



Seeps and Springs Inventory, Chattahoochee River National Recreation Area

Level 1 Report



Ravine spring at the Chattahoochee River National Recreation Area.

NPS / THOMAS MCCOY-BRUCE

Seeps and springs inventory, Chattahoochee River National Recreation Area: Level 1 report

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Abstract

Research on seeps and springs in the eastern United States is limited and few protocols for documenting and inventorying these valuable eastern ecosystems have been established. In the Chattahoochee River National Recreation Area (CRNRA), seeps and springs may host species of concern and represent hotspots of biodiversity within an already biodiverse park. This project's goal was to survey the entire park to identify seeps and springs, collect location data, document the hydrogeology and ecology of these systems, and determine sites for future study. Additionally, classification terminology was adapted from the Springs Stewardship Institute's Springs Ecosystem Inventory Protocols to create a classification scheme for seeps and springs in the Piedmont ecoregion (Stevens and Ledbetter 2023; A. Cressler, personal communication). These classifications were primarily based on the morphology and hydrologic conditions of the emergence point of the springs, which influence the structure of the spring and the habitats it may support. Seeps and springs were divided into four broad morphological categories: ravine, hillslope, floodplain, and bluff.

The data from this study has already conveyed benefits to natural and cultural resource management in the CRNRA. GIS layers have been updated to include seeps and springs sites in consideration for future project authorization, which will help preserve the delicate structure of these ecosystems. Information concerning historic structures associated with seeps and springs has been documented. In addition, the park now has an extensive dataset of floristic species presence and water quality measurements spanning the length of the park, which can be used as reference data in future studies. Further in-depth studies of a smaller number of seeps and springs will be undertaken in a planned Level 2 study.

Introduction

Seeps and springs create valuable habitat for a diverse array of wildlife through stable year-round temperatures and consistent freshwater supply. Existing research concerning springs ecosystems in the eastern United States is sparse, and there are few established protocols for documenting and creating inventories of these systems. In the Chattahoochee River National Recreation Area (CRNRA), seeps and springs may host species of concern and represent hotspots of biodiversity within an already biodiverse park. The CRNRA seeps and springs inventory project intends to create a comprehensive GIS database of seeps and springs habitats existing within the park boundaries and to document the hydrogeology and ecology of these systems.

Level 1 of the inventory involved surveying the park to identify seeps and springs, collect location data, and determine sites for future study. Success for Level 1 was defined by mapping 90 percent of seeps and springs occurring within the park. While 100 percent of springs encountered were documented, we reasonably expect that we have not recorded all springs within the park given the inaccessibility of some park areas. The 90 percent number represents the result of a thorough inventory process while leaving some flexibility given the park's complex geography. Expected products include maps showing the locations of seeps and springs within the CRNRA, GIS data layers in ArcGIS, and a written report synthesizing collected information.

Field work for Level 1 was conducted from June to December of 2023. During that time, 226 distinct seeps and springs sites were documented, representing the result of surveying over 4,000 acres of park land. Of these sites, 25 were selected to study in-depth in the Level 2 monitoring process. The data collected from this inventory will allow the CRNRA to understand, protect, and manage seeps and springs, which have previously remained undocumented throughout much of the park.

Background

Overview of the Park

The Chattahoochee River National Recreation Area (CRNRA) is a unit of the National Park Service that includes about 48 miles of the Chattahoochee River as well as approximately 5,300 acres of adjacent land within its authorized boundary. The CRNRA provides recreational opportunities for the over 3.5 million people living in the Atlanta metropolitan area and beyond, preserving the natural resources of one of the oldest and most stable river corridors in the eastern United States.

The geology of the CRNRA along the Brevard Zone reflects the complex natural history of the southern Appalachians and Piedmont and is considered one of the park's fundamental values. This unique geology is also responsible for the development of seeps and springs within the park. While the park is solidly located within the Piedmont ecoregion, it sits at the interface of the Blue Ridge Mountains, Piedmont, and Atlantic Coastal Plain. The park's location gives it a crucial role in the conservation of biodiversity in the state of Georgia, as it preserves critical habitat for migratory birds, bats, fish, amphibians, plants, and invertebrates (National Park Service 2017).

Seeps and Springs

Seeps and springs refer to ecosystems where groundwater meets the surface, effectively serving as the transition zone between groundwater and surface water systems (Stevens and Ledbetter 2023). In the southeastern United States, many springs form the headwaters of major stream systems, but the majority of springs are typically small in area and discharge. The distinction between 'seeps' and 'springs' is often unclear due to seasonal changes in baseflow, and it is often more semantic than based in specific qualities (O'Driscoll et al. 2019). In the Piedmont, seeps and springs represent one of the few opportunities for scientists in the Southeast to understand natural interactions between groundwater and surface water.

Seeps and springs provide a vast diversity of habitat types through varying slopes and moisture conditions that support sizable communities of plants, animals, and other organisms. Virtually all springs habitats are wetland ecosystems, regardless of scale, and so provide many of the same benefits to biodiversity and ecosystem productivity as other types of wetlands. Additionally, the structure of springs often creates multiple microhabitats, each of which can foster a unique suite of organisms that may interact across a relatively short distance. Some seepage areas in the CRNRA closely resemble floodplain wetlands, while others are small headwater springs in a dry, sandy ridgetop forest. This habitat diversity is reflected in the diversity of plant species recorded in the vicinity of springs sites, with numerous species ranging from obligate wetland (>99% occurrence exclusively in wetlands) to upland species (>99% occurrence exclusively outside of wetlands).

Additionally, the small stream ecosystem provides important habitat for salamanders, aquatic macroinvertebrates, and the species that feed on them. These headwater springs tend to have small catchment sizes and may be relatively free from human influence when located within the CRNRA boundaries, which provides habitat refuges for pollution-intolerant organisms within the Atlanta metropolitan area. Species of concern which may depend on seepage areas and springs habitats in the

southeastern Piedmont include the white fringeless orchid (*Platanthera integrilabia*), seepage salamander (*Desmognathus aeneus*), and Piedmont blue burrower (*Cambarus harti*).

Geologic Influences on Groundwater

The composition and structure of geologic units is in many cases the primary driver of surficial features, including ridges, stream valleys, and natural springs. To understand the processes that drive seeps and springs in the CRNRA, we first investigated the mechanics of groundwater storage and movement through bedrock and the park's underlying geology. A basic understanding of the local geology allowed us to predict and interpret the locations of seeps and springs on the landscape.

In general, groundwater refers to any water beneath the earth's surface. Most commonly, groundwater can be found occupying pore spaces within sediment and rocks. The amount of groundwater that can be stored within a particular rock unit is directly related to the amount of pore spaces in the rock (total porosity) and how connected those pore spaces are (effective porosity). Many major groundwater aquifers are associated with rock units that possess high primary porosity, meaning that their crystal structures naturally contain abundant spaces between mineral grains that water can occupy (Woessner and Poeter 2020). The crystalline rocks of the eastern Blue Ridge and Piedmont, however, are almost completely lacking in primary porosity, as the metamorphic processes that formed the Appalachians have effectively fused most mineral grains together.

Most groundwater storage in Blue Ridge and Piedmont crystalline rocks derives from secondary porosity, such as fractures and joints, which create additional spaces within the rock units for groundwater to occupy (Fernandes et al. 2023). Unlike primary porosity, secondary porosity through fracture is largely unpredictable and not inherent to the rock unit itself, making groundwater resources more difficult to track and identify in crystalline rock aquifers.

In the Piedmont and Blue Ridge regions of the southeastern United States, the main source of groundwater is crystalline bedrock aquifers. In these aquifers, groundwater is mostly constrained outside of the bedrock itself and is instead only found in fractures within the bedrock (Fernandes, Rouleau, and do Amaral Vargas Jr. 2023). The nature of groundwater resources in the region, therefore, means that individual points where groundwater reaches the surface are likely to be small, distinct, and spatially disparate compared to regions with permeable rock aquifers (such as the large Atlantic Coastal Plain aquifer). Unfortunately, the distribution of our groundwater resources means that it is much more difficult to map groundwater potential and transport in the Piedmont than it is in other regions of the country.

Although secondary porosity and fracture orientation cannot be easily predicted alone, fractures are much more likely to occur in rock units and areas with established planes of weakness. Examples of these weak points include the layering processes of metamorphism in foliated metamorphic rocks and contacts between major lithological units. In the CRNRA, the course of the Chattahoochee River largely follows the Brevard Zone, a major plane of deformation running roughly parallel to the Blue Ridge Mountains to the north. This fault zone is a complex formation of multiple faults and deformation events, all of which contribute to the likelihood of fractures and therefore the

development of secondary porosity. While there is no exact correspondence between fault lines, geologic contacts, and aquifer locations, investigating surface conditions around these planes of weakness can often yield more groundwater resources than searching in other areas.

An additional source of structural weakness in Piedmont rocks comes from major fold axes; these lines indicate areas that have been folded and deformed during mountain-building processes and are thus subject to additional strain along the fold axis. Multiple fold axes intersect the study area along the Chattahoochee River from Buford Dam south to the Palisades.

Despite the relative impermeability of Piedmont rocks, some units tend to have larger and more extensive pore connections, creating patches of rock with relatively high primary porosity. In the CRNRA, these units include the ridge-forming quartzites, including the Chattahoochee Palisades Quartzite (Ccp), which occurs in several major lenses along the Brevard Zone that cross the Chattahoochee River within the study area.

Piedmont Springs Ecology

Piedmont seeps and springs are unfortunately not well-researched, but what little information is present identifies their ecosystems as similar in nature to other headwater wetland ecosystems. These ecosystems are often described as containing a mix of Piedmont and Coastal Plain species. Dominant species in these ecosystems include eastern red maple (*Acer rubrum* var. *rubrum*), black gum (*Nyssa sylvatica*), tulip poplar (*Liriodendron tulipifera*), American holly (*Ilex opaca*), winterberry (*Ilex verticillata*), possumhaw viburnum (*Viburnum nudum*), cinnamon fern (*Osmundastrum cinnamomeum*), American royal fern (*Osmunda spectabilis*), netted chain fern (*Woodwardia areolata*), and peat moss (*Sphagnum* spp.) (NatureServe 2024). Because these sites are small and often blend in with the larger canopy of a forested area, not much is known about their function or unique properties. Several researchers have suggested that the constant saturation in Piedmont seeps may provide habitat refuge for water-dependent species during periods of drought or fire. Additionally, the consistent temperatures provided by an influx of groundwater help keep conditions in the seep more stable than the surrounding environment, providing an ideal habitat for species vulnerable to rapid temperature changes (Culver, Pipan, and Gottstein 2006).

In a broader systems perspective, seeps and springs provide a crucial linkage between surface water and groundwater systems and thus play a valuable role in the habitat structure and food webs of Piedmont ecosystems. The baseflow provided from springs forms the year-round consistent base level flows of small streams, which maintains proper conditions for riparian flora and fauna. Even some seeps can provide consistent connection between groundwater and surface water systems, despite expressing less flow on the surface (O'Driscoll et al. 2019).

Historical Value of Seeps and Springs

Throughout history, human settlement patterns have been driven by the availability of fresh potable water. With their consistent baseflow from groundwater, seeps and springs likely represented an important source of drinking water for early hominins, value which has carried into the present (Cuthbert and Ashley 2014). Within the park, historical and archaeological records indicate activity

surrounding several springs, including the spring box at Hewlett Lodge (site IF01) and a springhead surrounded by a stone wall and agricultural terraces in the Gold Branch unit (site GB10). The Gold Branch site displays signs of human activity dating as far back as the Early Archaic period, around 8000–6000 BCE (Gerdes, Messer, and Jones 2007).

Seeps and Springs Inventory

This project is intended to produce a comprehensive database of seeps and springs ecosystems within the Chattahoochee River National Recreation Area (CRNRA). The inventory process will be divided into three phases (or Levels) as outlined first by the Springs Stewardship Institute (Stevens and Ledbetter 2023). The following description of each level is adapted from Stevens and Ledbetter's Springs Ecosystem Inventory Protocols, published by the Institute (2023).

- Level 1 Inventory involves a rapid reconnaissance survey of springs within a landscape or land management unit, including brief (10–20 min./site) visits by 1–2 staff for the purpose of georeferencing, clarifying access, and determining sampling equipment needs.
- Level 2 Inventory is a detailed inventory of a springs ecosystem to describe baseline physical, biological, human impacts, and administrative context variables.
- Level 3 Inventory involves monitoring of springs selected for long-term studies, and includes variables measured in multiple Level 2 inventories, as well as other variables relevant to monitoring programs.

While the protocols and inventory methods proposed by the Springs Stewardship Institute are effective for delineating and classifying the spring ecosystems of the arid Western United States, these methods are not sufficient for identifying seeps and springs of the Southeastern Piedmont. Therefore, the operating procedures and methods outlined in this handbook do not necessarily reflect those produced by Stevens and Ledbetter and have been tailored for Southeastern ecosystems by professionals from the U.S. Geological Survey and CRNRA.

The Level 1 Inventory was developed and conducted from June to December of 2023 and involved extensive field surveys of 14 of the park's 15 distinct land units. The only land unit not surveyed, Suwanee Creek, was excluded due to the relatively flat topography of the unit, its low overall potential for hosting seeps and springs, and the prioritization of other more critical land units.

Survey Methods

Protocols for conducting seeps and springs surveys were formulated using the existing process documented by Stevens and Ledbetter (2023). Modifications to the Springer protocol were made in collaboration with subject-matter experts from the U.S. Geological Survey (A. Cressler, personal communication).

Level 1 seeps and springs surveys are brief initial site visits to document the site coordinates and major features. In addition to these primary objectives, the inventory also documented the spatial extent of the site, flow consistency, conductivity and water temperature, and identifiable plant species present. All data were collected using an ArcGIS Survey123 form that was developed specifically for our protocol, and the form information was synchronized with an ArcGIS Online web layer for ease of access and management (Environmental Systems Research Institute 2024).

Survey Form Overview

The intake form for springs inventory surveys is divided into six sections: General Information, Weather Conditions, Site Overview, Spring Overview, Spring Details, and Additional Notes. The General Information section records the project and protocol being used, the surveyors conducting the inventory, and the survey begin time and date. The Weather Conditions section documents current weather conditions, recent precipitation trends, and the stage of nearby streams, if known. The Site Overview section includes the coordinates of the site, CRNRA land unit, a unique identifier, access directions, and overview images of the site. The Spring Overview section includes a brief description of the spring ecosystem, comments about ecological conditions such as herbivory, invasive species, and human alterations, and the spring classification and hydrology. The Spring Details section includes the identification of emergence points, collection of conductivity and water temperature measurements, and plant species identification, as well as the submission of a sketch map detailing the overall structure of the site. The Additional Notes section provides space for any additional notes or comments pertaining to the survey or site as well as an option to flag the site for follow-up in a later inventory. A more detailed description of the Survey123 form and associated inventory protocols can be found in Appendix I: Seeps and Springs Inventory Level 1 Protocols.

Conductivity and Temperature Measurements

Conductivity and temperature readings were conducted using an Oakton ecoTestr Conductivity/Temperature/Salinity handheld probe (Cole-Parmer). The meter was calibrated with a one-point calibration using a 1410 $\mu\text{S}/\text{cm}$ conductivity standard and cleaned with purified distilled water or deionized water prior to all field outings. All conductivity readings were measured to the nearest 10 $\mu\text{S}/\text{cm}$ in specific conductivity. Temperature readings were measured to the nearest 0.1°C.

Specific locations to collect water quality measurements were identified at each site during the survey process. Before collecting measurements, the location was marked on the site sketch map and documented in the Survey123 inventory form using a brief description. The Level 1 inventory form contains space for up to 5 sets of conductivity and temperature readings. In some locations, there was

insufficient flowing water to collect water quality readings. These sites do not have recorded temperature and conductivity values.

Plant Species Identification

Plant species were identified in the field to species level whenever possible using *Weakley's Flora of the Southeastern United States* (Weakley and Southeastern Flora Team 2024). In addition, mobile applications were used as a supplement to floristic keys and for rapid observation, including iNaturalist and PictureThis. Specimens without identifying characteristics necessary for species-level identification were identified to the genus level. In the case that voucher specimens were necessary, specimens were collected and preserved by NPS staff for later identification. Where voucher specimen collection was not necessary, photos displaying critical identification characteristics of each specimen were captured to assist in later identification attempts. Bryophyte floras were documented with tentative field names and typically not identified to the species level with some exceptions. Plant species were recorded on a presence/absence basis at each site as an initial qualitative survey for Level 1 data collection.

Fauna Identification

If fauna were present, an opportunistic attempt at identification was made to the most precise taxonomic level possible, and the occurrence was documented in the survey notes. This level of the seeps and springs inventory did not attempt to categorically examine fauna species richness and diversity. Images were captured for notable fauna; otherwise, the occurrence was documented in the survey form. Examples of observations made during site visits include evidence of deer browsing/bedding, crayfish tunnels and burrows, and clumps of soil produced by worm burrowing/tunneling.

GIS Analysis

Following data collection, site location data was integrated into an ArcGIS database to analyze bedrock geology, vegetation community, and hydrologic drainage patterns for each site (Environmental Systems Research Institute 2024). Geologic map shapefiles were adapted from the Geologic Resources Inventory for the CRNRA (Thornberry-Ehrlich 2022). Due to the lack of precise geologic map data for the northern half of the study area, the geologic map layers for the CRNRA are divided into two sections: the more detailed southern unit based on the work of Higgins et al. (2003) at a 1:100,000 scale (CHTS), and the less detailed northern area based on the work of Dicken et al. (2005) at a 1:500,000 scale (CHTN). Figure 1 shows the area of the park covered by each digitized geologic map.

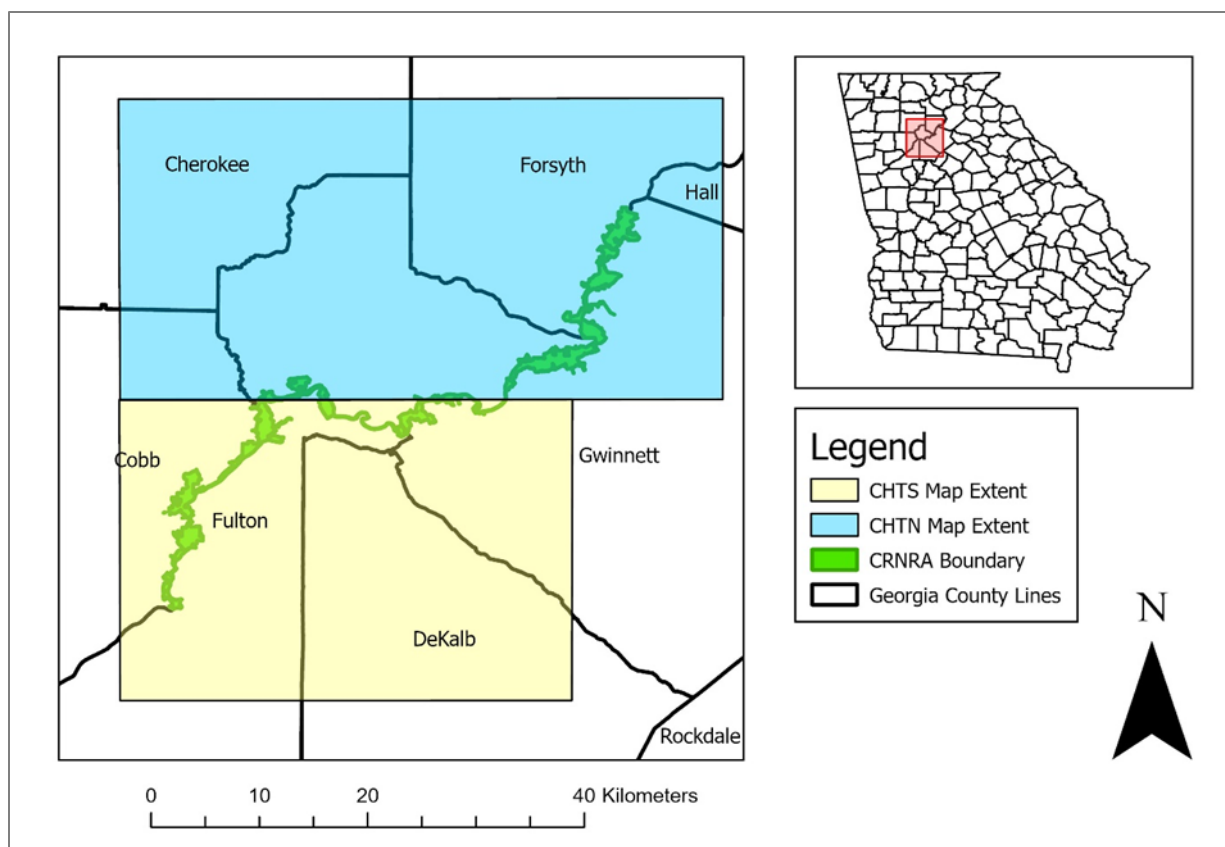


Figure 1. Overview map of the Chattahoochee River National Recreation Area (green) and the extent of the two geologic maps used for GIS analysis: CHTN (blue) and CHTS (yellow).
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Vegetation community shapefiles were adapted from the Vegetation Mapping Inventory Project for the CRNRA (Cotten et al. 2019). Each polygon in this dataset was assigned a Community Element Global (CEGL) code by professionals based on satellite imagery of the park area. Data points were verified in the field to confirm the accuracy of classification.

Drainage patterns and stream segments were calculated from a digital elevation raster produced by the U.S. Geological Survey's National Elevation Dataset at a 1/3 arcsecond resolution using the `r.watershed` and `r.water.outlet` functions in QGIS with GRASS (U.S. Geological Survey 2019; QGIS.org 2023). The raster outputs from stream segment calculation were vectorized and imported into ArcGIS Pro as line shapefiles. Based on field observations, these segments were characterized as perennial (consistent year-round flow sufficient to produce a stream channel), intermittent (flowing area sourced from a headwater spring that may experience periods of no/low flow) and ephemeral (no groundwater input, flowing water only during intense rainfall).

A final ArcGIS Online web layer was created containing the point data for all 226 sites, with associated attribute fields for local geology, vegetation community, and watershed data, as well as all data and images collected in field surveys. The distance to the nearest bedrock geologic contact for each spring site in the CHTS geologic map was calculated using the Near function in ArcGIS

Desktop and included in the web layer. The average conductivity and temperature measurement for each site was calculated from data entered into the ArcGIS Survey123 form using the Calculate Field tool in ArcGIS Online (ESRI 2024).

Methods for Identifying Seeps and Springs

The most difficult aspect of establishing a seeps and springs survey is first locating the springs. To accomplish this, we employed existing knowledge from park staff and volunteers. After further contact with the volunteers and the park's volunteer coordinator, we recruited a group of ten to assist in survey efforts. Volunteers who knew of existing spring locations joined park staff on survey outings to identify and document these springs, as well as providing additional personnel for longer surveys in less-studied units of the park.

Another crucial method for identifying Piedmont seeps and springs is using topography and drainage patterns to infer where springs are likely to occur. Using the stream segments map derived from elevation data, we were able to target our search to ravines and stream valleys first, which allowed us to identify the headwater springs of first-order streams which originate within the park. This technique also allowed us to ignore areas which were unlikely to host notable springs, such as the large floodplain wetlands along certain segments of the Chattahoochee River. A consequence of this technique, however, is that our data likely reflects a sampling bias in favor of ravine-influenced springs, which may have led to the omission of other more remote springs of different types.

Classifying Seeps and Springs

We adapted the classification terminology provided by the Springs Stewardship Institute's Springs Ecosystem Inventory Protocols to create a classification scheme for seeps and springs in the Piedmont ecoregion (Stevens and Ledbetter 2023; A. Cressler, personal communication). These classifications are primarily based on the morphology and hydrologic conditions of the emergence point of the springs, which influence the structure of the spring and the habitats it may support. Seeps and springs were divided into four broad morphological categories: ravine, hillslope, floodplain, and bluff. These categories omit many of the features suggested by Stevens and Ledbetter, which are more specific to the arid conditions of the Southwestern United States and focus instead on the conditions most commonly found during field surveys (2023).

Ravine seeps and springs emerge from a defined stream channel and are subject to regular flood scour from surface flow. More likely to be springs than seeps. Often perceived as the 'headwaters' of a perennial stream. Corresponds to Rheocrene sites in the Stevens and Ledbetter classification (2023).

Hillslope seeps and springs emerge from featureless slopes in upland habitats and are not subject to scour from stream channel flooding. These sites are common as seeps and springs, and they also feed every historic spring house found in the park.

Floodplain seeps and springs emerge on or adjacent to the bank of a perennial stream or within the margins of a larger floodplain. Depending on discharge volume, they may flow directly into the stream, or transfer water through saturated sediment. These sites are often seeps and easily overlooked. They are subject to scour from the stream channel but may not

directly contribute to streamflow like ravine springs. Corresponds to Helocrene sec. Rheocrene (floodplain seeps) and Hillslope sec. Rheocrene (floodplain springs) sites in the Stevens and Ledbetter classification (2023).

Bluff seeps and springs occur in association with bedrock outcrops, often manifesting as a dripping or wet rock surface with hydric vegetation. Flow can be nearly undetectable provided that the rock surface is consistently wet and water-loving flora and fauna inhabit the area. Corresponds to Hanging Gardens in the Stevens and Ledbetter classification (2023).

During surveys, newly identified springs were placed into one of these four broad categories, as well as being given the designation of ‘seep’ or ‘spring’ based on a qualitative assessment of discharge. If the site had sufficient discharge to produce a flowing outlet stream which continued beyond the vicinity of the emergence area, it was considered a spring; if not, it was considered a seep. For more information on methods for classifying seeps and springs, see Appendix III: Classification of Seeps and Springs.

Results

Survey Summary

Between June and December 2023, 226 unique seeps and springs sites were documented as part of the CRNRA seeps and springs inventory (Table 1). This inventory was the result of surveying nearly 4,400 acres of park land that was potentially suitable for these habitats. Sites were identified over 65 different survey outings with a total of over 400 person-hours dedicated to survey time alone. Survey participants included six NPS staff and interns as well as ten park volunteers for a total of 16 surveyors contributing to the inventory, representing over 160 hours of volunteer service to the park.

Table 1. Summary of area covered in seeps and springs inventory, sorted by land unit subdivisions. Survey acreage is approximate based on estimate using geospatial data.

Unit Name	Major Unit	Acres Surveyed	Sites Identified
Bowmans Island West	Bowmans Island	185	6
Bowmans Island East	Bowmans Island	590	25
Orrs Ferry	Orrs Ferry	115	1
Settles Bridge	Settles Bridge	120	2
McGinnis Ferry	McGinnis Ferry	155	3
Abbotts Bridge	Abbotts Bridge	210	2
Medlock Bridge	Medlock Bridge	40	1
Jones Bridge	Jones Bridge	170	4
Holcomb Bridge	Holcomb Bridge	30	0
Island Ford South	Island Ford	225	30
Island Ford North	Island Ford	55	2
Vickery Creek (incl. Allenbrook)	Vickery Creek	300	11
Gold Branch	Gold Branch	420	10
Hyde Farm	Johnson Ferry	135	26
Johnson Ferry North	Johnson Ferry	160	3
Johnson Ferry South	Johnson Ferry	70	0
Sope Creek	Cochran Shoals	320	24
Cochran Shoals	Cochran Shoals	425	13
Powers Island	Cochran Shoals	80	9
East Palisades	Palisades	260	29
West Palisades	Palisades	320	25
TOTAL	–	4,385	226

The Island Ford unit had the greatest density of springs per square kilometer, representing the greatest concentration of springs documented within the park (Table 2). The greatest concentration of springs across the park occurred in the northernmost and southern units, with more than half of

spring sites being located downstream of Morgan Falls Dam in the Johnson Ferry, Cochran Shoals, and Palisades units. The apparent lack of seeps and springs in the middle units of the park is likely a consequence of the CRNRA boundaries. In the middle and northern units of the park (from Holcomb Bridge to Settles Bridge), most of the park land is immediately on the banks of the Chattahoochee River. Thus, a large portion of the park land in this area is floodplain wetlands, which typically do not create conditions favorable for visible seeps and springs (Figure 2).

Table 2. List of CRNRA primary park units surveyed, area in square kilometers, and seeps and springs site density.

Unit Name	Area (km²)	Number of Sites	Site density (sites/km²)
Bowmans Island	3.13	31	9.9
Orrs Ferry	0.47	1	2.2
Settles Bridge	0.49	2	4.2
McGinnis Ferry	0.63	3	4.8
Abbotts Bridge	0.85	2	2.3
Medlock Bridge	0.17	1	5.8
Jones Bridge	0.68	4	5.9
Holcomb Bridge	0.13	0	0.0
Island Ford	1.14	32	28.1
Vickery Creek	1.20	11	9.2
Gold Branch	1.70	10	5.9
Johnson Ferry	1.48	29	19.6
Cochran Shoals	3.33	46	13.8
Palisades	2.35	54	23.0

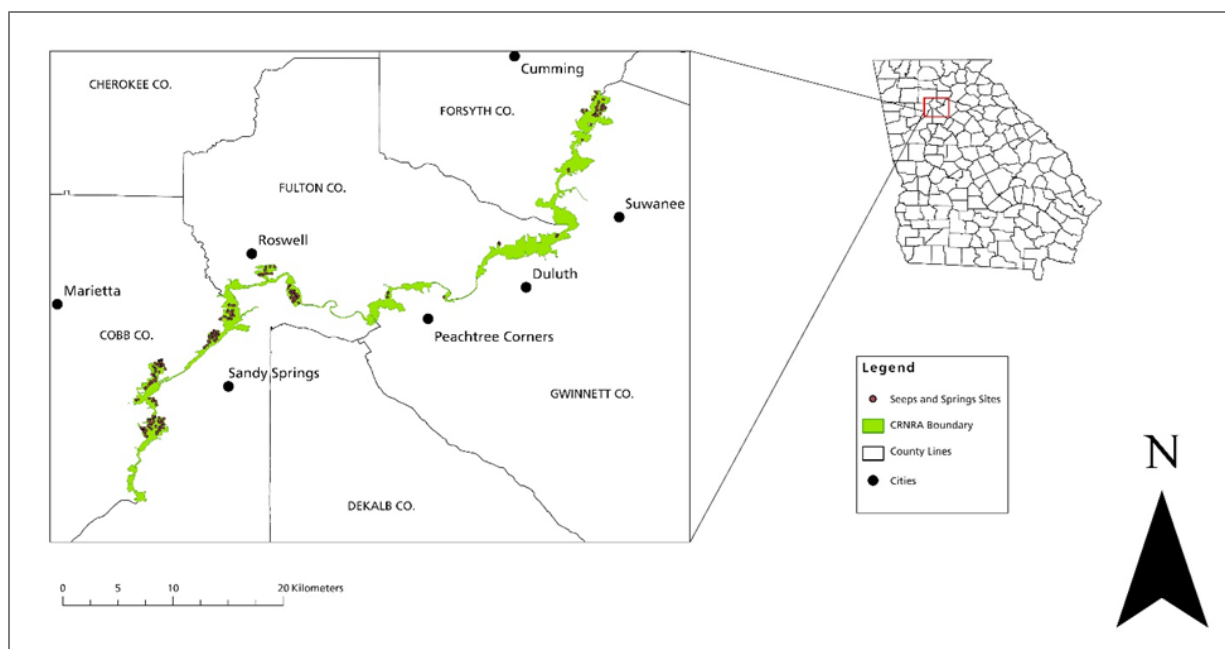


Figure 2. Overview map of the Chattahoochee River National Recreation Area and distribution of seeps and springs inventory sites in the park. Nearby counties and cities are labeled for reference.
NPS / THOMAS MCCOY-BRUCE

Spring Classification

In the CRNRA, the overwhelming majority of seeps and springs fall into the ravine category as the headwaters of first-order streams (Figure 3). However, the other spring types are frequently encountered in specific morphological settings, such as the steep slopes and extensive rock outcrops in the Palisades area. As mentioned previously, it is possible that some degree of sampling bias was introduced by our survey methods, as we used stream segment modeling to determine ideal sites to survey for springs. However, we find it unlikely that more than 10% of total springs in the study area remain undocumented, making ravine springs overwhelmingly the dominant spring type.

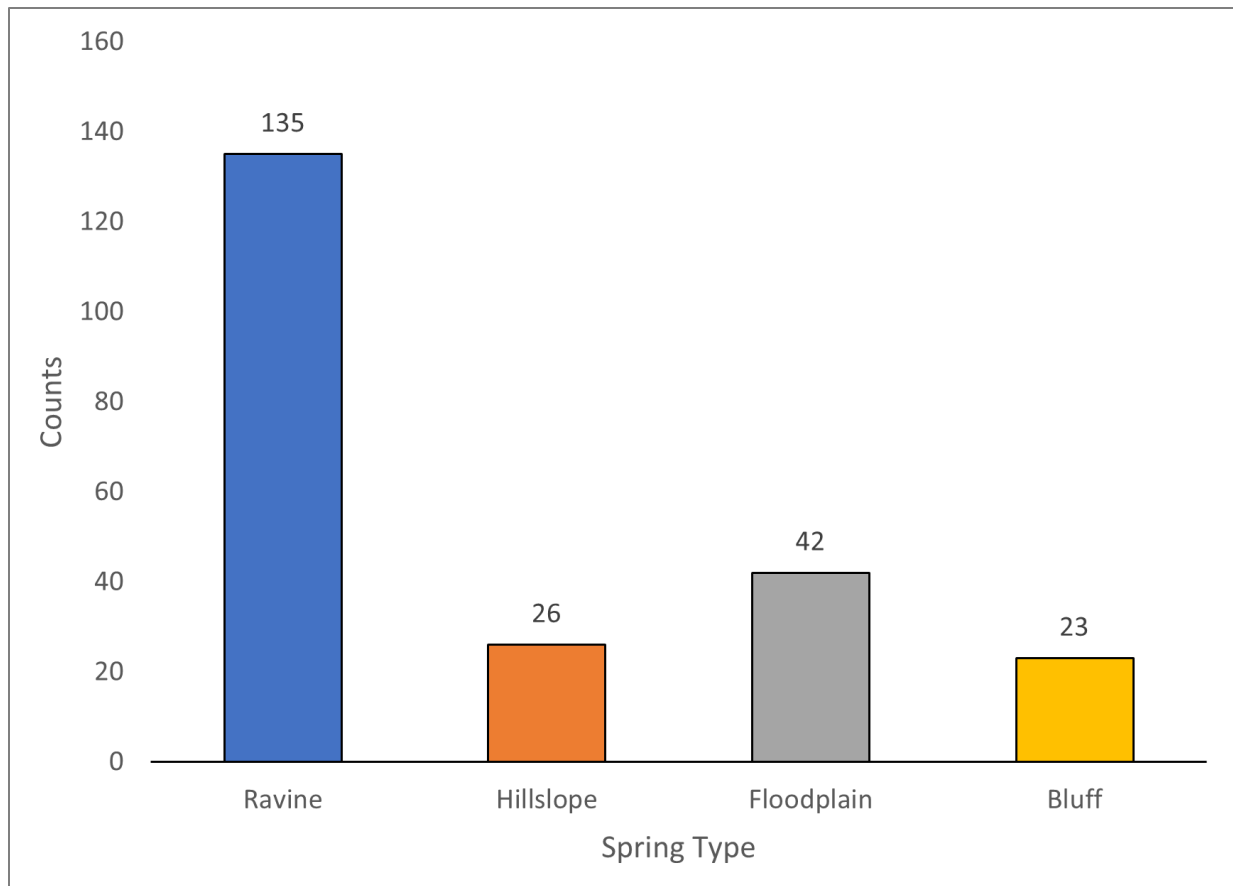


Figure 3. Distribution of seeps and springs in the Chattahoochee River National Recreation Area by spring type. Ravine seeps and springs account for over half of all springs documented in the CRNRA. NPS / THOMAS MCCOY-BRUCE

Seeps and springs were categorized into two ‘flow classes’ based on the volume of discharge and morphology. Seeps represent diffuse flow at low discharge, while springs represent concentrated/channelized flow at moderate to high discharge. As previously discussed, the distinction between seeps and springs can be slightly arbitrary (see O’Driscoll et al. 2021), so we labeled sites as seeps or springs based on the overall extent of persistent base flow. Different spring types displayed different proportions of sites in each flow class (Figures 4–5). Of the 226 seeps and springs identified, 67 were classified as seeps and 159 were classified as springs.

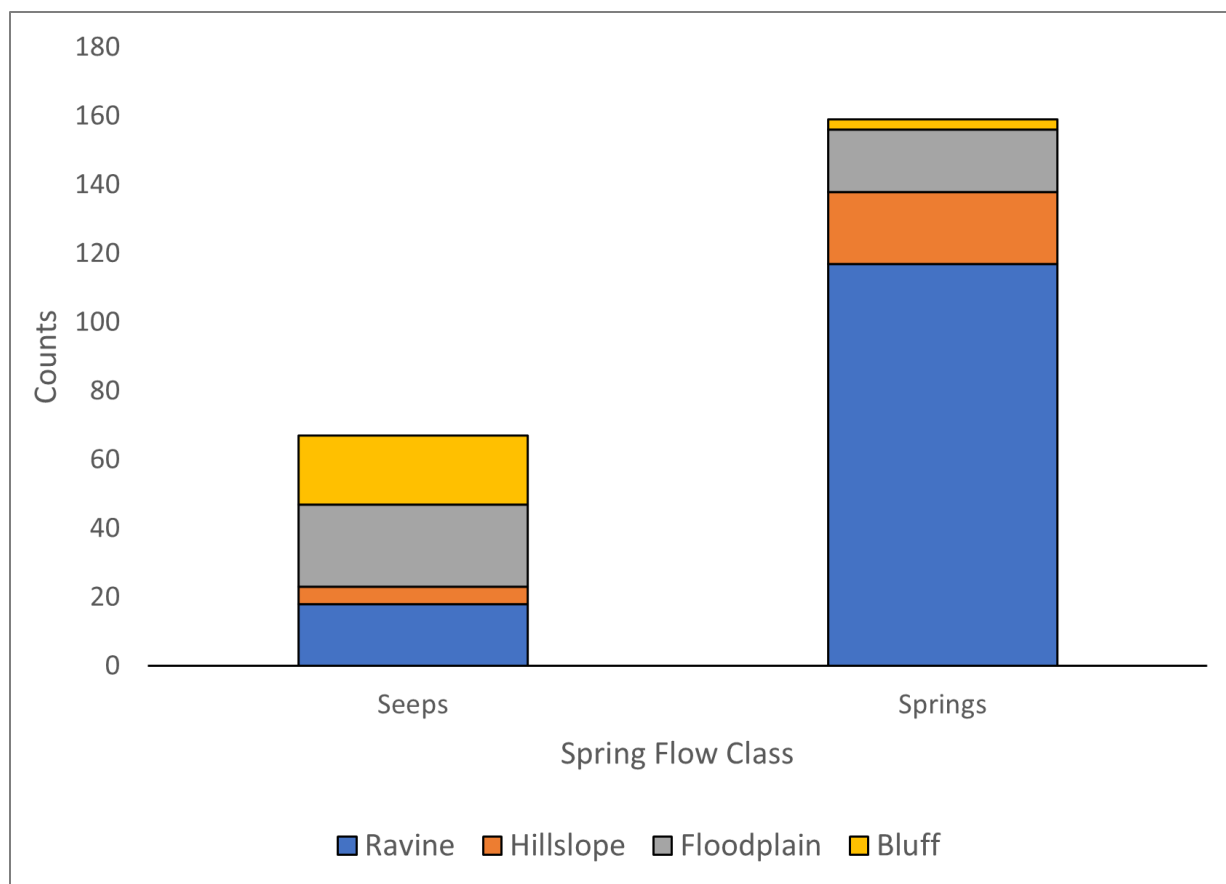


Figure 4. Seeps and springs in the Chattahoochee River National Recreation Area classified by flow class (seep or spring).

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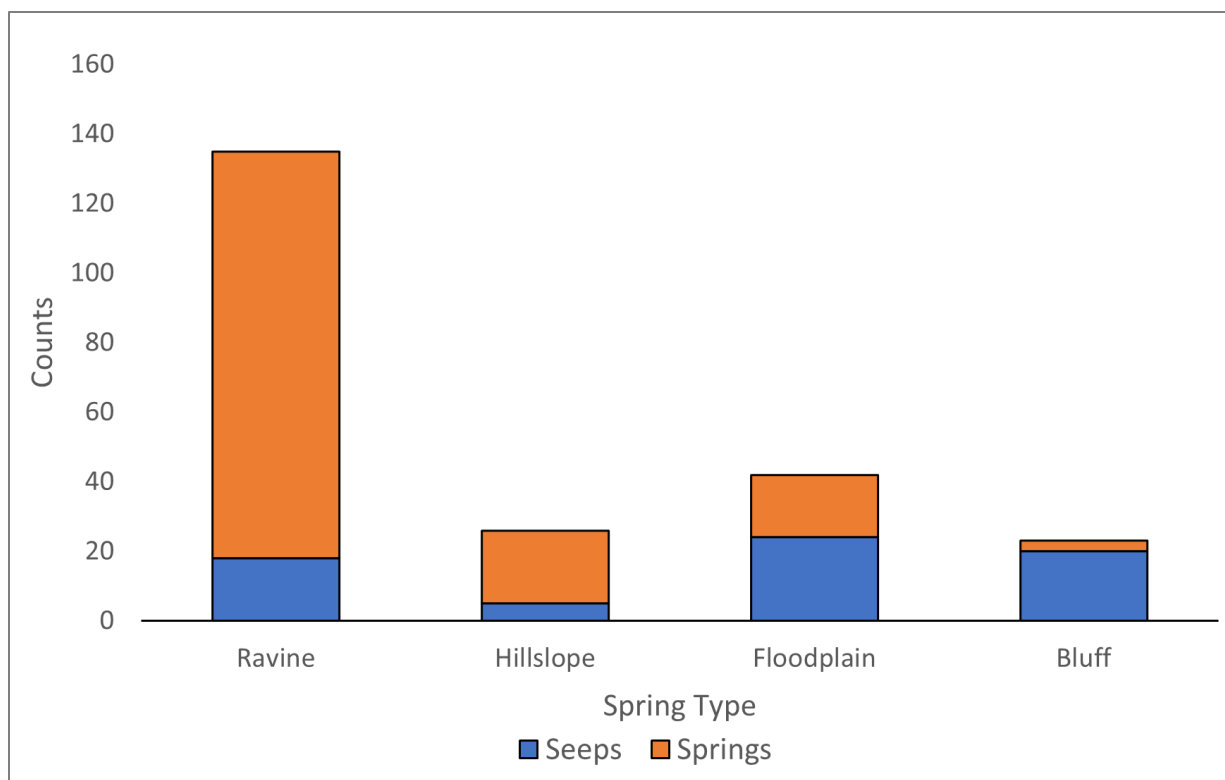


Figure 5. Seeps and springs in the Chattahoochee River National Recreation Area classified by spring types. Different spring types displayed different proportions of sites in each flow class.
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Geology of CRNRA Seeps and Springs

The bedrock geology of seeps and springs in the CRNRA is represented by eleven distinct geologic map units with an array of structural and chemical properties. As previously mentioned, the geologic data available for the CRNRA is derived from two different sources: a less detailed northern map (Table 3, CHTN) and a more detailed southern map (Table 4, CHTS). (See Figure 1 in the GIS Analysis section for a map overlay of the two different geologic study areas). Because the CHTS map presents a higher level of detail, defining the boundaries between different lithologies rather than general contacts, we can apply the underlying geology of seeps and springs in the CHTS map area to the water quality of those systems. In the northern map, however, the units are more broadly defined and include rocks of varying chemical composition in a single geologic unit, which makes determining specific influences of bedrock geology on spring water quality nearly impossible. The following Tables 3 and 4 provide a list and description of major geologic units present at seeps and springs sites within the study area. Figures 6 and 7 show the distribution of seeps and springs relative to major geologic units in the Island Ford unit and Palisades unit. Thirty-two sites were identified in the Island Ford unit, and 54 sites were identified in the Palisades unit, representing East Palisades and West Palisades sites combined.

Table 3. Distribution of seeps and springs by bedrock geology in the northern section of the Chattahoochee River National Recreation Area.

Code	Unit Description	Sites Identified
PZPCbg2	Biotite gneiss, mica schist and amphibolite	47
PZPCms	Mica schist, gneiss and amphibolite	4
PZPCs	Aluminous schist	1

Table 4. Distribution of seeps and springs by bedrock geology in the southern section of the Chattahoochee River National Recreation Area.

Code	Unit Description	Primary Lithology	# Sites
OZsp	Stonewall Gneiss, Powers Ferry Member	Biotite gneiss	48
OZm	Informal mixed unit	Sillimanite-mica schist	54
OZmgs	Garnet-rich schist	Garnet-rich mica schist	39
OZcr	Crider Gneiss	Biotite gneiss	26
OZr	Ropes Creek Metabasalt	Hornblende amphibolite	4
Cas	Aluminous schist unit	Kyanite or staurolite garnet mica schist	1
Ccp	Chattahoochee Palisades Quartzite	Quartzite	10
Caq	Thin (<2 m thick) mappable units of muscovite quartzite	Quartzite	2

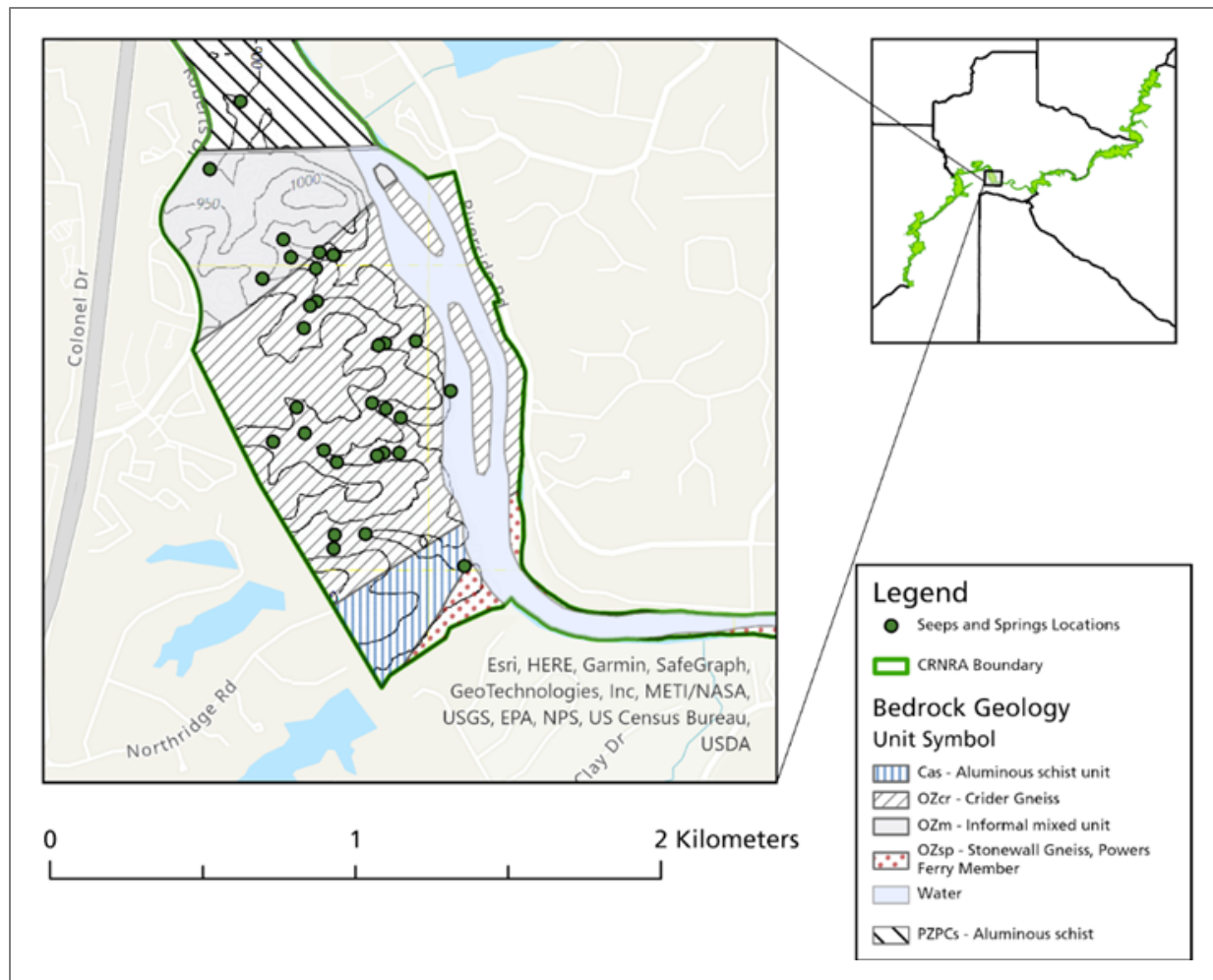


Figure 6. Distribution of seeps and springs relative to major geologic units in the Island Ford unit where 32 sites were identified.
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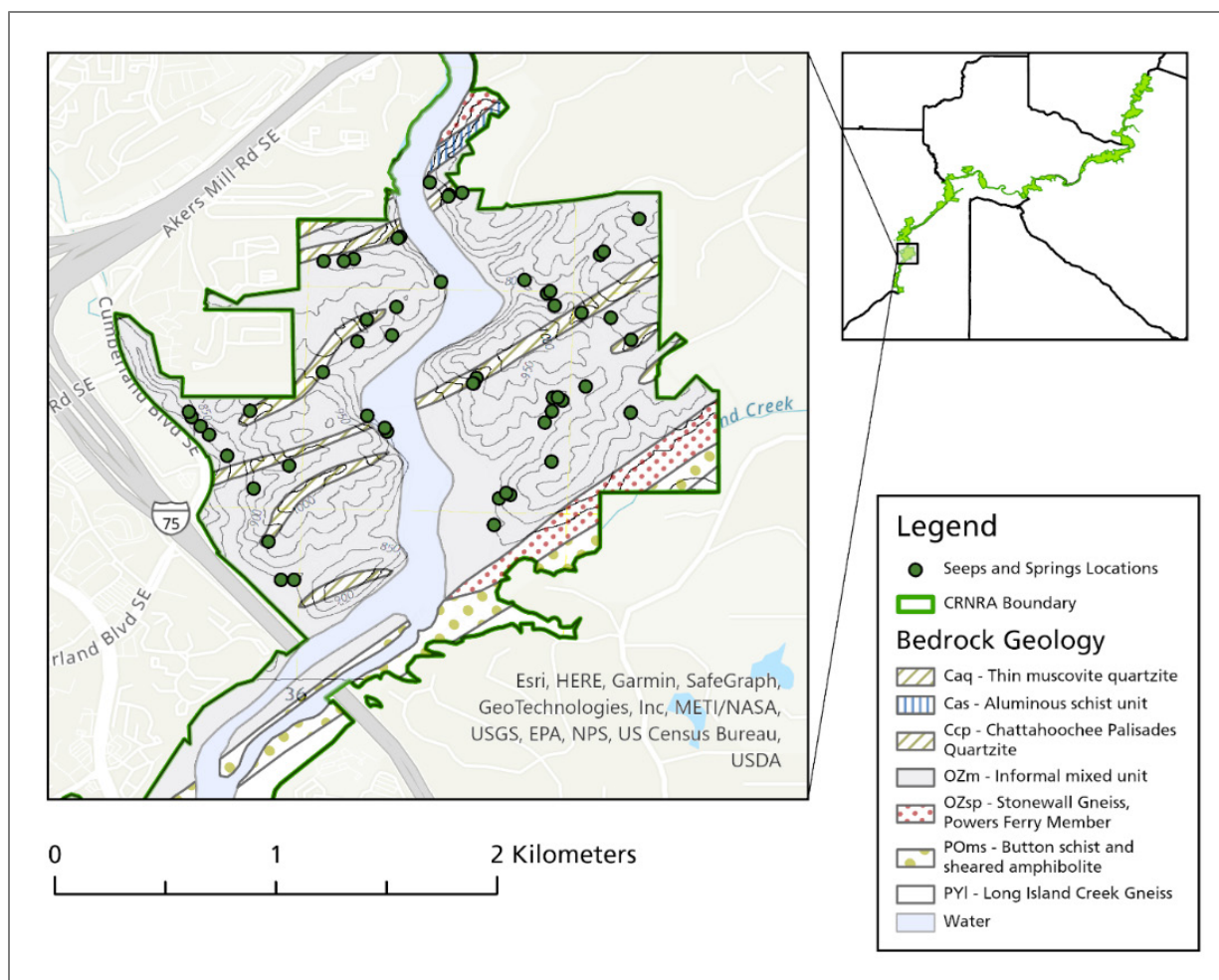


Figure 7. Distribution of seeps and springs relative to major geologic units in the Palisades unit (East Palisades and West Palisades sites combined) where 54 sites were identified.
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Water Quality

A total of 421 conductivity and temperature measurements were conducted across 192 of the total 226 seeps and springs in the study area (Figure 8). The 34 sites without measurements lacked sufficient discharge to produce an accurate reading of either parameter. Measurements were collected from July to November 2023.

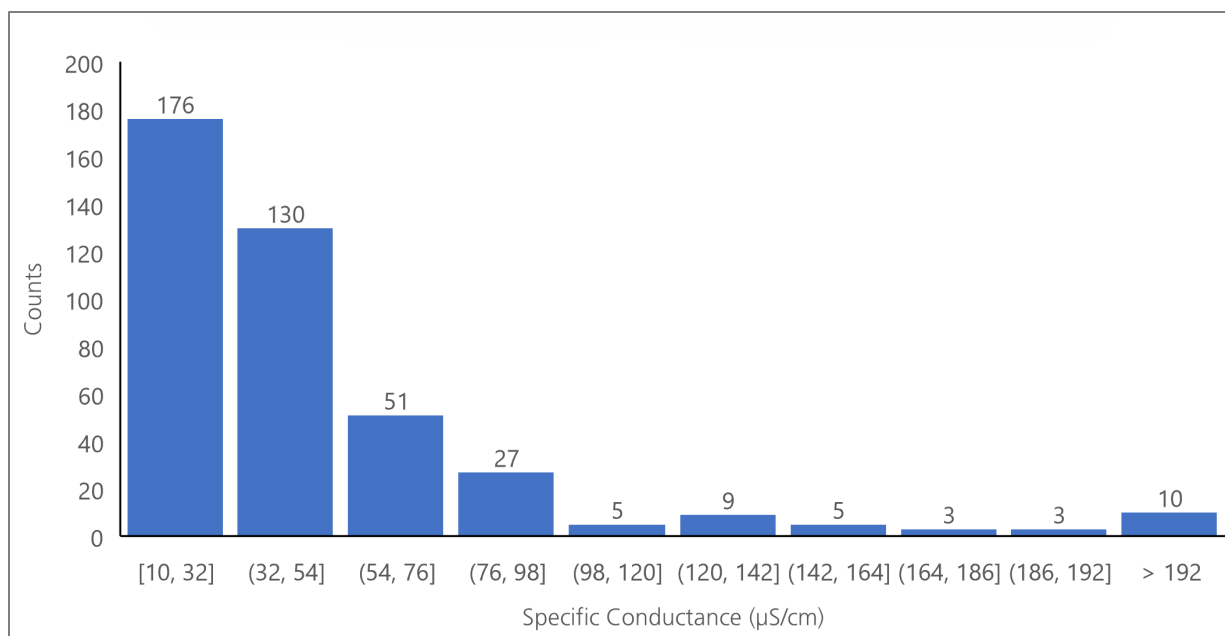


Figure 8. Histogram of all specific conductance measurements collected at seeps and springs in the Chattahoochee River National Recreation Area.
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Conductivity varied greatly by site but was generally reflective of geologic conditions (Figure 9). Over half of sites measured had specific conductance values of less than or equal to $50 \mu\text{S/cm}$, which represents very dilute conditions for surface waters. Although measurement frequency rapidly decreases with increasing conductivity, there are some anomalous outliers with extremely high conductivity readings ($>400 \mu\text{S/cm}$). These high readings were located nearby to either municipal wastewater infrastructure or adjacent areas with intensive land use patterns and are likely a reflection of those influences more so than that of local groundwater. For sites with anomalously high conductivity in proximity to wastewater infrastructure, we collected water samples and tested for *E. coli* abundance. None of these sites displayed signs of elevated bacterial counts.



Figure 9. Box plot of conductivity readings from seeps and springs sorted by spring types. Mean for each category is indicated by a cross; the median of each category is the horizontal line within each box.
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There were no clear patterns evident in the relationships between conductivity/temperature readings and spring types. Bluff and floodplain seeps and springs had a wider range of conductivity values than ravine and hillslope springs, but their median conductivity values across all sites were relatively consistent between spring types. Temperature (Celsius) values displayed similar variability and medians across all spring types (Figure 10).

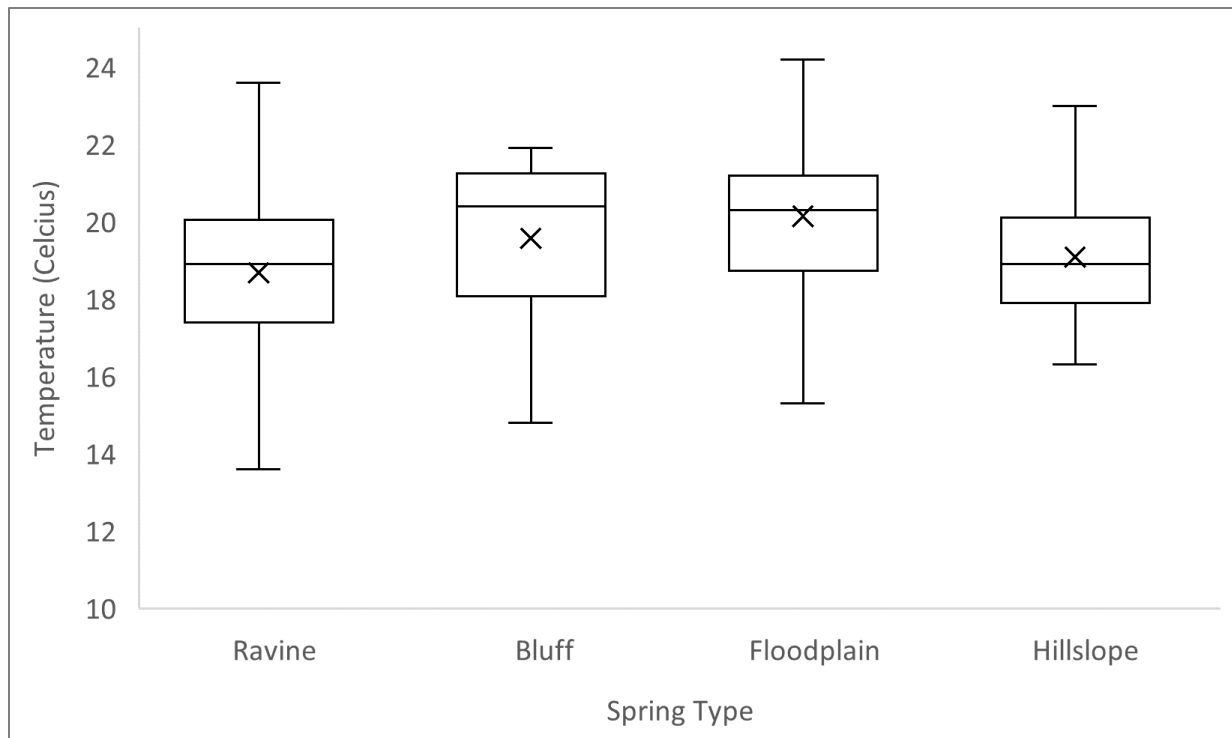


Figure 10. Box plot of temperature readings sorted by spring types. Mean for each category is indicated by a cross; the median of each category is the horizontal line within each box.

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Given the complexity of the bedrock geology in the study area, it is likely that the conductivity measurements from seeps and springs reflect the combined weathering influences of multiple rock units. However, clear differences emerged between conductivity measurements collected in areas with certain bedrock types (Figure 11). In seeps and springs emerging over quartzite bedrock (Higgins 2003 units: Ccp and Caq), specific conductivity values never exceeded 40 $\mu\text{S}/\text{cm}$, a low range even for the dilute waters of Piedmont streams. Seeps and springs emerging over amphibolite bedrock (Higgins 2003 unit: OZr), however, had an average specific conductivity of 130 to 140 $\mu\text{S}/\text{cm}$, and no measurements of conductivity below 50 $\mu\text{S}/\text{cm}$ were recorded for amphibolite-dominated seeps and springs. The difference in conductivity values between these rock types is a product of their chemical composition. The Chattahoochee Palisades Quartzite (Ccp) is predominately comprised of quartz (SiO_2), which forms a neutral ion (H_4SiO_4) when dissolved through chemical weathering processes and thus does not affect conductivity values. The Ropes Creek Metabasalt (OZr), on the other hand, is comprised primarily of hornblende and plagioclase, which form free metal cations (Na^+ , K^+ , Ca^{2+} , Mg^{2+}) when dissolved through chemical weathering processes. These cations, in particular the calcium ion (Ca^{2+}), are the primary determiners of conductivity in Piedmont surface waters (Andersen et al. 2001). The remaining geologic units (OZcr, OZmgs, OZsp, OZm, PZPCbg2) contain a variety of rock types and minerals which produce conductivity ranges that are intermediate between those of the quartzites and amphibolite.

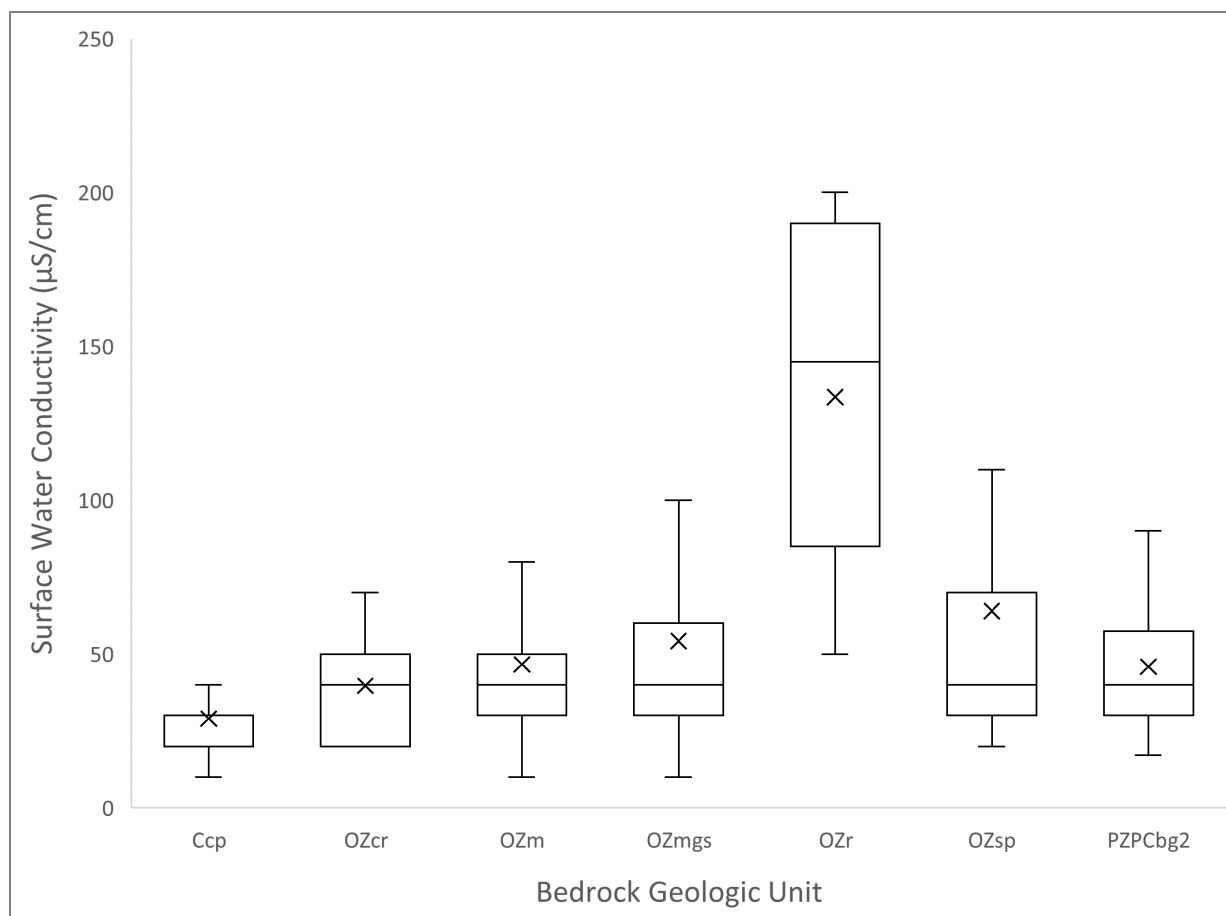


Figure 11. Surface water conductivity measurements for seeps and springs in the Chattahoochee River National Recreation Area grouped by bedrock geology.
NPS / THOMAS MCCOY-BRUCE

Water temperature measurements conducted during the summer months of surveys in the CRNRA reflect this pattern, with spring sources sometimes being recorded several degrees cooler than surrounding surface water. However, as the weather cools, this trend all but vanishes; in winter months, the groundwater sources may be slightly warmer than the surrounding surface water. Table 5 summarizes some highlights of the water temperature difference data collected in various seeps and springs within the study area. In many cases, the ‘seepage’ and ‘stream’ sample points at a given site were only a few meters apart, demonstrating that these techniques are applicable even on a small scale.

Table 5. Changing temperature patterns as atmospheric temperature decreases in various seeps and springs within the study area. In the heat of summer, spring temperatures tend to remain cooler than surface water temperatures downstream, but this distinction fades as air temperature decreases.

Site ID	Date	Seepage T °C	Stream T °C	Change from Seep to Stream
VC06	07/07/2023	17.2	20.2	+3.0
WP03	07/14/2023	18.4	21.0	+2.6
PI01 ('Little Powers Island Spring box')	07/25/2023	17.0	19.7	+2.7
EP16	07/28/2023	17.3	20.5	+3.2
IF09 ('Salamander Slope')	08/02/2023	17.6	20.5	+2.9
IF21	08/02/2023	15.7	20.1	+4.1
HF23	08/16/2023	16.8	19.0	+2.2
IF27	08/30/2023	17.3	25.3	+8.0
SC14 ('Big Rock Springs')	09/26/2023	17.9	18.8	+0.9
BI13	10/06/2023	17.0	17.8	+0.8
JB01	10/10/2023	14.1	14.4	+0.3
OF01	10/11/2023	15.7	15.8	+0.1
BI22	10/13/2023	16.8	16.4	-0.4
BI27	10/24/2023	14.3	15.3	+1.0
BI29	11/28/2023	10.5	11.3	+0.8

Plant Species Distribution

Floristic surveys were conducted for 177 of 226 seeps and springs in the study area. An average of 17 different species were found at each site, with a maximum species count of 48 species at site SC24 (see Appendix II for a map and unit codes). Floristic surveys were introduced partway into the inventory process, so the first 49 sites documented lack floristic data. Table 6 shows the 25 most abundant species and genera across the 177 sites recorded.

Table 6. The 25 most frequently encountered plant species at seeps and springs in the Chattahoochee River National Recreation Area. Wetland Status is derived from the National Wetland Plant List for the Eastern Mountains and Piedmont region (U.S. Army Corps of Engineers 2020). Key to NWPL ratings: UPL = Upland, FACU = Facultative Upland, FAC = Facultative, FACW = Facultative Wetland, OBL = Obligate Wetland, ND = not determined, N/A = not applicable.

Scientific Name	Common Name	Wetland Status	Counts
<i>Polystichum acrostichoides</i>	Christmas fern	FACU	141
<i>Fagus grandifolia</i>	American beech	FACU	111
<i>Liriodendron tulipifera</i>	Tulip poplar	FACU	98

^A Considered non-native invasive species of management concern (Georgia Forestry Commission 2023).

Table 6 (continued). The 25 most frequently encountered plant species at seeps and springs in the Chattahoochee River National Recreation Area. Wetland Status is derived from the National Wetland Plant List for the Eastern Mountains and Piedmont region (U.S. Army Corps of Engineers 2020). Key to NWPL ratings: UPL = Upland, FACU = Facultative Upland, FAC = Facultative, FACW = Facultative Wetland, OBL = Obligate Wetland, ND = not determined, N/A = not applicable.

Scientific Name	Common Name	Wetland Status	Counts
<i>Viola</i> spp.	Violets	N/A	91
<i>Parthenocissus quinquefolia</i>	Virginia creeper	FACU	84
<i>Ligustrum sinense</i> ^A	Chinese privet	FACU	76
<i>Smilax</i> spp.	Greenbriars	N/A	68
<i>Hydrangea barbara</i>	Woodvamp	OBL	66
<i>Athyrium asplenoides</i>	Southern lady fern	FAC	65
<i>Carpinus caroliniana</i>	American hornbeam	FAC	64
<i>Thuidium delicatulum</i>	Delicate fern moss	ND	62
<i>Vitis</i> spp.	Grape	N/A	62
<i>Toxicodendron radicans</i>	Poison ivy	FAC	58
<i>Microstegium vimineum</i> ^A	Nepal grass, Japanese stiltgrass	FAC	55
<i>Liquidambar styraciflua</i>	Sweetgum	FAC	52
<i>Quercus alba</i>	White oak	FACU	51
<i>Carex</i> spp.	Bladder sedges	FAC-OBL	46
<i>Phegopteris hexagonaptera</i>	Broad beech fern	FAC	42
<i>Bryoandersonia illecebra</i>	Spoon-leaved moss	ND	41
<i>Arisaema triphyllum</i>	Jack-in-the-pulpit	FACW	40
<i>Oxydendrum arboreum</i>	Sourwood	UPL	39
<i>Hexastylis arifolia</i>	Little brown jug	FAC	34
<i>Nyssa sylvatica</i>	Black gum	FAC	34
<i>Rubus</i> spp.	Brambles/Blackberries	N/A	34
<i>Acer rubrum</i>	Red maple	FAC	33

^A Considered non-native invasive species of management concern (Georgia Forestry Commission 2023).

Overall, over 270 taxa of plants were documented in seeps and springs. Of these, 18 taxa are listed as obligate wetland species and 26 are listed as facultative wetland species in the National Wetland Plant List (U.S. Army Corps of Engineers, 2020). The most abundant species overall was Christmas fern (*Polystichum acrostichoides*), followed by American beech (*Fagus grandifolia*), which are two of the most abundant species in the park overall.

Species that served as strong indicators of wetland conditions (and therefore the presence of springs) in multiple sites include woodvamp (*Decumaria barbara*), American royal fern (*Osmunda*

spectabilis), cinnamon fern (*Osmundastrum cinnamomeum*), jack-in-the-pulpit (*Arisaema triphyllum*), rice cutgrass (*Leersia oryzoides*), white grass (*Leersia virginica*), small-spike false nettle (*Boehmeria cylindrica*), swamp azalea (*Rhododendron viscosum*), netted chain fern (*Woodwardia areolata*), giant river cane (*Arundinaria gigantea*), and switch cane (*Arundinaria tecta*). These species are all included on the National Wetland Plant List as obligate or facultative wetland species (U.S. Army Corps of Engineers 2020). However, many seeps and springs also contained facultative upland or upland plant species in their vicinity, which is a testament to the habitat diversity surrounding these ecosystems. Common upland species found near seeps and springs included sourwood (*Oxydendrum arboreum*), chestnut oak (*Quercus montana*), tulip poplar (*Liriodendron tulipifera*), Virginia creeper (*Parthenocissus quinquefolia*), hophornbeam (*Ostrya virginiana*), and catbriar (*Smilax glauca*).

Overall, plant species diversity was greatest in the Sope Creek unit, where 132 distinct taxa were identified. The Bowmans Island and East Palisades units also possessed considerable diversity with 109 taxa identified in each. The most species overall were recorded at site SC24 with 48 distinct taxa, including 10 obligate wetland species and 8 facultative wetland species. A total of 21 sites had 4 or more combined facultative and obligate wetland species documented.

Documentation of New Species Records

The floristic surveys conducted as part of the seeps and springs inventory yielded multiple new vascular plant species for the park's official species list. These include the native species *Leersia virginica*, *Spiranthes vernalis*, and *Aralia racemosa*. The survey also documented nonvascular flora for the first time in park history, which yielded multiple new tentative nonvascular species (Table 7). These identifications require review by a bryophyte expert but could represent as many as 20 new species for park records.

Table 7. List of potential bryophyte species documented in the park, including the land unit(s) they were documented in and researcher confidence in the identification. All bryophyte observations are unconfirmed and subject to further review by subject matter experts.

Scientific Name	Common Name	Land Unit(s)	Confidence
<i>Anomodon minor</i>	Dwarf anomodon moss	BI	Low
<i>Atrichum angustatum</i>	Lesser smoothcap moss	BI MF AB JB IF VC GB SC CS EP	High
<i>Bryoandersonia illecebra</i>	Spoon-leaved moss	BI SB JB IF VC AL SC CS EP	High
<i>Callicladium imponens</i>	Brocade moss	IF AL	Medium
<i>Conocephalum conicum</i>	Great scented liverwort	IF SC	High
<i>Dumortiera hirsuta</i>	Dumortier's liverwort	BI AB MB IF HF	Very High
<i>Endoton seductrix</i>	Seductive entodon moss	BI	Very Low
<i>Fissidens taxifolius</i>	Common pocket moss	JB	Low
<i>Kindbergia praelonga</i>	Common feathermoss	MF JB	Low

Table 7 (continued). List of potential bryophyte species documented in the park, including the land unit(s) they were documented in and researcher confidence in the identification. All bryophyte observations are unconfirmed and subject to further review by subject matter experts.

Scientific Name	Common Name	Land Unit(s)	Confidence
<i>Leucobryum albidum</i>	White moss	VC SC	High
<i>Leucobryum glaucum</i>	Pincushion moss	BI SB IF VC SC EP	Very High
<i>Leucodon julaceus</i>	Smooth hook moss	BI SB MF AB JB IF	High
<i>Marchantia polymorpha</i>	Common liverwort	IF	Medium
<i>Pallavicinia lyellii</i>	Ribbonwort	BI IF CS	Medium
<i>Plagiomnium</i> spp.	Plagiomnium moss	BI MF JB IF SC CS	High
<i>Polytrichum commune</i>	Common hairmoss	BI MB SC CS	High
<i>Pseudanomodon attenuatus</i>	Tree-skirt moss	BI AB JB IF VC GB SC EP	High
<i>Sphagnum</i> spp.	Sphagnum moss	IF	Very High
<i>Tetraphis pellucida</i>	Pellucid four-tooth moss	JB	Very Low
<i>Thuidium delicatulum</i>	Delicate fern moss	BI SB MF AB MB JB IF VC AL GB SC CS EP	Very High

New non-native and invasive species documented in the inventory include *Dryopteris erythrosora* (autumn fern, Figure 12), *Achyranthes japonica* (Japanese chaff-flower), and *Deparia petersenii* (Japanese lady fern). All three of these species are emerging threats in the southeastern United States due to widespread transport and cultivation (Umstead and Diggs 2018; Wyatt 2020).



Figure 12. Image of autumn fern (*Dryopteris erythrosora*) showing diagnostic hairy black scales along the rachis and deep red sori with a “blistery” appearance (Umstead and Diggs 2018).
NPS / THOMAS MCCOY-BRUCE

Historic Structures

Several spring sites contain notable structures that retain historic and cultural value, including spring boxes, terraces, and other alterations to the spring environment (Figure 13). Some of these structures are documented in NPS cultural resource inventories, but others have yet to be evaluated as historic properties. Much further research is needed into the historical structures associated with springs along the Chattahoochee River, particularly regarding their use by indigenous peoples.



Figure 13. Small wooden spring box (top left) and larger stone spring houses in the Powers Island unit (top center and right); stone spring box in the East Palisades unit (bottom left); large stone dam in the Bowmans Island unit (bottom right).

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Conclusions

Springs Distribution

The concentration of seeps and springs in the southernmost units of the park, although notable, may not reflect the distribution of sites across the region. The park units below Morgan Falls Dam (Johnson Ferry, Cochran Shoals, and Palisades) do contain some of the most complex bedrock geology present in the park, as they fall where the Chattahoochee River runs roughly parallel to the Brevard Zone and then subsequently intersects a number of different rock units. Therefore, the abundance of contacts between geologic units could contribute to the relative abundance in this area compared to other portions of the park. However, the boundaries of the study area also contribute to the distribution of seeps and springs identified in the survey. Much of the northern section of the CRNRA's managed area comprises the Chattahoochee River itself and the nearby river terraces and floodplains with little upland terrain. These segments are less likely to host seeps and springs than the larger and hillier southern units, which include more of the surrounding Piedmont topography. Thus, the lack of major seeps and springs along the central and northern sections of the CRNRA is more likely to represent a lack of suitable terrain for seep and spring development within the park's boundaries rather than a geological or physical control on the distribution of these sites.

Water Quality and Geology

As measured through specific conductivity, water quality in CRNRA seeps and springs is largely dictated by bedrock geology and is reflective of chemical weathering patterns that produce Piedmont soils and sediment. There were few other meaningful relationships between water conductivity and other variables such as spring types. Temperature patterns also displayed little variability between differing spring types and were most influenced by seasonality and ambient air temperature.

A common struggle in working with seeps and springs in humid areas is the inability to distinguish surface water-derived flow (e.g., runoff or ephemeral pools) from groundwater-derived flow (such as seeps and springs). However, the temperature differences between runoff-fed streams and groundwater-derived spring flow, if captured near the emergence point of groundwater, are often distinct enough to form a comparison between surface water and groundwater flow with simply temperature measurements.

Due to the physical separation of groundwater from the atmosphere, groundwater is not subject to as great a range of temperature fluctuation as surface water when considering daily atmospheric temperature patterns. This means that groundwater remains cooler than surface water under high atmospheric temperatures, and it remains warmer than surface water under low atmospheric temperatures (Ozotta and Gerla 2021). In summer months, finding a source of water more than a degree Celsius cooler than surrounding surface water could suggest the influence of groundwater in a headwater stream ecosystem. The following thermal images from a 2011 study by Scheutz and Weiler show examples of groundwater-stream water temperature gradients (Figure 14).

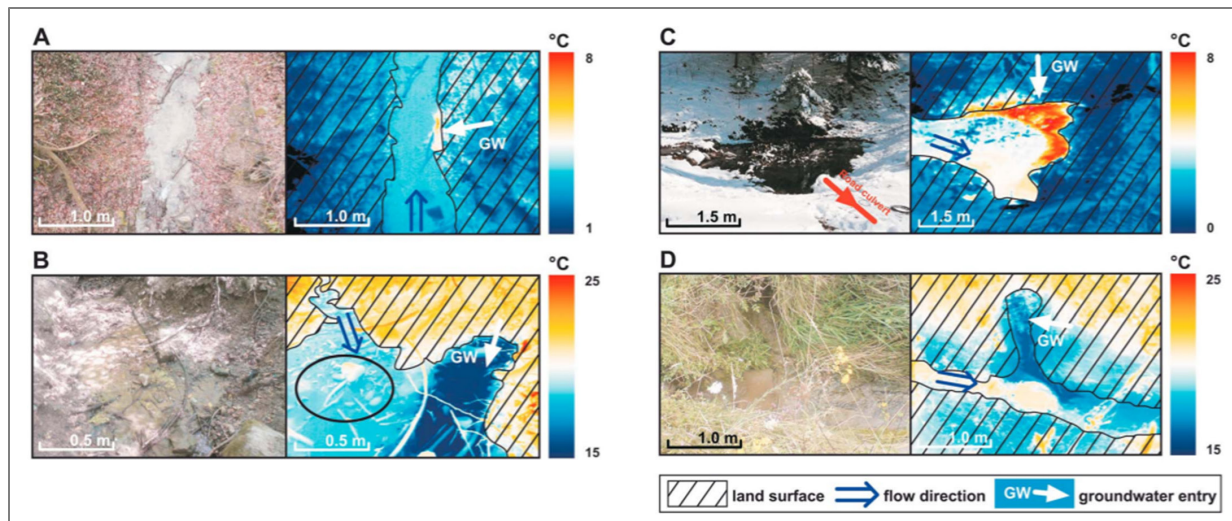


Figure 14. Thermal images showing difference between surface water and groundwater temperatures in a small seepage area. Adapted from Schuetz & Weiler (2011).

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Plant Species Distribution

Of particular interest from a resource management perspective is the distribution of common species across seep and spring locations, as these patterns likely reflect overall conditions in the park. The understory (and even canopy in some cases) of many seeps and springs sites is dominated by American beech (*Fagus grandifolia*), black gum (*Nyssa sylvatica*), tulip poplar (*Liriodendron tulipifera*) and maples (*Acer* spp.), all examples of mesophytic species that were historically less abundant in the southeastern Piedmont landscape. These trees have become more abundant in Piedmont forest ecosystems due to a lack of regular fire, which traditionally maintained the structure of southeastern oak and pine forests (Nowacki and Abrams 2008).

There was also a notable absence of canopy species, such as oaks (*Quercus alba*, *Q. rubra*, *Q. falcata*, *Q. montana*, and others) and hickories (*Carya* spp.) in the shrub and lower canopy vegetation levels across most sites. This “oak bottleneck” structure reflects the broader mesophication trends taking place in southeastern forests and suggests dire consequences for the future structure of Piedmont forests. Over time, the lack of replacement of overstory oak and hickory species could result in their replacement by mesophytes and opportunists such as sweetgum (*Liquidambar styraciflua*), American beech (*Fagus grandifolia*), and maples (*Acer* spp.) (Alexander et al. 2021). Level 2 of the CRNRA seeps and springs inventory may provide additional data to support the mesophication hypothesis through more detailed surveys of plant species distribution and canopy cover at selected springs.

Piedmont Seepage Bogs

The discovery of a developing seepage-fed Piedmont bog in the CRNRA may be one of the most consequential outcomes of this study. While the site lacks historical accumulation of peat to be considered a true bog, altered hydrology and influx of seepage from nearby groundwater sources have produced conditions ideal for bog development. The site has been colonized by sphagnum moss

(*Sphagnum* sp.) as well as multiple other obligate wetland species. Further research on the floristic diversity and water quality of this site are planned to understand its potential value as an example of a rare, critically threatened ecosystem.

Survey Methodology Development

As a result of this project, we have developed the first formal inventory process for seeps and springs in the Piedmont of the southeastern United States. We hope that these methods will be tested and evaluated by other researchers and natural resource managers within the Piedmont ecoregion to assess their applicability outside of the Chattahoochee River watershed. Additionally, we hope that the establishment of these protocols will encourage more interest in the inventory and monitoring of seeps and springs ecosystems in the southeastern United States and bring about a more comprehensive understanding of these habitats and their function in the greater Earth system.

Benefits to Park Natural and Cultural Resource Management

The seeps and springs inventory data has already conveyed benefits to natural and cultural resource management in the CRNRA. Existing GIS layers for riparian buffers have been updated to include seeps and springs sites in consideration for future project authorization, which will help preserve the delicate structure of these ecosystems. Information concerning historic structures associated with seeps and springs has been reported to the park archaeologist and included in web GIS databases. In addition, the park now has an extensive dataset of floristic species presence and water quality measurements spanning the length of the park, which can be used as reference data in future studies. The official park species list has also been improved and expanded thanks to these efforts, which helps park resource management staff bring more attention to the uniqueness and biodiversity of the Chattahoochee River corridor.

Future Studies

Park Service staff are currently developing updated protocols for a Level 2 seeps and springs inventory based on the results of this study. Level 2 surveys will involve more concentrated data collection efforts at a smaller number of sites, focusing on important morphological, ecological, and hydrologic factors. The protocols for Level 2 surveys are also being developed in conjunction with Alan Cressler from the U.S. Geological Survey and based on the original Level 2 protocols of Stevens and Ledbetter (2023).

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Appendix I: Seeps and Springs Inventory Level 1 Protocols

These protocols describe the standard method used for data collection in the 2023 Seeps and Springs Level 1 Inventory at Chattahoochee River National Recreation Area. **Bolded** items are represented as questions in the Level 1 Inventory Survey123 form.

Upon Arrival

- Unpack and account for all necessary equipment.
- Ensure the GPS receiver is turned on and paired with the collection device.
- Ensure the conductivity probe is functional and properly calibrated.
- Complete the “General Information” and “Weather Conditions” section of the Survey123 form.

Site Overview

Record basic elements such as location, access, and identifier within the Survey123 form.

- **Location:** Record the location of the spring, using the GPS receiver for maximum precision. Ideally, the point should be as close as possible to the emergence point of the spring (the highest elevation where groundwater is first visible at the surface). If there are multiple emergence points at the spring, record the location of the highest elevation emergence.
- **County:** Using the drop-down menu, specify the county the spring is located in.
- **Land Unit:** Using the drop-down menu, specify which land unit of the park the spring is located in.
- **Springs ID#:** Assign the spring site a unique identifier based on the land unit. See Appendix II for a list of land unit codes.
- **Access Directions:** If the spring is not in the immediate vicinity of an existing official trail, describe the directions from the nearest official trail to the site.
- **Images:** Submit images of the site facing each cardinal direction. Additional images may be submitted to provide better context for the site.
- **Sketch:** Begin the site sketch process as soon as possible, including major features such as emergence points, areas of standing or flowing water, landmarks (rock outcrops, large trees, etc.), and historic structures. Level 1 sketches need not be to scale but provide approximate distance in the spring area to verify area estimates.

Spring Overview

Record the essential characteristics of the spring site.

- **Site Description:** Site descriptions should detail the emergence points, flow patterns, and whether the spring flows into another body of water. Any notable flora or fauna (such as hydric plant species, crayfish burrows, salamanders, etc.) should be noted if observed.

- **Site Condition:** Include any relevant information about the human or other impacts on the spring environment. Other potential influences could be deer grazing, beaver dam construction, etc.
- **Seep or Spring:** Based on spring discharge, determine if the site should be considered a seep (flow does not leave the immediate vicinity of the site) or a spring (flow continues beyond the immediate vicinity of the site).
- **Spring Type:** Use the Dichotomous Key to Spring Types (Appendix III) to determine the proper classification.
- **Historic Structure Present:** Select ‘Yes’ if there are anthropogenic structures present in the spring’s area, excluding modern litter.
- **Flow Consistency:** Select the option that best reflects spring conditions. Note that flow consistency may not be evident upon a first visit.
 - Perennial: Year-round water flow.
 - Intermittent: Seasonal or periodic flow based on groundwater and precipitation patterns.
 - Ephemeral: Flow only in response to precipitation events. A site marked as ephemeral may not represent a true seep or spring.
- **Occurrence of Surface Water:** Select the best option to describe the setting. Larger sites will tend to be more heterogeneous in water conditions and may be difficult to describe in this section.
- **Area Estimate:** Include the area of seepage zones surrounding the primary spring area. These areas can usually be determined by observing vegetation, soil, and water temperature regimes.
- **Sketch:** Submit an image of the sketch map that displays all necessary information, including date and time, survey location, north arrow, approximate distance (if applicable), and sample points.

Plant Identification

At this time, it may be helpful to begin identifying plant species. Weakley’s Flora of the Southeastern United States (2024) should be the primary resource for plant species identification, but other resources may be consulted as needed. For Level 1 surveys, use of a digital tool (such as iNaturalist) may be acceptable, but identifications made this way should be verified with a flora/dichotomous key.

- Only a species list is necessary for Level 1; no abundance data needs to be collected.
- If a specimen cannot be identified in the field, take a photo, and note for later observation.

- Do NOT collect voucher specimens, or remove any natural material or artifacts, for any portion of the Seeps and Springs Inventory without prior approval from the park's natural resource managers and archaeologist.
- Volunteers may not collect voucher specimens or artifacts under any circumstance.

Spring Details

Identify emergence points and record basic water quality measurements.

- **Emergence Points:** Identify the number of unique emergence points. An emergence point is a source of groundwater flow that penetrates the surface and emerges as surface water. Emergence points are often higher in elevation than the surrounding seepage zone. Some seepage zones may be too diffuse to identify distinct emergence points.
- **Emergence Point Images:** Attach an image for each emergence point that shows the structure and location of the emergence.
- **Sample Points:** Indicate the number of conductivity and temperature readings being recorded. Up to 5 may be logged in the Survey123 form.
- **Sample Description:** Describe the location of the sample in relation to the spring hydrology (i.e., near emergence point, downstream of spring, in separate channel). Mark each sample on the site sketch with an approximate point. It is recommended to collect measurements starting with the farthest downstream site to avoid imprecise results caused by disturbance of the stream.
- **Conductivity and Temperature:** Use the conductivity probe to collect conductivity and temperature readings.
 - To measure conductivity: Ensure that the sample area is free of suspended sediment and disturbance. Use the plastic cap of the probe to collect a small volume of water without disturbing sediment. If the water is above the 'MAX' line indicated on the probe, pour off excess water in an area that will not drain into your next sample location. Insert the probe into the cap and gently swirl the sample in the cap. The conductivity reading will stabilize in a few seconds.
 - If there is insufficient water to collect a sample without disturbing the sediment: As a last resort, you can insert the probe directly into the surface water and get a less precise result. Be aware that any accidental disturbance of sediment can alter conductivity readings.
 - To measure temperature: Insert the probe directly into the water in approximately the same location as the conductivity reading was collected from. Gently swirling the probe may help the temperature reading stabilize faster. There is no need to avoid disturbing sediment for temperature readings.

Final Steps

- **Additional Notes:** Provide any notes or comments in this section that may help describe unique characteristics of the spring setting. (For example, one site may be severely undercut and channelized by backwash from the Chattahoochee River during flood events.)
- **Additional Images:** Provide any additional images that help display the spring's characteristics.
- **Flag for Follow-up:** Determine follow-up priority based on site characteristics. Sites with high plant diversity, extensive seepage area, unusually high conductivity, or historic/scenic value may all be worthy of further study in Level 2 or Level 3 surveys.
- Pack up all equipment. Make sure that all equipment is accounted for, clean, and undamaged. Submit the Survey123 form, if possible, or save it as a draft on the mobile device.

Appendix II: Study Area Map and Unit Codes

A park map showing the study area and locations of each unit (Figure 15). The following character codes for land units are currently in use:

- **BI** (Bowmans Island)
- **OF** (Orrs Ferry)
- **SB** (Settles Bridge)
- **MF** (McGinnis Ferry)
- **AB** (Abbotts Bridge)
- **MB** (Medlock Bridge)
- **JB** (Jones Bridge)
- **HB** (Holcomb Bridge)
- **IF** (Island Ford)
- **VC** (Vickery Creek)
- **AL** (Allenbrook)-*part of VC*
- **GB** (Gold Branch)
- **HF** (Hyde Farm)-*part of JF*
- **JF** (Johnson Ferry)
- **SC** (Sope Creek)-*part of CS*
- **CS** (Cochran Shoals)
- **PI** (Powers Island)-*part of CS*
- **EP** (East Palisades)-*part of Palisades (PA)*
- **WP** (West Palisades)-*part of Palisades (PA)*

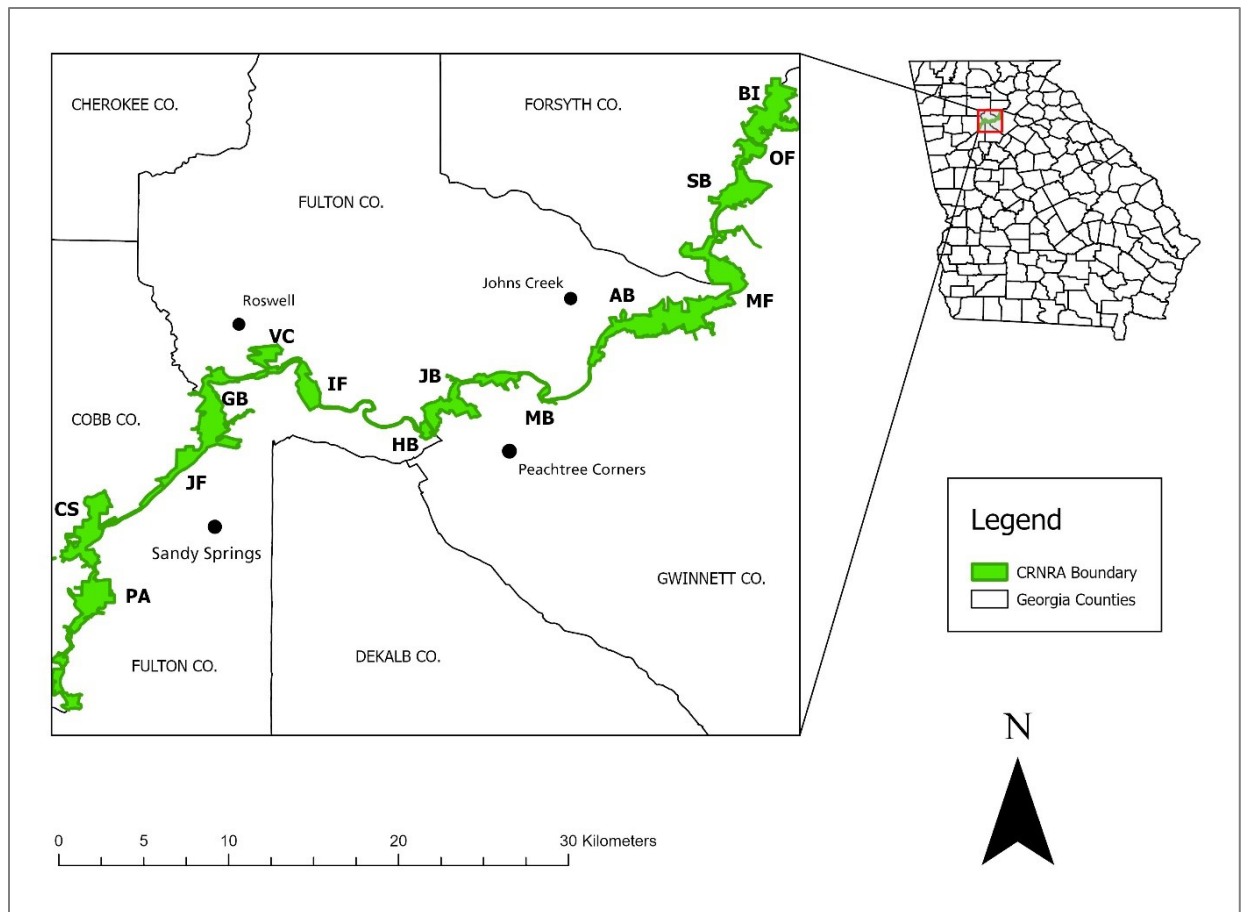


Figure 15. Map of the park showing locations of each unit.
NPS / THOMAS MCCOY-BRUCE

Appendix III: Dichotomous Key to Spring Types

Use this key to determine the classification of a spring site that has not been previously classified. This classification protocol was developed by Alan Cressler (USGS), Allyson Read (NPS), and Thomas McCoy-Bruce (NPS intern), based on the protocols published by Stevens and Ledbetter (2023).

- 1. Groundwater is not expressed at the time of visit; soil is dry or moist but is not saturated by groundwater. Groundwater is expressed solely through wetland or obligate riparian vegetation.....**Hypocrene Seep**
- 1. Groundwater is expressed at the time of visit; saturation, seepage, and/or flow are actively expressed. Lentic and/or lotic flow conditions can exist.
 - 2. Groundwater discharge is primarily lentic (standing or slow-moving), and flow downstream from the ecosystem may be absent or very limited. Typically referred to as seeps.
 - 3. Seepage originates from a bedrock cliff and not within an established surface flow channel. Flow emerges along a horizontal geologic contact, typically dripping along a seepage front and often creating a wet backwall.....**Bluff Seep**
 - 3. Not as above
 - 4. Groundwater is expressed at an origin point of high slope (typically >16 degrees) but is primarily lentic, often represented by saturated soil.
 - ◆ 5. Seepage originates within a defined erosional channel and is subject to regular flood scouring from perennial streams or runoff.....**Ravine Seep**
 - ◆ 5. Seepage does not originate from a defined channel, and instead emerges from a featureless hillslope not subject to regular flood scouring.....**Hillslope Seep**
 - 4. Groundwater is expressed at an origin point of low slope (typically <16 degrees) and may be represented by saturated soil or patches of standing water.
 - ◆ 6. Seepage originates in or near a defined erosional channel and is subject to regular flood scouring from surface water flow.....**Floodplain Seep**
 - ◆ 6. Seepage does not originate near a defined erosional channel and is not subject to regular flood scouring from surface flow.....**Helocrene Seep (Wet Meadow)**

- 2. Groundwater discharge is primarily lotic (flowing or fast-moving) and flows actively within and/or downstream away from the ecosystem. Spring's flow may emerge from a focused point but without substantial artesian rise above ground level. Typically referred to as springs.
 - 7. Flow emerges from a bedrock cliff and not within an established surface flow channel, although a surface flow channel may exist on top of the cliff, directly above the source. Groundwater typically flows or drips along a seepage front and creates a wet backwall on near-vertical or overhung bedrock walls.....**Bluff Spring**
 - 7. Not as above
 - 8. Flow emerges from a surface-flow dominated channel bed. Upstream of the spring may be a perennial stream or it may be dry. Lotic flow conditions generally prevail. These springs are subject to channel flood scour.....**Ravine Spring**
 - 8. Flow emerges from a non-bedrock dominated slope that does not have a surface flow channel upslope of the springs source. Sources may emerge within an upland habitat or a floodplain, but not within the bed of a surface flow channel. In some cases, these springs may emerge from the base of a cliff, but not from the cliff itself.
 - ◆ 9. Flow emerges from a 16 to 60-degree slope in an upland habitat, not associated with a floodplain or channel that is subject to regular surface flow stream flood scouring.....**Hillslope Spring**
 - ◆ 9. Flow emerges from the bank or terrace of an active riparian channel or floodplain and the source is subject to regular flood scour by the stream into which it feeds.....**Floodplain Spring**

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