *Carex crus-corvi* | Ravenfoot sedge | wetland | – | G5;S2 |

*20 total and 7 terrestrial

**Table 39a (continued).** Vascular plant species of concern (SoCs)* reported to occur in CONG (FSC–federal SoC, SCSC–South Carolina SoC). From NatureServe (2008), the SCDNR (2014) Rare, Threatened and Endangered Species List (SCDNR 2017a), the South Carolina Heritage Program, and NPS Certified Species List (NPS 2013a).

| Scientific Name | Common Name(s) | General Habitat | State Rare, Threatened, and Endangered Species Listing | State/Federal Status; State/Global Rank |
|---|---|---|---|---|
| *Carex elliottii* | Elliott's sedge | wetland | – | G4?;S1 |
| *Carex granularis* | Limestone meadow sedge, limestone-meadow sedge | wetland | – | G5;S2 |
| *Carex socialis* | Low woodland sedge | terrestrial | – | G4;S1 |
| *Cayaponia quinqueloba* | Fivelobe cucumber | wetland | – | G4;S1? |
| *Collinsonia serotina* | Blue Ridge horsebalm | terrestrial | – | G3,G4;S1 |
| *Dichanthelium aciculare* | Needleleaf rosette grass | terrestrial | – | G4,G5,SNR |
| *Helenium pinnatifidum* | Southeastern sneezeweed | wetland | – | G4;S2 |
| *Ilex amelanchier* | Sarvis holly | wetland | – | G4;S3 |
| *Lechea torreyi* | Piedmont pinweed | terrestrial | – | G4;SNR |
| *Macbridea caroliniana* | Carolina birds-in-a-nest | wetland | S-ARS | G2,G3;S3 |
| *Menispermum canadense* | Canadian moonseed, common moonseed | terrestrial | – | G5;S2,S3 |
| *Ophioglossum vulgatum* | Southern adder's-tongue, southern adderstongue | wetland | – | G5;S2 |
| *Rhododendron eastmanii* | Santee azalea | terrestrial | – | G2;S2 |
| *Rhynchospora pallida* | Pale beaksedge | wetland | – | G3;S1 |
| *Urtica chamaedryoides* | Heartleaf nettle, slim stingingnettle | wetland | – | G4,G5;S2 |

*20 total and 7 terrestrial

**Table 39b.** Fish, amphibian and reptilian species of concern (SoCs) reported to occur in CONG (FSC–federal SoC, SCSC–South Carolina SoC). From NatureServe (2008), the SCDNR (2014) Rare, Threatened and Endangered Species List (SCDNR 2017a), the South Carolina Heritage Program (SCDNR 2017b), and NPS Certified Species List (NPS 2013a).

| Biota Grou | Scientific Name | Common Name(s) | General Habitat | State Rare, Threatened, and Endangered Species Listing | State/Federal Status; State/Global Rank |
|---|---|---|---|---|---|
| Fish | *Anguilla rostrata* | American eel | aquatic | S-ARS | – |
| Amphibian | *Pseudacris feriarum* | Southeastern chorus frog, upland chorus frog | wetland | – | G5;S5 |
| Reptiles | *Clemmys guttata* | Spotted turtle | aquatic | ST | – |

**Table 39c.** Bird species of concern (SoCs) reported to occur in CONG (FSC–federal SoC, SCSC–South Carolina SoC). From NatureServe (2008), the SCDNR (2014) Rare, Threatened and Endangered Species List (SCDNR 2017a), the South Carolina Heritage Program (SCDNR 2017b), and NPS Certified Species List (NPS 2013a).

| Scientific Name | Common Name(s) | General Habitat | State Rare, Threatened, and Endangered Species Listing[a] | State/Federal Status; State/Global Rank[b] |
|---|---|---|---|---|
| *Accipiter cooperii* | Cooper's hawk | terrestrial | – | S3 |
| *Aimophila aestivalis* | Bachman's sparrow | terrestrial | – | G3 |
| *Egretta caerulea* | Little blue heron | aquatic | – | SNR |
| *Elanoides forficatus* | American swallow-tailed kite, swallow-tailed kite | aquatic | SE, SSC | G5;S2 |
| *Falco peregrinus** | Peregrine falcon | terrestrial | ST | – |
| *Haliaeetus leucocephalus* | Bald eagle | terrestrial | ST | G5;S2 |
| *Ictinia mississippiensis* | Mississippi kite | aquatic | – | G5;S4 |
| *Lanius ludovicianus* | Loggerhead shrike | terrestrial | – | G4;S3 |
| *Limnothlypis swainsonii* | Swainson's warbler | terrestrial | – | G4;S4 |
| *Melanerpes erythrocephalus* | Red-headed woodpecker | terrestrial | – | G5;SNR |
| *Mycteria americana* | Wood stork | aquatic | FT; SE | G4;S1,S2 |

**Falco peregrinus anatum* listed as At-Risk Species in Richland County (SC DNR 2014)

**Table 39d.** Mammal species of concern (SoCs) reported to occur in CONG (FSC–federal SoC, SCSC–South Carolina SoC). From NatureServe (2008), the SCDNR (2014) Rare, Threatened and Endangered Species List (SCDNR 2017a), the South Carolina Heritage Program (SCDNR 2017b), and NPS Certified Species List (NPS 2013a).

| Scientific Name | Common Name(s) | General Habitat | State Rare, Threatened, and Endangered Species Listing | State/Federal Status; State/Global Rank |
|---|---|---|---|---|
| *Condylura cristata* | Star-nosed mole | terrestrial | – | G5;S3 |
| *Corynorhinus rafinesquii* | Eastern big-eared bat, Rafinesque's big-eared bat, southeastern big-eared bat | terrestrial | SE | S2 |
| *Myotis austroriparius* | Southeastern myotis | terrestrial | – | G3,G4;S1 |
| *Neotoma floridana* | Eastern woodrat | terrestrial | – | G5;S3,S4 |
| *Sciurus niger* | Eastern fox squirrel, fox squirrel | terrestrial | – | G5;S4 |

[a] Federal rank definitions (F-federal): E–Endangered (U.S. Fish and Wildlife Service [U.S. FWS]); T–threatened (U.S. Fish and Wildlife Service [U.S. FWS]); T-USDA–threatened (USDA); FSC–Federal species of concern (U.S. Fish and Wildlife Service).

[b] South Carolina rank definitions (S-state): E–Endangered; T–Threatened; ARS–At-risk Species (S.C. DNR 2014); S1–Critically imperiled, S2–Imperiled, and S3–Vulnerable; S4–significantly rare (limited to North Carolina and adjacent states [endemic or near endemic]); SSC–State species of concern, SR-P–Significantly Rare-peripheral; SR-O–range is sporadic and is not described in the other Significantly Rare categories; W1–Watch List, rare but relatively secure; W7–Watch list, rare and poorly known; SNR–not yet ranked.

Global Rank System (GRank–from nonprofit organizations): G1–critically imperiled; G2–imperiled, G3–vulnerable, G4–apparently secure, G5–secure. T1-5 series can be used together with the GRank system; that is, intraspecific taxa (subspecies, plant varieties, etc. below the species level) can be assigned global T-ranks. The numbers for “T” designations are: 1–critically imperiled; 2–imperiled; 3–vulnerable; 4–apparently secure (uncommon but not rare, but with some cause for long-term concern); and 5–secure; ?–inexact numeric rank.

*Exotic and Invasive Species*

The National Park Service defines an invasive species as a species that is alien (introduced or nonindigenous to an ecosystem), whose presence causes or is likely to cause economic or environmental harm or harm to human health (NPS 2017d). Invasive species harm natural and cultural resources by outcompeting native species, threatening the safety of park employees and visitors, adversely affecting aesthetics for park visitors, requiring intensified maintenance and monitoring, and altering—usually adversely—natural ecological processes (Pimentel et al. 2005).

Exotic/invasive species, from those regarded as generally “benign” to the most highly invasive, all have the adverse impact of taking needed habitat and other resources from native species. These species are a major concern to the park because of their adverse effects on wildlife and biodiversity. A total of 47 exotic/invasive plant species and 10 exotic/invasive animal species are reported to occur in the park (Tables 41 and 42). These organisms characteristically have few or no natural predators and are highly resilient to mitigation/control efforts (Pimental et al. 2005). For example, fire top-kills

Japanese honeysuckle, wisteria and mimosa, but vigorous re-sprouting occurs so that groundcover is maintained (Zouhar et al. 2008; NPS 2018).

*Flora*

There are 411 exotic plant species reported for the entire state of South Carolina. These include 14 species of aquatic plants; one species of conifer tree; one species of fern; 205 species of forbs/herbs; 73 species of grasses or grasslike plants; 23 species of hardwood trees; 55 species of shrubs and 37 species of vines. Notably, Richland County ranks first in the state for the most invasive plant species with 253 species (EDDMapS 2014). The 47 exotic/invasive plant species in the park were ranked following NatureServe (2008) which ranked 20 of the exotic/invasive plant species based on information about their occurrence in vegetative alliances. First, NatureServe (2008) considered Randall et al.'s (2008) high, medium, and low rankings. Second, the South Carolina Exotic Pest Plant Council has produced a list of Terrestrial Exotic Invasive Plants in South Carolina (SC-EPPC 2014) with rankings for vascular plants as follows:

- *Severe Threat—(CAT1, R1)*—Exotic plant species are known to pose a severe threat to the composition, structure, or function of natural areas in the State of South Carolina;
- *Significant Threat—(CAT2, R2)*—Exotic plant species that are established in natural areas, spreading independently, and causing significant damage to natural communities; but may not be a widespread or difficult to manage as "severe threat" species;
- *Emerging Threat—(CAT3, R3)*—Exotic plant species found in South Carolina or in adjacent states, in limited infestations with substantial management difficulties; or widespread with minor management difficulties; and
- *Alert—(CAT4, R4)*—Exotic plants that are known to pose a severe threat to natural areas in adjacent states or in the southeast with a limited distribution in South Carolina or not currently recorded here. More distribution information is needed for most of these species.

South Carolina currently does not have a wetland and aquatic exotic/invasive plant list. Therefore, threat categories for these species were assigned by comparing the NPS Certified plant list with the NatureServe (2008) ranking, the Georgia list of exotic and invasive plants (USDA-NRCS 2017b) and the North Carolina Native Plant Society list of invasive exotic plants in North Carolina (NCNSP 2010).

We additionally indicated vegetative species inclusion on the NPS Top Ten Species List of the worst exotic/invasive species for national parks in the Southeast region (NPS 2017e; Table 40). Congaree National Park has 13 species ranked as R1—severe threat. Five of these species (Chinese privet [*Ligustrum sinense*], Japanese climbing fern [*Lygodium japonicum*], English ivy [*Hedera helix*], Chinese honeysuckle [*Lonicera japonica*], and kudzu [*Pueraria montana*]) are also on the NPS Top 10 list. Thus, Congaree National Park has five of the NPS Top Ten most invasive species for the Southeast region. Three species are listed as R2—significant threat (mimosa tree [*Albizia julibrissin*], white mulberry [*Morus alba*], and common chickweed [*Stellaria media*]); four are R3—emerging threat (Jerusalem cherry [*Solanum pseudocapsicum*], Johnson grass [*Sorghum halepense*], Florida betony [*Stachys floridana*], and annual bluegrass [*Poa annua*]); and three species are ranked R4—

alert (hairy clustervine [*Jacquemontia tamnifolia*], sawtooth oak [*Quercus acutissima*], and pretty verbena [*Verbena bonariensis*]). These plants rapidly overgrow and shade out native, beneficial plant species, inhibiting their growth and displacing them in forests, fields, and/or wetlands.

**Table 40.** The 47 highly invasive plant species reported to occur in CONG, including their invasive ranking and information about their habitats. From the South Carolina Exotic Pest Plant Council (SC-EPPC 2014), the South Carolina Aquatic Nuisance Species Program (SCDNR 2017c), USDA PLANTS database (USDA-NRCS 2017a) and the NPS Certified Species List (NPS 2013a).

| Species | Common name | Habitat | Threat category |
|---|---|---|---|
| *Albizia julibrissin* | Mimosa, mimosa tree, powderpuff tree, silk tree, silktree | terrestrial | Significant threat |
| *Alternanthera philoxeroides* | Alligator weed, alligatorweed, pig weed | wetland | CAT1, R1 |
| *Arabidopsis thaliana* | Mouse-ear cress, mouseear cress | terrestrial | – |
| *Briza minor* | Little quakinggrass | wetland | – |
| *Bromus catharticus* | Rescue brome, rescue grass, rescuegrass, rescuegrass | terrestrial | – |
| *Crotalaria spectabilis* | Showy crotalaria, showy rattlebox | terrestrial | – |
| *Cynodon dactylon* | Bermudagrass | terrestrial | – |
| *Dactylis glomerata* | Cocksfoot, orchard grass, orchardgrass | terrestrial | – |
| *Echinochloa crus-galli* | Barnyard grass, barnyardgrass, cockspur | wetland | – |
| *Elaeagnus umbellata* | Autumn olive, oleaster | terrestrial | Severe threat |
| *Facelis retusa* | Annual trampweed | terrestrial | – |
| *Glandularia pulchella* | South American mock vervain | terrestrial | – |
| *Hedera helix* | English ivy | terrestrial | Severe threat, NPS Top Ten |
| *Helenium amarum* | Bitter sneezeweed, yellowdicks | terrestrial | – |
| *Hypochaeris radicata* | Common cat's-ear, false dandelion, frogbit | terrestrial | – |
| *Jacquemontia tamnifolia* | Clustervine, hairy clustervine | wetland | CAT4, R4 |
| *Lamium amplexicaule* | Common henbit, giraffehead, henbit, henbit deadnettle | terrestrial | – |
| *Lamium purpureum* | Purple deadnettle, red deadnettle | terrestrial | – |
| *Lespedeza cuneata* | Chinese lespedeza, sericea lespedeza | terrestrial | Severe threat |
| *Ligustrum japonicum* | Japanese privet | terrestrial | Severe threat, NPS Top Ten |
| *Ligustrum sinense* | Chinese privet, common Chinese privet | wetland | CAT1, R1, NPS Top Ten |
| *Liriope muscari* | Big blue lilyturf | terrestrial | – |
| *Lolium perenne* | Italian ryegrass, perennial rye grass, perennial ryegrass | terrestrial | – |
| *Lonicera japonica* | Chinese honeysuckle, Japanese honeysuckle | wetland | NPS Top 10, R1 |
| *Lygodium japonicum* | Japanese climbing fern | wetland | CAT1, R1 |

**Table 40 (continued).** The 47 highly invasive vascular plant species reported to occur in CONG, including their invasive ranking and information about their habitats. From the South Carolina Exotic Pest Plant Council (SC-EPPC 2014), the South Carolina Aquatic Nuisance Species Program (SCDNR 2017c), USDA PLANTS database (USDA-NRCS 2017a) and the NPS Certified Species List (NPS 2013a).

| Species | Common name | Habitat | Threat category |
|---|---|---|---|
| *Macrothelypteris torresiana* | Swordfern | wetland | – |
| *Mazus pumilus* | Japanese mazus | wetland | – |
| *Melia azedarach* | Chinaberry, Chinaberry tree, Indian lilac | terrestrial | Severe threat |
| *Microstegium vimineum* | Japanese stiltgrass, Nepalese browntop | wetland | CAT1, R1 |
| *Morus alba* | Mulberry, white mulberry | terrestrial | Significant threat |
| *Murdannia keisak* | Aneilima, Asian spiderwort, wartermoving herb | wetland | CAT1, R1 |
| *Paspalum dilatatum* | Dallas grass, water grass | wetland | – |
| *Paspalum urvillei* | Vasey grass, Vasey's grass, vaseygrass | wetland | – |
| *Perilla frutescens* | Beefsteak, beefsteak mint, beefsteakplant, purple perilla, purple mint | terrestrial | – |
| *Plantago aristata* | Bottlebrush Indianwheat, largebracted plantain | terrestrial | – |
| *Poa annua* | Annual blue grass, annual bluegrass, walkgrass | wetland | CAT3, R3 |
| *Pueraria montana* | Kudzu | terrestrial | Severe threat, NPS Top 10 |
| *Quercus acutissima* | Sawtooth oak | terrestrial | Alert |
| *Rumex crispus* | Curley dock, curly dock, narrowleaf dock, sour dock, yellow dock | wetland | – |
| *Senna obtusifolia* | Java-bean, sicklepod | terrestrial | – |
| *Sida rhombifolia* | Arrowleaf sida, cuban jute, cuban-jute | terrestrial | – |
| *Solanum pseudocapsicum* | Jerusalem cherry | terrestrial | Emerging threat |
| *Sorghum halepense* | Johnson grass, Johnsongrass | wetland | CAT3, R3 |
| *Stachys floridana* | Florida betony, Florida hedgenettle | wetland | CAT3, R3 |
| *Stellaria media* | Chickweed, common chickweed, nodding chickweed | terrestrial | Significant threat, CAT2, R2 |
| *Verbena bonariensis* | Pretty verbena, purpletop vervain | wetland | CAT4, R4 |
| Wisteria sinensis | Chinese wisteria | terrestrial | Severe threat |

**Table 41.** The 57 exotic/invasive plant and animal species reported to occur in CONG, based on the NPS Certified Species List (NPS 2013a) and observations of the authors of this report.

| Biota Group | Scientific Name | Common Name(s) | Invasive Status |
|---|---|---|---|
| Terrestrial Plants (29) | *Albizia julibrissin* | Mimosa, mimosa tree, powderpuff tree, silk tree, silktree | Significant threat |
| | *Arabidopsis thaliana* | Mouse-ear cress, mouseear cress | – |
| | *Bromus catharticus* | Rescue brome, rescue grass, rescuegras, rescuegrass | – |
| | *Crotalaria spectabilis* | Showy crotalaria, showy rattlebox | – |
| | *Cynodon dactylon* | Bermudagrass | – |
| | *Dactylis glomerata* | Cocksfoot, orchard grass, orchardgrass | – |
| | *Elaeagnus umbellata* | Autumn olive, oleaster | Severe threat |
| | *Facelis retusa* | Annual trampweed | – |
| | *Glandularia pulchella* | South American mock vervain | – |
| | *Hedera helix* | English ivy | Severe threat |
| | *Helenium amarum* | Bitter sneezeweed, yellowdicks | – |
| | *Hypochaeris radicata* | Common cat's-ear, false dandelion, frogbit | – |
| | *Lamium amplexicaule* | Common henbit, giraffehead, henbit, henbit deadnettle | – |
| | *Lamium purpureum* | Purple deadnettle, red deadnettle | – |
| | *Lespedeza cuneata* | Chinese lespedeza, sericea lespedeza | Severe threat |
| | *Ligustrum japonicum* | Japanese privet | Severe threat |
| | *Liriope muscari* | Big blue lilyturf | – |
| | *Lolium perenne* | Italian ryegrass, perennial rye grass, perennial ryegrass | – |
| | *Melia azedarach* | Chinaberry, Chinaberry tree, Indian lilac | Severe threat |
| | *Morus alba* | Mulberry, white mulberry | Significant threat |
| | *Perilla frutescens* | Beefsteak, beefsteak mint, beefsteakplant, purple perilla, purple mint | – |
| | *Plantago aristata* | Bottlebrush Indianwheat, largebracted plantain | – |
| | *Pueraria montana* | Kudzu | Severe threat |
| | *Quercus acutissima* | Sawtooth oak | Alert |
| | *Senna obtusifolia* | Java-bean, sicklepod | – |
| | *Sida rhombifolia* | Arrowleaf sida, cuban jute, cuban-jute | – |
| | *Solanum pseudocapsicum* | Jerusalem cherry | Emerging threat |
| | *Stellaria media* | Chickweed, common chickweed, nodding chickweed | Significant threat |
| | *Wisteria sinensis* | Chinese wisteria | Severe threat |

**Table 41 (continued).** The 57 exotic/invasive plant and animal species reported to occur in CONG, based on the NPS Certified Species List (NPS 2013a) and observations of the authors of this report.

| Biota Group | *Scientific Name* | Common name(s) | Invasive status |
|---|---|---|---|
| Wetland Plants (18) | *Alternanthera philoxeroides* | Alligator weed, alligatorweed, pig weed | Severe threat |
| | *Briza minor* | Little quakinggrass | – |
| | *Echinochloa crus-galli* | Barnyard grass, barnyardgrass, cockspur | – |
| | *Jacquemontia tamnifolia* | Clustervine, hairy clustervine | Alert |
| | *Ligustrum sinense* | Chinese privet, common chinese privet | Severe threat |
| | *Lonicera japonica* | Chinese honeysuckle, Japanese honeysuckle | Severe threat |
| | *Lygodium japonicum* | Japanese climbing fern | Severe threat |
| | *Macrothelypteris torresiana* | Swordfern | – |
| | *Mazus pumilus* | Japanese mazus | – |
| | *Microstegium vimineum* | Japanese stiltgrass, Nepalese browntop | Severe threat |
| | *Murdannia keisak* | Aneilima, Asian spiderwort, wartremoving herb | Severe threat |
| | *Paspalum dilatatum* | Dallas grass, water grass | – |
| | *Paspalum urvillei* | Vasey grass, Vasey's grass, vaseygrass | – |
| | *Poa annua* | Annual blue grass, annual bluegrass, walkgrass | Emerging threat |
| | *Rumex crispus* | Curley dock, curly dock, narrowleaf dock, sour dock, yellow dock | – |
| | *Sorghum halepense* | Johnson grass, Johnsongrass | Emerging threat |
| | *Stachys floridana* | Florida betony, Florida hedgenettle | Emerging threat |
| | *Verbena bonariensis* | Pretty verbena, purpletop vervain | Alert |
| Fish (1) | *Cyprinus carpio* | Common carp, European carp | – |
| Birds (4) | *Branta canadensis* | Canada goose | – |
| | *Carpodacus mexicanus* | House finch | – |
| | *Passer domesticus* | House sparrow | – |
| | *Sturnus vulgaris* | European starling | – |
| Mammals (4) | *Canis familiaris* | Domestic dog, feral dog | – |
| | *Felis catus* | Feral cat | – |
| | *Sus scrofa* | Pig, pig (feral), wild boar | – |
| | *Vulpes vulpes* | Red fox | – |
| Molluscs (1) | *Corbicula fluminea* | Asiatic clam | – |

*Fauna*

There are currently ten exotic/invasive animals in Congaree National Park, including one fish (common carp), four birds (Canada goose, house finch, house sparrow, and European starling), four mammals (feral dog, feral cat, feral pig and red fox), and one mollusc (Asiatic clam; Table 41). One other exotic/invasive insect species merits mention as well: The Asian tiger mosquito (*Aedes albopictus*) is described as an especially aggressive biter and also a potential vector for LaCross encephalitis, yellow fever, and dengue fever.

The Asiatic clam (*Corbicula fluminea*) was first reported in South Carolina in the late 1960s to early 1970s. Infestations alter the benthic substrate and cause increased competition with native species for food and habitat. It is likely linked to the mortality, decline and extinction of native freshwater mussels (SCDNR 2014).

Arguably the most harmful invasive animal in the park, and the greatest threat to natural resources and bottomland hardwood ecosystem function, is the aggressive feral pig (or feral hog), *Sus scrofa*. This species is thought to have inhabited the Congaree and Wateree floodplains for at least 200 years if not more. In 1540, a herd of pigs was driven through the floodplains by the De Soto Expedition and by the time European colonist settled, a population of feral pigs existed for the Native Americans to hunt. (Towne and Wentworth 1950; Mayer and Brisbin 1991; NPS 2014c).

In a study conducted in 2005–2006, Friebel and Jodice (2009) radio-collared and tracked feral hogs in the western and central park. The mean home range sizes were 218 ± 43 hectares for seven males and 191 ± 31 hectares for nine females. Thus, good habitat was available for this species throughout most of the park. The animals commonly moved between the park and private lands, behavior which suggested that a successful feral hog management program in Congaree National Park should also involve adjacent private landowners.

The wild pig population has beenincreasing in the park and widespread damage has been documented throughout the floodplain predominantly in cypress-tupelo plots, followed by mixed bottomland hardwoods and seepage forest; in contrast, the least disturbance was found in the upland pine flatwoods plots adjacent to the floodplain (Zengle 2008). The rooting activity of feral pigs causes disturbance to plant communities such as the upland longleaf pine forest community and interrupts the regeneration of native plant species. Equally devastating is feral pig competition with other wildlife and grazing on threatened and endangered species such as Carolina birds-in-a-nest (*Macbridea caroliniana*) of which Congaree National Park has the largest known population. Destruction to cultural and historic structures in the park is also of concern (NPS 2014b; personal communication, S. Kidd, Acting Chief, Integrated Resource Management, Congaree National Park, 2014).

*Management Actions*

A non-native wild pig environmental assessment and draft management plan was being finalized at the time of this draft (NPS 2014c). Necessary funding is being put in place to address the growing and widespread issue in the park. The objectives on management are to manage the wild pig population thus prevent further loss of and protect natural resources, protect cultural and historic sites, decrease visitor health and safety risk by decreasing visitor and wild pig interaction, and reduce the "mark" these animals leave on the wilderness landscape. In addition, other alternatives include a sustained live-capture trapping and indefinite shooting program and fencing or other barrier for sensitive natural resources. Trucks, ORVs, motorboats and non-motorized boats would be used to disperse traps in the park via dirt roads, trails, old logging roads, and streams. Care to minimize the disturbance to vegetation and soils is proposed, but is unavoidable although short-term.

## 2.3. Resource Stewardship

### *2.3.1. Management Directives and Planning Guidance*

The NPS mission is to "preserve unimpaired the natural and cultural resources and values of the National Park System for the enjoyment, education, and inspiration of this and future generations" (NPS 2013b). About 15 years ago the NPS (1999) developed an action plan, the Natural Resources Challenge, for preserving the natural resources of the national parks (see Carter et al. 2007a), and has been engaged in many efforts to carry out that plan.

The General Management Plan (GMP) for Congaree National Park was written in 1987 (NPS 1988). At that time, as previously mentioned, the park was designated as Congaree Swamp National Monument. In 2003, the park became designated as Congaree National Park (Public Law 108-108). In addition to its central goal of protecting the old-growth bottomland hardwood forest and wilderness, the GMP addressed land protection for resource management; central goals were to:

- Protect, preserve and conserve the natural resources and scenic integrity through management as an undeveloped natural area.
- Provide protection of wildlife and natural resources in the context of providing a safe, educational, and enjoyable visitor experience.
- Minimize the proliferation of exotic biota and adverse effects caused by human activities.

More specifically and in support of the GMP, the 2004 Fire Management Plan (FMP) for Congaree National Park included the following resource management objectives:

- Returning fire management to upland areas to promote natural succession;
- Maintaining native plant and animal species diversity, abundance, and behavior reflect sustainable and naturally occurring conditions;
- Invasive, exotic species are eliminated from the natural ecosystem;
- Fires occur in a manner that sustains a healthy natural ecosystem reducing hazard fuel accumulations;
- Riverine systems within the park are healthy and biologically productive;

Congaree National Park staff have not developed a Resource Stewardship Strategy (RSS). The National Park Service has done considerable work to identify natural resources and indicators that are important from the perspective of the NPS Inventory & Monitoring Program and parks within its Southeast Coast Network.

Three general properties were identified that broadly affect the integrity of ecosystems and natural resources in SECN parks: (a) parks are generally surrounded by altered landscapes; (b) the ecosystems of the SECN are driven to a large extent by natural disturbance process such as hurricanes, flooding, and fire; and (c) the Southeast Coast Network region is increasingly subject to human development, resulting in diverse anthropogenic effects on park resources (DeVivo et al. 2008).

The NPS I&M Division was created as part of the NPS' efforts to improve park management through greater reliance on scientific knowledge. The Southeast Coast Network developed a suite of conceptual models to support and guide development of a monitoring program for the parks, using a general ecosystem model as a template for specific models of the six dominant ecosystem types found in Southeast Coast Network parks. Congaree National Park has three of these—upland forests, bottomland hardwoods, and rivers & streams. Each model includes a set of system drivers, local drivers, and park resources. Importantly as well, the SECN identified 25 Vital Signs, most of which are being/planned to be monitored as part of the I&M program (Table 42). The ecosystem-centered vital signs span all categories of the ecological monitoring framework: air & climate, geology & soils, water, biological integrity, human use, and ecosystem patterns and processes. Most—air quality, climate, geology & soils, water, and biological integrity (biological resources)— have been discussed in Chapters 2 and 3 of this report. The inventory also covers ecosystem patterns (land use/land cover) and various aspects of human use. Many of the measures were on our preliminary list of potential indicators for the park. For a major subset of these parameters, however, information for the park is not yet available, underscoring the importance of the I&M to establish present natural resource conditions in the park and track them over time to assess park ecosystem health.

**Table 42.** Vital signs identified by the Southeast Coast Network for its inland parks including CONG. 1—Vital Sign for which the SECN has implemented monitoring; 2—Vital Sign that is monitored by a network park, another NPS program, or another federal or state agency. Modified from DeVivo et al. (2008).

| Ecological Monitoring Framework Subcategories | Network Vital Sign | Measures | CONG |
|---|---|---|---|
| Air Quality | Ozone | Atmospheric ozone concentration, damage to sensitive vegetation | 2 |
| | Wet and Dry Deposition | Wet and dry sulfate and nitrate deposition | 2 |
| | Visibility and Particulate Matter | Suite for visibility and fine particulates, particle size analyses: pm 10, pm 2.5, haze index | 2 |
| | Air Contaminants | Concentration of mercury, semi-volatile organic compounds, acidic (N,S) and nutrient (N) components of contaminants | 2 |
| Weather and Climate | Weather and Climate | Air temperature, precipitation, relative humidity, tides, location and magnitude of extreme weather events | 2 |

**Table 42 (continued).** Vital signs identified by the Southeast Coast Network for its inland parks including CONG. 1—Vital Sign for which the SECN has implemented monitoring; 2—Vital Sign that is monitored by a network park, another NPS program, or another federal or state agency. Modified from DeVivo et al. (2008).

| Ecological Monitoring Framework Subcategories | Network Vital Sign | Measures | CONG |
|---|---|---|---|
| Geomorphology | Stream/River Channel Characteristics | Percent cover of coarse woody debris, detritus, distribution and extent of geomorphic features (runs, riffles, pools); grain size distribution; distribution, extent and rate of change of erosion features | 1 |
| Hydrology | Groundwater Dynamics | Water table levels for freshwater and saltwater | 2 |
| | Surface Water Dynamics | Discharge, magnitude and duration of flooding events | 2 |
| Water Quality | Riverine Water Quality | pH, temperature, dissolved oxygen, specific conductance, turbidity, nutrient concentrations | 1 |
| Invasive Species | Invasive/Exotic Plants | Occurrence of invasive plant species | 2 |
| Terrestrial species | Amphibians | Species occurrence, diversity, percent area occupied. | 1 |
| | Breeding Maritime Forest Birds | Species occurrence, diversity, relative abundance | 1 |
| | Plant Communities | Plant species occurrence, diversity; percent cover by herbaceous, shrub and overstory; occurrence of disease, occurrence of insect outbreaks, occurrence of non-native species; NVCS class | 1 |

### *2.3.2. Synopsis of Stressors to Natural Resources*

The present and potential stressors that are affecting or may affect Congaree National Park are summarized in Table 43. Despite the relatively remote and rural location of the park, degraded air quality is already a moderate to significant concern, encompassing ozone and particulate pollution, acidification from N and S chemical species, and reduced visibility. Surface-water quality indicates poor conditions; there are no groundwater-quality data, but groundwater use is mentioned as a potential resource municipalities could tap. Potential pollution sources in the watershed are mostly nonpoint sources such as poultry CAFOs, which are known to cause major adverse impacts on airsheds, soils, and watersheds; cropland runoff; and clearcutting activities from silviculture. Agricultural impacts may have resulted in local extirpations of herpetofauna (Tuberville et al. 2005).

Although the park still is in a rural setting, rapidly growing Columbia is only 32 kilometers (20 mi) away (see Section 2.1 of this Report). Lower Richland County continues to grow. Water demands could be exacerbated in the future depending on allocations to Columbia and other growing population centers. Congaree National Park could also sustain related increases in highway traffic, waste product pollution, noise, and other issues that accompany encroaching urbanization. Other concerns are soil erosion, habitat loss and disruption near the park, and the impacts of exotic/invasive plants and animals which are an identified major concern for park staff (personal communication, L. Serra, SEC-EPMT Liaison, Congaree National Park).

**Table 43.** Current and potential stressors that are affecting or may affect CONG (ND– no data to make judgment; NP–not a problem;– not applicable; EP–existing problem; PP–potential or pending problem).

| Stressor | Surface Waters | Groundwater | Airshed | Forest | Human Health |
|---|---|---|---|---|---|
| Acidification | EP | ND | PP | PP | PP |
| Algal blooms | PP | – | – | – | PP |
| Toxic algae | PP | – | – | – | PP |
| Encroaching development (clearcutting, etc.) | EP | EP | EP | EP | PP |
| Erosion (including dust) | EP | – | – | EP | – |
| Excessive nutrients | EP | ND | PP | – | PP[a] |
| Exotic invasive species[b] | EP | – | – | EP | ND (PP)[c] |
| Fecal bacteria, other microbial pathogens | EP | ND | PP[a] | ND | PP[a] |
| Habitat disruption | EP | ND | – | EP | – |
| Hypoxia | PP | – | – | – | – |
| Light Pollution | EP | – | – | EP | – |
| Metals contamination | PP | PP | PP | PP | PP |
| Noise pollution | ND | – | – | EP | ND |
| Other toxic substances | ND (PP) | ND (PP) | EP | ND (PP) | PP |
| Ozone pollution | – | – | EP | EP | EP |
| Particulate matter pollution | EP | – | EP | – | EP |
| Sedimentation | EP | – | – | PP | – |
| Trash/refuse pollution | ND (PP) | ND (PP) | – | ND (PP) | – |
| Visibility (air pollution) | – | – | EP | EP | EP |
| Water demand | PP | ND (PP) | – | – | PP |

[a] Excessive ammonia and pathogenic bacteria in the airshed from CAFOs represent a human health threat (Donham et al. 2007; Gilchrest et al. 2007; Heederik et al. 2007; Greger and Koneswaran 2010).

[b] Suspected for aquatic resources; known for terrestrial resources.

[c] Includes consideration of West Nile virus, carried by mosquitoes and known to be in S.C.

# 3. Study Scoping and Design

## 3.1. Preliminary Scoping

Former SoutheastCoast Network Program Manager Joe DeVivo organized an initial workshop for this project in Atlanta, wherein we received guidance about the background and foundation of NPS National Resource Condition Assessments. We also received counsel about the best NPS specialists to contact about various aspects of the project, available NPS data, and NPS websites with important information. This meeting addressed all project objectives, especially (ii)—Determine the subset of NPS-identified and PI-identified data and information sources that are most pertinent and useful for developing indicators and performance measures) and (vi)—Conduct a series of workshops to assist in project completion.

In recognition of the fact that park staff hasthe most advanced and comprehensive understanding of the natural resources of Congaree NP, we visited the park and spent several hours with Joe DeVivo, Terry Hogan, David Shelley, Theresa Thom and Theresa Yednock. They took an entire day to brief us on the natural resources of the park, as well as current research conducted at the park. We discussed each category of natural resources, and gained the staff’s perspective about issues for each category that would need to be considered in inventory and assessment efforts. The staff's input was truly essential to enable us to select an optimal set of natural resource indicators that would be the most useful to the park staff both short-term and long-term. We additionally were given guidance on which indicators should be emphasized as major priorities for the park. We were in accord that the indicator framework needed for the park should follow an ecosystem approach as in DeVivo et al. (2008).

An extensive, continued effort over the entire span of the project was then conducted to obtain all manner of natural resource information pertinent to the park—historic information, reports, books, peer-reviewed publications, management plans, GIS data, etc. All of this information was carefully considered in writing the final synthesis of the inventory and status of park natural resources. The findings were presented within an ecosystem framework (Figure 40), considering Congaree National Park as the ecosystem. Following a hierarchical framework patterned after Unnasch et al.’s (2009) *Ecological Integrity Assessment Framework*, we first considered the overall goal(s) of the park staff for the desirable status, i.e., the ecological integrity, of each category of natural resources in the park. *Ecological integrity* is defined here as the ability of an ecological system to support and maintain a community of organisms with species composition, diversity, and functional organization comparable to those of the natural/historic habitats in the park. We then conducted a macroscale inventory of landscape pattern (land cover/land use) surrounding the park; the “human biological factor,” i.e. human population demographics in the area surrounding the park and visitor statistics within the park; air quality (airshed level), water quality (within the park insofar as possible, but considering pollution sources near the park), the soundscape, and the lightscape; and stressors on the natural resources *within* the park. This included a concerted effort to gather and organize existing databases for multiple GIS data layers describing park natural resources. Next, we inventoried what is known about the present composition and condition of the vegetation, habitat structure, and including the natural communities, SoCs, exotic/invasive species, and species of special management concern for park staff. For each category of natural resources, we then identified an indicator or suite of indicators and measures for tracking natural resource health at the park.

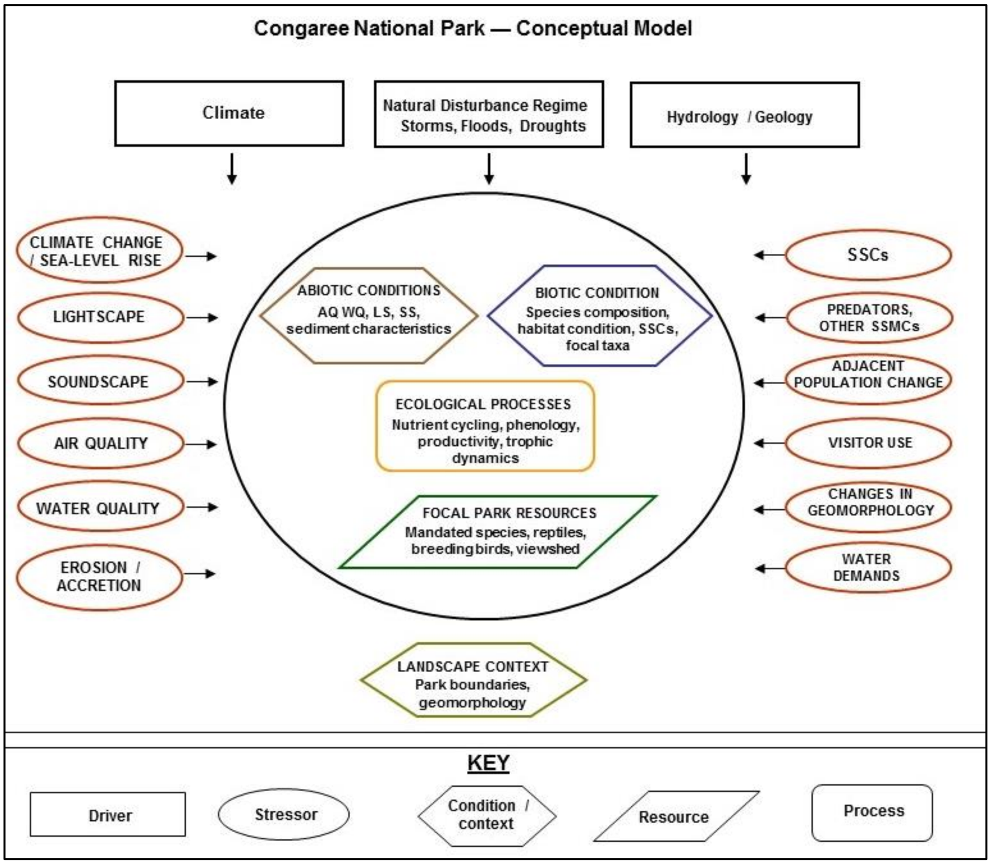


**Figure 40.** Conceptual model of the CONG ecosystem used as a general framework to select indicators of natural resource health for the park. Modified from DeVivo et al. (2008, Appendix: Conceptual Ecological Models; examples of stressors are shown).

These indicators were carefully selected to be scientifically sound while also providing the most user-friendly and straightforward method for evaluation.

Our intentions in meeting the latter requirement were two-fold. First, to provide a suite of indicators and the methods to assess them that park staff and the National Park Service in general will find clear, simple and rapid, and relatively inexpensive to conduct. Second, to provide an indicator system with powerful messages that are easy to explain to policy makers, who often have dramatic influence over our nation's increasingly precious national parks.

As noted by the South Florida Ecosystem Restoration Task Force (2011) from its "System-wide Indicators for Everglades Restoration—2010 Report:

> *Any method of communicating complex scientific and findings to non-scientists [for CONG, the general citizenry, visitors to the park, and politicians who strongly influence critically needed funding for the park] must: (1) be developed with consideration for the specific*

*audience, (2) be transparent as to how the science was used to generate the summary findings, (3) be easy to follow the simplified results back through the analyses and data to see a clear and unambiguous connection to the information used to roll up the results, (4) maintain the credibility of the scientific results without minimizing or distorting the science, and (5) should not be, or appear to be, simply a judgment call (Norton 1998, Dale and Beyeler 2001, Niemi and McDonald 2004, Dennison et al. 2007)….[T]he system must be effective in quickly and accurately getting-the-point-across to the audience in order for the information to be used effectively (Rowan 1991, 1992; Dunwoody 1992; Weigold 2001; Thomas et al. 2006; Dennison et al. 2007).*

*—U.S Department of the Interior Office of Everglades Restoration Initiatives*

Thus, here we use a "stoplight report card system" approach (e.g., Doren et al. 2009b) of good (green), fair (yellow), and poor (red) to summarize our evaluation of present natural resource conditions at Congaree National Park (Table 44). This system has been used with great success to assess natural resource conditions systems such as Chesapeake Bay and its watershed (Williams et al. 2007), and the Florida Everglades ecosystem (Ferriter et al. 2007; Doren et al. 2009 a,b). It is important to note that various indicators developed here to track natural resource conditions in Congaree National Park over time are for factors that are not possible for the National Park Service to control (NPC), because these external factors significantly affect the park.

**Table 44.** The color-coded "stoplight report card" system used to succinctly convey the status of CONG natural resources. Adapted from Ferriter et al. (2007).

| Good | Fair | Poor |
|---|---|---|
| Green | Yellow | Red |

We were instructed by the National Park Service to design indicators that were quantifiable insofar as possible, and supported by peer-reviewed science literature. We therefore clarify, with supporting scientific basis, any suggested indicators for which quantitative information for the park was not available. This stipulation, while logical, greatly restricted the suite of proposed indicators. Therefore, in Chapter 6 we include discussion of data gaps that we view as especially important to fill so that much-needed indicators can be developed. Finally, to ensure that the data used to develop the indicators and assessment were of acceptable quality, we restricted our inventory and this analysis to reliable sources (e.g., National Park Service, peer-reviewed literature, quality assured-quality controlled water-quality data), and to data collected by those sources within the past decade. This indicator framework and suite of indicators for the park support the identified goals of the National Park Service to "develop service-wide products that improve management of biological resources in parks, and maintain a broad ecosystem-based framework for park management (Unnasch et al. 2009)."

## 3.2. GIS Data Layers

### *3.2.1. Data Selection and Acquisition*

Data files available through NPS personnel were pared down to those relevant to natural resource management concerns. An FTP site was set up for file transfer from NPS personnel to the Center for Applied Aquatic Ecology (CAAE) server. Data considered necessary for specific analytical or display purposes, but unavailable from NPS files, were obtained from external databases. The databases that provided statewide data for use in assessing Congaree National Park included:

- National Land Cover Database 2006 (Fry et al. 2011) provided through the Multi-Resolution Land Characterization (MRLC) consortium (USGS 2015);
- Statewide hydrology, elevation, geographic names and government unit file were obtained from the South Carolina DHEC (SCDHEC 2016);
- National Wetlands Inventory (NWI), Critical Habitat, National Wildlife Refuge Boundaries, and Wilderness Preserve Boundaries were obtained from U.S. Fish and Wildlife (USFW 2016); and
- 2010 U.S. Census Population Density data obtained from U.S. Census Bureau (USCB 2016).

NPScape should also be mentioned here: It is a landscape dynamics monitoring project of the NPS that produces and delivers to parks a suite of landscape-scale datasets, maps, reports, and other products to inform resource management and planning at local, regional, and national scales. Initial analyses include six major categories (population, housing, roads, land cover, pattern, and conservation status) that broadly address the environmental drivers, natural attributes, and conservation context of the parks. In aggregate, these measures contribute to assessments of current natural resource status, potential threats, and conservation vulnerability and opportunity (NPS 2017f).

### *3.2.2. Database Management*

Each file was accessed and reviewed for spatial reference and availability, and accuracy of metadata. Where necessary, files were copied and post-processed to merge into a cohesive database for across-the-board integration in map-making and analyses. Aerial imagery was examined in ArcMap (ESRI 2011) and orthorectified where necessary.

Organizational efforts were made to maintain copies of NPS data in an “unadulterated” form digitally segregated from data that had been geoprocessed or created by the CAAE, while maintaining a logical directory structure. We separately maintained oversight of CAAE GIS systems (software and hardware), GIS computer hardware upkeep and maintenance, troubleshooting/updating of ArcGIS software, and, as needed, addressed any other database management requirements for spatial data amassed by CAAE staff.

### *3.2.3. Map Generation*

Maps depicting various geographic themes were developed for Congaree National Park, including soils, geology, hydrology, wetlands, population density, and land use coverage/change in the park, sub-watershed, and/or overall river basin. The maps were designed to address points of interest specific to the park, and to illustrate geographic positioning of known site localities and/or regional relationships.

# 4. Indicators to Assess Natural Resource Conditions

## 4.1. Landscape Dynamics in the Surrounding Watershed

Landscape dynamics refers to changes in natural land cover types and human land use (Piekielek and Hansen 2012). Many protected areas are incomplete "pieces" of larger surrounding ecosystems that are unprotected from human impacts (Hansen et al. 2011). The National Park Service has long recognized the need to create protective buffer areas around national parks, but private land rights issues since the 1980s, together with increasingly expensive land in many locations, have made this prospect untenable (Hansen et al. 2011). Thus, surrounding land-use intensification increasingly threatens many protected areas, and landscape dynamics have been identified as a high-priority indicator for national parks (Piekielek and Hansen 2012, p.13):

> *Habitat destruction and fragmentation are the leading causes of species loss globally, and many protected areas are experiencing declines in biodiversity as a result of human activity on surrounding lands (Newmark 1985, Parks and Harcourt 2002, Sanchez-Azofeifa et al. 2003)…[R]ecent studies have documented rates of land use change around U.S. national parks that exceed national or regional averages (Wade and Theobald 2009, Radeloff et al. 2010, Davis and Hansen 2011).*

### *4.1.1. Human Population in the Surrounding Area*

<u>Issue</u>: Population size and rate of growth have been strongly linked to adverse ecosystem impacts. Congaree National Park's rural setting is threatened by the associated effects of a rapid population growth from the Columbia Metropolitan Area.

Human-related land transformation is the primary driving force in the loss of biological diversity worldwide (Vitousek et al. 1997). The size, density, and rate of growth of the human population in a given area have been strongly linked to rapidly escalating environmental disruption (Ehrlich and Holdren 1971) and exotic plant species diversity and abundance (McKinney 2001). As noted by Meyer and Turner (1992), "population remains one of the few candidate driving forces that is readily measured and for which statistical associations have been found with ecosystem decline." The human population size, growth, and density surrounding national parks are unquestionably major influences on the park ecosystems. Thus, Rivard et al. (2000) found that species richness, extirpations, and alterations within other national parks were all strongly related to characteristics of the lands surrounding the parks. In addition, species invasions and introductions were more frequent in parks that were subject to the most human influence.

Although the science literature is replete with reports about environmental degradation linked to increasing human population density (HPD), information is mostly lacking about the quantitative level of HPD that acts as a threshold triggering significant damage to the adjacent natural ecosystem. Luck (2007) summarized the issue as follows: "…clear and predictable links between human population dynamics and environmental change remain elusive largely because of the complexity of the human enterprise and its many and varied impacts on nature" (Figure 41). Viewed from a quantitative standpoint, impacts of high HPD can extend many kilometers beyond city boundaries

(Myers 1994, Repetto 1994), but the effects can vary from minor to major in areas of lower HPD, largely depending on the main land use (Luck 2007, and references therein).

Context is also important: For example, a marked increase in HPD near a wilderness reserve would be expected to have quite different impacts than if the increase occurred near a city park. This difference is especially true of the rate of change: Nonnative species introductions (McKinney 2001) and species extinctions (Balmford 1996) have occurred faster in more rapidly growing areas with lower human population than in highly populated areas. Socioeconomics can also be an important influence on the degree of environmental impact, which has been shown to be higher per capita in economically depressed areas for reasons ranging from limited economic means to protect natural resources, to environmental injustice (Blaikie and Brookfield 1987, Durning 1989, Allen and Hoekstra 1991).

Regardless of these complexities, we felt it important to represent HPD and human population growth (HPG) as indicators of natural resource health in the park, to account for the fact that human population impacts on adjacent natural resources are not fully captured by related indicators such as land use (Figure 41). In addition, it generally can be stated with confidence that HPG results in increasing land changes and exotic species introductions; and that land protected for conservation is often greatly reduced near human population centers (Luck 2007).

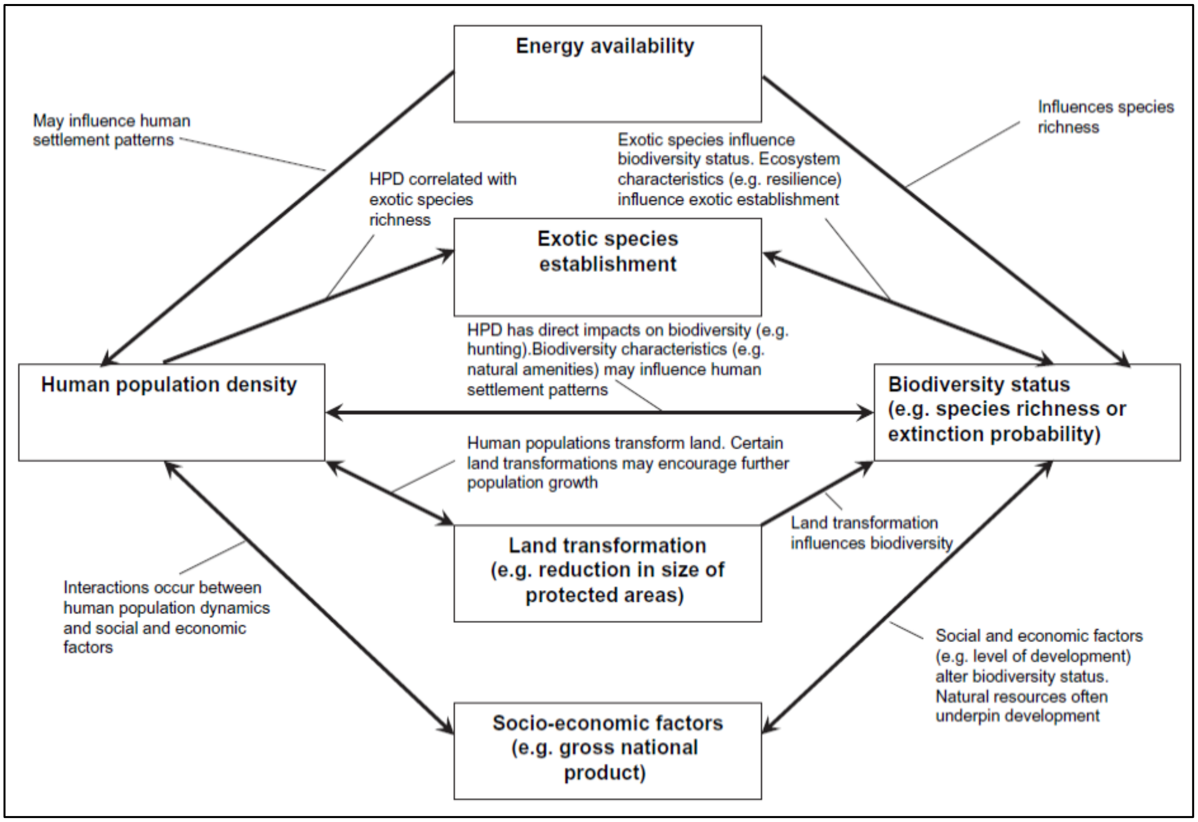


**Figure 41.** A schematic of possible relationships between human population density and biodiversity, especially focusing on the negative impacts of human population growth. The evidence for each of these relationships varies in the literature. The diagram includes biodiversity feedback loops, but not interconnections between energy availability, exotic species establishment, land transformation and socioeconomic factors. From Luck (2007), with permission.

Our evaluation system for human population indicators in the park considered the following information:

- Richland County (Figure 42) has a growing human population, 399,256 people as of 2013. The population density (HPD) is high, 198.5 people per square kilometer (514 people/mi$^2$). By comparison, the national average HPD in the past decade (2001–2010) was 31.4 people per square kilometer (81.3 people/mi$^2$).
- From April 2010 to July 2013, Richland County sustained a 3.8% increase in human population (about 1.3% per year). By comparison, the national average over the same period was a 9.71% increase in HPG, or about 1% increase per year.
- Richland County is moderately depressed economically; the median household income in 2008–2012 was $49,131; less than the national median over the same period ($52,703). Annual unemployment was 7.2% in 2013. Unemployment in Columbia, South Carolina, 32.2 kilometers (20 mi) northwest of Congaree National Park, is 7.2%, and median household income was $48,763 in 2012. (U.S. Census Records and Department of Numbers web site

[www.deptofnumbers.com]). Furthermore, Columbia has grown only 7.46% since 2000 (CLR 2017).

- As mentioned, Columbia, South Carolina is about 32.2 kilometers (20 mi) away (population 132,094 as of 2012; the city increased 2.6% from 2010–2013). The Columbia Metropolitan Statistical Area (MSA) includes Fairfield, Kershaw, Richland, Lexington, Saluda, and Calhoun counties, and its total population as of 2013 was 793,779 (83.3 per square kilometer, or 216 per mi$^2$). It is the second-largest MSA in South Carolina. The median household income of the Columbia MSA is $47,002, about 3% less than that of Richland County. The Columbia MSA grew 17.9**%** from 1990–2000 (549,000 to 647,000 people) and 18.6% from 2000–2010 (647,000 to 768,000) (USCB 2012; (City Population 2017; Forbes 2016).
- As an historic "reference" condition, about 500 years ago the HPD of the area was 0.9 people per square kilometer (2.3 people/mi$^2$) (area of the Southeast Region from Burkett et al. 2001; number of Native Americans in that region is from Fagan 1995, Smith 2000).
- Analysis of 24 present-day, relatively remote wilderness areas revealed that all had population densities of ≤ 5 people per square kilometer (12.8 people/mi$^2$; Mittermeier et al. 2003). It would be expected that present-day conditions, even in areas considered somewhat "remote," would have substantially higher human population density than did the southeastern U.S. about 500 years ago.
- Over the past decade (2001–2010), the national average for population growth was 9.71%, (1% per year), and the average HPD was 31.3 people per square kilometer (81.3 people/mi$^2$). The 1% per year value was used in developing the evaluation system for HPG; we centered the middle category, fair, around this value (0.8 to 1.2% per yr). Considering this information collectively, for HPG we centered the middle evaluation category, fair, around the +1% per year national average (0.8 to 1.2% increase/year).

For HPD we set the good category cutoff at ≤ 5 people per square kilometer (13 people per mi$^2$), comparable to present-day conditions near the above-mentioned wilderness areas. Fair was set to the high end of the range of the average for South Carolina excluding population centers, based on Figure 42 (40 people per km$^2$, or 100 people per mile$^2$). The evaluation of the five selected human population indicators in relation to Congaree National Park is shown in Tables 46a–c. All five indicators yielded a poor evaluation; thus, the overall evaluation of surrounding human population impact condition affecting Congaree National Park is poor.

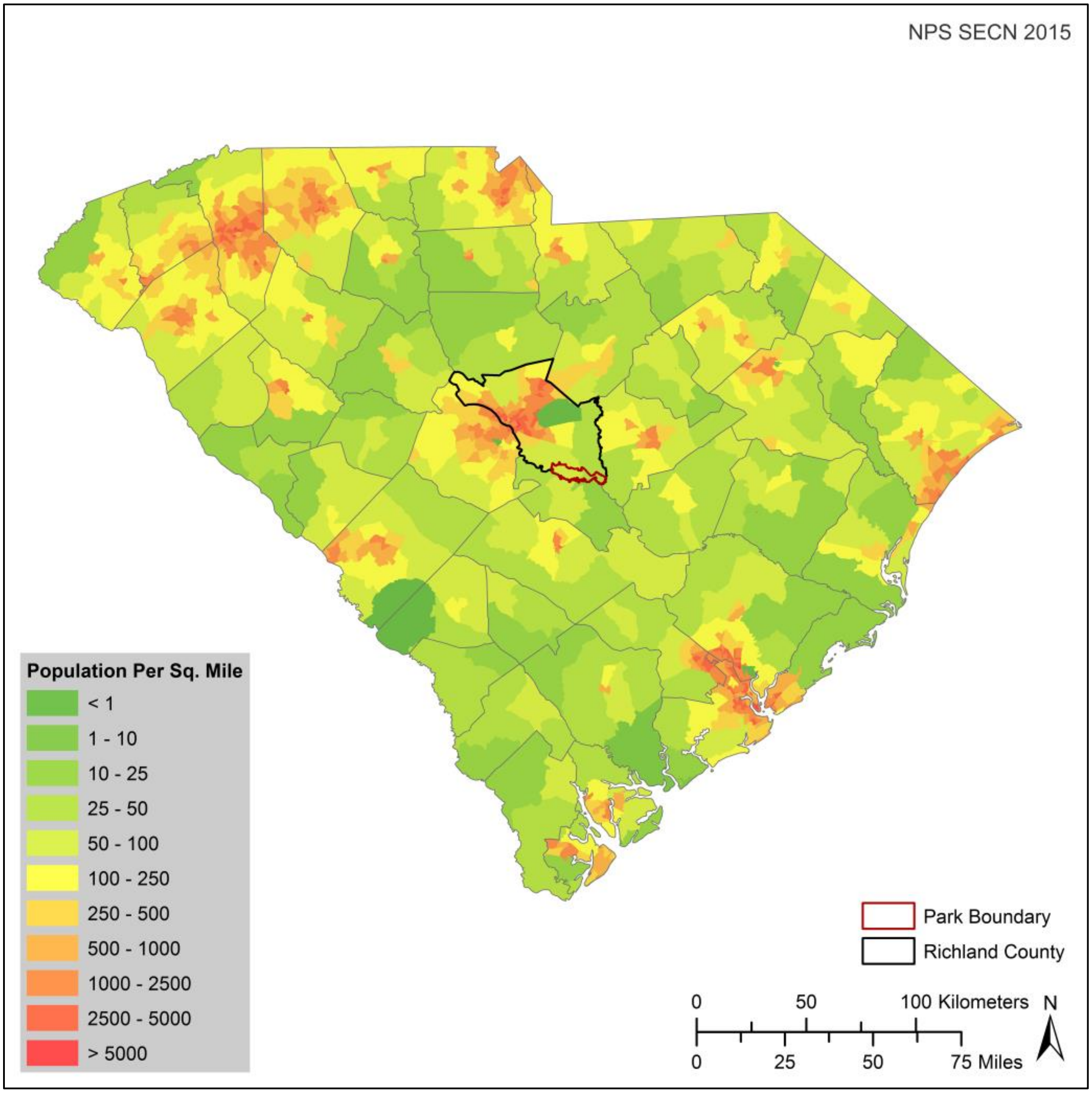


**Figure 42.** Human population distribution in South Carolina as of 2000; although somewhat outdated, it provides a general indication of the locations of population centers. Note that in the southern tip of Richland County the population density is 9.7–19.3 people per $km^2$ (25–50 people per $mile^2$). Modified by the NPS from the New World Encyclopedia (New World Encyclopedia 2017).

### *4.1.2. Visitors and Human Population within the Park*

Issue: Although the NPS mission is partly centered on excellence in service for park visitors, visitors have been shown to negatively impact another key portion of the agency's mission, to protect natural and cultural resources.

Visitors' impacts are identified by the National Park Service as among the Top Ten Issues for National Parks (National Geographic 2010; also see Buckley 2003; Taylor and Knight 2003; Park et al. 2008). The two central portions of the NPS mission statement are in conflict especially when visitor pressure is high. On the other hand, an economic analysis indicated that the 109,685 visitors to the park in 2012 spent nearly $5,150 and generated 66 jobs, for an overall positive impact (Cullinane et al. 2014) in the immediate area.

**Table 45a.** The reference criteria used to evaluate the population conditions surrounding Congaree NP.

| Indicator | Good[1] | Fair | Poor[1] |
|---|---|---|---|
| Human Population Growth within a 5-km (3.1-mile) radius ($HPG_{5\text{-km}}$) | < 0.8%/yr | > 0.8 to 1.2%/yr | > 1.2%/yr |
| Human Population Growth within an 80-km (50-mile) radius ($HPG_{80\text{-km}}$) | < 0.8%/yr | > 0.8 to 1.2%/yr | > 1.2%/yr |
| Human Population Density within a 5-km (3.1-mile) radius ($HPD_{5\text{-km}}$) | < 5 people/km$^2$ | > 5 to 40/km2 | > 40 per m$^2$ |
| Human Population Density within an 80-km (50-mile) radius ($HPD_{80\text{-km}}$) | < 5 people/km$^2$ | > 5 to 40/km2 | > 40 per m$^2$ |

[1] For this condition, good—minimal adverse impact, whereas poor—maximal adverse impact

**Table 45b**. The present surrounding population condition at Congaree NP, evaluated by the indicators in Table 45a.

| Indicator | Congaree evaluation | Rating |
|---|---|---|
| $HPG_{5\text{-km}}$ | Increasing 1.3% per year (average, 2010–2013) for Richland County | poor |
| $HPG_{80\text{-km}}$ | Increasing 1.9% per year (CMSA, past decade) | poor |
| $HPD_{5\text{-km}}$ | Richland County: 198 people/km$^2$ (514 people/mile$^2$) | poor |
| $HPD_{80\text{-km}}$ | CMSA: 83 people/km$^2$ (216 people/mile$^2$) | poor |
| **Overall condition rating** | | **poor** |

**Table 45c.** The overall evaluation of the present surrounding population condition in Congaree NP, based on the four indicators in Table 45b.

| Rating | Criteria |
|---|---|
| Good | $HPG_{5\text{-km}}$, $HPD_{5\text{-km}}$ both good, ≤ 2 others good, ≤ 1 fair, none poor |
| Fair | ≤ 2 fair, ≤ 1 poor |
| Poor | ≥ 2 poor |

The annual visitor number per area was estimated by dividing the number of visitors by the total park area. This approach tacitly assumes that visitors use all areas of the park equally; unrealistic because many visitors concentrate in certain areas such as trails. Therefore, the approach underestimates visitor pressure in the highly used areas, but enables a straightforward calculation of visitor pressure for the park. The final indicator, visitor pressure on trails, would be more realistic than visitor number per area (because people concentrate in trail areas). A similar approach was followed as for visitor number per area, using trail length rather than area. For these calculations, we assumed that two-thirds of the 120,340 visitors per year (as of 2013) use the trails. Evaluation of overall visitation condition in Congaree National Park is outlined in Tables 46a–c.

Additionally, two points should be noted: First, trail-side damage from recreational activities has been identified as a concern of park staff. More specific information about the damage along park trails and the incidence/damage of social trails is not available. Data on these issues would enable development of indicators specific to protecting authentic trails and eliminating (insofar as possible) social trails. Second, this visitation condition is intended to serve as a "place holder" until park staff can develop an RSS, including a targeted recreational carrying capacity for the park. This target could be developed, for example, following Cole and Thomas (2010). It would also be helpful for park staff to collect data on trail damage, if any, and trash left in the park to strengthen the visitation condition index.

Our evaluation of visitation condition is based on three indicators, which are detailed in Table 46a.

**Table 46a.** The three indicators used to evaluate visitation conditions in Congaree NP.

| Indicator | Good | Fair | Poor |
|---|---|---|---|
| Trend In Number of Visitors/Year (VIS) | VIS trend decreasing or no change | VIS trend decreasing | VIS trend increasing or no change |
| Visitor Pressure per Unit Area (VP-AYEAR) | < 10 visitors/hectare/day | ≥ 10 to 25 visitors/hectare/day | > 25 visitors/hectare/day |
| Visitor Pressure on Trails (VP-TYEAR) | < 5 visitors/km of trail/day | ≥ 5 to 15 visitors/km of trail/day | > 15 visitors/km of trail.day |

**Table 46b.** The present visitation conditions in Congaree NP, evaluated by the indicators in Table 46a.

| Indicator | Congaree evaluation | Rating |
|---|---|---|
| VIS | 120,340 visitors in 2013 (NPS statistics, visitor average from 2000–2013 is 113,106 per year | good |
| VP-AYEAR | Total park area is 10,742 hectares (24,546 acres) with average of 11.2 visitors/hectare/year or 0.03 visitors/hectare/day (4.9 visitors/acre/year or 0.01 visitors/acre/day). | good |
| VP-TYEAR | Visitation is fairly evenly distributed throughout the year on 32 km (20 miles) of trails. Assuming two thirds of visitors use the trails, CONG has 2,507 visitors/km of trail/year and 7 visitors/km of trail/day (4,011 visitors/mile of trail/year and 11 visitors/mile of trail/day). | fair |
| **Overall condition rating** | | **good** |

**Table 46c.** The overall evaluation of the present visitation condition in Congaree NP, based on the three indicators in Table 46a.

| Rating | Criteria |
|---|---|
| good | ≥ 2 indicators good, none poor |
| fair | ≥ 2 indicators fair or good, 1 poor |
| poor | ≥ 2 indicators poor |

## 4.2. Land Use and Land Cover

Issue: Watershed land use and land cover strongly affects the habitat quality and integrity of terrestrial and aquatic ecosystems. Congaree National Park is in an area that may be targeted for development due to sprawl from the Columbia Metropolitan area.

Changes in the composition and configuration of different land cover types within and adjacent to national parks has been shown to greatly affect biological and physical processes within those parks, such as habitat availability, animal movements, potential for invasion by nonnative plants, water quality, and in-stream habitat for fish and other aquatic life (NPS 2012). Information about changes and trends in landscape-scale indicators in and around parks can help park managers anticipate, plan for, and manage associated effects to park resources.

Changes in land use/land cover over time, especially loss of "green" or natural categories through increase in two land use/land cover categories—urbanization and agriculture—are increasingly used as broad-scale predictors of watershed conditions and ecosystem health (King et al. 2005, Rothenberger et al. 2009). Nonpoint-source pollution—especially from urban/ suburban areas, croplands (including silviculture), and industrialized animal production—has been identified as the greatest threat to water quality in the U.S. (EPA 1994b).

### *4.2.1. Agriculture*

Industrialized Animal Production

Major changes resulting from conversion of natural lands to agricultural use include soil erosion, chemical contamination of those lands and receiving waters, and increased water demands. Chemical contaminants—pesticides, fertilizers, heavy metals from animal feeds, etc.—cause diverse acute and chronic impacts on water quality and quantity, soil quality, air quality, pollination by beneficial fauna, seed dispersal, biodiversity, and habitat loss (Pickett et al. 2001, and references therein).

Land use/land cover information is deceiving when considering impacts from industrialized animal production. The information presented in Table 47 shows that confined animal feed operations occupy very little of the Congaree and Lower Wateree sub-watersheds. However, it would be a major mistake to infer from that information that CAFOs are a negligible problem with respect to environmental impacts; CAFOs, by design, force large numbers of animals into a small land area (Burkholder et al. 1997, Mallin 2000). There are ten animal agriculture operations (eight poultry, one quail and one horse) within 16 kilometers (10 mi) of the park within the three sub-watersheds surrounding the park (Table 47). Poultry CAFOs are a serious potential source of pathogens that cause human disease, including antibiotic-resistant microorganisms (Burkholder et al. 1997; Gilchrist et al. 2007). The correct inference, given the density of poultry CAFOs in the Congaree River Watershed and the known, extreme impacts of even a few CAFOs on adjacent waters, air, and soils (Burkholder et al. 2007 and references therein), is that the CAFOs upstream from the park represent an environmental threat to the park and should be investigated (Table 49) (Mallin and McIver 2010).

Confined poultry operations of industrialized agriculture, found mostly upstream from the park (Table 49), produce high quantities of effluent and manure (Burkholder et al. 1997, Mallin 2000, Burkholder et al. 2007 and references therein). Most of the solids settle out to the bottom of storage lagoons . The liquid and remaining suspended solids are sprayed onto small land areas ("spray-fields") that, in eastern North Carolina, for example, characteristically have a thin soil layer overlying a shallow water table (1 m or 3 ft from the land surface). Studies repeatedly have demonstrated that the shallow soil layer simply cannot absorb the massive wastes (Burkholder et al. 2007 and references therein). The Congaree River receives animal wastes from CAFOs in the watershed via runoff during precipitation events and via percolation through the shallow soil layer to the surficial groundwater (as in Null et al. 2011; note that groundwater contributes 50% of the flow in streams of the Coastal Plain during low-flow periods—Spruill et al. 1996, Spruill and Bratton 2008).

As shown in Table 47, the park lies only a short distance (1 to 30 kilometer, or 0.6 to 19 mi) from eight poultry CAFOs, one quail farm, and one horse stable. South Carolina is 11th in poultry (broiler) production among the states (USDA National Agricultural Statistics Service [NASS] 2013). The state officially does not permit agriculture facilities to discharge into waters of the state, but state does not consider the following non-swine facilities below to be CAFOs, even though they are permitted to operate barns, stables, pens, growing houses, lagoons, waste storage ponds and/or manure utilization areas at a 30.5-m (100-ft) setback from surface waters of the state (USB Environmental Audit, South Carolina State Summary).

**Table 47.** Confined animal feed operations (CAFOs) in the three CONG subwatersheds within 16 km (10 mi) of the park boundaries (SCDHEC 2016).

| CAFO | Ag operation | NPDES ID | Latitude | Longitude |
|---|---|---|---|---|
| Shealy Broiler Farm | poultry | ND0080543 | 33.726 | -80.672 |
| Walker Poultry | poultry | ND0072923 | 33.832 | -80.543 |
| Drake Farms | poultry | ND0082210 | 33.712 | -80.900 |
| Pounderosa Farms | poultry | ND0084310 | 33.712 | -80.900 |
| Sunnyview Farm | poultry | ND0010057 | 33.712 | -80.885 |
| Hamilton Stables | horse | ND0086428 | 33.899 | -80.726 |
| Zeigler Poultry Farm | poultry | ND0085979 | 33.711 | -80.893 |
| Woodward Vale/Broiler Facility | poultry | ND0068268 | 33.821 | -80.677 |
| Manchester Farms | quail | ND0072494 | 33.818 | -80.709 |
| Prickett Poultry Farm | poultry | ND0084581 | 33.695 | -80.819 |

Cropland Agriculture

Cropland agriculture represents 5.8% of the land use/land cover in the park sub-watersheds (Figure 5). Although agricultural land use has been clearly related to environmental degradation, thresholds in the percent land use linked to significant change in ecosystem health are seldom reported, likely because adverse impacts occur at very low levels of natural land conversion to agriculture. Thus, Hagen et al. (2010) documented major impacts on streams at a level of “light” (percentage undefined) agricultural land use in cropland. As another example, Cuffney et al. (2005) assessed invertebrates and algae in stream sites across a gradient of agricultural land use. The data suggested a threshold response with precipitous declines in biological metrics at low levels of agricultural intensity, for example, at 5% land use/land cover or less. Considering that nearly 5.8% of the land drained by the Congaree River is in cropland agriculture, the water quality and biota of Congaree River in the park are sustaining potentially adverse impacts from cropland runoff.

#### *4.2.2. Impervious Cover*

While urbanization is presently a minor influence in the surrounding lands affecting the park, urbanization is expected to become an increasingly important influence on the park within the coming one-two decades. South Carolina has overall 4.4% impervious cover statewide with 17.1% impervious cover within urban land use (Nowak and Greenfield 2012). The following information is included to assist in tracking natural resource health in the park over time.

Entire ecosystems, including all components from soil, air, and water to biota, have been “drastically modified” (Pickett et al. 2001) by watershed urbanization, in comparison to ecosystems in watersheds dominated by natural land cover or cropland cultivation (Paul and Meyer 2001). In the U.S. and other industrialized nations, conversion of land to urban/suburban development is growing more rapidly than the populations in urban areas, leading to increased urban sprawl and fragmentation of remaining green spaces (Makse et al. 1995). Urbanization severely degrades aquatic communities and terrestrial ecosystems (Garie and McIntosh 1986, Pickett et al. 2001, and references therein, Zielinski 2002). Increased urbanization promotes an increase in avian biomass but a reduction in species richness, and selection for omnivorous, granivorous, and cavity-nesting species (Chace and Walsh 2006). Analogous findings have been reported for a wide array of aquatic and terrestrial biota.

The percentage of impervious cover (IC) in particular—roads, parking lots, building roofs, etc.—has been a reliable “barometer” for ecosystem health in urbanizing areas. IC blocks water and associated pollutants from being able to percolate through soil, resulting in rapid transport of much higher volumes and pollutant loads directly to receiving surface waters. As a typical example, the total volume of pollutant-laden runoff from a 0.4-hectare (1-ac) parking lot was 16-fold more than the runoff from an undeveloped meadow (Schueler 1994; EPA 2001). Impervious cover thresholds have been developed for ecological damage, especially focusing on stream ecosystems. In fact, the term “urban stream syndrome” has been used to describe the state of ecological degradation common for “city streams” worldwide (Meyer et al. 2005). Key features are low species diversity, dominance of pollution-tolerant taxa, poor water quality, and degraded physical habitat (Schueler et al. 2009, and references therein). Schueler et al. (2009) developed an empirical impervious cover model (ICM;

Figure 43) that is improved over Schueler (1994), which is much more often cited; Schueler (1994) set a threshold of 10% as the initial IC at which adverse impacts on stream biota occur, but it turns out that that threshold was too high to protect sensitive aquatic life from urbanization impacts.

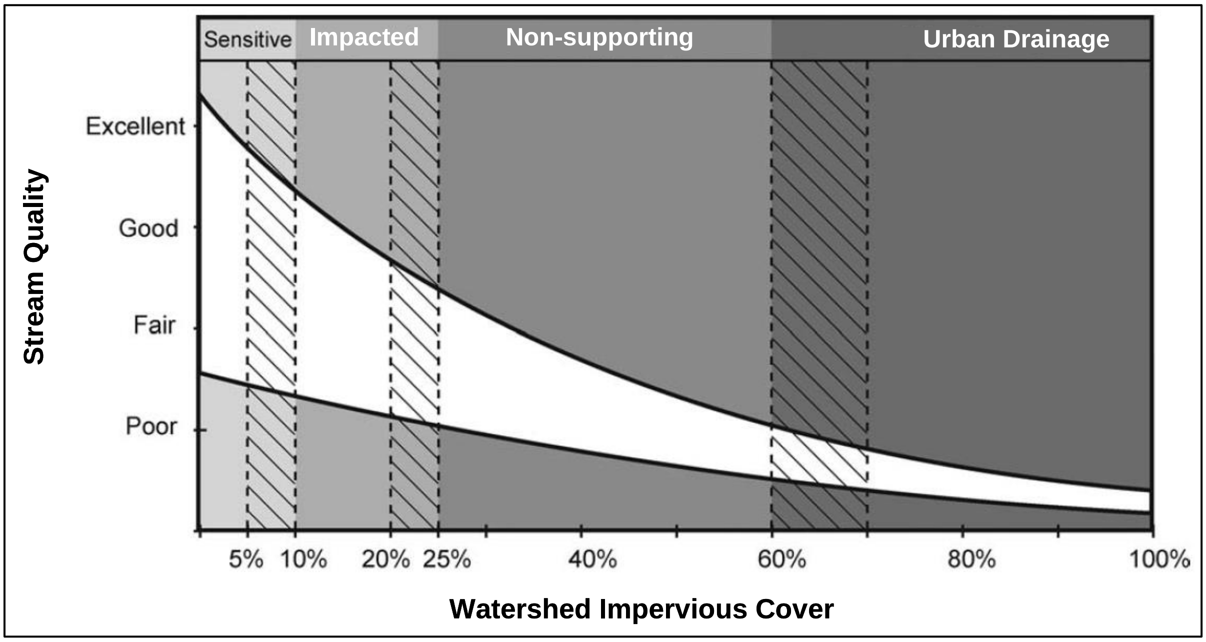


**Figure 43.** A widely used Impervious Cover Model (ICM) of stream quality and macroinvertebrate community response to urban development as the percentage of impervious cover in a given watershed or sub-watershed. Modified from Schueler et al. (2009).

Schuler et al. (2009) based his refined empirical ICM on data for many streams which indicated that detectable stream degradation generally occurs—sometimes described as "greatly depressed ecosystem health"—when the IC of a given watershed is 7 to 10% (overall range 2–15%; e.g., Booth and Reinelt 1993; Booth and Jackson 1994; Shaver et al. 1994; Booth and Jackson 1997; Wang et al. 1997; Mallin et al. 2000). The IC thresholds in these ICMs depended on the specific biological indicator, the ecoregion, and the history of watershed land use: Lower IC thresholds were found for streams in watersheds that had extensive forests or natural vegetation cover prior to urban development. Higher IC thresholds characterized streams in watersheds that had extensive prior disturbance (e.g., croplands) prior to urbanization (Harding et al. 1998; Ourso and Frenzel 2003; Cuffney et al. 2005) because the macroinvertebrate communities had already lost sensitive species to stressors from the pre-urban agricultural land use (Coles et al. 2012).

An underlying, widely accepted assumption in efforts to determine the first threshold for decline of stream biota in response to urbanization is that the "biological communities are resistant to change at low levels of urban development. Then, as levels of urban development increase, a period of rapid degradation occurs in the community condition, ending in a period of exhaustion when no further change occurs" (Coles et al. 2012; Figure 44). However, a detailed recent analysis conducted by the USGS, involving multiple study regions across the nation, found no evidence of a resistance threshold nor an exhaustion threshold. Instead, beneficial macroinvertebrate communities declined in response to very low levels of urbanization, so that stream macroinvertebrates showed a linear rather than threshold response to urbanization (Figure 45; also see Moore and Palmer 2005). The authors concluded that stream macroinvertebrate communities are much more sensitive to urbanization than previously thought (Coles et al. 2012). In fact, at 10% IC, the macroinvertebrate community composition had already decreased by 25%. The lack of an exhaustion threshold was also considered important, because it indicates that stream rehabilitation efforts have a high probability of improving biological condition (Coles et al. 2012). In other words, the data from this study indicate that, if given a chance, many streams can recover from "urban syndrome."

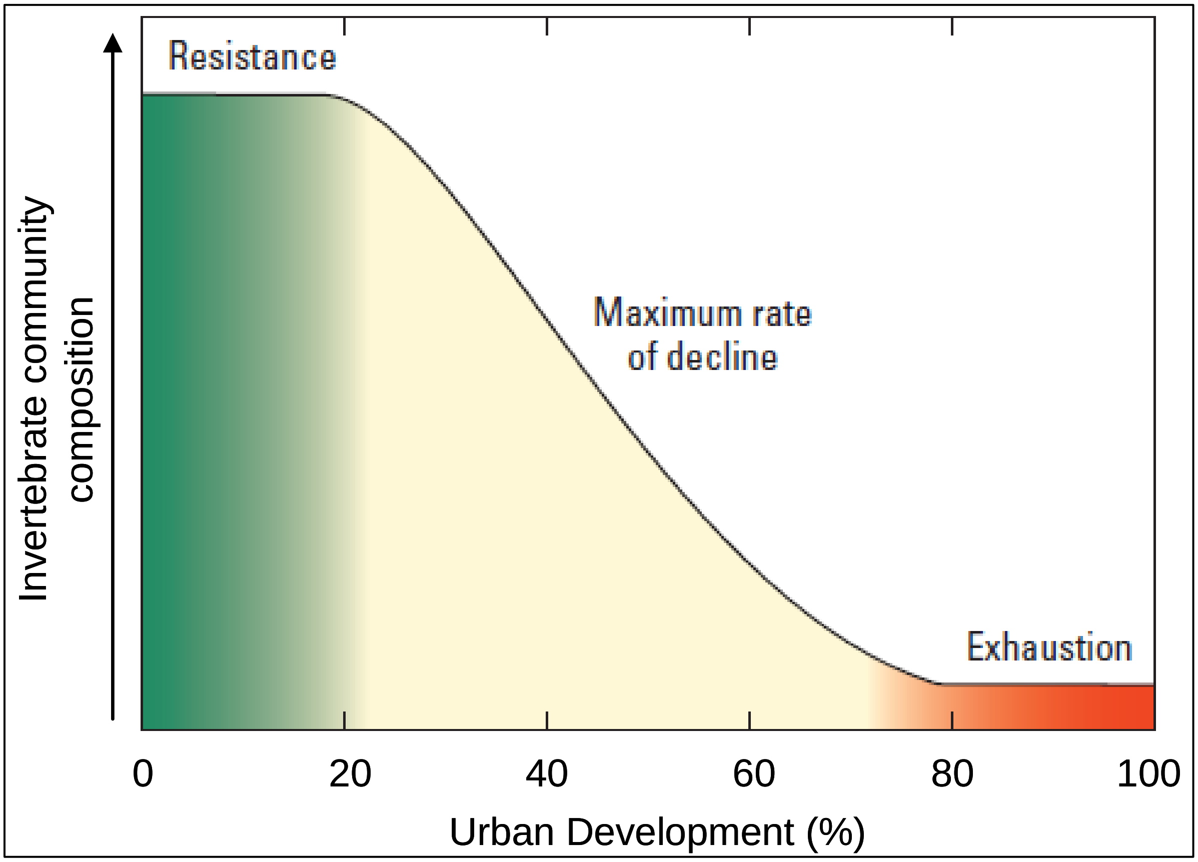


**Figure 44.** Previous widely accepted conceptual model of the response of stream biota to urban development—now questioned. Modified from Coles et al. (2012).

This background information is included here because IC thresholds to protect ecosystem health have mostly been based on the ICM approach, using a first threshold of 10% IC as good, and a second threshold of 20–25% as fair. The approach recently was re-evaluated as insufficiently protective, both the formerly accepted 10% IC primary threshold and the 20–25% IC secondary threshold (Coles et al. 2012). Regarding the latter, 20–25% IC would protect only highly tolerant biota from stress, disease and death due to urbanization impacts (Weaver and Garman 1994). Stream biological metrics were described as consistently shifting to poor condition at 20–25% watershed IC (Wang et al. 1997; Collier and Clements 2011; Cole et al. 2012).

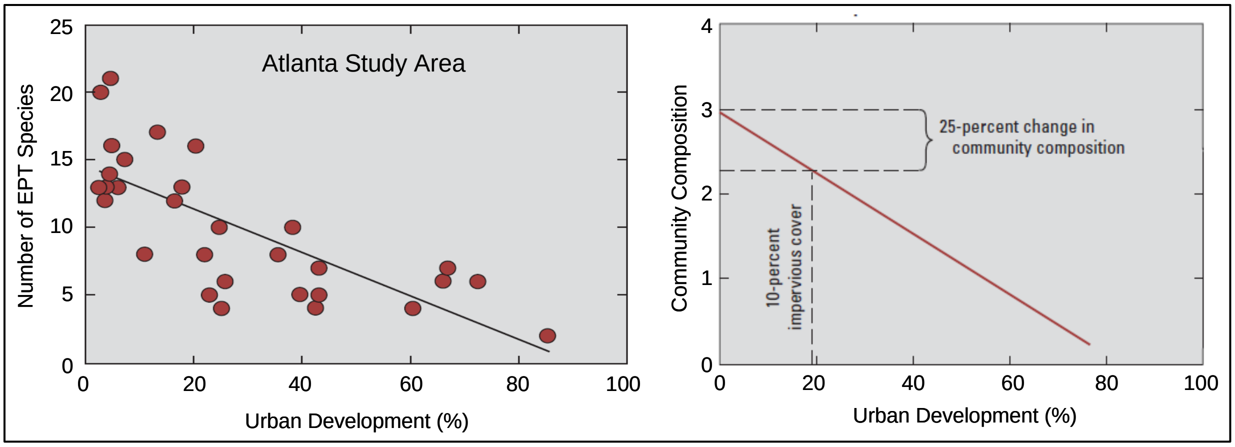


**Figure 45.** Response of Ephemeroptera, Plecoptera, and Trichoptera to urbanization. Left: Response of EPT species (Ephemeroptera—mayflies, Plecoptera—stoneflies, and Trichoptera—caddisflies) to urbanization in the Atlanta area. Many of these species are sensitive to contaminants, changes in stream flow, and other stressors caused by urbanization, and have been lost from streams in the Atlanta area. Right panel: Generalized schematic from the USGS (Coles et al. 2012). Right: Similar response of invertebrate communities to urban development in the Boston area: Note that at 10% impervious cover (= less than 20% urban development), the community composition had declined by 25%. Modified from Coles et al. (2012).

#### *4.2.3. Indicators for Land Use and Land Cover Influence*

Congaree National Park at present is influenced mostly by urbanizing development and by industrialized poultry production. In the coming decades, because of rapidly developing southeastern portion of Columbia and the CMA, the expected continued sprawl and associated supporting infrastructure northwest from the park has been identified as a major concern by park staff (personal communication, S. Kidd, Acting Chief, Integrated Natural Resources, Congaree National Park, 2014).

It is recommended that the following indicators and ratings should be tracked at 10-year intervals, or at 5-year intervals if park staff consider that more desirable. The greatest concern for agricultural impacts is from upstream/up-airshed CAFOs. It is assumed that loss, over time, of agricultural lands near the park will occur through urban/suburban development. The indicators describe conditions that are often economically difficult or impossible to reverse. Therefore, the good rankings are conservatively defined toward the goal of maximizing protection of the park.

Agricultural Land Use/Land Cover (IC)

Considering the above information, indicators were developed for assessing the potential impacts of both poultry CAFOs and croplands on Congaree National Park as described in Table 49a:

The Congaree River and Lower Wateree sub-watersheds, which include the park, have seven CAFOs located within ten kilometers (6 mi) upstream from the park. Croplands are within five kilometers (3 mi) upstream from the park (Figure 5), and croplands are 5.8% of the land use/land cover in the Cedar Creek, Toms Creek and Lower Wateree River sub-watersheds that includes the park. Therefore, both agricultural land use/land cover indicators are evaluated as poor.

Urbanization and Impervious Cover

Viewed from a natural resource protection standpoint, as explained above, it is not scientifically supported to evaluate a 25% loss in stream macroinvertebrate community composition with 10% IC in a given watershed as good. In fact, Figure 43, a widely accepted ICM, suggests that at 10% IC, streams develop "detectable" to "greatly depressed" ecosystem health. Although the lower end of range of percentage IC at which ecosystem health is seriously impacted is broad (2–15%), it also seems reasonable to err on the side of caution to afford more protection for the nation's national parks—especially in a park with a wilderness area such as Congaree National Park. Other studies have shown that wetlands exhibit signs of adverse impacts when watershed IC exceeds 2–4%, or about one house for every 3.2 to 4.0 hectares (8 to 10 ac) of watershed area (Hicks and Larson 1997, Reinelt and Horner 1991). The recent USGS analysis (Cole et al. 2012)—and the central conclusion that stream macroinvertebrate communities, commonly considered a major "barometer" of stream ecosystem health, are much more sensitive to urbanization that previously thought—also factored heavily in our considerations about the levels of %IC to be assigned to good, fair, and poor rankings. These rankings reflect the present status of what is known in the science literature about stream macroinvertebrate community response to urbanization. Fortunately, at this time urban land use/land cover surrounding the park is minor, in fact nearly negligible, so this indicator is evaluated as *good*.

*Change in Green Space*

The greenspace indicator (%GRN) tracks the change in the percentage of greenspace land over time. The change is generally as loss to development and urban/suburban lands. It has been demonstrated that only a 12% loss of forest cover in a watershed results in detectable adverse impacts on the macroinvertebrate communities of streams draining the area (Klein 1979). Conversion of a forest to homes on 0.10-hectare (0.25-ac) lots can increase the frequency and severity of flooding by 100-fold (basis—Soil Conservation Service 1986; Zielinski 2002; CEDS 2017). When the land is converted to IC rather than open space, impacts are sustained at lower percentages of impervious surface as explained above.

Congaree National Park is surrounded by woody wetlands, scrub/shrub/grasslands, forests, and shrub/scrub land and a small amount of "developed open space". There is very little urban land along the park perimeter (Figure 5). Columbia, the closest population center (32 km or 20 mi distant), has grown 13.3% in the past 15 year period before 2013. This information suggests that within the past decade, there has been negligible loss of greenspace immediately surrounding the park.

*Overall Evaluation of Land Use and Land Cover Condition*

The evaluation format used to assess the land use/land cover condition surrounding and potentially influencing park natural resources is shown in Tables 48a–c. The present overall condition of land use/land cover surrounding the park is poor.

**Table 48a.** The reference criteria used to evaluate land use/land cover conditions surrounding Congaree NP.

| Indicator | Good | Fair | Poor |
|---|---|---|---|
| Agricultural Influence from CAFOs ($AGRIC_{CAFOS}$) | No CAFOs within 10 km | 1 CAFO, > 5 km distant | ≥2 CAFOs within 10 km |
| Agricultural Influence from Croplands ($AGRIC_{CROPS}$) | crops ≥ 5 km, < 5% land | < 5 km, < 5% land | < 5 km, > 5% land |
| Impervious Cover (% $IC_{5\text{-km}}$ , 5-km Radius Surrounding Park[1]) | ≤ 5% (5 yr) | 5 to < 10% | ≥ 10% |
| Total Greenspace Loss (% GRN, Past 5-10 Year)[2] | < 1% (5 yr) | ≥ 1 to < 5% loss | ≥ 5% loss |

[1] Decadal basis

[2] Congaree watersheds

**Table 48b.** The present land use/land cover conditions surrounding Congaree NP, evaluated by the indicators in Table 48a.

| Indicator | Congaree evaluation | Rating |
|---|---|---|
| $AGRIC_{CAFOS}$ | There are 7 CAFOs within 10 km distance from the Park. | poor |
| $AGRIC_{CROPS}$ | Croplands are 5.8% of the land use/land cover in the sub-watersheds that include the park, and croplands are within a 5-km (3-mi) radius of the Park. | poor |
| IC | The only population center near the park, Columbia, had 131,686 people as of 2012 and grew 13.3% in 15 yr. IC in the 5-km (3-mi) radius surrounding the park is negligible, < 1% of .the land use/land cover. | good |
| % GRN | In the past 15 yr (since 2000), the nearest population center, Columbia, has .grown 13.3% (average of 0.89% per year, indicating low greenspace loss. | good |
| **Overall condition rating** | | **poor** |

**Table 48c.** The overall evaluation of the present land use / land cover conditions surrounding Congaree NP, based on the four indicators in Table 48b.

| Rating | Criteria |
|---|---|
| good | ≥ 3 Indicators good, ≤ 1 fair |
| fair | ≤ 1 Indicator poor |
| poor | ≤ 2 Indicators poor |

## 4.3. Air Quality

Issue: Air pollution is an ongoing, serious problem from urbanized areas mostly west of Congaree National Park, and is expected to adversely impact the park's natural resources.

Animals are exposed to air pollutants by inhaling gases or small particles, ingesting particles suspended in food or water, or absorbing gases through the skin (soft-bodied invertebrates, amphibians with thin, moist skin etc.; EPA 2008). Ozone, $SO_2$, and $NO_x$ mostly affect the respiratory system, and animals to with higher respiratory rates (e.g., many birds) are likely to be more adversely affected by gaseous pollutant injury. Metals such as mercury in air pollution can affect the circulatory, respiratory, gastrointestinal, and central nervous systems. Often organs such as the kidney, liver, and brain are targeted, and entire populations can be adversely affected with damage extending subsequent generations.

The many impacts of acid deposition on terrestrial and freshwater ecosystems is the subject of an exhaustive literature (Tomlinson and Tomlinson 1990; Charles and Christie 1991; Brimblecombe et al. 2007, and references therein). In terrestrial ecosystems species such as pines are especially sensitive to the elevated nitrate enrichment that results in the soils, and their growth and survival are depressed (Aber 1992). Leaves affected by acid deposition are damaged, especially the chlorophyll pigment that is vital to photosynthesis. Like many other pollutants, acid deposition depresses terrestrial biodiversity as sensitive species are eliminated and more acid-tolerant species can survive. Acidification effects in freshwater streams depend on the surrounding geology and soils, which determine the capacity of the water to neutralize acids. Streams most susceptible to acidification occur in watersheds with granite or gneiss bedrock, where thin soils have insufficient base cations freely available to neutralize incoming $H^+$ ions.

The effects of decreasing pH on aquatic invertebrates and fish have been summarized in National Acid Precipitation Assessment Program (NAPAP) reports (e.g., NAPAP 2005) and similar documents from Scandinavia where acidification impacts have been extreme: In early stages of acidification, acid-sensitive species are replaced by acid-tolerant ones. As the pH continues to decline, toxic metals become more bioavailable, and more species are lost until even the microbial consortium of decomposers is adversely affected. The worst problems with acid deposition result from acid spates, wherein a "slug" or high amount of acid moves into a stream in the early phases of a storm. Larval stages of amphibians and fish are eliminated by acid spates over a short period (hours to a few days).

Considering the entire Southeast region, the NPS Air Resources Division evaluates 10-year trends in air quality for parks with on-site or nearby monitoring. Maps in the most recently available progress report show trends in ozone, deposition, and visibility that can be used to discern regional trends (NPS 2007). For the period 1996–2005, ozone concentrations and nitrogen and sulfur deposition in the Southeast appear to be decreasing, while visibility is relatively unchanged.

More specific to Congaree National Park, the National Park Service (2011a, b) has developed guidance for assessing the air-quality conditions within its parks, focusing on five key indicators among the air pollutants potentially affecting the Congaree and Lower Wateree River basins. These indicators include ozone (with two sub-indicators: human health, and Congaree National Park flora), N deposition, S deposition, visibility, and acidification (with five sub-indicators: pollutant exposure, ecosystem sensitivity, park protection, and overall summary risk). For ozone, the National Park Service included consideration of vegetation sensitivity as well as human health because science has shown that some plant species are more sensitive to ozone than humans. Thus, use of an ozone standard for humans would not be sufficiently protective of those species.

The National Park Service has developed management targets or "thresholds" for these eleven indicators, summarized in Table 49a. The information and supporting science are given in several agency reports, especially NPS (2011a) and Sullivan et al. (2011) where the conditions in Congaree National Park are also described. All eleven of the NPS-selected air-quality indicators are not possible for park staff or the Southeast Coast I&M Network to control. Following the NPS guidance and stoplight system, one of the eleven indicators, ozone, is moderate concern (fair rating in the stop light approach); the other ten indicators are of significant concern (poor rating in the stop light approach). The EPA AQI is fair, and the overall park condition considering the potential for acidification is moderate (moderate risk). Therefore, the present overall air-quality condition at Congaree National park is evaluated as fair (Tables 50a–c).

**Table 49a.** The reference criteria used to evaluate air-quality conditions in Congaree National Park.

| Indicator | Good | Fair | Poor |
|---|---|---|---|
| AQI<br>(EPA air-quality index for Columbia, S.C.) | 0–50 for ≥ 90% of days | ≤100 for ≥ 90% of days | 101–500 for > 10% of days |
| OZONE: human health<br>(5 year impact) | ≤ 60 ppb | 61–75 ppb | ≥ 76 |
| OZONE W126<br>(impact on flora over the growing season) | < 7 ppm-hour | 7–13 ppm-hour | > 12 ppm-hour |
| OZONE SUM06<br>(cumulative ozone impact on flora) | < 8 ppm-hour | 8–15 ppm-hour | > 15 ppm-hour |
| N-DEP<br>(nitrogen deposition) | < 1 kg/ha/year | 1–3 kg/ha/year | > 3 kg/ha/year |
| S-DEP<br>(sulfur deposition) | < 1 kg/ha/year | 1–3 kg/ha/year | > 3 kg/ha/year |
| VIS<br>(visibility in deciviews(dv)) | < 2 dv | 2–8 dv | > 8 dv |
| ACID<br>(pollutant exposure) | rank < 13 | ≥ 13 to 23 | > 23 to 35 |
| ACID<br>(ecosystem sensitivity) | rank < 15 | ≥ 15 to 20 | > 20 to 35 |
| ACID<br>(park protection) | rank < 15 | ≥ 15 to < 23 | ≥ 23 to 35 |
| ACID<br>(summary risk index) | rank ≤ 2.5 | > 2.5 to 3.4 | > 3.4 to 5 |

**Table 49b.** The present eight air-quality conditions (the four acid indicators are combined) in Congaree NP, evaluated by the indicators in Table 49a.

| Indicator | Congaree evaluation | Rating |
|---|---|---|
| AQI | 2013: Ozone rated good 99.7% of days; CO rated good 100% of 346 days measured, $NO_2$ rated good 100% of 316 days measured, and $PM_{10}$ rated good 100% of days; $SO_2$ rated good 99.2% of days; $PM_{2.5}$ rated good 71.2% of days. Overall AQI rated good ≥ 69.6% of days and moderate 30.4% of days | good |
| OZONE: human health | 61–75 ppb for the 8-hour averaging time, 4th maximal value | fair |
| OZONE W126 | 7–13 ppm-hour | fair |
| OZONE SUM06 | 8–15 ppm-hour | fair |
| N-DEP | > 3 kg/ha/year | poor |
| S-DEP | > 3 kg/ha/year | poor |
| VIS | > 8 dv | poor |
| ACID (pollutant exposure) | rank > 23 (high) | fair |
| ACID (ecosystem sensitivity) | rank < 15 (low) | good |
| ACID (park protection) | rank ≥ 23 to < 35 (high) | fair |
| ACID (summary risk index) | rank 2.5–3.4 (moderate) | fair |
| **Overall condition rating** | | **fair** |

**Table 49c.** The overall evaluation of the air-quality conditions in Congaree NP, based on the eight indicators in Table 49b.

| Rating | Criteria |
|---|---|
| Good | ≥ 5 of 7 good, ≤ 2 fair (Moderate Concern), 0 poor (Significant Concern) |
| Fair | ≥ 3 fair, ≤ 3 poor |
| Poor | > 4 poor |

## 4.4. Soundscape

Issue: Noise pollution can adversely affect the physiology and behavior of fauna communities. Congaree National Park is within a predominantly rural area and noise pollution generally is minor with the exception of occasional military aircraft overflight, but it is also adjacent to a metropolitan area.

A clear need has been identified to more proactively buffer park-protected area-centered ecosystems (PACEs) such as Congaree National Park from adverse impacts of surrounding, increasing development (e.g., Hansen et al. 2011). Given the present trajectory of broad-scale environmental change, the cumulative and synergistic effects of changing land use, climate, and (increasing) invasive species are expected to dramatically impact ecosystem function and biodiversity in national parks (Hansen et al. 2011, 2014). Hansen et al. (2011) used comprehensive scientific methods to map and analyze land use changes within PACES around 13 U.S. national parks, and found that the resulting PACEs were, on average, 6.7 times larger than the parks in upper watersheds and 44.6 times larger than parks in middle watersheds, that is, 7 times more than in upper watersheds. Considering this information, the extent of the "buffer" needed around parks in upper watersheds, such as the park in the Congaree River watershed, should be even greater to be sufficiently protective from impacts of encroaching urbanization in the Columbia Metropolitan Area and two S.C. military bases, McEntire Air National Guard Base located 15 miles [24 km] southeast of Columbia and Shaw Air Force Base located 22 miles [35.4 km] northeast of the park near Sumter, South Carolina.

The linear dimension of Congaree National Park is approximately 25 kilometers (16 mi). Based on the above average findings for national parks, a protective buffer of at least 167 kilometers (107 mi) would, in an ideal world, be advisable for Congaree National Park since the park is located in a middle watershed. At present human-related environmental noise is minor and the park usually is very quiet with the exception of occasional military aircraft overflights and powered landings and take-offs (personal communication, S. Kidd, Acting Chief, Integrated Resource Management, Congaree National Park, April 2013). Given the rapid growth of the Columbia MSA, however, for the first soundscape indicator we used a protective distance of 80 kilometers (50 mi), and two other soundscape indicators are also suggested, and summarized in Tables 55a–c.

In the overall evaluation, the $DATA/OBS_{SOUND}$ indicator weighs more heavily than the other two indicators (Tables 53a–c). However, the other two indicators are used to evaluate the soundscape if data and/or reliable observations are not available.

**Table 50a.** The reference criteria used to evaluate soundscape conditions in Congaree NP.

| Indicator | Good | Fair | Poor |
|---|---|---|---|
| POPSOUND | The closest population center with < 50,000 people is > 80 km (> 50 miles) away | closest population center with > 50,000 people is > 16 to < 80 km (10 to < 50 miles) away | closest population center with > 50,000 people is < 16 km (< 10 mi) away |
| SOURCESOUND | The nearest major road or railroad is > 8 km (5 mi) distant; no major airport, flyway influence, etc. | One major road and/or railroad is nearby, or one railroad, or a major airport /airplane flyway | More than one major road and/or railroad and/or major airport nearby (within < 8 km or 5 mi) |
| DATA/OBSSOUND | Outside noise < 24 dB(A) during daytime when related (noise-generating) human activity is greatest; or, observations by Park staff as overall very quiet | Outside noise is > 24 to 55 dB(A) during daytime periods with greatest related human activity | Outside noise > 55 dB(A) during daytime periods with greatest related human activity |

**Table 50b.** The present soundscape condition in Congaree NP, evaluated by the indicators in Table 50a.

| Indicator | Congaree evaluation | Rating |
|---|---|---|
| POPSOUND | CONG is within the CMSA, and 16 km (10 mi) from Columbia (growing population center; population 132,094 as of 2012; the city increased +13.3% in population since 2000). The CMSA grew 18.7% since 2000. | fair |
| SOURCESOUND | U.S. highway 601 passes through the park between the Riverstone and Bates Fork Tracts; State Highway SC 48 is 2.4 km (1.5 mi) to the north, and I-26 is 14.5 km (9 mi) to the west and I-77 is 17.7 km (11 mi) to the northwest. The Columbia .Metropolitan Airport is 38.6 km (24 mi) from CONG, and some flight paths pass over the Park. | fair |
| DATA/OBSSOUND | Data not available (na); park staff describe CONG as usually very quiet except for occasional military aircraft overflight. | fair |
| **Overall condition rating** | | **fair** |

**Table 50c**. The overall evaluation of the present soundscape condition in Congaree NP.

| Rating | Criteria |
|---|---|
| Good | DATA/OBSSOUND and one other indicator good; third indicator good or fair; or no data but the other two indicators good |
| Fair | All three indicators fair; or no data but both other indicators fair |
| Poor | DATA/OBSSOUND poor; or no data but one or both other indicators poor |

### 4.5. Lightscape

Issue: Light pollution in urbanized or developing areas can adversely affect the physiology, behavior, and survival of naturally occurring, beneficial fauna.

The lightscape condition for Congaree National Park is somewhat analogous to its soundscape Condition: Neither are possible for the National Park Service to control, but both noise and light pollution are described by park staff as negligible. Park staff describe the park nighttime habitat as equivalent to the "truly dark skies" or, in some areas, "rural skies" of the Bortle Dark-Sky Scale. The lightscape indicator for Congaree National Park uses this scale to assess artificial light pollution (Table 51a).

These rankings are based on potential impacts of sufficient light to reveal "ground objects," meaning that sufficient light would be available to alter predator-prey interactions at least in some areas of the park. The night sky for Congaree National Park is Class 2 to 3, as noted above (truly dark skies—the ground is mostly dark; only objects projecting into the sky may be discernible; or rural sky—ground objects are vaguely apparent). Thus, the lightscape condition in the park based on this indicator would be good to fair (Table 51b).

The second indicator considered here is anthropogenic light ratio (ALR), as in Tables 14 and 15 of this report. Based on Figure 13, the modeled ALR for the Columbia area is red (ALR > 2.00 to < 18), and the surrounding areas are shown in Amber (ALR > 0.33 to 2.00). Although the Columbia MSA is expanding and, therefore, expected to begin to encroach on the park, the present condition is still fair (amber). Overall, evaluation using these two indicators suggests that the park is in fair condition for the nighttime lightscape (Table 51c).

**Table 51a.** The reference criteria used to evaluate lightscape conditions in Congaree NP.

| Indicator | Good | Fair | Poor |
|---|---|---|---|
| $LITE_{ARTIF}$ | Classes 1 to 2 (excellent, truly dark skies; or typical, truly dark skies). | Classes 3 to 4 (rural sky—ground objects vaguely apparent; or rural/suburban transition—sky noticeably brighter than the terrain, ground objects still fairly obscure). | > Class 5 (suburban sky—ground objects partly lit, to inner city sky. |
| ALR[1] | ALR < 0.33 (< 26 nL average anthropogenic light in the sky; low concern) | fair (amber)—ALR > 0.33–2.00 (26-156 nL average anthropogenic light; moderate concern) | 2.00 (> 156 nL average anthropogenic light; high concern) |

[1] The average anthropogenic all-sky luminance divided by the average natural all-sky luminance

**Table 51b.** The present lightscape condition in Congaree NP, evaluated by the indicators in Table 51a.

| Indicator | Congaree evaluation | Rating |
|---|---|---|
| Bortle Dark Sky Scale ($LITE_{ARTIF}$) | The park at present is still in a rural/suburban setting, and the lightscape is described as Class 4, Rural Skies. | fair |
| Anthropogenic Light Ratio (ALR)[1] | The modeled ALR for the expanding Columbia area is Red (> 2.00 to 18), and the modeled ALR for the surrounding area is Amber (> 0.33 to 2.00). | fair |
| **Overall condition rating** | | **fair** |

[1] The average anthropogenic all-sky luminance divided by the average natural all-sky luminance

**Table 51c.** The overall evaluation of the present lightscape condition in Congaree NP.

| Rating | Criteria |
|---|---|
| Good | The two indicators should yield comparable evaluations |
| Fair | The two indicators should yield comparable evaluations |
| Poor | The two indicators should yield comparable evaluations |

### 4.6. Soils and Streambank Erosion

Issue: The major soils in the park area are moderately erodible; streambanks are unstable and/or prone to caving along ditchbanks and cutbanks. Thus, there is high potential for damage along streambanks as well as park roads, trails, and other highly used areas. In the Congaree region of Richland County the soil is very strongly acidic to neutral throughout but some sections have a pH of 5.5 or higher (NCSS 2002). The high acid deposition sustained by the park could decrease the soil pH to conditions that impede the metabolism of beneficial microbial consortia while also enhancing solubility of porewater toxic metals (Bååth 1989).

The four major soil types of Congaree National Park are moderately erodible, but depositional in nature. Accretion rates have not been determined. All four of the major types are also prone to flooding. Streambank erosion is highly visible in some areas of the park along the Congaree River. Considering the available information for the major soils of this park, we developed a straightforward index of soil condition, summarized in Table 52a.

Soil Indicators $SOIL_{EROD}$ and $SOIL_{ACID}$ are based on information already provided to the park; indicators $SOIL_{VIS}$ and $BANK_{EROD}$ are based on surveys that can be conducted quickly (authors estimate within two hours). Assessment of these indicators can be conducted at intervals deemed appropriate by park staff (e.g., two-year or five-year) using a consistent, quantitative approach such as walking three 100-meter segments along the Congaree River (e.g., see Gordon et al. 2004), and including photographic documentation. It should also be noted that the National Park Service is developing a visual technique using a consistent approach with photography over time to document streambank erosion in Southeast Coast Network parks, which will strengthen the $Bank_{EROD}$ indicator (personal communication, J. DeVivo, former SECN program director, April 2013). To assess the overall soil and streambank erosion condition in the park, we suggest the evaluation system summarized in Table 52c.

As noted, all four of the major soil types found in Congaree National Park are moderately erodible, but exist in a highly dynamic floodplain ecosystem of constant erosion and deposition. In addition, the major soil types are frequently flooded or wet, and all of the major soils are moderately to highly acidic (Table 52b). There are a few areas along roadways that show signs of erosion, and there is visual evidence of major streambank erosion. Thus, all four indicators are poor, for an overall evaluation of poor.

**Table 52a.** The reference criteria used to evaluate soil and streambank erosion conditions in Congaree NP.

| Indicator | Good | Fair | Poor |
|---|---|---|---|
| Erodibility of soil types ($SOIL_{EROD}$) | < 10% of the soil types are eroded to severely eroded | > 10% to 20% of the soil types are eroded to severely eroded, including 1 abundant soil | > 20% of the major soil types are eroded to severely eroded, including > 2 abundant soils |
| Visual evidence of soil erosion ($SOIL_{VIS}$) | little or no streambank erosion in the park | a few areas along roadways and trails show signs of erosion | erosion is obvious and common along roadways and trails |
| Visual evidence of streambank erosion ($BANK_{EROD}$) | little or no streambank erosion is evident in the park | occasional signs of streambank erosion after major rain events | severe erosion is evident and common along major stream segments in the park |
| Soil acidification potential ($SOIL_{ACID}$) | low[1] | moderate | high |

[1] basis: NPS air quality analysis

**Table 52b.** The present soil and streambank erosion condition in Congaree NP, evaluated by the indicators in Table 52a.

| Indicator | Congaree evaluation | Rating |
|---|---|---|
| $SOIL_{EROD}$ | The four major soil types in Congaree are moderately erodible, unstable and/or prone to caving of ditchbanks and cutbanks and are frequently flooded | poor |
| $SOIL_{VIS}$ | There is visual evidence of soil erosion in the park. | poor |
| $BANK_{EROD}$ | There is visual evidence of major streambank erosion in the park | poor |
| $SOIL_{ACID}$ | High in Congaree NP | poor |
| **Overall condition rating** | | **poor** |

**Table 52c.** The overall evaluation of the present soil and streambank erosion condition in Congaree NP, based on the four indicators in Table 52a.

| Rating | Criteria |
|---|---|
| Good | > 2 indicators are good, < 2 indicators are fair, and there is no poor evaluation |
| Fair | > 2 indicators are fair or good, and < 2 indicators are poor |
| Poor | > 3 indicators are poor |

## 4.7. Water Quantity

Issue: Tracking changes to surface and groundwater quantity over time is important for natural resources in Congaree National Park. Frequent flooding of the Congaree and Wateree Rivers in the parkthe wetland and aquatic communities of Congaree National Park. Increasing watershed development leads to higher demands on water supplies, which has the potential to exacerbate the duration and severity of droughts in the future.

### *4.7.1. Surface-water Quantity and Hydrology*

Although the National Park Service has established a baseline year for monitoring the hydrology of two major streams in Congaree National Park, only one year of data are available for comparison with the baseline thus far, insufficient for use in assessing the hydrology of the park at this time. As Jones et al. (2010, pp.1–2) noted, stream hydrology data provide key support data for vital sign indicators including water chemistry, threatened and endangered SoCs, wetlands, and riparian habitats. Tracking surface water hydrologic changes over time is important for the natural resources in the park, considering that as development in the area increases, the urbanizing watershed will in turn increase flash flooding potential. This problem may be exacerbated by the escalating trend in climate change (Richter et al. 1997; Kundzewicz et al. 2007; Brekke et al. 2009). There are USGS gaging stations upstream from the park on both the Congaree River and the Wateree River. The longest period of record for streamflow data is at USGS station 02169500 near Columbia. The Congaree River and the Wateree River had similar patterns of flow as far as being influenced by upstream dams. Congaree River flows exceed 100,000 cubic feet per second (cfs) about every five years and exceeded 150,000 cfs in the late 1970s. The Wateree River streamflow at USGS station 02148315 was highly variable, not exceeding 10,000 cfs, and flow events greater than 10,000 cfs occur approximately every four to five years and infrequently go much higher (Jones et al. 2010).

In addition, the flow of water through the park floodplain during a flood event occurs by two processes. One, rivers overflow their banks and floodwaters spill into the floodplain replenishing nutrients and recharging aquifers. Two, the shallow groundwater levels in the park rise in conjunction with the Congaree River and tributaries transporting floodplain material to the river (Conrads et al. 2008; Graham 2014). While floodwaters reshape the geomorphic features of the park floodplain, they also enrich, hydrate and sustain plant and animal communities, and impact water supply by filtering and redistributing sediments and nutrients (Graham 2014; NPS 2013d).

The USGS analyzed historic hydrologic data to evaluate the effect of altered streamflow patterns from the Saluda Dam on the hydrology of surface water and groundwater to the park. These data can be used by water-resource managers as a benchmark to track how future decisions may potentially affect streamflow in the Congaree River (Conrads et al. 2008).

### *4.7.2. Groundwater*

A dataset from a USGS monitoring well in the Piedmont and Blue Ridge Aquifer, located near Columbia (USGS ID 340837081173800; more than 223 observations from January 2007 through December 2011) was used to document a statistically significant decreasing trend over the periods of record for groundwater levels in the area (Wright 2012b, Figure 46). Groundwater use is projected to increase over the coming years from the burgeoning demands of the growing human population in the Columbia MSA. Based on this information, we developed two indicators for groundwater supply (Table 53a–c). Our overall evaluation of groundwater supply condition in the park is poor.

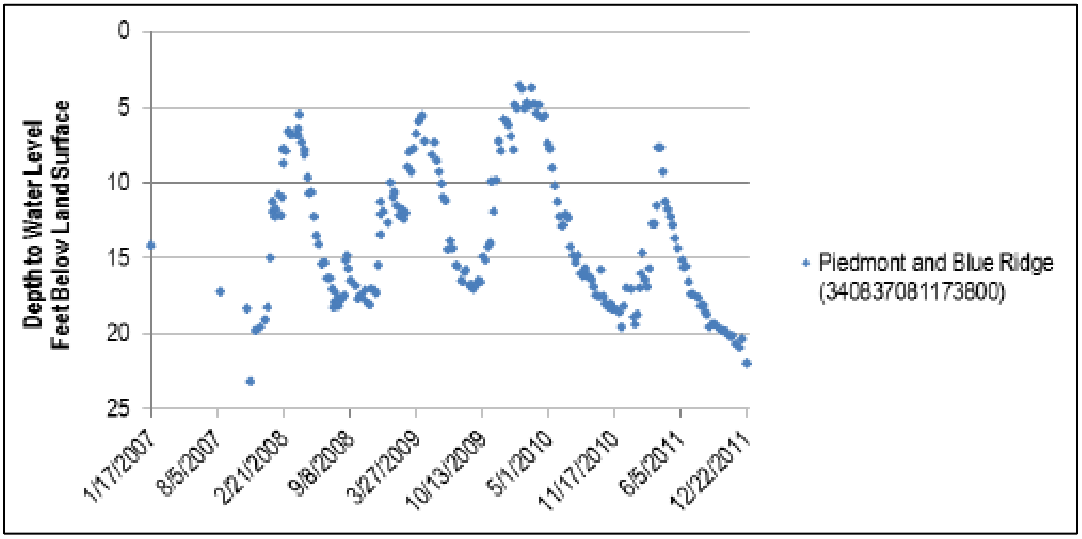


**Figure 46.** Water levels in a groundwater monitoring well near Columbia, S.C. (USGS ID 340837081173800) in the Piedmont and Blue Ridge Aquifer. (From Wright 2012b).

**Table 53a.** The two indicators used to evaluate groundwater conditions for Congaree NP.

| Indicator | Good | Fair | Poor |
|---|---|---|---|
| Groundwater Level ($GRW_{SUPPLY}$) | Statistically significant increasing trend in groundwater level for one or both USGS monitoring wells nearest the park over the period of record (decadal re-evaluation); if only for one well, the other has a stationary trend. | Stationary trend for both wells. | Statistically significant decreasing trend in groundwater level for one or both USGS monitoring wells nearest the park over the period of record (decadal re-evaluation); if only for one well, the other has a stationary trend. |
| Expected Groundwater Use ($GRW_{USE}$) | Over the next decade, groundwater use is projected to decrease. | Over the next decade, groundwater use is projected to remain stationary. | Over the next decade, groundwater use is projected to increase. |

**Table 53b.** The present groundwater conditions surrounding Congaree NP, evaluated by the indicators in Table 53a.

| Indicator | Congaree evaluation | Rating |
|---|---|---|
| $GRW_{SUPPLY}$ | Groundwater level has significantly decreased over the period of record in USGS monitoring wells nearest the park. | poor |
| $GRW_{USE}$ | Groundwater use is projected to increase significantly with the demands of the increasing population in the area. | poor |
| **Overall condition rating** | | **poor** |

**Table 53c.** The overall evaluation of the present groundwater conditions surrounding Congaree NP, based on the two indicators in Table 53b.

| Rating | Criteria |
|---|---|
| Good | Both indicators good |
| Fair | ≥ one indicator fair, ≥ indicator good |
| Poor | ≥ one indicator poor |

## 4.8. Water Quality

Issues: Water-quality degradation is a concern for Congaree National Park considering continued growth of the Columbia MSA encroaching on the northwestern portion of the park. Infrastructure to support the growing area includes an increasing number of NPDES and CERCLA (Superfund) point sources and nutrients from agricultural runoff threaten the park's water resources.

Information is not available for groundwater quality in or near the park; therefore, this section focuses on surface-water quality only. There is a wealth of peer-reviewed literature in support of widely accepted parameters indicating the status of surface-water quality in freshwaters, and state standards and/or federal recommendations for use in interpreting acceptable levels of these parameters (Hynes 1970; Whitton 1975; Wetzel 2001; EPA 2000, 2003). The parameters—pH, DO, $BOD_5$, turbidity, nutrients (especially TP and inorganic N as nitrate and/or ammonium), fecal indicator bacteria and various metals. We selected the suite of indicators and the evaluation procedure shown in Table 54a–c to assess surface-water quality condition in the park, using the information contained in Appendix B of this report. Good evaluation was based on protecting, at a minimum, the most sensitive aquatic life history stages in park waters.

Based on evaluation of available data for Congaree National Park, we suggested 12 indicators of surface-water condition. Parameters evaluated as good were DO and $BOD_5$, with 98% compliance; and metals with 92–100% compliant with water-quality criteria. We assigned pH a fair rating have only an 88% compliance. Turbidity, TP, $NO_x$, TKN, and TSS were all rated as poor due to a range of 22–44% compliance. Regarding fecal bacteria indicators, considering all data collectively and using the single sample criteria, the fecal coliform indicator was rated as good for 91% compliance overall. The indicator for metals includes six different heavy metals. Using data amenable to the calculation of geometric means, however, only 78% of the data were in compliance, resulting in a fair rating. Using either the single sample criteria or the geometric mean criteria, both *E. coli* and *Enterococcus* were given a poor rating. A total of seven of the twelve indicators rated as poor, resulting in an overall poor surface-water quality condition.

**Table 54a.** Twelve indicators used to evaluate surface water-quality conditions in Congaree NP. Values are the percentage of samples in each category that did not meet standards.

| Category | Indicator | Good | Fair | Poor |
|---|---|---|---|---|
| Field measures | pH | ≥ 90% | ≥ 80 to < 90% | < 80% |
| | DO (dissolved oxygen; mg/L) | ≥ 90% | ≥ 80 to < 90% | < 80% |
| | $BOD_5$ (biochemical oxygen demand; mg/L) | ≥ 90% | ≥ 80 to < 90% | < 80% |
| | Turbidity (NTU) | ≥ 90% | ≥ 75 to < 90% | < 75% |
| | TSS (total suspended solids; mg/L) | ≥ 90% | ≥ 75 to < 90% | < 75% |
| Nutrients | TP (total phosphorus; µg/L) | ≥ 90% | ≥ 75 to < 90% | < 75% |
| | $NO_x$-N (nitrate + nitrite; µg/L) | ≥ 90% | ≥ 75 to < 90% | < 75% |
| | TKN (total Kjeldahl nitrogen (TKN, µg/L) | ≥ 90% | ≥ 75 to < 90% | < 75% |
| Biologicals | FECAL (fecal coliform bacteria; cfu/100 mL) | ≥ 90% | ≥ 80 to < 90% | < 80% |
| | ECOLI (Escherichia coli; cfu/100 mL) | ≥ 90% | ≥ 80 to < 90% | < 80% |
| | ENT (Enterococcus; cfu/100 mL | ≥ 90% | ≥ 80 to < 90% | < 80% |
| Metals | • T-CD (cadmium)<br>• T-CR (chromium IV)<br>• T-CU (copper)<br>• T-PB (lead)<br>• T-NI (nickel)<br>• T-ZN (zinc) | 5–7 ≥ 90% | 5–7 at 80–89% and < 1 at < 70% | > 2 at < 70% |

**Table 54b.** Criteria and overall evaluation of surface water-quality conditions in Congaree NP, based on the 12 indicators in Table 54a.

| Indicator | NPS Management Target(s) | Congaree NP evaluation | Rating |
|---|---|---|---|
| pH | South Carolina standard: 6.0–8.5 | 88% met recommendation (821 of 932 samples) | fair |
| DO | South Carolina standard: Average 5.0 mg/L; minimum 4.0 mg/L | 98% met recommendation (874 of 890) | good |

**Table 54b (continued).** Criteria and overall evaluation of surface water-quality conditions in Congaree NP, based on the 12 indicators in Table 54a.

| Indicator | NPS Management Target(s) | Congaree NP evaluation | Rating |
|---|---|---|---|
| BOD | Mallin et al. (2006) recommendation: ≤ 3 mg/L | 98% met recommendation (736 of 754) | good |
| Turbidity | EPA recommendation: ≤ 6.2 NTU | 44% met recommendation (363 of 817) | poor |
| TSS | EPA recommendation: ≤ 10 mg/L | 35% met recommendation (149 of 424) | poor |
| TP | EPA recommendation: ≤ 22.5 µg/L | 22% met recommendation (161 of 726) | poor |
| $NO_x$-N | EPA recommendation: ≤ 95 µg/L | 22% met recommendation (173 of 794) | poor |
| TKN | EPA recommendation: ≤ 300 µg/L | 23% met recommendation (149 of 424) | poor |
| FECAL | South Carolina standard: ≤ 200 as the 30-day GM and < 400 in <10% of samples; or EPA recommendation: < 400 for data collected with insufficient frequency to calculate geometric means (GMs) | 91% met recommendation with single sample criteria (838 of 925 total samples)<br>78% met recommendation using GM (18 of 23 months) | good<br>fair |
| ECOLI | EPA recommendation: GM < 126; < 235 single sample | 71% met recommendation using single sample max (122 of 172 total samples); 26% (6 of 23 months) using GM recommendation | poor<br>poor |
| ENT | EPA recommendation: < 33 as the 30-day GM for freshwater, or < 104 single sample maximum | 74% met recommendation (515 of 692 total samples) using single sample max; 17% (4 of 23 months) using GM recommendation | poor<br>poor |
| T-CD | EPA recommendation: < 0.25 µg/L | 95% met recommendation (294 of 308) | good |
| T-CR | EPA recommendation: < 74 µg/L | < 98% met recommendation (202 of 206) | good |
| T-CU | EPA recommendation: < 9 µg/L | 98% met recommendation (305 of 310) | good |
| T-PB | EPA recommendation: < 2.5 µg/L | < 92% met recommendation (243 of 265) | good |
| T-NI | EPA recommendation: < 52 µg/L | 100% met recommendation (152 of 152) | good |
| T-ZN | EPA recommendation: < 87 µg/L | 99% met recommendation (315 of 319) | good |
| **Overall condition rating** | | | **poor** |

**Table 54c.** The overall evaluation of the present surface water-quality conditions at Congaree NP based on the 12 indicators (all six metals considered as a single indicator for this evaluation) in Table 54b.

| Rating | Criteria |
|---|---|
| Good | 8–10 parameters good; ≤ 2 parameters fair; 0 parameters poor |
| Fair | ≤ 2 groups poor |
| Poor | ≥ 3 groups poor |

### 4.9. Biological Resources

Issue: The southeastern U.S. is among the highest regions in terms of biodiversity nationwide and has many endemic species. Development has led to species extinctions at a rate unrivaled across the U.S. mainland. Various species are now threatened, endangered, or locally extirpated. Agricultural development, giving way to urbanization in various areas, has imposed fragmentation of green corridors and adversely affected faunal diversity, species distributions, and fisheries. Exotic/invasive taxa are a primary concern of park staff.

This suite of indicators was especially challenging because there is no quantitative information available about species of interest among the biological resources of Congaree National Park, a situation common to various other parks. Based on analyses of Southeast Coast Network parks for which recent, vouchered species lists were available for vascular plants (see Burkholder et al. submitted a,b,c), the NPS Certified Species List for Congaree National Park (NPS 2013a) should be updated and vouchered (e.g., see Carter et al. 2007b). Even for vascular plant communities, which have been well characterized with respect to species alliances and associations, very little ecological information exists about how these plant groups are quantitatively changing over time in the park.

Population abundance data are lacking for all species of interest in the park, from SoCs to exotic/invasive taxa to SSMCs. This information is needed to calculate reliable basic diversity indices such as Shannon Weaver (also known as the Shannon-Wiener index; Shannon and Weaver 1949; MacArthur and MacArthur 1961; Peet 1974). Other indices that rely solely on species numbers were considered, but have major limitations. For example, classic incidence-based indices such as the Jaccard and Sørensen Index (J&SI) estimate similarity between two communities, focusing on richness and composition. The efficacy of the J&SI in providing a realistic measure of species diversity is in debate because the presence/absence data used are neither quantitative nor abundance-based; typically a significant under-sampling bias is involved; and there is no accounting for rare species or unseen shared species (Gotelli and Colwell 2001; Chao et al. 2006). Because of these significant limitations, the J&SI often has been found to yield variable results for the same dataset (Koleff et al. 2003). The following biota indicators were developed within the major constraints imposed by the lack of abundance data for species in the park. The suite of available indicators should be modified as more information becomes available, especially abundance data for selected species.

### *4.9.1. Vascular Plant Associations Compromised by Exotic and Invasive Species*

Indicators for this large, important group were developed considering terrestrial and wetland habitats separately. For each of the two general habitats, the indicators were based on the proportion of exotic taxa and total number of exotic taxa as outlined in Table 55a–c, and on the proportion of invasive taxa. Thus, we considered vascular plant communities within the context of alteration by exotic plant species.

Exotic/invasive plants represent 8.8% of the terrestrial plant taxa in this park, and 3.9% of the wetland flora. While these percentages are small in comparison to various other regional parks, park terrestrial communities are infested with seven severe threat corresponding to Category R1, three significant threat corresponding to Category R2, one emerging threat corresponding to Category R3, and one alert species corresponding to Category R4 terrestrial invasive plants. Congaree National Park wetlands contain six severe threat (Category R1), three emerging threat (Category R3), and 2 alert species (Category R4) invasive plant species (abundance data not available). Three of these highly invasive taxa are on the NPS Top Ten List of the worst plant invaders. Based on the indicators and evaluation format shown in Table 55a, the overall vascular plant flora condition in the park is poor (Tables 55a–c).

**Table 55a.** The four indicators used to evaluate vascular flora conditions for Congaree NP.

| Indicator | Good | Fair | Poor |
|---|---|---|---|
| Proportion of exotic terrestrial taxa to total ($TERR_{EXOTIC}$) | < 5% of the terrestrial taxa are exotic/invasive | ≥ 5-15% are exotic/invasive | > 15% are exotic/invasive |
| Number of highly invasive taxa ($TERR_{CAT}$) | no Category R1-R3 taxa, no NPS Top Ten List taxa | ≤ 2 Category R1 taxa, < 1 NPS Top Ten List Taxon | 3 or more Category #1 taxa, > 1 NPS Top Ten List Taxa |
| Proportion of exotic wetland/aquatic taxa ($WET_{EXOTIC}$) | < 5% of the wetland taxa are exotic/ invasive | ≥ 5–15% are exotic/ invasive | > 15% are exotic/ invasive |
| Number of highly invasive wetland/aquatic taxa ($WET_{CAT}$) | no Category R1 taxa, < 2 R2–R3 taxa, no NPS Top Ten List taxa | ≤ 2 Category #1 taxa, < 1 NPS Top Ten List Taxon; or > 4 Category R2-R3 | 3 or more Category #1 taxa |

**Table 55b.** The present evaluate vascular flora conditions in Congaree NP, evaluated by the indicators in Table 55a.

| Indicator | Congaree evaluation | Rating |
|---|---|---|
| $TERR_{EXOTIC}$ | 328 terrestrial vascular plant taxa in the park, including 29 exotic/invasive taxa (8.8%). | fair |
| $TERR_{CAT}$ | Seven severe threat species (Category R1); three significant threat species (Category 2); one emerging threat (Category 3); one alert species (Category 4); (three of these are also on the NPS Top Ten List) | poor |
| $WET_{EXOTIC}$ | 515 wetland/aquatic vascular plant taxa including 20 exotic/invasive (3.9%). | good |
| $WET_{CAT}$ | Six severe threat (Category R1) species (two of these are also on the NPS Top Ten List); three emerging threat (Category R3) species; two alert (Category R4) species. | poor |
| **Overall condition rating** | | **poor** |

**Table 55c.** The overall evaluation of the present vascular flora conditions in Congaree NP, based on the four indicators in Table 55b.

| Rating | Criteria |
|---|---|
| Good | ≥ 3 indicators good, ≤ 1 indicator fair |
| Fair | ≥ 2 indicators fair, ≤ 1 indicator poor |
| Poor | ≥ 2 indicators poor |

### *4.9.2. Aquatic Benthic Macroinvertebrates*

The stream benthic macroinvertebrate community is an important and classic indicator of stream and river health (Barbour et al. 1999; Bowles et al. 2008). Quantitative assessment data was available for 1998–2013 throughout the park. The information from Pescador et al. (2004) indicates that aquatic benthic macroinvertebrate communities are in good condition with high species diversity and species richness within the park (Tables 56a–b).

**Table 56a**. The overall condition of stream macroinvertebrate communities in Congaree NP, based on species richness.

| Indicator | Good | Fair | Poor |
|---|---|---|---|
| Macroinvertebrate Species Richness ($INVERT_{SPP}$) | ≥ 38 native species | 30–37 native species | < 30 native species |

**Table 56b.** The present overall condition of stream macroinvertebrate communities in Congaree NP, based on species richness.

| Indicator | Congaree evaluation | Rating |
|---|---|---|
| $INVERT_{SPP}$ | As of 2004, 302 native stream macroinvertebrate species were found in the park | good |

### *4.9.3. Fish*

The southeastern U.S. is reported to have included 62% of the freshwater fish species in North America (Hocutt et al. 1986; Etnier 1997; American Rivers 2014 and references therein). Water quality has continued to degrade in this state over the past two decades, as nothing has been done to address nonpoint-source pollution impacts in particular, such as the agricultural runoff and CAFO pollution.

Fifty-six native freshwater fish species have been reported in Congaree National Park (Rose and Bulak 2004), and 60 species exist on the NPS Certified Species List. Only one freshwater fish is considered an at-risk species. From consideration of the above information, we developed two indicators for fish community condition in the park, and used those indicators to assess present condition as good (Table 57a–c).

**Table 57a.** The two indicators used to evaluate fish community conditions in Congaree NP.

| Indicator | Good | Fair | Poor |
|---|---|---|---|
| Fish Species Richness ($FISH_{SPP}$) | > 15 native species | 10–15 native species | ≤ 9 native species |
| Fish Species of Concern ($FISH_{SoC}$) | ≥ 8 native | 4–7 native species | ≤ 3 native species |

**Table 57b.** The present fish community conditions in Congaree NP, evaluated by the indicators in Table 57a.

| Indicator | Congaree evaluation | Rating |
|---|---|---|
| $FISH_{SPP}$ | 56 native fish species were reported in the park from the most recent survey (Rose and Bulak 2004), 60 native species exist on the NPS Certified Species List and an additional 11 native species are reported by the National Park Service | good |
| $FISH_{SoC}$ | Only one freshwater fish in Congaree is considered an at-risk species by the FWS. | good |
| **Overall condition rating** | | **good** |

**Table 57c.** The overall evaluation of the present fish community conditions in Congaree NP, based on the four indicators in Table 57b.

| Rating | Criteria |
|---|---|
| Good | both indicators good |
| Fair | ≥ 1 indicator fair, no indicators poor |
| Poor | ≥ 1 indicator poor |

### *4.9.4. Herpetofauna*

Although the recent surveys of herpetofauna in the park have yielded interesting and helpful information, abundance data for the species found are not yet available so that classic species diversity indices such as the Shannon Weaver cannot be developed (Peet 1974; Magurran 1988, 2004). Therefore, two indicators of herpetofauna condition are suggested, considering the NPS surveys of vocal anurans and the data from VESs. These parameters should be tracked over time, beginning with the 2010 baseline (Byrne et al. 2011a; Smrekar et al. 2013) and setting those findings as good (Tables 58a–c).

**Table 58a.** The three indicators used to evaluate herpetofauna community conditions in Congaree NP.

| Indicator | Good | Fair | Poor |
|---|---|---|---|
| Herpetofauna Species Richness ($HERP_{SPP}$) wherein # amphibians > # reptiles (evaluated at 5- to 10-yr intervals) | ≥ 47 native | 25–46 native species | ≤ 24 native species |
| Vocal Anuran Amphibians ($V_{ANURANS}$) detected with ARD (consistent procedure, same timing / sites) | ≥ 8 vocal anurans | 6–7 detected (up to 25% fewer) | < 6 detected |
| # of Species from VES, using consistent procedure, same timing / sites ($HERP_{VES}$) | ≥ 15 herpetofauna taxa | 11–14 taxa (up to 25% fewer) | < 11 taxa |

**Table 58b.** The present herpetofauna community conditions in Congaree NP, evaluated by the indicators in Table 58a.

| Indicator | Congaree evaluation | Rating |
|---|---|---|
| $HERP_{SPP}$ | 2004—Congaree was reported to contain 61 native species of herpetofauna, evaluated as high species richness reflecting diverse habitats; consisting of 29 amphibian taxa and 32 of reptilian taxa. (# amphibians < reptiles) | good |
| $V_{ANURANS}$ | March through May 2011—12 vocal anuran amphibian species detected at 12 established sites in Congaree. | good |
| $HERP_{VES}$ | 2010—Detected 19 amphibian and 15 reptilian species in the park. | good |
| **Overall condition rating** | | **good** |

**Table 58c.** The overall evaluation of the present herpetofauna community conditions in Congaree NP, based on the three indicators in Table 58b.

| Rating | Criteria |
|---|---|
| Good | $HERP_{SPP}$ good, > 1 other indicator good, ≤ 1 other indicator fair |
| Fair | ≤ 2 other indicators good or fair, ≤ 1 other indicator poor |
| Poor | ≤ 2 indicators poor |

#### *4.9.5. Birds*

Congaree National Park is listed as having 191 bird species (NPS 2013a). Unfortunately, abundance data are lacking for bird species in the park, preventing calculation of Shannon Weaver or other widely accepted diversity indices for bird diversity. The North American Breeding Bird Survey for the park area was incomplete for the last ten years, with only three surveys done in 2002, 2008, and 2009. Therefore, at present we have based indicators for bird fauna condition in this park on the Audubon Society Christmas Bird Count (CBC), and on the baseline survey conducted by Byrne et al. (2011b).

The CBC was developed by the Audubon Society in 1900, spurred by conservation efforts to count birds during the holidays instead of hunting them. In 2013 the program performed 2113 bird counts in the Western Hemisphere representing a cooperative volunteer effort of experienced birdwatchers and beginning birders. The CBC surveys a 24-kilometer (15-mi) wide diameter circle from 14 December through 5 January each year, following specific methodology (National Audubon Society 2017a). The Congaree Swamp Count (abbreviated SCCG) location is centered on the Congaree River approximately 400 meters northwest of its confluence with Bates Mill Creek. This count is sponsored by the National Audubon Society, Friends of Congaree Swamp, and Congaree National Park. Differences in experience among volunteers can sometimes cause inconsistencies in the results. Nevertheless, these annual surveys have proven valuable in assessments of bird population trends (Link and Sauer 1998; Sauer et al. 2003).

CBC summaries of the data by year allow a rapid, user-friendly analysis of trends in the number of individuals and the number of species detected over time at a station of interest (Manomet 2017). The data are also presented by individual species. For CBC SCCG, the number of species and the number of individuals appear to have remained comparable, given the scatter in the data, from 2000 to 2013 (Table 59).

Three other indicators suggested here for bird fauna condition in Congaree National Park were developed from the baseline survey conducted in 2009 by Byrne et al. (2011b). They include the observed number of species ($BIRD_{OBS\ SPP}$), total bird abundance ($BIRD_{ABUND}$, number of individuals), and $BIRD_{DIST}$ (the six most widely distributed birds in the park). The final indicator, $BIRD_{SoC}$, is based on the fact that ten of the seventeen bird SoCs for the state and one of the two SoCs for Richland County—a high percentage, 59% and 50% respectively of the total—that have been reported have been found in the park (Tables 60a–c; NPS 2013a; U.S. FWS 2014). Based on the five indicators and the evaluation format shown in Tables 60a–c, the overall status of bird fauna condition in this park is good.

Finally, the status of the NPS Certified Species List (2013a) for bird fauna in Congaree National Park merits mention. This valuable list should be verified at least on a decadal basis. Otherwise, there will be no way to track the total number of species that actually can be found in the park at some time during an annual cycle, or the percentage of neotropical migrants, or other important information. At present, the total number reported on the list is 189 native species. We did not suggest the total number of species on the NPS Certified Species List, tracked over time, as an indicator in consideration of the fact that extensive survey of the park over an annual cycle would require a major personnel- and time-intensive effort, but it is important nevertheless.

**Table 59.** Christmas Bird Count results for the Congaree Swamp Count (SCCG) conducted within a 24 kilometer (15 mi) radius centered on the Congaree River, 400 m northwest of its confluence with Bates Mill Creek (National Audubon Society 2017b).

| Metric | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Number of Species | 68 | 73 | 68 | 75 | 87 | 79 | 89 | 80 | 83 | 90 | 95 | 95 | 97 | 109 |
| Number of Individuals | 2,531 | 4,616 | 6,746 | 4,213 | 13,524 | 10,214 | 16,965 | 227,471 | 179,799 | 7,685 | 55,960 | 46,030 | 150,167 | 42,932 |

**Table 60a.** The five indicators used to evaluate bird fauna conditions in Congaree NP.

| Indicator | Good | Fair | Poor |
|---|---|---|---|
| Christmas Bird Count ($BIRD_{CBC}$), annual, routinely conducted by volunteers for the Audubon Society) | ≥ 64 native species (annual average, 4- to 5-yr period) | 55–63 species | < 55 species |
| $BIRD_{OBSSPP}$ (assessed at 10-yr intervals, same timing/sites as in 2009) | ≥ 50 native species | 41–49 native species | < 41 native species |
| $BIRD_{ABUND}$ (# individuals, same assessment)[1] | ≥ 180 individuals in total | 150–179 individuals | < 150 individuals |
| $BIRD_{DIST}$ (most widely distributed, same) | same 7 spp | 5-6 of the 7 spp | ≤ 4 of the 7 spp. |
| $BIRD_{SoC}$ (assessed at 10-yr intervals in "best" locations)[2] | ≥ 8 (of 10) SoCs observed | ≥ 5 to 8 SoCs observed | < 5 SoCs observed |

[1] Set to "baseline" of 2009 as good.

[2] Set to "baseline" of 2010 as good (i.e., 10 .SoCs reported for the park).

**Table 60b.** The present bird fauna conditions in Congaree NP, evaluated by the indicators in Table 60a.

| Indicator | Congaree evaluation | Rating |
|---|---|---|
| $BIRD_{CBC}$ | North American CBC averages in the Park area:<br>2000–2004: 74 spp., 6,326 individuals<br>2005–2008: 83 spp., 108,612 individuals<br>2009–2013: 97 spp., 60,555 individuals<br>The lowest # of species annually over the 2000–2013 period was 68 spp. in 2000 and 2002. | good |
| $BIRD_{OBSSPP}$ | April–June 2009: 68 native species detected at 32 established sites. | good |
| $BIRD_{ABUND}$ | April–June 2009: 1,047 individuals detected at 32 established sites<br>Most abundant taxa were the Carolina wren, northern cardinal, northern parula, tufted titmouse, blue-gray gnatcatcher, Acadian flycatcher, red-bellied woodpecker, red-eyed vireo, yellow billed cuckoo. Thirty priority species of conservation concern were detected. | good |
| $BIRD_{DIST}$ | April–June 2009 most widely distributed taxa: same as most abundant; these taxa were found at > 80% of the sites. | good |
| $BIRD_{SoC}$ | As of 2013 (NPS Certified Species List): Ten SoCs: American swallow-tailed kite, Bachman's sparrow, bald eagle, Cooper's hawk, little blue heron, loggerhead shrike, Mississippi kite, red-headed woodpecker, Swainson's warbler, wood stork. | good |
| **Overall condition rating** | | **good** |

**Table 60c.** The overall evaluation of the present bird fauna conditions in Congaree NP, based on the five indicators in Table 60b.

| Rating | Criteria |
|---|---|
| Good | $BIRD_{BBS}$ or $BIRD_{OBSSPP}$ good, ≥ 2 other indicators good, ≤ 1 other indicator fair, no indicator poor |
| Fair | $BIRD_{SPP}$ or $BIRD_{OBSSPP}$ fair; ≤ 2 other indicators fair, ≤ 1 other indicator poor |
| Poor | ≥ 2 indicators poor |

### *4.9.6. Mammals*

Due to the lack of species-abundance information or other population-level information, we based the present form of the mammalian species indicator on the proportion of exotic/invasive mammalian taxa (11%) relative to the total number of mammalian taxa inhabiting the park; and on the number of mammalian SoCs in the park (five of the six SoCs known to occur in the general area; Tables 61a–c).

**Table 61a.** The two indicators used to evaluate mammalian fauna conditions in Congaree NP.

| Indicator | Good | Fair | Poor |
|---|---|---|---|
| $MAM_{INV}$<br>(proportion of exotic/invasive species, assess every 10 years) | < 5%, none common | 5–10% | > 10% |
| $MAM_{SOC}$<br>(assess every 10 years) | 5–6 SoCs detected in the park | 3–4 SoCs detected in the park | ≤ 2 SoCs detected in the park |

**Table 61b.** The present mammalian fauna conditions in Congaree NP, evaluated by the indicators in Table 61a.

| Indicator | Congaree evaluation | Rating |
|---|---|---|
| $MAM_{INV}$ | 11% of the species in the park (4 of 37) are exotic/invasive taxa, including domestic / feral dogs, feral cats and feral pigs. | poor |
| $MAM_{SOC}$ | As of 2013: five mammalian SoCs were reported to occur in the park (NPS Certified Species List) | poor |
| **Overall condition rating** | | **poor** |

**Table 61c.** The overall evaluation of the mammalian fauna conditions in Congaree NP, based on the three indicators in Table 61b.

| Rating | Criteria |
|---|---|
| Good | both indicators good |
| Fair | ≥ 1 indicator fair, neither indicator poor |
| Poor | ≥ 1 indicator poor |

### *4.9.7. Special Management Issues*

The major long-term goal identified by park staff concerning natural resources is the management of feral hogs and the re-establishment of the historic landscape at the park. Feral hog management is essential to the preservation of the park's natural resources. The hog population currently threatens the bottomland hardwood ecosystem function, regeneration of vegetation, rare and imperiled species communities, and potential impairment of water quality among many other natural resources. The long-term benefits of feral hog management will result in an improvement of the natural quality of the wilderness. The latter goal largely involves re-establishment of longleaf pine ecosystems in both upland pine plantation and the floodplain. Therefore, two indicators are suggested to address special management issues involving longleaf pine restoration. The indicator for fire management, is included as well, in recognition of the fact that prescribed fires are integral to the success of the park pine rehabilitation efforts (Tables 62a–c).

Apart from an historic perspective, re-establishment of longleaf pine ecosystems will benefit the park by improving climate resilience and ecosystem vitality:

> Originally the dominant native pine of the South, now mostly eliminated from its historic range, longleaf pine is better suited to thrive in the coming decades than other southern pine species. Longleaf pine grows under very dry or very wet conditions; is tolerant of and even dependent on frequent fire; is better able to weather severe storms; and is more resistant to beetle infestations likely to be exacerbated by warmer and drier conditions….Longleaf pine trees live longer than other southern pine species [and] are less susceptible to fire, pests, and storms.—National Wildlife Federation (2009)

It should be noted that we elected not to develop specific indicators for exotic/invasive species, for two reasons: First, we have already factored exotic/invasive species into the indicators for vascular flora and mammals in this park. Second, as Ferriter et al. (2007) wrote,

> The indicator[s] for invasive exotics is not similar in nature or context to other indicators because nonindigenous [species] in themselves do not make good indicators of ecological function, process, or structure…

Based on their extensive experience combating exotic/invasive species in the Florida Everglades, Ferriter et al. (2007) suggested use of the following parameters to evaluate and report the status of invasive species: the number of different exotic/invasive species present; the number, abundance, and frequency of new exotic/invasive species in the ecosystem; the number and abundance of extant exotic/ invasive species found in new locations; the location and density of invasive exotic species, especially in relation to native communities; the rate of invasive species spread; and the effectiveness of control actions or programs for exotic/invasive species, generally measured as a decrease in the spatial extent of a (plant) species. Indicators should be developed, especially to address selected priority exotic/invasive species, as this information becomes available.

**Table 62a**. The three indicators used to evaluate progress on special management issues (SMIs) in Congaree NP.

| Indicator | Good | Fair | Poor |
|---|---|---|---|
| $MGMT_{FIRE}$ (fire management) | updated plan at 5-yr intervals | updated Plan at 7-8 yr intervals | updated Plan > 8-yr intervals |
| $LLEAF_{SAV}$ (Re-establishment of pine plantation for restoration close to historic reference conditions) | prescribed burns at 5-year intervals; hydrology is conducive to reestablishment. | prescribed burns every 6 to 7 years; hydrology improving toward desired conditions for re-establishment | prescribed burns at > 7 year intervals; hydrology not yet conducive to re-establishment |
| $MGMT_{HOG}$ (Feral Hog Environmental Assessment Management Plan) | plan is in place and updated every 5 years | updated plan at 7–8 year intervals | updated plan > 8 year intervals |

**Table 62b.** The present progress on special management issues (SMIs) conditions in Congaree NP, evaluated by the indicators in Table 62a.

| Indicator | Congaree evaluation | Rating |
|---|---|---|
| $MGMT_{FIRE}$ | A Fire Management Plan was adopted in 2004; an updated draft is in preparation | poor |
| $LLEAF_{SAV}$ | Pine plantation restoration has proceeded since the mid-2000s. Prescribed burns are continuing to be scheduled at 5 year intervals in an attempt to allow natural regrowth and maintain low/natural 'ground fuel' levels | good |
| $MGMT_{HOG}$ | A Feral Hog Management Plan is in draft form; public comment has been made. | good |
| **Overall condition rating** | | **fair** |

**Table 62c.** The overall evaluation of the present progress on special management issues in Congaree NP, based on the three indicators in Table 62b.

| Rating | Criteria |
|---|---|
| good | ≥ 2 indicators are good including $MGMT_{FIRE}$; ≤ 1 indicator is fair |
| fair | ≥ 2 indicators are fair including $MGMT_{FIRE}$, ≤ 1 indicator is poor |
| poor | ≥ $MGMT_{FIRE}$ is poor, ≥ 1 other indicator is poor |

# 5. Climate

Climate is defined as the long-term pattern and processes of weather events for a given location (Paz et al 2008). Climate is among the most significant influences dictating biotic components anywhere on Earth. Weather and climate are key drivers for ecosystem patterns and processes, affecting both biotic and abiotic components alike. Understanding the role of climate as a forcing agent for other vital signs (e.g., plant and animal communities) is a critical component of Southeast Coast Network monitoring…Continuous weather monitoring is [also] a key factor in separating the effects of climate from the effects of human-induced disturbance on plant and animal community and population dynamics.—Wright (2012a).

The climate in the park region is characterized as humid, with subtropical temperatures often reaching 32.2°C (mid-90s F) or higher in summer and decreasing to 4.4°C (mid-40s F) during winter (NWS 2014). The mean annual temperature was 17.6°C (63.6°F), with an annual temperature range of 11.0–24.1°C (51.8–75.4°F). Annual rainfall averaged 118.4 centimeters (46.6 in) per year (Southeast Regional Climate Center 2014, Weather Station ID 381939). Climate data are available from two stations near the park (Table 63).

**Table 63.** Weather stations in or near Congaree NP. From Wright (2012a).

| Distance (km [mi]) | Station Name | National Network | Station ID | Latitude (dd) | Long (dd) | County | Elev. (feet) | Start Date |
|---|---|---|---|---|---|---|---|---|
| 26.6 [16.5] | Columbia Metro Airport | COOP | 381939 | 33.95 | -81.1167 | Lexington | 225.1 | 11/1/1941 |
| NA [in park] | Congaree | RAWS | GDNS1 | 33.8147 | -80.7811 | Richland | 403.5 | 5/3/2005 |

## 5.1. Temperature

The analyses of climatic conditions for this report were completed in 2012–2013 and, thus, generally used data available through 2011 or 2012. Data from the National Weather Service of the National Oceanic and Atmospheric Administration (NOAA) provide information on changes in temperature, precipitation, and drought condition over time. South Carolina Climate Division 6 was chosen because of its central location and its historical record covers the period from 1930 through 2012 whereas records begin in 1948 for Columbia. The mean annual temperature for Climate Division 6 across that period was 17.3°C (63.2°F). There was no increasing trend per decade over the 82-year record, but there is an increasing trend since the 1960s (Figure 47). The same general pattern is shown for the summer mean temperature and July mean temperature, with increasing temperatures since the 1960s for Climate Division 6 (Figure 48 and 49, respectively).

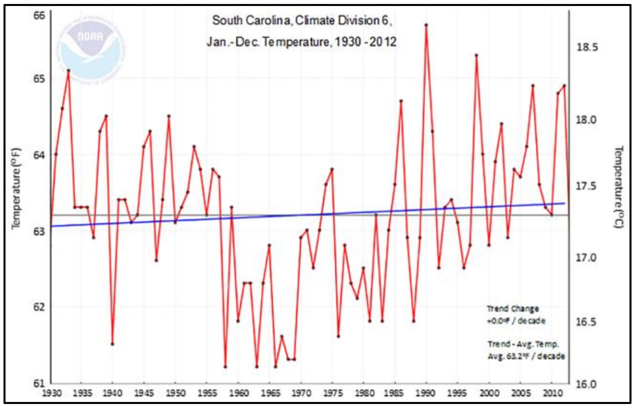


**Figure 47.** Mean annual temperature for Climate Division 6, South Carolina from 1930 to 2012 was 17.3°C (63.2°F; NOAA 2017a).

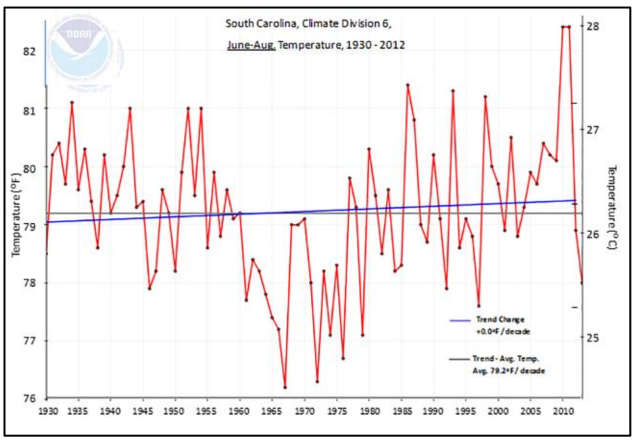


**Figure 48.** Mean summer temperature June– August for Climate Division 6, South Carolina from 1930 to 2012 was 26.2°C (79.2°F; NOAA 2017a).

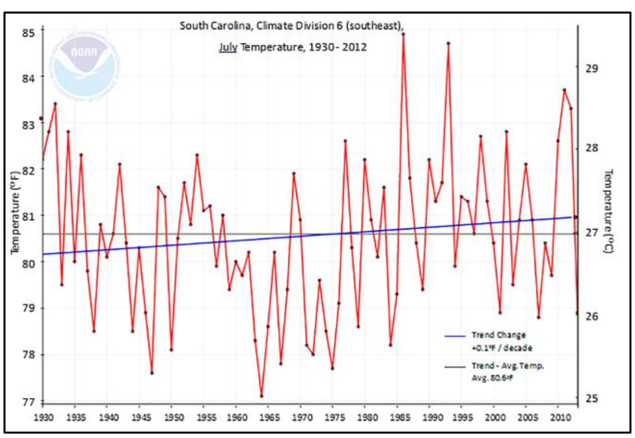


**Figure 49.** Mean temperature for the month of July during 1930 to 2012 in Climate Division 6, South Carolina was 27.0°C (80.6°F), suggesting a slight increase over time (NOAA 2017a).

### 5.2. Precipitation

Similar analyses were conducted for precipitation falling in Climate Division 6. Mean annual and mean summer (June–August) precipitation from 1930 to 2012 varied greatly, but showed no clear trend (only +0.48 centimeters or +0.19 in and +0.05 centimeters or +0.02 in per decade, respectively; Figures 50 and 51).

Overall, then, in the general area of the park, both annual and summer temperatures are increasing, long-term within the past five decades, whereas mean annual precipitation has shown a decrease in both annual and summer trends over the last decade. The increasing temperatures and decreasing precipitation could to lead to a decrease in available water and an increase in drying which may, in turn, promote more frequent and/or severe drought conditions. On the other hand, more recently in 2013, the Midlands region of South Carolina sustained the wettest year since 2009, with the first above-normal precipitation since 2009 (NWS 2014).

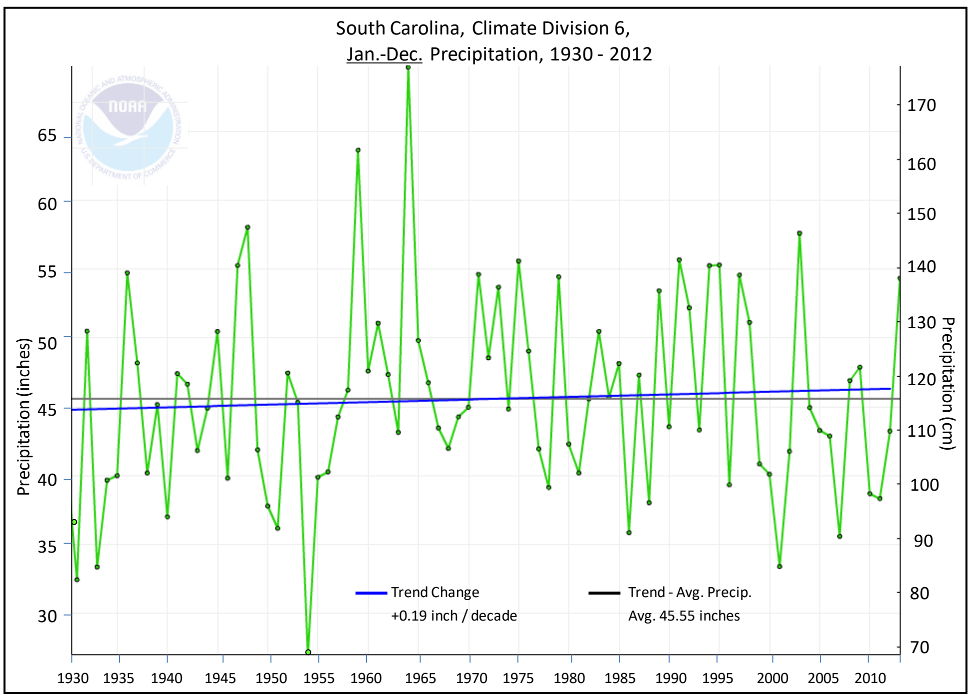


**Figure 50.** Mean annual precipitation for Climate Division 6, South Carolina from 1930 to 2012 was 115.7 centimeters (45.6 in), suggesting an increase of 0.48 centimeters (0.19 in) per decade (NOAA 2017a).

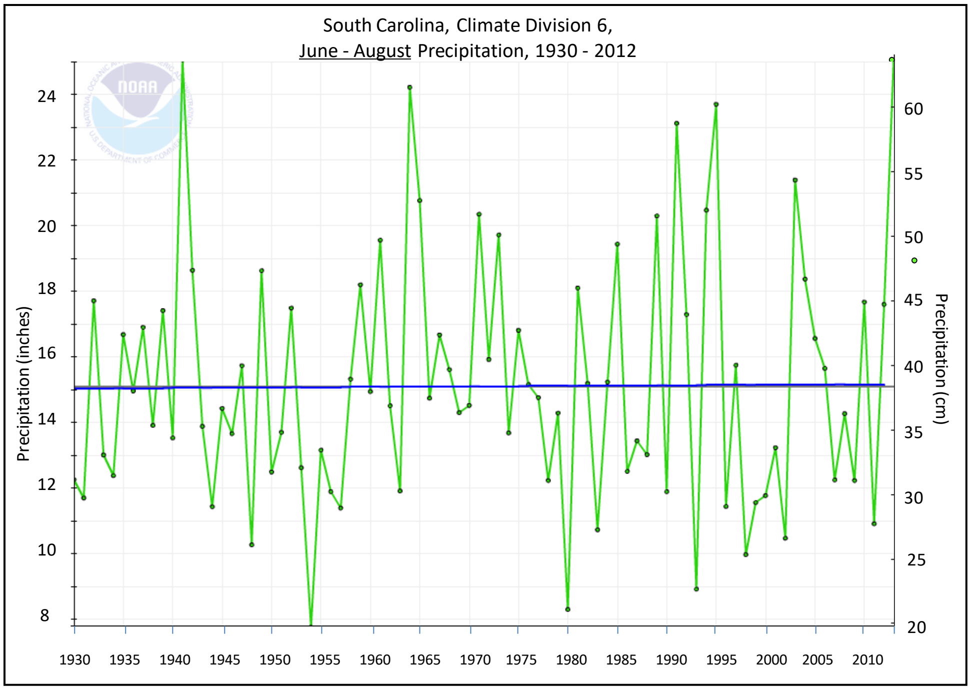


**Figure 51.** Mean summer (June–August) precipitation in Climate Division 6, South Carolina from 1930 to 2012, suggesting a slight increase (0.05 centimeters [0.02 in] per decade; NOAA 2017a).

### 5.3. Moisture

Drought severity was assessed (1932 to 2012) using the Palmer Drought Severity Index (PDSI, a scale ranging from -3 to +3), which assesses the duration and intensity of long-term drought-inducing circulation patterns (Dai et al. 2004; Dai 2011a, b). Since long-term drought is cumulative, the intensity of drought during the present month depends on the present weather patterns along with the cumulative conditions for previous months. PDSI values rank the severity of a given drought (Table 64). The indicated "classes" were used to assign a monthly PDSI value from 1932 to 2012, and the proportion of months in each class for each 9-year period was determined (Figure 52). Drought severity was highly variable over time, but the data show an increase in the proportion of months that were in the slightly dry/favorably moist since 1968.

**Table 64.** Palmer Drought Severity Index scale. From Dai et al. (2004).

| Scale Interval | Class Description |
|---|---|
| -3 or less | Severely dry |
| -2 to less than -3 | Excessively dry |
| -1 to less than -2 | Abnormally dry |
| -1 to less than 1 | Slightly dry / favorably moist |
| 1 to less than 2 | Abnormally wet |
| 2 to less than 3 | Wet |
| 3 or greater | Excessively wet |

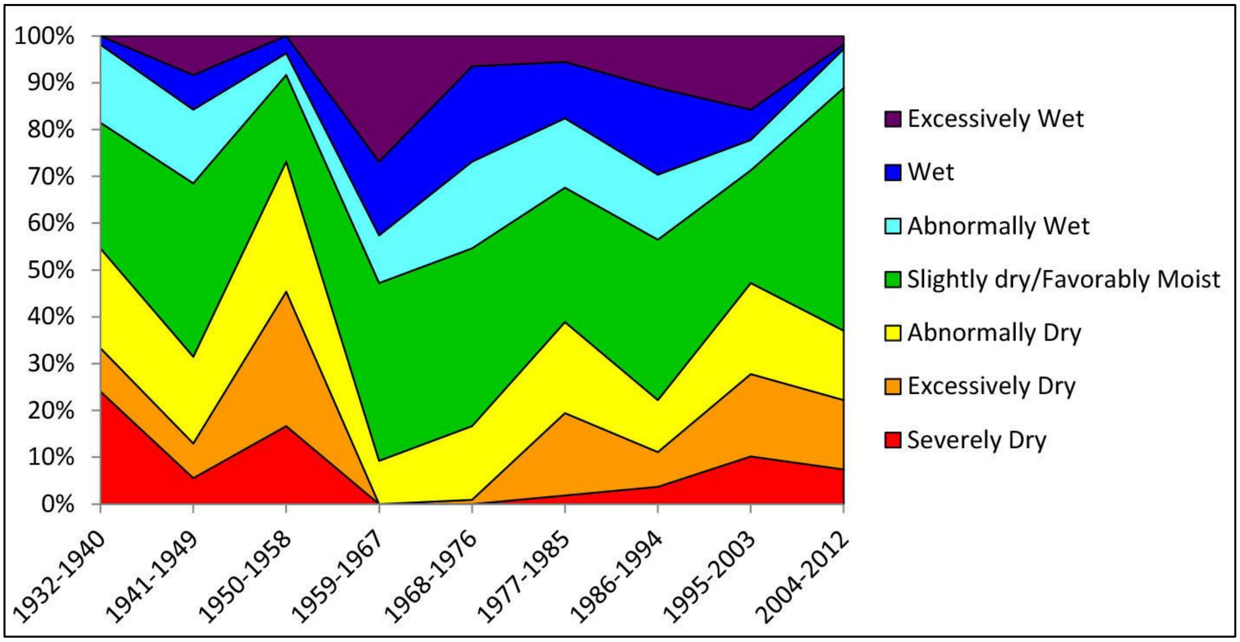


**Figure 52.** PDSI values for Columbia over 9-yr periods from 1932 to 2012. Data from the Southeast Regional Climate Center (SERCC).

### 5.4. Phenology

Phenology is the study of the effects of changes in the seasonal variation of temperature and precipitation on biological processes, reflected in the timing of reproduction, flowering, and the length of the growing season (NOAA NWS). We assessed changes in phenology as growing degree days (GDDs), defined as the total amount of time in an annual cycle when the temperature is above 4.4°C (40°F), roughly equivalent to the growing season when non-evergreen plants are able to photosynthesize. The monthly mean temperature for Columbia over time from 1949 to 2012 was used to estimate the approximate number of GDDs per month:

$$GDD = (Tm - 40)\,Dm$$

Where GDD = growing degree days, Tm = monthly mean temperature, and Dm = number of days in month. The GDDs for each month were added to estimate the GDDs per year, and these values were plotted over time to assess long-term changes in the numbers of GDDs in the Columbia area (Figure 53). We also considered phenology within the context of a calendar year by selecting an arbitrary GDD threshold of 1200 and then estimating the data at which that number of GDDs was reached. This would be similar to estimating the specific date when a phenological event such as cherry tree flowering in March or April. The total monthly accumulated GDD through March 31st was calculated by multiplying the mean daily temperature by the number of days in a month, and the difference from 1200 was determined. The number of days required to reach the 1200 GDD was estimated as the slope of the line for the approximate month. If the difference was positive, the exact date where 1200 was achieved was estimated as the slope of the line between the total GDD for March and the total for April. If the difference was negative, the same procedure was used between February and March. In this way, the calendar date when the 1200 GDD was achieved was calculated for each year (Figure 54). The GDD for the park area slightly increased over the period from 1990 to 2012. Corresponding to early 1200 GDD date, 2010–2012 had a high number of annual GDD. Overall, this analysis suggests that the phenology in the Columbia area may be advancing, but the annual variation for GDD is high so that the trend is weak. The 1200 GDD was reached very early in 2012. Although trend line over 83 years shows slight incline upward, since 1994, the 1200 GDD was, on average, reached earlier. There are no dates in late May or early June, as in previous decades. The analysis indicates that species found in warmer climates may, in time, be able to expand into the region, whereas more northern species may be limited.

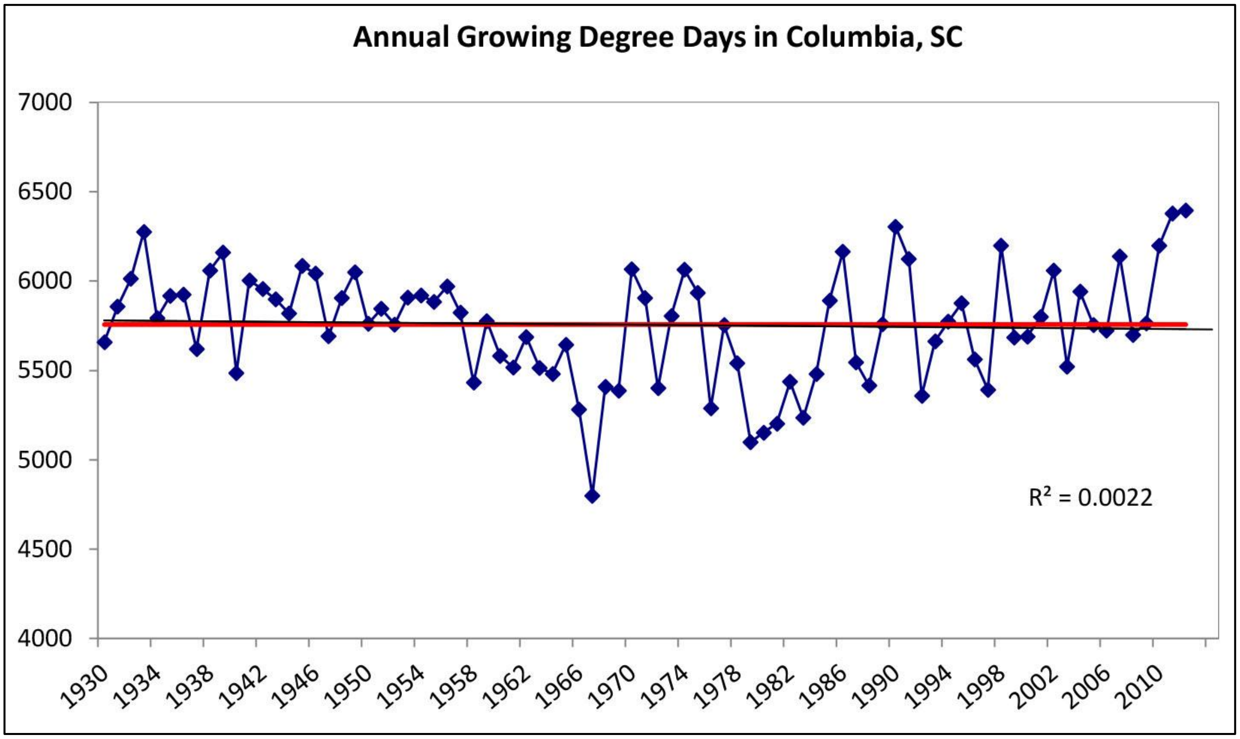


**Figure 53.** The total GDDs per year for Columbia from 1930 to 2012. The long-term mean annual GDD total is 5756 (red line). The number of GDD shows a very weak upward trend over the last two decades, indicating general warming. Data from the SERCC.

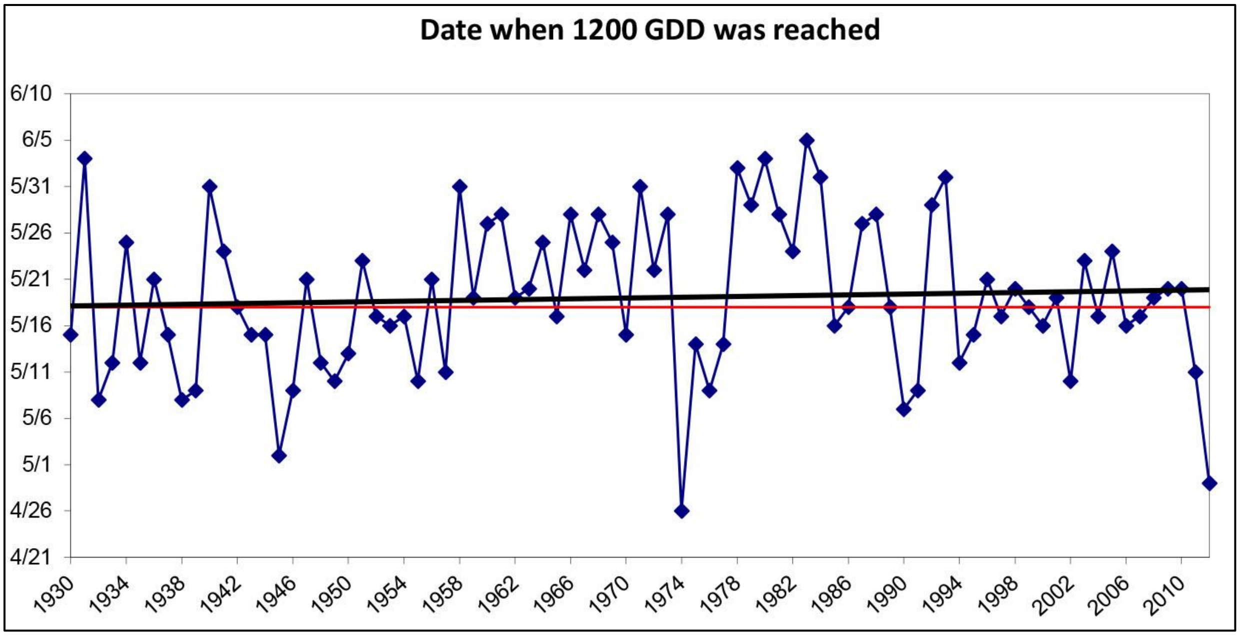


**Figure 54.** The approximate date when 1200 GDDs was reached for each year in the Columbia. South Carolina, area from 1930 to 2012. The slight increase over time indicates that this date is occurring earlier each year. The 1200 GDDs was reached very early in 2012. Data from the SERCC.

## 5.5. Extreme Weather Events

Storm tracks within a 161-kilometer (100-mi) radius of Columbia were acquired from 1851 to 2012 from the NOAA National Weather Service (Figure 55). Each storm was rated as a tropical depression (TD), a tropical storm (TS), and category 1–4 hurricanes. Storms categorized as tropical depressions have maximum sustained winds of 61 kilometers per hour (km/hr, 38 mi per hour, mph) or less. Tropical storms have maximum sustained winds of 63 to 117 kilometers per hour (39 to 73 mph; United States Department of Commerce 2013). The Saffir/Simpson Hurricane Scale (SSHS; Table 65) rates and categorizes hurricanes on a scale of 1 to 5 based on wind speeds (Blake et al. 2007), and a major hurricane is rated as a 3, 4, or 5 on the SSHS. Storms that occurred on successive days were combined into one storm event, and the event was assigned the most severe storm rating that it received). The data were considered by month and year (Figures 56 and 57).

**Table 65.** The Saffir/Simpson Hurricane Scale (SSHS). From Blake et al. (2007).

| Scale Number (Category) | Wind Speed (mph) | Millibars | Inches | Surge (feet) | Damage |
|---|---|---|---|---|---|
| 1 | 74–95 | > 979 | > 28.91 | 4 to 5 | Minimal |
| 2 | 96–110 | 965–979 | 28.50–28.91 | 6 to 8 | Moderate |
| 3 | 111–130 | 945–964 | 27.91–28.47 | 9 to 12 | Extensive |
| 4 | 131–155 | 920–944 | 27.17–27.88 | 13 to 18 | Extreme |
| 5 | > 155 | < 920 | < 27.17 | > 18 | Catastrophe |

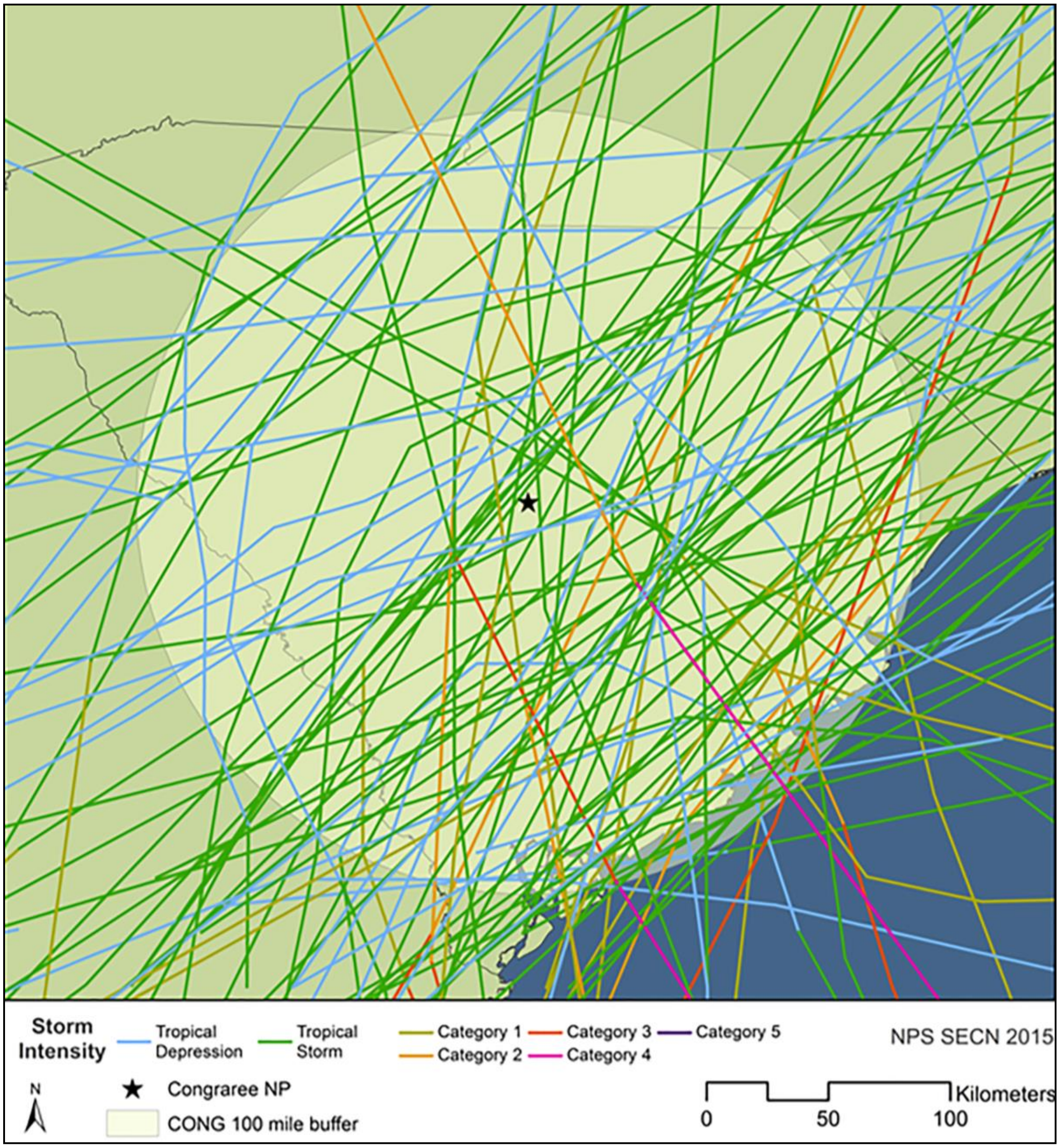


**Figure 55.** Tropical cyclones within 161 kilometers (100 mi) of CONG, 1851–2013. (NOAA 2017b)

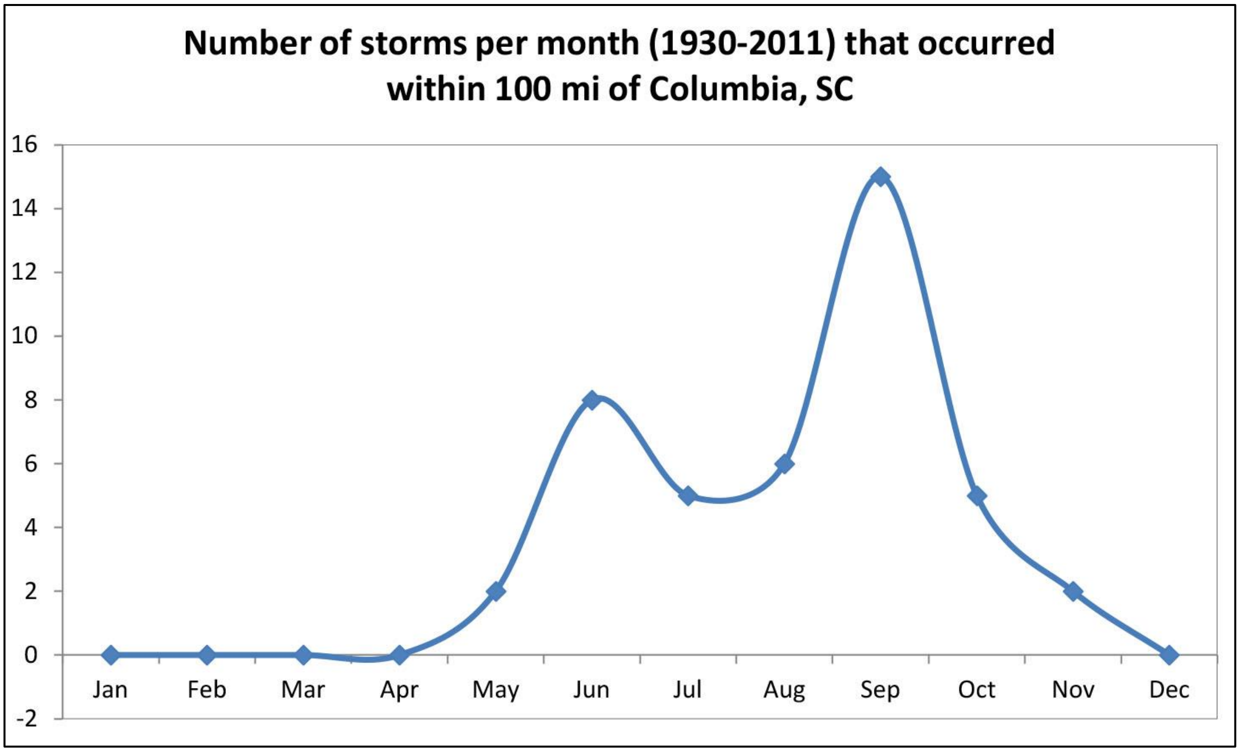


**Figure 56.** The number of major and minor storms by month (1930–2011) that occurred within 161 km (100 mi) of Columbia, South Carolina. Data from NOAA NWS.

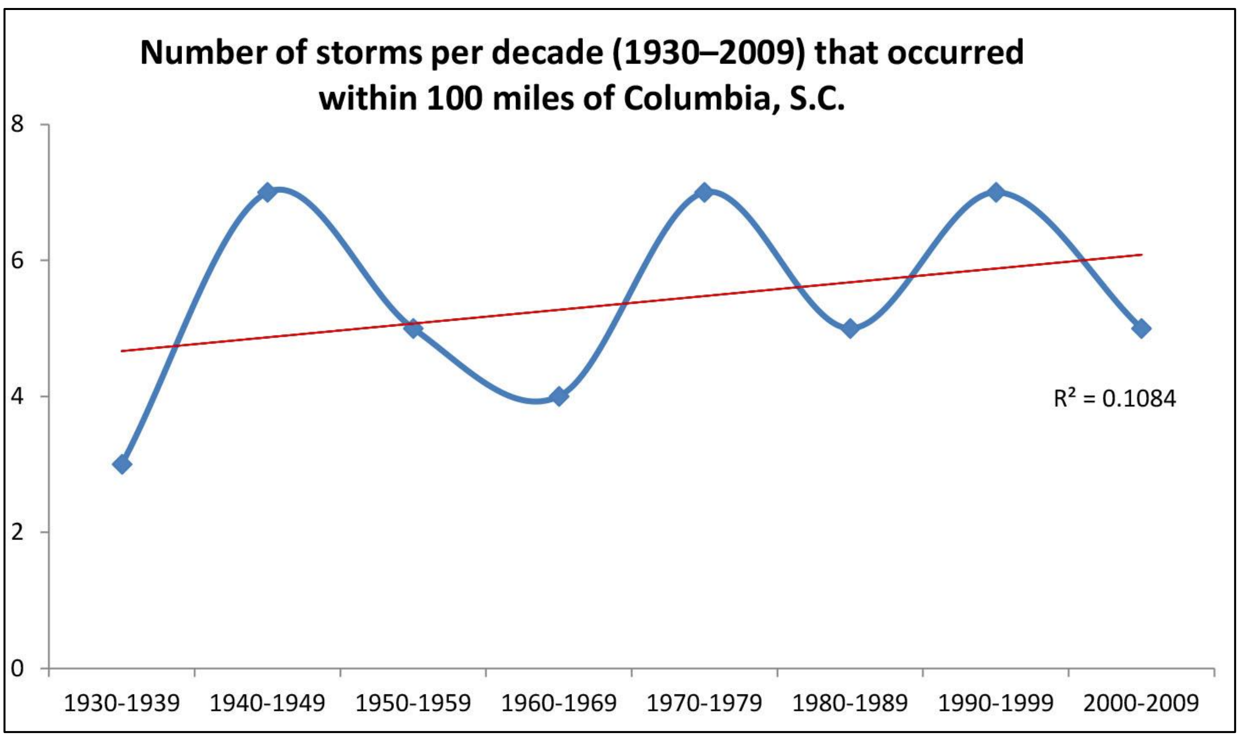


**Figure 57.** The number of major and minor storms per decade (1930–2009) that occurred within 161 km (100 mi) of Columbia, South Carolina (Data from NOAA NWS).

Of the 85 storms in total from 1851–2012, most were tropical depressions and tropical storms; no hurricanes affected Columbia throughout the entire period (Table 66). Most storms in the Columbia area have occurred during September–October (Figure 56). The total number has increased from 1930 to the present (Figure57).

**Table 66.** The total numbers of lows, extratropical storms, tropical depressions, subtropical storms, and tropical storms that affected the Columbia area, 1851–2012 (n=85) (State Climate Office of North Carolina 2017).

| Classification | # of Storms | % of Storms |
|---|---|---|
| Category 5 Hurricanes | 0 | 0% |
| Category 4 Hurricanes | 0 | 0% |
| Category 3 Hurricanes | 0 | 9% |
| Category 2 Hurricanes | 1 | 1.16 |
| Category 1 Hurricanes | 2 | 2.4% |
| Tropical Storms | 40 | 38.3% |
| Subtropical Storms | 1 | 0% |
| Tropical Depressions | 27 | 45.7% |
| Subtropical Depressions | 1 | 2.40% |
| Extratropical Storms | 13 | 10.0% |
| Lows | 0 | 1.2% |
| Total storms 1851–2012 | 85 | 100% |

# 6. Discussions

## 6.1. Summary of Natural Resource Conditions in Congaree National Park

This in-depth analysis of the natural resources of Congaree National Park considered available information for all natural resource categories (Tables 45a–c and 62a–c). A total of 57 indicators were used to evaluate the 16 categories of natural resources for which sufficient information was available to allow some level of assessment. The overall condition of five categories was rated as good; four were evaluated to be in fair condition, and seven were in poor condition (Tables 67 and 68). Nearly all of the fair and poor conditions, with possible exception of visitation—human population in the park, were strongly influenced by external forces, not possible for the National Park Service to control.

This report card can function as a valuable resource for Congaree National Park staff and the Southeast Coast Network by enabling rapid communication to concerned citizens, policymakers in local, state, and federal governments, industries etc. about the pressing need to improve protection of the natural resources in this valuable park. It is our hope that the many people who depend on Congaree National Park for recreation and insights about the early history of our nation—and who expect to continue to enjoy it—will respond to this report card by contributing more stewardship toward the goal of improving the status and the protection of the natural resource conditions in this national park.

**Table 67.** Overall Report Card of Natural Resource Condition in Congaree NP.

| Natural Resource Category | Indicator(s) | Rating |
|---|---|---|
| Human Population Surrounding the Park | 4 | poor |
| Visitation / Human Population in the Park | 3 | good |
| Surrounding Land Use/Land Cover | 4 | poor |
| Air Quality | 8 | fair |
| Soundscape | 3 | fair |
| Lightscape | 2 | fair |
| Soil and Streambank Erosion | 4 | poor |
| Groundwater Supply | 2 | poor |
| Surface-water quality | 8 | poor |
| Vascular Flora | 4 | poor |
| Aquatic Benthic Macroinvertebrates | 1 | good |
| Fish | 2 | good |
| Herpetofauna | 2 | good |
| Birds | 5 | good |
| Mammals | 2 | poor |
| Special Management Issues | 3 | fair |

**Table 68.** Summary of Natural Resource Conditions in Congaree NP, including 16 separate categories evaluated using the 58 listed indicators.

| Category | Subcategory | Indicators | Present Status In Congaree National Park | Indicator Rating |
|---|---|---|---|---|
| Physical/Chemical | Human population surrounding park | $HPG_{5\text{-}KM}$ (human population growth at 5-km radius) | Population increasing +1.3% per year (past decade) (Richland County) | poor |
| | | $HPG_{80\text{-}km}$ (human population growth at 80-km radius) | Population increasing +1.9% per year (CMSA) | poor |
| | | $HPD_{5\text{-}KM}$ (human population density at 5-km radius) | 198 people/km$^2$ (514 people/mi$^2$) (Richland County) | poor |
| | | $HPD_{80\text{-}km}$ (human population density at 80-km radius) | 83 people/km$^2$ (216 people/mi$^2$) (CMSA) | poor |
| | | **Overall rating for all indicators** | | **poor** |
| | Visitation | VIS (trends in # visitors/year) | 120,122 visitors (2014): little change for past several years. | good |
| | | $VP\text{-}A_{YEAR}$ (visitor pressure/area) | Avg. of 11.2 visitors/ha of park area per year (0.03/acre/year). | good |
| | | $VP\text{-}T_{YEAR}$ (visitor pressure on trails) | Avg. of 2,502 visitors/km of trail per year (4,003 visitors/mi), or 7 visitors/km trail/day (11/km trail/mi). | fair |
| | | **Overall rating for all indicators** | | **good** |
| | Land use/ land cover | $AGRIC_{CAFOS}$ (agricultural influence from CAFOs) | Several CAFOS are within 10 km (6 mi) upstream from CONG | poor |
| | | $AGRIC_{CROPS}$ (agricultural influence from croplands) | Croplands are 5.8% of the land use/land cover in the sub-watershed that includes the park. | poor |
| | | % $IC_{5\text{-}km}$ (impervious cover in 5-km radius around the park) | Closest population center had 131,686 people as of 2012; impervious cover near park is < 1% of land cover. | good |
| | | % GRN (total greenspace loss) | In the past 15 yr (since 2000), the nearest population center, Columbia, has grown 13.3% (average of 0.89% per year, indicating low greenspace loss. | fair |
| | | **Overall rating for all indicators** | | **poor** |

**Table 68 (continued).** Summary of Natural Resource Conditions in Congaree NP, including 16 separate categories evaluated using the 58 listed indicators.

| Category | Subcategory | Indicators | Present Status In Congaree National Park | Indicator Rating |
|---|---|---|---|---|
| Physical/Chemical (continued) | Air quality | AQI (air-quality index) | 2013: AQI good ≥ 69.6% of days, moderate 30.4%.of days, unhealthy for sensitive groups 0% of days. | fair |
| | | Ozone (ozone effects on humans) | 2005–2009: 61–75 ppb ozone (8-hour avg. time, 4th max. value) | fair |
| | | W126 (ozone effects on humans) | 2005–2009: W126: 7–13 ppm-hour | fair |
| | | SUM06 (ozone effects on plants) | 2005–2009: SUM06: 8–15 ppm-hour | fair |
| | | N-DEP (nitrogen deposition) | 2005–2009: N-DEP > 3 kg/ha/year | fair |
| | | S-DEP (sulfur deposition) | 2005–2009: S-DEP > 3 kg/ha/year | poor |
| | | VIS (visibility) | 2005–2009: VIS > 8 dv | poor |
| | | ACID (acidification) | 2002: pollutant exposure high, ecosystem sensitivity low, park protection high; overall moderate risk from acidic pollution | poor |
| | | **Overall rating for all indicators** | | **fair** |
| | Soundscape | POP$_{SOUND}$ (proximity to population center) | CONG is within the CMSA and 32 km (20 miles) from Columbia (population 132,094 and growing). | fair |
| | | SOURCE$_{SOUND}$ (proximity to major source [road, RR, etc.]) | A state highway transects the park; a federal highway is 14.5 km (9 mi) west; the Columbia airport is also nearby. | fair |
| | | DATA/OBS$_{SOUND}$ (noise pollution data available for the park) | Data not available for CONG; park staff describe the park as usually quiet, but with occasional loud periodic aircraft overflight. | fair |
| | | **Overall rating for all indicators** | | **fair** |

**Table 68 (continued).** Summary of Natural Resource Conditions in Congaree NP, including 16 separate categories evaluated using the 58 listed indicators.

| Category | Subcategory | Indicators | Present Status In Congaree National Park | Indicator Rating |
|---|---|---|---|---|
| Physical/Chemical (continued) | Lightscape | Bortle Dark Sky Scale classes ($LITE_{ARTIF}$):1-2 (truly dark skies),3-4 (rural.skies),≥ 5 (suburban sky, ground objects partly lit) to 9 (inner city sky) | CONG is still in a predominantly rural/suburban setting; its lightscape is described by park staff as Class 4, Suburban Skies, or better | fair |
| | | ALR: avg. anthropogenic all-sky luminance divided by avg. natural all-sky luminance: good < 0.33 (< 26 nL in > half of park) fair > 0.33 to 2.00 (26–156 nL) poor > 2.00 (> 156 nL) | The modeled ALR for the expanding Columbia area is red (> 2.00 to 18), and the modeled ALR for the surrounding area is amber (> 0.33 to 2.00). | fair |
| | | **Overall rating for all indicators** | | **fair** |
| | Soil and streambank erosion | $SOIL_{EROD}$ (characteristic erodibility of all major soil types) | All 4 major soil types in CONG are moderately erodible, unstable, and/or prone to caving of ditchbanks and cutbanks, and they are flooded frequently. | poor |
| | | $SOIL_{VIS}$ (visual evidence of soil erosion of lands) | There is visible evidence of soil erosion in CONG. | poor |
| | | $BANK_{EROD}$ (evidence of streambank erosion) | There is visual evidence of major streambank erosion in the park (cutbanks, etc.). | poor |
| | | $SOIL_{ACID}$ (soil acidification potential) | High soil acidification potential in CONG. | poor |
| | | **Overall rating for all indicators** | | **poor** |
| | Ground-water supply | $GRW_{SUPPLY}$ (groundwater level) | Groundwater level has significantly decreased over period of record in USGS monitoring wells nearest the park. | poor |
| | | $GRW_{USE}$ (expected groundwater use) | Groundwater use is projected to increase significantly in the next decade with demands of the increasing human population. | poor |
| | | **Overall rating for all indicators** | | **poor** |

**Table 68 (continued).** Summary of Natural Resource Conditions in Congaree NP, including 16 separate categories evaluated using the 58 listed indicators.

| Category | Subcategory | Indicators | Present Status In Congaree National Park | Indicator Rating |
|---|---|---|---|---|
| Physical/Chemical (continued) | Surface-water quality | pH 6.0 to 8.5 | pH: 88% compliance (821 of 932 samples) | fair |
| | | Turbidity ≤ 5.7 NTU | Turbidity: 44% met recommendation (363 of 817 samples) | poor |
| | | DO ≥ 4 mg/L (NC with caveats) | DO: 98% compliance (874 of 890 samples) | good |
| | | $BOD_5$ < 3 mg/L | $BOD_5$: 98% compliance (736 of 754 samples) | good |
| | | TP ≤ 30 µg/L | TP: 22% met recommendation (161 of 726 samples) | poor |
| | | $NO_x^-$N ≤ 177 µg/L | $NO_x^-$N: 22% met recommendation (173 of 794 samples) | poor |
| | | TKN ≤ 510 µg/L | TKN: 23% met recommendation (138 of 606 samples) | poor |
| | | TSS ≤ 10 mg/L | TSS: 35% met recommendation (149 of 424 samples) | poor |
| | | FECAL ≤ 200 cfu/100 mL (GM); ≤ 20% of samples ≤ 400 cfu/100 mL | FECAL: 91% met recommendation (SS) (838 of 925); 78% met recommendation (GM) (18 of 23 months) | good/fair |
| | | ECOLI < 126 cfu/100mL (GM); < 235 cfu/100 mL single sample | ECOLI: 71% met recommendation (SS) (122 of 172 samples) 26% met recommendation (GM) (6 of 23 months) | poor |
| | | ENT < 33 cfu/100 mL (GM) or < 104 cfu/100 mL single sample max | ENT: 74% met recommendation (SS) (515 of 692 samples) 17% (GM) (4 of 23 months) | poor |
| | | **Overall rating for all indicators** | | **poor** |
| Biological | Vascular flora | $TERR_{EX}$ (# exotics/total) | Based on the NPS Certified Species List (2013): 8.9% (29 spp.) of the terrestrial taxa are exotic/invasive. | fair |
| | | $TERR_{CAT}$ ( # highly invasive taxa) | CONG has 7 Category R1 species (including 3 on the NPS Top Ten List), 3 Category R2 species, 1 Category R3, and 1 Category R4 species. | poor |
| | | $WET_{EX}$ (# exotics/total) | 3.9% (20 spp.) of the total wetland/aquatic taxa are exotic/invasive. | good |
| | | $WET_{CAT}$ (# highly invasive taxa) | 6 Category R1 species (including 2 on the NPS Top Ten List), 3 Category R3 and 2 Category R4 occur in CONG) | poor |
| | | **Overall rating for all indicators** | | **poor** |

**Table 68 (continued).** Summary of Natural Resource Conditions in Congaree NP, including 16 separate categories evaluated using the 58 listed indicators.

| Category | Subcategory | Indicators | Present Status In Congaree National Park | Indicator Rating |
|---|---|---|---|---|
| Biological (continued) | Aquatic benthic macroinvertebrates | $INVERT_{SPP}$ (species richness) | 2001: 302 native species were found in CONG | good |
| | | **Overall rating for all indicators** | | **good** |
| | Fish | $FISH_{SPP}$ (fish species richness) (#) | 56 native fish species in the park as of 2004 (most recent survey) | good |
| | | $FISH_{SoC}$ (species of concern) | Only 1 SoC still occurred in CONG as of 2013 | good |
| | | **Overall rating for all indicators** | | **good** |
| | Herpeto-fauna | V-Anurans (# species detected with ARD) | 2011 survey: 12 vocal anuran amphibian species detected | good |
| | | $HERP_{VES}$ (# species detected with VES) | Short survey in 2010: 19 amphibian and 6 reptilian species detected | good |
| | | **Overall rating for all indicators** | | **good** |
| | Birds | $BIRD_{CBC}$ (# native spp./year) | 74 species/year in 2000–2004; 97/year in 2009–2013. | good |
| | | $BIRD_{OBS\ SPP}$ (# native spp.) | April–June 2009: 68 native spp. (32 sites in park); April–June 2009: 1,047 individuals; | good |
| | | $BIRD_{ABUND}$ (# individuals, top 7 species) | Top 7: Carolina wren, northern cardinal, northern parula, tufted titmouse, blue-gray gnatcatcher, Acadian flycatcher, red-bellied woodpecker, red-eyed vireo, yellow billed cuckoo. | good |
| | | $BIRD_{DIST}$ (7 most widely distributed species (same as for $BIRD_{ABUND}$) | The same 7 species as for $BIRD_{ABUND}$ | good |
| | | $BIRD_{SoC}$ ( # SoCs observed) | NPS Certified Species List (2013 'baseline') contains 10 SoCs. | good |
| | | **Overall rating for all indicators** | | **good** |
| | Mammals | $MAM_{INV}$ (percentage exotic/invasive) | 2003–2004 survey: CONG had 29 native species and 4 exotic/invasive species (11% of the total). | poor |
| | | $MAM_{SoC}$ (decadal evaluation) | NPS Certified Species List (2013a): 5 mammalian SoCs in the park | good |
| | | **Overall rating for all indicators** | | **poor** |

**Table 68 (continued).** Summary of Natural Resource Conditions in Congaree NP, including 16 separate categories evaluated using the 58 listed indicators.

| Category | Subcategory | Indicators | Present Status In Congaree National Park | Indicator Rating |
|---|---|---|---|---|
| Species of Concern and Special Management Issues | SMIs | $MGMT_{FIRE}$ (Fire Management Plan updated and evaluated every 5 years)- | CONG has a Fire Management Plan (2004); an updated draft is in preparation | poor |
| | | $LLEAF_{SAV}$ (re-establishment of longleaf pine plantation for rehabilitation to historic condition) | Pine plantation rehabilitation has been ongoing since the mid-2000s; efforts include prescribed burns at 5-year intervals | good |
| | | $MGMT_{HOG}$ (establishment of Feral Hog Management Plan and updated every 5 years) | CONG has a draft Wild Pig Management Plan; public comment is being incorporated. | good |
| | | **Overall rating for all indicators** | | **fair** |

## 6.2. Remaining Major Knowledge Gaps and Next Steps

Major knowledge gaps that restricted evaluation of the present condition for resource categories and efforts needed to fill them include:

- *Erosion/Weathing Processes Active in Congaree NP*—Geologic hazards such as slope creep, streambank erosion, and slumps would be especially expected to affect areas with weaker rock units such as the semi-consolidated sandstone, silts, and claystone underlying the Congaree River, and uncosolidated alluvium (Graham 2014). park staff identified the issue and there is a need for a comprehensive study of erosion/weathering processes, including data on rates of sediment accumulation and erosion in the Congaree River.
- More specifically for *streambank erosion*, a channel stability index should be developed for Congaree River within the park, following the approach of Heeren et al. (2012). The CSI is a type of rapid geomorphic assessment (RGA) that provides a quick, straightforward method for characterizing stream reaches in terms of stability (Simon and Downs 1995). The CSI would be applicable to Congaree National Park because this index was originally designed for areas that are highly sensitive to erosion. Required measurements include bank height, bank face length, river stage at baseflow, degree of constriction, and average diameter of streambed sediment, following guidance on a two-page sheet. Metrics include representative river stage (water-surface height, measured in the thalweg of the stream, avoiding local scour pools), river channel width at the cross section and 1/4th of a meander length upstream, measured at the bankfull height; and degree of constriction (relative decrease in channel width from upstream to downstream). Scores from several metrics are summed to create an aggregate score, with a higher score indicating greater instability: ≤ 10 = stable, 10–20 = moderately unstable, and ≥ 20 = highly unstable (Simon and Klimetz 2008). The simple approach recommended by Heeren et al. (2012), requiring about 30 minutes per site to complete, has been found to perform equivalently or even better than indices that require 3 years of bank erosion pin data (e.g., see Harmel et al. 1999). The CSI could then be developed as an indicator to provide a more quantitative evaluation of streambank erosion condition in the park over time.
- *Stream Sediment Quality*—Information is needed to enable assessment of the quality of stream sediments in Congaree National Park, focusing on toxic substances such as mercury, arsenic, copper, and PCBs—e.g. see MacDonald et al. 2000, and references therein).
- *Sewage overflows, septic tank leachate and agricultural pollution near Congaree NP*—The effects of urbanization, stormwater runoff, municipal and industrial wastewater discharges, septic tank leachate and agriculture and industrialized poultry operations are a threats to both surface and groundwater resources (Matz and Tucker 1998; DeVivo et al. 2008; Rasmussen et al. 2009). Adequate protection of park ecosystems will require accurate knowledge about the chemicals (fertilizers, pesticides, additives to feed such as heavy metals) used in agriculture in the region, together with an understanding of the airshed and hydrogeologic system within and surrounding the park.
- *Combined Studies on Surface Water Hydrology Water quality*—Data from the Congaree River gaging station 02169325 near the park is needed to track discharge and stream depth in the

Congaree River collected concomitant with data on pollutants, conductivity, and chloride. Data for the parameters selected as water-quality indicators should be collected at least monthly every other year to enable reliable assessment of water-quality conditions over time at water-quality stations, one coinciding with a flow gaging station as Congaree River enters the park (C-074), and at another station as the stream exits the park.

- *Groundwater Quantity*—Currently there is no monitoring of the Southeastern Coastal Plain Aquifer system in the park vicinity. One monitoring well should be installed in the park for deep aquifer characterization and monitoring (Rasmussen et al. 2009).
- *Groundwater Quality*—Groundwater-quality data is presently not available in the park. Monthly sampling at least every other year is needed to characterize pH, conductivity, chloride, and concentrations of potential contaminants known to contaminate groundwater from industrialized animal operations (Mallin 2000; Burkholder et al. 2007)—such as nitrate+nitrite, ammonia, sulfide, fecal bacteria, and metals (e.g., arsenic, copper), following the approach of Donahue (1999).
- *Stream Macroinvertebrate Communities*—Stream macroinvertebrates are commonly used to evaluate habitat conditions. The stream macroinvertebrate community while characterized as diverse in the Pescador (2004) study, presently needs reevaluating. Metrics for stream macroinvertebrates should be added to natural resource monitoring in Congaree National park so that a macroinvertebrate index of biological integrity (M-IBI; e.g., Barbour et al. 1999) can be calculated and tracked over time, because this community is an important biological component that provides integrative information about aquatic habitats and water quality. Stream macroinvertebrates should be sampled at 3-year intervals using well-established protocols (Barbour et al. 1999; NC DENR 2006; Bowles et al. 2008).
- *Fish Community*—Fish are widely understood by the general public as desirable organisms of value. The fish community of Congaree National Park in 2004 was in relatively good condition, (56 native species) but this info is now dated. Fish should be added as an important biological component, and should be sampled using a well-established protocol (Barbour et al. 1999; NC DENR 20013) at 5-year intervals to enable calculation of a fish index of biological integrity (F-IBI; e.g., Barbour et al. 1999), and used to track stream biological condition over time.
- *Additional surface water-quality monitoring*—Data for TSS was sparse and chlorophyll *a* data is necessary for sites monitored by SCDHEC near the park. Although, fecal coliform monitoring is consistent throughout the three sub-watersheds, enterococcus and *E. coli* monitoring should be increased at sites C-077, C-076, CW-222 to accurately characterize and indicate water quality coming into the park.
- *Population Studies*—Species of special management concern, such as selected SoCs, should be quantitatively assessed over time to inform park staff so that adequate efforts to strengthen protective measures can be made. Selected highly invasive taxa should be quantitatively tracked as well, to inform park staff as they work to develop and/or modify management plans to reduce these species and mitigate their impacts on Congaree National Park ecosystems.

- *Updated Biota Surveys*—Rigorous efforts on a decadal basis should be conducted to track the natural resource conditions of the flora and fauna in Congaree National Park. Up-to-date, vouchered species lists of vascular flora in terrestrial and wetland habitats are needed. For example, the most recent survey of mammals in Congaree National Park is already a decade old, and should be updated in order to track the condition of this important natural resource category over time.
- *Analysis of the Cumulative and Synergistic Effects of Pressures from Climatic, Land Use, and Exotic/Invasive Species Changes*—The rate of climate warming in this century is projected to be from 2.5- to 5.8-fold higher than the rate measured during the 1900s (Hansen et al. 2014, and references therein). Temperatures are expected to increase by 2.5°C to 4.5°C. Watershed development is expected to accelerate; for example, an average 255% increase in housing density is projected by 2100 in lands surrounding national parks throughout the nation. Exotic/invasive species generally are favored by disturbances such as these (Ferriter et al. 2007). The cumulative, synergistic effects of such changes could have dramatically impact ecosystem function and biodiversity in national parks (Hansen et al. 2014). In fact, it has been estimated that 30% of the parklands may lose their present biomes by as early as 2030 (Hansen et al. 2014). We have recommended various additional efforts by the Southeast Coast Network which, together with the present and planned I&M works, will greatly strengthen understanding about how each of these pressures affects Congaree National Park natural resources. The resulting databases will make it possible for the Southeast Coast Network to consider climatic, land use, and exotic/invasive species changes more realistically—through integrative rather than separate analyses of cumulative/synergistic impacts over time.

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# Appendix A. GIS Layers for Congaree NP including the Congaree River and Lower Wateree River Watersheds

**Table A-1.** GIS layers for Congaree National Park.

| Layer Name | Category | Description | Source | Scale/ Resolution | Projection | Datum | Metadata Available |
|---|---|---|---|---|---|---|---|
| Southeast Coast Network Alternate Administrative Park Boundaries (from park data holdings) | Boundary | This is a vector polygon dataset representing the park version of the administrative boundaries for CONG. | Park GIS Library | unknown | UTM Zone 17N | NAD 83 | Yes |
| Current NPS Administrative Boundary for Congaree National Park | Boundary | Vector polygon shapefile representing the NPS administrative boundary for CONG. This boundary was originally part of a larger NPS regional dataset and is intended for use at the regional level. This boundary is also found in the state_regional_gis directory and it may need to be updated as the NPS national administrative boundary dataset is updated. | NPS | 1:10,000,000 | UTM Zone 17N | NAD 83 | Yes |
| Digital Elevation Model (DEM) Data | Elevation | This directory contains DEM quad level imagery that covers the extent of CONG in NAD 27 and a number of larger mosaicked images (aspect, elevation, hillshade, and slope) in NAD 83 that also cover the park extent. There is one html metadata file that covers one particular quad but nothing else so please use these carefully. | USGS | unknown | UTM Zone 17N | NAD 27 | Yes–text file only |
| National Elevation Dataset (aspect) | Elevation | The U.S. Geological Survey has developed a National Elevation Dataset (NED). The NED is a seamless mosaic of best-available elevation data. The 7.5-minute elevation data for the conterminous United States are the primary initial source data. Aspect was derived by using the aspect tool in the surface tool set within the Spatial Analyst toolbox. The dataset includes NED coverage for CONG and surrounding areas. | U.S. Geological Survey (USGS), EROS Data Center | 30 meters | UTM Zone 17N | NAD 83 | Yes |
| National Elevation Dataset (elevation) | Elevation | The U.S. Geological Survey has developed a National Elevation Dataset (NED). The NED is a seamless mosaic of best-available elevation data. The 7.5-minute elevation data for the conterminous United States are the primary initial source data. The dataset includes NED coverage for CONG and surrounding areas. | U.S. Geological Survey (USGS), EROS Data Center | 30 meters | UTM Zone 17N | NAD 83 | Yes |

**Table A-1 (continued).** GIS layers for Congaree National Park.

| Layer Name | Category | Description | Source | Scale/ Resolution | Projection | Datum | Metadata Available |
|---|---|---|---|---|---|---|---|
| National Elevation Dataset (Hillshade) | Elevation | The U.S. Geological Survey has developed a National Elevation Dataset (NED). The NED is a seamless mosaic of best-available elevation data. The 7.5-minute elevation data for the conterminous United States are the primary initial source data. Hillshade was derived using the hillshade tool in the surface tool set within the Spatial Analyst toolbox. The dataset includes NED coverage for CONG and surrounding areas. | U.S. Geological Survey (USGS), EROS Data Center | 30 meters | UTM Zone 17N | NAD 83 | Yes |
| Digital line graph (DLG) hydrography data (7.5 minute quadrangles) | Hydrography | This folder contains hydrographic DLG data downloaded from the SCDNR via the USGS. The five quads that cover CONG are in separate folders in shapefile format and in the original coverage format. The folder also contains a merged quad shapefile that covers the entire extent of the park. | USGS; S.C. Dept. of Natural Resources | 1:24,000 | UTM Zone 17N | NAD 83 | Yes–text file only |
| Digital line graph (DLG) hypsography data (7.5 minute quadrangles) | Hypsography | This folder contains hypsographic DLG data downloaded from the SCDNR via the USGS. The five quads that cover CONG are in separate folders in shapefile format and in the original coverage format. The folder also contains a merged quad shapefile that covers the entire extent of the park. | USGS; S.C. Dept. of Natural Resources | 1:24,000 | UTM Zone 17N | NAD 83 | Yes–text file only |
| Industrial Solid Waste Landfills in South Carolina | Land Use | This dataset provides the locations of industrial solid waste landfills in the State of South Carolina. Industrial solid waste landfills collect waste generated through industrial processes. Most of the waste is similar to the type of waste sent to municipal solid waste landfills but is landfilled at the facility's own site rather than being hauled to a MSW landfill. | S.C. Dept. of Health and Env. Control; Bureau of Land and Waste Mgmt. | unknown | UTM Zone 17N | NAD 83 | Yes |
| Municipal Solid Waste Sites in South Carolina | Land Use | This dataset provides the locations of private and commercial municipal solid waste landfills located in the State of South Carolina. | S.C. Dept. of Health and Env. Control; Bureau of Land and Waste Mgmt. | unknown | UTM Zone 17N | NAD 83 | Yes |
| Underground Storage Tank Locations for South Carolina | Land Use | This dataset provides the locations of underground storage tanks located in the State of South Carolina. | S.C. Dept. of Health and Env. Control; Bureau of Land and Waste Mgmt. | unknown | UTM Zone 17N | NAD 83 | Yes |

**Table A-1 (continued).** GIS layers for Congaree National Park.

| Layer Name | Category | Description | Source | Scale/ Resolution | Projection | Datum | Metadata Available |
|---|---|---|---|---|---|---|---|
| National Wetlands Inventory | NWI | NWI digital data files are records of wetlands location and classification as developed by the U.S. Fish & Wildlife Service. These data are individual NWI quads in polygon and polyline shapefile format and a polygon mosaic (both cover the extent of CONG). | USFWS | 1:24,000 | UTM Zone 17N | NAD 83 | Yes–text file only |
| Wetlands (Land Use/Land Cover Data) for the Fort Jackson South 7.5 minute quadrangle | NWI | This dataset contains NWI data based on land use/cover quadrangles downloaded from the SCDNR via the USFWS. This set covers a much larger extent than the one above (Fort Jackson South quadrangle) but it is not as descriptive/detailed due to the fact that the individual quadrangles were dissolved base on a general land use field. This data set differs from the one above in that it covers a complete block around and including CONG whereas the one above is an incomplete block. | USFWS; S.C. Dept. of Natural Resources | 1:24,000 | UTM Zone 17N | NAD 83 | Yes |
| Wetlands (Land Use/Land Cover Data) for the St. Matthews 7.5 minute quadrangle | NWI | This dataset contains NWI data based on land use/cover quadrangles downloaded from the SCDNR via the USFWS. This set describes the NWI features found in the St. Matthews quadrangle that is found in the southwest corner of the CONG extent. | USFWS; S.C. Dept. of Natural Resources | 1:24,000 | UTM Zone 17N | NAD 83 | Yes |
| Wetlands (Land Use/Land Cover Data) for the Staley Crossroads 7.5 minute quadrangle | NWI | This dataset contains NWI data based on land use/cover quadrangles downloaded from the SCDNR via the USFWS. This set describes the NWI features found in the Staley Crossroads quadrangle that is found in the southwest corner of the CONG extent. | USFWS; S.C. Dept. of Natural Resources | 1:24,000 | UTM Zone 17N | NAD 83 | Yes |
| Railroads Data for Congaree National Park | Transportation | This dataset contains railroad transportation DLG data downloaded from the SCDNR via the USGS. The extent is the same as the previous pipe_trans dataset (Fort Jackson South quadrangle). | USGS; S.C. Dept. of Natural Resources | 1:24,000 | UTM Zone 17N | NAD 83 | Yes |
| 1:24,000-scale Digital Line Graphs | Transportation | This dataset contains railroad transportation DLG data downloaded from the USGS. The set consists of one quad that shows the railroad features that fall within the western half of the park. | USGS | 1:24,000 | UTM Zone 17N | NAD 83 | Yes |

**Table A-1 (continued).** GIS layers for Congaree National Park.

| Layer Name | Category | Description | Source | Scale/ Resolution | Projection | Datum | Metadata Available |
|---|---|---|---|---|---|---|---|
| 1:24,000-scale Digital Line Graphs | Transportation | This dataset contains road transportation DLG data downloaded from the SCDNR via the USGS. The extent is the same as the previous cong_railroads dataset (Fort Jackson South quadrangle). | USGS; S.C. Dept. of Natural Resources | 1:24,000 | UTM Zone 17N | NAD 83 | Yes |
| General Geologic Map Series | Geology | This data set is a digital version of the general geologic map data developed by the South Carolina Geological Survey. This data was created from original field work and/or compiled from existing geologic map data. The data was constructed by digitizing maps, compiling information onto a planimetric correct base, or revising digitized maps using remotely sensed and other information. | South Carolina Geological Survey | 1:1,000,000 | UTM Zone 17N | NAD 83 | Yes |
| Air Monitoring Stations for South Carolina | Monitoring | This dataset contains all the current Ambient Air Monitoring Network Sites in S.C. Both continuous air monitor sites and 24-hour sampling sites are represented. | S.C. Dept of Health and Environmental Control | unknown | UTM Zone 17N | NAD 83 | Yes |
| Biological Monitoring Stations in South Carolina | Monitoring | This dataset provides the spatial locations of past and present biological monitoring stations within the State of South Carolina. | S.C. Dept of Health and Environmental Control; Bureau of Water | 1:24,000 | UTM Zone 17N | NAD 83 | Yes |
| Comprehensive, Environmental Response, Compensation and Liability Act of 1980 (CERCLA) Sites in South Carolina | Monitoring | This layer includes sites identified for cleanup under the CERCLA regulations (Superfund sites). The CERCLA program is intended to identify sites from which releases of hazardous substances into the environment might occur or have occurred, to ensure cleanup by the responsible parties or the government, and to evaluate damages to natural resources. | S.C. Dept. of Health and Env. Control; Bureau of Land and Waste Mgmt. | unknown | UTM Zone 17N | NAD 83 | Yes |

**Table A-1 (continued).** GIS layers for Congaree National Park.

| Layer Name | Category | Description | Source | Scale/ Resolution | Projection | Datum | Metadata Available |
|---|---|---|---|---|---|---|---|
| National Pollutant Discharge Elimination System (NPDES) Discharge Sites in the Congaree and Wateree Watersheds | Monitoring | This directory contains the NPDES discharge sites that are located in the Congaree and Wateree River watersheds. The data was downloaded from the Permit Compliance System (PCS) database. The attributes include the name of the discharge location, the receiving waterbody, and coordinate values for each site among others. The directory specifically contains the NPDES shapefile and the comma-delimited tabular file that was originally downloaded as well as a dbf form of the table. | EPA | unknown | UTM Zone 17N | NAD 83 | Yes–text file only |
| CONG_wq_stationlocation.shp | Monitoring | This dataset contains the locations of a series of water-quality monitoring stations within CONG and in the surrounding areas. There is no metadata attached to the file or within the file folder. The data seems to be informative but use caution when utilizing the set since there is no source information. The data appears to match a set found in the wq_gis directory (below) so it is very possible that the metadata that corresponds to those datasets may also apply to this set. | Unknown | unknown | Geographic CS | NAD 83 | No |
| Water-quality Monitoring Stations for South Carolina | Monitoring | This dataset provides the spatial locations of all water-quality monitoring stations within the State of South Carolina. | S.C. Dept of Health and Environmental Control; Bureau of Water | 1:24,000 | UTM Zone 17N | NAD 83 | Yes–text file only |
| Water-quality Monitoring Stations for South Carolina (Edisito-Santee Hydrologic Subregion) | Monitoring | This dataset provides the spatial locations of water-quality monitoring stations within the Edisto-Santee Hydrologic Subregion (roughly). | S.C. Dept of Health and Environmental Control; Bureau of Water | 1:24,000 | UTM Zone 17N | NAD 83 | Yes |

**Table A-1 (continued).** GIS layers for Congaree National Park.

| Layer Name | Category | Description | Source | Scale/ Resolution | Projection | Datum | Metadata Available |
|---|---|---|---|---|---|---|---|
| Soil Survey Geographic (SSURGO) database for Calhoun County, South Carolina | Soils | This dataset is a SSURGO digital soil survey and generally is the most detailed level of soil geographic data developed by the National Cooperative Soil Survey. The data is divided into spatial files in polygon format by the survey area and map unit boundaries that contain and surround the park. Descriptive attribute files in text and database tabular formats are also contained in the directory. | U.S. Dept of Agriculture, Natural Resources Conservation Service | 1:24,000 | UTM Zone 17N | NAD 83 | Yes–text file only |
| National Park Service–Soil Survey Geographic (SSURGO) database for Congaree Swamp National Monument, South Carolina | Soils | This data set is a digital soil survey and generally is the most detailed lever of soil geographic data. Specifically, the data set is identical to the one listed above except that it has undergone some additional processing by NPS personnel such as clipping the set to the park extent and adding the musym names to the attribute table. | NPS–GRD -SIMP | 1:24,000 | UTM Zone 17N | NAD 83 | Yes |
| State Soil Geographic (STATSGO) data base for South Carolina | Soils | This data set is a digital general soil association map developed by the National Cooperative Soil Survey. It consists of a broad based inventory of soils and nonsoil areas that occur in a repeatable pattern on the landscape and that can be cartographically shown at the scale mapped. The soil maps for STATSGO are compiled by generalizing more detailed soil survey maps. The data is in shapefile format in both NAD 83 and UTM 17 NAD 83 and is accompanied by a large amount of descriptive tabular data. | U.S. Dept of Agriculture, Soil Conservation Service | 1:250,000 | UTM Zone 17N | NAD 83 | Yes–text file only |
| cosw_soils1 | Soils | This dataset is a SSURGO digital soil survey and generally is the most detailed level of soil geographic data developed by the National Cooperative Soil Survey. The dataset is essentially a duplicate of the files found in the soil_cong directory but with a smaller extent that matches the Fort Jackson South quad that has been referenced in previous CONG files. | U.S. Department of Agriculture, Natural Resources Conservation Service | 1:24,000 | UTM Zone 17N | NAD 83 | Yes |

**Table A-1 (continued).** GIS layers for Congaree National Park.

| Layer Name | Category | Description | Source | Scale/ Resolution | Projection | Datum | Metadata Available |
|---|---|---|---|---|---|---|---|
| Herpetofaunal Species Locations | Species | This directory contains the locations of herpetofauna found in Congaree National Park (COSW) during a study performed by Tuberville, Willson, Dorcas, and Gibbons in conjunction with the Savannah River Ecology Laboratory (SREL) between May 2001 and October 2003. Please refer to: "Herpetofaunal Species Richness of Southeastern National Parks." Southeastern Naturalist 4.3 (2005): 537-569 for more detailed information about the study. The data is divided into one spatial file and one tabular file in order to provide all of the features found during the study as some of the sampling locations were not defined spatially. | SREL/SECN | 1:30,000 | UTM Zone 17N | NAD 83 | Yes |
| Herpetofaunal Species Locations | Species | This directory contains the locations of herpetofauna found in Congaree National Park (COSW) during a study performed by Tuberville, Willson, Dorcas, and Gibbons in conjunction with the Savannah River Ecology Laboratory (SREL) between May 2001 and October 2003. Please refer to: "Herpetofaunal Species Richness of Southeastern National Parks." Southeastern Naturalist 4.3 (2005): 537-569 for more detailed information about the study. The data is divided into one spatial file and one tabular file in order to provide all of the features found during the study as some of the sampling locations were not defined spatially. | SREL/SECN | 1:30,000 | UTM Zone 17N | NAD 83 | Yes |
| USGS-NPS VEGETATION MAPPING PROGRAM | Veg | This directory includes the vegetation classification, accuracy assessment, field study, and photointerpretation key data and reports that were derived from the vegetation mapping study undertaken by the USGS and the NPS. The file also includes the final maps and an assortment of photos that resulted from the study as well as two spatial files that will be described in the following two records. | USGS | NA | Other | Other | Yes |

**Table A-1 (continued).** GIS layers for Congaree National Park.

| Layer Name | Category | Description | Source | Scale/ Resolution | Projection | Datum | Metadata Available |
|---|---|---|---|---|---|---|---|
| Congaree Swamp National Monument Spatial Vegetation Data; Cover Type / Association level of the National Vegetation Classification System | Veg | This polygon shapefile dataset describes the vegetation classifications that were established by the USGS-NPS veg mapping study undertaken at CONG. | American Geographic Data, Inc. | 1:12,000 | UTM Zone 17N | NAD 83 | Yes |
| Congaree Swamp National Monument Boundary Dataset | Veg | This dataset contains a CONG park boundary that was included in the veg mapping data. The boundary is similar to the one found in the basedata directory. It is added as a reference only. | USGS, Center for Biological Informatics | 1:24,000 | UTM Zone 17N | NAD 83 | Yes |
| 12-Digit Watershed Boundary Data 1:24,000 | Watershed | This dataset is a complete digital hydrologic unit boundary layer to the Sub-watershed (12-digit) 6th level for the State of South Carolina. This dataset consists of geo-referenced digital data and associated attributes including huc-10 and 12 codes, names, types, and modifications. | U.S. Geological Survey, Water Resources Discipline, South Carolina District | 1:24,000 | UTM Zone 17N | NAD 83 | Yes |
| Navigable Streams within South Carolina | Watershed | This dataset provides the spatial locations of navigable streams within the State of South Carolina. The dataset also contains the huc codes that the streams fall under. | S.C. Dept of Health and Environmental Control; Bureau of Water | 1:24,000 | UTM Zone 17N | NAD 83 | Yes |
| Congaree National Park-Small Scale Base GIS Data | WQ GIS | The data are comprised of small-scale base GIS data layers, including roads, hydrography, political boundaries, trails and other layers as available and appropriate, compiled for the purpose of displaying the locations of point-based hydrologic features (water-quality monitoring stations, stream gages, industrial discharges, drinking intakes, and water impoundments) proximate to national park units. The data are intended to be used as a set to ensure spatial alignment. The accompanying Microsoft Excel file,sources.xls, lists the data sources for each data layer. | NPS–WRD | varies: 1:100,000 or larger | UTM Zone 17N | NAD 83 | Yes |

**Table A-1 (continued).** GIS layers for Congaree National Park.

| Layer Name | Category | Description | Source | Scale/ Resolution | Projection | Datum | Metadata Available |
|---|---|---|---|---|---|---|---|
| National Agriculture Imagery Program (NAIP) 2005 County Mosaic | Images | This directory contains true color digital ortho quarter quad imagery from the National Agricultural Imagery Program (NAIP) in MrSid format. NAIP acquires digital ortho imagery during the agricultural growing seasons in the continental U.S. The original county extent was clipped to an extent containing CONG and the surrounding areas. Please note that the imagery is of interim class quality and should be viewed as such. | USDA-FSA-APFO Aerial Photography Field Office | 1 and 2 Meter | UTM Zone 17N | NAD 83 | Yes |
| DOQQs | Images | False color DOQQs in MrSid format that cover the extent of CONG minus a portion of the Fork Swamp tract. There is no metadata or any other identifying documentation. | Unknown | Unknown | Unknown | Unknown | No |
| DOQQs | Images | False color DOQQs in .bip format that cover the northwestern extent of CONG. There is no metadata or any other identifying documentation. | Unknown | Unknown | Unknown | Unknown | No |
| Digital Raster Graphics–NAD83 | DRGs | These directories contain non-collared DRGs in both NAD 27 and 83. The 27 group are grouped by quads, spatially undefined according to the properties, and are in TIFF format. The 83 group is divided into a folder for a mosaic that covers CONG and a folder that contains the individual quads. The mosaic is in the correct projection and in MrSid format while the quads are spatially undefined for the most part and are in both MrSid and TIFF formats. There is also an image called sumter100k_n83 that is spatially undefined and in TIFF format. | USGS | Unknown | UTM Zone 17N | NAD 83 | Yes–text file only |
| Congaree maps | Images | This directory contains .jpeg maps of the following: canopy, LIDAR elevation, nwi, visitor centers, and watershed. There are no metadata or any other identifying documentation. | Unknown | Unknown | Other | Other | No |

**Table A-1 (continued).** GIS layers for Congaree National Park.

| Layer Name | Category | Description | Source | Scale/ Resolution | Projection | Datum | Metadata Available |
|---|---|---|---|---|---|---|---|
| South Carolina 27-class Land Cover | Images | This statewide land cover map was produced from Landsat TM imagery with a spatial resolution of 30x30m as a part of the South Carolina GAP Analysis Project. The original dataset was clipped to the spatial extent of CONG. There is also a dataset named cong_gap that contains the same data as the cosw_gap set; there is no discernable difference between the two. The sc_gap text metadata contains more descriptive attribute definitions than the other metadata in the gap directory. | South Carolina Cooperative Fish and Wildlife Research Unit,USGS Biological Resources | 30 meters | UTM Zone 17N | NAD 83 | Yes |
| South Carolina Land Cover Dataset | Images | The National Land Cover Dataset was compiled from Landsat satellite TM imagery (circa 1992) with a spatial resolution of 30 meters and supplemented by various ancillary data (where available). The original image was clipped to include the area containing and surrounding the park area. | USGS | 30 meters | UTM Zone 17N | NAD 83 | Yes |
| National Land Cover Database 2001 | Images | The National Land Cover Dataset was compiled from Landsat satellite TM imagery (circa 2001) with a spatial resolution of 30 meters and supplemented by various ancillary data (where available). The original image was clipped to include the area containing and surrounding the park area. | USGS | 30 meters | UTM Zone 17N | NAD 83 | Yes |
| Landsat Orthoimagery Mosaic | Images | The Landsat Mosaic orthoimagery database contains Landsat Thematic Mapper imagery for the conterminous United States. The more than 700 Landsat scenes have been resampled to a 1-arc-second (approximately 30-meter) sample interval in a geographic coordinate system using the North American Horizontal Datum of 1983. The original image was clipped to include the area containing and surrounding the park area. | USGS | 30 meters | UTM Zone 17N | NAD 83 | Yes |

**Table A-1 (continued).** GIS layers for Congaree National Park.

| Layer Name | Category | Description | Source | Scale/ Resolution | Projection | Datum | Metadata Available |
|---|---|---|---|---|---|---|---|
| NAIP Digital Georectified Image(s) | Images | This directory contains true color digital ortho quarter quad imagery from the National Agricultural Imagery Program (NAIP) in GeoTIFF format. NAIP acquires digital ortho imagery during the agricultural growing seasons in the continental U.S. Specifically, the directory contains 2005 NAIP imagery for the extent of CONG. | USDA-FSA-APFO Aerial Photography Field Office | 1 and 2 Meter | UTM Zone 17N | NAD 83 | Yes |
| Landcover datasets | Images | This directory contains the same data as the cosw92_nlcd and cosw_nlcd01 datasets described above. Please refer to these listings for complete descriptions. | USGS | 30 meters | UTM Zone 17N | NAD 83 | Yes |

# Appendix B. Water Quality Data for the Congaree National Park in the Cedar Creek–Congaree River Watershed.

**Table B-1**. C-071 (South Carolina Department of Health and Environmental Control [SCDHEC], Cedar Creek at S-40-734, Richland Co.; latitude 33.8410, longitude -80.8602).

| Parameter | Date | n | Mean (range) | Median | Number unacceptable |
|---|---|---|---|---|---|
| $NO_3$-N + $NO_2$-N (µg/L) | 9/21/2011 | 1 | (brl) | – | – |
| $NH_4$+N (µg/L) | 9/21/2011 | 1 | 110 | – | 1[a] |
| TKN (µg/L) | 9/21/2011 | 1 | 780 | – | 1[a] |
| TN (µg/L) | 9/21/2011 | 1 | (brl) | – | – |
| TP (µg/L) | 9/21/2011 | 1 | (brl) | – | – |

[a] Values in blue are nutrient levels that could support noxious algal blooms (e.g., Mallin 2000) or data that exceeded EPA (2000)

**Table B-2.** C-074 (SCDHEC, Congaree River, West boundary of Congaree Swamp Monument, Richland Co.; latitude 33.8091, longitude -80.8670)

| Parameter | Date | n | Mean (range) | Median | Number unacceptable |
|---|---|---|---|---|---|
| Temperature (°C) | Jan 00–Dec 12 | 121 | 19.5 (7.3–32.1) | 20 | – |
| Turbidity (NTU) | Jan 00–Dec 12 | 121 | 14.1 (1.4–130) | 7.8 | 83[a] |
| Spec. cond. (µmhos/cm) | Jan 00–Nov 00 | 10 | 105 (48.6–145) | 104 | – |
| DO (mg/L) | Jan 00–Dec 12 | 120 | 8 (5.0–11.8) | 7.9 | – |
| pH | Jan 00–Dec 12 | 120 | 7.2 (5.1–8.1) | 7.1 | 1[a] |
| Chlorophyll *a* (µg/L) | May 01–Jul 01 | 2 | 1.6 (1.5–1.7) | 1.6 | 2[a] |
| $NO_3$-N + $NO_2$-N (µg/L) | Jan 00–Dec 12 | 121 | 520 (140–1,100) | 480 | 121[b] |
| $NH_4$+N (µg/L) | Aug 01–Dec 12 | 83 | 228 (brl–560) | 210 | 72[b] |
| TKN (µg/L) | Aug 01–Dec 12 | 88 | 496 (brl–1,100) | 475 | 74[b] |
| TN (µg/L) | Aug 01–Dec 12 | 88 | 1,027 (300–1,800) | 990 | 87[b] |
| TP (µg/L) | May 01–Dec 12 | 106 | 68 (brl–180) | 64 | 104[b] |

[a] Values in red—data in violation of state standards; or data that exceeded U.S. EPA (2000, 2002b) recommendations; or data exceeded recommended values to protect aquatic life (BOD5–see Mallin et al. 2006).

[b] Values in blue—nutrient levels that could support noxious algal blooms (e.g., Mallin 2000) or data that exceeded EPA (2000) recommendations.

[c] More than 50% of the samples were below detection or below the reporting limit with the analytical technique used; thus, statistical interpretation was not attempted.

[d] Values in green (fecal coliform bacteria, *Escherichia coli*)—suggest degraded conditions, based on the South Carolina water-quality standards, or the EPA (2003).

[e] Sample values in STORET for bacteria were noted as "Present Above Quantification Limit." The value for the upper reporting limit was used for statistical analysis.

[f] Values were reported as "less than" a range of values that include the CCC and the EPA; or, for chromium, the chemical species was not designated.

**Table B-2 (continued).** C-074 (SCDHEC, Congaree River, West boundary of Congaree Swamp Monument, Richland Co.; latitude 33.8091, longitude -80.8670)

| Parameter | Date | n | Mean (range) | Median | Number unacceptable |
|---|---|---|---|---|---|
| TOC (mg/L) | Jul 00–May 09 | 33 | 3.1 (brl–6) | 3.2 | – |
| TSS (mg/L) | Jan 00–Dec 12 | 115 | 13 (0.7–110) | 8.5 | 47[a] |
| $BOD_5$ (mg/L) | Jul 00–Dec 12 | 113 | (brl–2.3)[c] | – | – |
| Fecal coliforms, MF (cfu/100 mL) | Jan 00–Oct 12 | 128 | 265 (5–3,500[d])[e] | 39 | 22[d] (17% > 400) |
| *Enterococcus*, Quanti-Tray (cfu/100 mL) | Jan 00–Dec 09 | 103 | 99 (brl–2,400[d]) | 11 | 17[d] (17% > 104) |
| *Escherichia coli*, Quanti-Tray (cfu/100 mL) | Sep 04–Dec 09 | 14 | 350f (brl–1,000[d]) | 313 [d] | 8[d] (57% > 235) |
| Alkalinity, carbonate as $CaCO_3$ (mg/L) | Jan 00–Dec 12 | 109 | 23 (12–60) | 22 | – |
| Hardness, Ca+Mg (mg/L) | Feb 00–Dec 12 | 19 | 17 (13–20) | 18 | – |
| Calcium (mg/L) | Feb 02–Nov 12 | 17 | 4.1 (2.9–4.8) | 4.3 | – |
| Magnesium (mg/L) | Feb 02–Nov 12 | 17 | 1.6 (1.4–1.9) | 1.6 | – |
| Cadmium, total (µg/L) | Feb 00–Dec 12 | 46 | (brl–0.4)[c] | – | 1[a] |
| Chromium, total (µg/L) | Feb 00–Dec 12 | 46 | (brl–27)[c] | – | 1[a]; uncertain[f] |
| Copper, total (µg/L) | Feb 00–Dec 12 | 52 | (brl–46)[c] | – | 2[a] |
| Iron, total (µg/L) | Feb 00–Dec 12 | 46 | 662 (240–2,400) | 500 | – |
| Lead, total (µg/L) | Feb 00–Jun 11 | 40 | (brl–8.8)[c] | – | 5[a]; uncertain[f] |
| Manganese, total (µg/L) | Feb 00–Dec 12 | 46 | 68.5 (20–310) | 49 | – |
| Mercury, total (µg/L) | Feb 00–Aug 13 | 55 | (brl–0.65)[c] | – | – |
| Nickel, total (µg/L) | Feb 00–Aug 13 | 55 | (brl–50)[c] | – | – |
| Zinc, total (µg/L) | Feb 00–Dec 12 | 46 | (brl–170)[c] | – | 2[a] |

[a] Values in red—data in violation of state standards; or data that exceeded U.S. EPA (2000, 2002b) recommendations; or data exceeded recommended values to protect aquatic life (BOD5–see Mallin et al. 2006).

[b] Values in blue—nutrient levels that could support noxious algal blooms (e.g., Mallin 2000) or data that exceeded EPA (2000) recommendations.

[c] More than 50% of the samples were below detection or below the reporting limit with the analytical technique used; thus, statistical interpretation was not attempted.

[d] Values in green (fecal coliform bacteria, *Escherichia coli*)—suggest degraded conditions, based on the South Carolina water-quality standards, or the EPA (2003).

[e] Sample values in STORET for bacteria were noted as "Present Above Quantification Limit." The value for the upper reporting limit was used for statistical analysis.

[f] Values were reported as "less than" a range of values that include the CCC and the EPA; or, for chromium, the chemical species was not designated.

**Table B-3.** C-075 (SCDHEC, Cedar Creek south of S-40-734 at old USGS gaging platform, Richland Co.; latitude 33.8399, longitude -80.8604)[a]

| Parameter | Date | n | Mean (range) | Median | Number unacceptable |
|---|---|---|---|---|---|
| Temperature (°C) | Feb 00–Aug 13 | 136 | 18.7 (2–29) | 19.4 | – |
| Turbidity (NTU) | Feb 00–Aug 13 | 139 | 4.2 (1.3–40) | 3.4 | 13[b] |
| DO (mg/L) | Feb 00–Aug 13 | 136 | 7.9 (4.56–13.4) | 7.4 | – |
| pH | Feb 00–Aug 13 | 136 | 6.3 (3.75–8.6) | 6.3 | 40[b] |
| $NO_3$-N + $NO_2$-N (µg/L) | Feb 00–Aug 13 | 138 | 49 (brl–310) | 27 | 24[c] |
| $NH_4$+N (µg/L) | May 00–Aug 13 | 109 | 90 (brl–330) | 84 | 36[c] |
| TKN (µg/L) | Jun 01–Aug 13 | 102 | 830 (brl–27,000) | 540 | 88[c] |
| TN (µg/L) | Jun 01–Aug 13 | 101 | 876 (brl–27,010) | 552 | 82[c] |
| TP (µg/L) | May 01–Aug 13 | 123 | 22 (brl–120) | 20 | 50[c] |
| TOC (mg/L) | Feb 01–Aug 09 | 35 | 7.1 (brl–23) | 5.4 | – |
| TSS (mg/L) | Mar 00–Feb 07 | 4 | 2.3 (1.1–3.8) | 2.2 | – |
| BOD5 (mg/L) | Jul 00–Aug 13 | 131 | (brl–4.0)[d] | – | 4[b] |
| Fecal coliforms, MF (cfu/100 mL) | Feb 00–Nov 12 | 135 | 99 (brl–2,000[ef]) | 53 | 3[e] (2% > 400) |
| *Enterococcus*, Quanti-Tray (cfu/100 mL) | Feb 00–Dec 09 | 117 | 64.5 (brl–690[e]) | 22 | 22[e] (19% > 104) |
| *Escherichia coli*, Quanti-Tray (cfu/100 mL) | Jan 09–Aug 13 | 14 | 97 (39–205) | 72 | – |
| Alkalinity, carbonate as $CaCO_3$ (mg/L) | Feb 00–Aug 13 | 121 | 2.4 (brl–11) | 2.3 | – |
| Hardness, Ca+Mg (mg/L) | Feb 00–Nov 12 | 20 | 4.6 (2.8–7.4) | 4.4 | – |
| Calcium (mg/L) | Feb 03–Nov 12 | 18 | 1.0 (0.6–1.7) | 0.9 | – |
| Magnesium (mg/L) | Feb 03–Nov 12 | 18 | 0.5 (0.3–0.8) | 0.5 | – |
| Cadmium, total (µg/L) | Feb 00–Aug 13 | 55 | (brl–0.4)[d] | – | 4[b] |
| Copper, total (µg/L) | Feb 00–Aug 13 | 55 | (brl–23)[d] | – | 1[b] |

[a] All values reported less than the level of detection or less than the reporting limit (brl, below reporting limits) were replaced with 1/2 the value, following Ellis and Gilbert (1980) and Zirschky et al. (1985).

[b] Values in red—data in violation of state standards; or data that exceeded EPA (2000, 2002b) recommendations; or data exceeded recommended values to protect aquatic life (BOD5–see Mallin et al. 2006).

[c] Values in blue—nutrient levels that could support noxious algal blooms (e.g., Mallin 2000) or data that exceeded EPA (2000) recommendations.

[d] More than 50% of the samples were below detection or below the reporting limit with the analytical technique used; thus, statistical interpretation was not attempted.

[e] Values in green (fecal coliform bacteria, *Escherichia coli*) – suggest degraded conditions, based on the South Carolina water-quality standards, or the EPA (2003).

[f] Sample values in STORET for bacteria were noted as "Present Above Quantification Limit." The value for the upper reporting limit was used for statistical analysis.

[g] Values were reported as "less than" a range of values that include the CCC and the U.S. EPA; or, for chromium, the chemical species was not designated.

**Table B-3 (continued).** C-075 (SCDHEC, Cedar Creek south of S-40-734 at old USGS gaging platform, Richland Co.; latitude 33.8399, longitude -80.8604)[a]

| Parameter | Date | n | Mean (range) | Median | Number unacceptable |
|---|---|---|---|---|---|
| Iron, total (µg/L) | Feb 00–Aug 13 | 55 | 1,089 (170–3,700) | 900 | – |
| Lead, total (µg/L) | Feb 00–Jul 11 | 47 | (brl–2.9)[b] | – | 1[b]; uncertain[g] |
| Manganese, total (µg/L) | Feb 00–Aug 13 | 55 | 53 (brl–300) | 45 | – |
| Mercury, total (µg/L) | Feb 00–Aug 13 | 55 | (brl–0.26)[b] | – | – |
| Zinc, total (µg/L) | Feb 00–Aug 13 | 55 | 19 (brl–230) | 11 | 2[b] |

[a] All values reported less than the level of detection or less than the reporting limit (brl, below reporting limits) were replaced with 1/2 the value, following Ellis and Gilbert (1980) and Zirschky et al. (1985).

[b] Values in red—data in violation of state standards; or data that exceeded EPA (2000, 2002b) recommendations; or data exceeded recommended values to protect aquatic life (BOD5–see Mallin et al. 2006).

[c] Values in blue—nutrient levels that could support noxious algal blooms (e.g., Mallin 2000) or data that exceeded EPA (2000) recommendations.

[d] More than 50% of the samples were below detection or below the reporting limit with the analytical technique used; thus, statistical interpretation was not attempted.

[e] Values in green (fecal coliform bacteria, *Escherichia coli*) – suggest degraded conditions, based on the South Carolina water-quality standards, or the EPA (2003).

[f] Sample values in STORET for bacteria were noted as "Present Above Quantification Limit." The value for the upper reporting limit was used for statistical analysis.

[g] Values were reported as "less than" a range of values that include the CCC and the U.S. EPA; or, for chromium, the chemical species was not designated.

**Table B-4.** C-076 (SCDHEC, Cedar Creek, Richland Co.; latitude 33.8184, longitude -80.7880)[a]

| Parameter | Date | n | Mean (Range) | Median | Number unacceptable |
|---|---|---|---|---|---|
| Fecal coliforms, MF (cfu/100 mL) | Jan 09–Dec 09 | 52 | 206 (17–2,200[b]) | 120 | 5[b] (10% > 400) |
| *Enterococcus*, Quanti-Tray (cfu/100 mL) | Jan 09–Dec 09 | 52 | 290[b] (1–1,986[b]) | 233[b] | 33[b] (63% > 104) |
| *Escherichia coli*, Quanti-Tray (cfu/100 mL) | Jan 09–Dec 09 | 52 | 263[b] (33.6–2,318[b]) | 132 | 14[b] (27% > 235) |

[a] All values reported less than the level of detection or less than the reporting limit (brl, below reporting limits) were replaced with 1/2 the value, following Ellis and Gilbert (1980) and Zirschky et al. (1985).

[b] Values in green (fecal coliform bacteria, Escherichia coli) – suggest degraded conditions, based on the South Carolina water-quality standards, or the EPA (2003).

**Table B-5.** C-077 (South Carolina Department of Health and Environmental Control, Cedar Creek, Richland Co.; latitude 33.8199, longitude -80.8231)

| Parameter | Date | n | Mean (Range) | Median | Number unacceptable |
|---|---|---|---|---|---|
| Fecal coliforms, MF (cfu/100 mL) | Jan 09–Nov 09 | 46 | 356 (21–6,800[a]) | 150 | 7[a] (15% > 400) |
| *Enterococcus*, Quanti-Tray (cfu/100 mL) | Jan 09–Nov 09 | 46 | 433[a] (6.3–2,419.6[ab]) | 242[a] | 28[a] (61% > 104) |
| *Escherichia coli*, Quanti-Tray (cfu/100 mL) | Jan 09–Nov 09 | 46 | 440[a] (52.5–7.945[a]) | 203 | 19[a] (41% > 235) |

[a] Values in green (fecal coliform bacteria, *Escherichia coli*) – suggest degraded conditions, based on the South Carolina water-quality standards, or the EPA (2003).

[b] Sample values in STORET for bacteria were noted as "Present Above Quantification Limit." The value for the upper reporting limit was used for statistical analysis.

**Table B-6.** C-578 (SCDHEC, Myers Creek at SR 734, Richland Co.; latitude 33.8407, longitude -80.8600)

| Parameter | Date | n | Mean (Range) | Median | Number unacceptable |
|---|---|---|---|---|---|
| Turbidity (NTU) | Sep 09–Jul 10 | 2 | 8.9 (8.9–8.9) | 8.9 | 2[a] |
| $NO_3^-N + NO_2^-N$ (µg/L) | Sep 09–Jul 10 | 2 | 1,081 (62–2,100) | 1,081 | 1[b] |
| $NH_4^+N$ (µg/L) | Sep 09–Jul 10 | 2 | 270 (200–340) | 270 | 2[b] |
| TKN (µg/L) | Sep 09–Jul 10 | 2 | 750 (580–920) | 750 | 2[b] |
| TN (µg/L) | Sep 09–Jul 10 | 2 | 1,831 (642–3,020) | 1,831 | 2[b] |
| TP (µg/L) | Sep 09–Jul 10 | 2 | 60 (58–61) | 60 | 2[b] |
| TSS (mg/L) | Sep 09–Jul 10 | 2 | 6.9 (5.7–8) | 6.9 | – |
| Alkalinity–carbonate as $CaCO_3$ (mg/L) | Sep 09–Jul 10 | 2 | 6.7 (5.2–8.2) | 6.7 | – |
| Hardness–Ca+Mg (mg/L) | Sep 09–Jul 10 | 2 | 8.3 (7.3–9.2) | 8.3 | – |
| Calcium (mg/L) | Sep 09–Jul 10 | 2 | 1.9 (1.6–2.1) | 1.9 | – |
| Chloride (mg/L) | Sep 09–Jul 10 | 2 | 4.9 (4.7–5.1) | 4.9 | – |
| Iron (mg/L) | Sep 09–Jul 10 | 2 | 3.8 (3.5–4.1) | 3.8 | – |
| Magnesium (mg/L) | Sep 09–Jul 10 | 2 | 0.9 (0.8–0.95) | 0.9 | – |
| Potassium (mg/L) | Sep 09–Jul 10 | 2 | 1.4 (1.3–1.4) | 1.4 | – |
| Sodium (mg/L) | Sep 09–Jul 10 | 2 | 3.2 (3.0–3.4) | 3.2 | – |

[a] Values in red—data in violation of state standards; or data that exceeded U.S. EPA (2000, 2002b) recommendations; or data exceeded recommended values to protect aquatic life (BOD5–see Mallin et al. 2006).

[b] Values in blue—nutrient levels that could support noxious algal blooms (e.g., Mallin 2000) or data that exceeded EPA (2000) recommendations.

**Table B-7.** RS-01041 (SCDHEC, Bates Mill Creek at County Rd 24, 4 mi N of St Mathews, Calhoun Co.; latitude 33.7225, longitude -80.7800)

| Parameter | Date | n | Mean (Range) | Median | Number unacceptable |
|---|---|---|---|---|---|
| Temperature (°C) | Jan 01–Dec 01 | 10 | 17.9 (3.5–26.2) | 16.8 | – |
| Turbidity (NTU) | Jan 01–Dec 01 | 12 | 6.1 (2.1–36) | 3.5 | 1[a] |
| DO (mg/L) | Jan 01–Dec 01 | 10 | 8.3 (5.6–10.9) | 8.8 | – |
| pH | Jan 01–Dec 01 | 10 | 6.5 (5.3–7.6) | 6.5 | 3[a] |
| $NO_3^-N + NO_2^-N$ (µg/L) | Jan 01–Dec 01 | 12 | 169 (45–380) | 170 | 7[b] |
| $NH_4^+N$ (µg/L) | Jun 01–Dec 01 | 4 | 80 (brl–130) | 82 | 1[b] |
| TKN (µg/L) | Jun 01–Dec 01 | 4 | 245 (180–300) | 250 | – |
| TN (µg/L) | Jun 01–Dec 01 | 4 | 345 (271–440) | 335 | 1[b] |
| TP (µg/L) | Jun 01–Dec 01 | 7 | 62 (39–120) | 55 | 7[b] |
| TOC (mg/L) | Feb 01–Nov 01 | 4 | 1.1 (brl–2.4) | 1 | – |
| TSS (mg/L) | Jun 01 | 1 | (6.2) | – | – |
| $BOD_5$ (mg/L) | Jan 01–Dec 01 | 11 | (all brl)[c] | – | – |
| Fecal coliforms, MF (cfu/100 mL) | Jan 01–Dec 01 | 12 | 162 (33–470[d]) | 110.5 | 1[d] (8% > 400) |
| *Enterococcus*, Quanti-Tray (cfu/100 mL) | Jan 01–Dec 01 | 12 | 113[f] (5–820[d]) | 40.5 | 2[d] (17% > 104) |
| Alkalinity, carbonate as $CaCO_3$ (mg/L) | Mar 01–Dec 01 | 8 | 12 (6.1–26) | 12 | – |
| Hardness, Ca+Mg (mg/L) | Feb 01 | 1 | (12) | – | – |
| Iron, total (µg/L) | Feb 01–Nov 01 | 4 | 965 (700–1,300) | 930 | – |
| Manganese, total (µg/L) | Feb 01–Nov 01 | 4 | 35 (30–40) | 35 | – |

[a] Values in red—data in violation of state standards; or data that exceeded EPA (2000, 2002b) recommendations; or data exceeded recommended values to protect aquatic life (BOD5–see Mallin et al. 2006).

[b] Values in blue—nutrient levels that could support noxious algal blooms (e.g., Mallin 2000) or data that exceeded EPA (2000) recommendations.

[c] More than 50% of the samples were below detection or below the reporting limit with the analytical technique used; thus, statistical interpretation was not attempted.

[d] Values in green (fecal coliform bacteria, *Escherichia coli*)—suggest degraded conditions, based on the South Carolina water-quality standards, or the EPA (2003).

**Table B-8.** RS-12094 (SCDHEC, Congaree River between C-074 and C-007, Richland Co.; latitude 33.7747, longitude -80.7598)

| Parameter | Date | n | Mean (Range) | Median | Number unacceptable |
|---|---|---|---|---|---|
| Temperature (°C) | Jan 12–Dec 12 | 11 | 20.5 (10.7–30.6) | 20.2 | – |
| Turbidity (NTU) | Jan 12–Dec 12 | 11 | 14.1 (4.2–40) | 12 | 9[a] |
| DO (mg/L) | Jan 12–Dec 12 | 11 | 7.8 (6–10.2) | 7.7 | – |
| pH | Jan 12–Dec 12 | 11 | 7.1 (6.8–7.5) | 7.1 | – |
| $NO_3^-N + NO_2^-N$ (µg/L) | Jan 12–Dec 12 | 11 | 714 (430–2,000) | 570 | 11[b] |
| $NH_4^+N$ (µg/L) | Jan 12–Dec 12 | 9 | 81 (brl–150) | 81 | 2[b] |
| TKN (µg/L) | Jan 12–Dec 12 | 9 | 374 (brl–540) | 380 | 7[b] |
| TN (µg/L) | Jan 12–Dec 12 | 9 | 1,111 (brl–2,370) | 1,080 | 9[b] |
| TP (µg/L) | Jan 12–Dec 12 | 11 | 61 (42–90) | 58 | 11[b] |
| $BOD_5$ (mg/L) | Jan 12–Dec 12 | 11 | (all brl)[c] | – | – |
| Fecal coliforms, MF (cfu/100 mL) | Jan 12–Dec 12 | 10 | 94 (10–240) | 70 | – |
| Alkalinity, carbonate as $CaCO_3$ (mg/L) | Jan 12–Dec 12 | 11 | 22 (20–25) | 23 | – |
| Hardness, Ca+Mg (mg/L) | Nov 12 | 1 | (19) | – | – |
| Calcium (mg/L) | Nov 12 | 1 | (4.6) | – | – |
| Magnesium (mg/L) | Nov 12 | 1 | (1.8) | – | – |
| Iron, total (µg/L) | Jan 12–Nov 12 | 4 | 815 (230–1,500) | 765 | – |
| Manganese, total (µg/L) | Jan 12–Nov 12 | 4 | 55 (32–81) | 54 | – |
| Zinc, total (µg/L) | Jan 12–Nov 12 | 4 | (brl–13)[c] | – | – |

[a] Values in red—data in violation of state standards; or data that exceeded EPA (2000, 2002b) recommendations; or data exceeded recommended values to protect aquatic life (BOD5–see Mallin et al. 2006).

[b] Values in blue—nutrient levels that could support noxious algal blooms (e.g., Mallin 2000) or data that exceeded (2000) recommendations.

[c] More than 50% of the samples were below detection or below the reporting limit with the analytical technique used; thus, statistical interpretation was not attempted.

**Table B-9**. RS-13158 (SCDHEC, Congaree River same location as C-074, West boundary of Congaree Swamp Monument, Richland Co.; latitude 33.8091, longitude -80.8670)

| Parameter | Date | n | Mean (Range) | Median | Number unacceptable |
|---|---|---|---|---|---|
| Temperature (°C) | Jan 13–Nov 13 | 9 | 18.5 (10–26.8) | 20 | – |
| Turbidity (NTU) | Jan 13–Nov 13 | 9 | 26.7 (7.3–85) | 20 | 9[a] |
| DO (mg/L) | Jan 13–Nov 13 | 9 | 8.7 (6.4–10.9) | 8.7 | – |
| pH | Feb 13–Nov 13 | 8 | 7.2 (7.1–7.7) | 7.2 | – |
| $NO_3^-N + NO_2^-N$ (µg/L) | Jan 13–Nov 13 | 9 | 303 (220–430) | 280 | 9[b] |
| $NH_4^+N$ (µg/L) | Jan 13–Nov 13 | 9 | 87 (brl–150) | 72 | 4[b] |
| TKN (µg/L) | Jan 13–Nov 13 | 9 | 546 (160–960) | 480 | 8[b] |
| TN (µg/L) | Jan 13–Nov 13 | 9 | 849 (500–1,390) | 820 | 9[b] |
| TP (µg/L) | Jan 13–Nov 13 | 9 | 48 (25–100) | 42 | 9[b] |
| $BOD_5$ (mg/L) | Jan 13–Nov 13 | 9 | (all brl)[c] | – | – |
| *Escherichia coli*, Quanti-Tray (cfu/100 mL) | Jan 13–Nov 13 | 9 | 192 (24–770[d]) | 70 | 2[d] (22% > 235) |
| Alkalinity, carbonate as $CaCO_3$ (mg/L) | Jan 13–Nov 13 | 9 | 20 (8.1–23) | 22 | – |
| Iron, total (µg/L) | Feb 13–Aug 13 | 3 | 540 (290–740) | 590 | – |
| Manganese, total (µg/L) | Feb 13–Aug 13 | 3 | 58 (43–69) | 62 | – |

[a] Values in red—data in violation of state standards; or data that exceeded EPA (2000, 2002b) recommendations; or data exceeded recommended values to protect aquatic life (BOD5–see Mallin et al. 2006).

[b] Values in blue—nutrient levels that could support noxious algal blooms (e.g., Mallin 2000) or data that exceeded EPA (2000) recommendations.

[c] More than 50% of the samples were below detection or below the reporting limit with the analytical technique used; thus, statistical interpretation was not attempted.

[d] Values in green (fecal coliform bacteria, *Escherichia coli*)—suggest degraded conditions, based on the South Carolina water-quality standards, or the EPA (2003).

**Water-quality data for the Congaree National Park in the Toms Creek—Congaree River sub-watershed.**

**Table B-10.** C-007 (SCDHEC, Congaree River at US 601, Calhoun Co.; latitude 33.7529, longitude -80.6450)

| Parameter | Date | n | Mean (range) | Med | Number unacceptable |
|---|---|---|---|---|---|
| Temperature (°C) | Jan 00–Sep 13 | 132 | 19.7 (6.5–31.4) | 19.9 | – |
| Turbidity (NTU) | Jan 00–Sep 13 | 133 | 17.2 (2.3–100) | 12 | 115[a] |
| Spec. cond. (µmhos/cm) | Jan 00–Nov 00 | 9 | 103 (75.5–144) | 100 | – |
| DO (mg/L) | Jan 00–Sep 13 | 132 | 7.9 (5.3–11.5) | 7.7 | – |
| pH | Jan 00–Sep 13 | 132 | 7.1 (4.9–8.25) | 7.1 | 2[a] |
| Chlorophyll *a* (µg/L) | Jun 01–Jul 01 | 2 | 3.3 (2.9–3.6) | 3.3 | 2[a] |
| $NO_3^-N + NO_2^-N$ (µg/L) | Jan 00–Sep 13 | 132 | 546 (220–1800) | 490 | 132[b] |
| $NH_4^+N$ (µg/L) | Mar 00–Sep 13 | 98 | 109 (brl–310) | 90 | 46[b] |
| TKN (µg/L) | Jun 01–Sep 13 | 98 | 367 (brl–1,300) | 340 | 57[b] |
| TN (µg/L) | Jun 01–Sep 13 | 97 | 924 (400–2,290) | 840 | 97[b] |
| TP (µg/L) | May 01–Sep 13 | 118 | 61 (27–120) | 60 | 118[b] |
| TOC (mg/L) | Jun 00–Aug 09 | 36 | 3.1 (brl–11) | 2.9 | – |
| TSS (mg/L) | Jan 00–Sep 13 | 128 | 19 (brl–140) | 14 | 88[a] |
| $BOD_5$ (mg/L) | Jul 00–Sep 13 | 124 | (all brl)[c] | – | – |
| Fecal coliforms, MF (cfu/100 mL) | Jan 00–Nov 12 | 129 | 140 (4–1800[d]) | 47 | 10[d] (8% > 400) |
| Enterococcus, Quanti-Tray (cfu/100 mL) | Jan 00–Oct 09 | 111 | 62.5 (brl–1,400[d]) | 14 | 10[d] (9% > 104) |
| Escherichia coli, Quanti-Tray (cfu/100 mL) | Jan 09–Sep 13 | 12 | 92.5 (brl–249[d]) | 38 | 2[d] (17% > 235) |
| Alkalinity, carbonate as CaCO3 (mg/L) | Jan 00–Sep 13 | 119 | 21 (14–29) | 22 | – |
| Hardness, Ca+Mg (mg/L) | Feb 00–Nov 12 | 19 | 17 (13–19) | 18 | – |
| Calcium (mg/L) | Feb 02–Nov 12 | 17 | 3.9 (2.7–4.8) | 4.2 | – |
| Magnesium (mg/L) | Feb 02–Nov 12 | 17 | 1.7 (1.3–1.9) | 1.7 | – |
| Cadmium, total (µg/L) | Feb 00–May 13 | 50 | (brl–1)[c] | – | 2[a] |
| Copper, total (µg/L) | Feb 00–May 13 | 50 | (brl–20)[c] | – | 2[a] |
| Iron, total (µg/L) | Feb 00–May 13 | 50 | 907 (230–3,800) | 730 | – |

[a] Values in red—data in violation of state standards; or data that exceeded EPA (2000, 2002b) recommendations; or data exceeded recommended values to protect aquatic life (BOD5–see Mallin et al. 2006).

[b] Values in blue—nutrient levels that could support noxious algal blooms (e.g., Mallin 2000) or data that exceeded EPA (2000) recommendations.

[c] More than 50% of the samples were below detection or below the reporting limit with the analytical technique used; thus, statistical interpretation was not attempted.

[d] Values in green (fecal coliform bacteria, *Escherichia coli*)—suggest degraded conditions, based on the South Carolina water-quality standards, or the EPA (2003).

[e] Values were reported as "less than" a range of values that include the CCC and the EPA; or, for chromium, the chemical species was not designated.

**Table B-10 (continued).** C-007 (SCDHEC, Congaree River at US 601, Calhoun Co.; latitude 33.7529, longitude -80.6450)

| Parameter | Date | n | Mean (range) | Med | Number unacceptable |
|---|---|---|---|---|---|
| Lead, total (µg/L) | Feb 00–Jun 11 | 42 | (brl–9.7)[c] | – | 5[a]; +uncertain[e] |
| Manganese, total (µg/L) | Feb 00–May 13 | 50 | 70.7 (20–160) | 60 | – |
| Zinc, total (µg/L) | Feb 00–May 13 | 50 | (brl–39)[c] | – | – |

[a] Values in red—data in violation of state standards; or data that exceeded EPA (2000, 2002b) recommendations; or data exceeded recommended values to protect aquatic life (BOD5–see Mallin et al. 2006).

[b] Values in blue—nutrient levels that could support noxious algal blooms (e.g., Mallin 2000) or data that exceeded EPA (2000) recommendations.

[c] More than 50% of the samples were below detection or below the reporting limit with the analytical technique used; thus, statistical interpretation was not attempted.

[d] Values in green (fecal coliform bacteria, *Escherichia coli*)—suggest degraded conditions, based on the South Carolina water-quality standards, or the EPA (2003).

[e] Values were reported as "less than" a range of values that include the CCC and the EPA; or, for chromium, the chemical species was not designated.

**Table B-11.** C-072 (SCDHEC, Toms Creek at S.C. 48, Richland Co.; latitude 33.8413, longitude -80.7318)

| Parameter | Date | n | Mean (Range) | Median | Number unacceptable |
|---|---|---|---|---|---|
| Temperature (ºC) | Feb 00–Aug 13 | 135 | 17.2 (1.5–27) | 18.3 | – |
| Turbidity (NTU) | Feb 00–Aug 13 | 138 | 3.5 (1.4–19) | 2.9 | 9[a] |
| DO (mg/L) | Feb 00–Aug 13 | 135 | 7.6 (4.2–12) | 7.2 | – |
| pH | Feb 00–Aug 13 | 135 | 6.1 (4.8–7.7) | 6 | 62[a] |
| $NO_3^-N + NO_2^-N$ (µg/L) | Feb 00–Aug 13 | 138 | 294 (brl–4,200) | 200 | 115[b] |
| $NH_4^+N$ (µg/L) | Feb 00–Aug 13 | 110 | 116 (brl–780) | 94 | 44[b] |
| TKN (µg/L) | Aug 00–Aug 13 | 102 | 676 (brl–2,700) | 600 | 86[b] |
| TN (µg/L) | Aug 00–Aug 13 | 101 | 960 (325–5,400) | 750 | 98[b] |
| TP (µg/L) | May 01–Aug 13 | 124 | 24 (brl–230) | 20 | 52[b] |
| TOC (mg/L) | Aug 00–Aug 09 | 35 | 8.5 (brl–22) | 7 | – |
| TSS (mg/L) | Mar 00–May 02 | 4 | 1.7 (1.4–2) | 1.6 | – |

[a] Values in red—data in violation of state standards; or data that exceeded EPA (2000, 2002b) recommendations; or data exceeded recommended values to protect aquatic life (BOD5–see Mallin et al. 2006).

[b] Values in blue—nutrient levels that could support noxious algal blooms (e.g., Mallin 2000) or data that exceeded EPA (2000) recommendations.

[c] More than 50% of the samples were below detection or below the reporting limit with the analytical technique used; thus, statistical interpretation was not attempted.

[d] Values in green (fecal coliform bacteria, *Escherichia coli*)—suggest degraded conditions, based on the South Carolina water-quality standards, or the EPA (2003).

[e] Values were reported as "less than" a range of values that include the CCC and the EPA; or, for chromium, the chemical species was not designated.

**Table B-11 (continued).** C-072 (SCDHEC, Toms Creek at S.C. 48, Richland Co.; latitude 33.8413, longitude -80.7318)

| Parameter | Date | n | Mean (Range) | Median | Number unacceptable |
|---|---|---|---|---|---|
| BOD5 (mg/L) | Jul 00–Aug 13 | 130 | (brl–5.5)[c] | – | 12g |
| Fecal coliforms, MF (cfu/100 mL) | Feb 00–Nov 12 | 147 | 308 (30–4,400[d]) | 180 | 26[d] (18% > 400) |
| Enterococcus, Quanti-Tray (cfu/100 mL) | Feb 00–Dec 09 | 117 | 177.5[d] (brl–1,300[d]) | 65 | 49[d] (42% > 104) |
| Escherichia coli, Quanti-Tray (cfu/100 mL) | Jan 09–Aug 13 | 14 | 279[d] (64–1,203f) | 195 | 5[d] (36% > 235) |
| Alkalinity, carbonate as CaCO3 (mg/L) | Feb 00–Aug 13 | 119 | 2.5 (brl–13) | 2.3 | – |
| Hardness, Ca+Mg (mg/L) | Feb 00–Nov 12 | 21 | 6 (3.5–12) | 6 | – |
| Calcium (mg/L) | Feb 02–Nov 12 | 17 | 1.1 (0.6–3.7) | 1 | – |
| Magnesium (mg/L) | Feb 02–Nov 12 | 19 | 0.8 (0.5–1.2) | 0.9 | – |
| Cadmium, total (µg/L) | Feb 00–Aug 13 | 55 | (brl–9.5)b | – | 3[a] |
| Chromium, total (µg/L) | Feb 00–Aug 13 | 55 | (brl–15)b | – | 1[a]; uncertain[e] |
| Copper, total (µg/L) | Feb 00–Aug 13 | 55 | (brl–22)b | – | 1[a] |
| Iron, total (µg/L) | Feb 00–Aug 13 | 55 | 1,039 (260–2,600) | 850 | – |
| Lead, total (µg/L) | May 00–Jul 11 | 46 | (brl–4.2)[c] | – | 3[a]; uncertain[e] |
| Manganese, total (µg/L) | Feb 00–Aug 13 | 55 | 54.5 (12–200) | 43 | – |
| Zinc, total (µg/L) | Feb 00–Aug 13 | 55 | 16 (brl–47) | 12 | – |

[a] Values in red—data in violation of state standards; or data that exceeded EPA (2000, 2002b) recommendations; or data exceeded recommended values to protect aquatic life (BOD5–see Mallin et al. 2006).

[b] Values in blue—nutrient levels that could support noxious algal blooms (e.g., Mallin 2000) or data that exceeded EPA (2000) recommendations.

[c] More than 50% of the samples were below detection or below the reporting limit with the analytical technique used; thus, statistical interpretation was not attempted.

[d] Values in green (fecal coliform bacteria, *Escherichia coli*)—suggest degraded conditions, based on the South Carolina water-quality standards, or the EPA (2003).

[e] Values were reported as "less than" a range of values that include the CCC and the EPA; or, for chromium, the chemical species was not designated.

**Table B-12.** RS-04521 (SCDHEC, Buckhead Creek at S-09-151, 2.1 mi NE of Fort Motte, Calhoun Co.; latitude 33.7535, longitude -80.6619)

| Parameter | Date | n | Mean (Range) | Median | Number unacceptable |
|---|---|---|---|---|---|
| Temperature (°C) | Jan-Dec 04, 06 | 23 | 18.5 (6.9–30.7) | 20 | – |
| Turbidity (NTU) | Jan-Dec 04, 06 | 24 | 10.8 (3.7–54) | 8.5 | 14[a] |
| DO (mg/L) | Jan-Dec 04, 06 | 23 | 7.2 (3.9–12) | 7.1 | 1[a] |
| pH | Jan-Dec 04, 06 | 23 | 6.5 (6–7.4) | 6.4 | 1[a] |
| $NO_3^-N + NO_2^-N$ (µg/L) | Jan-Dec 04, 06 | 24 | 90 (26–230) | 66 | 10[b] |
| $NH_4^+N$ (µg/L) | Jan-Dec 04, 06 | 20 | 147 (65–280) | 125 | 13[b] |
| TKN (µg/L) | Jan-Dec 04, 06 | 21 | 659 (240–1,200) | 670 | 20[b] |
| TN (µg/L) | Jan-Dec 04, 06 | 21 | 741 (301–1,310) | 743 | 20[b] |
| TP (µg/L) | Jan-Dec 04, 06 | 24 | 59 (brl–120) | 55 | 22b[h] |
| TOC (mg/L) | Jan-Dec 04, 06 | 7 | 6.4 (2.8–10) | 6.1 | – |
| $BOD_5$ (mg/L) | Jan-Dec 04, 06 | 22 | (brl–5.2)[c] | – | 1[a] |
| Fecal coliforms, MF (cfu/100 mL) | Jan-Dec 04, 06 | 24 | 196 (30–2,220[d]) | 90.5 | 1[d] (4% > 400) |
| *Enterococcus*, Quanti-Tray (cfu/100 mL) | Jan-Dec 04, 06 | 24 | 58 (2 – 690[d]) | 18.5 | 3[d] (12.5% > 104) |
| Alkalinity, carbonate as $CaCO_3$ (mg/L) | Jan-Dec 04, 06 | 22 | 5.9 (2.1–8.8) | 6 | – |
| Hardness, Ca+Mg (mg/L) | Feb 04, 06 | 2 | 5.7 (5.5–5.8) | 5.7 | – |
| Calcium (mg/L) | Feb 04, 06 | 2 | 1.2 (1.2–1.2) | 1.2 | – |
| Magnesium (mg/L) | Feb 04, 06 | 2 | 0.65 (0.61–0.69) | 0.65 | – |
| Chromium, total (µg/L) | Jan-Dec 04, 06 | 7 | (brl–13)[c] | – | 1[a] uncertain[e] |
| Iron, total (µg/L) | Jan-Dec 04, 06 | 7 | 5,071 (1,000–8,000) | 5,800 | – |
| Manganese, total (µg/L) | Jan-Dec 04, 06 | 7 | 211 (37–530) | 180 | – |
| Zinc, total (µg/L) | Jan-Dec 04, 06 | 7 | 13 (brl–32) | 10 | – |

[a] Values in red—data in violation of state standards; or data that exceeded EPA (2000, 2002b) recommendations; or data exceeded recommended values to protect aquatic life (BOD5–see Mallin et al. 2006).

[b] Values in blue—nutrient levels that could support noxious algal blooms (e.g., Mallin 2000) or data that exceeded EPA (2000) recommendations.

[c] More than 50% of the samples were below detection or below the reporting limit with the analytical technique used; thus, statistical interpretation was not attempted.

[d] Values in green (fecal coliform bacteria, *Escherichia coli*)—suggest degraded conditions, based on the South Carolina water-quality standards, or the EPA (2003).

[e] Values were reported as "less than" a range of values that include the CCC and the EPA; or, for chromium, the chemical species was not designated.

**Table B-13.** RS-10408 (SCDHEC, Buckhead Creek at S.C.-419, Calhoun Co.; latitude 33.7360, longitude -80.6915)

| Parameter | Date | n | Mean (Range) | Median | Number unacceptable |
|---|---|---|---|---|---|
| Temperature (°C) | Jan 10–Dec 10 | 12 | 17.3 (3.4–26.9) | 21 | – |
| Turbidity (NTU) | Jan 10–Dec 10 | 12 | 12.6 (4.2–30) | 9.5 | 7[a] |
| DO (mg/L) | Jan 10–Dec 10 | 12 | 8.4 (5.1–13) | 7.3 | – |
| pH | Jan 10–Dec 10 | 12 | 6.5 (5.7–7.6) | 6.4 | 1[a] |
| $NO_3^-N + NO_2^-N$ (µg/L) | Jan 10–Dec 10 | 12 | 58 (brl–150) | 54 | 2[b] |
| $NH_4^+N$ (µg/L) | Jan 10–Nov 10 | 11 | 153 (72–360) | 130 | 7[b] |
| TKN (µg/L) | Jan 10–Dec 10 | 12 | 589 (360–970) | 555 | 12[b] |
| TN (µg/L) | Jan 10–Dec 10 | 12 | 647 (433–1,004) | 606 | 12[b] |
| TP (µg/L) | Jan 10–Dec 10 | 12 | 59 (20–130) | 55 | 11[b] |
| $BOD_5$ (mg/L) | Jan 10–Dec 10 | 12 | (brl–4.2)[c] | – | 1[a] |
| Fecal coliforms, MF (cfu/100 mL) | Jan 10–Dec 10 | 12 | 417 (20–3,200[d]) | 215 | 1[d] (8% > 400) |
| Alkalinity, carbonate as $CaCO_3$ (mg/L) | Jan 10–Dec 10 | 12 | 4.6 (1.8–7.8) | 4.6 | – |
| Hardness, Ca+Mg (mg/L) | Nov 10 | 1 | (6.4) | – | – |
| Calcium (mg/L) | Nov 10 | 1 | (1.3) | – | – |
| Magnesium (mg/L) | Nov 10 | 1 | (0.77) | – | – |
| Cadmium, total (µg/L) | Jan 10–Nov 10 | 4 | 0.5 (brl–0.9) | 0.6 | 3[a] |
| Iron, total (µg/L) | Jan 10–Nov 10 | 4 | 3,450 (1,800–5,100) | 3,450 | – |
| Manganese, total (µg/L) | Jan 10–Nov 10 | 4 | 98 (41–160) | 96 | – |
| Zinc, total (µg/L) | Jan 10–Nov 10 | 4 | 15 (brl–28) | 14 | – |

[a] Values in red—data in violation of state standards; or data that exceeded EPA (2000, 2002b) recommendations; or data exceeded recommended values to protect aquatic life (BOD5–see Mallin et al. 2006).

[b] Values in blue—nutrient levels that could support noxious algal blooms (e.g., Mallin 2000) or data that exceeded EPA (2000) recommendations.

[c] More than 50% of the samples were below detection or below the reporting limit with the analytical technique used; thus, statistical interpretation was not attempted.

[d] Values in green (fecal coliform bacteria, *Escherichia coli*)—suggest degraded conditions, based on the South Carolina water-quality standards, or the EPA (2003).

**Table B-14.** S-950 (SCDHEC, at Red Bluff Road, private road running between SSR1288 and SSR489.D483, Richland Co.; latitude 33.8116, longitude -80.7252)

| **Parameter** | **Date** | **N** | **Mean (Range)** | **Median** | **Number unacceptable** |
|---|---|---|---|---|---|
| Temperature (°C) | Feb-05 | 1 | (10.7) | – | – |
| Spec. cond. (µmhos/cm) | Feb-05 | 1 | (18.8) | – | – |
| DO (mg/L) | Feb-05 | 1 | (10.7) | – | – |
| pH | Feb-05 | 1 | (6.6) | – | – |
| $NO_3^-N + NO_2^-N$ (µg/L) | Feb-05 | 1 | (130) | – | 1[a] |
| $NH_4^+N$ (µg/L) | Feb-05 | 1 | (70) | – | – |
| TKN (µg/L) | Feb-05 | 1 | (400) | – | 1[a] |
| TN (µg/L) | Feb-05 | 1 | (530) | – | 1[a] |
| TP (µg/L) | Feb-05 | 1 | (brl) | – | – |
| Fecal coliforms, MF (cfu/100 mL) | Apr 03–Oct 03 | 19 | 231 (20–2,200[b]) | 67 | 2[b] (11% > 400) |

[a] Values in blue—nutrient levels that could support noxious algal blooms (e.g. Mallin 2000) or data that exceeded U.S. EPA (2000) recommendations.

[b] Values in green (fecal coliform bacteria, *Escherichia coli*)—suggest degraded conditions, based on the South Carolina water-quality standards, or the U.S. EPA (2003).

**Table B-15.** S.C.-001 (Santee Cooper–South Carolina Public Service Authority, Congaree River at U.S. 601 bridge, Richland Co.; latitude 33.7528, longitude -80.6456)

| Parameter | Date | n | Mean (Range) | Median | Number unacceptable |
|---|---|---|---|---|---|
| Temperature (°C) | Jan 00–Feb 09 | 87 | 19.2 (6.5–31.1) | 19.7 | – |
| Turbidity (NTU) | Jan 00–Dec 06 | 42 | 14.3 (3.3–76) | 10.4 | 31[a] |
| Spec. cond. (µmhos/cm) | Jan 00–Feb 09 | 47 | 89 (41–123) | 88 | – |
| DO (mg/L) | Jan 00–Feb 09 | 87 | 8.3 (5.8–12.3) | 8.0 | – |
| pH | Jan 00–Feb 09 | 109 | 7.2 (6.0–8.25) | 7.2 | – |
| $NO_3^-N + NO_2^-N$ (µg/L) | Jan 00–Dec 04 | 31 | 407 (brl–800) | 430 | 28[h] |
| $NH_4^+N$ (µg/L) | Jan 00–Dec 06 | 31 | 101 (brl–780) | 70 | 11[h] |
| TKN (µg/L) | Jan 00–Dec 06 | 30 | 378 (brl–1,570) | 330 | 16[h] |
| TP (µg/L) | Jan 00–Dec 06 | 36 | 50 (brl–120) | 45 | 31[h] |
| SRP (µg/L) | Jan 00–Dec 06 | 14 | (brl–90)[b] | – | – |
| Solids, Total Fixed (mg/L) | Jan 00–Dec 06 | 41 | 55 (brl–255) | 64 | – |
| TSS (mg/L) | Jan 00–Dec 06 | 22 | 20 (brl–153) | 16 | 13[a] |
| $BOD_5$ (mg/L) | Jan 00–Nov 06 | 34 | (all brl)[c] | – | – |
| Fecal coliforms, EC (mpn/100 mL) | Jan 00–Dec 06 | 42 | 165 (brl–1,500[f]) | 34 | 5 (12% > 400) |
| Alkalinity, carbonate as $CaCO_3$ (mg/L) | Jan 00–Dec 06 | 37 | 22 (13–29) | 22 | – |
| Hardness, Ca+Mg (mg/L) | Jan 00–Nov 06 | 17 | 18 (10–23) | 17 | – |
| Bromide (mg/L) | Oct 06–Dec 06 | 3 | 0.08 (brl–0.12) | | – |
| Calcium (mg/L) | Jan 00–Nov 06 | 17 | 3.8 (brl–5.3) | 4 | – |
| Chloride (mg/L) | Aug 06–Dec 06 | 5 | 7.5 (6.4–8.7) | 7 | – |
| Fluoride (mg/L) | Aug 06–Dec 06 | 5 | 0.13 (0.1–0.21) | 0.12 | – |
| Magnesium (mg/L) | Jan 00–Nov 06 | 18 | 2.0 (1.7–2.4) | 2.0 | – |
| Potassium (mg/L) | Jan 00–Nov 06 | 18 | 2.2 (1.0–3.0) | 2.2 | – |
| Sodium (mg/L) | Jan 00–Nov 06 | 18 | 10.8 (7.5–17.6) | 10.5 | – |
| Sulfur (mg/L) | Aug 06–Dec 06 | 5 | 6.5 (6.1–6.9) | 6.5 | – |
| Arsenic, total (µg/L) | Jan 06–Nov 06 | 8 | (all brl)[c] | – | – |
| Cadmium, total (µg/L) | Jan 00–Nov 06 | 24 | (all brl)[c] | – | – |
| Chromium, total (µg/L) | Jan 00–Nov 06 | 24 | (all brl)[c] | – | – |
| Copper, total (µg/L) | Jan 00–Nov 06 | 24 | (brl–4.57)[c] | – | – |

[a] Values in red—data in violation of state standards; or data that exceeded EPA (2000, 2002b) recommendations; or data exceeded recommended values to protect aquatic life (BOD5–see Mallin et al. 2006).

[b] Values in blue—nutrient levels that could support noxious algal blooms (e.g., Mallin 2000) or data that exceeded U.S. EPA (2000) recommendations.

[c] More than 50% of the samples were below detection or below the reporting limit with the analytical technique used; thus, statistical interpretation was not attempted.

[d] Values in green (fecal coliform bacteria, *Escherichia coli*)—suggest degraded conditions, based on the South Carolina water-quality standards, or the EPA (2003).

**Table B-15 (continued).** S.C.-001 (Santee Cooper–South Carolina Public Service Authority, Congaree River at U.S. 601 bridge, Richland Co.; latitude 33.7528, longitude -80.6456)

| Parameter | Date | n | Mean (Range) | Median | Number unacceptable |
|---|---|---|---|---|---|
| Iron, total (µg/L) | Jan 00–Nov 06 | 23 | 753 (6.3–2,200) | 650 | – |
| Lead, total (µg/L) | Jan 00–Nov 06 | 24 | (brl–51)[c] | – | 2[a] |
| Manganese, total (µg/L) | Jan 00–Nov 06 | 24 | 72.1 (22–310) | 56 | – |
| Mercury, total (µg/L) | Aug 03–Nov 04 | 6 | (all brl)[c] | – | – |
| Nickel, total (µg/L) | Jan 00–Nov 06 | 24 | (all brl)[c] | – | – |
| Selenium, total (µg/L) | Jan 06–Nov 06 | 8 | (all brl)[c] | – | – |
| Zinc, total (µg/L) | Jan 00–Nov 06 | 24 | (brl–34)[c] | – | – |

[a] Values in red—data in violation of state standards; or data that exceeded EPA (2000, 2002b) recommendations; or data exceeded recommended values to protect aquatic life (BOD5–see Mallin et al. 2006).

[b] Values in blue—nutrient levels that could support noxious algal blooms (e.g., Mallin 2000) or data that exceeded U.S. EPA (2000) recommendations.

[c] More than 50% of the samples were below detection or below the reporting limit with the analytical technique used; thus, statistical interpretation was not attempted.

[d] Values in green (fecal coliform bacteria, *Escherichia coli*)—suggest degraded conditions, based on the South Carolina water-quality standards, or the EPA (2003).

## Water-quality data for the Congaree National Park in the Lower Wateree–Congaree River sub-watershed

**Table B-16.** CW-222 (SCDHEC, Wateree River at junction with Congaree, Richland Co.; latitude 33.7519, longitude -80.6108).

| Parameter | Date | n | Mean (range) | Median | Number unacceptable |
|---|---|---|---|---|---|
| Temperature (°C) | Jan 00–Sep 13 | 130 | 20.7 (7.2–32.2) | 21.8 | – |
| Turbidity (NTU) | Jan 00–Sep 13 | 132 | 19.2 (3.4–56) | 17 | 121[a] |
| Spec. cond. (µmhos/cm) | Jan 00–Nov 00 | 10 | 205 (107–258) | 208 | – |
| DO (mg/L) | Jan 00–Sep 13 | 131 | 7.8 (4.6–11.3) | 7.5 | – |
| pH | Jan 00–Sep 13 | 130 | 7.2 (5.2–8.9) | 7.2 | 1[a] |
| Chlorophyll *a* (µg/L) | Jun 01–Jul 01 | 3 | 6.6 (3.2–11.8) | 4.9 | 3[a] |
| $NO_3$-N + $NO_2$-N (µg/L) | Jan 00–Sep 13 | 131 | 414 (190–850) | 410 | 131[b] |
| $NH_4$+N (µg/L) | May 00–Sep 13 | 100 | 102 (brl–390) | 88 | 38[b] |
| TKN (µg/L) | Jun 01–Sep 13 | 97 | 408 (brl–1,000) | 400 | 73[b] |
| TN (µg/L) | Jun 01–Sep 13 | 96 | 826 (brl–1,460) | 805 | 93[b] |
| TP (µg/L) | May 01–Sep 13 | 116 | 73 (29–120) | 68 | 116[b] |
| TOC (mg/L) | Dec 00–Aug 09 | 32 | 5.8 (brl–11) | 5.5 | – |
| TSS (mg/L) | Jan 00–Sep 13 | 126 | 23 (0.55–61) | 22 | 110[a] |
| $BOD_5$ (mg/L) | Jul 00–Sep 13 | 123 | (all brl)[c] | – | – |
| Fecal coliforms, MF (cfu/100 mL) | Jan 00–Nov 12 | 128 | 53 (6–960[d]) | 34 | 2[d] (2% > 400) |
| *Enterococcus*, Quanti-Tray (cfu/100 mL) | Jan 00–Aug 09 | 110 | 89 (brl–2,000[d]) | 23.5 | 13[d] (12% > 104) |
| *Escherichia coli*, Quanti-Tray (cfu/100 mL) | Jan 09–Sep 13 | 11 | 53 (11–150) | 35.5 | – |
| Alkalinity, carbonate as $CaCO_3$ (mg/L) | Jan 00–Sep 13 | 117 | 35 (16–71) | 33 | – |
| Hardness, Ca+Mg (mg/L) | Feb 00–Nov 12 | 19 | 28 (19–36) | 30 | – |
| Calcium (mg/L) | Feb 02–Nov 12 | 17 | 6.8 (4.5–9.2) | 7 | – |
| Magnesium (mg/L) | Feb 02–Nov 12 | 17 | 2.7 (1.9–3.3) | 2.8 | – |

[a] Values in red—data in violation of state standards; or data that exceeded EPA (2000, 2002b) recommendations; or data exceeded recommended values to protect aquatic life (BOD5–see Mallin et al. 2006).

[b] Values in blue—nutrient levels that could support noxious algal blooms (e.g., Mallin 2000) or data that exceeded EPA (2000) recommendations.

[c] More than 50% of the samples were below detection or below the reporting limit with the analytical technique used; thus, statistical interpretation was not attempted.

[d] Values in green (fecal coliform bacteria, *Escherichia coli*)—suggest degraded conditions, based on the South Carolina water-quality standards, or the EPA (2003).

[e] Values were reported as "less than" a range of values that include the CCC and the U.S. EPA; or, for chromium, the chemical species was not designated.

**Table B-16 (continued).** CW-222 (SCDHEC, Wateree River at junction with Congaree, Richland Co.; latitude 33.7519, longitude -80.6108).

| Parameter | Date | n | Mean (range) | Median | Number unacceptable |
|---|---|---|---|---|---|
| Cadmium, total (µg/L) | Feb 00–May 13 | 50 | (brl–0.95)[c] | – | 1[a] |
| Chromium, total (µg/L) | Feb 00–May 13 | 50 | (brl–72)[c] | – | 1[a]; uncertain[e] |
| Copper, total (µg/L) | Feb 00–May 13 | 50 | (brl–10)[c] | – | 1[a] |
| Iron, total (µg/L) | Feb 00–May 13 | 50 | 965 (310–3,600) | 865 | – |
| Lead, total (µg/L) | Feb 00–Jun 11 | 42 | (brl–8.8)[c] | – | 4[a]; uncertain[e] |
| Manganese, total (µg/L) | Feb 00–May 13 | 50 | 87 (46–140) | 86 | – |
| Nickel, total (µg/L) | Feb 00–May 13 | 49 | (brl–27)[b] | – | – |
| Zinc, total (µg/L) | Feb 00–May 13 | 50 | (brl–43)[b] | – | – |

[a] Values in red—data in violation of state standards; or data that exceeded EPA (2000, 2002b) recommendations; or data exceeded recommended values to protect aquatic life (BOD5–see Mallin et al. 2006).

[b] Values in blue—nutrient levels that could support noxious algal blooms (e.g., Mallin 2000) or data that exceeded EPA (2000) recommendations.

[c] More than 50% of the samples were below detection or below the reporting limit with the analytical technique used; thus, statistical interpretation was not attempted.

[d] Values in green (fecal coliform bacteria, *Escherichia coli*)—suggest degraded conditions, based on the South Carolina water-quality standards, or the EPA (2003).

[e] Values were reported as "less than" a range of values that include the CCC and the U.S. EPA; or, for chromium, the chemical species was not designated.

**Table B-17.** S.C.-002 (Santee Cooper–South Carolina Public Service Authority, Wateree River at Little River, Sumter Co.; latitude 33.7481, longitude -80.6167)

| Parameter | Date | n | Mean (Range) | Median | Number unacceptable |
|---|---|---|---|---|---|
| Temperature (°C) | Jan 00–Feb 09 | 83 | 20.2 (7.1–32) | 21.7 | – |
| Turbidity (NTU) | Jan 00–Dec 06 | 42 | 18.3 (6.0–61.6) | 13.6 | 40[g] |
| Spec. cond. (µmhos/cm) | Jan 00–Feb 09 | 47 | 176 (45–281) | 183 | – |
| DO (mg/L) | Jan 00–Feb 09 | 83 | 8.0 (4.7–13.6) | 7.5 | – |
| pH | Jan 00–Feb 09 | 105 | 7.3 (6.6–8.9) | 7.3 | – |
| $NO_3^-N + NO_2^-N$ (µg/L) | Jan 00–Dec 04 | 31 | 382 (brl–1,110) | 380 | 29[h] |
| $NH_4^+N$ (µg/L) | Jan 00–Dec 06 | 31 | 84 (brl–250) | 75 | 9[h] |
| TKN (µg/L) | Jan 00–Dec 06 | 30 | 453 (brl–1,000) | 445 | 23[h] |
| TP (µg/L) | Jan 00–Dec 06 | 36 | 74 (brl–160) | 70 | 32[h] |
| SRP (µg/L) | Jan 00–Dec 06 | 14 | 31 (brl–90) | 23 | – |
| Solids, Total Fixed (mg/L) | Jan 00–Dec 06 | 41 | 84 (brl–178) | 90 | – |
| TSS (mg/L) | Jan 00–Dec 06 | 22 | 19 (brl–31) | 21 | 17[g] |
| $BOD_5$ (mg/L) | Jan 00–Nov 06 | 34 | (brl–2.2)[b] | – | – |
| Fecal coliforms, EC (mpn/100 mL) | Jan 00–Dec 06 | 41 | 62.5 (brl – 960[f]) | 25 | 2[f] (5% > 400) |
| Alkalinity, carbonate as $CaCO_3$ (mg/L) | Jan 00–Dec 06 | 37 | 32 (17–45) | 32 | – |
| Hardness, $Ca^+Mg$ (mg/L) | Jan 00–Nov 06 | 17 | 27.5 (14–38) | 27 | – |
| Bromide (mg/L) | Aug 06–Dec 06 | 4 | 0.12 (brl–0.17) | 0.155 | – |
| Calcium (mg/L) | Jan 00–Nov 06 | 17 | 6.0 (brl–8.9) | 6.0 | – |
| Chloride (mg/L) | Aug 06–Dec 06 | 5 | 13.7 (6.9–17.9) | 14.9 | – |
| Fluoride (mg/L) | Aug 06–Dec 06 | 5 | 0.13 (brl–0.2) | 0.15 | – |
| Magnesium (mg/L) | Jan 00–Nov 06 | 18 | 3.0 (2.3–3.7) | 3.1 | – |

[a] Values in red—data in violation of state standards; or data that exceeded EPA (2000, 2002b) recommendations; or data exceeded recommended values to protect aquatic life (BOD5–see Mallin et al. 2006).

[b] Values in blue—nutrient levels that could support noxious algal blooms (e.g., Mallin 2000) or data that exceeded EPA (2000) recommendations.

[c] More than 50% of the samples were below detection or below the reporting limit with the analytical technique used; thus, statistical interpretation was not attempted.

[d] Values in green (fecal coliform bacteria, *Escherichia coli*)—suggest degraded conditions, based on the South Carolina water-quality standards, or the EPA (2003).

**Table B-17 (continued).** S.C.-002 (Santee Cooper–South Carolina Public Service Authority, Wateree River at Little River, Sumter Co.; latitude 33.7481, longitude -80.6167)

| Parameter | Date | n | Mean (Range) | Median | Number unacceptable |
|---|---|---|---|---|---|
| Potassium (mg/L) | Jan 00–Nov 06 | 18 | 3.3 (1.4–5.1) | 3.6 | – |
| Sodium (mg/L) | Jan 00–Nov 06 | 18 | 25.6 (11.9–43.5) | 25.9 | – |
| Sulfur (mg/L) | Aug 06–Dec 06 | 5 | 19.8 (11.25–28.7) | 18.7 | – |
| Arsenic, total (µg/L) | Jan 06–Nov 06 | 8 | (all brl)[b] | – | – |
| Cadmium, total (µg/L) | Jan 00–Nov 06 | 24 | (all brl)[b] | – | – |
| Chromium, total (µg/L) | Jan 00–Nov 06 | 24 | (all brl)[b] | – | – |
| Copper, total (µg/L) | Jan 00–Nov 06 | 24 | (brl–2.65)[b] | – | – |
| Iron, total (µg/L) | Jan 00–Nov 06 | 23 | 947 (497–1,943) | 870 | – |
| Lead, total (µg/L) | Jan 00–Nov 06 | 24 | (brl–52)[b] | – | **2**[g] |
| Manganese, total (µg/L) | Jan 00–Nov 06 | 24 | 90.5 (49–168) | 90.5 | – |
| Mercury, total (µg/L) | Aug 03–Nov 04 | 5 | (all brl)[b] | – | – |
| Nickel, total (µg/L) | Jan 00–Nov 06 | 24 | (all brl)[b] | – | – |
| Selenium, total (µg/L) | Jan 06–Nov 06 | 8 | (all brl)[b] | – | – |
| Zinc, total (µg/L) | Jan 00–Nov 06 | 24 | (brl–43)[b] | – | – |

[a] Values in red—data in violation of state standards; or data that exceeded EPA (2000, 2002b) recommendations; or data exceeded recommended values to protect aquatic life (BOD5–see Mallin et al. 2006).

[b] Values in blue—nutrient levels that could support noxious algal blooms (e.g., Mallin 2000) or data that exceeded EPA (2000) recommendations.

[c] More than 50% of the samples were below detection or below the reporting limit with the analytical technique used; thus, statistical interpretation was not attempted.

[d] Values in green (fecal coliform bacteria, *Escherichia coli*)—suggest degraded conditions, based on the South Carolina water-quality standards, or the EPA (2003).

# Appendix C. Updated Species Lists for Congaree National Park.

**Table C-1.** Terrestrial plants reported to occur in Congaree National Park. From the NPS Certified Species List (2013a)

| Scientific Name | Common Name(s) | Notes |
|---|---|---|
| *Acalypha gracilens* | Slender copperleaf, slender threeseed mercury | – |
| *Adiantum pedatum* | Maidenfern, maidenhair, maidenhair fern | – |
| *Aesculus pavia* | Red buckeye | – |
| *Agalinis tenuifolia* | Slender-leaf false foxglove, slenderleaf false foxglove | – |
| *Albizia julibrissin* | Mimosa, mimosa tree, powderpuff tree, silk tree, silktree | Significant threat; exotic/invasive |
| *Allium vineale* | Wild garlic | – |
| *Amaranthus spinosus* | Pigweed species, spiny amaranth, spiny amaranthus | – |
| *Ambrosia artemisiifolia* | Annual ragweed, common ragweed, low ragweed | – |
| *Amelanchier arborea* | Allegheny serviceberry, apple shadbush, common serviceberry | – |
| *Amphicarpaea bracteata* | American hogpeanut, hog-peanut | – |
| *Antennaria plantaginifolia* | Plantainleaf pussytoes, woman's tobacco | – |
| *Antennaria solitaria* | Singlehead pussytoes | – |
| *Apocynum cannabinum* | Indianhemp, dogbane, common dogbane, hemp dogbane | – |
| *Arabidopsis thaliana* | Mouse-ear cress, mouseear cress | exotic/invasive |
| *Aristolochia serpentaria* | Virginia dutchmanspipe, Virginia snakeroot | – |
| *Arthraxon hispidus* | Small carpgrass | *Arthraxon hispidus* is given as *Arthraxon hispidus* var. *cryptatherus* (synonym) in the NPS Certified Species List |
| *Arundinaria gigantea* | Giant cane | – |
| *Asarum canadense* | Canadian wild ginger, Canadian wildginger | – |

**Table C-1 (continued).** Terrestrial plants reported to occur in Congaree National Park. From the NPS Certified Species List (2013a)

| Scientific Name | Common Name(s) | Notes |
|---|---|---|
| *Asclepias tuberosa* | Butterfly milkweed, butterflyweed | – |
| *Asimina parviflora* | Smallflower pawpaw | – |
| *Asplenium platyneuron* | Ebony spleenwort | – |
| *Aster pilosus* | White heath aster, white oldfield aster | – |
| *Aureolaria pectinata* | Combleaf yellow false foxglove | – |
| *Axonopus fissifolius* | Carpetgrass, common carpetgrass, Louisiana grass | – |
| *Baptisia alba* | White wild indigo, white false indigo, white wildindigo | – |
| *Baptisia albescens* | Spiked wild indigo | – |
| *Baptisia tinctoria* | Horseflyweed, yellow wildindigo | – |
| *Berberis thunbergii* | Japanese barberry | – |
| *Botrychium biternatum* | Sparselobe grapefern | – |
| *Botrychium lunarioides* | Winter grapefern | SoC G4?,S1 |
| *Botrychium virginianum* | Rattlesnake fern | – |
| *Bromus catharticus* | Rescue brome, rescue grass, rescuegras, rescuegrass | exotic/invasive |
| *Callicarpa americana* | American beautyberry | – |
| *Cannabis sativa* | Grass, hashish, hemp, marijuana, Mary Jane, pot | – |
| *Carex communis* | Fibrousroot sedge | – |
| *Carex digitalis* | Slender wood sedge, slender woodland sedge | – |
| *Carex leavenworthii* | Leavenworth's sedge | – |
| *Carex muehlenbergii* | Muhlenberg's sedge, Muhlenberg's sedge | – |
| *Carex nigromarginata* | Black edge sedge | – |
| *Carex peckii* | Peck's sedge | – |
| *Carex pensylvanica* | Penn sedge, Pennsylvania sedge | – |

**Table C-1 (continued).** Terrestrial plants reported to occur in Congaree National Park. From the NPS Certified Species List (2013a)

| Scientific Name | Common Name(s) | Notes |
|---|---|---|
| *Carex retroflexa* | Reflexed sedge | – |
| *Carex rosea* | Rosy sedge | – |
| *Carex socialis* | Low woodland sedge | SoC G4,S1 |
| *Carex striatula* | Lined sedge | – |
| *Carex texensis* | Texas sedge | – |
| *Carex tonsa* | Shaved sedge | – |
| *Carya alba* | Mockernut hickory | – |
| *Cassia fasciculata* | Partridge pea, showy partridgepea, sleepingplant | – |
| *Ceanothus americanus* | Jersey tea, jerseytea, New Jersey tea | – |
| *Centrosema virginianum* | Butterflypea, spurred butterfly pea | – |
| *Cerastium nutans* | Nodding chickweed | – |
| *Cercis canadensis* | Eastern redbud, redbud | – |
| *Chamaecrista fasciculata* var. *fasciculata* | Sleepingplant | – |
| *Chamaecrista nictitans* | Partridge pea, partridge-pea | – |
| *Chenopodium album* | Lambsquarters, common lambsquarters, lambsquarters goosefoot, white goosefoot | – |
| *Chenopodium ambrosioides* | Mexican tea, Mexican-tea | – |
| *Chimaphila maculata* | Striped prince's pine, striped prince's-pine | – |
| *Chrysogonum virginianum* | Green and gold | – |
| *Chrysopsis gossypina* | Cottony goldenaster | – |
| *Chrysopsis mariana* | Maryland goldenaster | – |
| *Clematis viorna* | Vasevine | – |
| *Clinopodium georgianum* | Georgia calamint | – |
| *Clitoria mariana* | Atlantic pigeonwings, pidgeonwings | – |
| *Cnidoscolus stimulosus* | Finger rot | – |

**Table C-1 (continued).** Terrestrial plants reported to occur in Congaree National Park. From the NPS Certified Species List (2013a)

| Scientific Name | Common Name(s) | Notes |
|---|---|---|
| *Collinsonia serotina* | Blue Ridge horsebalm | SoC G3G4,S1 |
| *Conopholis americana* | American squawroot, squaw-root | – |
| *Conyza bonariensis* | Asthmaweed, flaxleaved fleabane, hairy fleabane | – |
| *Conyza canadensis* var. *canadensis* | Canadian horseweed | *Conyza canadensis* var. *canadensis* is given as *Erigeron canadensis* (synonym) in the NPS Certified Species List. |
| *Coreopsis major* | Greater tickseed | – |
| *Cornus florida* | Flowering dogwood | – |
| *Corydalis flavula* | Pale corydalis, yellow fumewort | – |
| *Crataegus flava* | Yellow hawthorn, yellowleaf hawthorn | – |
| *Crepis pulchra* | Hawksbeard, smallflower hawksbeard | – |
| *Crotalaria spectabilis* | Showy crotalaria, showy rattlebox | exotic/invasive |
| *Cucumis sativus* | Garden cucumber | – |
| *Cynodon dactylon* | Bermudagrass | exotic/invasive |
| *Cyperus lupulinus* ssp. *lupulinus* | Great Plains flatsedge | – |
| *Dactylis glomerata* | Cocksfoot, orchard grass, orchardgrass | exotic/invasive |
| *Dactyloctenium aegyptium* | Crowfoot grass, Durban crowsfoot grass, Egyptian grass | – |
| *Descurainia pinnata* | Green tansymustard, pinnate tansy mustard, pinnate tansymustard | – |
| *Desmodium ciliare* | Hairy small-leaf ticktrefoil, littleleaf tickclover | – |
| *Desmodium fernaldii* | Fernald's ticktrefoil | – |
| *Desmodium nudiflorum* | Bare-stemmed tick-treefoil, barestem tickclover, nakedflower ticktrefoil | – |
| *Desmodium obtusum* | Stiff tickclover, stiff ticktrefoil | – |
| *Desmodium pauciflorum* | Fewflower ticktrefoil, fewflowered tickclover | – |
| *Desmodium rotundifolium* | Prostrate ticktrefoil, roundhead tickclover | – |

**Table C-1 (continued).** Terrestrial plants reported to occur in Congaree National Park. From the NPS Certified Species List (2013a)

| Scientific Name | Common Name(s) | Notes |
|---|---|---|
| *Desmodium sessilifolium* | Sessile tickclover, sessileleaf tickclover, sessileleaf ticktrefoil | – |
| *Desmodium tenuifolium* | Slimleaf ticktrefoil | – |
| *Dichanthelium aciculare* | Needleleaf rosette grass | SoC G4,G5;SNR |
| *Dichanthelium acuminatum* | Tapered rosette grass, hotsprings panicum, hotsprings rosette grass | – |
| *Dichanthelium acuminatum* var. *acuminatum* | Tapered rosette grass | *Dichanthelium acuminatum* var. *acuminatum* is given as *Panicum acuminatum* (synonym) in the NPS Certified Species List. |
| *Dichanthelium boscii* | Bosc's panicgrass | – |
| *Dichanthelium laxiflorum* | Openflower rosette grass | – |
| *Dichanthelium sphaerocarpon* var. *isophyllum* | Roundseed panicgrass, roundseed panicum | – |
| *Digitaria sanguinalis* | Crabgrass, hairy crab grass, hairy crabgrass | – |
| *Dioscorea floridana* | Florida yam | – |
| *Dioscorea oppositifolia* | Chinese yam | – |
| *Duchesnea indica* | India mockstrawberry, Indian strawberry | – |
| *Eclipta prostrata* | Eclipta, false daisy, yerba de tago, yerba de tajo | – |
| *Elaeagnus umbellata* | Autumn olive, oleaster | Severe threat; exotic/invasive |
| *Elephantopus tomentosus* | Devil's grandmother, hairy elephantfoot | – |
| *Eleusine indica* | Crowsfoot grass, goose grass, Indian goose grass | – |
| *Epifagus virginiana* | Beechdrops | – |
| *Eragrostis hirsuta* | Bigtop lovegrass | – |
| *Erigeron strigosus* | Daisy fleabane, prairie fleabane, rough fleabane | – |
| *Euonymus americanus* | Bursting-heart | – |
| *Eupatorium album* | White thoroughwort | – |

**Table C-1 (continued).** Terrestrial plants reported to occur in Congaree National Park. From the NPS Certified Species List (2013a)

| Scientific Name | Common Name(s) | Notes |
|---|---|---|
| *Euphorbia corollata* | Flowering spurge, floweringspurge euphorbia | – |
| *Euphorbia dentata* | Toothed euphorbia, toothed spurge, toothedleaf poinsettia | – |
| *Euphorbia heterophylla* | Mexican fireplant, painted euphorbia | – |
| *Euphorbia spathulata* | Warty spurge, roughpod spurge | – |
| *Eurybia divaricata* | White wood aster | – |
| *Elymus hystrix* var. *hystrix* | Eastern bottlebrush grass | *Elymus hystrix* var. *hystrix* is given as *Hystrix patula* (synonym) in the NPS Certified Species List. |
| *Facelis retusa* | Annual trampweed | exotic/invasive |
| *Fagopyrum esculentum* | Buckwheat, common buckwheat, fagopyrum | – |
| *Fagus grandifolia* | American beech | – |
| *Fraxinus americana* | White ash | – |
| *Galactia elliotti* | Elliott's milkpea | – |
| *Galactia volubilis* | Downy milkpea | – |
| *Galium circaezans* | Licorice bedstraw, wild licorice, woods bedstraw | – |
| *Galium pilosum* | Hairy bedstraw | – |
| *Galium triflorum* | Fragrant bedstraw, sweet bedstraw, sweetscented bedstraw | – |
| *Gamochaeta falcata* | Narrowleaf purple everlasting | – |
| *Gamochaeta purpurea* | Spoon-leaf purple everlasting | – |
| *Geranium carolinianum* | Carolina crane's-bill, Carolina geranium | – |
| *Geranium maculatum* | Spotted crane's-bill, spotted geranium, wild crane's-bill | – |
| *Glandularia pulchella* | South American mock vervain | exotic/invasive |
| *Glechoma hederacea* | Ground ivy | *Glechoma hederacea* is misspelled as *Glecoma hederacea* in the NPS Certified Species List. |

**Table C-1 (continued).** Terrestrial plants reported to occur in Congaree National Park. From the NPS Certified Species List (2013a)

| Scientific Name | Common Name(s) | Notes |
|---|---|---|
| *Glycine max* | Soybean | – |
| *Goodyera pubescens* | Downy rattlesnake plantain, downy rattlesnake-plantain | – |
| *Goodyera repens* | Dwarf rattlesnake-plantain, lesser rattlesnake plantain | – |
| *Halesia carolina* | Carolina silverbell, silverbell | – |
| *Hedera helix* | English ivy | exotic/invasive |
| *Helenium amarum* | Bitter sneezeweed, yellowdicks | exotic/invasive |
| *Helianthus atrorubens* | Purpledisk sunflower | – |
| *Helianthus divaricatus* | Woodland sunflower | – |
| *Helianthus microcephalus* | Small woodland sunflower | – |
| *Hepatica nobilis* var. *obtusa* | Roundlobe hepatica | *Hepatica nobilis* var. *obtusa* is given as *Hepatica americana* (synonym) in the NPS Certified Species List. |
| *Heterotheca subaxillaris* | Camphorweed, golden aster | – |
| *Heuchera americana* | Alumroot, American alumroot | – |
| *Hexastylis arifolia* | Littlebrownjug | – |
| *Hibiscus syriacus* | Althea, rose of Sharon, rose-of-sharon, shrub althea, shrub-althea | – |
| *Hypericum gentianoides* | Orangegrass, pinweed st. johnswort | – |
| *Hypochaeris radicata* | Common cat's-ear, false dandelion, frogbit | exotic/invasive |
| *Ilex aquifolium* | English holly | – |
| *Ipomoea cordatotriloba* | Cotton morningglory, tievine | – |
| *Ipomoea nil* | Whiteedge morning-glory, whiteedge morningglory | – |
| *Juglans nigra* | Black walnut | – |
| *Juniperus virginiana* | Eastern red-cedar, eastern redcedar, red cedar juniper | – |

**Table C-1 (continued).** Terrestrial plants reported to occur in Congaree National Park. From the NPS Certified Species List (2013a)

| Scientific Name | Common Name(s) | Notes |
|---|---|---|
| *Kalmia latifolia* | Mountain laurel | – |
| *Kummerowia striata* | Common lespedeza, Japanese clover | – |
| *Lactuca canadensis* | Canada lettuce, Florida blue lettuce, wild lettuce | – |
| *Lagerstroemia indica* | Crapemyrtle | – |
| *Lamium amplexicaule* | Common henbit, giraffehead, henbit, henbit deadnettle | exotic/invasive |
| *Lamium purpureum* | Purple deadnettle, red deadnettle | exotic/invasive |
| *Lechea mucronata* | Hairy pinweed | – |
| *Lechea pulchella* | Leggett's pinweed | – |
| *Lechea torreyi* | Piedmont pinweed | – |
| *Lepidium virginicum* | Peppergrass, poorman pepperweed, poorman's pepper | – |
| *Lespedeza capitata* | Roundhead lespedeza | – |
| *Lespedeza cuneata* | Chinese lespedeza, sericea lespedeza | exotic/invasive |
| *Liatris pilosa* | Shaggy blazing star | *Liatris pilosa* is given as *Liatris graminifolia* (synonym) in the NPS Certified Species List. |
| *Ligustrum japonicum* | Japanese privet | exotic/invasive |
| *Liriope muscari* | Big blue lilyturf | exotic/invasive |
| *Lolium perenne* | Italian ryegrass, perennial rye grass, perennial ryegrass | exotic/invasive |
| *Lolium pratense* | Meadow fescue, meadow ryegrass | – |
| *Maianthemum racemosum* ssp. *racemosum* | False Solomon's-seal, feather Solomon's seal, feathery false lily of the valley | – |
| *Malus angustifolia* | Southern crabapple | – |
| *Manfreda virginica* | False aloe | – |
| *Matelea carolinensis* | Maroon Carolina milkvine | – |

**Table C-1 (continued).** Terrestrial plants reported to occur in Congaree National Park. From the NPS Certified Species List (2013a)

| Scientific Name | Common Name(s) | Notes |
|---|---|---|
| *Melia azedarach* | Chinaberry, Chinaberry tree, Indian lilac | exotic/invasive |
| *Melica mutica* | Oniongrass, twoflower melic, twoflower melicgrass | – |
| *Melilotus alba* | White sweetclover | – |
| *Menispermum canadense* | Canadian moonseed, common moonseed | – |
| *Milium effusum* | American milletgrass | – |
| *Morella caroliniensis* | Evergreen bayberry, southern bayberry | – |
| *Morella cerifera* | Wax myrtle, waxmyrtle | – |
| *Morus alba* | Mulberry, white mulberry | exotic/invasive |
| *Nothoscordum bivalve* | Crowpoison | – |
| *Nothoscordum gracile* | Slender false garlic | – |
| *Nuttallanthus canadensis* | Canada toadflax, oldfield toadflax, oldfield-toadflax | – |
| *Oenothera biennis* | Common evening primrose, hoary eveningprimrose, king's-cureall | – |
| *Oenothera fruticosa ssp. glauca* | Narrowleaf evening-primrose, shrubby sundrops | – |
| *Oenothera laciniata* | Cut-leaf evening-primrose | – |
| *Ophioglossum crotalophoroides* | Bulbous adderstongue | – |
| *Oplismenus hirtellus* | Bristle basketgrass | – |
| *Opuntia ficus-indica* | Indian fig, Indian-fig, tuna cactus | – |
| *Orbexilum pedunculatum* var. *psoralioides* | Sampson's snakeroot | *Orbexilum pedunculatum* var. *psoralioides* is given as *Psoralea psoralioides* (synonym) in the NPS Certified Species List. |
| *Ostrya virginiana* | Eastern hophornbeam, hophornbeam | – |
| *Oxalis stricta* | Common yellow oxalis, erect woodsorrel, sheep sorrel | – |
| *Oxalis violacea* | Purple woodsorrel, violet wood-sorrel, violet woodsorrel | – |

**Table C-1 (continued).** Terrestrial plants reported to occur in Congaree National Park. From the NPS Certified Species List (2013a)

| Scientific Name | Common Name(s) | Notes |
|---|---|---|
| *Packera anonyma* | Small's ragwort | – |
| *Parthenocissus quinquefolia* | American ivy, fiveleaved ivy, Virginia creeper, woodbine | – |
| *Paspalum notatum* | Bahiagrass | Can be both native and exotic/invasive |
| *Passiflora incarnata* | Purple passionflower | – |
| *Passiflora lutea* | Passionflower, yellow passionflower | – |
| *Penstemon australis* | Eustis Lake beardtongue | – |
| *Perilla frutescens* | Beefsteak, beefsteak mint, beefsteakplant, purple perilla, purple mint | exotic/invasive |
| *Phegopteris hexagonoptera* | Broad beech fern, broad beechfern | – |
| *Philadelphus inodorus* | Scentless mock orange | – |
| *Phlox carolina* | Thickleaf phlox | – |
| *Phoradendron leucarpum* | Oak mistletoe | – |
| *Physalis virginiana* | Ground cherry (Virginia), lanceleaf groundcherry | – |
| *Pinus echinata* | Arkansas pine, shortleaf pine, shortleaf yellow pine | – |
| *Pinus taeda* | Loblolly pine | – |
| *Pityopsis graminifolia* var. *graminifolia* | Narrowleaf silkgrass | *Heterotheca graminifolia*, included in the NPS Certified Species List, is a synonym of *Pityopsis graminifolia* var. *graminifolia*. |
| *Plantago aristata* | Bottlebrush Indianwheat, largebracted plantain | exotic/invasive |
| *Plantago wrightiana* | Wright plantain, Wright's plantain | – |
| *Pleopeltis polypodioides* | Resurrection fern | – |
| *Pleopeltis polypodioides* ssp. *polypodioides* | Resurrection fern | *Polypodium polypodioides*, included in the NPS Certified Species List, is a synonym of *Pleopeltis polypodioides* ssp. *polypodioides*. |
| *Podophyllum peltatum* | May apple, mayapple | – |
| *Polygala polygama* | Bitter milkwort, racemed milkwort | – |

**Table C-1 (continued).** Terrestrial plants reported to occur in Congaree National Park. From the NPS Certified Species List (2013a)

| Scientific Name | Common Name(s) | Notes |
|---|---|---|
| *Polygonatum biflorum* | Smooth Solomon's seal, King Solomon's seal, Solomon's seal | – |
| *Polygonum erectum* | Devil's shoestring, erect knotweed, wireweed | – |
| *Polystichum acrostichoides* | Christmas fern | – |
| *Poncirus trifoliata* | Hardy orange | – |
| *Portulaca amilis* | Paraguayan purslane | – |
| *Potentilla canadensis* | Dwarf cinquefoil | – |
| *Prenanthes serpentaria* | Cankerweed | – |
| *Prenanthes trifoliolata* | Gall of the earth, gall-of-the-earth, three-leaved rattlesnakeroot | *Prenanthes trifoliolata* is misspelled as *Prenanthes trifoliata* in the NPS Certified Species List. |
| *Prunus angustifolia* | Chickasaw plum | – |
| *Prunus serotina* | Black cherry, black chokecherry | – |
| *Prunus serotina* var. *serotina* | Black cherry | – |
| *Prunus umbellata* | Flatwood plum, hog plum | – |
| *Pseudognaphalium obtusifolium* ssp. *obtusifolium* | Rabbittobacco | *Gnaphalium obtusifolium*, included in the NPS Certified Species List, is a synonym of *Pseudognaphalium obtusifolium* ssp. *obtusifolium*. |
| *Pteridium aquilinum* | Bracken fern, northern bracken fern, western brackenfern | – |
| *Pueraria montana* | Kudzu | Severe threat; exotic/invasive |
| *Pycnanthemum flexuosum* | Appalachian mountainmint | – |
| *Pyracantha coccinea* | Scarlet firethorn | – |
| *Pyrrhopappus carolinianus* | Carolina desert chicory, Carolina false-dandelion | – |
| *Pyrus communis* | Common pear, pear | – |
| *Quercus acutissima* | Sawtooth oak | Alert; exotic/invasive |
| *Quercus alba* | White oak | – |
| *Quercus falcata* | Southern red oak | – |

**Table C-1 (continued).** Terrestrial plants reported to occur in Congaree National Park. From the NPS Certified Species List (2013a)

| Scientific Name | Common Name(s) | Notes |
|---|---|---|
| *Quercus ilicifolia* | Bear oak | – |
| *Quercus margaretta* | Runner oak, sand post oak | *Quercus margaretta* is given as *Quercus margarettiae* (synonym) in the NPS Certified Species List. |
| *Quercus marilandica* | Blackjack oak | – |
| *Quercus rubra* | Northern red oak | – |
| *Quercus stellata* | Post oak | – |
| *Quercus velutina* | Black oak | – |
| *Raphanus sativus* | Cultivated radish, garden radish, radish, wild radish | – |
| *Rhododendron eastmanii* | Santee azalea | SoC G2,S2 |
| *Rhus copallina* | Dwarf sumac, shining sumac | – |
| *Rhus glabra* | Smooth sumac | – |
| *Rhynchosia reniformis* | Dollarleaf | – |
| *Rhynchospora recognita* | Globe beaksedge | – |
| *Rubus canadensis* | Smooth blackberry | – |
| *Ruellia caroliniensis* | Carolina wild petunia | – |
| *Saccharum alopecuroidum* | Silver plumegrass | – |
| *Salvia lyrata* | Lyreleaf sage | – |
| *Sanguinaria canadensis* | Bloodroot | – |
| *Sanicula canadensis* | Canada sanicle, Canadian blacksnakeroot | – |
| *Sanicula marilandica* | Black sanicle, Maryland black-snakeroot, Maryland sanicle | – |
| *Sanicula odorata* | Cluster sanicle, clustered blacksnakeroot | – |
| *Sanicula smallii* | Small's blacksnakeroot | – |
| *Saponaria officinalis* | Bouncing bet, soapwort, sweet Betty | – |
| *Sassafras albidum* | Sassafras | – |
| *Scutellaria elliptica* | Hairy skullcap | – |

**Table C-1 (continued).** Terrestrial plants reported to occur in Congaree National Park. From the NPS Certified Species List (2013a)

| Scientific Name | Common Name(s) | Notes |
|---|---|---|
| *Selaginella apoda* | Meadow spike-moss, meadow spikemoss | – |
| *Senecio vulgaris* | Common groundsel, old-man-in-the-spring | – |
| *Senna obtusifolia* | Java-bean, sicklepod | exotic/invasive |
| *Sericocarpus asteroides* | Toothed whitetop aster | – |
| *Sericocarpus linifolius* | Narrowleaf whitetop aster | – |
| *Sericocarpus tortifolius* | Dixie whitetop aster | – |
| *Setaria viridis* | Bottle grass, green bristle grass, green foxtail, pigeongrass | – |
| *Sida rhombifolia* | Arrowleaf sida, cuban jute, cuban-jute | exotic/invasive |
| *Sideroxylon lycioides* | Buckthorn bumelia | – |
| *Silene caroliniana* | Sticky catchfly | – |
| *Sinapis arvensis* | Charlock, charlock mustard, corn mustard | – |
| *Sisyrinchium albidum* | White blue-eyed grass, white blueeyed grass | – |
| *Smallanthus uvedalius* | Hairy leafcup | – |
| *Smilax hugeri* | Huger's carrionflower | – |
| *Smilax pumila* | Sarsparilla vine | – |
| *Solanum americanum* | American black nightshade | – |
| *Solanum carolinense* | Apple of Sodom, bull nettle, Carolina horsenettle | – |
| *Solanum pseudocapsicum* | Jerusalem cherry | Emerging threat; exotic/invasive |
| *Solanum ptychanthum* | Black nightshade, eastern black nightshade, nightshade | – |
| *Solidago canadensis* | Canada goldenrod, Canadian goldenrod, common goldenrod | – |
| *Solidago nemoralis* | Dyersweed goldenrod, gray goldenrod | – |
| *Solidago odora* | Anisescented goldenrod, fragrant goldenrod | – |
| *Solidago puberula* var. *pulverulenta* | Downy goldenrod | – |

**Table C-1 (continued).** Terrestrial plants reported to occur in Congaree National Park. From the NPS Certified Species List (2013a)

| Scientific Name | Common Name(s) | Notes |
|---|---|---|
| *Sorghastrum nutans* | Indiangrass, yellow indian-grass | – |
| *Spigelia marilandica* | Indianpink, woodland pinkroot | – |
| *Stellaria media* | Chickweed, common chickweed, nodding chickweed | exotic/invasive |
| *Stellaria pubera* | Star chickweed | – |
| *Stylisma humistrata* | Southern dawnflower | – |
| *Stylosanthes biflora* | Endbeak pencilflower, sidebeak pencilflower | – |
| *Symphyotrichum concolor* | Eastern silver aster | – |
| *Symphyotrichum cordifolium* | Common blue wood aster | – |
| *Symphyotrichum patens* var. *patens* | Late purple aster | – |
| *Taraxacum officinale* | Blowball, common dandelion, dandelion, faceclock | – |
| *Tephrosia spicata* | Spiked hoarypea | – |
| *Tephrosia virginiana* | Virginia tephrosia | – |
| *Thalictrum thalictroides* | Rue anemone | – |
| *Thelypteris kunthii* | Kunth's maiden fern | – |
| *Thelypteris noveboracensis* | New York fern | – |
| *Tillandsia usneoides* | Spanish moss | – |
| *Tilia americana* var. *heterophylla* | American basswood | *Tilia americana* var. *heterophylla* is given as *Tilia heterophylla* (synonym) in the NPS Certified Species List. |
| *Tipularia discolor* | Crippled cranefly | – |
| *Tragia urens* | Wavyleaf noseburn | – |
| *Trifolium repens* | Dutch clover, ladino clover, white clover | – |
| *Trifolium vesiculosum* | Arrowleaf clover | – |
| *Tripsacum dactyloides* | Eastern gamagrass | – |
| *Vaccinium arboreum* | Farkleberry, tree sparkleberry, tree-huckelberry | – |
| *Vaccinium corymbosum* | Highbush blueberry | – |

**Table C-1 (continued).** Terrestrial plants reported to occur in Congaree National Park. From the NPS Certified Species List (2013a)

| Scientific Name | Common Name(s) | Notes |
|---|---|---|
| *Vaccinium formosum* | Southern blueberry | – |
| *Vaccinium fuscatum* | Black highbush blueberry | – |
| *Vaccinium stamineum* | Deerberry | – |
| *Vaccinium tenellum* | Small black blueberry | – |
| *Vaccinium virgatum* | Smallflower blueberry | – |
| *Vernicia fordii* | Tungoil tree | – |
| *Vernonia acaulis* | Stemless ironweed | – |
| *Vernonia angustifolia* | Tall ironweed | – |
| *Vernonia glauca* | Broadleaf ironweed | – |
| *Viburnum acerifolium* | Mapleleaf viburnum | – |
| *Viburnum prunifolium* | Blackhaw | – |
| *Viburnum rufidulum* | Rusty blackhaw, rusty viburnum | – |
| *Vicia angustifolia* | Garden vetch | – |
| *Viola palmata* | Early blue violet, trilobed violet | – |
| *Vitis aestivais* | Summer grape | – |
| *Vitis aestivalis* var. *aestivalis* | Summer grape | – |
| *Vulpia octoflora* var. *octoflora* | Eight-flower six-weeks grass, sixweeks fescue | – |
| *Wahlenbergia marginata* | Southern rockbell | – |
| *Wisteria sinensis* | Chinese wisteria | Severe threat; exotic/invasive |
| *Xanthium spinosum* | Bathurst burr, cocklebur, spiny cocklebur | – |
| *Youngia japonica* | Oriental false hawksbeard | – |
| *Yucca filamentosa* | Adam's needle | – |

**Table C-2.** Wetland plants reported to occur in Congaree National Park. From the NPS Certified Species List (2013a).

| Scientific Name | Common Name(s) | Notes |
|---|---|---|
| *Acalypha rhomboidea* | Virginia threeseed mercury | – |
| *Acer negundo* | Ashleaf maple, box elder, boxelder, boxelder maple | – |
| *Acer rubrum* | Red maple | – |
| *Acer rubrum var. trilobum* | Red maple | – |
| *Acer saccharinum* | Silver maple | – |
| *Acmella oppositifolia var. repens* | Creeping spotflower, oppositeleaf spotflower | – |
| *Aesculus sylvatica* | Painted buckeye | – |
| *Agalinis fasciculata* | Beach false foxglove | – |
| *Agalinis obtusifolia* | Tenlobe false foxglove | – |
| *Agrostis hyemalis* | Winter bentgrass | – |
| *Alisma subcordatum* | American water plantain, waterplaintain | – |
| *Alnus serrulata* | Alder, brook-side alder, hazel alder | – |
| *Alopecurus carolinianus* | Carolina foxtail, tufted meadow-foxtail | – |
| *Alternanthera philoxeroides* | Alligator weed, alligatorweed, pig weed | exotic/invasive |
| *Amianthium muscitoxicum* | Flypoison | – |
| *Ammannia coccinea* | Purple ammannia, valley redstem | – |
| *Ammannia latifolia* | Pink redstem | – |
| *Amorpha fruticosa* | Desert false indigo, desert indigobush, dullleaf indigo | – |
| *Ampelopsis arborea* | Peppervine | – |

**Table C-2 (continued).** Wetland plants reported to occur in Congaree National Park. From the NPS Certified Species List (2013a).

| Scientific Name | Common Name(s) | Notes |
|---|---|---|
| *Ampelopsis cordata* | Heartleaf ampelopsis, heartleaf peppervine | – |
| *Anagallis arvensis* | Pimpernel, scarlet pimpernel | – |
| *Andropogon glomeratus* | Bushy bluestem | – |
| *Andropogon virginicus* | Broomsedge, broomsedge bluestem, yellow bluestem | – |
| *Apios americana* | Apios americana, groundnut, potatobean | – |
| *Aralia spinosa* | Angelicatree, devil's walkingstick, devils walkingstick | – |
| *Arisaema dracontium* | Green dragon, greendragon | – |
| *Arisaema triphyllum* | Indian jack in the pulpit, Jack in the pulpit, Jack-in-the-pulpit | – |
| *Aristida purpurascens* var. *virgata* | Arrowfeather threeawn | – |
| *Aristida stricta* | Pineland threeawn | – |
| *Aristolochia tomentosa* | Common dutchmanspipe, woolly dutchman's pipe | SoC G5, S1 |
| *Arnica acaulis* | Common leopardbane | – |
| *Arundinaria gigantea* ssp. *gigantea* | Giant cane | – |
| *Arundinaria gigantea* ssp. *tecta* | Switchcane | *Arundinaria tecta*, included in the NPS Certified Species List, is a synonym of *Arundinaria gigantea* ssp. *tecta*. |
| *Asclepias perennis* | Aquatic milkweed | – |
| *Asimina triloba* | Pawpaw | – |
| *Aster dumosus* | Rice button aster | – |
| *Aster paludosus ssp. paludosus* | Southern swamp aster | – |

**Table C-2 (continued).** Wetland plants reported to occur in Congaree National Park. From the NPS Certified Species List (2013a).

| Scientific Name | Common Name(s) | Notes |
|---|---|---|
| *Athyrium filix-femina* | Common ladyfern, subarctic ladyfern | – |
| *Athyrium filix-femina* ssp. *asplenioides* | Asplenium ladyfern | *Athyrium asplenioides*, included in the NPS Certified Species List, is a synonym of *Athyrium filix-femina* ssp. *asplenioides*. |
| *Axonopus fissifolius* | Common carpetgrass, carpetgrass, Louisiana grass | – |
| *Baccharis halimifolia* | Eastern baccharis | – |
| *Bacopa monnieri* | Coastal waterhyssop, herb of grace, herb-of-grace | – |
| *Berchemia scandens* | Alabama supplejack | – |
| *Betula nigra* | River birch | – |
| *Bidens frondosa* | Bur marigold, devil's beggartick, devil's bootjack | – |
| *Bignonia capreolata* | Cross vine, crossvine | – |
| *Boehmeria cylindrica* | Small-spike false nettle | – |
| *Boltonia asteroides* | Star boltonia, white doll's daisy, white doll's-daisy | – |
| *Boltonia caroliniana* | Carolina doll's daisy | – |
| *Botrychium dissectum* | Cut-leaf grape fern, cutleaf grapefern | – |
| *Briza minor* | Little quakinggrass | exotic/invasive |
| *Bulbostylis capillaris* | Densetuft hairsedge, threadleaf beakseed | – |
| *Calycanthus floridus* | Eastern sweetshrub | – |
| *Campsis radicans* | Common trumpetcreeper, cow-itch, trumpet creeper | – |
| *Cardamine bulbosa* | Bulb bittercress, bulbous bitter-cress, bulbous bittercress | – |
| *Cardamine hirsuta* | Hairy bittercress | exotic/invasive |

**Table C-2 (continued).** Wetland plants reported to occur in Congaree National Park. From the NPS Certified Species List (2013a).

| Scientific Name | Common Name(s) | Notes |
|---|---|---|
| *Cardamine pensylvanica* | Pennsylvania bittercress, Quaker bittercress | – |
| *Carex abscondita* | Thicket sedge | – |
| *Carex alata* | Broadwing sedge | – |
| *Carex albolutescens* | Greenwhite sedge | – |
| *Carex amphibola* | Amphibious sedge, eastern narrowleaf sedge | SoC G5, SNR |
| *Carex annectens* | Yellowfruit sedge | – |
| *Carex atlantica* | Prickly bog sedge | – |
| *Carex atlantica* ssp. *capillacea* | Howe sedge, prickly bog sedge | *Carex howei*, included in the NPS Certified Species List, is a synonym of *Carex atlantica* ssp. *capillacea*. |
| *Carex baileyi* | Bailey's sedge | – |
| *Carex blanda* | Eastern woodland sedge, woodland sedge | – |
| *Carex bromoides* | Bromelike sedge | – |
| *Carex caroliniana* | Carolina sedge | – |
| *Carex cephalophora* | Oval-leaf sedge | – |
| *Carex cherokeensis* | Cherokee sedge | SoC G4G5, S2 |
| *Carex comosa* | Longhair sedge | – |
| *Carex complanata* | Blue sedge, hirsute sedge | – |
| *Carex crebriflora* | Coastalplain sedge | – |
| *Carex crus-corvi* | Ravenfoot sedge | SoC G5, S2 |
| *Carex debilis* | White edge sedge | – |
| *Carex elliottii* | Elliott's sedge | SoC G4?, S1 |
| *Carex festucacea* | Fescue sedge | – |
| *Carex flaccosperma* | Thinfruit sedge | – |
| *Carex floridana* | Florida sedge | – |

**Table C-2 (continued).** Wetland plants reported to occur in Congaree National Park. From the NPS Certified Species List (2013a).

| Scientific Name | Common Name(s) | Notes |
|---|---|---|
| *Carex frankii* | Frank's sedge | – |
| *Carex gigantea* | Giant sedge | – |
| *Carex glaucescens* | Clustered sedge, southern waxy sedge | – |
| *Carex granularis* | Limestone meadow sedge, limestone-meadow sedge | SoC G5, S2 |
| *Carex grayi* | Gray's sedge | – |
| *Carex intumescens* | Greater bladder sedge | – |
| *Carex joorii* | Cypress swamp sedge | – |
| *Carex laevivaginata* | Smoothsheath sedge, wooly sedge | – |
| *Carex leptalea* | Bristlestalked sedge, bristly-stalk sedge, bristlystalked sedge | – |
| *Carex lonchocarpa* | Southern long sedge | *Carex folliculata* var. *australis*, included in the NPS Certified Species List, is a synonym of *Carex lonchocarpa*. |
| *Carex longii* | Long's sedge | – |
| *Carex louisianica* | Louisiana sedge | – |
| *Carex lupulina* | Hop sedge | – |
| *Carex lurida* | Shallow sedge | – |
| *Carex oxylepis* | Sharpscale sedge | – |
| *Carex scoparia* | Broom sedge, pointed broom sedge | – |
| *Carex seorsa* | Weak stellate sedge | – |
| *Carex squarrosa* | Squarrose sedge | – |
| *Carex stipata* | Owlfruit sedge, sawbeak sedge, stalk-grain sedge | – |
| *Carex styloflexa* | Bent sedge | – |

**Table C-2 (continued).** Wetland plants reported to occur in Congaree National Park. From the NPS Certified Species List (2013a).

| Scientific Name | Common Name(s) | Notes |
|---|---|---|
| *Carex tribuloides* | Blunt broom sedge | – |
| *Carex turgescens* | Pinebarren sedge | – |
| *Carex typhina* | Cat-tail sedge, cattail sedge | – |
| *Carex venusta* | Darkgreen sedge | – |
| *Carex vulpinoidea* | Common fox sedge, fox sedge | – |
| *Carphephorus tomentosus* | Woolly chaffhead | – |
| *Carpinus caroliniana* | American hornbeam, American hornbean | – |
| *Carya aquatica* | Water hickory | – |
| *Carya cordiformis* | Bitternut hickory | – |
| *Carya glabra* | Pignut hickory | – |
| *Carya ovata* | Carya ovata australis, shag-bark hickory | – |
| *Catalpa bignonioides* | Southern catalpa | – |
| *Cayaponia quinqueloba* | Fivelobe cucumber | SoC G4, S1? |
| *Celtis laevigata* | Sugar berry, sugar hackberry, sugarberry | – |
| *Cephalanthus occidentalis* | Buttonbush, common buttonbush | – |
| *Chaerophyllum procumbens* | Spreading chervil | – |
| *Chaerophyllum tainturieri* | Chervil, hairy-fruit chervil, hairyfruit chervil | – |
| *Chamaelirium luteum* | Fairywand | – |
| *Chamaesyce maculata* | Large spurge, spotted sandmat, spotted spurge | – |
| *Chasmanthium latifolium* | Broadleaf uniola, Indian wood-oats, Indian woodoats | – |

**Table C-2 (continued).** Wetland plants reported to occur in Congaree National Park. From the NPS Certified Species List (2013a).

| Scientific Name | Common Name(s) | Notes |
|---|---|---|
| *Chasmanthium laxum* | Slender woodoats, spike uniola | – |
| *Chasmanthium sessiliflorum* | Longleaf spikegrass, longleaf woodoats | – |
| *Chionanthus virginicus* | Fringetree, white fringetree | – |
| *Cinna arundinacea* | Stout wood reed-grass, stout woodreed | – |
| *Cirsium nuttallii* | Nuttall's thistle | – |
| *Cirsium virginianum* | Virginia thistle | – |
| *Clematis crispa* | Curly virginsbower, swamp leather flower | – |
| *Clematis virginiana* | Devil's-darning-needles, virgin's bower, Virginia bower | – |
| *Clethra alnifolia* | Coastal sweetpepperbush, summersweet clethra | – |
| *Cocculus carolinus* | Carolina coralbead, Carolina snailseed, redberry moonseed | – |
| *Collinsonia canadensis* | Richweed | – |
| *Commelina communis* | Asiatic dayflower, common dayflower | – |
| *Commelina virginica* | Virginia dayflower | – |
| *Conoclinium coelestinum* | Blue mistflower | – |
| *Cornus amomum* | Silky dogwood | – |
| *Cornus foemina* | Stiff dogwood | – |
| *Crataegus crus-galli* | Bush hawthorne, cockspur hawthorn | – |
| *Crataegus marshallii* | Parsley hawthorn | – |
| *Crataegus phaenopyrum* | Washington hawthorn | – |
| *Crataegus spathulata* | Littlehip hawthorn | – |

**Table C-2 (continued).** Wetland plants reported to occur in Congaree National Park. From the NPS Certified Species List (2013a).

| Scientific Name | Common Name(s) | Notes |
|---|---|---|
| *Crataegus viridis* | Green hawthorn | – |
| *Cryptotaenia canadensis* | Canadian honewort, honewort | – |
| *Cuphea carthagenensis* | Colombian waxweed | – |
| *Cuscuta compacta* | Compact dodder | – |
| *Cyclospermum leptophyllum* | Marsh parsley | – |
| *Cyperus croceus* | Baldwin's flatsedge | – |
| *Cyperus echinatus* | Globe flatsedge | – |
| *Cyperus erythrorhizos* | Red-root flat sedge, redroot flatsedge, redroot nutgrass | – |
| *Cyperus haspan* | Haspan flatsedge | – |
| *Cyperus odoratus* | Fragrant flatsedge, rusty flat sedge | – |
| *Cyperus polystachyos* | Manyspike flatsedge | – |
| *Cyperus pseudovegetus* | Marsh flatsedge | – |
| *Cyperus strigosus* | Strawcolor flatsedge, strawcolor nutgrass | – |
| *Cyperus virens* | Green flatsedge | – |
| *Cyrilla racemiflora* | Swamp cyrilla, swamp titi | – |
| *Decodon verticillatus* | Swamp loosestrife | – |
| *Decumaria barbara* | Woodvamp | – |
| *Dichanthelium dichotomum* | Cypress panicgrass | – |
| *Dichanthelium dichotomum* var. *dichotomum* | Cypress panicgrass | *Dichanthelium dichotomum* var. *dichotomum* is given as *Panicum dichotomum* (synonym) in the NPS Certified Species List. |
| *Dichanthelium oligosanthes* var. *scribnerianum* | Scribner's rosette grass | *Dichanthelium oligosanthes* var. *scribnerianum* is given as *Panicum scoparium* (synonym) in the NPS Certified Species List. |
| *Dichondra carolinensis* | Carolina ponysfoot, grass ponyfoot | – |

**Table C-2 (continued).** Wetland plants reported to occur in Congaree National Park. From the NPS Certified Species List (2013a).

| Scientific Name | Common Name(s) | Notes |
|---|---|---|
| *Dicliptera brachiata* | Branched foldwing | – |
| *Diodia teres* | Poor joe, poorjoe, rough buttonweed | – |
| *Diodia virginiana* | Virginia buttonweed | – |
| *Dioscorea villosa* | Wild yam | – |
| *Diospyros virginiana* | Common persimmon, eastern persimmon, Persimmon | – |
| *Drosera brevifolia* | Dwarf sundew | – |
| *Dryopteris ludoviciana* | Southern woodfern | – |
| *Dulichium arundinaceum* | Threeway sedge | – |
| *Dyschoriste humistrata* | Swamp snakeherb | – |
| *Echinochloa colona* | Jungle rice, Jungle ricegrass, junglerice, watergrass | – |
| *Echinochloa crus-galli* | Barnyard grass, barnyardgrass, cockspur | exotic/invasive |
| *Echinochloa walteri* | Coast cockspur, coast cockspur grass, walter's barnyard grass | – |
| *Eleocharis microcarpa* | Smallfruit spikerush | – |
| *Eleocharis obtusa* | Blunt spikerush, blunt spikesedge | – |
| *Eleocharis parvula* | Dwarf spikesedge, little-head spike-rush | – |
| *Eleocharis tortilis* | Twisted spikerush | – |
| *Elephantopus carolinianus* | Carolina elephantsfoot, leafy elephantfoot | – |
| *Elephantopus nudatus* | Naked elephantfoot, smooth elephantsfoot | – |

**Table C-2 (continued).** Wetland plants reported to occur in Congaree National Park. From the NPS Certified Species List (2013a).

| Scientific Name | Common Name(s) | Notes |
|---|---|---|
| *Elymus virginicus* | Virginia wild rye, Virginia wildrye | – |
| *Eragrostis refracta* | Coastal lovegrass | – |
| *Eragrostis spectabilis* | Petticoat-climber, purple lovegrass | – |
| *Erechtites hieraciifolia* | American burnweed | – |
| *Eryngium prostratum* | Creeping eryngo | – |
| *Euonymus atropurpureus* | Burningbush, eastern burningbush | – |
| *Eupatorium capillifolium* | Dogfennel | – |
| *Eupatorium leucolepis* | Justiceweed | – |
| *Eupatorium rotundifolium* | Roundleaf eupatorium, roundleaf thoroughwort | – |
| *Eupatorium serotinum* | Late eupatorium, lateflowering thoroughwort | – |
| *Euthamia caroliniana* | Slender goldentop | *Euthamia caroliniana* is given as *Euthamia tenuifolia* var. *tenuifolia* and *Solidago microcephala* (synonyms) in the NPS Certified Species List. |
| *Fimbristylis autumnalis* | Slender fimbry | – |
| *Foeniculum vulgare* | Fennel, sweet fennel | – |
| *Forestiera acuminata* | Eastern swampprivet, swamp privet, Texas forestiera | – |
| *Fraxinus caroliniana* | Carolina ash | – |
| *Fraxinus pennsylvanica* | Green ash | *Fraxinus pennsylvanica* var. *subintegerrima*, included in the NPS Certified Species List, is a synonym of *Fraxinus pennsylvanica*. |
| *Fuirena pumila* | Dwarf umbrella-sedge, dwarf umbrellasedge | – |
| *Galium aparine* | Bedstraw, catchweed bedstraw, cleavers, cleaverwort | – |

**Table C-2 (continued).** Wetland plants reported to occur in Congaree National Park. From the NPS Certified Species List (2013a).

| Scientific Name | Common Name(s) | Notes |
|---|---|---|
| *Galium obtusum* | Blunt-leaf bedstraw, bluntleaf bedstraw, bristly bedstraw | – |
| *Galium obtusum* var. *obtusum* | Large marsh bedstraw | – |
| *Gaylussacia dumosa* | Dwarf huckleberry | – |
| *Gaylussacia frondosa* | Blue huckleberry | – |
| *Gelsemium sempervirens* | Carolina jessamine, evening trumpetflower | – |
| *Geum canadense* | White avens | – |
| *Geum laciniatum* | Rough avens | – |
| *Geum virginianum* | Cream avens | – |
| *Gleditsia aquatica* | Water honeylocust, water locust, waterlocust | – |
| *Gleditsia triacanthos* | Common honeylocust, Honey locust | – |
| *Glottidium vesicarium* | Bagpod | – |
| *Glyceria melicaria* | Melic mannagrass | – |
| *Glyceria striata* | Fowl manna grass, fowl mannagrass | – |
| *Gratiola virginiana* | Roundfruit hedgehyssop, Virginia hedgehyssop | – |
| *Hamamelis virginiana* | American witchhazel, witch-hazel, witchhazel | – |
| *Helenium autumnale* | Bitterweed, common sneezeweed, fall sneezeweed | – |
| *Helenium flexuosum* | Purplehead sneezeweed | – |
| *Helenium pinnatifidum* | Southeastern sneezeweed | – |
| *Helianthus angustifolius* | Swamp sneezeweed, swamp sunflower | – |

**Table C-2 (continued).** Wetland plants reported to occur in Congaree National Park. From the NPS Certified Species List (2013a).

| Scientific Name | Common Name(s) | Notes |
|---|---|---|
| *Helianthus floridanus* | Florida sunflower | – |
| *Heliotropium indicum* | India heliotrope, Indian heliotrope | – |
| *Hibiscus moscheutos* | Crimsoneyed rosemallow, swamp rosemallow | – |
| *Houstonia caerulea* | Azure bluet | – |
| *Hydrocotyle ranunculoides* | Floating marsh pennywort, floating marshpennywort, floating pennyroyal | – |
| *Hydrocotyle sibthorpioides* | Lawn marshpennywort | – |
| *Hydrocotyle umbellata* | Manyflower marshpennywort | – |
| *Hydrocotyle verticillata* | Whorled marsh pennywort, whorled marshpennywort, whorled pennyroyal | – |
| *Hydrocotyle verticillata* var. *verticillata* | Whorled marsh pennywort, whorled marshpennywort | – |
| *Hypericum crux-andreae* | Atlantic St. Peter's-wort, St. Peterswort | – |
| *Hypericum gymnanthum* | Claspingleaf St. Johnswort | – |
| *Hypericum hypericoides* | St. Andrew's cross, St. Andrews cross | – |
| *Hypericum mutilum* | Dwarf St. Johnswort | – |
| *Hypericum punctatum* | Spotted St. Johnswort | – |
| *Hypoxis curtissii* | Curtis' star-grass | *Hypoxis curtissii* is given as *Hypoxis hirsuta* var. *leptocarpa* (synonym) in the NPS Certified Species List. |
| *Hypoxis hirsuta* | Common goldstar, eastern yellow star-grass | – |
| *Hyptis alata* | Clustered bushmint | – |
| *Ilex amelanchier* | Sarvis holly | – |

**Table C-2 (continued).** Wetland plants reported to occur in Congaree National Park. From the NPS Certified Species List (2013a).

| Scientific Name | Common Name(s) | Notes |
|---|---|---|
| *Ilex decidua* | Possumhaw | – |
| *Ilex glabra* | Inkberry | – |
| *Ilex laevigata* | Smooth winterberry | – |
| *Ilex opaca* | American holly | – |
| *Ilex verticillata* | Common winterberry | – |
| *Ilex vomitoria* | Yaupon | – |
| *Impatiens capensis* | Jewelweed, spotted touch-me-not | – |
| *Ipomoea coccinea* | Mexican morningglory, red morningglory, redstar, scarlet morningglory | – |
| *Ipomoea lacunosa* | Pitted morningglory, white morninglory, whitestar | – |
| *Ipomoea pandurata* | Bigroot morningglory, bigroot morninglory, man of the earth, man-of-the-earth | – |
| *Iris virginica* | Virginia iris | – |
| *Isotria verticillata* | Purple fiveleaf orchid | – |
| *Itea virginica* | Virginia sweetspire | – |
| *Jacquemontia tamnifolia* | Clustervine, hairy clustervine | exotic/invasive |
| *Juncus acuminatus* | Sharp-fruit rush, tapertip rush | – |
| *Juncus biflorus* | Bog rush | – |
| *Juncus brachycarpus* | Whiteroot rush | – |
| *Juncus bufonius* | Toad rush | – |
| *Juncus coriaceus* | Leathery rush | – |
| *Juncus dichotomus* | Forked rush | – |
| *Juncus effusus* | Common rush, lamp rush | – |
| *Juncus elliottii* | Elliott's rush | – |

**Table C-2 (continued).** Wetland plants reported to occur in Congaree National Park. From the NPS Certified Species List (2013a).

| Scientific Name | Common Name(s) | Notes |
|---|---|---|
| *Juncus repens* | Lesser creeping rush | – |
| *Juncus scirpoides* | Needlepod rush | – |
| *Justicia ovata* | Looseflower water-willow, looseflower waterwillow | – |
| *Laportea canadensis* | Canada lettuce, Canada woodnettle | – |
| *Leersia hexandra* | Southern cutgrass | – |
| *Leersia lenticularis* | Catchfly grass | – |
| *Leersia oryzoides* | Rice cut grass, rice cutgrass | – |
| *Leersia virginica* | White grass, whitegrass | – |
| *Leucothoe axillaris* | Coastal doghobble | – |
| *Leucothoe racemosa* | Swamp doghobble | – |
| *Liatris spicata* | Dense blazing star | – |
| *Ligustrum sinense* | Chinese privet, common chinese privet | exotic/invasive |
| *Lindera benzoin* | Northern spicebush, spicebush | – |
| *Lindernia dubia* | Moistbank pimpernel, shortstalk lindernia, yellow-seed false pimpernel | – |
| *Lindernia dubia* var. *anagallidea* | False pimpernel, yellow-seed false pimpernel | – |
| *Lindernia dubia* var. *dubia* | Yellow-seed false pimpernel, yellowseed false pimpernel | – |
| *Linum medium* var. *texanum* | Stiff yellow flax, sucker flas | – |
| *Linum striatum* | Ridged yellow flax, rigid flax | – |
| *Liquidambar styraciflua* | Sweetgum | – |

**Table C-2 (continued).** Wetland plants reported to occur in Congaree National Park. From the NPS Certified Species List (2013a).

| Scientific Name | Common Name(s) | Notes |
|---|---|---|
| *Liriodendron tulipifera* | Tulip poplar, tuliptree, yellow poplar, yellow-poplar | – |
| *Lobelia cardinalis* | Cardinal flower, cardinalflower | – |
| *Lobelia elongata* | Longleaf lobelia | – |
| *Lobelia nuttallii* | Nuttall's lobelia | – |
| *Lobelia puberula* | Downy lobelia | – |
| *Lonicera japonica* | Chinese honeysuckle, Japanese honeysuckle | exotic/invasive |
| *Lonicera sempervirens* | Trumpet honeysuckle | – |
| *Ludwigia alata* | Winged primrose-willow | – |
| *Ludwigia alternifolia* | Bushy seedbox, seedbox | – |
| *Ludwigia decurrens* | Wingleaf primrose-willow, wingleaf waterprimrose | – |
| *Ludwigia glandulosa* | Creeping seedbox, cylindricfruit primrose-willow | – |
| *Ludwigia leptocarpa* | Anglestem primrose-willow, anglestem waterprimrose | – |
| *Ludwigia palustris* | Marsh primrose-willow, marsh seedbox | – |
| *Ludwigia pilosa* | Hairy primrose-willow, hairy primrosewillow | – |
| *Ludwigia uruguayensis* | Uruguay waterprimrose, Uruguayan primrose-willow | – |
| *Luzula echinata* | Hedgehog woodrush | – |
| *Lycopus rubellus* | Taperleaf bugleweed, taperleaf water horehound | – |
| *Lycopus virginicus* | Virginia bugleweed, Virginia water horehound | – |

**Table C-2 (continued).** Wetland plants reported to occur in Congaree National Park. From the NPS Certified Species List (2013a).

| Scientific Name | Common Name(s) | Notes |
|---|---|---|
| *Lygodium japonicum* | Japanese climbing fern | exotic/invasive |
| *Lyonia ligustrina* | He-huckleberry, maleberry | – |
| *Lyonia lucida* | Fetterbush lyonia | – |
| *Lysimachia nummularia* | Creeping jenny, moneywort | – |
| *Macbridea caroliniana* | Carolina birds-in-a-nest | – |
| *Macrothelypteris torresiana* | Swordfern | exotic/invasive |
| *Magnolia virginiana* | Sweetbay | – |
| *Malaxis unifolia* | Green adder's-mouth orchid, green addersmouth orchid | – |
| *Matelea gonocarpos* | Angularfruit milkvine | *Matelea suberosa*, included in the NPS Certified Species List, is a synonym of *Matelea gonocarpos*. |
| *Mazus pumilus* | Japanese mazus | exotic/invasive |
| *Mecardonia acuminata* | Axilflower | – |
| *Medeola virginiana* | Indian cucumber | – |
| *Melothria pendula* | Drooping melonnettle, Guadeloupe cucumber | – |
| *Microstegium vimineum* | Japanese stiltgrass, Nepalese browntop | exotic/invasive |
| *Mikania scandens* | Climbing hempvine, climbing hempweed | – |
| *Mimulus alatus* | Sharpwing monkeyflower | – |
| *Mimulus ringens* | Allegheny monkeyflower, ringen monkeyflower | – |
| *Mitchella repens* | Partridgeberry | – |
| *Mitreola petiolata* | Lax hornpod | – |
| *Mitreola sessilifolia* | Swamp hornpod | – |
| *Modiola caroliniana* | Carolina bristlemallow, Carolina modiola | – |

**Table C-2 (continued).** Wetland plants reported to occur in Congaree National Park. From the NPS Certified Species List (2013a).

| Scientific Name | Common Name(s) | Notes |
|---|---|---|
| *Mollugo verticillata* | Carpetweed, green carpetweed | – |
| *Morus rubra* | Red mulberry | – |
| *Murdannia keisak* | Aneilima, Asian spiderwort, wartremoving herb | exotic/invasive |
| *Myosotis macrosperma* | Largeseed forget-me-not, southern forget me not | – |
| *Nemophila aphylla* | Smallflower baby blue eyes | – |
| *Nyssa aquatica* | Water tupelo | – |
| *Nyssa biflora* | Swamp tupelo | *Nyssa sylvatica* var. *biflora*, included in the NPS Certified Species List, is a synonym of *Nyssa biflora*. |
| *Nyssa sylvatica* | Black gum, black tupelo, blackgum | – |
| *Onoclea sensibilis* | Sensitive fern | – |
| *Ophioglossum vulgatum* | Southern adder's-tongue, southern adderstongue | – |
| *Orontium aquaticum* | Goldenclub | – |
| *Osmunda cinnamomea* | Cinnamon fern | – |
| *Osmunda regalis* | Royal fern | – |
| *Osmunda regalis* var. *spectabilis* | Royal fern | – |
| *Packera glabella* | Butterweed | – |
| *Panicum anceps* | Beaked panicgrass, beaked panicum | – |
| *Panicum dichotomiflorum* | Fall panic, fall panicgrass, fall panicum, western witchgrass | – |
| *Panicum hemitomon* | Maidencane, mountain panic | – |
| *Panicum rigidulum var. pubescens* | Redtop panicgrass | – |

**Table C-2 (continued).** Wetland plants reported to occur in Congaree National Park. From the NPS Certified Species List (2013a).

| Scientific Name | Common Name(s) | Notes |
|---|---|---|
| *Panicum rigidulum var. rigidulum* | Redtop panicgrass | *Panicum rigidulum* var. *rigidulum* is given as *Panicum agrostoides* (synonym) in the NPS Certified Species List. |
| *Panicum verrucosum* | Warty panicgrass | – |
| *Parietaria pensylvanica* | Pennsylvania pellitory | – |
| *Paspalum dilatatum* | Dallas grass, water grass | exotic/invasive |
| *Paspalum floridanum* | Florida paspalum | – |
| *Paspalum fluitans* | Horsetail paspalum | – |
| *Paspalum laeve* | Field paspalum | – |
| *Paspalum urvillei* | Vasey grass, Vasey's grass, vaseygrass | exotic/invasive |
| *Peltandra virginica* | Green arrow arum, Virginia peltandra | – |
| *Penthorum sedoides* | Ditch stonecrop, ditch-stonecrop, Virginia penthorum | – |
| *Persea borbonia* | Redbay | – |
| *Persea palustris* | Swamp bay | – |
| *Phalaris caroliniana* | Carolina canarygrass | – |
| *Phanopyrum gymnocarpon* | Savannah panic grass, savannah panicum, savannah-panicgrass | – |
| *Phlox glaberrima* | Smooth phlox | – |
| *Photinia pyrifolia* | Red chokeberry | – |
| *Phytolacca americana* | American pokeweed, common pokeweed, inkberry | – |
| *Pilea pumila* | Canada clearweed, Canadian clearweed | – |
| *Pinus palustris* | Longleaf pine | – |

**Table C-2 (continued).** Wetland plants reported to occur in Congaree National Park. From the NPS Certified Species List (2013a).

| Scientific Name | Common Name(s) | Notes |
|---|---|---|
| *Planera aquatica* | Planertree, water elm, water-elm | – |
| *Platanthera blephariglottis* | White fringed orchid, white-fringe orchis | – |
| *Platanthera clavellata* | Green woodland orchid, small green wood orchid | – |
| *Platanthera flava* | Palegreen orchid, southern rein-orchid | – |
| *Platanthera flava var. flava* | Palegreen orchid | *Habenaria flava*, included in the NPS Certified Species List, is a synonym of *Platanthera flava* var. *flava*. |
| *Platanus occidentalis* | American sycamore, sycamore | – |
| *Pluchea camphorata* | Camphor pluchea, camphor weed | – |
| *Pluchea odorata* | Marsh fleabane, sweetscent | – |
| *Pluchea rosea* | Rosy camphorweed | – |
| *Poa annua* | Annual blue grass, annual bluegrass, walkgrass | exotic/invasive |
| *Poa autumnalis* | Autumn bluegrass | – |
| *Polygala incarnata* | Procession flower | – |
| *Polygala mariana* | Maryland milkwort | – |
| *Polygonum caespitosum* var. *longisetum* | Oriental ladysthumb | – |
| *Polygonum hydropiperoides* | Swamp smartweed | – |
| *Polygonum pensylvanicum* | Pennsylvania knotweed, Pennsylvania smartweed, pinkweed | – |
| *Polygonum punctatum* | Dotted smartweed | – |

**Table C-2 (continued).** Wetland plants reported to occur in Congaree National Park. From the NPS Certified Species List (2013a).

| Scientific Name | Common Name(s) | Notes |
|---|---|---|
| *Polygonum scandens* var. *scandens* | Climbing false buckwheat | – |
| *Polygonum setaceum* | Bog smartweed | – |
| *Polygonum virginianum* | Jumpseed, Virginia smartweed | – |
| *Polypremum procumbens* | Juniper leaf | – |
| *Populus deltoides* | Common cottonwood, cottonwood, eastern cottonwood, plains cottonwood | – |
| *Populus heterophylla* | Swamp cottonwood | – |
| *Proserpinaca palustris* | Marsh mermaid-weed, marsh mermaidweed | – |
| *Proserpinaca pectinata* | Combleaf mermaidweed, mermaidweed | – |
| *Prunella vulgaris* | Common selfheal, heal all, healall, selfheal | – |
| *Ptilimnium capillaceum* | Herbwilliam, threadleaf mockbishopweed | – |
| *Pycnanthemum tenuifolium* | Narrowleaf mountainmint, narrowleaf mountianmint | – |
| *Quercus laurifolia* | Laurel oak | – |
| *Quercus lyrata* | Overcup oak | – |
| *Quercus michauxii* | Swamp chestnut oak | – |
| *Quercus nigra* | Water oak | – |
| *Quercus pagoda* | Cherrybark oak, texas oak | *Quercus falcata* var. *pagodifolia*, included in the NPS Certified Species List, is a synonym of *Quercus pagoda*. |
| *Quercus phellos* | Willow oak | – |
| *Quercus prinus* | Chestnut oak | – |
| *Quercus shumardii* | Shumard oak, Shumard's oak | – |

**Table C-2 (continued).** Wetland plants reported to occur in Congaree National Park. From the NPS Certified Species List (2013a).

| Scientific Name | Common Name(s) | Notes |
|---|---|---|
| *Ranunculus abortivus* | Early woodbuttercup, kidney-leaf buttercup, littleleaf buttercup | – |
| *Ranunculus acris* | Meadow buttercup, tall buttercup | – |
| *Ranunculus hispidus* | Bristly buttercup | – |
| *Ranunculus recurvatus* | Blisterwort, littleleaf buttercup | – |
| *Ranunculus sardous* | Hairy buttercup | – |
| *Rhexia mariana* | Maryland meadowbeauty | – |
| *Rhexia mariana* var. *mariana* | Maryland meadowbeauty | – |
| *Rhexia mariana* var. *ventricosa* | Maryland meadowbeauty | – |
| *Rhexia nashii* | Maid Marian | – |
| *Rhexia virginica* | Common meadowbeauty, handsome Harry | – |
| *Rhododendron canescens* | Mountain azalea, Piedmont azalea | – |
| *Rhododendron periclymenoides* | Pink azalea | – |
| *Rhododendron viscosum* | Swamp azalea | – |
| *Rhynchospora cephalantha* | Bunched beaksedge | – |
| *Rhynchospora chalarocephala* | Loosehead beaksedge | – |
| *Rhynchospora corniculata* | Shortbristle horned beaksedge | – |
| *Rhynchospora globularis* | Globe beakrush, globe beaksedge | – |
| *Rhynchospora glomerata* | Clustered beaksedge | – |
| *Rhynchospora inexpansa* | Nodding beaksedge | – |

**Table C-2 (continued).** Wetland plants reported to occur in Congaree National Park. From the NPS Certified Species List (2013a).

| Scientific Name | Common Name(s) | Notes |
|---|---|---|
| *Rhynchospora miliacea* | Millet beaksedge | – |
| *Rhynchospora pallida* | Pale beaksedge | – |
| *Rhynchospora torreyana* | Torrey's beaksedge | – |
| *Rorippa islandica* | Northern marsh yellowcress | – |
| *Rosa palustris* | Swamp rose | – |
| *Rotala ramosior* | Lowland rotala, lowland toothcup, rotala | – |
| *Rubus argutus* | Prickly Florida blackberry, sawtooth blackberry | – |
| *Rubus cuneifolius* | Sand blackberry | – |
| *Rubus hispidus* | Bristly dewberry | – |
| *Rubus trivialis* | Southern dewberry | – |
| *Rudbeckia fulgida* | Orange coneflower | – |
| *Rumex acetosella* | Common sheep sorrel, field sorrel, red (or sheep) sorrel | – |
| *Rumex crispus* | Curley dock, curly dock, narrowleaf dock, sour dock, yellow dock | exotic/invasive |
| *Sabal minor* | Dwarf palmetto | – |
| *Sabatia angularis* | Rosepink, squarestem rosegentian | – |
| *Saccharum baldwinii* | Narrow plumegrass | – |
| *Saccharum giganteum* | Sugarcane plumegrass | – |
| *Sacciolepis striata* | American cupscale | – |
| *Sagittaria latifolia* | Broadleaf arrowhead, common arrowhead | – |
| *Salix caroliniana* | Coastal plain willow | – |
| *Salix nigra* | Black willow | – |

**Table C-2 (continued).** Wetland plants reported to occur in Congaree National Park. From the NPS Certified Species List (2013a).

| Scientific Name | Common Name(s) | Notes |
|---|---|---|
| *Sambucus canadensis* | American elder | – |
| *Samolus parviflorus* | Water-pimpernel | – |
| *Saururus cernuus* | Lizard's tail, lizards tail | – |
| *Schizachyrium scoparium* | Little bluestem | – |
| *Schizachyrium scoparium* var. *scoparium* | Little bluestem | *Schizachyrium scoparium* var. *scoparium* is given as *Andropogon scoparius* (synonym) in the NPS Certified Species List. |
| *Scirpus atrovirens* | Dark-green bulrush, green bulrush | – |
| *Scirpus cyperinus* | Bulrush, woolgrass | – |
| *Scleria pauciflora* | Fewflower nutrush | – |
| *Scleria triglomerata* | Whip nutrush | – |
| *Scutellaria integrifolia* | Helmet flower | – |
| *Scutellaria lateriflora* | Blue skullcap, mad dog skullcap | – |
| *Setaria parviflora* | Marsh bristle grass, marsh bristlegrass, Knotroot bristlegrass, yellow bristlegrass | – |
| *Setaria pumila ssp. pumila* | Yellow foxtail | *Setaria pumila* var. *pumila* is given as *Setaria glauca* (synonym) in the NPS Certified Species List. |
| *Seymeria cassioides* | Yaupon blacksenna | – |
| *Sisyrinchium atlanticum* | Eastern blue-eyed grass, eastern blueeyed grass | – |
| *Sisyrinchium mucronatum* | Needle-tip blue-eyed-grass, needletip blue-eyed grass | – |
| *Smilax bona-nox* | Saw greenbrier | – |
| *Smilax glauca* | Cat greenbrier | – |
| *Smilax laurifolia* | Laurel greenbrier | – |

**Table C-2 (continued).** Wetland plants reported to occur in Congaree National Park. From the NPS Certified Species List (2013a).

| Scientific Name | Common Name(s) | Notes |
|---|---|---|
| *Smilax rotundifolia* | Bullbriar, common catbriar, common greenbrier | – |
| *Smilax smallii* | Lanceleaf greenbrier, small greenbrier | – |
| *Smilax tamnoides* | Bristly greenbrier | – |
| *Smilax walteri* | Coral greenbrier | – |
| *Solidago altissima* | Canada goldenrod | – |
| *Solidago gigantea* | Giant goldenrod | – |
| *Solidago rugosa* | Wrinkleleaf goldenrod | – |
| *Sorghum halepense* | Johnson grass, Johnsongrass | exotic/invasive |
| *Sphenoclea zeylanica* | Chickenspike, sphenoclea | – |
| *Spiranthes cernua* | Nodding ladies'-tresses, white nodding ladies'-tresses | – |
| *Spiranthes odorata* | Marsh ladies'-tresses, marsh ladiestresses | – |
| *Spiranthes ovalis* var. *erostellata* | October ladies'-tresses | – |
| *Spiranthes ovalis* var. *ovalis* | October ladies'-tresses | – |
| *Spiranthes praecox* | Greenvein ladies'-tresses, greenvein ladiestresses | – |
| *Stachys aspera* | Hyssopleaf hedgenettle | – |
| *Stachys crenata* | Mouse's-ear, mousesear | – |
| *Stachys floridana* | Florida betony, Florida hedgenettle | exotic/invasive |
| *Stachys hyssopifolia* | Hyssopleaf hedgenettle | – |
| *Styrax americana* | American snowbell | – |

**Table C-2 (continued).** Wetland plants reported to occur in Congaree National Park. From the NPS Certified Species List (2013a).

| Scientific Name | Common Name(s) | Notes |
|---|---|---|
| *Symphyotrichum divaricatum* | Southern annual saltmarsh aster | – |
| *Symphyotrichum dumosum* var*. dumosum* | Rice button aster | – |
| *Symphyotrichum lanceolatum ssp. lanceolatum* var. *lanceolatum* | White panicle aster | *Symphyotrichum lanceolatum* ssp. *lanceolatum* var. *lanceolatum* is given as *Aster simplex* (synonym) in the NPS Certified Species List. *Symphyotrichum lanceolatum* var. *lanceolatum*, included in the NPS Certified Species List, is not in the USDA Plants Database. This taxon likely is either *Symphyotrichum lanceolatum* ssp. *lanceolatum*, or *Symphyotrichum lanceolatum* ssp. *lanceolatum* var. *lanceolatum*. |
| *Symphyotrichum lateriflorum* var. *lateriflorum* | Calico aster | *Symphyotrichum lateriflorum* var. *lateriflorum* is given as *Aster vimineus* (synonym) in the NPS Certified Species List. |
| *Symphyotrichum pilosum* var. *pilosum* | Hairy white oldfield aster | – |
| *Symphyotrichum puniceum* var. *puniceum* | Purplestem aster | – |
| *Symplocos tinctoria* | Common sweetleaf, sweetleaf | – |
| *Taxodium ascendens* | Pond cypress, pondcypress | – |
| *Taxodium distichum* | Bald cypress, baldcypress | – |
| *Thelypteris palustris* | Eastern marsh fern, marsh fern, meadow fern | – |
| *Toxicodendron radicans ssp. radicans* | Eastern poison ivy | – |
| *Toxicodendron vernix* | Poison sumac | – |
| *Trachelospermum difforme* | Climbing dogbane | – |
| *Tradescantia virginiana* | Virginia spiderwort | – |
| *Triadenum virginicum* | Marsh St. John's wort, Virginia marsh St. Johnswort | – |
| *Triadenum walteri* | Greater marsh St. Johnswort | – |

**Table C-2 (continued).** Wetland plants reported to occur in Congaree National Park. From the NPS Certified Species List (2013a).

| Scientific Name | Common Name(s) | Notes |
|---|---|---|
| *Typha latifolia* | Broadleaf cattail, cattail, cattail (common), common cattail | – |
| *Ulmus alata* | Winged elm | – |
| *Ulmus americana* | American elm | – |
| *Ulmus rubra* | Slippery elm | – |
| *Uvularia sessilifolia* | Sessileleaf bellwort, sessile-leaf bellwort | – |
| *Urtica chamaedryoides* | Heartleaf nettle, slim stingingnettle | SoC,G4G5, S2 |
| *Vaccinium elliottii* | Elliott's blueberry | – |
| *Verbena bonariensis* | Pretty verbena, purpletop vervain | exotic/invasive |
| *Verbena brasiliensis* | Brazilian vervain | exotic/invasive |
| *Verbena urticifolia* | White verbena, white vervain | – |
| *Verbesina occidentalis* | Yellow crownbeard | – |
| *Verbesina virginica* | Iceweed, Virginia crownbeard, white crownbeard | – |
| *Vernonia noveboracensis* | New York ironweed | – |
| *Veronica peregrina* | Neckweed, purslane speedwell | – |
| *Viburnum dentatum* | Arrow-wood viburnum, arrowwood, southern arrowwood | – |
| *Viburnum nudum* | Possumhaw, possumhaw viburnum | – |
| *Viburnum nudum* var. *cassinoides* | Withe-rod | *Viburnum nudum* var. *cassinoides* is given as *Viburnum cassinoides* (synonym) in the NPS Certified Species List. |
| *Viola affinis* | Arizona bog violet, lecontes violet, sand violet | – |

**Table C-2 (continued).** Wetland plants reported to occur in Congaree National Park. From the NPS Certified Species List (2013a).

| Scientific Name | Common Name(s) | Notes |
|---|---|---|
| *Viola x primulifolia* (pro sp.) [*lanceolata x macloskeyi*] | Primrose violet, violet | *Viola x primulifolia* (pro sp.) [*lanceolata x macloskeyi*] is given as *Viola x primulifolia* (synonym) in the NPS Certified Species List. |
| *Viola septemloba* | Southern coastal violet | – |
| *Viola sororia* | Common blue violet, hooded blue violet | – |
| *Vitis cinerea* var. *floridana* | Florida grape | – |
| *Vitis rotundifolia* | Muscadine, muscadine grape | – |
| *Vitis vulpina* | Fox grape, frost grape, wild grape | – |
| *Wisteria frutescens* | American wisteria | – |
| *Woodwardia areolata* | Chainfern, netted chainfern | – |
| *Woodwardia virginica* | Virginia chainfern, virginia chainfern | – |
| *Xanthium strumarium* | Cocklebur, common cocklebur, rough cocklebur | – |
| *Xanthorhiza simplicissima* | Yellowroot | – |
| *Xyris caroliniana* | Carolina yelloweyed grass | – |
| *Zephyranthes atamasca* | Atamasco lily | – |

**Table C-3.** Aquatic vascular plants reported to occur in Congaree National Park. From the NPS Certified Species List (NPS 2013a).

| Scientific Name | Common Name(s) |
|---|---|
| *Azolla caroliniana* | Carolina mosquitofern |
| *Callitriche heterophylla* | Differentleaf waterstarwort, greater water starwort, larger waterstarwort |
| *Lemna valdiviana* | Pale duckweed, valdivia duckweed, Valdivia's duckweed |

**Table C-4.** Mosquito species reported to occur in Congaree National Park. From the NPS Certified Species List (NPS 2013a).

| Scientific Name | Notes |
|---|---|
| *Aedes albopictus* | exotic |
| *Aedes vexans* | – |
| *Anopheles barberi* | – |
| *Anopheles crucians complex* | multiple species |
| *Anopheles punctipennis* | – |
| *Anopheles quadrimaculatus* | – |
| *Coquillettidia perturbans* | – |
| *Culex erraticus* | – |
| *Culex nigripalpus* | – |
| *Culex quinquefasciatus* | – |
| *Culex restuans* | – |
| *Culex salinarius* | – |
| *Culex territans* | – |
| *Culiseta melanura* | – |
| *Ochlerotatus canadensis* | – |
| *Ochlerotatus infirmatus* | – |
| *Ochlerotatus sticticus* | – |
| *Ochlerotatus triseriatus* | – |
| *Orthopodomyia signifera* | – |
| *Psorophora ferox* | – |
| *Uranotaenia sapphirina* | – |

**Table C-5.** Beetles in Congaree National Park. From the NPS Certified Species List (NPS 2013a).

| Species (number of species) | Scientific Name |
|---|---|
| Burrowing Water Beetles (2) | *Hydrocanthus atripennis* |
| | *Suphisellus puncticollis* |
| Crawling Water Beetles (12) | *Peltodytes dunavani* |
| | *Peltodytes sexmaculatus* |
| | *Haliplus fasciatus* |
| | *Haliplus leopardus* |
| | *Haliplus pantherinus* |
| | *Haliplus punctatus* |
| | *Haliplus triopsis* |
| | *Peltodytes bradleyi* |
| | *Peltodytes floridensis* |
| | *Peltodytes muticus* |
| | *Peltodytes oppositus* |
| | *Peltodytes shermani* |
| Ground Beetles (3) | *Clivina americana* |
| | *Clivina dentipes* |
| | *Semiardistomis viridis* |
| Long-Toed Water Beetle (1) | *Helichus lithophilus* |
| Marsh Beetles (7) | *Cyphon americanus* |
| | *Cyphon padi* |
| | *Cyphon perplexus* |
| | *Cyphon variabilis* |
| | *Elodes pulchella* |
| | *Prionocyphon discoideus* |
| | *Scirtes tibialis* |
| Minute Marsh-Loving Beetles (3) | *Eulimnichus ater* |
| | *Eulimnichus nitidulus* |
| | *Hydraena marginicollis* |
| Predaceous Diving Beetles (40 species, 20 genera) | *Bidessonotus pulicarius* |
| | *Acilius fraternus* |
| | *Agabus gagates* |
| | *Anodocheilus exiguus* |
| | *Bidessonotus inconspicuus* |
| | *Bidessonotus longovalis* |
| | *Celina angustata* |
| | *Celina contiger* |
| | *Celina slossoni* |

**Table C-5 (continued).** Beetles in Congaree National Park. From the NPS Certified Species List (NPS 2013a).

| Species (number of species) | Scientific Name |
|---|---|
| Predaceous Diving Beetles (40 species, 20 genera) (continued) | *Copelatus caelatipennis princeps* |
| | *Copelatus chevrolati chevrolati* |
| | *Copelatus glyphicus* |
| | *Copelatus punctulatus* |
| | *Coptotomus interrogatus* |
| | *Coptotomus lenticus* |
| | *Coptotomus loticus* |
| | *Coptotomus venustus* |
| | *Desmopachria convexa* |
| | *Dytiscus carolinus* |
| | *Hoperius planatus* |
| | *Hydaticus bimarginatus* |
| | *Hydroporus rufilabris* |
| | *Hydroporus signatus youngi* |
| | *Laccophilus fasciatus rufus* |
| | *Laccophilus proximus* |
| | *Lioporeus triangularis* |
| | *Neobidessus pullus* |
| | *Neoporus aulicus* |
| | *Neoporus carolinus* |
| | *Neoporus cimicoides* |
| | *Neoporus clypealis* |
| | *Neoporus effeminatus* |
| | *Neoporus hybridus* |
| | *Neoporus lobatus* |
| | *Neoporus shermani* |
| | *Neoporus undulatus* |
| | *Neoporus venustus* |
| | *Neoporus vittatipennis* |
| | *Rhantus calidus* |
| | *Thermonectus basillaris basillaris* |
| | *Uvarus falli* |
| | *Uvarus granarius* |
| | *Uvarus lacustris* |

**Table C-5 (continued).** Beetles in Congaree National Park. From the NPS Certified Species List (NPS 2013a).

| Species (number of species) | Scientific Name |
|---|---|
| Riffle Beetles (11) | *Anronyx variegata* |
| | *Dubiraphia vittata* |
| | *Macronychus glabratus* |
| | *Microcylloepus pusillus pusillus* |
| | *Stenelmis bicarinata* |
| | *Stenelmis convexula* |
| | *Stenelmis decorata* |
| | *Stenelmis fuscata* |
| | *Stenelmis lignicola* |
| | *Stenelmis sinuata* |
| | *Stenelmis* sp. |
| Rove Beetles (8) | *Anotylus insignitus* |
| | *Bledius punctatissimus* |
| | *Bledius semiferrugineus* |
| | *ledius* sp. |
| | *Bledius wudus* |
| | *Carpelimus dentiger* |
| | *Carpelimus* sp. |
| | *Thinodromus arcifer* |
| Snout Beetles and Weevils (6) | *Bagous transversus* |
| | *Listronotus porcellus* |
| | *Stenopelmus rufinasus* |
| | *Tanysphyrus lemnae* |
| | *Tyloderma aerea* |
| | *Tyloderma capitale* |
| Toed-Winged Beetles (5) | *Ptilodactyla acuta* |
| | *Ptilodactyla angustata* |
| | *Ptilodactyla carinata* |
| | *Ptilodactyla serricollis* |
| | *Ptilodactyla* sp. |
| Turtle Beetle (1) | *Chelonarioum lecontei* |
| Variegated Mud-Loving Beetles (5) | *Heterocerus fatuus* |
| | *Heterocerus mollinus* |
| | *Heterocerus tenuis* |
| | *Heterocerus texanus* |
| | *Tropicus pusillus* |

**Table C-5 (continued).** Beetles in Congaree National Park. From the NPS Certified Species List (NPS 2013a).

| Species (number of species) | Scientific Name |
|---|---|
| Water Scavenger Beetles (41 species in 13 genera) | *Berosus aculeatus* |
| | *Berosus corrini* |
| | *Berosus exiguus* |
| | *Berosus infuscatus* |
| | *Berosus ordinatus* |
| | *Berosus pantherinus* |
| | *Berosus peregrinus* |
| | *Berosus pugnax* |
| | *Berosus striatus* |
| | *Cymbiodyta blanchardi* |
| | *Cymbiodyta chamberlaini* |
| | *Cymbiodyta vindicata* |
| | *Enochrus blatchleyi* |
| | *Enochrus cinctus* |
| | *Enochrus consors* |
| | *Enochrus consortus* |
| | *Enochrus interruptus* |
| | *Enochrus ochraceus* |
| | *Enochrus perplexus* |
| | *Enochrus pygmaeus* |
| | *Enochrus sayi* |
| | *Enochrus sublongus* |
| | *Helocombus bifidus* |
| | *Helophorus marginicollis* |
| | *Hydrobius melaenus* |
| | *Hydrochara soror* |
| | *Hydrochus excavatus* |
| | *Hydrochus inaequalis* |
| | *Hydrochus rufipes* |
| | *Hydrochus simplex* |
| | *Hydrochus* sp. 5 (= *undulatus*) |
| | *Hydrochus* sp. 6 (= *woodi*) |
| | *Hydrochus* sp. covered with brown coating |
| | *Hydrochus subcupreus* |
| | *Hydrophilus ovatus* |
| | *Paracymus dispersus* |
| | *Paracymus reductus* |

**Table C-5 (continued).** Beetles in Congaree National Park. From the NPS Certified Species List (NPS 2013a).

| Species (number of species) | Scientific Name |
|---|---|
| Water Scavenger Beetles (41 species in 13 genera) (continued) | *Paracymus subcupreus* |
| | *Phaenonotum exstriatum* |
| | *Sperchopsis tessellata* |
| | *Tropisternus blatchleyi blatchleyi* |
| | *Tropisternus collaris* |
| | *Tropisternus lateralis nimbatus* |
| Whirligig Beetles (9) | *Dineutus americanus* |
| | *Dineutus carolinus* |
| | *Dineutus ciliatus* |
| | *Dineutus discolor* |
| | *Dineutus emarginatus* |
| | *Dineutus serrulatus serrulatus* |
| | *Gyrinus analis* |
| | *Gyrinus gibber* |
| | *Gyrinus sayi* |

**Table C-6.** Molluscs and crustaceans reported to occur in Congaree National Park (partial list).

| Category | Scientific Name | Common Name(s) | Notes |
|---|---|---|---|
| Molluscs | *Cepaea hortensis* | White-lipped forest snail, Marked forest snail, Tooth-bearing forest snail | – |
| | *Mesomphix vulgatus* | Common great zonite | – |
| | *Ventridens intertextus* | Woven belly-tooth snail | – |
| | *Anguispira alternata* | Striped forest snail, Furguson's forest snail | – |
| | *Stenotrema stenotrema* | Southern pill snail, Pill snail | – |
| | *Haplotrema concavum* | Disc cannibal snail | – |
| | *Viviparus georgianus* | Georgian mystery snail, banded mystery snail | – |
| | *Corbicula fluminea* | Asiatic clam | exotic/invasive |
| | *Sphaerium corneum* | Fingernail clam, European fingernail clam | – |
| | gastropod mollusc–general term: | Slug | – |
| Crustaceans | several species | Swamp Crayfish | – |
| | *Cambarus diogenes* | Chimney Crayfish, devil crayfish, thunder crawfish, meadow crayfish | – |

**Table C-7a.** Benthic stream macroinvertebrates species reported to occur in Congaree National Park. From Pescador et al. (2004). For Order Coleoptera (beetles).

| Family | Scientific Name |
|---|---|
| Carabidae | *Clivina Americana* |
| | *Clivina dentipes* |
| | *Semiardistomis viridis* |
| Chelonarium | *Chelonarium lecontei* |
| Curculionidae | *Bagonus transversus* |
| | *Listronotus porcellus* |
| | *Stenopelmus rufinasus* |
| | *Tanysphyrus lemnae* |
| | *Tyloderma aerea* |
| | *Tyloderma capitale* |
| Dryopidae | *Helichus lithophilus* |
| Dytiscidae | *Acilius fraternus* |
| | *Agabus gagates* |
| | *Anodocheilus exiguous* |
| | *Bidessonotus inconspicuous* |
| | *Bidessonotus longovalis* |
| | *Bidessonotus pulicarius* |
| | *Celina angustata* |
| | *Celina contiger* |
| | *Celina slossoni* |
| | *Copelatus caelatipennis princes* |
| | *Copelatus lenticus* |
| | *Copelatus loticus* |
| | *Copelatus venustus* |
| | *Desmopachria convexa* |
| | *Dytiscus carolinus* |
| | *Hoperius planatus* |
| | *Hydaticus bimarginatus* |
| | *Hydroporus rufilabris* |
| | *Hydroporus signatus youngi* |
| | *Laccophilus fasciatus rufus* |
| | *Laccophilus proximus* |
| | *Lioporeus triangularis* |
| | *Neobidessus pullus* |
| | *Neoporus aulicus* |
| | *Neoporus carolinus* |
| | *Neoporus cimicoides* |

**Table C-7a (continued).** Benthic stream macroinvertebrates species reported to occur in Congaree National Park. From Pescador et al. (2004). For Order Coleoptera (beetles).

| Family | Scientific Name |
|---|---|
| Dytiscidae (continued) | *Neoporus clypealis* |
| | *Neoporus effeminatus* |
| | *Neoporus hybridus* |
| | *Neoporus lobatus* |
| | *Neoporus shermani* |
| | *Neoporus undulatus* |
| | *Neoporus venustus* |
| | *Neoporus vittatipennis* |
| | *Rhantus calidus* |
| | *Thermonectus basillaris bacillaris* |
| | *Uvarus falli* |
| | *Uvarus granarius* |
| | *Uvarus lacustris* |
| Elmidae | *Ancyronyx variegate* |
| | *Dubiraphia vittata* |
| | *Macronychus glabratus* |
| | *Microcylloepus pusillus pusillus* |
| | *Stenelmis bicarinata* |
| | *Stenelmis convexula* |
| | *Stenelmis decorata* |
| | *Stenelmis fuscata* |
| | *Stenelmis lignicola* |
| | *Stenelmis sinuate* |
| | *Stenelmis spp.* |
| Gyrinidae | *Dineutus americanus* |
| | *Dineutus carolinus* |
| | *Dineutus ciliatus* |
| | *Dineutus discolor* |
| | *Dineutus emarginatus* |
| | *Dineutus serrulatus* |
| | *Gyrinus analis* |
| | *Gyrinus gibber* |
| | *Gyrinus sayi* |
| Haliplidae | *Haliplus fasciatus* |
| | *Haliplus leopardus* |
| | *Haliplus pantherinus* |
| | *Haliplus punctatus* |

**Table C-7a (continued).** Benthic stream macroinvertebrates species reported to occur in Congaree National Park. From Pescador et al. (2004). For Order Coleoptera (beetles).

| Family | Scientific Name |
|---|---|
| Haliplidae (continued) | *Haliplus triopsis* |
| | *Peltodytes bradleyi* |
| | *Peltodytes dunavani* |
| | *Peltodytes floridensis* |
| | *Peltodytes muticus* |
| | *Peltodytes oppositus* |
| | *Peltodytes sexmaculatus* |
| | *Peltodytes shermani* |
| Heteroceridae | *Heterocerus fatuus* |
| | *Heterocerus mollinus* |
| | *Heterocerus tenuis* |
| | *Heterocerus texanus* |
| | *Tropicus pusillus* |
| Hydraenidae | *Hydraena marginicollis* |
| Hydrophilidae | *Berosus aculeatus* |
| | *Berosus corrini* |
| | *Berosus exiguous* |
| | *Berosus infuscatus* |
| | *Berosus ordinatus* |
| | *Berosus pantherinus* |
| | *Berosus peregrinus* |
| | *Berosus pugnax* |
| | *Berosus striatus* |
| | *Cymbiodyta blanchardi* |
| | *Cymbiodyta chamberlaini* |
| | *Cymbiodyta vindicata* |
| | *Enochrus blatchleyi* |
| | *Enochrus cinctus* |
| | *Enochrus consors* |
| | *Enochrus consortus* |
| | *Enochrus interruptus* |
| | *Enochrus ochraceus* |
| | *Enochrus perplexus* |
| | *Enochrus pygmaeus* |
| | *Enochrus sayi* |
| | *Enochrus sublongus* |
| | *Helocombus bifidus* |

**Table C-7a (continued).** Benthic stream macroinvertebrates species reported to occur in Congaree National Park. From Pescador et al. (2004). For Order Coleoptera (beetles).

| Family | Scientific Name |
|---|---|
| Hydrophilidae (continued) | *Helophorus marginicollis* |
| | *Hydrobius melaenus* |
| | *Hydrochara soror* |
| | *Hydrochus excavatus* |
| | *Hydrochus inaequalis* |
| | *Hydrochus rufipes* |
| | *Hydrochus simplex* |
| | *Hydrochus subcupreus* |
| | *Hydrochus spp.* |
| | *Hydrophilus ovatus* |
| | *Paracymus disperses* |
| | *Paracymus reductus* |
| | *Paracymus subcupreus* |
| | *Phaenonotum exstriatum* |
| | *Sperchopsis tessellata* |
| | *Tropisternus blatchleyi* |
| | *Tropisternus collaris* |
| | *Tropisternus lateralis nimbatus* |
| Limnichidae | *Eulimnichus ater* |
| | *Eulimnichus nitidulus* |
| Noteridae | *Hydrocanthus atripennis* |
| | *Suphisellus puncticollis* |
| Ptilodactylidae | *Ptilodactyla acuta* |
| | *Ptilodactyla angustata* |
| | *Ptilodactyla carinata* |
| | *Ptilodactyla serricollis* |
| | *Ptilodactyla spp.* |
| Scirtidae | *Cyphon americanus* |
| | *Cyphon padi* |
| | *Cyphon perplexus* |
| | *Cyphon variabilis* |
| | *Elodes pulchella* |
| | *Prionocyphon discoideus* |
| | *Scirtes tibialis* |
| Staphylinidae | *Anotylus insignitus* |
| | *Bledius punctatissimus* |
| | *Bledius semiferrugineus* |

**Table C-7a (continued).** Benthic stream macroinvertebrates species reported to occur in Congaree National Park. From Pescador et al. (2004). For Order Coleoptera (beetles).

| Family | Scientific Name |
|---|---|
| Staphylinidae (continued) | *Bledius wudus* |
| | *Bledius sp.* |
| | *Carpelimus dentiger* |
| | *Carpelimus sp.* |
| | *Thinodromus arcifer* |
| | *Thinodromus corvinus* |

**Table C-7b.** Benthic stream macroinvertebrates species reported to occur in Congaree National Park. From Pescador et al. (2004). For Order Ephemeroptera (mayflies).

| Family | Scientific Name |
|---|---|
| Baetidae | *Acerpenna pygmaea* |
| | *Callibaetis pretiosus* |
| | *Heterocloeon sp.* |
| | *Procloeon viridoculare* |
| | *Procloeon sp.* |
| | *Pseudocloeon ephippiatum* |
| | *Pseudocloeon frondale* |
| Caenidae | *Brachycercus maculates* |
| | *Caenis macafferti* |
| | *Caenis sp.* |
| Ephemerellidae | *Eurylophella doris* |
| Ephemeridae | *Hexagenia bilineata* |
| | *Hexagenia limbata* |
| Heptageniidae | *Stenacron interpunctatum* |
| | *Stenonema lenati* |
| | *Stenonema modestum* |
| Isonychiidae | *Isonychia arida* |
| | *Isonychia sp.* |
| Leptophlebiidae | *Leptophlebia bradleyi* |
| | *Leptophlebia intermedia* |
| | *Paraleptophlebia volitans* |
| | *Paraleptophlebia sp.* |
| Metretopodidae | *Siphloplecton sp.* |

**Table C-7c.** Benthic stream macroinvertebrates species reported to occur in Congaree National Park. From Pescador et al. (2004). For Order Odonata (dragonflies and damselflies).

| Family | Scientific Name |
|---|---|
| Aeshnidae | *Anax junius* |
| | *Basiaeschna junata* |
| | *Boyeria vinosa* |
| | *Epiaeschna heros* |
| | *Gomphaeschna antilope* |
| | *Nasiaeschna pentacantha* |
| Calopterygidae | *Calopteryx dimidiate* |
| | *Calopteryx maculata* |
| | *Calopteryx sp.* |
| Coenagrionidae | *Argia bipunctulata* |
| | *Argia fumipennis* |
| | *Argia moesta* |
| | *Argia tibialis* |
| | *Argia sp.* |
| | *Chomagrion conditum* |
| | *Enallagma basidens* |
| | *Enallagma divagans* |
| | *Enallagma sp.* |
| | *Ischnura posita* |
| Cordulegastridae | *Cordulegaster oblique* |
| Gomphidae | *Dromogomphus armatus* |
| | *Dromogomphus spinosus* |
| | *Erpetogomphus designatus* |
| | *Gomphus abbreviatus* |
| | *Gomphus exilis* |
| | *Gomphus hybridus* |
| | *Gomphus lividus* |
| | *Gomphus parvidens* |
| | *Gomphus sp.* |
| | *Hagenius brevistylus* |
| | *Progomphus obscurus* |
| | *Stylurus ivae* |
| Libellulidae | *Celithemis elisa* |
| | *Celithemis fasciata* |
| | *Celithemis ornate* |
| | *Celithemis verna* |
| | *Didymops transversa* |

**Table C-7c.** Benthic stream macroinvertebrates species reported to occur in Congaree National Park. From Pescador et al. (2004). For Order Odonata (dragonflies and damselflies).

| Family | Scientific Name |
|---|---|
| Libellulidae (continued) | *Epicordulia pinceps* |
| | *Erythemis simplicicollis* |
| | *Erythrodiplax minuscule* |
| | *Ladona deplanata* |
| | *Libellula auripennis* |
| | *Libellula cyanea* |
| | *Libellula incesta* |
| | *Libellula semifasciata* |
| | *Libellula vibrans* |
| | *Macromia illinoiensis* |
| | *Macromia sp.* |
| | *Neurocordulia alabamensis* |
| | *Neurocordulia obsoleta* |
| | *Orthemis ferruginea* |
| | *Pachydiplax longipennis* |
| | *Pantala flavescens* |
| | *Perithemis tenera* |
| | *Plathemis lydia* |
| | *Tetragoneuria costalis* |
| | *Tetragoneuria cynosure* |
| | *Tetragoneuria semiaquea* |
| | *Tetragoneuria spinosa* |
| | *Tetragoneuria sp.* |
| | *Tramea carolina* |

**Table C-7d.** Benthic stream macroinvertebrates species reported to occur in Congaree National Park. From Pescador et al. (2004). For Order Plecoptera (stoneflies).

| Family | Scientific Name |
|---|---|
| Nemouridae | *Amphinemura sp.* |
| | *Prostoia sp.* |
| Perlidae | *Neoperla carlsoni* |
| | *Neoperla clymene* |
| | *Perlesta shubuta* |
| | *Perlesta sp.* |
| | *Perlinella sp.* |
| Perlodidae | *Helopicus bogaloosa* |
| Taeniopterygidae | *Taeniopteryx lonicera* |
| | *Taeniopteryx sp.* |

**Table C-7e.** Benthic stream macroinvertebrates species reported to occur in Congaree National Park. From Pescador et al. (2004). For Order Trichoptera (caddisflies).

| Family | Scientific Name |
|---|---|
| Brachycentridae | *Brachycentrus chelatus* |
| | *Brachycentrus sp.* |
| Calamoceratidae | *Anisocentropus pyraloides* |
| | *Heteroplecton americanum* |
| Dipsuedopsidae | *Phylocentropus placidus* |
| | *Phylocentropus sp.* |
| Hydopsychidae | *Cheumatopsyche pasella* |
| | *Cheumatopsyche pettiti* |
| | *Cheumatopsyche pinaca* |
| | *Cheumatopsyche sp.* |
| | *Hydropsyche alvata* |
| | *Hydropsyche incommoda* |
| | *Hydropsyche rossi* |
| | *Hydropsyche sp.* |
| | *Macrostemum carolina* |
| | *Macrostemum sp.* |
| Hydroptilidae | *Hydroptila armata* |
| | *Hydroptila delineate* |
| | *Hydroptila molsonae* |
| | *Hydroptila novicola* |
| | *Hydroptila quinola* |
| | *Hydroptila remita* |

**Table C-7e (continued).** Benthic stream macroinvertebrates species reported to occur in Congaree National Park. From Pescador et al. (2004). For Order Trichoptera (caddisflies).

| Family | Scientific Name |
|---|---|
| Hydroptilidae (continued) | *Hydroptila scheiringi* |
| | *Hydroptila waubesiana* |
| | *Neotrichia vibrans* |
| | *Ochrotrichia tarsalis* |
| | *Ochrotrichia aegerfasciella* |
| | *Oxyethira grisea* |
| | *Oxyethira janella* |
| | *Oxyethira lumosa* |
| | *Oxyethira novastota* |
| | *Oxyethira pallida* |
| | *Oxyethira pescadori* |
| Leptoceridae | *Ceraclea cancellata* |
| | *Ceraclea diluta* |
| | *Ceraclea maculata* |
| | *Ceraclea ophioderus* |
| | *Ceraclea protonepha* |
| | *Ceraclea tarsipunctata* |
| | *Ceraclea transversa* |
| | *Leptocerus americanus* |
| | *Nectopsyche candida* |
| | *Nectopsyche candita/equisita* |
| | *Nectopsyche pavida* |
| | *Oecetis cinerascens* |
| | *Oecetis ditissa* |
| | *Oecetis georgia* |
| | *Oecetis inconspicua complex* |
| | *Oecetis nocturna* |
| | *Oecetis osteni* |
| | *Oecetis persimilis* |
| | *Oecetis scala* |
| | *Triaenodes helo* |
| | *Triaenodes igitus* |
| | *Triaenodes perna* |
| Limnephilidae | *Ironoquia sp.* |
| | *Pycnopsyche sp.* |
| Molannidae | *Molanna tryphena* |
| | *Molanna ulmerina* |

**Table C-7e (continued).** Benthic stream macroinvertebrates species reported to occur in Congaree National Park. From Pescador et al. (2004). For Order Trichoptera (caddisflies).

| Family | Scientific Name |
|---|---|
| Philopotamidae | *Chimarra florida* |
| | *Chimarra sp.* |
| Phryganeidae | *Agrypnia vestita* |
| | *Ptilostomis ocellifera* |
| Phryganeidae | *Ptilostomis* sp. |
| Polycentropodidae | *Cernotina calcea* |
| | *Cernotina spicata* |
| | *Cyrnellus fraternus* |
| | *Neureclipsis crepuscularis* |
| | *Neureclipsis melco* |
| | *Nyctiophylax affinis* |
| | *Nyctiophylax serratus* |
| | *Nyctiophylax sp.* |
| | *Polycentropus sp.* |
| Psychomyiidae | *Lype diversa* |
| Sericostomatidae | *Agarodes libalis* |

**Table C-8a.** Fish species reported to occur in Congaree National Park. NPS Certified Species List (NPS 2013a).

| Scientific Name | Common Name(s) | Notes |
|---|---|---|
| *Acantharchus pomotis* | Mud sunfish | – |
| *Ameiurus brunneus* | Snail bullhead | – |
| *Ameiurus natalis* | Yellow bullhead | – |
| *Ameiurus nebulosus* | Brown bullhead | – |
| *Ameiurus platycephalus* | Flat bullhead | – |
| *Amia calva* | Bowfin | – |
| *Anguilla rostrata* | American eel | At-risk Species-species that the FWS has been petitioned to list and for which a positive 90-day finding has been issued, no Federal protections currently exist; exotic/invasive |
| *Aphredoderus sayanus* | Pirate perch | – |
| *Centrarchus macropterus* | Flier, peacock sunfish, round sunfish | – |
| *Chaenobryttus gulosus* | Warmouth | – |
| *Chologaster cornuta* | Swampfish | – |
| *Cyprinella chloristia* | Greenfin shiner | – |
| *Cyprinella nivea* | Whitefin shiner | – |

**Table C-8a (continued).** Fish species reported to occur in Congaree National Park. NPS Certified Species List (NPS 2013a).

| Scientific Name | Common Name(s) | Notes |
|---|---|---|
| *Cyprinus carpio* | Common carp, European carp | exotic/invasive |
| *Dorosoma cepedianum* | American gizzard shad, eastern gizzard shad, hickory shad | – |
| *Dorosoma petenense* | Threadfin shad | – |
| *Elassoma zonatum* | Banded pygmy sunfish | – |
| *Enneacanthus chaetodon* | Blackbanded sunfish | – |
| *Enneacanthus gloriosus* | Bluespotted sunfish | – |
| *Erimyzon oblongus* | Creek chubsucker | – |
| *Erimyzon sucetta* | Lake chubsucker | – |
| *Esox americanus* | Grass pickerel, redfin or grass pickerel, redfin pickerel | – |
| *Esox niger* | Chain pickerel | – |
| *Etheostoma fusiforme* | Swamp darter | – |
| *Etheostoma olmstedi* | Tessellated darter | – |
| *Etheostoma serrifer* | Sawcheek darter | – |
| *Fundulus lineolatus* | Lined topminnow | – |
| *Gambusia affinis* | Mosquitofish, western mosquitofish | – |
| *Gambusia holbrooki* | Eastern mosquitofish | – |
| *Hybognathus regius* | Eastern silvery minnow | – |
| *Ictalurus punctatus* | Channel catfish, graceful catfish | – |
| *Labidesthes sicculus* | Brook silverside | – |
| *Lepisosteus osseus* | Longnose gar | – |
| *Lepomis auritus* | Redbreast sunfish | – |
| *Lepomis cyanellus* | Green sunfish | – |
| *Lepomis gibbosus* | Kiver, pumpkinseed | – |
| *Lepomis macrochirus* | Bluegill | – |
| *Lepomis marginatus* | Dollar sunfish | – |
| *Lepomis microlophus* | Redear sunfish | – |
| *Lepomis punctatus* | Spotted sunfish | – |
| *Micropterus salmoides* | Largemouth bass | – |
| *Minytrema melanops* | Spotted sucker | – |
| *Morone americana* | White perch | – |
| *Moxostoma macrolepidotum* | Shorthead redhorse | – |
| *Nocomis leptocephalus* | Bluehead chub | – |
| *Notemigonus crysoleucas* | Golden shiner | – |
| *Notropis chalybaeus* | Ironcolor shiner | – |

**Table C-8a (continued).** Fish species reported to occur in Congaree National Park. NPS Certified Species List (NPS 2013a).

| Scientific Name | Common Name(s) | Notes |
|---|---|---|
| *Notropis cummingsae* | Dusky shiner | – |
| *Notropis hudsonius* | Spottail shiner | – |
| *Notropis maculatus* | Taillight shiner | – |
| *Notropis petersoni* | Coastal shiner | – |
| *Noturus gyrinus* | Tadpole madtom | – |
| *Noturus insignis* | Margined madtom | – |
| *Noturus leptacanthus* | Speckled madtom | – |
| *Perca flavescens* | Yellow perch | – |
| *Percina crassa* | Piedmont darter | – |
| *Pomoxis nigromaculatus* | Black crappie | – |
| *Pteronotropis hypselopterus* | Sailfin shiner | – |
| *Pylodictis olivaris* | Flathead catfish | – |
| *Umbra pygmaea* | Eastern mudminnow | – |

**Table C-8b.** Fish species reported to occur in Congaree National Park. Additional Species Reported in CONG[A].

| Scientific Name | Common Name(s) |
|---|---|
| *Acipenser oxyrinchus* | Atlantic sturgeon |
| *Ameiurus catus* | White catfish |
| *Carpiodes cyprinus* | Quillback |
| *Catostomus commersonii* | White sucker |
| *Enneacanthus obesus* | Banded sunfish |
| *Etheostoma thalassinum* | Seagreen darter |
| *Hybognathus nuchalis* | Mississippi silvery minnow |
| *Morone chrysops* | White bass |
| *Morone saxatilis* | Striped bass |
| *Notropis altipinnis* | Highfin shiner |
| *Pomoxis annularis* | White crappie |

[a] See http://www.nps.gov/cong/planyourvisit/upload/Freshwater%20Fish,%20Mollusks%20&%20Crustaceans%20Partial%20Species%20List.pdf (last accessed April 2017).

**Table C-9.** Amphibians reported to occur in Congaree National Park. From the NPS Certified Species List (NPS 2013a).

| Scientific Name | Common Name(s) | Notes |
|---|---|---|
| *Acris crepitans* | Northern cricket frog | – |
| *Acris gryllus* | Southern cricket frog | – |
| *Acris gryllus gryllus* | Coastal plain cricket frog, southern cricket frog | – |
| *Ambystoma opacum* | Marbled salamander | – |
| *Ambystoma talpoideum* | Mole salamander | – |
| *Bufo terrestris* | Southern toad | – |
| *Desmognathus auriculatus* | Southern dusky salamander | – |
| *Eurycea guttolineata* | Three-lined salamander | – |
| *Gastrophryne carolinensis* | Eastern narrow-mouthed toad, eastern narrowmouth toad | – |
| *Hyla chrysoscelis* | Cope's gray treefrog | – |
| *Hyla cinerea* | Green tree frog, Green treefrog | – |
| *Hyla femoralis* | Pine woods treefrog | – |
| *Hyla gratiosa* | Barking treefrog | – |
| *Hyla squirella* | Squirrel treefrog | – |
| *Hyla versicolor* | Gray treefrog | – |
| *Necturus punctatus* | Dwarf waterdog | – |
| *Plethodon chlorobryonis* | Atlantic coast slimy salamander | – |
| *Pseudacris brimleyi* | Brimley's chorus frog | – |
| *Pseudacris crucifer* | Spring peeper | – |
| *Pseudacris crucifer crucifer* | Northern spring peeper | – |
| *Pseudacris feriarum* | Southeastern chorus frog, upland chorus frog | G5,S5 |
| *Pseudacris nigrita* | Southern chorus frog | – |
| *Pseudacris ornata* | Ornate chorus frog | – |
| *Pseudotriton montanus* | Eastern mud salamander, mud salamander | – |
| *Rana catesbeiana* | American bullfrog | – |
| *Rana clamitans* | Green frog | – |
| *Rana clamitans clamitans* | Bronze frog | – |
| *Rana heckscheri* | River frog | – |
| *Rana palustris* | Pickerel frog | – |
| *Rana sphenocephala* | Florida leopard frog, Southern leopard frog | – |
| *Rana virgatipes* | Carpenter frog | – |
| *Scaphiopus holbrookii* | Eastern spadefoot | – |
| *Siren lacertina* | Greater siren | – |

**Table C-10.** Reptiles reported to occur in Congaree National Park. From the NPS Certified Species List (NPS 2013a).

| Scientific Name | Common Name(s) | Notes |
|---|---|---|
| *Agkistrodon contortrix* | Copperhead | – |
| *Agkistrodon contortrix contortrix* | Southern copperhead | – |
| *Agkistrodon piscivorus* | Cottonmouth | – |
| *Agkistrodon piscivorus piscivorus* | Eastern cottonmouth | – |
| *Alligator mississippiensis* | Alligator, American alligator, Florida alligator | – |
| *Anolis carolinensis* | Green anole | – |
| *Carphophis amoenus* | Eastern worm snake, eastern wormsnake | – |
| *Chelydra serpentina* | Common snapping turtle, snapping turtle | – |
| *Chelydra serpentina serpentina* | Common snapping turtle | – |
| *Clemmys guttata* | Spotted turtle | State: Threatened |
| *Coluber constrictor* | Eastern racer, racer | – |
| *Crotalus horridus* | Timber rattlesnake | – |
| *Diadophis punctatus* | Ring-necked snake, ringneck snake | – |
| *Elaphe obsoleta* | Eastern rat snake, rat snake, Texas ratsnake | – |
| *Elaphe obsoleta obsoleta* | Black rat snake | – |
| *Eumeces fasciatus* | Five-lined skink | – |
| *Eumeces inexpectatus* | Southeastern five-lined skink | – |
| *Eumeces laticeps* | Broad-headed skink, broadhead skink | – |
| *Farancia abacura* | Mud snake, mudsnake | – |
| *Farancia abacura abacura* | Eastern mud snake | – |
| *Heterodon platirhinos* | Eastern hog-nosed snake, eastern hognose snake | – |
| *Kinosternon subrubrum* | Common mud turtle, Eastern mud turtle | – |
| *Kinosternon subrubrum subrubrum* | Eastern mud turtle | – |
| *Lampropeltis getula* | Common kingsnake | – |
| *Lampropeltis getula getula* | Eastern kingsnake | – |
| *Masticophis flagellum* | Coachwhip | – |
| *Nerodia erythrogaster* | Plain-bellied water snake, plainbelly water snake | – |
| *Nerodia erythrogaster erythrogaster* | Red-bellied water snake, redbelly water snake | – |
| *Nerodia fasciata* | Banded water snake, southern water snake | – |
| *Nerodia fasciata fasciata* | Banded water snake, southern water snake | – |
| *Nerodia taxispilota* | Brown water snake | – |
| *Opheodrys aestivus* | Rough green snake, rough greensnake | – |
| *Pseudemys concinna* | Eastern river cooter, river cooter | – |
| *Pseudemys concinna concinna* | Eastern river cooter | – |
| *Scincella lateralis* | Ground skink, little brown skink | – |
| *Sternotherus odoratus* | Common Musk Turtle | – |
| *Storeria dekayi* | Dekay's brown snake, northern brown snake | – |

**Table C-10 (continued).** Reptiles reported to occur in Congaree National Park. From the NPS Certified Species List (NPS 2013a).

| Scientific Name | Common Name(s) | Notes |
|---|---|---|
| *Storeria occipitomaculata* | Red-bellied snake, redbelly snake | – |
| *Terrapene carolina* | Common box turtle, eastern box turtle | – |
| *Terrapene carolina carolina* | Eastern box turtle | – |
| *Thamnophis sauritus* | Eastern ribbon snake | – |
| *Thamnophis sauritus sauritus* | Eastern ribbon snake | – |
| *Thamnophis sirtalis* | Common garter snake | – |
| *Trachemys scripta* | Common slider, slider | – |
| *Trachemys scripta scripta* | Yellow-bellied slider, yellowbelly slider | – |

**Table C-11.** Bird species reported to occur in Congaree National Park. From the NPS Certified Species List (2013a).

| Scientific Name | Common Name(s) | Notes |
|---|---|---|
| *Accipiter cooperii* | Cooper's hawk | S3 |
| *Accipiter striatus* | Sharp-shinned hawk | – |
| *Actitis macularia* | Spotted sandpiper | – |
| *Agelaius phoeniceus* | Red-winged blackbird | – |
| *Aimophila aestivalis* | Bachman's sparrow | G3 |
| *Aix sponsa* | Wood duck | – |
| *Ajaia ajaja* | Roseate spoonbill | – |
| *Ammodramus henslowii* | Henslow's sparrow | – |
| *Anas americana* | American wigeon | – |
| *Anas clypeata* | Northern shoveler | – |
| *Anas crecca* | Green-winged teal | – |
| *Anas discors* | Blue-winged teal | – |
| *Anas platyrhynchos* | Mallard | – |
| *Anas rubripes* | American black duck | – |
| *Anhinga anhinga* | Anhinga | – |
| *Anthus rubescens* | American pipit | – |
| *Aquila chrysaetos* | Golden eagle | – |
| *Archilochus colubris* | Ruby-throated hummingbird | – |
| *Ardea alba* | Great egret | – |
| *Ardea herodias* | Great blue heron | – |
| *Aythya collaris* | Ring-necked duck | – |
| *Baeolophus bicolor* | Tufted titmouse | – |
| *Bombycilla cedrorum* | Cedar waxwing | – |
| *Botaurus lentiginosus* | American bittern | – |

**Table C-11 (continued).** Bird species reported to occur in Congaree National Park. From the NPS Certified Species List (2013a).

| Scientific Name | Common Name(s) | Notes |
|---|---|---|
| *Branta canadensis* | Canada goose | – |
| *Bubo virginianus* | Great horned owl | – |
| *Bubulcus ibis* | Cattle egret | – |
| *Buteo jamaicensis* | Red-tailed hawk | – |
| *Buteo lineatus* | Red-shouldered hawk | – |
| *Buteo platypterus* | Broad-winged hawk | – |
| *Buteo swainsoni* | Swainson's hawk | – |
| *Butorides virescens* | Green heron | – |
| *Caprimulgus carolinensis* | Chuck-will's-widow | – |
| *Caprimulgus vociferus* | Whip-poor-will | – |
| *Cardinalis cardinalis* | Northern cardinal | – |
| *Carduelis pinus* | Pine siskin | – |
| *Carduelis tristis* | American goldfinch | – |
| *Carpodacus mexicanus* | House finch | – |
| *Carpodacus purpureus* | Purple finch | – |
| *Cathartes aura* | Turkey vulture | – |
| *Catharus bicknelli* | Bicknell's thrush | – |
| *Catharus fuscescens* | Veery | – |
| *Catharus guttatus* | Hermit thrush | – |
| *Catharus minimus* | Gray-cheeked thrush | – |
| *Catharus ustulatus* | Swainson's thrush | – |
| *Certhia americana* | Brown creeper | – |
| *Chaetura pelagica* | Chimney swift | – |
| *Charadrius vociferus* | Killdeer | – |
| *Chordeiles minor* | Common nighthawk | – |
| *Circus cyaneus* | Northern harrier | – |
| *Coccothraustes vespertinus* | Evening grosbeak | – |
| *Coccyzus americanus* | Yellow-billed cuckoo | – |
| *Coccyzus erythropthalmus* | Black-billed cuckoo | – |
| *Colaptes auratus* | Northern flicker | – |
| *Colinus virginianus* | Northern bobwhite | – |
| *Columba livia* | Rock dove | – |
| *Contopus borealis* | Olive-sided flycatcher | – |
| *Contopus virens* | Eastern wood-pewee | – |
| *Coragyps atratus* | Black vulture | – |
| *Corvus brachyrhynchos* | American crow | – |
| *Corvus ossifragus* | Fish crow | – |

**Table C-11 (continued).** Bird species reported to occur in Congaree National Park. From the NPS Certified Species List (2013a).

| Scientific Name | Common Name(s) | Notes |
|---|---|---|
| *Cyanocitta cristata* | Blue jay | – |
| *Dendroica caerulescens* | Black-throated blue warbler | – |
| *Dendroica castanea* | Bay-breasted warbler | – |
| *Dendroica cerulea* | Cerulean warbler | – |
| *Dendroica coronata* | Yellow-rumped warbler | – |
| *Dendroica discolor* | Prairie warbler | – |
| *Dendroica dominica* | Yellow-throated warbler | – |
| *Dendroica fusca* | Blackburnian warbler | – |
| *Dendroica magnolia* | Magnolia warbler | – |
| *Dendroica palmarum* | Palm warbler | – |
| *Dendroica pensylvanica* | Chestnut-sided warbler | – |
| *Dendroica petechia* | Yellow warbler | – |
| *Dendroica pinus* | Pine warbler | – |
| *Dendroica striata* | Blackpoll warbler | – |
| *Dendroica tigrina* | Cape May warbler | – |
| *Dendroica virens* | Black-throated green warbler | – |
| *Dolichonyx oryzivorus* | Bobolink | – |
| *Dryocopus pileatus* | Pileated woodpecker | – |
| *Dumetella carolinensis* | Gray catbird | – |
| *Egretta caerulea* | Little blue heron | SNR |
| *Egretta thula* | Snowy egret | – |
| *Elanoides forficatus* | American swallow-tailed kite, swallow-tailed kite | SE: Endangered |
| *Empidonax minimus* | Least flycatcher | – |
| *Empidonax virescens* | Acadian flycatcher | – |
| *Eudocimus albus* | White ibis | – |
| *Euphagus carolinus* | Rusty blackbird | – |
| *Falco columbarius* | Merlin | – |
| *Falco peregrinus* | Peregrine falcon | – |
| *Falco sparverius* | American kestrel | – |
| *Gallinago gallinago* | Common snipe | – |
| *Geothlypis trichas* | Common yellowthroat | – |
| *Guiraca caerulea* | Blue grosbeak | – |
| *Haliaeetus leucocephalus* | Bald eagle | ST: Threatened |

**Table C-11 (continued).** Bird species reported to occur in Congaree National Park. From the NPS Certified Species List (2013a).

| Scientific Name | Common Name(s) | Notes |
|---|---|---|
| *Helmitheros vermivorus* | Worm-eating warbler | Species spelling in accord with Avibase, The World Bird Database (http://avibase.bsc-eoc.org/avibase.jsp?lang=EN [last accessed in April 2017]). The NPS Certified Species List (NPS 2013a) lists this species as *Helmitheros vermivorus*. |
| *Hirundo pyrrhonota* | Cliff swallow | – |
| *Hirundo rustica* | Barn swallow | – |
| *Hylocichla mustelina* | Wood thrush | – |
| *Icteria virens* | Yellow-breasted chat | – |
| *Icterus galbula* | Baltimore oriole, northern oriole | – |
| *Icterus spurius* | Orchard oriole | – |
| *Ictinia mississippiensis* | Mississippi kite | G5,S4 |
| *Junco hyemalis* | Dark-eyed junco | – |
| *Lanius ludovicianus* | Loggerhead shrike | G4,S3 |
| *Larus delawarensis* | Ring-billed gull | – |
| *Larus philadelphia* | Bonaparte's gull | – |
| *Limnothlypis swainsonii* | Swainson's warbler | G4,S4 |
| *Lophodytes cucullatus* | Hooded merganser | – |
| *Megaceryle alcyon* | Belted kingfisher | – |
| *Megascops asio* | Eastern screech-owl | – |
| *Melanerpes carolinus* | Red-bellied woodpecker | – |
| *Melanerpes erythrocephalus* | Red-headed woodpecker | G5,SNR |
| *Meleagris gallopavo* | Wild turkey | – |
| *Melospiza georgiana* | Swamp sparrow | – |
| *Melospiza lincolnii* | Lincoln's sparrow | – |
| *Melospiza melodia* | Song sparrow | – |
| *Mimus polyglottos* | Northern mockingbird | – |
| *Mniotilta varia* | Black-and-white warbler | – |
| *Molothrus ater* | Brown-headed cowbird | – |
| *Mycteria americana* | Wood stork | LE:Endangered; SE:Endangered |
| *Myiarchus crinitus* | Great crested flycatcher | – |
| *Nyctanassa violacea* | Yellow-crowned night-heron | – |
| *Oporornis formosus* | Kentucky warbler | – |
| *Oporornis philadelphia* | Mourning warbler | – |
| *Pandion haliaetus* | Osprey | – |

**Table C-11 (continued).** Bird species reported to occur in Congaree National Park. From the NPS Certified Species List (2013a).

| Scientific Name | Common Name(s) | Notes |
|---|---|---|
| *Parula americana* | Northern parula | – |
| *Passer domesticus* | House sparrow | exotic/invasive |
| *Passerculus sandwichensis* | Savannah sparrow | – |
| *Passerella iliaca* | Fox sparrow | – |
| *Passerina cyanea* | Indigo bunting | – |
| *Phalacrocorax auritus* | Double-crested cormorant | – |
| *Pheucticus ludovicianus* | Rose-breasted grosbeak | – |
| *Picoides pubescens* | Downy woodpecker | – |
| *Picoides villosus* | Hairy woodpecker | – |
| *Pipilo erythrophthalmus* | Eastern towhee, rufous-sided towhee | – |
| *Piranga olivacea* | Scarlet tanager | – |
| *Piranga rubra* | Summer tanager | – |
| *Podilymbus podiceps* | Pied-billed grebe | – |
| *Poecile carolinensis* | Carolina chickadee | – |
| *Polioptila caerulea* | Blue-gray gnatcatcher | – |
| *Pooecetes gramineus* | Vesper sparrow | – |
| *Progne subis* | Purple martin | – |
| *Protonotaria citrea* | Prothonotary warbler | – |
| *Quiscalus quiscula* | Common grackle | – |
| *Regulus calendula* | Ruby-crowned kinglet | – |
| *Regulus satrapa* | Golden-crowned kinglet | – |
| *Riparia riparia* | Bank swallow | – |
| *Sayornis phoebe* | Eastern phoebe | – |
| *Scolopax minor* | American woodcock | – |
| *Seiurus aurocapillus* | Ovenbird | – |
| *Seiurus motacilla* | Louisiana waterthrush | – |
| *Seiurus noveboracensis* | Northern waterthrush | – |
| *Setophaga ruticilla* | American redstart | – |
| *Sialia sialis* | Eastern bluebird | – |
| *Sitta canadensis* | Red-breasted nuthatch | – |
| *Sitta carolinensis* | White-breasted nuthatch | – |
| *Sitta pusilla* | Brown-headed nuthatch | – |
| *Sphyrapicus varius* | Yellow-bellied sapsucker | – |
| *Spizella passerina* | Chipping sparrow | – |
| *Spizella pusilla* | Field sparrow | – |
| *Stelgidopteryx serripennis* | Northern rough-winged swallow | – |

**Table C-11 (continued).** Bird species reported to occur in Congaree National Park. From the NPS Certified Species List (2013a).

| Scientific Name | Common Name(s) | Notes |
|---|---|---|
| *Sterna caspia* | Caspian tern | – |
| *Streptopelia decaocto* | Eurasian collared dove | – |
| *Strix varia* | Barred owl | – |
| *Sturnella magna* | Eastern meadowlark | – |
| *Sturnus vulgaris* | European starling | exotic/invasive |
| *Tachycineta bicolor* | Tree swallow | – |
| *Thryothorus ludovicianus* | Carolina wren | – |
| *Toxostoma rufum* | Brown thrasher | – |
| *Tringa flavipes* | Lesser yellowlegs | – |
| *Tringa solitaria* | Solitary sandpiper | – |
| *Troglodytes aedon* | House wren | – |
| *Troglodytes troglodytes* | Winter wren | – |
| *Turdus migratorius* | American robin | – |
| *Tyrannus tyrannus* | Eastern kingbird | – |
| *Tyrannus verticalis* | Western kingbird | – |
| *Vermivora celata* | Orange-crowned warbler | – |
| *Vermivora chrysoptera* | Golden-winged warbler | – |
| *Vermivora peregrina* | Tennessee warbler | – |
| *Vermivora pinus* | Blue-winged warbler | – |
| *Vermivora ruficapilla* | Nashville warbler | – |
| *Vireo flavifrons* | Yellow-throated vireo | – |
| *Vireo gilvus* | Warbling vireo | – |
| *Vireo griseus* | White-eyed vireo | – |
| *Vireo olivaceus* | Red-eyed vireo | – |
| *Vireo philadelphicus* | Philadelphia vireo | – |
| *Vireo solitarius* | Blue-headed vireo, solitary vireo | – |
| *Wilsonia canadensis* | Canada warbler | – |
| *Wilsonia citrina* | Hooded warbler | – |
| *Zenaida macroura* | Mourning dove | – |
| *Zonotrichia albicollis* | White-throated sparrow | – |

**Table C-12.** Mammal species reported to occur in Congaree National Park (green—SoC). From the NPS Certified Species List (NPS 2013a).

| Scientific Name | Common Name(s) | Notes |
|---|---|---|
| *Blarina brevicauda* | Mole shrew, northern short-tailed shrew, short-tailed shrew | – |
| *Blarina carolinensis* | Southern short-tailed shrew | – |
| *Canis familiaris* | Domestic dog, feral dog | exotic/invasive |
| *Canis latrans* | Coyote | – |
| *Castor canadensis* | American beaver, beaver | – |
| *Condylura cristata* | Star-nosed mole | SoC G5, S3 |
| *Corynorhinus rafinesquii* | Eastern big-eared bat, Rafinesque's big-eared bat, southeastern big-eared bat | SoC; SE S2 |
| *Cryptotis parva* | Bee shrew, least shrew, little short-tailed shrew | – |
| *Didelphis virginiana* | Virginia opossum | – |
| *Eptesicus fuscus* | Big brown bat | – |
| *Felis catus* | Feral cat | exotic/invasive |
| *Glaucomys volans* | Southern flying squirrel | – |
| *Lasiurus borealis* | Eastern red bat, red bat | – |
| *Lontra canadensis* | Northern river otter, river otter | – |
| *Lynx rufus* | Bobcat | – |
| *Mephitis mephitis* | Striped skunk | – |
| *Mustela vison* | American mink, mink | – |
| *Myotis austroriparius* | Southeastern myotis | SoC G3G4; S1 |
| *Neotoma floridana* | Eastern woodrat | SoC G5,S3S4 |
| *Nycticeius humeralis* | Evening bat | – |
| *Odocoileus virginianus* | White-tailed deer | – |
| *Oryzomys palustris* | Marsh rice rat | – |
| *Peromyscus gossypinus* | Cotton mouse | – |
| *Peromyscus leucopus* | White-footed mouse | – |
| *Pipistrellus subflavus* | Eastern pipistrelle | – |
| *Procyon lotor* | Common raccoon, northern raccoon, raccoon | – |
| *Reithrodontomys humulis* | Eastern harvest mouse | – |
| *Scalopus aquaticus* | Eastern mole, topos | – |
| *Sciurus carolinensis* | Eastern gray squirrel, gray squirrel | – |
| *Sciurus niger* | Eastern fox squirrel, fox squirrel | SoC G5,S4 |
| *Sigmodon hispidus* | Hispid cotton rat | – |
| *Sorex longirostris* | Southeastern shrew | – |
| *Sus scrofa* | Pig, pig (feral), wild boar | exotic/invasive |
| *Sylvilagus floridanus* | Eastern cottontail | – |
| *Sylvilagus palustris* | Marsh rabbit | – |
| *Urocyon cinereoargenteus* | Common gray fox, gray fox | – |
| *Vulpes vulpes* | Red fox | exotic/invasive |

## Appendix D. Automated Program for Computing the Date When the GDD Threshold is Reached, and the Severity of Drought Over Seven Moisture Classes.

**Program pgm_GDD_columbia.sas.**

```
data a;
input   Year      Jan   Feb   Mar   Apr   May   Jun   Jul   Aug   Sep   Oct
     Nov   Dec;
*ACUMTEMP=JAN; *output;
 datalines;
1930 109  159  104  474  746  786  1012 877  847  362  158  25
1931 61   58   64   340  596  882  1019 915  866  553  328  175
1932 231  183  202  418  648  869  1049 936  726  475  141  135
1933 173  100  232  395  841  914  921  947  893  488  165  207
1934 91   14   178  427  618  917  1023 959  815  459  248  43
1935 102  53   375  407  696  911  950  936  730  471  270  18
1936 35   52   279  340  748  885  1011 969  817  539  159  92
1937 227  69   193  385  710  899  953  922  695  386  145  35
1938 63   154  374  430  734  815  918  1011 768  452  297  44
1939 94   183  316  422  660  962  987  923  854  574  107  78
1940 3    45   186  365  610  890  964  923  723  481  202  94
1941 53   2    80   500  743  848  968  962  836  693  214  105
1942 54   26   235  492  698  912  1029 911  790  504  253  52
1943 123  124  213  392  746  974  963  993  676  424  158  112
1944 68   167  201  409  771  963  905  892  797  466  165  15
1945 20   149  469  525  599  922  958  910  842  439  248  4
1946 120  75   372  449  665  868  929  897  738  481  312  137
1947 125  28   52   526  715  854  886  956  780  589  114  67
1948 23   115  292  504  704  918  1048 921  677  308  268  128
1949 210  171  236  365  711  883  1039 930  692  585  135  94
1950 271  104  146  373  756  923  912  889  695  524  145  23
1951 54   102  215  363  638  907  981  1003 772  557  118  135
1952 181  74   161  384  734  1020 1040 938  712  321  165  28
1953 94   74   217  378  853  909  999  943  744  478  141  78
1954 68   121  230  510  523  902  1060 1033 849  484  99   41
1955 48   101  295  517  755  747  1018 1012 790  390  145  67
1956 14   125  193  378  740  889  1016 998  684  502  177  255
1957 133  193  155  475  701  883  969  913  794  325  215  68
1958 6    42   54   416  686  857  997  991  760  355  244  24
1959 55   107  132  479  735  853  947  987  731  516  176  59
1960 57   28   81   470  650  875  975  971  784  518  158  14
1961 11   132  273  269  589  820  972  893  789  375  323  71
```

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *1962* | *83* | *153* | *130* | *341* | *833* | *827* | *988* | *951* | *726* | *500* | *110* | *46* |
| *1963* | *37* | *5* | *291* | *466* | *654* | *827* | *931* | *991* | *676* | *448* | *183* | *5* |
| *1964* | *26* | *6* | *183* | *433* | *702* | *920* | *899* | *890* | *720* | *291* | *276* | *136* |
| *1965* | *54* | *97* | *158* | *470* | *815* | *771* | *933* | *952* | *768* | *409* | *168* | *50* |
| *1966* | *44* | *57* | *139* | *398* | *633* | *756* | *985* | *913* | *720* | *402* | *167* | *67* |
| *1967* | *51* | *36* | *269* | *474* | *534* | *713* | *864* | *802* | *526* | *325* | *83* | *122* |
| *1968* | *19* | *1* | *212* | *421* | *612* | *843* | *953* | *1029* | *680* | *445* | *180* | *14* |
| *1969* | *53* | *34* | *138* | *460* | *643* | *856* | *1035* | *857* | *690* | *483* | *103* | *34* |
| *1970* | *29* | *54* | *249* | *535* | *719* | *870* | *1041* | *978* | *865* | *463* | *118* | *145* |
| *1971* | *57* | *76* | *110* | *348* | *623* | *915* | *935* | *938* | *819* | *620* | *197* | *268* |
| *1972* | *153* | *59* | *175* | *408* | *579* | *723* | *915* | *910* | *763* | *406* | *184* | *126* |
| *1973* | *57* | *41* | *290* | *310* | *561* | *825* | *959* | *955* | *863* | *524* | *308* | *112* |
| *1974* | *317* | *109* | *375* | *467* | *774* | *838* | *976* | *897* | *681* | *367* | *185* | *78* |
| *1975* | *133* | *125* | *200* | *408* | *773* | *840* | *907* | *953* | *767* | *539* | *236* | *53* |
| *1976* | *43* | *206* | *353* | *440* | *599* | *741* | *925* | *907* | *681* | *292* | *74* | *27* |
| *1977* | *0* | *80* | *319* | *491* | *702* | *857* | *1014* | *894* | *767* | *306* | *261* | *63* |
| *1978* | *14* | *0* | *155* | *398* | *600* | *819* | *931* | *943* | *826* | *438* | *305* | *111* |
| *1979* | *25* | *45* | *203* | *379* | *595* | *701* | *890* | *926* | *720* | *377* | *202* | *36* |
| *1980* | *14* | *53* | *114* | *350* | *597* | *778* | *995* | *952* | *812* | *323* | *122* | *43* |
| *1981* | *9* | *61* | *119* | *510* | *565* | *947* | *964* | *814* | *650* | *376* | *146* | *42* |
| *1982* | *30* | *86* | *252* | *320* | *689* | *827* | *949* | *871* | *658* | *382* | *195* | *178* |
| *1983* | *2* | *36* | *163* | *264* | *625* | *768* | *1038* | *1023* | *699* | *434* | *134* | *49* |
| *1984* | *6* | *77* | *187* | *299* | *628* | *878* | *901* | *913* | *657* | *642* | *106* | *187* |
| *1985* | *43* | *99* | *265* | *465* | *671* | *867* | *933* | *867* | *678* | *575* | *385* | *44* |
| *1986* | *21* | *136* | *227* | *420* | *693* | *966* | *1125* | *934* | *797* | *473* | *319* | *53* |
| *1987* | *22* | *18* | *163* | *337* | *760* | *890* | *1036* | *1036* | *765* | *214* | *195* | *109* |
| *1988* | *31* | *54* | *199* | *383* | *607* | *816* | *1001* | *1020* | *771* | *282* | *199* | *52* |
| *1989* | *71* | *143* | *268* | *391* | *595* | *901* | *965* | *947* | *750* | *466* | *233* | *30* |
| *1990* | *123* | *211* | *305* | *409* | *687* | *904* | *1048* | *989* | *785* | *516* | *190* | *138* |
| *1991* | *47* | *132* | *280* | *518* | *792* | *877* | *1030* | *941* | *757* | *463* | *161* | *126* |
| *1992* | *29* | *102* | *183* | *384* | *554* | *785* | *1056* | *900* | *753* | *367* | *200* | *46* |
| *1993* | *65* | *35* | *136* | *276* | *677* | *902* | *1128* | *997* | *805* | *431* | *183* | *29* |
| *1994* | *33* | *119* | *290* | *531* | *604* | *913* | *976* | *883* | *682* | *416* | *233* | *93* |
| *1995* | *48* | *63* | *265* | *473* | *758* | *812* | *1036* | *1008* | *729* | *532* | *107* | *46* |
| *1996* | *39* | *136* | *135* | *383* | *753* | *862* | *998* | *902* | *732* | *395* | *115* | *113* |
| *1997* | *97* | *132* | *367* | *312* | *564* | *757* | *977* | *916* | *753* | *408* | *84* | *25* |
| *1998* | *82* | *76* | *167* | *387* | *782* | *976* | *1055* | *966* | *795* | *491* | *242* | *180* |
| *1999* | *119* | *117* | *118* | *499* | *620* | *810* | *990* | *1041* | *688* | *410* | *228* | *44* |
| *2000* | *69* | *102* | *274* | *348* | *796* | *911* | *983* | *950* | *700* | *404* | *145* | *8* |
| *2001* | *46* | *118* | *148* | *463* | *706* | *870* | *947* | *1005* | *687* | *379* | *279* | *152* |
| *2002* | *101* | *58* | *282* | *576* | *618* | *884* | *1058* | *966* | *830* | *545* | *126* | *15* |
| *2003* | *36* | *48* | *276* | *365* | *669* | *812* | *929* | *960* | *693* | *430* | *297* | *7* |
| *2004* | *57* | *26* | *278* | *419* | *801* | *899* | *997* | *890* | *747* | *528* | *234* | *65* |

```
2005 140   66    185   361   580   831   1006 995   861   493   212   25
2006 104   50    195   516   654   839   1001 1001  709   377   174   103
2007 100   54    312   386   652   864   919   1122 823   603   159   144
2008 63    148   225   374   652   956   970   927   745   369   97    174
2009 56    86    222   401   709   935   964   989   767   420   180   35
2010 37    8     168   482   814   1019 1073 1046  875   488   176   13
2011 25    148   241   541   756   1007 1109 1054  797   382   204   115
2012 85    135   489   516   794   833   1093 953   775   475   102   145
;

%macro check;
 data new;
 %do year = 1930 %to 2013;
  date1 = mdy(01,1, &year);
  date2 = mdy(02,1, &year);
  do i = 0 to 11;
   start=  intnx('month',date1 ,i);
   end= (intnx('month',date2,i)) ;
   count=intck('days',start,end);
   * put 'In the month of ' start monyy7. ', there are ' count
'days.';
   output;
  end;
 %end;

*proc print data=new(obs=30);;
*run;
%mend;

 %check

ods listing close;
ods tagsets.rtf  file="GDD_columbia.rtf";;

 data numberdays(keep=year month ndays);
  set new;
  year=year(date1);
  month=month(start);
  ndays=count;
  run;

 * proc print data=numberdays(obs=30);
 * run;
```

```
proc sort data=numberdays;
by year month;
run;

proc transpose data=numberdays out=out1(drop=_NAME_) prefix=ndays;
 by year  ;
 id month;
 var ndays;
 run;

 title "Number of days per month";
 *proc print data=out1;
 *run;

 proc sort data=a;
  by year;
  run;

  data c;
   merge a(in=a) out1(in=b);
   by year;
   if a and b;
   run;

  * proc print data=c (obs=10);
  * run;

data d3(keep = year date1200 plotdate2013);
set c;  by year;
format date1200 date8.;
format plotdate2013 date8.;
array temp {12} Jan--Dec;
Array CUMTEMP {12} CUMTEMP1-CUMTEMP12;
Array id1200 {12} id1200_1-id1200_12;
Array ndays {12} ndays1-ndays12;
ACUMTEMP=0;
do i=1 to 12;
 cumtemp{i}= ACUMTEMP + TEMP{i};
 ACUMTEMP=CUMTEMP{i};
 id1200{i} = (acumtemp ge 1200);
end;
do i=2 to 12;
```

```
 j=i-1;
  if id1200{i}=1  and id1200{j}=0 then do;
   incrm=1200-cumtemp{j};
   adddays=incrm/( temp{i}/ndays{i});
   days=ceil(adddays);
   date1200= mdy( i ,days, year);
   plotdate2013= mdy( i, days, 2013);
   newCheck = cumtemp{j}+  ( temp{i}/ndays{i})*adddays;
  end;
end;
If last.year then output d3 ;
run;

title "date1200 is date when gdd is 1200";
proc print data = d3 ;
run;

quit;
ods tagsets.rtf close;
ods listing;
Program pgm_PDSI_columbia.sas
data b2; yrid+1;
input   Year Jan     Feb  Mar  Apr  May  Jun  Jul  Aug  Sep  Oct
     Nov  Dec;
period = ceil(yrid/ 9) ;
datalines;
1896 -1.82-0.85-1.41-2.19-2.99-2.8 -2   -2.1 -2.37-2.61-2.3 -2.06
1897 -2.16-0.58-0.79-0.87-1.19-0.82-0.78-0.57-0.76-0.68-0.87-1.49
1898 -2.2 -2.92-3.18-2.08-2.89-3.070.28 1.41 1.4  1.4  2.1  1.83
1899 1.96 2.75 -0.34-0.31-1.12-1.45-1.92-1.72-2.05-1.28-1.24-1.47
1900 -1.790.6  0.57 1.31 0.82 2.15 -0.38-1.37-1.96-0.040.02 0.56
1901 0.52 0.41 0.41 1.27 2.24 2.83 2.22 2.83 2.87 -0.44-0.75-0.34
1902 -0.71-0.04-0.2 -0.43-0.82-0.82-1.48-1.5 -1.680.35 0.45 0.63
1903 0.69 1.47 1.33 1.05 0.71 2.04 -0.460.43 -0.04-0.09-0.51-0.86
1904 -1.03-0.95-1.24-1.65-2.17-2.32-2.04-0.83-1.05-1.36-1.21-1.45
1905 -1.92-1.32-1.89-1.53-0.94-1.68-1.55-1.44-2.21-2.49-2.890.57
1906 0.96 -0.31-0.09-0.79-1   1.26 2.04 2.31 2.25 2.32 -0.47-0.5
1907 -1.46-1.3 -2.260.41 0.72 1.18 0.96 1.06 1.39 0.71 1.01 1.6
1908 1.82 2.17 1.68 1.63 1.08 1.15 0.84 1.75 1.44 1.8  -0.27-0.58
1909 -1.280.08 0.21 -0.360.36 1.12 0.02 0.06 0.12 -0.06-0.75-0.99
1910 -1.21-0.7 -1.52-2.16-2.081.01 1.29 1.59 1.37 1.68 -0.35-0.66
1911 -1.49-2.19-2.63-2.81-3.68-4.15-4.59-4.34-4.480.69 0.81 1.01
1912 1.42 2.23 2.5  2.09 1.88 2.04 -0.07-0.53-0.22-0.42-0.44-0.73
```

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1913 | -1.28 | 0.3 | 0.82 | -0.38 | -1.13 | -0.85 | -1.35 | -1.79 | -1.6 | -1.3 | -1.48 | -1.21 |
| 1914 | -1.37 | -1.02 | -1.3 | -1.45 | -2.26 | -2.74 | -2.77 | -2.58 | -2.48 | -2.33 | -2.09 | -1.95 |
| 1915 | -1.05 | -1.28 | -1.36 | -1.74 | 1.15 | 1.11 | -0.67 | -0.23 | -0.9 | -0.46 | -0.61 | -0.94 |
| 1916 | -1.74 | -1.59 | -1.96 | -2.22 | -2.81 | -0.04 | 2.33 | -0.49 | -0.79 | -0.9 | -1.43 | -1.98 |
| 1917 | -2.22 | -2 | -1.86 | -1.82 | 0.12 | 0.18 | 0.63 | 0.12 | 0.59 | -0.35 | -0.88 | -1.41 |
| 1918 | -1.35 | -1.83 | -2.48 | -1.45 | -1.38 | -1.57 | -1.52 | -1.72 | -1.58 | -1.59 | -1.46 | -1.18 |
| 1919 | -1.18 | -0.83 | -1.38 | -1.69 | 0.39 | 0.95 | 1.56 | 1.61 | -0.66 | -1.47 | -2.23 | -2.49 |
| 1920 | -2.56 | 0.03 | 0.68 | 0.96 | -0.37 | -0.79 | -0.94 | 0.51 | 0.85 | -0.55 | -0.26 | -0.44 |
| 1921 | -0.44 | -0.2 | -1.01 | -1.42 | 0.75 | 0.18 | 0.68 | -0.26 | -0.85 | -1.16 | -1.24 | -2.11 |
| 1922 | -2.5 | 0.5 | 0.85 | 1.15 | 1.87 | 2 | 2.56 | 2.7 | 1.78 | 2.51 | -0.58 | -0.29 |
| 1923 | -0.89 | -0.82 | -0.77 | -0.78 | 1.27 | -0.7 | -0.99 | -0.44 | -0.87 | -1.33 | -1.29 | -1.25 |
| 1924 | -1.12 | -1.16 | -1.38 | 0.84 | 1.07 | 1.22 | 1.69 | 1.01 | 3.57 | 3.06 | 2.43 | 2.67 |
| 1925 | 3.84 | -0.77 | -1.52 | -1.94 | -2.24 | -2.81 | -3.42 | -4.46 | -5.36 | -5.26 | -4.5 | -4.44 |
| 1926 | -3.43 | -3.11 | -2.7 | -2.57 | -3.14 | -2.83 | -2.73 | -3.51 | -4.04 | -4.37 | -3.95 | -4.15 |
| 1927 | -4.7 | -4.58 | -4.28 | -4.79 | -5.13 | -4.21 | -3.54 | -3.31 | -3.79 | -3.46 | -3.79 | -3.08 |
| 1928 | -3.44 | 0.65 | 0.38 | 1.36 | 1.93 | 2.35 | 2.56 | 3.69 | 6.46 | 5.37 | 4.23 | 3.28 |
| 1929 | 2.92 | 3.78 | 3.89 | 3.64 | 4.31 | 4.53 | 3.93 | 3.2 | 3.51 | 4.33 | 4.19 | 4.27 |
| 1930 | 4.05 | -0.91 | -0.98 | -1.18 | -1.4 | -1.31 | -1.7 | -2.29 | -2.23 | -2.2 | -1.7 | -1.46 |
| 1931 | -1.46 | -2 | -2.1 | -1.87 | -1.3 | -1.78 | -1.65 | -2.16 | -3.13 | -3.64 | -4.31 | -3.79 |
| 1932 | -3.68 | -3.23 | -3.17 | -3.41 | -3.15 | 0.72 | -0.73 | 0.37 | 0.33 | 1.03 | 1.15 | 1.39 |
| 1933 | -0.45 | -0.03 | -0.74 | -1.24 | -1.47 | -2.15 | -2.43 | -2.82 | -2.99 | -3.24 | -3.53 | -4.59 |
| 1934 | -5.27 | -5.02 | -4.88 | -4.74 | -3.68 | -3.7 | -3.86 | -4.08 | -4.05 | -3.99 | -3.64 | -3.83 |
| 1935 | -4.25 | -4.53 | -4.84 | -4.45 | -4.49 | -4.92 | 0.23 | 0.71 | 1.45 | 0.91 | 0.83 | 0.77 |
| 1936 | 1.26 | 1.44 | 1.27 | 2.93 | -1.03 | -1.74 | -1.81 | -1.43 | -1.68 | 0.74 | 0.49 | 0.92 |
| 1937 | 1.12 | 1.19 | 0.77 | 1.79 | 1.13 | 1.29 | 1.01 | 1.58 | -0.19 | -0.25 | -0.08 | -0.17 |
| 1938 | -0.87 | -1.82 | -2.7 | 1.14 | 1.24 | 1.88 | 2.26 | -0.87 | -0.84 | -1.15 | -1.06 | -1.35 |
| 1939 | -1.79 | 1.55 | -0.61 | -0.72 | -0.82 | -1.07 | -1.03 | 0.41 | -0.06 | -0.68 | -1.13 | -1.56 |
| 1940 | -1.59 | -1.27 | -1.4 | -1.6 | -1.7 | -1.67 | -2.36 | -1.88 | -2.43 | -2.91 | -2.21 | -2.58 |
| 1941 | -2.92 | -3.05 | -2.65 | -2.79 | -3.62 | 1.83 | 2.25 | 2.33 | -0.63 | -1.14 | -1.74 | 1.05 |
| 1942 | 0.7 | 0.58 | 1.37 | 0.75 | 1.07 | 1.22 | 1.54 | 1.73 | -0.23 | -0.75 | -1.06 | -0.84 |
| 1943 | -0.68 | -1.35 | 0.52 | 0.63 | -0.08 | -0.51 | -0.17 | -0.67 | -0.87 | -1.52 | -1.7 | 0.1 |
| 1944 | 0.12 | 0.43 | 1.27 | 1.46 | -0.79 | -1.6 | -1.19 | -1.91 | -2.13 | -1.59 | -1.7 | -2.27 |
| 1945 | -2.62 | -2.59 | -3.23 | -3.34 | -3.1 | -3.11 | -2.93 | 0.19 | 2.75 | 2.29 | 1.76 | 2.97 |
| 1946 | -0.28 | -0.62 | -1.01 | -0.96 | -0.7 | -1.2 | -0.95 | -0.79 | -1.27 | -0.57 | -0.59 | -1.27 |
| 1947 | -1.25 | -1.98 | 0.38 | 0.85 | 0.75 | 0.52 | 1.14 | 1.56 | 1.99 | 1.93 | 3.71 | 4.21 |
| 1948 | 3.89 | 3.99 | 4.18 | 3.38 | 3.63 | 2.76 | 1.97 | 1.3 | 2.07 | 2.51 | 4.02 | 4.13 |
| 1949 | -0.93 | -0.46 | -1.16 | -0.63 | -0.73 | -1.12 | -1.58 | 1.95 | -0.02 | -0.32 | -0.27 | -0.72 |
| 1950 | -1.25 | -2 | -1.77 | -2.1 | -1.91 | -2.18 | -1.26 | -1.45 | -0.86 | -0.87 | -1.01 | -0.6 |
| 1951 | -1.17 | -1.76 | -1.34 | -1.15 | -1.96 | -2.1 | -1.87 | -2.61 | -2.51 | -2.96 | -2.71 | -2.75 |
| 1952 | -3.03 | -2.51 | -1.62 | -1.36 | -0.96 | -1.32 | -2.14 | -0.66 | -0.6 | -0.92 | -1.14 | -1.08 |
| 1953 | -1.28 | -0.65 | -0.83 | -1.18 | -1.39 | -1.45 | -1.9 | -1.78 | -0.99 | -1.59 | -1.79 | -0.65 |
| 1954 | -1.05 | -1.78 | -2.17 | -2.24 | -1.99 | -2.22 | -3.21 | -3.69 | -4.45 | -4.16 | -4.23 | -4.43 |
| 1955 | -3.75 | -3.86 | -4.17 | -3.75 | -3.12 | -2.89 | -2.72 | -2.94 | -2.79 | -2.58 | -2.52 | -3.16 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1956 | -3.52 | -2.73 | -2.57 | -2.17 | -2.48 | -2.68 | -2.85 | -2.99 | -2.37 | -2.04 | -2.4 | -2.75 |
| 1957 | -3.05 | -3.56 | -3.06 | -3.28 | 0.88 | 0.92 | -0.8 | -0.98 | 0.25 | 0.15 | 1.44 | 1.2 |
| 1958 | 1.39 | 1.5 | 1.55 | 2.6 | 2.26 | 2.18 | 2.35 | -0.17 | -0.84 | -0.78 | -1.58 | -1.59 |
| 1959 | -1.59 | 0.46 | 1.06 | 0.88 | 1.35 | 0.88 | 2.74 | 2.43 | 3.89 | 5.72 | 4.78 | 4.45 |
| 1960 | 4.92 | 5.22 | 5.31 | 4.95 | -0.54 | -0.98 | -0.46 | -0.91 | -0.43 | -0.58 | -1 | -1.34 |
| 1961 | -1.4 | 0.75 | 0.62 | 2.25 | 2.28 | 2.39 | 2.54 | 4.12 | -0.38 | -0.85 | -1.18 | -1.26 |
| 1962 | 0.63 | 0.77 | 0.99 | 1 | 0.11 | 0.87 | -0.26 | -0.9 | -0.73 | -1.09 | 0.75 | 0.55 |
| 1963 | 1.3 | 1.27 | -0.42 | -0.53 | -0.53 | -0.17 | -0.17 | -1.13 | 0.46 | -0.7 | 0.7 | 0.93 |
| 1964 | 2.12 | 2.7 | 2.92 | 2.75 | 2.22 | 2 | 3.16 | 4.25 | 4.13 | 6.25 | 5.22 | 5.07 |
| 1965 | 3.96 | 4.22 | 4.82 | 4.4 | 3.29 | 4.5 | 4.7 | 4.33 | 3.98 | 3.68 | 3.27 | 2.34 |
| 1966 | 3.1 | 2.81 | 2.52 | 2.2 | 3.19 | 3.28 | -0.09 | -0.04 | -0.09 | -0.31 | -0.81 | -0.87 |
| 1967 | -0.82 | -0.61 | -1.11 | -1.38 | 1.09 | 0.92 | 1.33 | 2.01 | 1.89 | 1.24 | 1.47 | 1.31 |
| 1968 | 1.76 | -0.67 | -1.23 | 0.01 | 0.07 | 0.88 | 1.34 | -0.63 | -1.4 | 0.6 | 1.11 | 1.12 |
| 1969 | 0.78 | 0.8 | 0.91 | 1.07 | 1.68 | -0.14 | -0.4 | -0.36 | -0.51 | -0.75 | -1.07 | -1.03 |
| 1970 | -1.03 | -1.08 | 0.94 | -0.8 | -1.05 | -1.07 | -1.42 | 0.46 | 0.18 | 0.82 | 0.5 | 0.72 |
| 1971 | 0.91 | 1.03 | 2.3 | 2.23 | 1.99 | 1.93 | 2.78 | 3.22 | 2.7 | 3.11 | 2.84 | 2.16 |
| 1972 | 2.86 | 2.61 | 2.06 | 1.06 | 1.82 | 2.36 | 2.19 | 2 | 1.55 | 1.09 | 1.61 | 2.07 |
| 1973 | 2.32 | 2.86 | 3.09 | 3.24 | 2.95 | 4.97 | -0.24 | -0.28 | -0.56 | -0.98 | -1.72 | -1.25 |
| 1974 | -0.9 | -0.54 | -1.05 | -1.21 | -0.97 | -1.15 | -1.35 | 0.24 | 0.54 | -0.61 | 0.04 | 0.58 |
| 1975 | 0.92 | 1.25 | 1.29 | 1.57 | 2.68 | 2.65 | 3.67 | -0.57 | -0.1 | -0.59 | -0.71 | -0.35 |
| 1976 | -0.13 | -1.04 | -1.26 | -2.05 | 1.09 | 2.42 | 2.28 | 1.56 | 1.57 | 2.11 | 2.62 | 3.57 |
| 1977 | 3.36 | -0.62 | -0.1 | -0.9 | -1.36 | -1.33 | -2.19 | -1.62 | -1.96 | -1.64 | -1.87 | 0.45 |
| 1978 | 1.73 | -0.58 | -0.77 | -0.37 | -0.2 | -0.47 | -0.58 | -0.97 | -1.39 | -1.84 | -1.74 | -2.1 |
| 1979 | 0.46 | 1.52 | 1.03 | 1.53 | 2.06 | 2.21 | 2.4 | 2.06 | 3.58 | 2.95 | 3.29 | 2.73 |
| 1980 | 2.89 | 2.24 | 3.64 | -0.34 | -0.21 | -0.56 | -1.55 | -2.58 | -1.91 | -1.77 | -1.72 | -2.08 |
| 1981 | -2.61 | -2.5 | -2.56 | -2.96 | -2.92 | -2.75 | -2.29 | -1.4 | -2.01 | -1.94 | -2.24 | 1.17 |
| 1982 | 1.53 | 1.67 | 0.69 | 1.39 | 0.77 | 1 | 1.4 | -0.15 | -0.09 | -0.12 | -0.37 | 0.28 |
| 1983 | 0.59 | 1.12 | 2.29 | 2.85 | -0.73 | -1.08 | -1.61 | -2.37 | -2.2 | -2.27 | 0.29 | 1.27 |
| 1984 | 1.42 | 1.6 | 1.84 | 2.23 | 3.43 | 2.82 | 3.46 | -0.35 | -1.06 | -1.48 | -1.84 | -2.64 |
| 1985 | -2.53 | -1.56 | -2.43 | -3.08 | -3.14 | 0.09 | 0.49 | 1.21 | 0.41 | 0.78 | 2.19 | -0.19 |
| 1986 | -0.73 | -1.24 | -1.33 | -2.13 | -2.71 | -3.64 | -4.52 | -3.42 | -3.9 | 0.49 | 1.3 | 1.24 |
| 1987 | 2.46 | 2.59 | 2.79 | -0.6 | -1.28 | -0.89 | -1.47 | -1.72 | 0.86 | 0.64 | 1 | -0.34 |
| 1988 | -0.05 | -0.47 | -0.96 | -0.68 | -0.65 | -0.99 | -1.21 | 0.29 | 0.81 | 0.75 | 0.76 | -0.58 |
| 1989 | -0.95 | -1.11 | 0.22 | 0.66 | 0.78 | 1.53 | 2.42 | 2.34 | 2.99 | 3.16 | 2.86 | 3.24 |
| 1990 | -0.26 | -0.7 | -1.2 | -1.79 | -1.54 | -2.01 | -2.67 | -2.37 | -2.85 | 2.97 | 2.58 | 1.92 |
| 1991 | 2.66 | 1.79 | 2.39 | 2.13 | 2.73 | 2.64 | 3.97 | 4.69 | 4.01 | 3.26 | 2.74 | 2.28 |
| 1992 | 2.17 | 2.06 | 1.6 | 1.33 | 1.26 | 1.76 | 0.92 | 1.72 | 1.6 | 1.87 | 3.03 | 3.1 |
| 1993 | 4.26 | 3.69 | 3.85 | -0.16 | -0.61 | -1.16 | -2.02 | -2.87 | 0.1 | 0.64 | 0.47 | 0.3 |
| 1994 | 0.62 | 0.53 | 0.72 | -0.82 | -1.21 | 0.73 | 0.91 | 1.43 | 1.77 | 2.52 | 2.82 | 3.44 |
| 1995 | 3.86 | 4.39 | 3.42 | 2.24 | 1.45 | 2.64 | 2.43 | 3.25 | 3.18 | 3.57 | 3.74 | -0.02 |
| 1996 | 0.11 | -0.69 | -0.16 | -0.1 | -0.35 | -0.88 | -1.46 | -1.38 | -0.01 | 0.25 | -0.1 | -0.32 |
| 1997 | 0.35 | 0.55 | -0.59 | 0.65 | 0.48 | 1.28 | 1.75 | 1.09 | 1.48 | 2.1 | 2.89 | 3.49 |
| 1998 | 4.39 | 5.04 | 4.84 | 5.07 | 0.04 | -0.46 | -1.25 | -1.93 | -1.29 | -1.75 | -2.22 | -2.38 |

```
1999 -1.74-1.92-2.08-1.86-1.92-1.55-2.08-2.84-2.2 -1.89-2.16-2.41
2000 -0.98-1.55-1.31-1.46-2.25-2.57-2.75-3.06-1.85-2.35-1.79-1.99
2001 -2.1 -2.22-1.52-2.18-2.13-1.48-1.54-2.26-2.47-2.82-3.47-4.31
2002 -4.38-4.74-4.47-4.49-3.43-3.81-4.44-4.240.03 0.47 0.74 1.07
2003 0.59 0.77 1.63 2.59 2.9  3.47 4.47 3.96 3.62 3.7  -0.39-0.4
2004 -0.9 -0.09-1.1 -1.69-2   0.64 0.6  0.83 1.99 -0.43-0.17-0.46
2005 -0.750.23 0.27 0.27 0.49 0.84 1.45 1.4  -1.06-0.99-1.06-0.74
2006 -0.7 -0.59-1.33-1.82-2.010.99 0.28 0.23 0.22 0.3  1.41 1.5
2007 1.46 -0.17-0.41-0.37-1.1 -0.66-1.07-2   -2.77-2.86-3.380.57
2008 0.61 0.71 -0.26-0.1 -0.05-0.63-0.860.83 0.77 1.27 2.43 -0.02
2009 -0.43-0.730.18 0.09 0.84 0.91 -0.03-0.64-1.390.77 1.38 3.09
2010 3.26 -0.04-0.36-1.04-1.39-1.63-1.62-1.4 -1.81-2.01-2.33-2.7
2011 -3.02-2.84-2.27-2.02-1.99-2.41-3.02-3.23-2.77-2.5 -2.48-2.93
2012 -3.25-3.35-3.6 -3.630.66 0.83 0.96 1.87 -0.38-0.65-0.73-0.48
;

proc freq data= b2;
tables period*year/list;
run;

/**

class      PDSI range
Severely Dry          -3 or less
Excessively Dry       -2 to -3
Abnormally Dry        -1 to -2
Slightly dry/Favorably Moist        -1 to 1
Abnormally Wet        1 to 2
Wet        2 to 3
Excessively Wet       3 or greater

***/

data bb2 (KEEP= PERIOD  YEAR JAN--DEC  N_SEVdry  n_EXCDry  n_ABNDry
n_SLGDry  n_ABNWET  n_NORWEt   n_EXCWET) ;
set b2;  by year;
array PDSI {12} Jan--Dec;
Array SevDry {12} SevDry1-SevDry12;
Array EXCDRY {12} EXCDRY1-EXCDRY12;
Array ABNDRY {12} ABNDRY1-ABNDRY12;
Array SLGDRY {12} SLGDRY1-SLGDRY12;
Array ABNWET {12} ABNWET1-ABNWET12;
Array NORWET {12} NORWET1-NORWET12;
```

```
Array EXCWET {12} EXCWET1-EXCWET12;
do i=1 to 12;
 SevDry{i}=  1*(PDSI{i} LE -3);
 EXCDry{i}=  1*(PDSI{i} LE -2 AND PDSI{i} GT -3);
 ABNDry{i}=  1*(PDSI{i} LE -1 AND PDSI{i} GT -2);
 SLGDry{i}=  1*(PDSI{i} LT  1 AND PDSI{i} GT -1);
 ABNWET{i}=  1*(PDSI{i} LT  2 AND PDSI{i} GE  1);
 NORWET{i}=  1*(PDSI{i} LT  3 AND PDSI{i} GE  2);
 EXCWET{i}=  1*(PDSI{i} GE  3);
END;
N_SEVdry=0;
n_EXCDry=0;
n_ABNDry=0;
n_SLGDry=0;
n_ABNWET=0;
n_NORWEt=0;
n_EXCWET=0;
DO I= 1 TO 12;
n_SevDry= N_sevdry + sevdry{i} ;;
n_EXCDry= N_EXCdry + EXCdry{i} ;;
n_ABNDry= N_ABNdry + ABNdry{i} ;;
n_SLGDry= N_SLGdry + SLGdry{i} ;;
n_ABNWET= N_ABNWET + ABNWET{i} ;;
n_NORWET= N_NORWET + NORWET{i} ;;
n_EXCWET= N_EXCWET + EXCWET{i} ;;
end;
If last.year then output  ;
run;

PROC PRINT DATA=BB2;
RUN;

PROC MEANS DATA=BB2 NWAY NOPRINT;
  CLASS PERIOD;
  VAR  N_SEVdry  n_EXCDry  n_ABNDry  n_SLGDry  n_ABNWET  n_NORWEt
n_EXCWET;
  OUTPUT OUT=OUTMN (DROP=_freq_ _type_)  SUM=;
  RUN;

  PROC SORT DATA=OUTMN;
    BY PERIOD;
     RUN;
```

```
     PROC  TRANSPOSE DATA=OUTMN  name=catPDSI  OUT=OUTP PREFIX=P;
     VAR N_SEVdry  n_EXCDry  n_ABNDry  n_SLGDry  n_ABNWET  n_NORWEt
n_EXCWET;
     ID PERIOD;
     RUN;


 proc format ;
 value $  fmtpdsi
 N_SEVdry ="Severely Dry"
 n_EXCDry = "Excessively Dry"
 n_ABNDry = "Abnormally Dry"
 n_SLGDry = "Slightly dry/Favorably Moist"
 n_ABNWET = "Abnormally Wet"
 n_NORWEt = "Wet"
 n_EXCWET = "Excessively Wet" ;
run;



ods listing close;
ods tagsets.rtf  file="PDSI_columbia_sas.rtf";;
title "COUNT days by period and PDSI category";
     PROC PRINT DATA=OUTP;
    format   catPDSI   $fmtpdsi.;
     RUN;
     quit;

     ods tagsets.rtf close;
     ods listing;
```

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 178/146228, June 2018

National Park Service
U.S. Department of the Interior

**Natural Resource Stewardship and Science**
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