



Monitoring Wadeable Stream Habitat Conditions in Southeast Coast Network Parks

Protocol Narrative

Natural Resource Report NPS/SECN/NRR—2018/1715



ON THE COVER

Upstream facing picture of a large woody debris step and floodplain (in the background) on Long Island Creek (CHAT013) at Chattahoochee National Recreation Area. Photograph by Southeast Coast Network

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Executive Summary

The Southeast Coast Network (SECN) has initiated a monitoring effort to assess habitat conditions in wadeable streams at national parks, recreation areas, battlefields, and monuments in Alabama, Georgia, and South Carolina. This monitoring effort includes Chattahoochee River National Recreation Area, Kennesaw Mountain National Battlefield Park, Congaree National Park, Horseshoe Bend National Military Park, and Ocmulgee National Monument.

Stream habitat monitoring was implemented in 2016, and focuses specifically on providing relevant data to assess the physical condition of Piedmont and upper Coastal Plain streams with respect to aquatic and riparian habitats and how these habitats may be changing over time. The habitat assessment methods proposed in this protocol rely on standard data collection methods and standard operating procedures currently in use by the U.S. Geological Survey, U.S. Environmental Protection Agency, and U.S. Forest Service that have been modified to better meet the needs of National Park Service (NPS) managers.

The Southeast Coast Network's wadeable stream protocol was developed to begin a monitoring program that will provide insight into the status of, and trends in, stream and riparian habitat conditions. The number of reaches surveyed at each park is dependent on the spatial extent of the park and the total number of wadeable streams that are present within park boundaries. Regardless of the size of the park and the number of reaches that are to be monitored, selected reaches (1) are representative of the processes influencing the streams in each park; (2) can address current and anticipated management concerns, and (3) offer the most utility for future complementary studies.

For the purposes of this protocol, wadeable streams are narrowly defined as small- to medium-sized, perennially-flowing waterbodies with identifiable channel banks that can be accessed and traversed without the use of a watercraft. The wadeable streams referred to herein do not include ephemeral channel-like features typically found on large river flood plains and within hillslope gully systems.

The objectives of this protocol are to:

- Determine the status of upstream watershed characteristics such as basin area, basin slope, and drainage density, and changes to land cover that may affect stream habitat;
- Determine the status of and trends in the geomorphic dimensions (cross-sectional morphology) of selected wadeable stream reaches including channel widths, bank characteristics (e.g., heights, angles, and vegetative cover), and reach slope and sinuosity; and
- Determine the status of and trends in physical measures of benthic and riparian habitat features present in selected wadeable stream reaches such as the size, type, and distribution of bed sediment and large woody debris, the distribution of geomorphic channel units, and canopy cover.

In addition to these monitoring objectives, the data collected under this protocol allows the network to broadly summarize the wadeable stream resources within SECN parks, highlighting similarities

and differences in these resources as they relate to stream habitat and geomorphic conditions. This protocol also makes a strong case for the relevance of monitoring wadeable stream habitats by highlighting known issues related to stream habitats in SECN parks; and identifying the important linkages between the physical condition of streams and park resources. Most importantly, the data collected by following this protocol provide early warnings of changing conditions and help to inform managers of major changes in stream channel habitat.

Data collected as part of this effort are stored locally on the SECN internal file server and uploaded annually to the Integrated Resource Management Applications (IRMA) website. In addition to utilizing customized data handling and reporting procedures, this protocol, and its accompanying standard operating procedures, sets guidelines for data to be made available both internally and externally via publication of data reports and briefing statements.

Acknowledgments

As this protocol represents a hybrid sampling approach incorporating previously published instructions, the authors would like to acknowledge several programs that provided helpful guidance and instructions including the U.S. Environmental Protection Agency's Wadeable Stream Assessment Program (U.S. EPA 2013), the U.S. Geological Survey's National Water Quality Assessment Program (Fitzpatrick et al. 1998) and the U.S. Forest Service's *Stream Channel Reference Site: An Illustrated Guide to Field Techniques* (Harrelson et al. 1994). Additional thanks to Jennifer Asper for her assistance with early versions of the maps used in this report, Paula Capece for her review of the protocol and contribution to data management standard operating procedures, and Christopher S. Cooper for his help with standard operating procedure development and field testing. Jennifer Krstolic and Sandra Cooper (both from the USGS) provided helpful comments and technical advice on drafts of this report and accompanying standard operating procedures. The authors would also like to thank Wendy Wright and the SER I&M editing team for tirelessly toiling away on the many versions of this document and associated standard operating procedures.

List of Terms

The terms in this report are based largely on those defined in Fitzpatrick et al. (1998) and may not be the only valid definitions. Some terms have been modified for clarity with regard to how they are used within this protocol.

Active channel—the area within the channel that is inundated by the normal range in baseflow. The active channel is unvegetated and measured from the wetted edge of the stream to the abrupt increase in slope that demarcates the bank.

Aggradation—a long-term, persistent rise in the elevation of a streambed by deposition of sediment. Aggradation can result from a reduction in discharge with no corresponding reduction in sediment load, or an increase in sediment load with no change in discharge.

Bank—the sloping ground that borders a stream and confines water in a stream channel when the water level, or flow, is below bankfull stage. It is bordered by the flood plain and channel. In the southeastern United States, stream banks can often be recognized by a change in material composition and are often composed of cohesive, fine grained material whereas bed material is often coarser and non-cohesive.

Bankfull stage—stage at which a stream completely fills its natural channel and typically occurs during floods with recurrence intervals of one to three-year (Langbein and Iseri 1960; Leopold et al. 1964).

Bankfull width—measured perpendicular to flow at the height above thalweg that corresponds to bankfull stage. Bankfull widths will only be measured where a flood plain is present.

Base flow—sustained low flow in a stream; groundwater discharge is the source of base flow in most streams.

Channel—the area contained between the banks which includes the streambed, thalweg, and bars formed by the movement of bedload.

Channel full width—measured perpendicular to flow at the height of the lowest flat surface above bankfull stage. This surface often corresponds to the historical terrace in entrenched southeastern streams.

Channelization—modification of a stream, typically by straightening the channel, to provide more uniform flow. Channelization is often done for flood control or for improved agricultural drainage or irrigation.

Confluence—occurs where two or more streams join (e.g., where a tributary joins the main stream).

Contributing area—the area in a drainage basin that contributes runoff to a stream.

Cross-section—a line across a stream perpendicular to the flow along which measurements are taken to characterize geomorphologic features within the channel, with reference to a known vertical datum. Compare to transect.

Drainage area—the area of land, measured on a horizontal plane, that drains water, sediment, and dissolved materials to a common outlet.

Drainage basin—a part of the surface of the Earth that is occupied by a drainage system, which consists of a surface stream or a body of impounded surface water, including all tributary surface streams and bodies of impounded surface water and is enclosed by a drainage divide. Can also include subsurface flow.

Flood—occurs when streamflow overtops the natural or artificial banks of a stream.

Flood plain—the relatively flat area of land bordering a stream channel that is inundated by the one-to three-year flood.

Geomorphic channel units—fluvial geomorphic features created by fluctuations in channel shape and stream velocity. Pools, riffles, and runs are three types of geomorphic channel units considered for habitat sampling.

Habitat—in general, aquatic habitat includes all nonliving (physical) aspects of the aquatic ecosystem (Orth 1983), although living components like aquatic macrophytes and riparian vegetation are usually included. Measurements of habitat are typically made over a wider geographic scale than measurements of species distribution.

Lotic—flowing waters, as in streams and rivers.

Perennial stream—a stream that carries some flow at all times of the year (Leopold and Miller 1956).

Physiography—a description of the surface features of the Earth, with an emphasis on the origin of landforms.

Pool—an area of a stream with low velocity, commonly with water deeper than surrounding areas.

Reach—a length of stream that is chosen to represent a uniform set of physical, chemical, and biological conditions within a segment. It is the principal sampling unit for collecting physical, chemical, and biological data.

Riffle—a relatively shallow part of the stream where water flows swiftly over completely or partially submerged obstructions to produce surface agitation.

Riparian zone—the area adjacent to a stream that is directly or indirectly affected by the stream. The biological community or physical features of this area are different or modified from the surrounding uplands by its proximity to the river or stream.

Run—a relatively shallow part of a stream with moderate velocity and little to no surface turbulence.

Segment—a section of stream bounded by confluences or physical or chemical discontinuities, such as major waterfalls, landform features, substantial changes in gradient, or point-source discharges.

Sinuosity—the ratio of the channel length between two points on a reach to the straight-line distance between the same two points.

Stage—the height of a water surface above an established datum; same as gage height.

Stream flow—a general term for water that flows through a channel.

Stream order—a ranking of streams within a watershed based on the nature and/or number of their tributaries.

Terrace—an abandoned flood plain surface. Terraces are level or slightly inclined surfaces that are contained within a valley and bounded by steeper ascending or descending slopes and always higher than the flood plain.

Thalweg—the line formed by connecting points of minimum streambed elevation (deepest part of the channel; Leopold et al. 1964).

Tie-in point—additional survey location needed to connect benchmarks. Tie-in-points are used when vegetation or topographic features obscure the line of sight between survey benchmarks.

Transect—a line across a stream, perpendicular to the flow, along which measurements are taken to describe the morphological and flow characteristics of a channel. Unlike a cross-section, no attempt is made to use a known vertical datum.

Wadeable—sections of a stream where an investigator can wade from one end of the reach to the other, even though the reach may contain some pools that cannot be waded.

Wetted width—measured perpendicular to flow from wetted edge on river left to wetted edge on river right.

Background

In 1999, the National Park Service's (NPS) Inventory and Monitoring (I&M) Program (now the I&M Division) substantially expanded a pilot long-term ecological monitoring program known as "Vital Signs Monitoring" to cover more than 270 parks. The program was designed to provide the minimum infrastructure required to identify and monitor the conditions of the highest priority resources within the National Park System (Fancy et al. 2009). The Southeast Coast Network (SECN) was one of thirty-two networks formed to implement the I&M Division's program and is tailored to the specific needs of the parks within the network. The overarching purpose of the SECN's natural resource monitoring is to (1) collect and produce scientifically sound data that describes the current status of—and long-term trends in—the composition, structure, and function of park ecosystems and (2) to determine how current management practices are sustaining these systems. Efforts implemented under vital signs monitoring seek to address the following five major goals for all parks with important natural resources:

1. Determine the status and trends in selected indicators of the condition of park ecosystems to allow managers to make better-informed decisions and to work more effectively with other agencies and individuals for the benefit of park resources.
2. Provide early warning of abnormal conditions of selected resources to help develop effective mitigation measures and reduce costs of management.
3. Provide data to better understand the dynamic nature and condition of park ecosystems and to provide reference points for comparisons with other, altered environments.
4. Provide data to meet certain legal and Congressional mandates related to natural resource protection and visitor enjoyment.
5. Provide a means of measuring progress toward performance goals.

Protocol Development

In 2004, in order to develop the SECN Vital Signs Monitoring Plan, SECN staff provided parks with resource prioritization surveys. These surveys asked natural resource staff to rank the importance of the natural resources within their parks and to identify potential concerns that a monitoring program might address. Findings from this survey indicated that additional information addressing the spatial extent and quality of stream habitats are of value to managers in six SECN parks with extensive riverine resources (Figure 1): Chattahoochee National Recreation Area (CHAT, Chattahoochee River NRA), Congaree National Park (CONG, Congaree NP), Horseshoe Bend National Military Park (HOBE, Horseshoe Bend NMP), Kennesaw Mountain National Battlefield Park (KEMO, Kennesaw Mountain NBP), Moores Creek National Battlefield (MOCR, Moores Creek NB), and Ocmulgee National Monument (OCMU, Ocmulgee NM) (DeVivo et al. 2008). Using this survey as a guide, and acknowledging both the scenic and ecological importance of river and stream habitats, monitoring of wadeable stream habitat was selected as a high priority network vital sign.

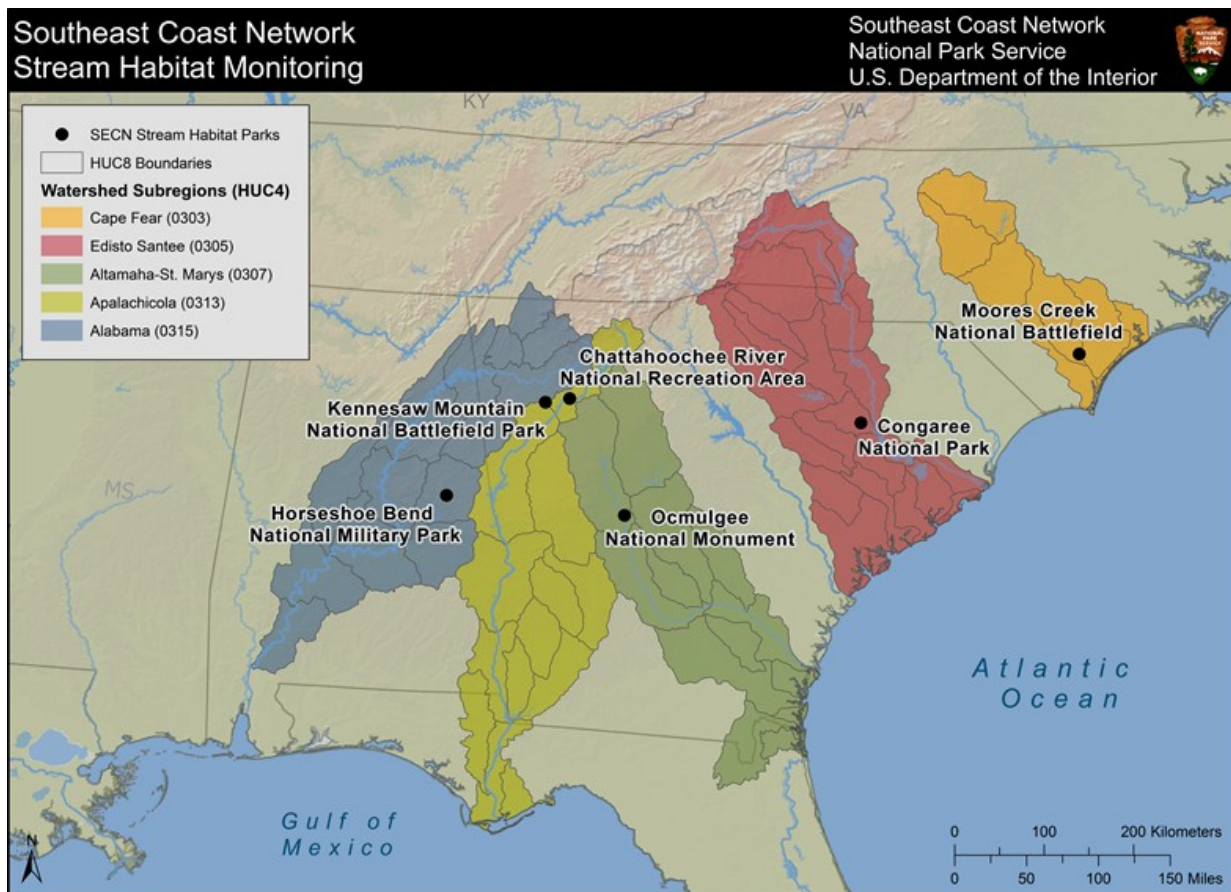


Figure 1. Map showing locations of inland river parks in the Southeast Coast Network.

Providing useful stream habitat information presents both technical and logistical challenges due to the abundance of data collection methods available, and the diversity of stream types present in SECN parks. Network management consulted with stream habitat and geomorphic specialists to help develop adequate and appropriate assessment techniques to be used in southeastern stream systems. In 2009, the U.S. Geological Survey (USGS), in cooperation with the network, began evaluating existing methods and protocols used by federal, state, and private organizations. This exercise yielded an exhaustive list of potential methods that could be used to assess the condition of network rivers and streams; although only a limited number of these techniques and measures were deemed appropriate for the specific management objectives guiding the Vital Signs Monitoring Program. For example, while the United States Environmental Protection Agency (EPA) Wadeable Stream Assessment Program (EPA 2013) provided adequate instructions for habitat assessments, it focused more on the collection of water quality and biological sampling, which are lesser priorities for SECN resources managers. Another example is the EPA's rapid bio-assessment protocol (Barbour et al. 1999) which was deemed too subjective to meet the goals of the Vital Sign Monitoring Program. The USGS National Water Quality Assessment (NAWQA) Program's stream habitat assessment (Fitzpatrick et al. 1998) standard operating procedures (SOPs) were deemed adequately detailed but focused primarily on measures of fish habitat quality rather than geomorphic indicators of overall stream health and required additional instructions to insure that accurate measurements were

replicable. The United States Forest Service (USFS) reference stream channel sites guide (Harrelson et al. 1994) provided detailed instructions for establishing permanent sites and conducting surveys, but focused mainly on taking geomorphic and hydrologic measurements rather than characterizing habitats and stream health conditions. This protocol represents a hybrid approach integrating many of the most useful aspects of each of these programs with additional and updated procedures meant to better target the goals of the NPS Vital Signs Monitoring Program.

The two main goals of this protocol are: (1) to provide the rationale and the specific methods for implementation of a monitoring program that will assess the status of and trends in the quantity and quality of stream and riparian habitat in wadeable streams; and (2) to provide a specific set of instructions in the form of SOPs that are sufficiently detailed to ensure data are collected consistently and comparably through time. Although Moores Creek NB is considered an SECN river park, it does not have any wadeable stream reaches within its boundary; therefore this protocol will only be implemented at five SECN parks (CHAT, CONG, HOBE, KEMO, and OCMU).

Natural History of Lotic Systems in Network Riverine Parks

The regional river systems and drainage networks within the SECN geographic area originate on the south- and east-facing escarpments of the southern Blue Ridge Mountains and traverse the Piedmont and Coastal Plain as the water drains to either the Atlantic Ocean or the Gulf of Mexico (Figure 1). The hydro-climatic conditions of this area are generally characterized as humid subtropical with annual rainfall ranging from 43 to 55 inches (in) per year (110 to 140 centimeters [cm] per year). Monthly rainfall totals are distributed rather evenly from October through May due to the influence of frontal systems that sweep through the region. Snowfall is negligible and winters are mild, whereas summers are hot and humid. Convective thunderstorms influence the region from late spring through early fall resulting in a multimodal distribution of precipitation. Hurricanes and tropical storms have a distinct influence on the delivery of rainfall and flood-climatology of the study area, contributing to a July–August mode in monthly rainfall distributions. The July–August precipitation mode tends to be most pronounced in the coastal localities because of the more direct influence of tropical systems (Gamble and Meentemeyer 1997).

Rivers draining this region are somewhat unique due to their relative protection from past glacial conditions that affected most other regions of North America; though late Quaternary climate change may have produced distinctive shifts in channel form in the larger rivers systems of the region (Leigh 2008). Marple and Talwani (2000) suggest that subtle variations in meander form may relate to tectonic anomalies and the coastal courses of these rivers are controlled by the location of Pleistocene barrier islands. Wollock et al. (2004) developed a conceptual model to group U.S. drainage areas by major land surface forms, geological texture, and dominant climate characteristics. This system of classification delineated two major hydrologic landscape regions in the Southeast Coast Network. These regions were both described as humid plains regions with permeable soils. Where the two regions differ is in the permeability of the bedrock (permeable closer to coast and relatively impermeable for the majority of the Piedmont region). Drainage areas encompassing Coastal Plain river parks were classified as similar to the areas of the lower Piedmont (plains region with permeable soils and bedrock) but with a sub-humid designation reflecting higher rates of rainfall

(Wollock et al. 2004). The natural conditions of rivers draining the southeastern U.S. are generally characterized by meandering channels with densely vegetated banks (Leigh 2008); though modern stream habitat and flow conditions may not reflect prehistoric conditions in most river systems in the Southeast. Contemporary river systems in the southeastern U.S. are in variously altered states that have been affected by multiple legacies of anthropogenic disturbance. Thus, SECN monitoring efforts are focused on characterizing the existing, and probably altered, geomorphic and hydrologic conditions rather than the pristine conditions that may characterize larger parks, especially those in the western U.S.

Timeline of Human Activities Affecting Network Streams

Agriculture was developed by American Indians during the last half of the Holocene. Although much of their activity was centered along rivers, no evidence has been found that suggests that their activities had a major impact on river or stream channel form (Delcourt and Delcourt 2004). Beginning in the late 1600s, European settlers began impounding small tributary streams across the region, substantially impacting natural channel forms by altering sedimentation and erosion rates. Mill dam construction was especially pervasive in the south- and mid-Atlantic Piedmont where stream gradients were favorable. By 1840, over 65,000 mill dams had been constructed in the settled portions of the eastern U.S. (Walter and Merritts 2008). Walter and Merritts (2008) also proposed that prior to mill dam construction, wetlands dominated the flood plains along these smaller streams and the modern, incised, meandering stream is an artifact of the rise and fall of the use of mid-Atlantic streams for water power. Other types of activities associated with agriculture, such as extensive ditching, channel straightening, and the building of dikes, levees and diversion canals were also associated with a decrease in flood plain wetlands.

After 1880, agriculture became the dominant driver of change for southeastern stream systems due to steadily decreasing amounts of forested lands, an increasing proportion of row crops, and a general lack of soil conservation measures (Trimble 1969). Most of the observable changes to valley and stream morphology in the southern Piedmont occurred after the 1880s when extensive mill pond sedimentation began. Between 1890 and 1940, Trimble (1969) documented a massive loss of topsoil from the steeply sloped upland areas in the Piedmont region of north Georgia. This sediment was transported to streams and flood plains, burying productive in-stream shoal and riffle habitats. Streambed aggradation further exacerbated flooding already worsened by the loss of upland vegetation. Many small streams in the region were transformed, from the hard-bottomed, clear-flowing streams described by early land surveyors, into conduits of turbid water and sand. This pattern of land use and associated geomorphic response continued until about 1919 when approximately 40 percent of the Piedmont in Georgia was used to grow corn and/or cotton, both of which are known to exacerbate soil erosion (Trimble 1969).

Between 1920 and 1940, the cotton market was devastated by the boll weevil, which led farmers to abandon large areas of cropland. As row-crop agriculture became less dominant and forest cover increased, sediment delivery to streams slowed. Streambeds began to degrade, returning to near early historical levels (Trimble 1969). During the 1950s and 1960s, some mill dams and bridge structures became visible again after having been buried in as much as 10 feet (ft; or 3 meters [m]) of sediment.

Today, streambeds in many of the region's small streams have returned to historic or near historic levels although their geomorphic characteristics (width, depth, degree of entrenchment) are quite different from early settlement (pre-1800) conditions.

In addition to the legacy effects of agricultural land use in the region on geomorphic conditions, many southeastern streams (including those in SECN parks) have been subjected to further hydrologic alterations caused by more recent development in their watersheds. Urban expansion and the associated threat of hydrologic alteration has been identified as a major water resource management concern for all of the riverine parks served by the network (Frank Henning 2014, written communication with park superintendents at CHAT, CONG, HOBE, KEMO, and OCMU). Increases in impervious surface area associated with urban/suburban development upstream of many of the small streams that flow through urban parks, such as Kennesaw Mountain NBP and Chattahoochee River NRA, are susceptible to more frequent and higher than normal peak discharges, which greatly influence available in-stream and riparian habitats (Paul and Meyer 2001). An additional threat to streams impacted by urban development is lower-than-normal base flow during dry periods and the associated reduction in in-stream habitat due to impaired groundwater recharge (Rose and Peters 2001).

Southeast Coast Network Riverine Parks

The following sections describe the wadeable stream resources in the SECN riverine parks that have significant wadeable stream resources (CHAT, CONG, HOBE, KEMO, and OCMU).

Chattahoochee River National Recreation Area

The Chattahoochee River NRA is made up of 6,800 acres (2,752 hectares [ha]) of mixed pine/hardwood forests and wetlands that buffer 48 miles (77.2 kilometers [km]) of the Chattahoochee River (Figure 2). The park consists of 16 non-contiguous management units along this stretch of the river as it flows through north Atlanta, Georgia, the Southeast's largest metropolitan area (U.S. Census Bureau 2010). Chattahoochee River NRA offers green space and water-based recreational opportunities for the Atlanta metropolitan area and was designated as America's first official National Water Trail in 2012. This section of the Chattahoochee River is highly regulated by flows from Buford Dam, which was completed in 1957, and is heavily utilized for power generation, water supplies and waste-water assimilation for the greater metropolitan Atlanta area.

Chattahoochee River National Recreation Area - Hydrology

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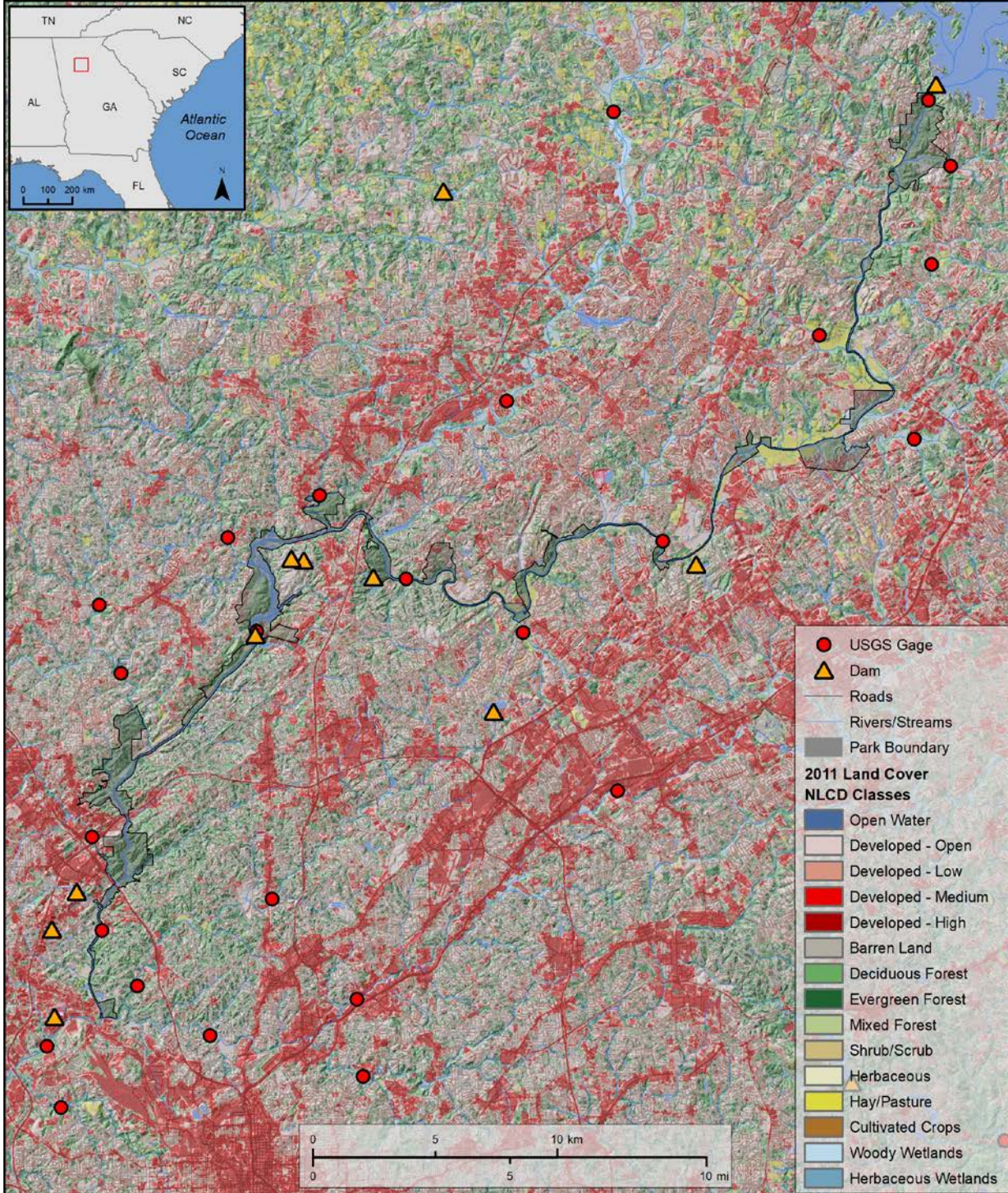


Figure 2. Water resources and USGS gaging stations in and near Chattahoochee River National Recreation Area near Atlanta, Georgia.

The Upper Chattahoochee River's position in a relatively stable fault zone has resulted in a long and narrow watershed (Burkholder et al. 2010) that is dominated by many small tributaries feeding the mainstream along most of the Chattahoochee River NRA-authorized area. Flow alteration associated with the impoundment and release of water for power generation has a pronounced effect on the flow patterns of the main stem. The majority of the streams flowing through Chattahoochee management units are small, lower-order (first to third order) tributaries that are heavily impacted by the direct and indirect effects of urbanization. Changes in the watersheds outside and upstream of the park have led to higher peak flows and lower base flow in the tributaries (Gregory et al. 2012 and Starkey 2015). Stormwater discharges from the urban areas that feed into these tributaries also impact the quality of the water supplied by these small streams by increasing the temperature, turbidity, and bacterial and heavy metal loads. Stream habitat and water quality are also influenced by highways and roads, power line rights-of way, and sewer lines that commonly cross both the wadeable and non-wadeable streams in the park. Within the park, stream bank conditions are impacted by bicycle and foot trails. Additionally, altered stormflow regimes potentially threaten park infrastructure (e.g., parking lots, bridges) due to increased channel instability.

Congaree National Park

Congaree National Park is located at the confluence of the Congaree and Wateree Rivers and covers more than 26,000 acres (10,521 ha) of biologically and geomorphically diverse flood plain forest (11,000 acres [4,452 ha] are old-growth bottomland forest) (Figure 3). The park has the largest concentration and highest diversity of fluvial features in the network, and includes both wadeable and non-wadeable perennial streams. The park also contains a complex group of natural channel features such as meander channels, crevasse channels, meander-scroll swales, and chute channels that typically form on large alluvial flood plains (Meitzen 2011). These channel-like features are not typically found in upland areas and do not function as traditional hierarchical stream systems. The flow of water through Congaree NP is closely tied to flooding and flow volume on the Congaree and Wateree Rivers (Meitzen 2011). During most of the year the channel-like features on the floodplain may be completely dry and at other times have even been shown to exhibit reverse flows depending on the stage of the Congaree and Wateree Rivers. Up to 90 percent of the park may be annually flooded by major high-flow events in the Congaree River (Knowles et al. 1996). These flows are driven primarily by the Broad River and releases from the Monticello and Parr Reservoirs, as well as flows from the Saluda River and releases from Lake Murray at the Dreher Shoals (Saluda) Dam. Natural flows in the Congaree River have been altered since the late 1920s by the construction of Lake Murray, and by Lake Monticello and the Parr Reservoir since 1978.

Congaree National Park Hydrology

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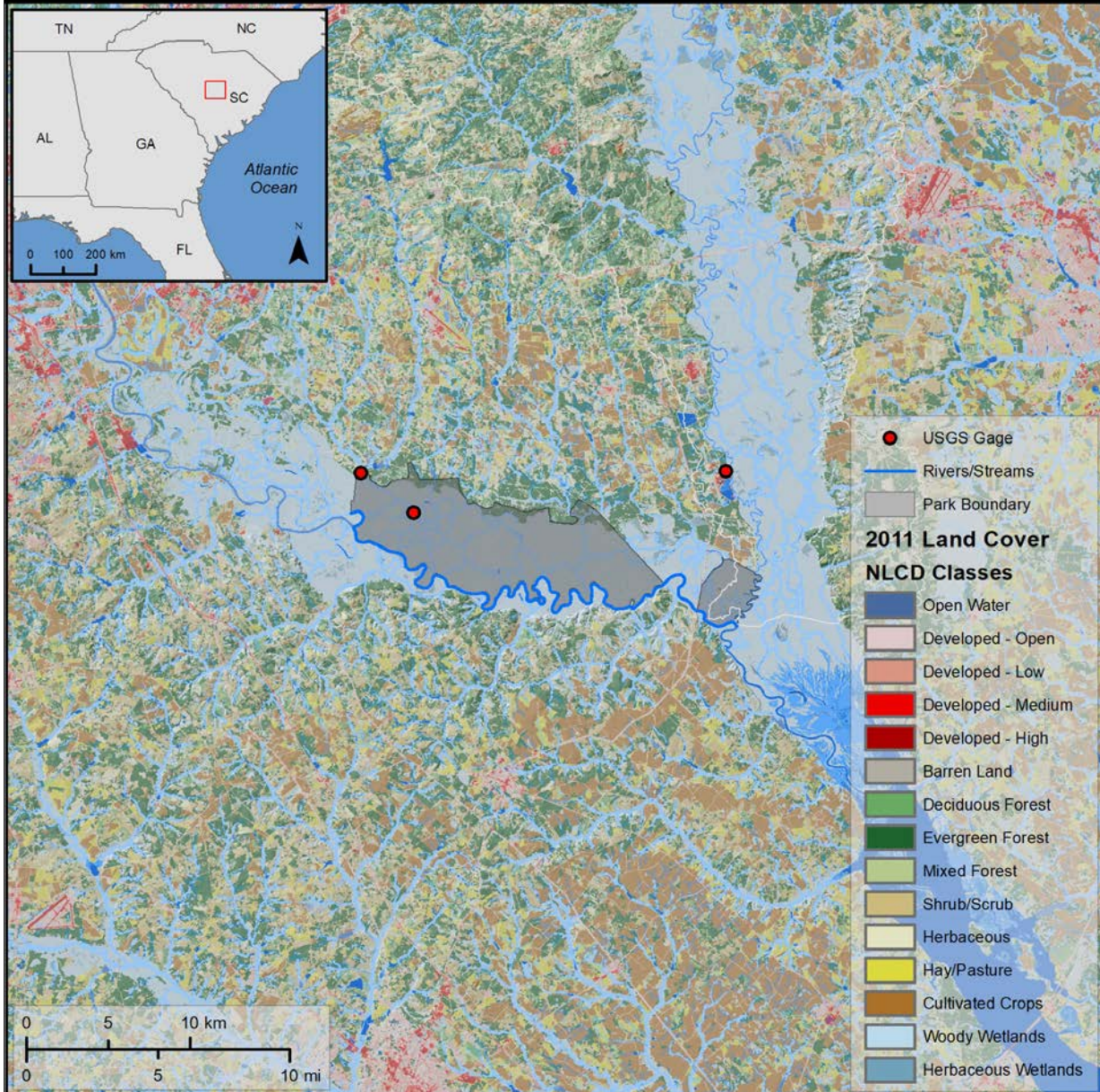


Figure 3. Water resources and USGS gaging stations in and near Congaree National Park near Columbia, South Carolina.

Horseshoe Bend National Military Park

Horseshoe Bend National Military Park is located in eastern Alabama and is made up of 2,040 acres (825 ha) of mixed hardwood forest (Figure 4). Most of the park is upland forest, and a portion of the area along the southern bank of the Tallapoosa River is covered by successional forest on historical farmland. Approximately 10 percent of the area (mostly in depressional areas on the floodplain) is classified as wetlands. The remainder of the park is open areas and fields that commemorate historic

battlefronts. Surface-water resources at Horseshoe Bend NMP include the flow-regulated Tallapoosa River, its relatively narrow flood plain, small intermittent streams along the northern boundary of the Tallapoosa, and a small, unnamed perennial stream on the south side of the Tallapoosa River. Recent reconnaissance surveys indicated that under the drought conditions that existed during fall 2012, most of the park's ephemeral streams ceased to flow (M. B. Gregory, SECN Program Manager, personal observation).



Figure 4. Water resources and USGS gaging station in and near Horseshoe Bend National Military Park near Daviston, Alabama.

Kennesaw Mountain National Battlefield Park

Kennesaw Mountain National Battlefield Park consists of approximately 3,000 acres (1,214 ha) of mixed hardwood pine forest and open fields. The park is located within the Atlanta metropolitan area in the Allatoona Mountain range (Figure 5). Kennesaw Mountain itself is located in the northern portion of the park and receives approximately 2.6 million visitors per year. Water resources include some small bog wetlands and mountain seeps (less than ten percent of the area) and two perennial streams. These relatively small third-order streams, Noses Creek and John Ward Creek, originate outside the park boundaries and drain mostly urban and suburban areas prior to flowing through the park. Due to the intense urban and suburban development outside the park, the hydrology of these streams has been substantially altered and they exhibit typical flashy flows consistent with urban streams (Gregory and Calhoun 2007, Gregory et al. 2012, and Starkey 2015). The heavy visitor loads and popularity of horseback riding on trails throughout this urban park have created areas where stream bank erosion is a potential management concern (Stan Bond, former KEMO Park Superintendent, verbal communication).

Kennesaw Mountain National Battlefield Park - Hydrology

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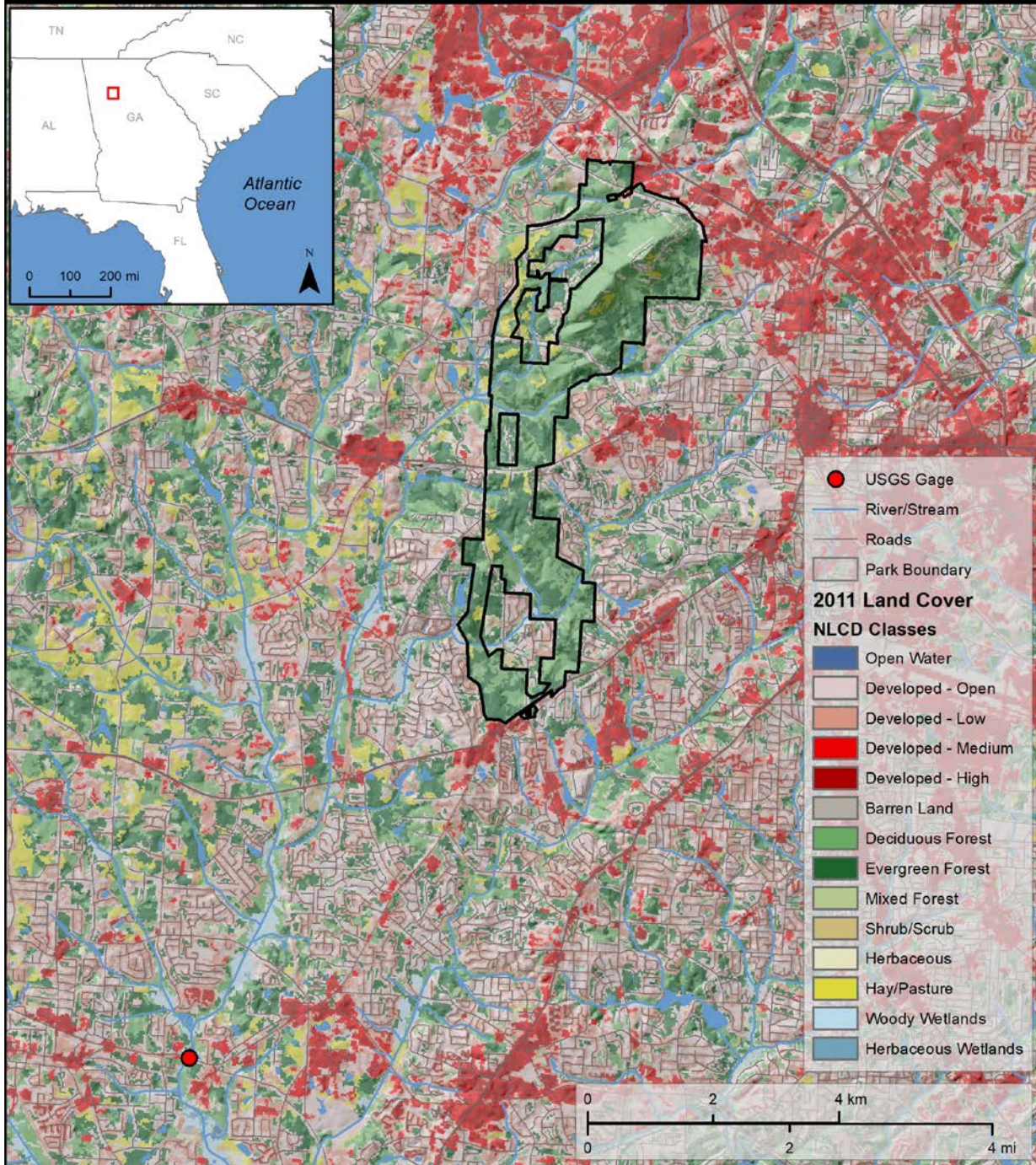


Figure 5. Water resources and USGS gaging station within the boundaries and in the vicinity of Kennesaw Mountain National Battlefield near Atlanta, Georgia.

Ocmulgee National Monument

Ocmulgee National Monument is located on the Ocmulgee River just below the fall line (which separates the Piedmont and Coastal Plain physiographic provinces) in Macon, Georgia (Figure 6). The monument preserves burial and temple mounds, constructed by American Indians, on the Oconee River flood plain and provides recreational opportunities with its green spaces and hiking trails. The 702-acre (284-ha) monument is surrounded by mostly urban and suburban development. Development in eastern Macon has altered sediment delivery and streamflow inside the monument's boundaries (Middle Georgia Regional Development Center 2003). Portions of the monument's North Plateau are rapidly eroding and this material is being deposited on the Middle and South Plateaus (KellerLynn 2013). Walnut Creek, the park's largest perennial stream, originates outside of the monument's boundaries and has several areas of severe bank erosion and sedimentation (Middle Georgia Regional Development Center 2003). Other smaller, intermittent streams at Ocmulgee NM have been similarly impacted. Roughly 300 acres (121 ha) of the park are classified as emergent wetlands, and stream reconnaissance conducted in 2012 noted extensive beaver activity within the monument along Walnut Creek, which has significantly altered flowing stream habitats in this stream corridor (M.B. Gregory, SECN Program Manager, personal observation). Although the monument owns approximately 1 mile (1.6 km) of river frontage along the Ocmulgee River, the construction of Interstate 16 through the monument's flood plain severed its direct connection with the river.

Ocmulgee National Monument Hydrology

Southeast Coast Network
National Park Service
U.S. Department of the Interior

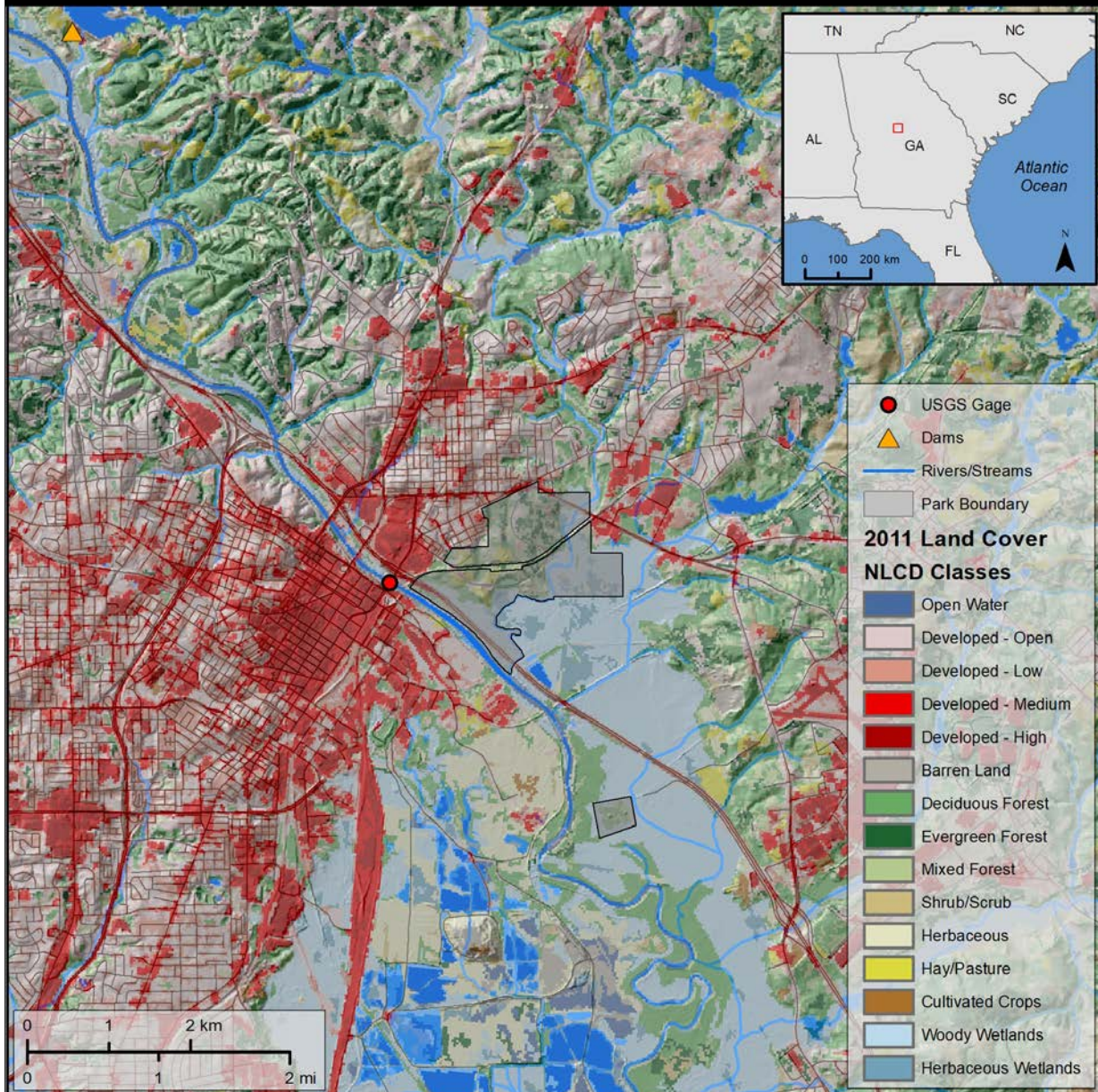


Figure 6. Water resources and USGS gaging station in and near Ocmulgee National Monument in Macon, Georgia.

Rationale for Monitoring Wadeable Stream Habitat

Understanding the physical condition of a river or stream is important due to its strong influence on the structure of biological communities (Schlosser 1982; Newson and Newson 2000; Peterson and Rabeni 2001). Assuming there are no major problems with water quality, the aquatic communities present in a river or stream are largely controlled by the condition and type of in-stream habitat; which is a product of stream channel morphology and any imposed disturbances (Leopold et al.

1964; Yarnell 2006). In-stream habitats may be altered as a result of stream channel adjustments; which could lead to decreased biotic integrity. Alterations to base flows, peak flows, and the flashiness of the flow also will influence the biotic integrity of a stream (Roy et al. 2005; Poff et al. 2010; Carlisle et al. 2011). Roy et al. (2005) studied the impact of flow alterations—caused by varying degrees of imperviousness—on the fish assemblages of 30 small streams in the Etowah River watershed near Atlanta, Georgia. The study found that increased amounts of imperviousness caused conditions that favored flashier flows, larger peak flows, and an increase in the duration of low flow events during the autumn low-flow period. These altered flow conditions were related to an increased richness in cosmopolitan and lentic tolerant species. Increasing the magnitude of peak flow events and the flashiness of flows also increases the suspended sediment in affected streams, further influencing the fish assemblages of the disturbed catchments (Sutherland et al. 2002).

The influence suspended sediment and sediment dynamics have on in-stream biotic integrity and overall water quality has led the U.S. EPA to classify sediment as one of the top pollutants of our nation's waters (U.S. EPA 2009). When sediment supply increases without a proportional increase in discharge, sediment is deposited on the stream bed, smothering the benthic habitat needed to support many macroinvertebrates and fish (Waters 1995). An increase in the supply of fine sediment also increases turbidity and affects solar radiation penetration and primary production. Habitat disturbance also occurs when a stream has greater energy than available material to transport (Lane 1955). This is often the case in urbanizing watersheds (Wolman 1967) where impervious surfaces quickly shed water into storm drains that have little friction or sediment load (Booth and Jackson 1997). This scenario is a potential stressor in many SECN parks and often leads to stream bank erosion and channel entrenchment. Extensive down cutting of channels and/or rapid aggradation of flood plain surfaces may result in a lowering of the water table, causing riparian vegetation to shift to more upland-type species. Additionally, increased channel entrenchment also creates conditions that result in less frequent interactions between the stream and its flood plain which can further impact riparian vegetation and habitat (Benke 2001).

Stream habitats are also intricately linked to aesthetics, allowing visitors to enjoy the natural beauty of the dynamic interaction of land and water while hiking, fishing, bird watching, or enjoying the solitude of nature. Channel adjustments can lead to altered habitat conditions that may result in degraded aesthetics. This may also lead to a disruption of trophic interactions, negatively impacting recreational activities such as fishing and migratory bird watching. Visitor experiences are also tied to the condition of banks, especially in highly populated areas where visitor use may involve hiking or fishing along stream banks, or where foot traffic may cross or run parallel to stream channels. In addition to habitat degradation, substantial lateral adjustments of the stream channel may result in the loss of park land and threaten cultural sites. Other pertinent wadeable stream metrics and their management relevance are shown in Table 1. Fluvial environments are dynamic and often change chaotically. It is difficult to predict how a specific stream will be affected by changes to upstream land use/land cover and associated hydrologic alterations. For example, a flashier hydrologic regime may cause a stream channel to narrow because sediment from bank failures is not transported out of the reach or the channel may widen because the sediment from the failed banks is transported downstream. The purpose of this protocol is not to predict how each stream may be affected by

different stressors but rather to detect that the streams are deviating from their baseline condition; providing a warning that additional investigations may be needed (e.g., significant fining of the representative riffle within a stream reach represents a significant loss of in-stream habitat that may concern the park).

Table 1. Relevance of the protocol to management and potential measures for vital signs monitoring for wadeable streams within SECN parks.

Management Relevance	Appropriate Measures
Understanding Dynamics of Geomorphic Processes. In an undisturbed state, streams are naturally dynamic systems controlled by local and upstream geology, soils, groundwater, and surficial hydrology. The combination of local and watershed conditions drive erosive potential, rates of channel migration, stream type classification, habitat-type and availability, and suitability of those habitats to support ecological functions.	Bank geometry¹, channel morphology¹, grain size distribution¹, slope¹, bank erosion/stability¹, large woody debris distribution¹, discharge/velocity², and distribution/area of geomorphic channel units (runs, riffles, pools)¹.
Contextualization of Watershed Landscape Dynamics. The type, distribution, and proximity of land use and land cover types to stream systems affect the rate and pathways for delivery of water and sediment to and through stream systems.	Land use type and distribution¹, soil type², watershed shape, relief, and complexity¹.
Visitor Experience. Visitors have an expectation of aesthetics, particularly natural sights and sounds, when using park riverine systems for recreation (including streams and adjacent riparian zones).	Type and volume of sounds present, riparian zone vegetation density / age ² , turbidity ² , water odor ² , canopy cover¹ , visitor use ² .
Recreational Potential. In-stream habitats provide boating, hiking and fishing experiences to visitors, but access points also serve as potential areas of localized habitat disturbance.	Distribution / area of geomorphic channel units (runs, riffles, pools)¹, woody debris distribution, bank erosion/stability¹, fisheries population demographics, human disturbance type/extent²

¹ Measures collected under this protocol.

² Measures not collected.

Monitoring Objectives

In the most general sense, the habitat of a stream refers to the living space available to stream biota. However, due to the interaction between the physical structure of a stream and its hydrologic regime, available habitat is spatially and temporally variable (Maddock 1999). The structural component of a stream is highly variable and is a function of geology, slope, geomorphic landforms, and bed and bank material. These components, along with regional- and local-scale climatic and land use histories, dictate the complexity of a stream channel. Ultimately, the current hydrologic regime dictates the quantity and quality of available habitat. Although physical space is the primary variable, specific features and conditions (bed sediment size, velocity, depth variability, shear stress) nested within this space often dictate suitability for specific organisms. The living space and condition of these habitats vary depending on channel size, morphology, slope, and bedforms. In undisturbed systems, this often results in a diverse mosaic of habitat patches suitable for generalist as well as niche species.

Although many of the parks in the network contain some relatively pristine terrestrial areas, the streams flowing into and through the parks have been and continue to be influenced by upstream land use. To determine the influence upstream stressors have on the wadeable streams in SECN parks, it is necessary to monitor the in-stream and riparian habitats of these streams as well as the upstream basin morphology and land cover characteristics that are known to affect fluvial systems. Besides providing an understanding of how upstream stressors are influencing channel morphology and habitat conditions within the parks, these data are important baselines from which other resources (e.g., macroinvertebrate and fish communities) can be managed. Other issues such as lateral stream channel migration occurring near park infrastructure or near important cultural or historical sites also might be of management concern and warrant management actions.

The network has identified three monitoring objectives related to assessing the status, condition, and distribution of in-stream and riparian habitats and how these features are changing through time in SECN parks with wadeable stream resources. These objectives are targeted to assess both watershed-scale drivers of channel morphology and localized responses to these upstream influences.

Specific objectives are:

1. Determine the status of upstream watershed characteristics such as basin area, basin slope, and drainage density, and changes to land cover that may affect stream habitat.

Justification: Basin characteristics are important for interpreting stream and river channel conditions and include both natural (geomorphic and climatic) and anthropogenic (land use/land cover) drivers that influence stream and sediment flows (Fitzpatrick et al. 1998). Developing an understanding of the entire watershed (not just within the park) aids the interpretation of any observed changes in reach-scale habitats.

2. Determine the status of and trends in the geomorphic dimensions (cross-sectional morphology) of selected wadeable stream reaches including channel widths, bank characteristics (e.g., heights, angles, and vegetative cover), and reach slope and sinuosity.

Justification: These data allow managers to better understand the normal/potential range of variability in channel morphology, help predict the types (and magnitude) of changes that may occur at each reach, and provide an understanding of the stability of each reach.

3. Determine the status of and trends in physical measures of benthic and riparian habitat features present in selected wadeable stream reaches such as the size, type, and distribution of bed sediment and large woody debris, the distribution of geomorphic channel units, and canopy cover.

Justification: The quality and suitability of physical habitat for organisms is ultimately dictated by the overall physical integrity of the stream system (Asmus et al. 2009). Streams with diverse and complex habitats often foster greater biodiversity than those that are more homogenous. Physical integrity and habitat diversity may be compromised when an imbalance occurs between the sediment supply and the transport capacity of a stream. This imbalance may lead to aggradation or degradation of the stream bed which can cause habitat homogenization and a resultant decrease in biodiversity.

Sample Design

The number of reaches that are surveyed at each park is dependent on the spatial extent of the park and the total number of wadeable stream segments that are present within park boundaries. Regardless of the size of the park and the number of reaches that are to be monitored, reaches are selected using professional judgement to: (1) represent the processes influencing the streams in each park; (2) address current and anticipated management concerns, and (3) offer the most utility for future complementary studies.

In order to make the data comparable within and between park units, the same data collection methods are used to assess each stream's habitat and geomorphic conditions. Using standardized methods allows changes (and trends) to be detected across reaches and through time.

Prior to field assessments, all monitoring reaches are pre-approved by park resource managers. If deemed necessary by the resource manager, the park is responsible for completion of compliance (such as those required pursuant to the National Environmental Protection Act (NEPA) (42 United States Code (USC) 4321 et seq.), National Historic Preservation Act (NHPA) (Section 106 of 16 USC 470 et seq.).

Sample Frame

This protocol's focus is on wadeable stream reaches; defined here as small- to medium-sized waterbodies with perennial flow within defined channel banks that can be accessed and traversed during baseflow conditions without the use of watercraft. The sampling frame includes all perennial stream segments, within park boundaries, that are included in the USGS National Hydrography Dataset (NHD) high-definition dataset (U.S. Geological Survey 2013). Other stream-like features such as ephemeral stream channels or geomorphic features (paleochannels and flood chutes) typical of large river flood plains are not included as part of the sampling frame.

Due to the hierarchical nature of stream systems (Figure 7), once the sampling reaches have been selected, data are collected at four spatial-scales (modified from Fitzpatrick et al. 1998):

Basin: The area of land from which water and sediments drain into a stream network. For sampling reaches included in this protocol, basins are defined as the drainage area upstream of the downstream end of the stream reach being monitored.

Stream Segment: Defined as a length of stream, bounded by confluences or physical or chemical discontinuities, such as major waterfalls, landforms, substantial changes in gradient, or point-source discharges.

Stream Reach: A length of stream up to 500 meters (0.3 miles) in length chosen to represent a uniform set of physical, chemical, and biological conditions. A stream reach is the principal sampling unit for collecting and summarizing stream habitat data. Reaches are wholly contained within a stream segment.

Transect: A line across a stream extending onto the out-of-channel areas on river left and river right perpendicular to flow. Eleven transects are sampled at each sample reach. Three of the eleven transects are designated “detailed transects” and are chosen to represent the diversity of channel features found within the reach. At the detailed transects, permanent benchmarks are installed and surveyed using a survey-grade total station to facilitate precise relocation (Figure 8). Detailed transects are the locations at which “cross-section” surveys are conducted.

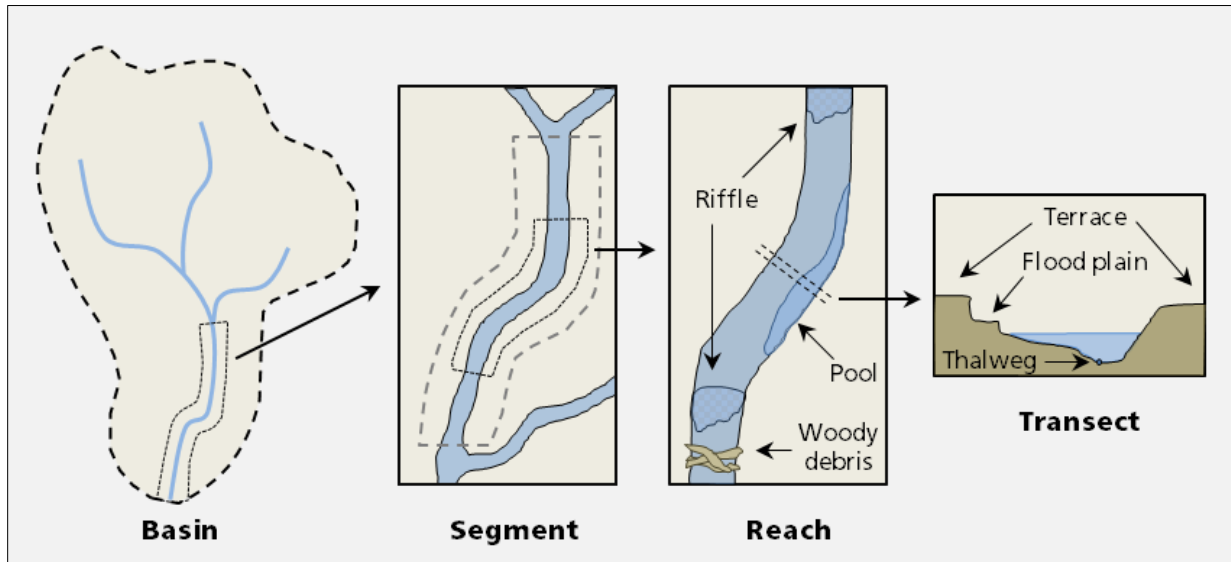


Figure 7. Spatial hierarchy of stream systems and scales of data collection (modified from Fitzpatrick et al. 1998).

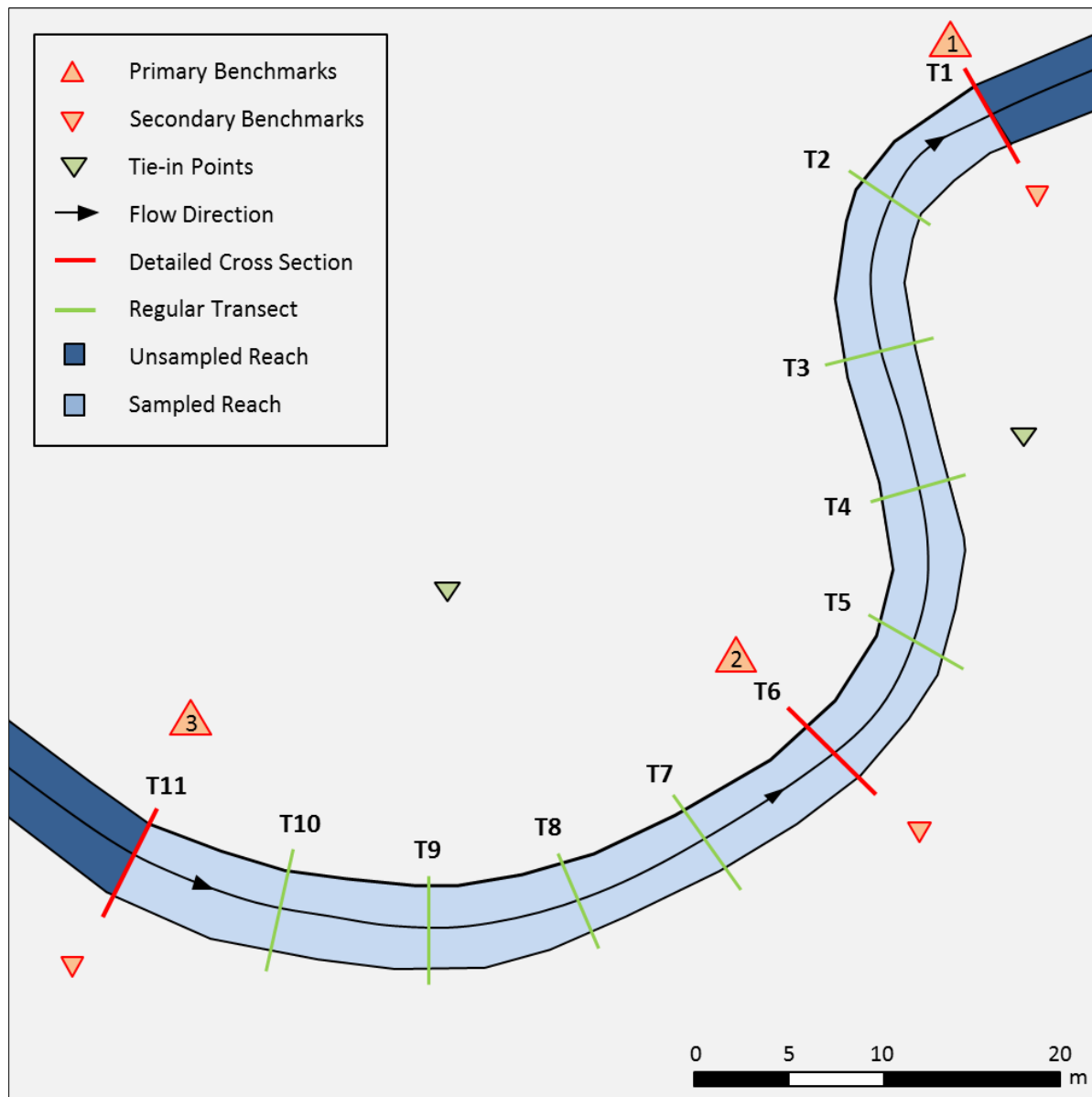


Figure 8. Example layout of stream reach with benchmarks, tie-in points, and transects. The distance between each transect is equal to two times mean active channel width. Total reach length is equal to twenty times mean wetted width. Tie-in points are only required when there is no line-of-sight between benchmarks

Reach Selection

Three levels of selection criteria are applied to all sample reaches: (1) based on GIS analyses of relevant data layers that are available, accurate, and reliable; (2) based on relevant management concerns; and (3) based on field assessments. Field evaluations of potential reaches are necessary because the resolution of available geospatial data is often too imprecise for a determination of the suitability of any given sample reach. In order to provide the most relevant information for management, reaches are either: (1) paired (based on drainage area) to represent disturbed versus undisturbed conditions; or (2) chosen to represent conditions/processes affecting multiple similar-

sized streams within the park. A probabilistic approach to reach selection was not used due to the limited number of potential reaches within each park.

Reaches are selected in five stages:

1. Identification of potential stream segments in GIS;
2. consultation with park staff;
3. field suitability evaluation;
4. basin-scale assessment in GIS; and
5. final decision (with park staff input).

Each of these stages is discussed in detail below and step-by-step instructions are provided in SOP 1.2.14 *Wadeable Stream Reach Selection and Location of Sampling Points—Version 1.0* (McDonald et al. 2018a).

Identification of potential stream segments in GIS

Potential stream segments are identified in a GIS using the NHD high definition (NHDhd) dataset and the park ownership boundaries. A point coverage needs to be created that represents the potential stream segments within each park. This point coverage is used to discuss potential survey reaches with park staff as well as locate the stream segments in the field.

Potential stream segments need to meet the following criteria:

1. Perennial (as classified by the NHDhd data set)
2. Within park ownership boundaries
3. The segment is at least 400 feet (122 m) in length.

A total of 43 segments were identified within the boundaries of CHAT (Figure 9), 14 segments within CONG (Figure 10), 1 segments at OCMU (Figure 11), 1 segment at HOBE (Figure 12), and 8 segments at KEMO (Figure 13).

Consultation with park staff

Once all potentially wadeable stream segments are identified in GIS, a resource manager at each park needs to be consulted to 1) identify reaches with current or potential management concerns, 2) determine issues that may prevent accessing the segment, and 3) determine the long-term applicability of each stream segment. One important consideration for long-term monitoring is the need to have access to the stream segment in perpetuity. If a stream segment not fully-contained within the park boundary is deemed relevant to park management, it is the responsibility of the park to obtain the permits that are required to gain access to the stream segment, install needed benchmarks, and survey the reach. After an updated and annotated list of potential stream segments is assembled, all accessible potential stream segments need to be evaluated in the field.

Field suitability evaluation

Field surveys need to be conducted on each accessible stream segment to locate a stream reach within the candidate segment that is suitable for data collection. Conditions that are likely to make a stream segment unsuitable for sampling include: presence of beaver dams or ponds; lack of a defined channel; or hazardous conditions such as wildlife or treacherous wading conditions. Although the goal is to identify a representative reach within the stream segment and not to provide easy access, it is also important to consider crew fatigue and strike a balance between these two goals.

Stream segments are excluded if upon inspection:

- The stream segment is not wadeable.
- The stream segment is not a free-flowing (e.g., flow obstructed due to beaver impoundments), perennial, single channel, lotic system.
- The stream segment is potentially unsafe (due to extreme entrenchment or potentially toxic waste material).
- The stream segment can only be accessed by traversing through large wetlands.
- Impenetrable vegetation or manmade obstructions prevent sampling of a reach within the stream segment of sufficient length (20 times mean wetted width).

Basin-scale assessment in GIS

Using the list of suitable potential stream segments, a basin analysis is conducted to characterize the variability of the geomorphic and land cover conditions represented by the potential stream survey segments. The purpose of this stage of reach selection is to determine basin-scale similarities between segments so that paired segments can be selected or a representative segment can be chosen that would provide an understanding of similar streams in the park. The measures used to determine the geomorphic and land cover conditions represented by each stream segment are the same as those described in the “Basin and Segment Measures” section below.

Final decision

The results of the basin-scale assessment are used to assist in the final selection of stream segments. Final stream segment selection is done by SECN personnel who can provide the best professional judgment required to adequately assess reach utility, safety, and suitability issues. Chosen stream segments should strike a balance between being relevant to management goals, are complementary to future studies, and are representative of conditions within the park. All ‘final’ stream segment selections need to be confirmed by park staff prior to installing the permanent benchmarks and conducting the initial reach survey. A report is provided to the park and uploaded to IRMA outlining why each stream segment was chosen or rejected.

Sampling Schedule and Frequency

Based on the number of potential stream segments identified in each park and the amount of effort required to implement this protocol, a total of fourteen reaches were chosen at Chattahoochee NRA,

two reaches at Kennesaw Mountain NBP, one reach at Horseshoe Bend NMP, one reach at Ocmulgee NM, and four reaches at Congaree NP (Figures 9-13). Additional reaches may be added in the future pending management needs and park expansion.

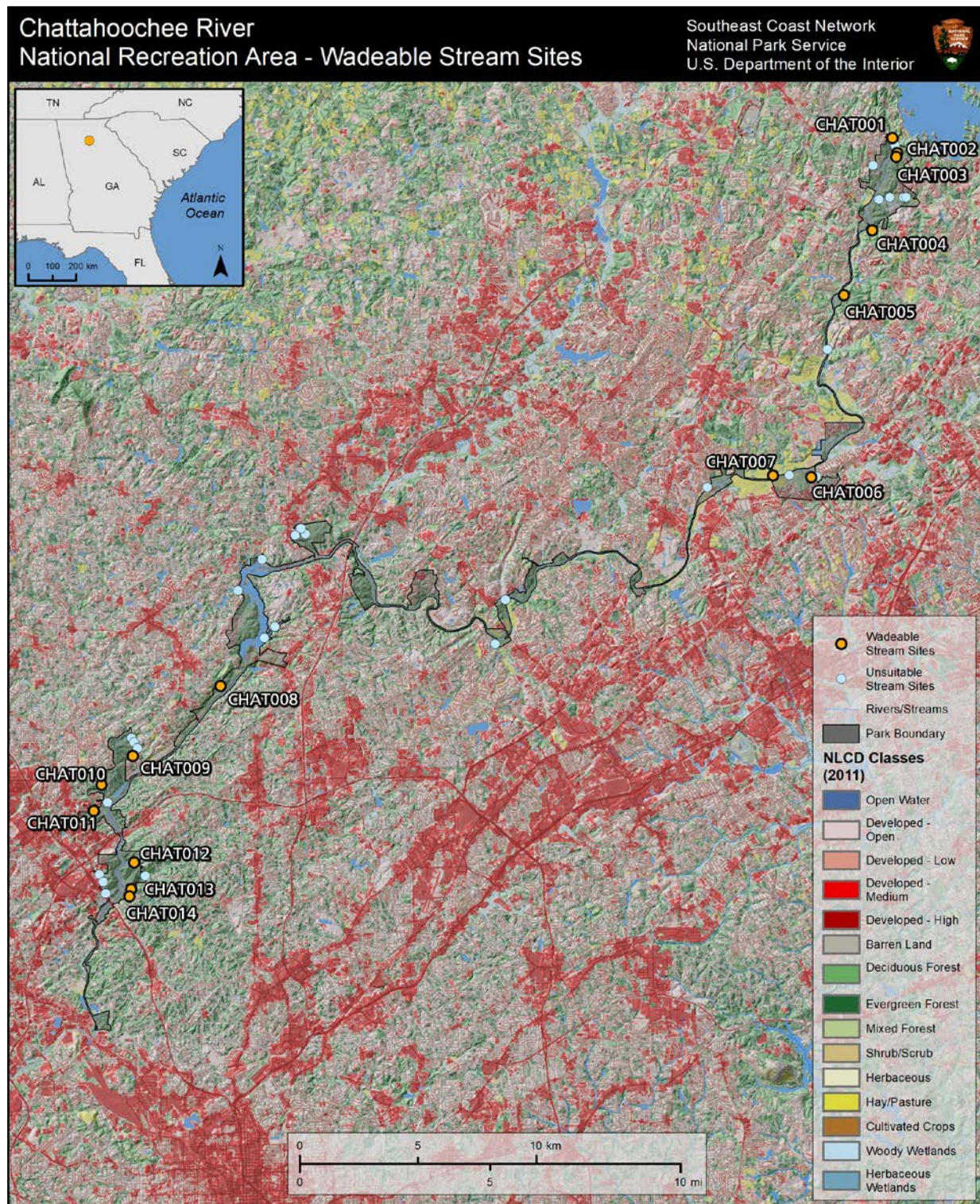


Figure 9. Stream habitat sample reaches at Chattahoochee River National Recreational Area, Georgia.

Ocmulgee National Monument Wadeable Stream Site

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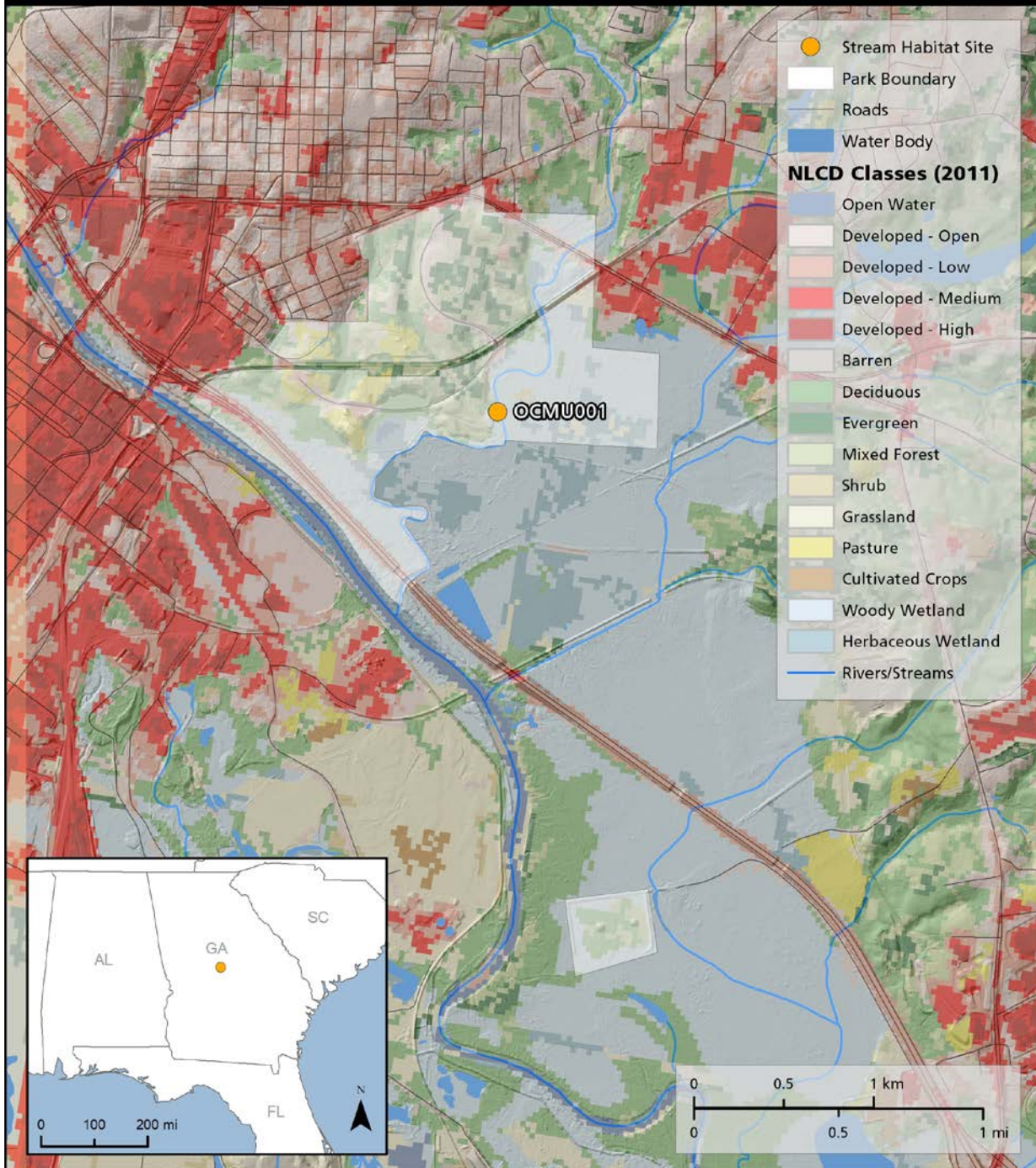


Figure 10. Stream habitat sample reach at Ocmulgee National Monument, Georgia.

Horseshoe Bend National Military Park - Wadeable Stream Site

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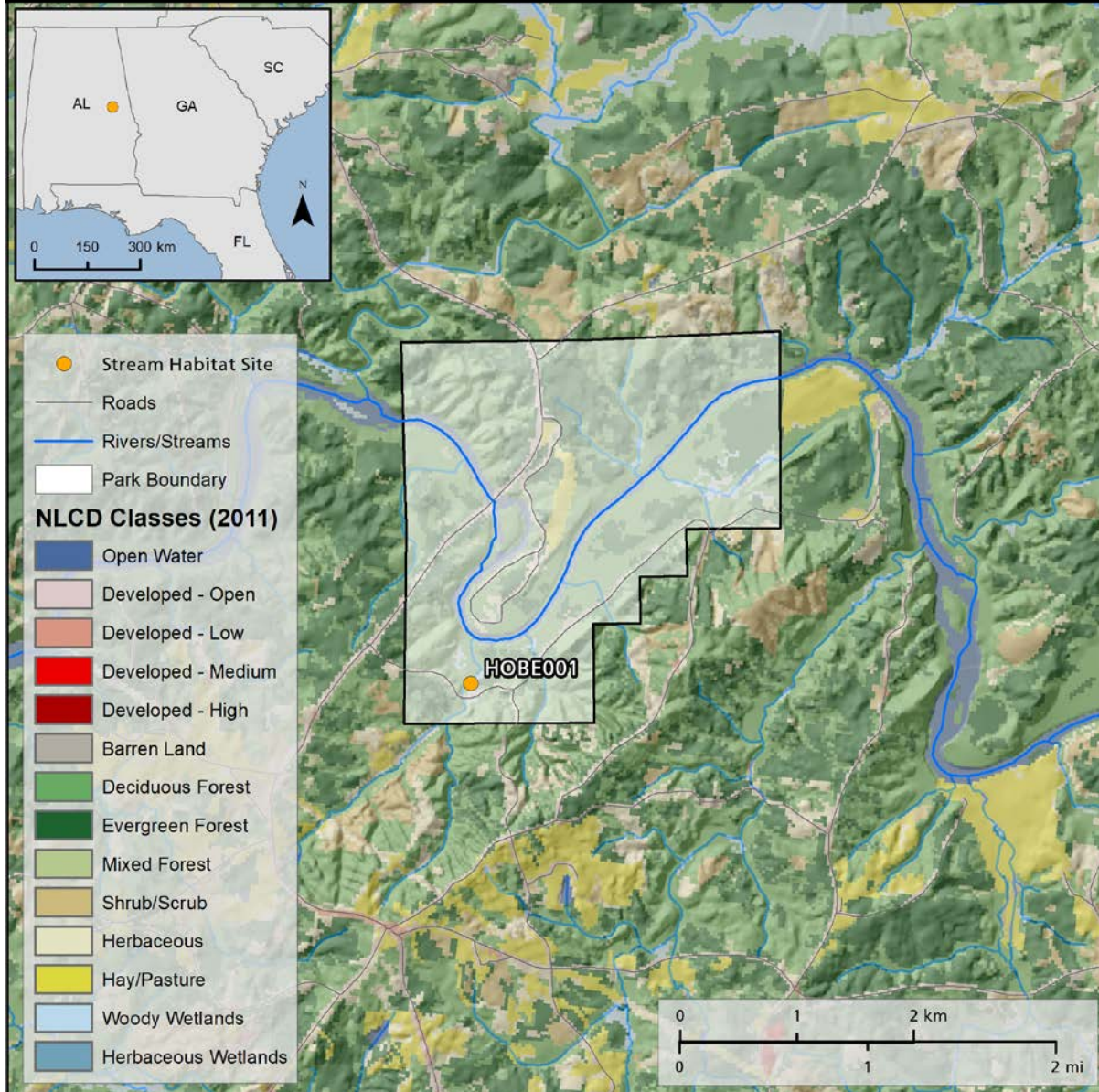


Figure 11. Stream habitat sample reach at Horseshoe Bend National Military Park, Alabama.

Kennesaw Mountain National Battlefield Park - Wadeable Stream Sites

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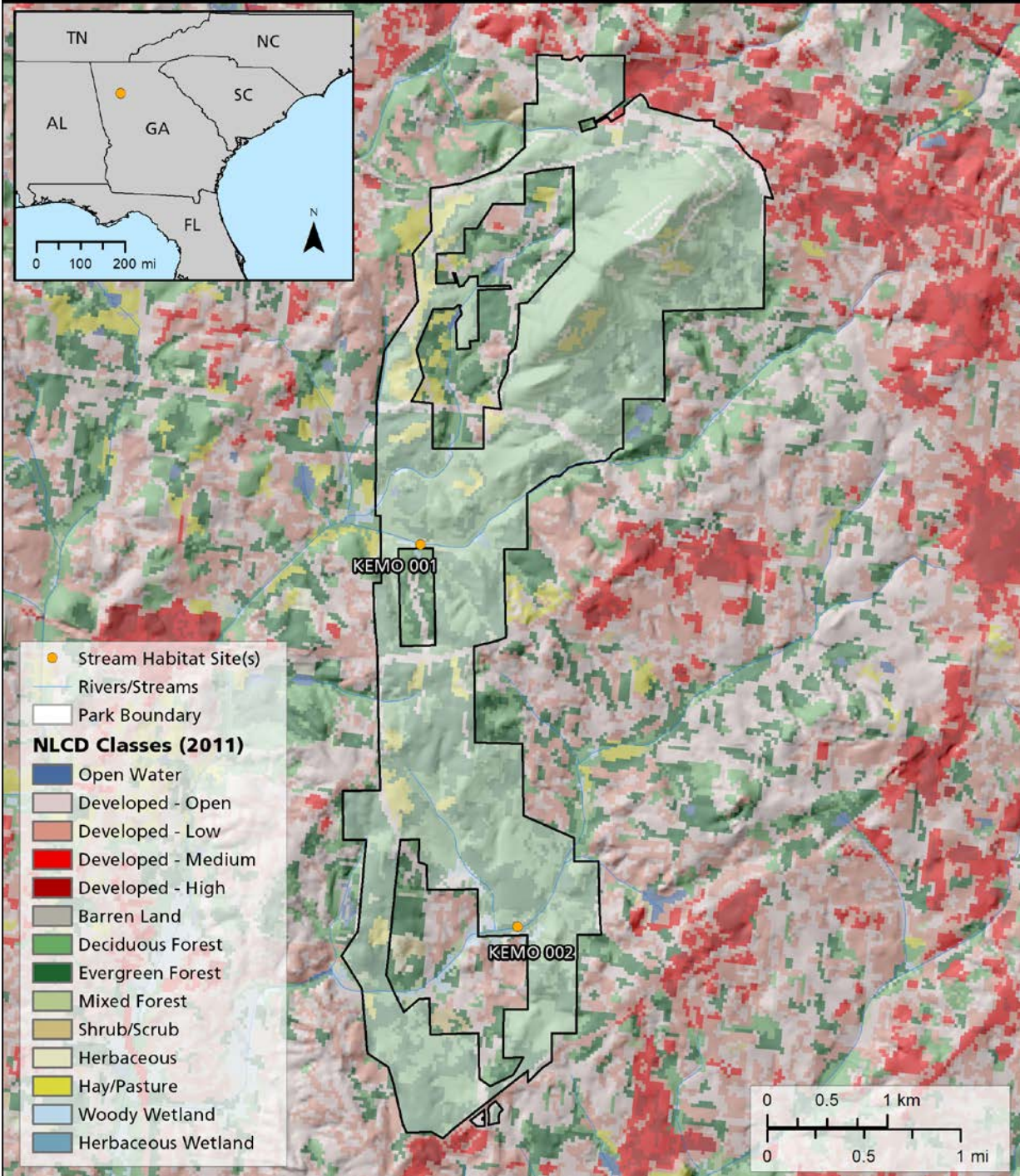


Figure 12. Stream habitat sample reaches at Kennesaw Mountain National Battlefield Park in Georgia.

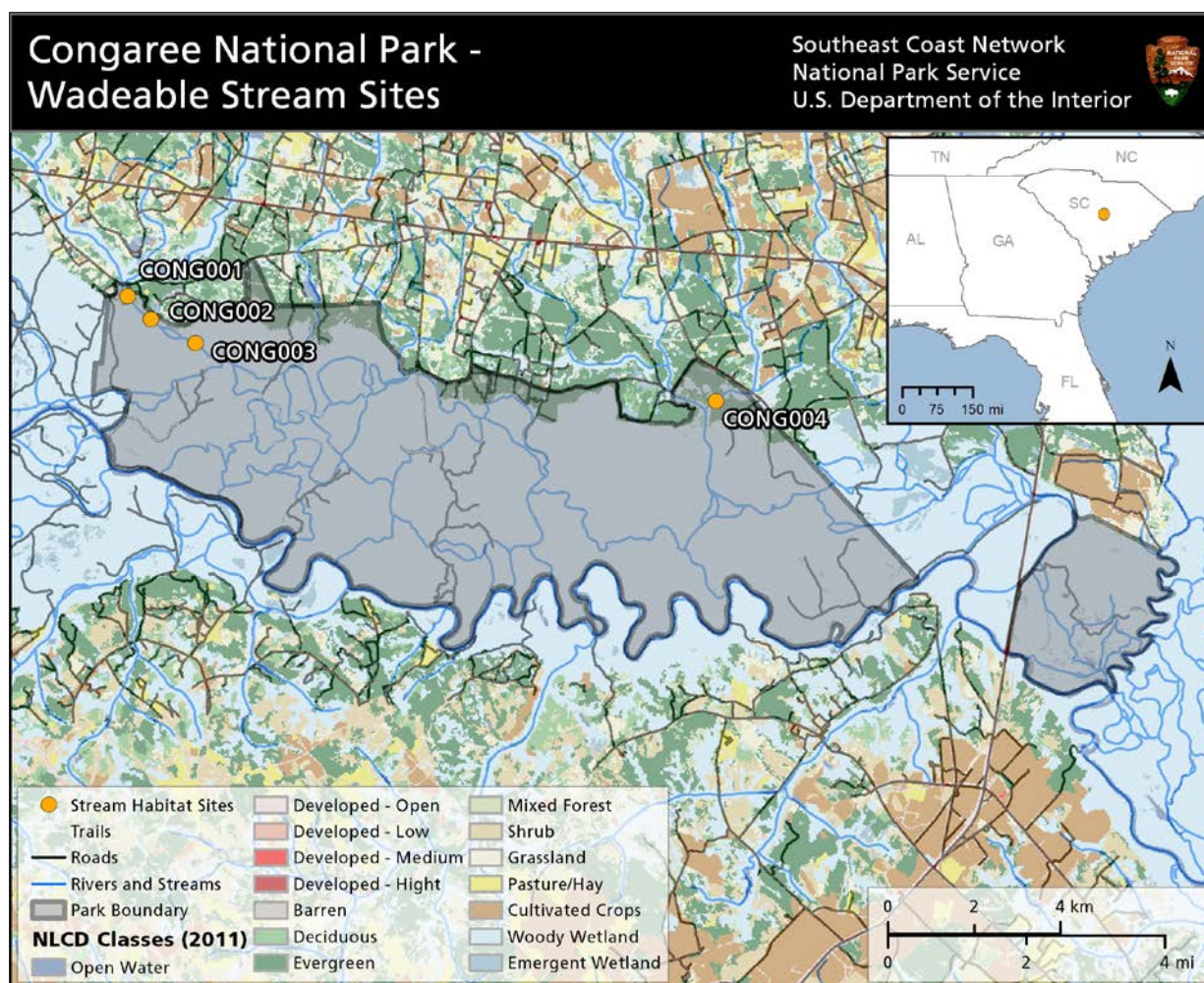


Figure 13. Locations of potential sample reaches on perennial streams at Congaree National Park, South Carolina.

Most aspects of basin- and segment-scale characterization are done very infrequently compared to the reach-scale assessments (Table 2). Measures at the basin- and segment-scale are provided to the Southeast Coast Network through a variety of external sources (such as the National Elevation Dataset and the National Land Cover Database [NLCD]) and are assumed to not be rapidly changing. Basin- and segment-scale metrics are determined for all reaches during the first year of protocol implementation and then updated thereafter no less than once every nine years for the geomorphic characteristics (if a higher resolution digital elevation model is available for all survey reaches) and once every six years for the land use/land cover characteristics (if a new NLCD coverage is available). All reach-scale field data collection occurs once every three years during baseflow conditions; typically during late spring and early summer (Table 3). If needed, field surveys will continue into late summer and early fall; however, all surveys must be completed prior to canopy leaf fall.

Table 2. Objectives, data scales, protocol measurements, sampling intervals and numbers of sampling reaches for stream habitat monitoring at Southeast Coast Network parks.

Objective	Sampling Unit/Data Scale	Protocol Measures	Sampling Interval	CHAT ^a	CONG ^{ab}	HOBE ^a	KEMO ^a	OCMU ^a
(1) Basin Characteristics	Basin	Drainage area, total stream length, drainage density, basin length, basin shape, average slope, standard deviation of slope, basin relief, basin relief ratio, standard deviation of elevation, entire stream gradient, and bifurcation ratio	9 years ^c	14	4	1	2	1
	Basin	Land use/land cover	6 years	14	4	1	2	1
	Segment	Segment gradient and Strahler stream order	9 years ^c	14	4	1	2	1
(2) Geomorphic Dimensions	Reach	Longitudinal profile (channel slope), reach sinuosity, bearing sinuosity, thalweg sinuosity	3 years	14	4	1	2	1
	Transects (detailed) ^b	Bankfull area, bankfull perimeter, bankfull hydraulic radius, bankfull width, bankfull depth, bankfull width to depth ratio, channel-full area, channel-full perimeter, channel-full hydraulic radius, channel-full width, channel-full depth, channel-full width to depth ratio	3 years	42	12	3	6	3
	Transects (all)	Wetted width, active channel width, bankfull width, channel full width, floodplain width, thalweg position, thalweg depth, in-channel features, bankfull height, channel full height, bank undercut depth, bank undercut height, bank angle, bank sediment, bank erosion (presence and type), bank stability index	3 years	154	44	11	22	11

^a Numbers are presented here to illustrate the level of effort planned for each monitoring objective at each park. The number of sampling units for transect-based measures is based on the number of transects used (3 detailed and 11 standard) multiplied by the number of reaches selected for the park.

^b Measures are calculated using survey data collected using a total station.

^c These measures are recalculated only if higher resolution data are available; the measures should not change over time.

Table 2 (continued). Objectives, data scales, protocol measurements, sampling intervals and numbers of sampling reaches for stream habitat monitoring at Southeast Coast Network parks.

Objective	Sampling Unit/Data Scale	Protocol Measures	Sampling Interval	CHAT ^a	CONG ^{ab}	HOBE ^a	KEMO ^a	OCMU ^a
(3) Habitat Features	Reach	Large woody debris amount, volume, position and function, bed material (pebble count), distribution of geomorphic channel units	3 years	14	4	1	2	1
	Transects (all)	Canopy closure, dominant particle size, dominant habitat, vegetative cover, ground cover	3 years	154	44	11	22	11

^a Numbers are presented here to illustrate the level of effort planned for each monitoring objective at each park. The number of sampling units for transect-based measures is based on the number of transects used (3 detailed and 11 standard) multiplied by the number of reaches selected for the park.

^b Measures are calculated using survey data collected using a total station.

^c These measures are recalculated only if higher resolution data are available; the measures should not change over time.

Table 3. Sampling schedule for wadeable stream habitat monitoring within SECN parks. Additional reaches may be added depending on the needs of the park.

Park	2016	2017	2018	2019	2020	2021	2022
CHAT	–	14	–	–	14	–	–
CONG	–	–	4	–	–	4	–
HOBE	1	–	–	1	–	–	1
KEMO	2	–	–	2	–	–	2
OCMU	1	–	–	1	–	–	1

At the end of each field season, one reach that was surveyed is randomly selected for resurvey. This resurvey will provide a check on the previous survey and provide an understanding of the quality of the data that are collected on each reach using the methods outlined in the protocol. See Quality Assurance/Quality Control (QA/QC) of Data Collection section below for more details.

Measures Used for Analyses

The following sections outline the variables that are measured as part of this monitoring protocol. Additional information is provided to justify each variable’s inclusion as part of this monitoring effort. See Appendix A for a table containing a description of each of the variables that will be measured and their corresponding objectives (Table A-3).

Upstream Basin Characteristics

Basin characteristics are important for interpreting stream and river channel conditions and include both basin morphometry and land use and land cover characteristics. All analyses need to use a consistent digital elevation model (DEM) resolution because DEM resolution can have a large influence on the values calculated for the metrics described below. The parameters calculated for each reach include:

- Drainage area: The topographical area to which precipitation, sediment, and dissolved constituents are funneled to a common outlet point along a given stream channel (Dunne and Leopold 1978). Drainage area describes the amount of land that contributes to discharge generation (e.g., larger drainage basins generally have greater average discharge than smaller basins within the same physiographic/climatic region).
- Total stream length: The length of stream within a watershed that flows year round during normal (or average) precipitation conditions. Operationally, this parameter is defined as the sum of all flowlines derived from a hydrologically-corrected digital elevation model using a flow accumulation threshold of 20 hectares (49.4 ac; see SOP 1.2.15 *Wadeable Stream Basin- and Segment-Scale Field Data Collection—Version 1.0* [McDonald et al. 2018b] for detailed instructions). In reality, this quantity can vary greatly depending on short-term fluctuations in precipitation (leading to drainage network contraction or extension [Gregory

and Walling 1968]) and based on the representativeness of the flow accumulation threshold used to create the drainage network.

- Drainage density: The ratio of total perennial stream length to drainage area. This ratio relates to the degree to which the catchment is dissected and reflects the relationship between lithological resistance and the erosive power of the stream within the catchment (Knighton 1998). This parameter can also be viewed as the efficiency with which the basin is able to shed precipitation and discharge water.
- Basin shape and length: Basin shape is controlled by geologic factors, and influences the drainage patterns and runoff characteristics of a watershed. Drainage basins may be round/tear drop shaped or may be more elongated. Differences in basin shape affect the magnitude and duration of floods (Gregory and Walling 1973) and subsequent energy dissipation. More circular basins tend to have flashier and higher peak flows. Basin shape may be quantified using several different descriptors. This protocol uses the basin shape of Horton (1932) where the basin area is divided by basin length squared, which gives a dimensionless ratio of basin shape. Basin length refers to the length of the line that bisects a watershed running from outlet to drainage divide.
- Slope: In this protocol, slope (i.e., watershed slope) is characterized by determining the average and standard deviation of the slope values of each pixel of the DEM within the watershed. Slope often has a large impact on the infiltration and storage potential of soils within a watershed and can be used to determine the rainfall-runoff potential of the watershed draining to each reach (Hewlett and Hibbert 1967)
- Basin Relief: The maximum amount of relief (maximum elevation minus minimum elevation) found within the basin. The amount of relief within a basin has a large impact on the amount of energy that is available to water flowing from the landscape and into the stream network.
- Basin Relief Ratio: A ratio calculated by dividing basin relief by basin length. In a general way, the basin relief ratio is related to the overall slope of a watershed and has been used to estimate a watershed's potential sediment yield (Strahler 1957).
- Standard Deviation of Elevation: The standard deviation of elevation is a measure of the variability in elevation within the drainage basin. This metric has been shown to be positively correlated with the amount and magnitude of storm discharge (McDonald et al. 2018c).
- Entire Stream Gradient: Calculated by determining the difference in elevation at 85% and 10% of the main stem stream length divided by the stream length between the two points. This measure is another descriptor of basin slope and has been shown to have a strong influence on flood magnitude (Craig and Rankl 1978; Fitzpatrick et al. 1998).
- Land Use/Land Cover will be calculated from the NLCD datasets. All available years will be used to identify the dominant land use/land cover classes in each watershed and how they

have changed through time. This dataset classifies land cover using a modification of Anderson et al. (1976).

- Segment Gradient: Calculated by determining the difference in elevation between the upstream extent of the stream segment and the downstream extent of the stream segment and dividing this difference by the length of the stream segment. Segment gradient is an indicator of the amount of energy available to move sediment within and through a reach (Fitzpatrick et al. 1998).
- Stream order: Stream ordering is a standardized way to classify the relative size of a stream and in some cases can correlate with certain habitat types and aquatic communities. The two common stream ordering systems are the Strahler (1957) system and the Shreve (1966) system. In both systems, the smallest streams (those that do not have tributaries) are first order streams. Stream order increases in the Strahler system when streams of equal magnitude or order join (e.g., when two first order streams join, a second order stream begins below the confluence). Where higher and lower order streams join, the downstream portion retains the stream order of the higher order stream. In the Shreve system, stream order magnitude is additive for every branch. For example, if two first-order streams come together, they would form a second-order stream, and if another first order stream entered, it would become a third-order stream, and so on. This protocol uses the Strahler stream order because it is easy to understand and compute.
- Bifurcation ratio: The ratio of streams in a given Strahler order to streams in the next highest order (e.g., number of first order streams/number of second order streams). This ratio can indicate the ability of the stream to carry runoff delivered from the tributaries. It can also be used to compare the convergence between networks and their relative potential for flooding (Strahler 1957). An overall watershed bifurcation ratio is determined by averaging each order's bifurcation ratio.

Additional measures applicable to basin -scale characterization (e.g. precipitation and discharge) are collected and reported through other efforts by the Southeast Coast Network, the National I&M Division, and other agencies, and will be summarized at the basin and segment scale as appropriate.

Geomorphic Dimensions

The geomorphic dimensions of the selected stream reaches are measured to understand the natural range of variability of similar sized streams within and between the park units. Understanding the variability in channel morphology between study reaches will determine which reaches are being negatively impacted by upstream land use and land cover and provide an understanding of long-term trajectories of change along each stream reach.

- Longitudinal Profile: A longitudinal profile (channel slope) allows energy grade lines to be determined and aids in the identification of bed features, flow obstructions, and knickpoints or knickzones (Simon and Castro 2003). Channel slope is a useful metric in comparing similar sized streams and provides an understanding of the stream power available on each

reach. Multiple methods (different equipment and associated procedures) are available for surveying longitudinal profiles (Fitzpatrick 1998; U.S. EPA 2013). To account for the gradually sloping topography found in SECN parks, a survey-grade total station is used to survey the longitudinal profile of the study reaches.

- Reach Sinuosity: Sinuosity is calculated by dividing reach length by valley length. The water surface points collected for the longitudinal profile will provide the reach length (cumulative straight line distance between successive points) and valley length (straight line distance from the most downstream water surface point to the most upstream water surface point). A straight reach will have a sinuosity close to one and a highly sinuous reach will have a sinuosity greater than 1.5 (Leopold and Wolman 1957).
- Bearing Sinuosity: The average difference in compass bearing per meter (bearing difference divided by distance between transects) from the middle of one transect to the middle of the next upstream transect will be used to provide an estimate of reach sinuosity (U.S. EPA 2013).
- Thalweg Sinuosity: The sinuosity of a reach's thalweg can be used to develop an understanding of the types of erosion and deposition that will occur within the reach (Knighton 1998). At each transect, the depth and position of the thalweg are measured. The coefficient of variation of the position of the thalweg will be used as a standardized measure of thalweg sinuosity. A high coefficient of variation indicates that the thalweg is relatively sinuous.
- Channel Cross-Sections at Detailed Transects: Repeat cross-sectional surveys allow for the identification and documentation of channel adjustments in response to various disturbances (Leopold 1973). For example, in Redwood National Park, California, monumented cross-sections were established in 1973 (Varnum 1984; Madej and Ozaki 1996). These cross-sections have provided a substantial amount of data describing channel response to floods and timber harvesting and were also used to supplement fishery habitat studies. Another example, Hogan and Church (1989), used surveyed cross-sections and discharge measurements to develop hydraulic geometry relationships to predict fish habitat.

Detailed channel geometry information can be obtained by surveying channel cross-sections using various methods. Information obtained from cross-sections can be used to identify bankfull and channel full: widths, depths, areas, perimeters, hydrologic radii, and width to depth ratios. In addition, cross-sections can be used to determine spatial heterogeneity in water depth, the presence and/or absence of bedforms, and bar morphology. Detailed cross-section surveys occur at all three detailed transects, which are described in more detail in the procedures and data collection section below.

- Channel Dimensions and measures at All Transects: Measures of channel dimensions and features at the standard transects allow for reach-scale understanding of channel form and adjustments over time (Fitzpatrick et al. 1998). Measures include: wetted and active channel

widths, bankfull and channel full widths and heights; floodplain width; thalweg position/depth; presence/absence of in-channel features (e.g., sand bar or island); undercut height and depth; bank angle and sediment, and presence/type of bank erosion. For operational definitions of the measured channel dimensions see SOP 1.2.16 *Wadeable Stream Reach-Scale Field Data Collection—Version 1.0* (McDonald et al. 2018c).

- Bank Erosion: The presence/absence and type of bank erosion at each transect is indicative of the processes acting on each bank and the potential for change. For this protocol, erosion will be classified as one of the three following types:
 - Lateral— lateral reworking/erosion of the bank
 - Slump— vertical movement/reworking of the bank
 - Undercut— the bank is undercut
- Bank Stability Index: Estimates of bank vegetative cover, angle, height above thalweg, and dominant sediment composition are used to calculate a bank stability index (Fitzpatrick et al. 1998), which is most suitable for reaches that have been subject to a disturbance. In low gradient areas, or areas with little disturbance, such as Congaree NP, stream banks are generally low, vertical or undercut, and composed mostly of fine material. These streams may be in their natural state, but the occurrence of fine material and near vertical profiles may put them in a category other than stable, which could be misleading. However, this index can be useful and will be used to make comparisons over time, especially in the higher gradient streams influenced by anthropogenic stressors such as the streams at Chattahoochee NRA and Kennesaw Mountain NBP.

Habitat Features

The habitat features that are measured as part of this protocol were chosen to provide an understanding of the habitats that are available for colonization by benthic invertebrates within each stream reach. Habitat measures selected for this protocol focus on inventorying large woody debris and bed sediment within each reach. These components of habitat have been shown to be highly influential in the distribution and character of biota within a stream (Allan 1995). These data will also facilitate future complementary studies that can focus on the other physical factors (e.g., current, temperature, and oxygen) that influence biotic assemblages.

- Large Woody Debris Counts: Large woody debris (LWD) plays an important role in many aspects of stream ecosystems. It can alter flow, creating multidirectional flow fields, and often leads to greater turbulence (White and Hodges 2003). Additionally, LWD can affect channel morphology (Baillie and Davies 2002) by slowing water velocities and reducing sediment transport capacity. By becoming lodged at stream margins and along stream banks, LWD can influence where bank erosion occurs by diverting flow around debris jams and into stream banks or can armor banks from further erosion.

One of the most studied aspects of LWD in the southeastern U.S. is its addition of a structural element to lotic ecosystems, particularly for invertebrates and fishes (Wallace and Benke 1984; Smock et al. 1985; Benke and Wallace 1990). In addition to serving as cover for fish and an attachment site for invertebrates and algae, LWD also creates other unique habitats by inducing lateral bank erosion, bed-scour, or causing deposition (Robison and Beschta 1990; Nakamura and Swanson 1993; Webb and Erskine 2005). In lower gradient streams, LWD can often be the main pool-forming mechanism and determinant of channel complexity. Measures of large woody debris include: total count, volume, and function.

- **Bed Material:** The distribution and size of bed material largely dictates the availability and quality of habitat for benthic organisms, and may be altered by both natural and anthropogenic processes. Many studies have found bed material to be more responsive to disturbances than channel morphology (Jackson et al. 2001; Walters et al. 2003; Price and Leigh 2006). Excessive fine material may substantially alter the structure of aquatic communities; often decreasing diversity and leading to communities dominated by more generalist species (Roy et al. 2005). Bed material is a useful variable to monitor when evaluating the effects of land use on streamflow and habitat conditions. The size and distribution of particles (pebble count) from a representative riffle will be used to characterize the bed material of each reach (Wolman 1954).
- **Geomorphic Channel Units:** Geomorphic channel units (GCU) are important descriptors of reach-scale channel and habitat conditions. GCU are partially determined by channel slope and shape, bed material, and scour pattern (Fitzpatrick et al. 1998). Although somewhat subjective (due to differences between surveyors), GCU estimates are widely used in stream habitat assessment surveys by state agencies in the SECN and help classify stream habitat at a biologically-relevant spatial scale (Frissell et al. 1986). The spatial extent of five GCUs (riffles, runs, glides, pools, and steps) will be estimated at each surveyed reach. This protocol uses operational definitions published by Fitzpatrick et al. (1998) and used by the USGS NAWQA Program.

The following GCU definitions will be used by this protocol:

Riffles—relatively shallow areas of the channel where water flows swiftly over completely or partially submerged obstructions to produce surface turbulence. Usually, riffles have relatively coarser bed material than pools or runs and occur in straight reaches. Riffles include low gradient riffles, rapids, and cascades (Bisson et al. 1982), and can look like a run during a flooding event.

Runs—areas with moderate depth. Runs have variable velocities (either high or low) but are characterized by having little to no surface turbulence. Runs typically are found in the transition zone between riffles and pools and in low gradient reaches with no flow obstructions. Bed material in runs

typically ranges from cobble to sand. Runs may become riffles during periods of low flows or droughts.

Glide—relatively deep portions of the stream that are free-flowing and have no surface turbulence. Similar to a run through the water depth is greater and dissimilar to a pool in that they have relatively high velocities.

Pools—areas of the channel with reduced velocity, little surface turbulence, and deeper water than surrounding areas. Pools can form downstream from depositional bars, in backwater areas around boulders or woody debris, or in trenches or chutes. Eddies may be present. Pools also can form behind channel blockages (i.e., beaver dams or logjams) where water is impounded.

Step—created when a blockage (e.g., due to large woody debris) is created in a stream creating a step-like structure in the longitudinal profile of the stream. Pools often form directly up and downstream of a step.

- Canopy Cover: Although riparian vegetation is biological, it often functions as physical structure in stream ecosystems (Kauffman et al. 1999). Overhanging riparian vegetation provides habitat by directly interacting with the water or by shading (Kauffman et al. 1999) and provides cover from terrestrial predators. The shading provided by riparian vegetation also helps to regulate stream temperature. Riparian areas serve many vital functions to both aquatic and terrestrial organisms, providing or creating conditions necessary for many organisms to survive and can also be an important source of organic matter, especially in smaller streams. Riparian vegetation also aids in stabilizing stream banks, with the tensile strength of roots, and increases flood plain roughness, slowing flood waters and reducing energy. Measuring canopy cover helps provide an understanding of the density of riparian vegetation and can help determine the reaches that are most impacted by past land use.
- Dominant habitat: The dominant GCU occurring in the stream at each transect. See the Geomorphic Channel Units section above for the types and definitions of the GCUs that will be encountered during field surveys.
- Dominant particle size: A visual estimate of the dominant particle size of bed sediment at each transect. To facilitate the visual estimate, a modified Wentworth particle size scale will be used as the basis for these estimates (Table 4). All sand classes are combined into one class (sand) and the smallest particle size classes, silt and clay, are combined because it is difficult to visually classify such small particle sizes.

Table 4. A modified Wentworth scale for classifying particle size.

Size Class	Diameter (mm)
Boulder	> 256
Cobble	64–256
Pebble	4–64
Gravel	2–4
Sand	0.062–2
Silt/Clay	< 0.062

Detection of Change

The geomorphic and habitat characteristics of the streams monitored as part of this protocol were chosen so that they can be used as indicators of changing conditions over short (three to five year) intervals (Dan Calhoun, USGS NAWQA, unpublished data). The monitored variables also were chosen because they can be repeatedly measured with the desired level of precision/accuracy to detect change over short- and long-timeframes. Measured variables (e.g., widths and depths) are expected to have precision between observers of 5–10% (Platts et al. 1983; Archer et al. 2004) and visual estimates (e.g., GCU coverage) are expected to be repeatable to within 10–15% (Wang et al. 1996). By adopting data collection techniques currently in use by the NAWQA Program, the data collected as part of this protocol are not only relevant for management purposes (on short time scales of 3–5 years) but ensure compatibility with existing long-term datasets (i.e., NAWQA surveys).

Reach-scale conditions are determined using the central tendency (mean and/or median) of the measurements from the 11 equidistant standard transects. An analysis of survey accuracy conducted by Simonson et al. (1994) suggests that 11 equidistant transects provide estimates of mean reach-scale conditions that have approximately a 90 percent chance of being within 5 percent of the true mean. Simonson et al. (1994) also found that while increasing the number of transects often increased the representativeness of the measurements, the amount of time these extra measurements added to the survey was often substantial. Additionally, the USGS (Fitzpatrick et al. 1998) and U.S. EPA (U.S. EPA 2013) wadeable stream surveys monitor 11 equidistant transects to provide the best balance between representativeness and effort.

To determine the power to detect a 20% change in the width and bank height variables measured as part of the protocol, the data collected during the first round of surveys were used to create simulated second surveys. These simulated datasets assumed that the measurements at-a-transect will be correlated with the first survey and that the coefficient of variation for the second survey is proportional to the first survey. Only the width and bank height variables were analyzed because these are the variables that will be used to determine if the processes that are influencing the reach (e.g., channel-forming discharge) are changing through time. The results of the power analyses indicate that the majority of the reaches have more than 80% power to detect a 20% change in the

width and bank height variables (Appendix B). The power to detect change at-a-reach is dependent on within reach variability of the measured variable (i.e., high variability lowers the power to detect change). After the second survey, a power analysis will be run for each reach to determine the power to detect change in the monitored variables between surveys.

Due to insufficient reach-specific data and the stochastic nature of fluvial processes, an a priori power analysis to detect a trend was not performed. Based on the results of the power analyses of the simulated second surveys, the methods used in this protocol are expected to be able to detect a 20% change in all of the channel morphology variables (widths and bank characteristics) with 80% power at all survey reaches with an alpha probability of 0.05. Once sufficient data have been collected (at least two reach surveys), a power analysis will be conducted to determine the power to detect trends in the monitored variables at each site through time.

Procedures and Data Collection

The approach of this monitoring protocol is to document channel morphology and riparian characteristics that provide an understanding of the condition of in- and near-channel habitats. This approach provides information regarding the physical suitability of stream reaches for organism occupation; assuming no limiting water quality or biological factors. Parameters selected for habitat assessment and geomorphic characterization are based on methods used by other organizations and published studies that have found the physical structure of in-stream and riparian habitat to exert a strong influence on the biological communities and overall ecological integrity of lotic ecosystems (Newson and Newson 2000). Although habitat monitoring can indicate the suitability of a given reach, it is not a substitute for monitoring biological communities or for indicating actual ecological conditions. Monitoring stream habitat does have an advantage in that it not only indicates physical suitability for aquatic species but it can also identify stressors that could degrade other park resources and negatively affect visitor experiences.

The following sections outline procedures selected for inclusion in this stream habitat monitoring protocol. Many of the methods are based on those used by other state and federal agencies and that have been implemented in monitoring programs across a wide range of physical settings and stream types and allow comparisons to be made across a much larger area. Much of this protocol is based on procedures used by the USGS NAWQA Program (Fitzpatrick et al. 1998) and supplemented with procedures used in the U.S.EPA Environmental Monitoring and Assessment Program (U.S. EPA 2013) and the USFS Stream Channel Reference Site: An Illustrated Guide to Field Techniques (Harrelson et al. 1994). For additional information on the protocols cited above see; Fitzpatrick et al. (1998) for [NAWQA protocols](#), U.S.EPA (2013) for [EPA protocols](#), and Harrelson et al. (1994) for [USFS Stream Channel Reference Sites](#). Tables A-1 and A-2 compare the measures collected by the Southeast Coast Network and the above cited protocols (Appendix A).

Reach-scale data collection is conducted during base-flow (non-stormflow) conditions during the growing season so that accurate estimates of bank vegetation and canopy cover can be made. If biological/ecological data collection efforts are added in the future, they will coincide with the physical habitat and geomorphic data collection efforts. Most importantly, the timing of data collection will be consistent so temporal comparisons can be made without having to deal with the added effects of seasonality. The following sections outline general data collection methods, with details on specific sampling methods presented in standard operating procedures (SOP) included as part of this protocol (see Appendix C, Table C-2 for a complete list of SOPs).

Basin- and Segment-Scale Characterization

Basin- and segment-scale characterization is performed in an office setting after permanent reaches have been selected. Measurements and analyses are conducted with a GIS using data sets that are readily available from states, municipalities, universities, and federal agencies. Most aspects of the basin- and segment-scale characterizations will be done once or very infrequently compared to reach-scale assessments (Table 2). An exception is land use/land cover which will be updated every six years or when a new NLCD coverage is released. Basin- and segment-scale metrics are calculated

using ArcGIS or other applications as appropriate. Specific detailed instructions for the data analysis are found in SOP 1.2.15 *Wadeable Stream Basin- and Segment-Scale Data Summary—Version 1.0* (McDonald et al. 2018b).

Establishing Permanent Reaches

During stream segment reconnaissance, optimal access routes are determined. While visiting each stream segment, the crew determines whether a representative reach can be safely assessed or if an alternative stream segment needs to be chosen. A map of the reach is drawn with notes indicating potential locations for total station setup, benchmark installation, and transects. Notes include a brief description or illustration of how the reach was accessed, any hazards found during reconnaissance (e.g., insect nest, barbed wire), and any other supplemental information that could be helpful in locating the reach. These notes ensure that upon future arrival for data collection, the team can easily re-locate the reach, setup, and collect data with maximum certainty and efficiency.

Reach Delineation

Operationally, reach length is 20 times the mean wetted width (Figure 8). In meandering streams, this length (20 times mean wetted width) usually covers at least one complete meander wavelength (Leopold et al. 1964). Using these specifications, reach boundaries extend 10 times the mean wetted width upstream and 10 times the mean wetted width downstream of the reach midpoint. There is no minimum reach length; however, no reaches longer than 500 meters (1,640 ft) are assessed as part of this protocol. Transect locations (separated by a distance of two times the mean wetted width) are flagged when the reach endpoints are located. Permanent benchmarks are installed as specified below.

Monument Installation

In order for a stream channel monitoring program to be successful through time, Leopold et al. (2005) suggests that field reaches be marked or monumented, so that: (1) its principal characteristics (i.e., elevation) can be reestablished; (2) measurements can be repeated in a comparable manner; and (3) later observers are assured of comparable results. Benchmarks set up for this protocol are well documented so that if one monument is lost, positional control can be regained by way of another monument. Southeast Coast Network stream benchmarks are installed according to the guidance in Harrelson et al. (1994), the Northeast Coast and Barrier Network (NCBN) coastal monitoring protocol (Psuty et al. 2010), and with specific detailed instructions for SECN streams in SOP 1.2.14 *Wadeable Stream Reach Selection and Location of Sampling Points—Version 1.0* (McDonald et al. 2018a).

Preferentially, identify a location on river left on the first, sixth, and eleventh transect to install permanent (concrete) benchmarks and a location on river right opposite these permanent locations (and perpendicular to flow) to install the secondary (rebar) benchmark. If impenetrable vegetation, unsafe bank conditions, or bedrock prevent total station surveying of the first, sixth, or eleventh transect, the permanent benchmarks/detailed transects should be moved to the closest suitable transect. Additionally, be sure to install monuments where they will not affect visitor experience and will have a reduced chance of vandalism (e.g., install off of trails and near ground level). If the geography of the reach prohibits installation of the permanent benchmark on river left, identify a

location on river right to install the permanent benchmark and make a note of the change in benchmark location.

Once total station survey-suitable transects are identified, benchmark locations should be located that are at least 10–15 meters (32.8–49.2 ft) outside of areas of active geomorphic activity (e.g., at least 10 meters [32.8 ft] from the top of cutbanks or point bar crests). Additionally, all benchmarks need to have a line-of-sight to at least one other benchmark so that they can be tied together when conducting the total station surveys. If the geography of the reach or impenetrable vegetation prevents a line-of-sight connection of the benchmark network, install an additional ‘tie-in’ benchmark(s) so that all benchmarks can be tied together.

Reach Assessments

After delineating the reach and relocating transects, the reach is surveyed and a reach map is drawn. The geomorphic condition of the stream, presence of woody vegetation near the channel, and any human or natural disturbances on the stream bank or in the riparian corridor is noted on the map as well as in the comments field on the data sheet. Although this type of notation often consists only of qualitative or descriptive data, it is valuable information, especially for documenting possible adjustments or recovery time in response to disturbance(s). The reach is drawn approximately to scale using the map area on the data sheet. Important habitat features such as riffles and pools as well as any substantially eroded areas are also noted.

In addition: the location of surveyed transects and benchmarks are recorded; any symbols used in the maps are defined in a simple key; and the approximate direction of north is indicated with a north arrow on each map. Following the reach visit, this map is scanned, saved to the SECN file server, reproduced in data reports, and used as an aid in collecting and interpreting raw data. Figure 14 is an example reach scale map reproduced in an annual report.

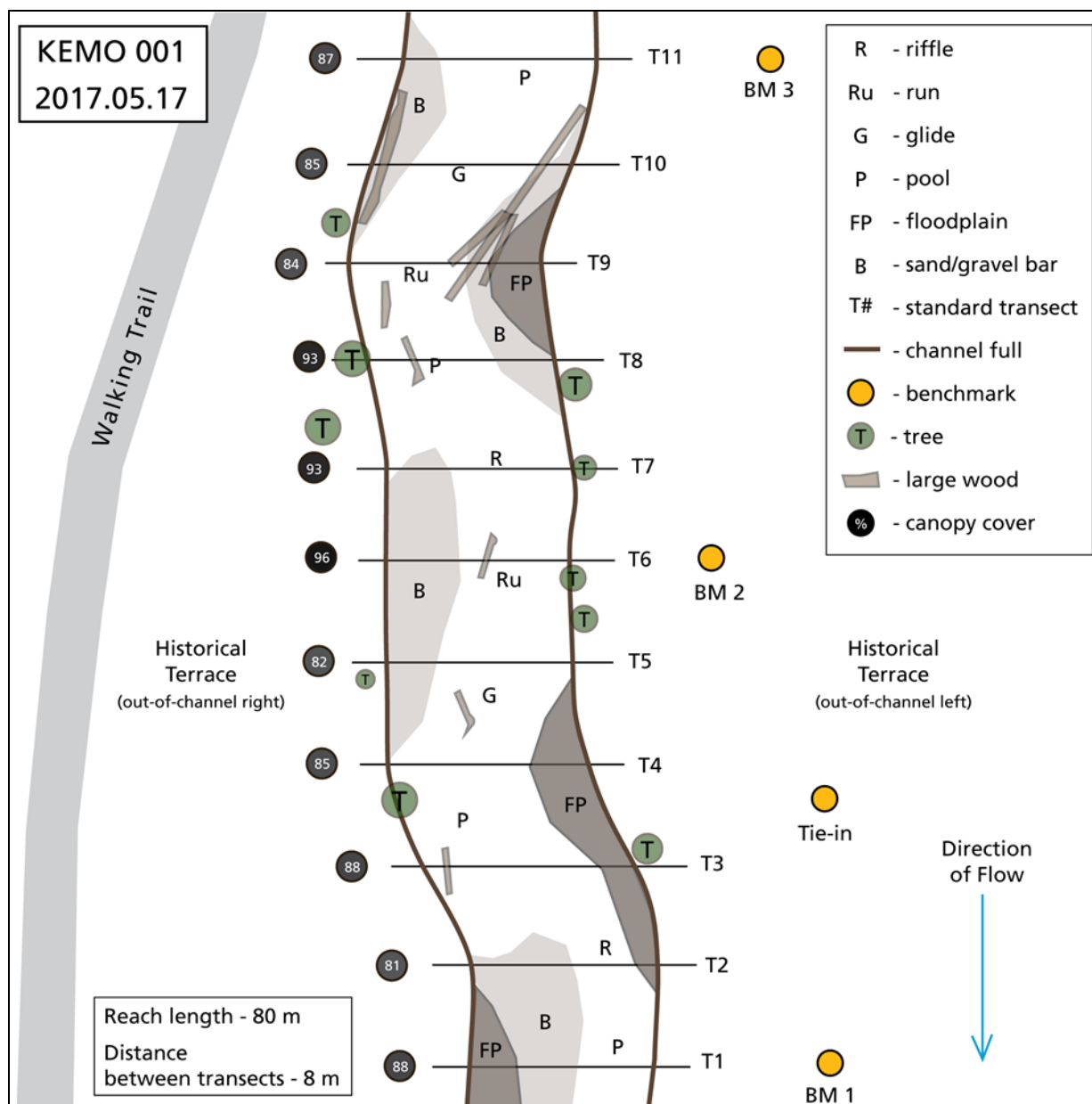


Figure 14. Reach-scale map of KEMO 001. Diagnostic geomorphic surfaces and in-channel features are labeled to provide a context for the standard and detailed transect information provided in the annual report. The canopy cover circles are varying shades of grey which indicate the amount of canopy cover at each transect (high and low coverages are labeled).

Large Woody Debris Estimate

Large woody debris (LWD) is defined as a piece of dead wood material that is greater than 0.10 meter (3.9 in) in diameter and greater than 1 meter (3.2 ft) in length. The data collection procedure for large woody debris (LWD) includes:

1. Between each transect, the midpoint location (closest downstream transect), size, position, and function of all LWD are recorded (Warren et al. 2008).

2. The length and diameter (at the center) of each LWD is measured to the nearest 0.01 meter (0.4 in) using a tape, calipers, or calibrated pole.
3. If a LWD is not perfectly cylindrical, the diameter is estimated as if it were.

Additionally, LWD presence and function is recorded on the reach characterization form and its location drawn on the reach map. Functional definitions are based on those used by Wohl and Jaeger (2009) and include:

- **Ramp**—a piece that has one end supported on the bank and one in the channel;
- **Bridge**—a piece that is spanning above the channel resting on both banks;
- **Buried**—a piece of LWD that is partially buried/stabilized by alluvium or bank material; or
- **Free**—a piece which is fully in the channel and is not held in place by bed or bank material.
- **Jam**—when three or more pieces are touching or function as bank protection.
- **Bank Protection**—when a piece of LWD is diverting flow away from a bank.

These data are used to determine the volume and dominant function of LWD in each reach and are expressed as the volume of LWD per area of channel (m^3/m^2).

Channel Geomorphic Unit Delineation

The type, frequency, and distribution of geomorphic channel units (GCUs) within each reach are determined. The distribution and percent coverage of pools, glides, runs, riffles, and steps are visually estimated for the entire reach by recording the distribution of GCU between each pair of adjacent transects. Additionally, the dominant GCU is recorded at each transect to provide a context for the geomorphic measurements.

Bed Material Characterization

Given the diverse physiographic settings and stream types of the SECN parks, methods for sampling bed material and accurately characterizing particle size distributions may vary. In streams that have gravel or mixed sand-gravel beds, a pebble count (Wolman 1954) is conducted. At least one hundred particles are randomly selected and measured on a riffle representative of the reach. For narrow channels, the observer walks back and forth across the riffle until 100 particles have been recorded. Particles are measured along their intermediate or b-axis which can be visualized as the axis that would prevent the particle from passing through the smallest possible sieve opening. If the particle encountered is too small to pick up, the observer determines whether it is sand (gritty; given a diameter of 1 mm) or silt/clay (smooth; given a diameter of 0.062 mm). For reporting purposes, particle sizes are recorded in raw millimeters (mm). Reporting grain size distributions in mm is precise and generally forgoes any confusion when communicating the results (Kondolf et al. 2003).

Many Coastal Plain and low gradient streams may not have areas that can be classified as riffles and the dominant bed material is usually sand, silt, organic material, or often a combination. When riffles

are not present and bed material is composed solely of sand-sized and smaller particles, pebble counts are of little use. If the reach has a homogeneous fine bed, visual estimates of the dominant material are made. If no riffles are present and the dominant bed material is not sand-sized or smaller, the pebble count methods are used on a representative run (do not collect these data in a pool).

Standard Transects

Standard transect measurements are used to characterize the reach as a whole based on measures of habitat variability. The data also are used to describe the reach relative to its hydrologic, geomorphic and vegetative components. Data collected at each of the standard transects includes: canopy and vegetative bank cover; presence of eroding banks; bed and bank material; wetted, bankfull, and channel-full widths; water depth; and bank heights/angles. These measurements are collected at all 11 transects. For detailed instructions on how to conduct the standard transect surveys, see SECN SOP 1.2.16 Wadeable Stream Reach-Scale Field Data Collection (McDonald et al. 2018d). Three transects are designated as detailed transects and are surveyed using a total station as described below (see Detailed Transect Cross-Sections).

Canopy Cover Characterization

Canopy cover is an important indicator of riparian vegetation condition which is critical for channel stability as well as shading and organic matter input. For this protocol, the vegetation immediately bordering the stream channel is assessed using a modified spherical densiometer to obtain an estimate of canopy cover (Fitzpatrick et al. 1998). The canopy cover at each standard transect is estimated using the modified spherical densiometer and these estimates are used to derive a reach-scale estimate of canopy cover.

Detailed Transect Cross-Sections

Total station surveys of the detailed transects allow for the identification of lateral migration rates and variability of channel morphology to be monitored through time. Surveying channel cross-sections allows changes in streambed elevation and bank profiles to be quantitatively assessed in relation to a known point (benchmark). Survey points are spaced to capture changes in elevation across the channel and surrounding riparian area. The actual spacing and number of points along a cross-section depends on the size, slope, and complexity of the channel and riparian area. Survey data are used to calculate various geomorphic metrics (i.e., entrenchment ratio and width-depth ratio) and are used to assess channel conditions and bank stability (Figure 15).

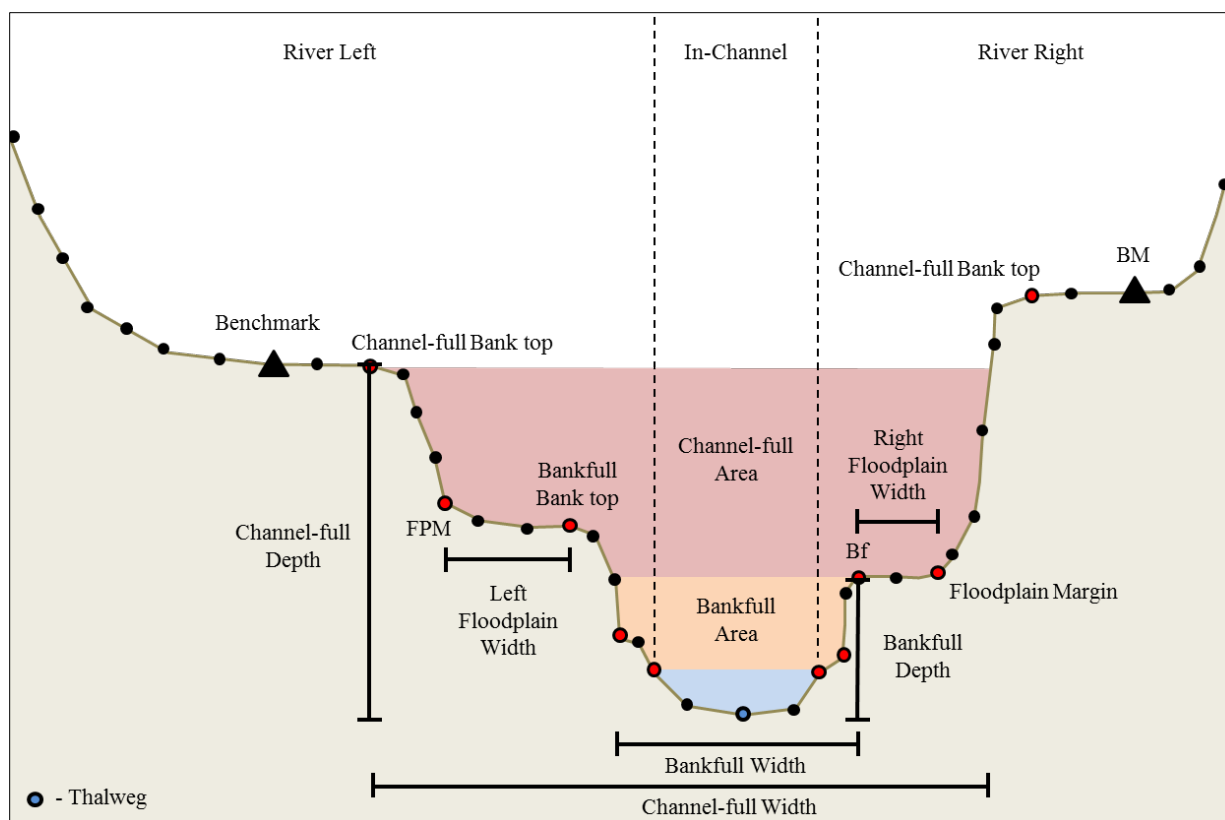


Figure 15. Diagram of detailed transect survey (looking downstream) showing the diagnostic geomorphic surfaces and the descriptive metrics that are derived from the survey point data.

Longitudinal (Thalweg) Profile

Stream slope is an important determinant of the energy available to do geomorphic work within a stream reach. Slope is related to bed material size, and is often used as a classification variable. A longitudinal profile (or energy grade line) is created by surveying the water surface elevation at all 11 standard transects as well as at the top of each riffle and step.

Photographic Documentation

Photographic time series images can provide a visual means of assessing channel conditions and provide visually interesting information to accompany summary data tables. A minimum of forty-four photos are taken (up- and downstream and left and right bank at each transect). In addition, general photos that document relevant habitat features at the reach are also taken. Any distinctive, permanent features that will persist through time are captured by these photos. General photos should characterize, to the greatest extent possible, the overall character of the reach. All photographs taken at each transect are shot in the same order (upstream, downstream, left bank, then right bank) so that they can be easily renamed when downloaded. Each photograph also needs to include a sign indicating the transect and the direction/bank that is being captured (e.g., T1 Up or T1 Left). All photographs collected as part of this protocol are considered data photographs and are handled, named, and archived according to procedures set forth in SOP 2.1.07 *Digital Image Management—Version 3.1* (SECN 2017).

Quality Assurance/Quality Control (QA/QC) of Survey Data

Data collected during training sessions and one resurvey of a randomly selected reach (that was surveyed that field season) will be used to assure that the data collection methods are sufficient to provide data of sufficient quality to achieve the objectives of this protocol. During the annual training session all field crew members take turns collecting data on the standard and detailed transects. While conducting the random reach resurvey, the field crew members that collected the data on the standard transects will collect the detailed transect data and vice versa with the detailed transect workers. Variability between surveys are expected to be within the acceptable range of variability (data quality objectives) outlined in this protocol's data quality standards document (Starkey and McDonald 2018).

Data Handling Procedures

The general data model for stream habitat monitoring consists of spatial/GIS data, tabular field data, certified and processed data, and metadata. Because one of the goals of the I&M Program is to provide scientific knowledge on which management decisions can be based (Fancy et al. 2009), it is incumbent upon the Southeast Coast Network to ensure that data are available for managers to make decisions informed by the most up-to-date information possible. The following sections describe the process for properly storing and processing data, and creating report ready tables and figures for data reports.

Overview

Two primary data management documents were developed to assist current and future users in handling the data collected as part of the protocol: (1) the Data Entry and Storage SOP (2.2.13), and (2) the Data Processing and Analysis SOP (2.2.14). The data entry and storage SOP provides SECN and park staff instructions on how and where to enter data (getting data onto the server). The data processing and analysis SOP describes the process by which these data are to be processed and analyzed. The data entry and storage SOP provides a preliminary data dictionary that will be updated as a permanent database solution is created and finalized. The following sections outline general data management procedures, with details on specific data handling methods presented in SOPs included as part of this protocol (see Appendix C, Table C-2 for a complete list).

Data Collection

Data collection includes physically recording and downloading the data outlined in the Procedures and Data Collection section of this protocol. To assure data quality, dedicated time is set aside to train field staff before the field season begins. These training sessions ensure consistent application of data collection procedures. Field forms have been designed to be as intuitive as possible, including all pertinent information for proper recording (such as legends for optional values and indications of measurement units). Field forms are reviewed for incomplete entries or obvious errors before leaving the reach, when accurate corrections can immediately be made.

Data Storage and Processing

The Southeast Coast Network will develop a formal relational database to store and manage tabular wadeable stream habitat monitoring data once the protocol has been fully implemented and final data needs are fully itemized and described. This system will consist of a number of user interface (front-end) features (i.e., data entry forms) that will automatically populate a back-end database. Report services will also be built, allowing tables and datasets to be exported for use in appropriate analysis software and used in the data reports. Until these finalizations occur, all tabular data will be entered into Microsoft Excel worksheets and stored on the local SECN file server.

Data Entry

Where manual data entry is required, data are entered by SECN interns or staff. Upon completion of the final database, validation rules will be enforced by the database including designating required fields in the back-end database, and the use of pick-lists to support the entering and storage of high

quality data. Paper field forms are digitally scanned and archived immediately upon returning from the field survey, to insure the preservation of the data collected in the field.

Data Verification

Data verification is a vital quality control step that ensures data integrity and reduces the risk of incorrect data being stored in the database and used for analysis. For this protocol, 100% of the computerized records are checked for accuracy against the original source by someone other than the person who entered the data —either paper field records in the case of manually-collected tabular data, or original file downloads in the case of spatial data. The primary goal of this 100% verification check is to determine if and where errors are being introduced into the database. After the digitized data are verified and/or corrected to accurately reflect the original field data, the paper forms are archived and the electronic version is used for all subsequent data processing and analysis.

Data Certification

Prior to data publication the protocol lead must certify that all data have been validated and meet quality standards. Quality control validation includes running reports to reveal potential problematic entries or generating summary statistics to identify outlier values, checking these aberrant values, and flagging any that are deemed unusable. Data are evaluated within the context of regional geomorphology and existing reach-specific data. This step relies on comparisons to similar reaches from the region (within and between parks) as well as comparisons to prior surveys. This step also relies on any additional notes taken in the field. The protocol lead certifies the data after quality control validation is complete. Certification procedures seek to identify generic errors (missing, mismatched, or duplicate records). Data quality standards for stream habitat monitoring are discussed in more detail in Starkey and McDonald (2018).

Data Documentation (Metadata)

Data documentation is a critical step toward ensuring that data sets are useable for their intended purposes well into the future. This involves the development of metadata, which can be defined as information about the content, quality, condition and other characteristics of data. Metadata, or more specifically a metadata file, is a file that describes a database, GIS data, spreadsheet, or some other data file previously created. Metadata is critical because the information it provides may not be evident even by close inspection of the data set itself. Such information is often indispensable for the relevance and usefulness of the data file.

Metadata provide the means to catalog data sets within data dissemination systems, thus making the data available to a broad range of potential users. Properly-formatted metadata is a key component of external data discovery and usage of park data. Automated systems publish the availability and location of park data for public use from the [NPS Data Store](#). Elements of the metadata allow external users to understand how to use and interpret the data, such as coded values and data quality status.

All datasets have metadata documentation that includes the following components: dataset identification information, data quality information, entity and attribute information, spatial reference information (if applicable), distribution information, and contact information. Metadata will also

include information about all related reports and their location on IRMA. These metadata facilitate data longevity and facilitate access and use of the data.

Protected Information

We do not anticipate that protected information will be collected as part of the wadeable stream habitat condition monitoring protocol. However, part of metadata development includes determining whether or not the data include any protected information (e.g., specific locations of rare, threatened, or endangered species). Prior to completing metadata, the SECN Aquatic Ecologist and Park Resource Manager will work together to identify any protected information in the data. Their decisions will be documented and communicated to the Data Manager.

Data Archiving

All paper (hard copy) data sheets are filed by park and year immediately following data entry at SECN headquarters. Hard copy data sheets are also scanned and saved to the SECN file server. Data photographs showing transect and reach conditions are stored and archived according to procedures set forth in SOP 2.1.07 *Digital Image Management—Version 3.1* (SECN 2017). Static, milestone products (i.e., data summary reports) and datasets that have been uploaded to the NPS Data Store are automatically archived according to NPS records retention schedules.

Data Analysis and Reporting

The purpose of collecting wadeable stream habitat condition data at SECN parks is to provide relevant information that can be used to help guide management decisions or to inform resource management of possible areas of concern. A secondary purpose is to provide an understanding of how stream habitat conditions are changing within and between parks over time. The data collected following the methods described above will be made publicly available (pending park approval, see Protected Information section above) in their certified form as well as in annual data reports and periodic synthesis reports.

Data Analysis

The data collected at each reach are used to determine: (1) the status of each stream reach; (2) whether detectable change occurred at each stream reach between sample intervals; and (3) whether there are detectable trends in the surveyed variable at each stream reach through time. Summary statistics of channel morphology (e.g., reach characterizations of transect-level data), calculated for each reach assessment, provide an understanding of the status of each surveyed reach and help provide an understanding of similar-sized streams in the park. Standardized reach-scale metrics will be used to facilitate comparisons between similar-sized streams (based on stream order) within the network. Statistical significance of differences between paired sites (e.g., KEMO 001 and KEMO 002) at the transect-level is tested using a paired *t*-test or Fisher exact test (for proportion data), or Wilcoxon signed rank test (if the data are non-normal). Information on which reaches were chosen as paired sites is available in the reach suitability report for each park. Reports are available on IRMA or by request from the Southeast Coast Network.

After the second and all subsequent sampling interval(s), paired *t*-tests or Wilcoxon signed rank tests (if non-normally distributed) will be used to determine if there has been a significant change in the surveyed variables between two sampling intervals (i.e., from time 1 to time 2 as well as from time 1 to time *n*). After each reach has been surveyed at least four times (minimum number needed for trend analysis), linear mixed models, linear or multiple regression, or the Mann-Kendall test will be used to evaluate trends at the reach-scale. Groups of three or more reaches (e.g., all first order streams within a park or physiographic province) may be compared using linear mixed models or the regional Kendall test. For detailed instructions on how data will be analyzed see SOP 2.2.14 *Wadeable Stream Data Processing and Analysis—Version 1.0* (McDonald et al 2018e).

Reporting

Baseline (Status) Reports

Baseline reports are concise and highlight the results of the first reach survey. The reports provide an outline of methods and a summary of the data, and describe known conditions (e.g., recent flooding) and/or major issues (e.g., beavers building dam upstream) that may have influenced the results. All baseline reports contain a bulleted list of important findings as part of the executive summary. The body of the baseline report will provide a detailed summary of the results of the initial reach survey.

At a minimum, baseline reports will provide:

- A summary of how data were collected during the prior year's field season.
- A summary of the data that were collected.
- Summary tables with basin and reach scale summary statistics for use in park reporting and resource stewardship strategies.
- An evaluation of data quality and identification of any data quality concerns and/or deviations from the protocol that may have affected data quality and subsequent interpretations.

Change Reports

Reach-scale change reports are concise and highlight the results of the most recent survey and how measures may have changed since the previous survey. The reports provide an outline of methods and a summary of the data, and describe known conditions (e.g., recent flooding) and/or major issues (e.g., beavers building dam upstream) that may have influenced the results. All reach-scale change reports contain a bulleted list of important findings as part of the executive summary. The body of the change reports will provide a detailed summary of the results of all of the surveys and include the results of the change analyses.

At a minimum, reach-scale change reports will provide:

- A summary of how data were collected during the prior year's field season.
- A summary of the data that were collected.
- Summary tables comparing the basin- and reach-scale summary statistics for all surveys that have been conducted at the reach.
 - Parametric and nonparametric tests will be used to determine if the changes that were seen are statistically significant
- An evaluation of data quality and identification of any data quality concerns or deviations from the protocol that may have affected data quality and subsequent interpretations.

Trend Reports

On the fourth and all subsequent surveys, a trend report will replace the change reports. Trend reports will continue on the same reporting schedule as the change reports. Change from the previous surveys will be evaluated and the results of trend analyses will be presented. The reports provide an outline of methods and a summary of the data, and describe known conditions (e.g., recent flooding) and/or major issues (e.g., large tree fall) that may have influenced the results. All reach-scale trend reports contain a bulleted list of important findings as part of the executive summary. The body of the report will include a detailed summary of the results of the most recent survey and will include the change and trend analyses.

At a minimum, reach-scale trend reports will provide:

- A summary of how data were collected during the prior year's field season.
- A summary of the data that were collected.
- Summary tables comparing the basin- and reach-scale summary statistics for all surveys that have been conducted at the reach.
 - Parametric and nonparametric tests will be used to determine if the changes that were seen are statistically significant
- Results of trend analyses of the geomorphic and habitat characteristics of the reach
- An evaluation of data quality and identification of any data quality concerns or deviations from the protocol that may have affected data quality and subsequent interpretations.

Synthesis Reports

Synthesis reports are published every six years and provide a broader look at how physical habitat conditions are changing through time. These reports focus on intra- and inter-park differences between reaches and provide an analysis of the physical habitat conditions of the wadeable streams within the context of the processes that are influencing the evolution of these streams. Two types of analyses will be included in the synthesis reports, network-status and paired reach differences. The status of each reach compared to the other surveyed reaches within the network will provide a context for the variability observed at each reach. Differences between pairs or groups of sites will be reported to provide park management-relevant information. These reports will provide greater analytical and interpretive detail than the annual reports and will evaluate the relevance of the findings within the context of long-term management and restoration goals. All synthesis reports contain a bulleted list of important findings as part of the executive summary. The body of the synthesis report will provide the network-scale comparison between reaches and the results of the paired reach difference tests.

At a minimum, network-scale synthesis reports will provide:

- A summary of how data were collected during the prior year's field season.
- Summary tables comparing the basin- and reach-scale summary statistics for all of the reaches that were surveyed.
- Results of the difference tests of the geomorphic and habitat characteristics of the paired reaches
- An evaluation of data quality and identification of any data quality concerns or deviations from the protocol that may have affected data quality and subsequent interpretations.

Protocol Review and Revision

As needed, additional reports are produced that evaluate: (1) the operational aspects of the monitoring protocol and (2) design aspects of the monitoring protocol. The protocol review helps to answer such questions as: Does allocation of samples appear to be adequate for all parks? Are there new management concerns that might dictate some reallocation of effort or additions to the indicator metrics that are examined? Is the sampling schedule still appropriate? These reports help guide future monitoring efforts and provide information that can be used to update SOPs and allow the data to be used effectively and efficiently.

Scientific Journal Articles and Conference Presentations

Publication of findings in scientific journals allows the network to reach a broader scientific community and promote investigation by members of the scientific community, either independently or in cooperation with Southeast Coast Network. Ultimately, publication in peer-reviewed journals and the collaboration that ensues fosters a greater understanding of the physical processes that affect stream habitat conditions in and around SECN parks. Similarly, the presentation of findings or subsets of data at professional conferences allows the network to reach the broader scientific community and potentially fosters partnership efforts. All journal articles and conference presentations made by the SECN aquatic program are made available to the parks whose data are included within the article or presentation.

Publication Standards

Annual reports follow NPS publication standards available on the [publications website](#), as well as additional regional guidelines (Wright et al. 2015).

Current versions of the protocol, resource briefs, annual reports, comprehensive reports, and regional synthesis reports are made available on the [SECN website](#). The protocol and technical reports are also available from the national [IRMA portal](#).

Personnel Requirements and Training

Personnel and Qualifications

Implementation of this protocol relies on permanent and seasonal network staff to conduct annual field work, data analysis, management, and reporting. At a minimum, the SECN program manager, aquatic ecologist, lead stream technician, seasonal field technician and data manager need to be involved in order for this protocol to be properly implemented. The exact duties of each of these positions depend on individual levels of technical experience. Additional support from other SECN staff, park staff, interns, or volunteers may be used on a part-time basis during the late summer and early fall field seasons to assist with data collection and data entry as well as other tasks that require, for safety reasons, more than one person. Tasks related to the implementation of this protocol are generally year round with substantial field efforts conducted during late spring and early summer. Data entry tasks are split among staff with the primary reporting duties falling on the protocol lead. Personnel should be hired or identified at least three months in advance to allow time to properly train the data collection team and ensure high quality data are collected.

Program Manager

The program manager is responsible for supervisory oversight of the protocol lead, completion of contracting (if necessary), and will serve as the peer review manager for reports resulting from this monitoring effort.

Protocol Lead: Aquatic Ecologist

The protocol lead is responsible for technical and supervisory oversight of the implementation of the protocol, including: scheduling field work; training field crews; certifying and analyzing data; data reporting; SOP revision; and assisting network, park, and partner staff with interpreting findings and incorporating the results into park management. The protocol lead must have the knowledge, skill, and ability to apply known theories, principles and concepts of stream ecology/geomorphology sufficient to design and implement scientific studies; as well as the ability to statistically analyze data, synthesize the results, write reports, and publish papers related to the monitoring effort. The protocol lead is also responsible for ensuring that high-quality data are collected and interpreted within the context of established assessment criteria, regulatory requirements, and management targets. The protocol lead routinely performs statistical tests and analyses, and uses geographic information systems and modeling procedures to analyze and synthesize data. These results will need to be communicated effectively to a wide variety of audiences, in both technical and non-technical language, in the form of memoranda, reports, management plans, environmental assessments, briefings, and peer-reviewed scientific papers.

Lead Stream Technician

The principal duties of the lead stream technician are to complete stream surveys, enter survey data, and help produce data summary reports. This position is also responsible for performing basic quality reviews of the data to ensure they are complete, and that the data are within expected ranges. In addition, the lead stream technician is responsible for routine maintenance of the equipment required

to implement the protocol. This position may be filled by a permanent NPS staff member or a cooperator, such as a University of Georgia (UGA) Research Associate.

Seasonal Field Technician

The principal duty of the seasonal field technician is to assist with the stream surveys (May through September). The additional field support provided by this position is especially important during peak field efforts at Chattahoochee River NRA and Congaree NP. In addition, this position may assist with other SECN vital signs monitoring efforts. This position may be filled by a seasonal employee, student intern, or intern hired in partnership with an SECN park.

Data Manager

The data manager is responsible for ensuring that the data management system for this protocol meets NPS and federal information management standards, including but not limited to: security, data documentation, database structure, and consistency with other applicable NPS information management systems.

Training

Every March, all personnel responsible for protocol implementation will review the entire protocol and associated SOPs, and complete all annual field preparation requirements. In addition to preparing the required field equipment, and completing training to maintain technical competencies, the aquatic ecologist and stream technician will receive safety training in accordance with NPS safety guidelines that includes obtaining active American Red Cross or equivalent first aid and cardiopulmonary resuscitation (CPR) certification. Additional annual training is further documented in the field seasonal preparation SOP 1.2.13 *Wadeable Stream Field Season Preparation—Version 1.0* (Gregory et al. 2018).

The protocol lead will be the primary focus of technical training and will be required to maintain skills necessary for the use of the equipment, as well as data analysis and interpretation. Training may include surveying, or operation of a total station or survey-grade GPS system. These courses are available through instrument manufacturers as well as the USGS. All staff responsible for protocol implementation will attend training classes offered by Department of Interior (DOI) agencies that are deemed appropriate and/or necessary to maintain and improve data quality during collection efforts. If personnel require training to implement any aspect of the protocol, it should be done early enough to allow the surveyors to practice before the first survey to ensure high quality data is collected on the day of the assessment.

Training involves a mock stream survey with all members of the data collection team collecting data at a stream near the SECN office. This training: serves as an equipment check, ensuring that all needed equipment is assembled and in good working order; allows for existing personnel to re-familiarize themselves with the data collection process and data sheets; and allows new personnel to become acquainted with the techniques required to collect the data accurately and efficiently.

Operational Requirements

Annual Workload

Field work is scheduled to be conducted during mid-summer and early fall, prior to canopy leaf-off conditions, to coincide with the low-flow conditions that occur during this time of year (Table 5). However, field season preparations begin at least two months prior to the field season so that sufficient time is available for training, equipment purchases or repairs, etc.

Table 5. General staffing matrix and approximate time periods required to complete major tasks associated with the protocol for assessing Wadeable Stream Habitat Conditions.

Position	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Project Lead	–	–	1	1	2	2	2	–	3	–	–	4
Lead Stream Technician	–	–	1	1	2	2	2	3	3	4	4	4
Seasonal Stream Technician	–	–	–	–	2	2	2	–	–	–	–	–
Data Manager	–	–	5	5	–	–	–	–	–	5	–	5
Park Supplied Support ⁶	–	–	–	–	2	2	2	–	–	–	–	–

¹ Field prep/training

² Field work

³ Data entry and QA/QC

⁴ Report Prep

⁵ Data management

⁶ Required at CHAT and CONG

Before and after each field season, supplies and materials are inventoried to ensure that the necessary equipment is available in proper quantities for the planned field operations. All surveying equipment (levels, GPS units, total stations) are checked and calibrated to ensure they are measuring to an acceptable accuracy (consult manual for criteria). Batteries are also checked to ensure they will maintain sufficient charge. Most pre-season planning will take place indoors, so equipment checks can be performed during the off-season or when weather prohibits field activities.

Permitting Requirements

Prior to field assessments, all monitoring reaches are pre-approved by park resource managers. If deemed necessary by the resource manager, the network will work with the park personnel responsible for completion of necessary compliance (such as that required pursuant to the National Environmental Protection Act [NEPA; 42 USC 4321 et seq.], National Historic Preservation Act [NHPA; Section 106 of 16 USC 470 et seq.], etc.). The network will apply for annual park science permits in the Research Proposal and Reporting System (RPRS), as per individual park policies.

Facilities and Equipment

Transportation to and from parks requires a vehicle with a carrying capacity sufficient to safely transport the field crew and all of the gear required to conduct the assessments. The network maintains several such vehicles in its fleet that are available for use during scheduled monitoring events. Specific safety, surveying, and habitat assessment equipment to be used in field operations are detailed in SOP 1.2.13, *Field Season Preparation for Stream Habitat Monitoring* (Gregory et al. 2018).

Estimated Operating Costs

Operational costs include roughly one FTE split among three federal positions, and a half-time student intern with the network being 50 percent dedicated to day-to-day protocol activities. An additional \$7,750 in non-personnel costs related to equipment maintenance, station maintenance, and travel to and from monitoring locations is also required.

In some cases due to the nature of the work, the specific area of expertise or budgetary constraints some tasks may be contracted to qualified third parties or other government agencies. For example, survey instrument work (total station) may be cost effectively managed through agreements with other agencies that currently have this expertise in-house.

After initial purchase of equipment, the primary operational costs are associated with personnel and travel. Table 6 summarizes operational costs including one-time equipment purchases.

Table 6. Estimated annual operating costs, based on FY 2017 information for wadeable stream monitoring in the Southeast Coast; salary costs are mid-step positions plus 35% overhead using locality rates of Atlanta-Athens-Sandy Springs, Georgia.

Category	Sub-Category	Cost	Notes
Personnel	Aquatic Ecologist	\$46,330	0.4 FTE, GS-12
	Lead Stream Technician	\$32,650	0.5 FTE, GS-07
	Data Manager	\$11,580	0.1 FTE, GS-12
	Seasonal Technician	\$15,000	0.25 FTE Student Intern
	Total Personnel	\$105,560	—
Travel	Estimate/10 days/2 people ^a	\$4,180	—
	Vehicle usage	\$750	—
	Total travel	\$4,930	—

^a Pier diem rates for Atlanta Georgia

^b Indicates one-time cost.

^c Does not include one-time costs.

Table 6 (continued). Estimated annual operating costs, based on FY 2017 information for wadeable stream monitoring in the Southeast Coast; salary costs are mid-step positions plus 35% overhead using locality rates of Atlanta-Athens-Sandy Springs, Georgia.

Category	Sub-Category	Cost	Notes
Maintenance	Total Station Calibration and Equipment Maintenance	\$1,820	–
	Monitoring reach supplies and maintenance	\$1,000	–
	Total maintenance	\$2,820	–
Start-up costs ^b	Stream Habitat Assessment Gear	\$3,000	–
	Survey Equipment	\$40,000	–
Total annual cost ^c		\$113,310	–

^a Pier diem rates for Atlanta Georgia

^b Indicates one-time cost.

^c Does not include one-time costs.

Safety

Implementation of this protocol has multiple and complex risks. Injury or loss of life while in transit to and from reaches and while performing data collection activities are major risks encountered when conducting this activity. Staff must continuously evaluate all risks at the program, personnel, and reach level. Programmatic-level safety information is presented here and procedures to mitigate risks associated with specific activities related to protocol implementation (such as vehicle use and operation, injury reporting and accident reporting) are presented in Appendix C.

Job hazard analyses (JHAs) were completed for all personnel who implement portions of the protocol in which risks and risk abatement strategies (including training needs) were identified. Risks and abatement strategies for all staff were synthesized to develop a protocol-level JHA.

Specific safety concerns include:

- Crew members spend many hours (and miles) driving to, between, and from sampling locations to conduct the requisite sampling.
- Crew members regularly working in park areas outside of communications range (either by park radio or by cell phone).

Based on the JHA and associated risk abatement measures it was determined that this protocol can be safely implemented provided that SECN and partner staff implement it in accordance with the referenced SOPs and recommended risk abatement strategies including injury reporting procedures (SOP 3.1.01, Corbett et al. 2016); vehicle use and operation (SOP 3.1.03, SECN 2016), motor vehicle accident reporting (SOP 3.1.04, SECN 2016), and communicating field operations with park personnel (SOP 3.1.07, DeVivo and Corbett 2016). In addition, in SOPs that have been developed to safely implement this protocol, specific training needs for all staff have been identified including certification in basic first aid. To increase the overall level of safety and awareness, obtaining additional levels of training beyond basic certifications is encouraged. Staff should refer to Safety in field activities: U.S. Geological Survey Techniques of Water-Resources Investigations, book 9, chap. A9 (Lane and Fay 1997) for more information on risk abatement and safety while working around water.

Safety procedures will be routinely reviewed with network staff and partners before field operations as prescribed in the SOPs. Personnel-level JHAs for staff are reviewed and revised annually as a part of the performance review cycle. Safety SOPs are reviewed annually and updated as necessary to ensure that they adequately mitigate risks to personnel, property, and the public.

In addition to protocol-specific safety procedures and guidelines, SECN staff will follow the general guidelines set forth in the NPS Occupational Safety and Health Program (National Park Service 2008). These procedures are generally outlined as follows:

1. Adhere to established occupational safety and health procedures, including those contained within Reference Manual 50B (NPS 2008).

2. Work collaboratively with supervisors to develop and use JHAs or equivalent for all routine tasks, and help develop and use reach-specific safety plans for non-routine, complex, multi-phase jobs.
3. Properly use and maintain required clothing and/or personal protective equipment.
4. Maintain a level of personal wellness and fitness as needed for assigned work tasks.
5. Identify and correct unsafe conditions and work practices.
6. Report unsafe/unhealthful conditions and/or operations to his or her immediate supervisor or the appropriate chain of command.
7. Report mishaps, including minor accidents and "near-hits," to a supervisor as soon as possible, but in no case later than the end of the work shift.
8. Participate in establishing a safe working culture, and practice safe work procedures, especially when working alone.

Administrative Record

The administrative record shown in Table 7 summarizes the major events leading to the development and revision of the Protocol for Monitoring Wadeable Stream Habitat Conditions in Southeast Coast Network Parks.

Table 7. Protocol administrative history log.

Date	Development Step	Documentation
2007	Joe DeVivo, program manager for the SECN, contracted the USGS to develop a draft protocol for monitoring stream channel characteristics. Brian Gregory, then an employee of the USGS, was the primary author of this draft. Brian left USGS in 2009 and work was taken over by Jeff Riley (USGS).	First draft of narrative and field techniques
2010	Brian Gregory became a full time National Park Service Employee and served as the SECN aquatic ecologist 2010–2015. Brian continued development of the protocol and SOPs and recommended that protocol development be split into two efforts- one for wadeable stream and one for non-wadeable streams; work continued on each effort	Various drafts of the narrative and field SOPs
August 2014	Jacob McDonald, University of Georgia PhD. candidate, began work on the protocol and SOPs with Brian Gregory and Jeff Riley (USGS).	Pilot data collected methods tested in Whitehall Forest training reach (UGA)
May 2015	The protocol narrative and field SOPs were externally reviewed by the USGS.	Draft narrative and field SOPs
June-August 2015	Reviewer comments in the protocol narrative and field SOPs were addressed by Jacob McDonald. Following revisions, the protocol was resubmitted to the USGS	Draft protocol narrative and SOPs with comments.
August 2015	Following protocol revisions by the network, Sandy Cooper/BAO at the USGS approved the protocol for release as a cooperator publication.	Draft protocol narrative with comments
June 2016	Eric Starkey replaced Brian Gregory as the SECN aquatic ecologist.	–
July 2016	Eric Starkey and Jacob McDonald began field testing of existing SOPs. SOPs were extensively revised based on field work at a Whitehall Forest training reach.	Draft SOPs
August 2016	Pilot data was collected at Horseshoe Bend National Military Park. Began extensive revision of the protocol narrative due to changes to SOPs. No protocol objectives were changed. Non-field related SOPs were developed and revised.	Draft narrative and SOPs
January 2017	The protocol narrative and data management SOPs were reviewed by the SECN data manager, Paula Capece.	Draft narrative and SOPs with comments.
February 2017	Revisions were completed to the protocol narrative and SOPs based on the data management review.	Draft narrative and SOPs

Table 7 (continued). Protocol administrative history log.

Date	Development Step	Documentation
May 2017	The draft Protocol and SOPs for Monitoring Wadeable Stream Habitat Conditions in Southeast Coast Network Parks was submitted to the Southeast Region I&M Division Chief for review.	Draft protocol and SOPs
October 2017	Completed revisions to the protocol narrative and SOPs following review by the Southeast Region I&M Division Chief.	Draft protocol and SOPs
April 2018	Completed revisions to the protocol narrative and SOPs following external reviews.	Draft protocol and SOPs
June 2018	Completed final revisions to the protocol narrative and SOPs following final internal review.	Final protocol and SOPs

This monitoring protocol is an actively evaluated and updated document that reflects the latest procedures of the monitoring program. Revisions are expected, and can involve minor changes with little overall impact or occasional major revisions and course corrections. Evaluation and revision of the protocol is directed by the protocol lead on an annual basis. The narrative (Table 7) as well as each SOP has a revision history log whereby changes can be recorded. Older versions of the narrative and SOPs should be archived to ensure proper legacy of past work is maintained. Each revision will require the updating of the version number. Minor changes are recorded as decimal numbers (e.g., 1.0, 1.1, 1.2). Major changes are recorded as a change in the primary number of the protocol version (e.g., 1.0, 2.0, 3.0). Major revisions to the protocol will prompt the need for additional peer-review. The protocol leader and network program manager will coordinate revisions with the Regional I&M Division Chief.

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Appendix A. Protocol Measure Comparison and Measures by Objective

Table A-1. Basin characteristics and reach-scale metrics measured by the SECN cross referenced with cited protocols. “X” denotes that a metric is measured by the cited monitoring programs. “O” denotes that the measure is considered optional by the cited monitoring program.

Monitoring Program	Drainage Area ^a	Total Stream Length ^a	Drainage Density ^a	Basin Length ^a	Basin Shape ^a	Average Slope ^a	Standard Deviation of Slope ^a	Basin Relief ^a	Standard Deviation of Elevation ^a	Basin Relief Ratio ^a	Entire Stream Gradient ^a	Segment Gradient ^a	Strahler Stream Order ^a	Bifurcation Ratio ^a	Land Use/Land Cover ^a	Geomorphic Channel Units ^b	Large Woody Debris ^b	Pebble Count ^b	Canopy Closure (Densimeter) ^b	Reach Sinuosity (Bearing) ^b	Reach map ^b
Fitzpatrick et al. (1998)	X	O	O	O	O	–	–	O	–	O	O	X	O	–	O	X	–	O	X	X	X
US EPA (2013)	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	X	X	–	X	X	–
Harrelson et al. (1994)	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	X
Barbour et al. (1999)	–	–	–	–	–	–	–	–	–	–	–	–	–	–	X	–	–	–	X	X	–

^aBasin Characteristics

^bReach-scale Characteristics

Table A-2. Transect-scale characteristics and detailed transect metrics measured by the SECN cross referenced with cited protocols. “X” denotes that a metric is measured by the cited monitoring program. “O” denotes that the measure is considered optional by the cited monitoring program. A blank cell indicates that it is not measured by the cited monitoring program.

Monitoring Program	Number of Transects ^a	Wetted Width ^a	Active Channel Width ^a	Bankfull Width ^a	Channel full width ^a	Thalweg Position ^a	Thalweg Depth ^a	Dominant Particle Size ^a	Dominant Habitat ^a	In-channel features ^a	Floodplain width ^a	Bankfull height ^a	Channel full height ^a	Bank Undercut ^a	Bank Angle ^a	Bank Sediment ^a	Bank Erosion ^a	Bank Cover ^a	Detailed Cross-sections ^b	Longitudinal Profile ^b
Fitzpatrick et al. (1998)	11	X	–	X	–	–	X	X	–	X	–	X	–	–	X	X	O	X	O	X
US EPA (2013)	11	X	–	X	–	–	X	X	X	X	–	X	–	X	X	–	–	–	–	X
Harrelson et al. (1994)	N/A	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	X	X
Barbour et al. (1999)	11	X	–	X	–	–	X	X	–	–	–	X	–	X	X	–	–	–	–	X

^aTransect Scale Characteristics

^bDetailed Transects

Table A-3. Description of variables used in the protocol and their related objectives.

Variable	Variable Scale	Description	Related Objective
Drainage Area	Basin	The topographical area to which precipitation, sediment, and dissolved constituents are funneled to a common outlet point along a given stream channel (Dunne and Leopold 1978).	1
Total Stream Length	Basin	The length of stream within a watershed that flows year round during normal (or average) precipitation conditions.	1
Drainage Density	Basin	The ratio of total perennial stream length to drainage area.	1
Basin Length	Basin	Basin length refers to the length of the line that bisects a watershed running from outlet to drainage divide.	1
Basin Shape	Basin	This protocol uses the basin shape of Horton (1932) where the basin area is divided by basin length squared, which gives a dimensionless ratio of basin shape.	1
Average Watershed Slope	Basin	The within watershed average of the slope values of each pixel of a digital elevation model.	1
Standard Deviation of Watershed Slope	Basin	The within watershed standard deviation of the slope values of each pixel of a digital elevation model.	1
Basin Relief	Basin	The maximum amount of relief (maximum elevation minus minimum elevation) found within the basin.	1
Standard Deviation of Elevation	Basin	The standard deviation of elevation within a watershed.	1
Basin Relief Ratio	Basin	A ratio calculated by dividing basin relief by basin length.	1
Entire Stream Gradient	Basin	Calculated by determining the difference in elevation at 85% and 10% of the main stem stream length divided by the stream length between the two points.	1
Segment Gradient	Basin	Calculated by determining the difference in elevation between the upstream extent of the stream segment and the downstream extent of the stream segment and dividing this difference by the length of the stream segment.	1
Strahler Stream Order	Basin	A stream ordering system where order increases when two orders of the same magnitude join.	1
Bifurcation Ratio	Basin	The ratio of streams in a given Strahler order to streams in the next highest order (e.g., number of first order streams/number of second order streams).	1

Variable	Variable Scale	Description	Related Objective
Land Use/Land Cover	Basin	Land use/land cover is derived from the NLCD dataset.	1
Geomorphic Channel Units	Reach	Geomorphic channel units are a way to classify in-channel habitat (e.g., riffles and pools)	3
Large Woody Debris	Reach	Pieces of woody material that have a diameter greater than 0.1 m and are 1 m or longer.	3
Pebble Count	Reach	The size and distribution of particles (pebble count) from a representative riffle will be used to characterize the bed material of each reach (Wolman 1954).	2, 3
Canopy Closure	Reach	Canopy closure is estimated by measuring canopy cover at each standard transect using a spherical densiometer.	3
Reach Sinuosity	Reach	Sinuosity is calculated by dividing reach length by valley length.	2
Longitudinal Profile	Reach	The gradient of the line that connects the tops of the steps and riffles within a reach (channel slope)	2
Wetted Width	Transect	Wetted channel width is measured where water is flowing (including undercuts)	2
Active Channel Width	Transect	Active channel width is measured to the beginning of vegetation within the stream channel	2, 3
Bankfull Width	Transect	Bankfull widths should only be measured if there is a floodplain (or incipient floodplain) present	2
Channel full width	Transect	Channel full widths are measured from the top of the lowest bank that is not a floodplain.	2
Thalweg Position	Transect	The position of the thalweg as a percent distance of the wetted width from left water's edge	2, 3
Thalweg Depth	Transect	The greatest depth of water along a transect	2, 3
Dominant Particle Size	Transect	A visual estimate of the dominant sediment size along a transect	2, 3
Dominant Habitat	Transect	A visual estimate of the dominant geomorphic channel unit along a transect	2, 3
In-channel features	Transect	A description of the in-channel features that are present along a transect	2, 3
Floodplain width	Transect	A separate measure of the width of floodplain along rivers left and right	2, 3
Bankfull height	Transect	The height of the channel bank where a floodplain is present	2

Variable	Variable Scale	Description	Related Objective
Channel full height	Transect	The height of the channel bank where a floodplain is not present (channel full height is also measured where a floodplain is inset within an entrenched channel)	2
Bank Undercut	Transect	Where the bank overhangs the channel due to lateral erosion at the base of the bank	2, 3
Bank Angle	Transect	The dominant bank angle from active channel boundary to the top of the bank	2
Bank Sediment	Transect	The dominant sediment composition of the channel banks	2
Bank Erosion	Transect	The presence of and type erosion that is observed on the channel banks	2
Bank Cover	Transect	A visual estimate of the percent of the channel banks that has vegetative cover	2, 3

Appendix B. Power to Detect Change At-A-Reach

To determine the power to detect a 20% change in the measured variables, the data collected during the first round of surveys were used to create simulated second surveys with differing correlations. It was assumed that the coefficient of variation of the second survey was proportional to the coefficient of variation from the first survey. Five levels of correlation (0.5, 0.6, 0.7, 0.8, and 0.9) were used to simulate the potential power to detect change in wetted width, active channel width, channel full width, minimum flood width, minimum flood height, and channel full height. The results of these simulations are presented below in Tables B-1 to B-6. The code used to simulate the second surveys is included at the end of this appendix.

The results indicate that the power to identify change is site and variable dependent. For the wetted width of all but two of the sites (CHAT 006 and CHAT 014), if the correlation coefficient between the first and second surveys is 0.9 there is more than 80% power to detect a 20% change (average power was 88%; Table B-1). The low power to detect change in wetted width is acceptable as this variable is going to be used to determine whether the baseflow conditions from time 1 to time n are significantly different (i.e., greater than 20%).

The power to detect a 20% change in active channel width is nearly 80% if the correlation coefficient is 0.7 and is almost 1.0 for all sites if the correlation coefficient is 0.9 (Table B-2).

The power to detect a 20% change in channel full width is very high in almost all of the sites at most correlation levels (Table B-3). The reason there are a few sites with low power is because the variability in channel full widths is very high due to floodplains being present on a few transects. The presence of a floodplain on a few transects causes channel full width to be greater on these transects. If these outlier transects were excluded from the analysis, the power to detect change would likely be just as high as the other sites.

The power to detect change in minimum flood width is high for all sites at correlations of 0.8 and higher (Table B-4).

The power to detect change in minimum flood height is high for almost all sites at correlations levels of 0.6 or higher (Table B-5). Similar to channel full width, the reason for the low power to detect change at a few of the sites is due to outlier transects. These outlying heights are due to hillslopes encroaching on a few of the transects. This causes the variability to greatly increase and reduces the power to detect change.

Due to the low variability in channel full heights, the power to detect change at nearly all sites and at all levels of correlation is extremely high (Table B-6). Similar to minimum flood height and channel full width, the reason a few of the sites have low power is because there are a few transects that are significantly different and the standard deviation in the original survey is very high.

Table B-1. Simulated power to detect a 20% change in wetted width using a paired *t*-test (n of 11). The second survey was simulated assuming the coefficient of variation of the second survey is proportional to the first survey and the correlation coefficient (*r*) between the first and second surveys is 0.5, 0.6, 0.7, 0.8, or 0.9.

Site	<i>r</i> = 0.5	<i>r</i> = 0.6	<i>r</i> = 0.7	<i>r</i> = 0.8	<i>r</i> = 0.9
KEMO 001	0.40	0.48	0.59	0.74	0.94^a
KEMO 002	0.50	0.59	0.70	0.85^a	0.98^a
CHAT 001	0.34	0.41	0.50	0.65	0.88^a
CHAT 002	0.29	0.34	0.43	0.57	0.81^a
CHAT 003	0.63	0.72	0.83^a	0.94^a	1.00¹
CHAT 004	0.74	0.82^a	0.91^a	0.98^a	1.00^a
CHAT 005	0.33	0.39	0.49	0.64	0.87^a
CHAT 006	0.15	0.17	0.21	0.29	0.46
CHAT 007	0.40	0.48	0.59	0.74	0.94^a
CHAT 008	0.51	0.60	0.72	0.86^a	0.98^a
CHAT 009	0.32	0.38	0.47	0.62	0.86^a
CHAT 010	0.50	0.59	0.70	0.85^a	0.98^a
CHAT 011	0.41	0.49	0.60	0.76	0.94^a
CHAT 012	0.29	0.34	0.43	0.57	0.81^a
CHAT 013	0.35	0.42	0.52	0.67	0.90^a
CHAT 014	0.23	0.27	0.34	0.45	0.69
Mean	0.40	0.47	0.56	0.70	0.88 ^a
Median	0.38	0.45	0.55	0.71	0.92 ^a
SD	0.15	0.17	0.18	0.18	0.14

^aEstimated power greater than 0.8.

Table B-2. Simulated power to detect a 20% change in active channel width using a paired *t*-test (n of 11). The second survey was simulated assuming the coefficient of variation of the second survey is proportional to the first survey and the correlation coefficient (*r*) between the first and second surveys is 0.5, 0.6, 0.7, 0.8, or 0.9.

Site	<i>r</i> = 0.5	<i>r</i> = 0.6	<i>r</i> = 0.7	<i>r</i> = 0.8	<i>r</i> = 0.9
KEMO 001	0.99^a	1.00^a	1.00^a	1.00^a	1.00^a
KEMO 002	0.48	0.56	0.68	0.83¹	0.97^a
CHAT 001	0.42	0.50	0.61	0.76	0.95^a
CHAT 002	0.53	0.61	0.73	0.87^a	0.98^a
CHAT 003	0.43	0.51	0.62	0.78	0.95^a
CHAT 004	0.39	0.47	0.57	0.73	0.93^a
CHAT 005	0.70	0.79	0.88^a	0.96^a	1.00^a
CHAT 006	0.42	0.50	0.61	0.76	0.95¹
CHAT 007	0.68	0.76	0.86^a	0.96^a	1.00^a
CHAT 008	0.57	0.66	0.78	0.90^a	0.99^a
CHAT 009	0.65	0.74	0.84^a	0.94^a	1.00^a
CHAT 010	0.63	0.73	0.83^a	0.94^a	1.00^a
CHAT 011	0.91^a	0.95^a	0.99^a	1.00^a	1.00^a
CHAT 012	0.65	0.74	0.84^a	0.95^a	1.00^a
CHAT 013	0.57	0.66	0.77	0.90^a	0.99^a
CHAT 014	0.52	0.61	0.72	0.86^a	0.98^a
Mean	0.60	0.67	0.77	0.88^a	0.98^a
Median	0.57	0.66	0.77	0.90^a	0.99^a
SD	0.17	0.16	0.13	0.09	0.02

^a Estimated power greater than 0.8.

Table B-3. Simulated power to detect a 20% change in channel full width using a paired *t*-test (n of 11). The second survey was simulated assuming the coefficient of variation of the second survey is proportional to the first survey and the correlation coefficient (r) between the first and second surveys is 0.5, 0.6, 0.7, 0.8, or 0.9. ¹Estimated power greater than 0.8 is in bold.

Site	r = 0.5	r = 0.6	r = 0.7	r = 0.8	r = 0.9
KEMO 001	1.00^a	1.00^a	1.00^a	1.00^a	1.00¹
KEMO 002	1.00^a	1.00^a	1.00^a	1.00^a	1.00^a
CHAT 001	0.54	0.62	0.74	0.88^a	0.99^a
CHAT 002	0.17	0.20	0.25	0.34	0.54
CHAT 003	0.61	0.70	0.81^a	0.93^a	1.00^a
CHAT 004	0.54	0.63	0.74	0.88^a	0.99^a
CHAT 005	1.00^a	1.00^a	1.00^a	1.00^a	1.00^a
CHAT 006	0.16	0.19	0.23	0.31	0.50
CHAT 007	0.70	0.79	0.88^a	0.97^a	1.00^a
CHAT 008	0.69	0.78	0.88^a	0.96^a	1.00^a
CHAT 009	0.83^a	0.90^a	0.96^a	0.99^a	1.00^a
CHAT 010	0.57	0.66	0.78	0.90^a	0.99^a
CHAT 011	0.85^a	0.92^a	0.97^a	1.00^a	1.00^a
CHAT 012	0.47	0.55	0.67	0.82¹	0.97^a
CHAT 013	0.43	0.51	0.62	0.78	0.95^a
CHAT 014	0.69	0.78	0.88^a	0.96^a	1.00^a
Mean	0.64	0.70	0.78	0.86^a	0.93^a
Median	0.65	0.74	0.84^a	0.94^a	1.00^a
SD	0.26	0.25	0.24	0.22	0.16

^a Estimated power greater than 0.8.

Table B-4. Simulated power to detect a 20% change in minimum flood width using a paired *t*-test (n of 11). The second survey was simulated assuming the coefficient of variation of the second survey is proportional to the first survey and the correlation coefficient (*r*) between the first and second surveys is 0.5, 0.6, 0.7, 0.8, or 0.9. ¹Estimated power greater than 0.8 is in bold.

Site	<i>r</i> = 0.5	<i>r</i> = 0.6	<i>r</i> = 0.7	<i>r</i> = 0.8	<i>r</i> = 0.9
KEMO 001	0.86^a	0.92^a	0.97^a	1.00^a	1.00^a
KEMO 002	0.71	0.80	0.89^a	0.97^a	1.00^a
CHAT 001	0.53	0.62	0.74	0.88^a	0.99^a
CHAT 002	0.40	0.47	0.57	0.73	0.93¹
CHAT 003	0.47	0.56	0.67	0.82^a	0.97^a
CHAT 004	0.54	0.63	0.74	0.88^a	0.99^a
CHAT 005	0.84^a	0.90^a	0.96^a	0.99¹	1.00¹
CHAT 006	0.72	0.81^a	0.90^a	0.97^a	1.00^a
CHAT 007	0.47	0.55	0.67	0.82^a	0.97^a
CHAT 008	0.39	0.46	0.57	0.72	0.93^a
CHAT 009	0.83^a	0.90^a	0.96^a	0.99^a	1.00^a
CHAT 010	0.30	0.35	0.44	0.59	0.83^a
CHAT 011	0.54	0.63	0.75	0.88^a	0.99^a
CHAT 012	0.43	0.51	0.62	0.77	0.95^a
CHAT 013	1.00^a	1.00^a	1.00^a	1.00^a	1.00^a
CHAT 014	0.63	0.72	0.83¹	0.94¹	1.00^a
Mean	0.60	0.68	0.77	0.87^a	0.97^a
Median	0.54	0.63	0.74	0.88^a	0.99^a
SD	0.20	0.19	0.17	0.12	0.05

^a Estimated power greater than 0.8.

Table B-5. Simulated power to detect a 20% change in minimum channel height using a paired *t*-test (n of 22). The second survey was simulated assuming the coefficient of variation of the second survey is proportional to the first survey and the correlation coefficient (*r*) between the first and second surveys is 0.5, 0.6, 0.7, 0.8, or 0.9. ¹Estimated power greater than 0.8 is in bold.

Site	<i>r</i> = 0.5	<i>r</i> = 0.6	<i>r</i> = 0.7	<i>r</i> = 0.8	<i>r</i> = 0.9
KEMO 001	0.86^a	0.92^a	0.97^a	1.00^a	1.00^a
KEMO 002	0.52	0.61	0.72	0.87^a	0.98^a
CHAT 001	0.43	0.51	0.62	0.78	0.95^a
CHAT 002	0.37	0.44	0.55	0.70	0.92^a
CHAT 003	0.67	0.76	0.86^a	0.96^a	1.00^a
CHAT 004	0.84^a	0.91^a	0.96^a	0.99^a	1.00^a
CHAT 005	0.96^a	0.99^a	1.00^a	1.00^a	1.00^a
CHAT 006	0.94^a	0.98^a	0.99^a	1.00^a	1.00^a
CHAT 007	0.20	0.24	0.30	0.40	0.63
CHAT 008	0.48	0.56	0.67	0.82^a	0.97^a
CHAT 009	1.00^a	1.00^a	1.00^a	1.00^a	1.00^a
CHAT 010	0.72	0.80^a	0.90^a	0.97^a	1.00^a
CHAT 011	0.09	0.10	0.12	0.15	0.24
CHAT 012	0.80^a	0.88^a	0.95^a	0.99^a	1.00^a
CHAT 013	0.75	0.84^a	0.92^a	0.98^a	1.00^a
CHAT 014	0.83^a	0.90^a	0.96^a	0.99^a	1.00^a
Mean	0.66	0.71	0.78	0.85^a	0.92^a
Median	0.73	0.82^a	0.91^a	0.98^a	1.00^a
SD	0.28	0.28	0.27	0.25	0.20

^a Estimated power greater than 0.8.

Table B-6. Simulated power to detect a 20% change in channel full height using a paired *t*-test (n of 22). The second survey was simulated assuming the coefficient of variation of the second survey is proportional to the first survey and the correlation coefficient (*r*) between the first and second surveys is 0.5, 0.6, 0.7, 0.8, or 0.9. ¹Estimated power greater than 0.8 is in bold.

Site	<i>r</i> = 0.5	<i>r</i> = 0.6	<i>r</i> = 0.7	<i>r</i> = 0.8	<i>r</i> = 0.9
KEMO 001	1.00^a	1.00^a	1.00^a	1.00^a	1.00^a
KEMO 002	0.97^a	0.99^a	1.00^a	1.00^a	1.00^a
CHAT 001	0.61	0.70	0.81^a	0.93^a	1.00^a
CHAT 002	0.68	0.77	0.87^a	0.96^a	1.00^a
CHAT 003	0.99^a	1.00^a	1.00^a	1.00^a	1.00^a
CHAT 004	0.84^a	0.91^a	0.96^a	0.99^a	1.00^a
CHAT 005	1.00^a	1.00^a	1.00^a	1.00^a	1.00^a
CHAT 006	1.00¹	1.00¹	1.00¹	1.00¹	1.00¹
CHAT 007	0.26	0.31	0.38	0.52	0.76
CHAT 008	0.82^a	0.89^a	0.95¹	0.99^a	1.00^a
CHAT 009	1.00^a	1.00^a	1.00^a	1.00^a	1.00^a
CHAT 010	0.98^a	0.99^a	1.00^a	1.00^a	1.00^a
CHAT 011	0.11	0.12	0.14	0.19	0.30
CHAT 012	1.00^a	1.00^a	1.00^a	1.00^a	1.00^a
CHAT 013	1.00^a	1.00^a	1.00^a	1.00^a	1.00^a
CHAT 014	0.98^a	0.99^a	1.00^a	1.00^a	1.00^a
Mean	0.83^a	0.85^a	0.88^a	0.91^a	0.94^a
Median	0.98^a	0.99^a	1.00^a	1.00^a	1.00^a
SD	0.28	0.27	0.25	0.23	0.18

^a Estimated power greater than 0.8.

```
## R-code used to simulate datasets and determine power to detect
change
```

```
setwd("E:/_NPS/Wadeable/Data/powerAnalysis")
```

```
library(pwr)
```

```
## set % change
change <- 0.2
```

```
input <- read.csv("for_PWR.csv")
colnames(input) <- c("site", "transect", "distance", "ww", "acw",
"bfw", "cfw",
"mfw", "tp", "td", "dp", "dh", "feature", "fpp", "fwl", "fwr",
"bh", "bfh", "cfh", "ba", "vc")
```

```
sites <- unique(as.character(input$site))
```

```
bank <- read.csv("Heights_n22.csv")
```

```
## Function to create correlated data sets given values or mean,
sd, and n
gen_cor_data <- function(values, mean = NULL, sd = NULL, n = NULL,
                        prop_diff = change,
                        corrs = c(0.5, 0.6, 0.7, 0.8, 0.9),
                        seed = NULL) {
```

```
  if (all(!is.null(mean), !is.null(sd), !is.null(n))) {
```

```
    mu1 <- mean; sd1 <- sd; n <- n
```

```
  } else {
```

```
    n <- length(values)
```

```
    mu1 <- mean(values); sd1 <- sd(values)
```

```
  }
```

```
  cv <- sd1/mu1
```

```
  mu2 <- rep(mu1 * (1 + prop_diff), length(corrs))
```

```
  sd2 <- rep(mu2 * cv)
```

```
  if (is.null(seed)) set.seed(seed)
```

```
  sig <- matrix(0.5, nrow = length(corrs) + 1,
                ncol = length(corrs) + 1)
```

```
  sig[1, ] <- c(1, corrs)
```

```
  sig[, 1] <- c(1, corrs)
```

```
  diag(sig) <- 1
```

```

## Make correlation matrix positive definite
## Corrs won't match exactly but will be close
sig <- Matrix::nearPD(sig, TRUE, TRUE)$mat
## Convert to covariance matrix
sds <- c(sd1, sd2)
b <- sds %*% t(sds)
sig_cov <- b * sig
dat <- MASS::mvrnorm(11, mu = c(mu1, mu2),
                    Sigma = sig_cov,
                    empirical = TRUE)
act_corrs <- round(tail(sig[1, ], length(corrs)), 2)
dat <- data.frame(dat)
names(dat) <- c("x1", paste0("x2_", act_corrs))
return(dat)
}

##Example of how gen_cor_data() is run
#test <- gen_cor_data(mean = 1.665, sd = 0.324, n = 11)

## Function to calculate sd of differences between original dataset
and
### simulated correlated datasets
diff.sd <- function(x)
{
diff.1 <- sd(x[,1] - x[,2])
diff.2 <- sd(x[,1] - x[,3])
diff.3 <- sd(x[,1] - x[,4])
diff.4 <- sd(x[,1] - x[,5])
diff.5 <- sd(x[,1] - x[,6])

diff.all <- c(diff.1, diff.2, diff.3, diff.4, diff.5)
return(diff.all)
}

## Function to calculate the power to detect change given mean of
dataset,
### amount of change, sd of differences in observations, and number
of samples
#### Uses a 'paired' t-test
diff.power <- function(vmean, vchange, vdiffsd, num, ty)
{
power1 <- pwr.t.test(d = (vmean-vchange)/vdiffsd[1], n = num, type
= ty)

```

```

power2 <- pwr.t.test(d = (vmean-vchange)/vdiffsd[2], n = num, type
= ty)
power3 <- pwr.t.test(d = (vmean-vchange)/vdiffsd[3], n = num, type
= ty)
power4 <- pwr.t.test(d = (vmean-vchange)/vdiffsd[4], n = num, type
= ty)
power5 <- pwr.t.test(d = (vmean-vchange)/vdiffsd[5], n = num, type
= ty)
return(c(power1$power, power2$power, power3$power, power4$power,
power5$power))
}

```

Create objects to hold the calculated power to detect change

```

ww.power <- data.frame()
ac.power <- data.frame()
cf.power <- data.frame()
mf.power <- data.frame()

```

```

bh.power <- data.frame()
ch.power <- data.frame()
bs.power <- data.frame()

```

Loop to fill the empty data.frames

```

for(i in 1:length(sites))
{
  ## Subset datasets by site
  site <- subset(input, site == sites[i])
  h.site <- subset(bank, Site == sites[i])

```

Calculate power to detect change by variable by simulated correlation

Wetted Width

```

ww.mean <- mean(site[, 'ww'])
ww.sd <- sd(site[, 'ww'])
ww.sim <- gen_cor_data(mean = ww.mean, sd = ww.sd, n = 11)
ww.diff.sd <- diff.sd(ww.sim)
ww.change <- ww.mean * (1 - change)
ww.power <- rbind(ww.power, diff.power(ww.mean, ww.change,
ww.diff.sd, 11, "paired"))

```

Active Channel Width

```

ac.mean <- mean(site[, 'acw'])
ac.sd <- sd(site[, 'acw'])
ac.sim <- gen_cor_data(mean = ac.mean, sd = ac.sd, n = 11)

```

```

ac.diff.sd <- diff.sd(ac.sim)
ac.change <- ac.mean * (1 - change)
ac.power <- rbind(ac.power, diff.power(ac.mean, ac.change,
ac.diff.sd, 11, "paired"))
## Channel full Width
cf.mean <- mean(site[, 'cfw'])
cf.sd <- sd(site[, 'cfw'])
cf.sim <- gen_cor_data(mean = cf.mean, sd = cf.sd, n = 11)
cf.diff.sd <- diff.sd(cf.sim)
cf.change <- cf.mean * (1 - change)
cf.power <- rbind(cf.power, diff.power(cf.mean, cf.change,
cf.diff.sd, 11, "paired"))
## Minimum Flood Width
mf.mean <- mean(site[, 'mfw'])
mf.sd <- sd(site[, 'mfw'])
mf.sim <- gen_cor_data(mean = mf.mean, sd = mf.sd, n = 11)
mf.diff.sd <- diff.sd(mf.sim)
mf.change <- mf.mean * (1 - change)
mf.power <- rbind(mf.power, diff.power(mf.mean, mf.change,
mf.diff.sd, 11, "paired"))
## Channel full Height
ch.mean <- mean(h.site[, 'CFH'])
ch.sd <- sd(h.site[, 'CFH'])
ch.sim <- gen_cor_data(mean = ch.mean, sd = ch.sd, n = 22)
ch.diff.sd <- diff.sd(ch.sim)
ch.change <- ch.mean * (1 - change)
ch.power <- rbind(ch.power, diff.power(ch.mean, ch.change,
ch.diff.sd, 22, "paired"))
## Minimum Flood Height
bh.mean <- mean(h.site[, 'BH'])
bh.sd <- sd(h.site[, 'BH'])
bh.sim <- gen_cor_data(mean = bh.mean, sd = bh.sd, n = 22)
bh.diff.sd <- diff.sd(bh.sim)
bh.change <- bh.mean * (1 - change)
bh.power <- rbind(bh.power, diff.power(bh.mean, bh.change,
bh.diff.sd, 22, "paired"))
## Bank Stability Index
bs.mean <- mean(h.site[, 'BSI'])
bs.sd <- sd(h.site[, 'BSI'])
bs.sim <- gen_cor_data(mean = bs.mean, sd = bs.sd, n = 22)
bs.diff.sd <- diff.sd(bs.sim)
bs.change <- bs.mean * (1 - change)

```

```

bs.power <- rbind(bs.power, diff.power(bs.mean, bs.change,
bs.diff.sd, 22, "paired"))
}

## Specify column names
cnames <- c("cor50", "cor60", "cor70", "cor80", "cor90")

## Rename rows/columns
colnames(ww.power) <- cnames
colnames(ac.power) <- cnames
colnames(cf.power) <- cnames
colnames(mf.power) <- cnames
colnames(bh.power) <- cnames
colnames(ch.power) <- cnames
colnames(bs.power) <- cnames

## Rename rows/columns
rownames(ww.power) <- sites
rownames(ac.power) <- sites
rownames(cf.power) <- sites
rownames(mf.power) <- sites
rownames(bh.power) <- sites
rownames(ch.power) <- sites
rownames(bs.power) <- sites

## Export data.frames with simulated power to detect change
write.csv(ww.power, paste("Pwr_ww_", change,
"_simulated_change.csv", sep = ""))
write.csv(ac.power, paste("Pwr_ac_", change,
"_simulated_change.csv", sep = ""))
write.csv(cf.power, paste("Pwr_cf_", change,
"_simulated_change.csv", sep = ""))
write.csv(mf.power, paste("Pwr_mf_", change,
"_simulated_change.csv", sep = ""))
write.csv(bh.power, paste("Pwr_bh_", change,
"_simulated_change.csv", sep = ""))
write.csv(ch.power, paste("Pwr_ch_", change,
"_simulated_change.csv", sep = ""))
write.csv(bs.power, paste("Pwr_bs_", change,
"_simulated_change.csv", sep = ""))

```

Appendix C. Standard Operating Procedures

The Southeast Coast Network (SECN) maintains a single library of standard operating procedures (SOP) that will be used network-wide to ensure consistent procedures. All approved SOPs are available for download at the [NPS Integrated Resource Management Applications \(IRMA\) portal](#).

All SECN SOPs conform to a standard three-part numbering system to aid in the identification of the portion(s) of the program to which the procedures apply (Table C-1).

Table C-1. Numbering system and categories for Standard Operating Procedures (SOPs) used by the Southeast Coast Network. Within each category, SOPs are numbered sequentially as they are produced.

Level 1	Level 2	Topic
1	1.1.x	General field methods shared by multiple branches of the SECN (i.e., those related to GIS, GPS location, photo points, or use of shared instrumentation).
	1.2.x	Field methods for water resource monitoring.
	1.3.x	Field methods for coastal resource monitoring.
	1.4.x	Field methods for terrestrial resource monitoring (plants and animals).
2	2.1.x	Data management procedures shared by multiple branches of the SECN, such as those pertaining to reporting, file management.
	2.2.x	Data management procedures related to water resource monitoring.
	2.3.x	Data management procedures related to coastal resource monitoring.
	2.4.x	Data management procedures related to terrestrial resource monitoring (plants and animals).
3	3.1.x	Field Safety.
	3.2.x	Equipment use and maintenance.
4	4.1.x	Network administration.
5	5.1.x	User Manuals.

The following subset of SECN SOPs is necessary for the implementation of the SECN Wadeable Stream Habitat Condition Monitoring Protocol (Table C-2). All SOPs are subject to modification with changes made in accordance with standard procedures documented in SECN SOP 2.1.01 (Wright and Curry 2016).

Table C-2. Standard Operating Procedures required to implement the SECN Wadeable Stream Habitat Conditions Monitoring Protocol. The subject category, SOP number, title, and Integrated Resources Management Applications (IRMA) record numbers are provided.

Subject	SOP#	Citation	IRMA Record Number
Monitoring	1.2.13	Gregory, M.B., E. N. Starkey, and J. M. McDonald. 2018. Wadeable stream field season preparation for stream habitat monitoring—Version 1.0. Southeast Coast Network Standard Operating Procedure NPS/SECN/SOP—1.2.13. Southeast Coast Network, Athens, Georgia.	2253885
	1.2.14	McDonald, J. M., E. N. Starkey, J. W. Riley, and M. B. Gregory. 2018. Wadeable stream reach selection and location of sampling points—Version 1.0. Southeast Coast Network Standard Operating Procedure NPS/SECN/SOP—1.2.14. Southeast Coast Network, Athens, Georgia.	2253887
	1.2.15	McDonald, J. M., M. B. Gregory, and J. Riley. 2018. Wadeable stream basin- and segment-scale data summary—Version 1.0. Southeast Coast Network Standard Operating Procedure NPS/SECN/SOP—1.2.15. Southeast Coast Network, Athens, Georgia.	2254012
	1.2.16	McDonald, J. M., E. N. Starkey, M. B. Gregory, and J. Riley. 2018. Wadeable stream reach-scale field data collection—Version 1.0. Southeast Coast Network Standard Operating Procedure NPS/SECN/SOP—1.2.16. Southeast Coast Network, Athens, Georgia.	2254013
	1.2.17	McDonald, J. M., M. B. Gregory, J. Riley, and E. N. Starkey. 2018. Setting up and configuration of total station. Southeast Coast Network Standard Operating Procedure NPS/SECN/SOP—1.2.17. Southeast Coast Network, Athens, Georgia.	2254014
	1.2.18	McDonald, J. M., E. N. Starkey, M. B. Gregory, and J. Riley. 2018. Using a total station to conduct a stream survey—Version 1.0. Southeast Coast Network Standard Operating Procedure NPS/SECN/SOP—1.2.18. Southeast Coast Network, Athens, Georgia.	2254016
Data Management	2.1.01	Southeast Coast Network (SECN). 2016. Revision of Southeast Coast Network protocols and standard operating procedures—Version 2.0. Southeast Coast Network Standard Operating Procedure NPS/SECN/SOP—2.1.01. Southeast Coast Network, Athens, Georgia.	2237739
	2.1.02	Wright, W. and S. Curry. 2016. Southeast Coast Network reporting guidelines—Version 2.0. Southeast Coast Network Standard Operating Procedure NPS/SECN/SOP—2.1.02. Southeast Coast Network, Athens, Georgia.	2237905
	2.1.03	Southeast Coast Network (SECN). 2016. Southeast Coast Network authorship guidelines—Version 2.0. Southeast Coast Network Standard Operating Procedure NPS/SECN/SOP—2.1.03. Southeast Coast Network, Athens, Georgia.	2237829

Subject	SOP#	Citation	IRMA Record Number
	2.1.07	Southeast Coast Network (SECN). 2017. Digital image management—Version 3.1. Southeast Coast Network Standard Operating Procedure NPS/SECN/SOP—2.1.07. Southeast Coast Network, Athens, Georgia.	2243092
	2.1.08	Southeast Coast Network (SECN). 2016. Dataset and metadata publication—Version 2.0. Standard Operating Procedure NPS/SECN/SOP—2.1.08. Southeast Coast Network, Athens, Georgia.	2238047
	2.2.13	McDonald, J. M., E. N. Starkey, P. Capece, and M. B. Gregory. 2018. Wadeable stream data entry and storage—Version 1.0. Southeast Coast Network Standard Operating Procedure NPS/SECN/SOP—2.2.13. Southeast Coast Network, Athens, Georgia.	2254018
	2.2.14	McDonald, J. M., E. N. Starkey, and M. B. Gregory. 2018. Wadeable stream data processing and analysis—Version 1.0. Southeast Coast Network Standard Operating Procedure NPS/SECN/SOP—2.2.14. Southeast Coast Network, Athens, Georgia.	2254015
	2.2.15	McDonald, J.M., E. N. Starkey, and M. B. Gregory. 2018. Wadeable stream reporting guide—Version 1.0. Southeast Coast Network Standard Operating Procedure NPS/SECN/SOP—2.2.15. Southeast Coast Network, Athens, Georgia.	2254020
Safety	3.1.01	Corbett, S. L. and Smrekar B. D. 2017. Reporting of on-duty injury and illness—Version 4.1. Southeast Coast Network Standard Operating Procedure NPS/SECN/SOP—3.1.01. Southeast Coast Network, Athens, Georgia.	2244006
	3.1.03	Southeast Coast Network (SECN). 2016. Vehicle use and operation—Version 2.0. Southeast Coast Network Standard Operating Procedure NPS/SECN/SOP—3.1.03. Southeast Coast Network, Athens, Georgia.	2237830
	3.1.04	Corbett, S. L., and B. Smrekar. 2016. Motor vehicle accident reporting procedures—Version 2.0. Southeast Coast Network Standard Operating Procedure NPS/SECN/SOP—3.1.04. Southeast Coast Network, Athens, Georgia.	2237832
	3.1.07	DeVivo, J. C., and S. L. Corbett. 2016. Communicating field operations with SECN parks—Version 3.0. Southeast Coast Network Standard Operating Procedure NPS/SECN/SOP—3.1.07. National Park Service, Athens, Georgia.	2238044

Appendix D. Job Hazards Risk Assessment and Training and Proficiencies

This appendix outlines hazards and risks associated with the implementation of the Southeast Coast Network (SECN) wadeable stream habitat monitoring protocol. The combined list of hazards and abatement actions are taken from individual JHAs on file at the Southeast Coast Network. Additionally, this appendix outlines both required and optional trainings needed to more safely fulfill activities associated with the safe implementation of this protocol.

Recommended reading:

Lane, S. L., and R. G. Fay. 1997. Safety in field activities: U.S. Geological Survey Techniques of Water-Resources Investigations, book 9, chap. A9.

Table D-1. Combined Job Hazard Analysis (JHA) for safe implementation of the SECN wadeable stream monitoring protocol, including potential hazards and recommended abatement actions for tasks and procedures associated with all tasks and procedures.

Potential accidents or hazards	Recommended safety procedures/abatement actions
Lack of knowledge and experience with tasks	All people (permanent, seasonal, VIPs) involved in any project should receive a general orientation and tailgate safety session specific to the task prior to beginning of work.
General accidents	Complete First Aid and CPR training course. Always carry standard PPE, which includes a first aid kit.
Poison ivy/oak	Wear long sleeve shirts and long pants. Make sure you can identify poison ivy in all its growth forms, including foliage, bare twigs, and berries (the plant is toxic in winter when foliage is absent!); wear long sleeves; avoid sitting with arms resting on knees; use Technu lotion (or something similar) to prevent exposure; wash with soap immediately after returning from the field; bring an extra set of clothes and shoes to change into after coming out of field; wash field clothes separately from other laundry.
Bees/Wasps/Hornets	Determine if any field crew are allergic to bee stings. Notify other crew members and the supervisor if you know you are allergic to bee stings; ensure that allergic individual carries prescribed medication to prevent anaphylactic shock; carry a bee sting kit or Benadryl or other antihistamine; be aware of the ground where you step- some hornets build nests in the ground at the base of trees or shrubs, or in rotten logs- watch for bees buzzing in and out of holes or around ground level; if possible, flag a nest so future surveyors won't run into it.

Potential accidents or hazards	Recommended safety procedures/abatement actions
Ticks	Spray clothing with insect repellent such as DEET, as a barrier. Wear light colored clothing that fits tightly at the wrists, ankles, and waist. Each outer garment should overlap the one above it. Cover trouser legs with high socks, boots, or nylon gaiters OR duct tape pant legs to shoes. Tuck in shirt tails. Search the body on a regular basis, especially hair and clothing; ticks generally do not attach for a couple of hours. If a tick becomes attached, use a tick removal tool or tweezers to grasp the tick as close as possible to the point of attachment and pull straight out with gentle pressure. Wash skin with soap and water then cleanse with rubbing alcohol. Place the tick in an empty container for later identification, if the victim should have a reaction. Record dates of exposure and removal. Do not try to remove the tick by burning with a match or covering it with chemical agents. If you cannot remove the tick, or the head detaches, seek prompt medical help. If you are bitten by a tick, first document it on a calendar or injury log, and then watch for warning signs of illness: a large red spot on the bite area; fever, chills, headache, joint and muscle ache, major fatigue, and facial paralysis are reactions that may appear within two weeks of the bite. Symptoms specific to Lyme disease include: confusion, short term memory loss, and disorientation. Review the CDC documents relating to tick-borne diseases at http://www.cdc.gov/ticks/diseases
Scorpions	Inspect items left lying on the ground, e.g., clothing, for scorpions prior to putting them on
Mosquitoes	Wear long sleeves and pants. Avoid heavy scents, such as strong soap, lotion, or perfume. Use insect repellents and follow manufacture instructions. Carry after-bite medication to reduce skin irritation.
Venomous snakes	Wear high top boots and snake gaiters or chaps. When going through thick underbrush, be alert. Walk slowly and give snakes ample time to move out of the way. Walk on clear paths as much as possible. Be careful where placing feet and hands at all times. Always step ON the log, not OVER the log! In the unlikely event you're bitten by a venomous snake, stay calm, sit still, and call and wait for help. Do not walk on or place hands in debris or log jams.
Disease (Tetanus, bubonic plague, hanta virus, Lyme disease, rocky mountain spotted fever)	Ensure tetanus booster is up-to-date. Wear all-leather-upper protective footwear. Stay away from dead rodents and rodent feces, especially in closed buildings. For Lyme disease and rocky mountain spotted fever see 1e.
Encounters with strangers	Report uncomfortable encounters with strangers in the park to a supervisor as soon as possible; report apparent illegal activity to a park ranger, do not get into a confrontation with visitors in the park.

Potential accidents or hazards	Recommended safety procedures/abatement actions
Hypothermia	Always anticipate bad weather and dress accordingly, or carry warm clothes with you; always travel in pairs as a minimum; keep clothing as dry as possible; eat high energy nutritional supplements between meals; cover the head and neck to prevent heat loss; keep active to maintain the body's metabolism; drink plenty of liquids to prevent dehydration, although an individual does not "feel" thirsty; drink warm liquids not cold; understand the effects of cold and wind; most hypothermia cases develop between 30°F and 50°F. If someone falls in cold water they need to get dry and warm as soon as possible. If possible, leave the field quickly and get inside a heated vehicle or building. Cover the victim with blankets or sleeping bags. Call emergency services if necessary.
Heat Stress/Hyperthermia	Take appropriate breaks. Maintain proper hydration and electrolyte consumption. Slow pace or reduce field hours if heat index is high (over 95 degrees Fahrenheit). Hyperthermia may occur during high temperatures, monitor for dehydration, heat exhaustion, heat cramps, and heat stroke; symptoms include nausea, headache, and flushed, red skin; drink plenty of cold/cool water (even when you are not thirsty); as heat increases, take frequent breaks in cool locations; wear a light shirt.
Dehydration	Drink at least 1/2 quart of water every hour. Limit caffeine intake, as caffeine dehydrates you. Carry sufficient amounts of water. Avoid long exposure to sun. Wear hat with wide brim for shade. Use electrolyte supplements or drink sports drinks (e.g., Gatorade).
Sunburn	Much of the work may take place in full sunlight so to prevent sunburn, use 30+ or greater SPF sunscreen and lip balm; and wear a wide brim hat, sunglasses, and long-sleeve shirt.
No one available in the park office	Attempt to call park contacts using a cellular phone or send a text via satellite beacon. If no one responds, check in with the SECN supervisor/program manager to let them know you have arrived at your destination.
No cellular signal	Use alternate method of communication such as the satellite beacon or navigate to a location with cellular signal.
Falling on slippery, steep, and rugged terrain.	Assess terrain conditions to find safe route and modify sampling plans to avoid unsafe areas. Wear boots with slip-resistant soles with tops well above the ankle, broken in before the field season, plus wool socks. Tennis shoes are not permitted. If wearing wading boots, be cognizant that they are slippery on grass and mud. Carry supplies in backpack, make sure pack is comfortable and secure, a waist belt is recommended. Take care when walking on hardwood leaf litter and on wet ground. Maintain an erect posture when contouring steep slopes. Avoid walking below another person due to the potential for rocks to dislodge from above. Do not walk on wet logs and log jams.
Cuts and/or eye injury caused by undergrowth	Wear gloves and safety glasses (or other glasses) when hiking in brushy areas to protect hands and eyes from protruding objects.

Potential accidents or hazards	Recommended safety procedures/abatement actions
Stream crossing	Wear proper slip-resistant footwear and life jacket. Unfasten backpack hip belt before crossing. Cross streams only if you are sure they are safely wadeable. Cross in shallow relatively calm area with limited obstacles (boulders, logs, etc.). Use a walking stick or pole to balance and check for deep pools. Cross at a slight downstream angle to avoid fighting the current.
Barbed wire fence crossing	Barbed wire fences may be crossed during the course of work. When possible use gates (leave them open or closed depending on how you find them). If no gate is available cross under or over with caution.
Fatigue	Get a good night's sleep before field work. Know the limits of your own body (e.g., tolerance to heat, cold, allergies, strength, endurance, etc.), pursue physical conditioning prior to the field season if necessary, and do not over-exert yourself. Tighten stomach muscles when standing for long periods of time to support the lower back. When hiking up / down hills, avoid walking on your toes as this cause muscle fatigue rapidly. Using the entire sole of your foot uses the large muscles of your legs thus avoiding leg-muscle fatigue.
Hunting season	Wear bright colored clothing, hat or orange vests during hunting season. Observe the area for possible hunters.
Ergonomics hazard	Use proper mechanics when bending over or lifting objects (i.e., lift with your knees, bend knees when bending over).
Cuts and/or eye injury caused by flying debris	Wear gloves and safety glasses (or other glasses) to protect hands and eyes.
Falling on slippery stream bank or substrate	Wear proper waders, felt or lug soled chest or hip boots for conditions. When using waders, wear wading belt or similar. Purchase and use waders with felt soles or retrofitted with anti-slip devices.
Working near unstable, steep, deep channels, swiftflows.	Reconnoiter to familiarize yourself with stream and adjacent reach; know the current and projected flow conditions from weather forecasts and stream gauge information; familiarize yourself with work area prior to fieldwork; review maps and aerial photos to determine access points, reference points, and potential evacuation points; develop evacuation plans for remote stream reaches and make sure you leave a trip plan with supervisors (written plan is preferred).
Improper hand tool use	Always take care to use hand tools for the purpose for which they are intended (use the "right tool for the job.")

Potential accidents or hazards	Recommended safety procedures/abatement actions
Wading/walking in and across streams and other aquatic areas	Wear chest/hip waders or wading boots. Lug-soled boots are recommended for the fine sediment streams that will be monitored by this protocol. In cold weather, wear neoprene waders or wear warm, preferably polyester garments with standard waders. Use walking stick to improve stability in current. Walk slowly and carefully. Work in teams of two or more and within sight of one another. Cross-stream at shallow riffles, and avoid deep, swift areas (do not attempt to wade a stream for which values of depth multiplied by velocity equal or exceed 10 ft²/s. [Lane and Fay 1997]). When wading in aquatic sites with deep, fine sediments, test fine sediment depths with wading rod or pole before entering. Do not enter when fine sediment depths extend above knee. Consult weather forecast each morning or call local observer to determine stream and flow conditions. Carry a means of communication (e.g., cell phone or radio).
Flash floods	DO NOT TRY TO WALK, DRIVE, OR OTHERWISE CROSS FLOODWATERS. Keep in mind that floodwaters are swift moving, even if they do not appear to be on the surface. It is possible to drown in just a few inches of water if swept away by floodwaters. Especially important when working in stream and river areas, workers should be aware of the possibility of flash floods. When working in stream and river environments, at least one team member should watch nightly weather reports, or monitor weather band radio, to assess if weather conditions for flash floods may exist. If caught in a flash flood while in an automobile, abandon the vehicle immediately and move to higher ground. If the vehicle is submerged, do not panic, allow the vehicle to fill with water, and open the doors when the vehicle is full (doors will not open until the water pressure is equal outside and in). Opening windows will expedite the process. Hold your breath, and swim for the surface and toward the bank if possible. If caught in a flash flood while on foot, immediately move to higher ground.
Crossing debris jams	Avoid crossing debris jams when possible. If there is no other route, determine the safest route along the creek; either climbing around on either side of the banks, or by going under and/or on top of the jam. When crossing you should be in sight of your coworkers in case anything should occur. Free both hands to assist with climbing jams. If crossing under and/or on top of the jam, be cognizant of its structural integrity. Walk or crawl on the larger key pieces/logs in the jam as smaller woody pieces are more prone to shift, break, or completely give way. Usually, the larger pieces are the most stable and structurally sound. The same is true for any handholds you may use when climbing the jam. If unsure, do not put all your weight on a piece at once, be slow and maintain your handholds if possible. Avoid slick wet logs without bark and if cold, be aware of ice that may be on their surfaces. DO NOT JUMP onto log pieces.
Drowning	Wear proper protective/floatation gear (life vests, water repellent clothing) at all times; work in pairs or teams; consult flow gauge to determine stream safety level; it is advisable for those conducting aquatic work to be able to swim; if swept away, point feet downstream (to avoid rocks and other debris), swim towards the bank.

Potential accidents or hazards	Recommended safety procedures/abatement actions
Giardia	Giardia is caused by drinking contaminated water – carry plenty of water on outings; also carry water treatment tablets; consider all streams contaminated. Take care not to get stream water on your water bottle. Wash your hands before eating.

Training and proficiencies required or recommended for the safe implementation of this protocol.

Required Training and Proficiencies

- First Aid and CPR training for field workers (terrestrial ecology, coastal ecology, and water quality positions) renewed annually (American Red Cross training) or biannually (American Heart Association training).
- All employees riding or operating a motorized or non-motorized vessel will undergo a safety briefing by a certified operator or the SECN safety officer.
- All field staff must read and understand the document *On-Duty Injury and Illnesses SOP* and complete a short written exam.
- All SECN staff who operate a vehicle must complete a defensive driving course.
- All employees required to operate a government vehicle must read and understand the document *Government Motor Vehicle Accident SOP* and complete a short written exam.

Optional / Recommended Training and Proficiencies

- Authorities, Roles, and Responsibilities (free DOI LEARN online course).
- Blood borne Pathogens (free DOI LEARN online course).
- Fall Protection (free DOI LEARN online course).
- Fire Protection (free DOI LEARN online course).
- Office Safety (free DOI LEARN online course).
- Flammable and Combustible Liquids (free DOI LEARN online course).
- Hand and Portable Powered Tools (free DOI LEARN online course).
- Resources, References, and Standards (free DOI LEARN online course).
- Personal Safety through Awareness (free DOI LEARN online course).

- Laboratory Safety (free DOI LEARN online course).
- Hazard Communication (free DOI LEARN online course).
- First Responder Awareness Level (free DOI LEARN online course).
- NSC Defensive Driving II (See Collateral Duty Safety Officer [CDSO] for more information).).
- Personal Protective Equipment (free DOI LEARN online course).
- Stress Management (free DOI LEARN online course).
- Read and understand the document *Towing a Trailer: Being Equipped for Safety* for all positions requiring towing of a trailer and complete a short written exam.
- USDI Motorboat Operators Safety Training for positions that require operation of a motorized vessel.
- Read and understand the SECN Boat Operation SOP for positions that require operation or riding in a motorized vessel and complete a short written exam.

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.

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National Park Service
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