



Wadeable Stream Habitat Monitoring at Horseshoe Bend National Military Park

2019 Baseline Report

Natural Resource Report NPS/SECN/NRR—2020/2067



ON THE COVER

Picture looking downstream on river left near transect 6 at the wadeable stream monitoring site on “Claybed Creek” (HOBE001) at Horseshoe Bend National Military Park.

Photograph taken by SECN staff on April 24, 2019.

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Summary and Key Findings

The Southeast Coast Network (SECN) stream habitat monitoring protocol collects data to give park resource managers insight into the status of and trends in stream and near-channel habitat conditions (McDonald et al. 2018a). Wadeable stream assessments are currently implemented at the five SECN inland parks with wadeable streams: Horseshoe Bend National Military Park (HOBE), Kennesaw Mountain National Battlefield Park (KEMO), Ocmulgee Mounds National Historical Park (OCMU), Chattahoochee River National Recreation Area (CHAT), and Congaree National Park (CONG). Streams chosen for assessment were specifically targeted for management interest (e.g., trail erosion issues and upstream urban development) or to provide a context for similar-sized stream(s) within the park or network (McDonald 2019).

The objectives of the SECN stream habitat monitoring protocol are to:

- Determine status of upstream watershed characteristics (basin morphology) and trends in land cover that may affect stream habitat.
- Determine the status of and trends in benthic and near-channel habitat in selected wadeable stream reaches (e.g., bed sediment, geomorphic channel units, and large woody debris).
- Determine the status of and trends in cross-sectional morphology, longitudinal gradient, and sinuosity of selected wadeable stream reaches.

On April 24, 2019, data were collected at Horseshoe Bend National Military Park (HOBE) to characterize the in- and near-channel habitat on a permanently monumented reach on a second Strahler stream order stream (Strahler 1957) nicknamed “Claybed Creek” (HOBE001). These data, along with analysis of remotely-sensed geographic information system (GIS) data, are presented in this report to describe and compare the watershed-, reach-, and transect-scale characteristics of HOBE001 to selected second-order streams at Chattahoochee River National Recreation Area (CHAT004, -008, -010, and -014). Though the historic and contemporary land use/land cover in the watersheds draining to HOBE001 and the CHAT streams are very different (and thus the streams are expected to be significantly different) these comparisons are included to provide a context for the survey at HOBE001.

HOBE001’s watershed (“Claybed Creek”) has high basin shape and moderate slope/relief and is covered by forest, pasture, and shrubland. The major defining characteristics of the stream were the presence of claybeds in the bed of the stream, a groundwater seep along one side of the stream, and floodplains along both sides of the stream. Based on the different geomorphic surfaces observed within and immediately surrounding the reach, the stream appears to be in channel evolution model (CEM) stage III. The floodplain surfaces are interpreted as evidence that the stream is widening (common characteristic of CEM stage III) through progressive slumping of the stream banks.

The presence of the claybeds within the reach could potentially disrupt progression along the channel evolution continuum due to its high rate of erodability. Should a knickpoint (large change in slope)

migrate upstream into the reach, these exposed claybeds would not provide sufficient protection of the channel bed. This knickpoint could migrate upstream relatively quickly and set the stream back in its evolutionary stage. The rate at which this knickpoint migrates upstream is dependent on the sediment composition of the boundary layer (bed sediment), the amount of LWD available to increase bed and bank resistance, and the flow regime that shapes the stream.

With regard to habitat, the distinguishing features of the stream were the homogeneity of geomorphic channel units (predominately run) and the lack of large woody debris (LWD) within the reach. While the reach lacked fine and very fine sediment in its representative riffle (where the pebble count was conducted), the lack of cobble-sized particles within the reach increases the potential for increased bed mobility if a large flood event affects the reach. Due to the lack of coarser sediment, the type or distribution of geomorphic channel units (GCUs) within the reach, and the lack of LWD, habitat within the reach was classified as “poor to fair.” This classification is a generalized interpretation of in-stream habitat and additional work is needed to determine how flow (e.g., flashiness of flow and baseflow conditions), water quality, and in-stream physical characteristics affect biodiversity and stream health at Horseshoe Bend National Military Park. Habitat within the reach may degrade to a “poor” rating if fine or very fine sediment is added to the reach (potentially from a disturbance upstream). Alternatively, if LWD can become established within the reach, this additional habitat complexity could make the reach more habitable which would result in a “fair” classification of the habitat (Allan and Castillo 2007). The stream does not have immediate management concerns, although there is extensive privet growth in the area outside of the channel.

List of Acronyms

ANOVA—Analysis of variance

B—Sand/gravel bar

Be—Bench

Bf—Bankfull

BM—Benchmark

BSi—Bank stability index

CHAT—Chattahoochee National Recreation Area

CONG—Congaree National Park

CV—Coefficient of variance

DEM—Digital elevation model

FP—Floodplain

FPM—Floodplain margin

GCU—Geomorphic channel unit

GIS—Geographic information system

Gl—Glide

HOBE—Horseshoe Bend National Military Park

KEMO—Kennesaw Mountain National Battlefield Park

LWD—Large woody debris

LT—Low terrace

NED—National Elevation Dataset

NL—Natural levee

NLCD—National Land Cover Dataset

NPS—National Park Service

OCMU—Ocmulgee Mounds National Historical Park

P—Pool

R—Riffle

Ru—Run

SECN—Southeast Coast Network

SOP—Standard operating procedure

T#—Standard transect

Introduction

The Southeast Coast Network (SECN) Stream Habitat Monitoring Protocol collects data to provide park resource managers insight into the status of and trends in stream and near-channel habitat conditions (McDonald et al. 2018a). The data provided through this monitoring effort will provide park staff with information regarding the physical linkage between streams and park resources. Additionally, this monitoring program will provide early warnings of changing conditions that may negatively affect visitor experience or park infrastructure.

Wadeable stream monitoring is currently implemented at the five SECN inland parks with wadeable streams. These parks include Horseshoe Bend National Military Park (HOBE) in Alabama, Kennesaw Mountain National Battlefield (KEMO), Ocmulgee Mounds National Historical Park (OCMU), and Chattahoochee River National Recreation Area (CHAT) in Georgia, and Congaree National Park (CONG) in South Carolina. The streams at Horseshoe Bend NMP, Kennesaw Mountain NBP, and Chattahoochee River NRA are typical Appalachian Piedmont streams that are beginning to re-equilibrate to their modern flow and sediment regimes following the poor land use practices of the late 19th and early 20th centuries (McDonald 2019; McDonald and Starkey 2018a; McDonald and Starkey 2018b). The streams at Congaree NP are typical low gradient, blackwater, Coastal Plain streams (McDonald and Starkey 2018c) while the streams at Ocmulgee Mounds NHP are a mixture of Appalachian Piedmont and Coastal Plain type streams (McDonald and Starkey 2019). Streams chosen for monitoring were specifically targeted due to management interest (e.g., trail erosion issues and upstream urban development) or to provide a context for similar-sized streams in the park or network (see suitability reports for each park [cited in this paragraph] for more information).

The objectives of the SECN stream habitat monitoring protocol are to:

- Determine status of upstream watershed characteristics, including basin area, basin slope, and drainage density, and trends in land cover that may affect stream habitat;
- Determine the status of and trends in the geomorphic dimensions of selected wadeable stream reaches, including cross-sectional morphology, 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, including the size, type, and distribution of bed sediment and large woody debris, the distribution of geomorphic channel units, and canopy cover.

For the purposes of this report, wadeable streams are narrowly defined as small- to medium-sized, perennially-flowing waterbodies, with easily identifiable channel banks, that can be accessed and traversed without the use of a watercraft. The wadeable streams referred to herein do not include non-perennial channel-like features typical of a highly disturbed and gullied landscape.

This report presents the results of the wadeable stream habitat survey conducted at Horseshoe Bend NMP in spring 2019. This report describes the basin characteristics (i.e., basin morphology and land use/land cover) and the reach-scale physical characteristics of the surveyed stream reach on “Claybed Creek” (HOBE001). A regional context is provided by comparing HOBE001 to four previously surveyed streams at Chattahoochee River National Recreation Area (CHAT004, -008, -010, and -014; McDonald et al. 2019).

Study Area

The hydro-climatic conditions of the study area are characterized as humid subtropical with average annual rainfall around 45.85 inches (1,164.6 millimeters [mm]) per year (Wright et al. 2011). Snowfall is negligible and winters are mild; summers are hot and humid. Average monthly temperature ranges from a low in December of approximately 25.6°F (-3.55°C) to a high in July of 94.3°F (34.6°C; Wright et al. 2011). Monthly rainfall totals are distributed rather evenly from October through May due to the influence of frontal systems that sweep through the region (Lecce 2000). Convective thunderstorms influence the region from late spring through early fall. While monthly precipitation tends to be high in the summer, the high levels of evapotranspiration attenuate streamflow during this part of the year (Lins 1997).

The natural condition of rivers draining the southeastern U.S. is generally characterized by meandering channels with densely vegetated banks (Leigh 2008). Contemporary river systems in the southeastern U.S. are in variously altered states that reflect multiple legacies of anthropogenic disturbance (James 2018). Beginning in the late 1800s, deforestation, increased row crop agriculture, and a general lack of soil conservation measures caused widespread erosion of topsoil from steeply sloped upland areas in the Appalachian Piedmont region (Trimble 1969). Sediment was transported to streams and floodplains, burying productive shoal and riffle habitats. 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. As row-crop agriculture became less dominant and forest cover increased, sediment delivery to streams was reduced and streambeds began to degrade (Schumm et al. 1984). Today, streambed elevations in many of the region’s small streams have returned to historic or near historic levels though their geomorphic characteristics (width, depth, and level of entrenchment) are quite different from early settlement conditions (Schoonover et al 2007; Mukudan et al 2011).

In addition to the legacy effects of agriculture, many Appalachian Piedmont streams (including those draining to and through Horseshoe Bend NMP) have been further subjected to hydrologic alterations caused by urban or suburban development. Increases in impervious surface area associated with development creates conditions that increase the frequency and magnitude of peak discharges (Paul and Meyer 2001). Impervious surface area is also associated with lower-than-normal base flow during dry periods due to impaired groundwater recharge (Rose and Peters 2001). These flow alterations greatly influence available in- and near-stream habitats and can have a large negative impact on the biota found within a stream (Wenger et al. 2008).

As each stream recovers from its unique history of land use and equilibrates to its current flow and sediment regimes it will pass through a series of semi-predictable stages of evolution (James 2018). These stages include aggradation (receiving more sediment than flow regime can transport), degradation and narrowing (from a reduction in sediment and/or increased runoff), further degradation and widening, and finally stabilization and more natural reworking of in-channel alluvium (Figure 1). The exact stage that each stream is currently experiencing is dependent on the location of the stream within its network and the drainage basin's historical and contemporary land use/land cover conditions. In general, streams in the Appalachian Piedmont are at the third stage of channel development (further degradation and widening) and their banks are quite unstable and subject to undercutting and slumping (Ruhlman and Nutter 1999).

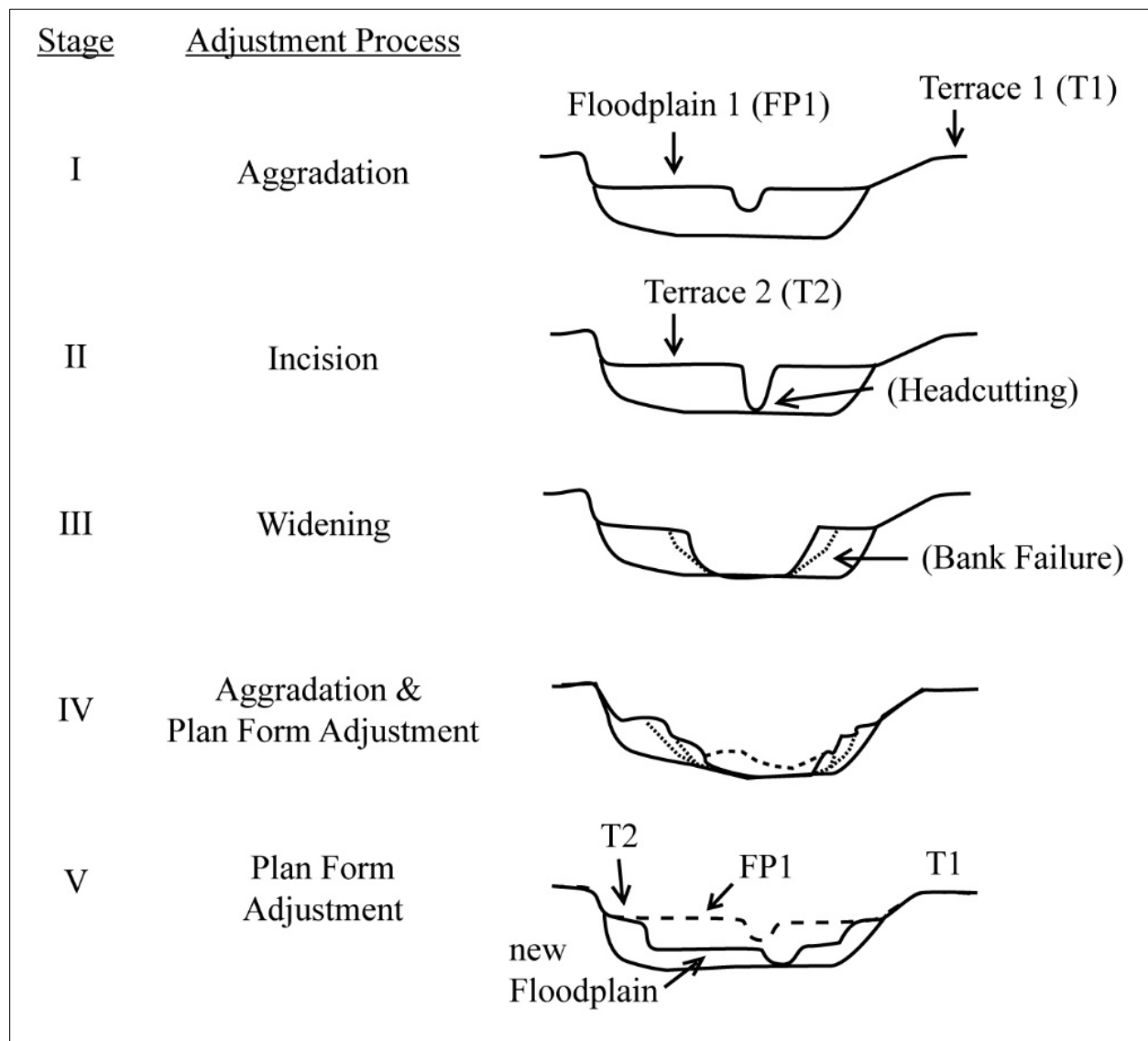


Figure 1. Generalized channel evolution model (modified from Schumm et al. 1984).

Horseshoe Bend National Military Park

Horseshoe Bend NMP is located in eastern Alabama and is made up of 2,040 acres (825 hectares [ha]) of mixed hardwood forest (Figure 2). 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% 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. Reconnaissance surveys, conducted in 2012, 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).

Horseshoe Bend National Military Park- Wadeable Stream Habitat Survey Site

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



Figure 2. Map showing Horseshoe Bend National Military Park and its wadeable stream site (HOBE001). The watershed draining to the study reach is shown to provide a context for the data presented in this report. The land use/land cover (NLCD 2011; Homer et al. 2015) and perennial streams (derived from a 10-meter (32.8 feet [ft]) digital elevation model; data available from the U.S. Geological Survey) in the vicinity of the park are also shown.

Methods

The habitat characteristics and geomorphic parameters that were selected for monitoring are based on those collected by other federal organizations (USGS, Fitzpatrick et al., 1998; USEPA, Hughes 2000; and USFS, Harrelson et al. 1994). The physical structure of in- and near-stream habitat has a strong influence on the biological communities and overall ecological integrity of lotic ecosystems (Newson and Newson 2000). Monitoring stream habitat not only provides an understanding of the physical suitability for aquatic species but can also identify stressors that could degrade other park resources and negatively affect visitor experiences.

The data collected as part of the SECN wadeable stream monitoring protocol are divided into three scales of analysis: (1) basin-scale characteristics; (2) reach-scale measurements, along and between 11 standard transects per reach, and (3) detailed cross-sectional measurements, at three of the 11 transects per reach (Figure 3). A table containing list and definition of the variables collected under the protocol can be found in Appendix A. While summarized in this document, a list of standard operating procedures and an overview of the methods used to collect and process the survey data are available in McDonald et al. (2018a).

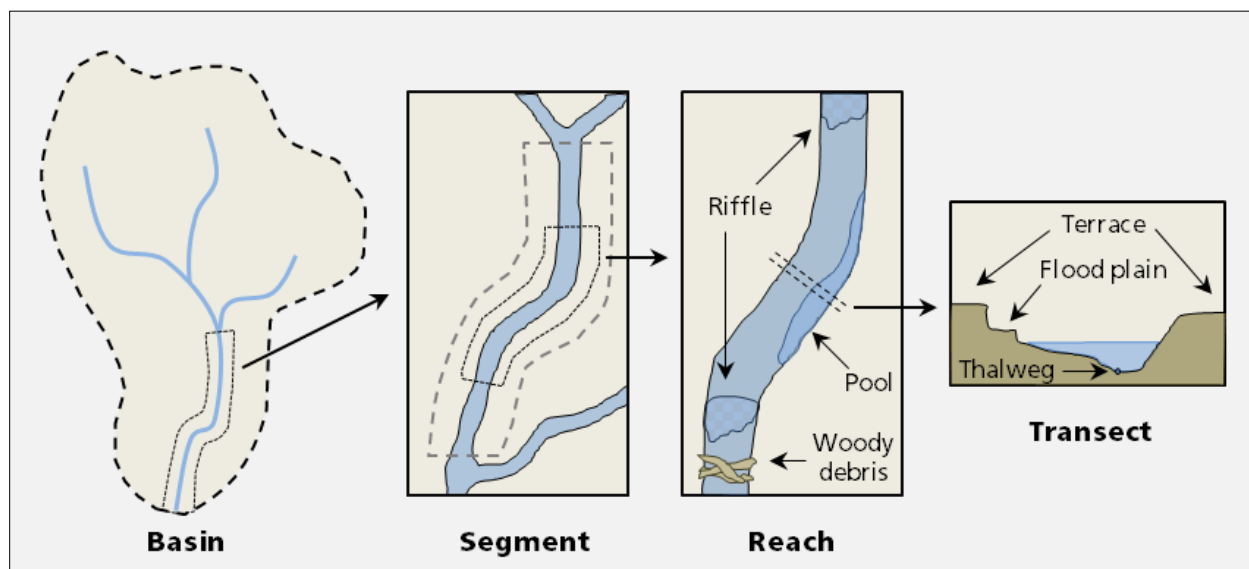


Figure 3. Spatial hierarchy of stream systems and scales of data collection (modified from Fitzpatrick et al. 1998).

Basin Characteristics

Understanding the physical characteristics of a drainage basin as well as the land use and land cover upstream of a reach is critical to understanding changes to and differences between streams. The parameters collected for this protocol describe how dissected the watershed is (drainage density; Knighton 1998), the magnitude and duration of floods (basin shape; Gregory and Walling 1973), the rainfall-runoff potential of a watershed (average watershed slope; Hewlett and Hibbert 1967), potential sediment yield (basin relief ratio; Strahler 1957), and the amount of energy available to

move sediment through a stream network (entire stream gradient; Craig and Rankl 1978; Fitzpatrick et al. 1998). A description of these basin characteristics can be found in McDonald et al. (2018a).

Basin-scale measures are calculated after permanent sites have been determined. These measurements and analyses are conducted within a GIS using digital elevation models (DEMs) from the National Elevation Dataset (NED) and land cover data from the National Land Cover Database (NLCD). Instructions for the GIS basin analysis can be found in SOP 1.2.15 *Wadeable Stream Basin- and Segment-scale Data Summary—Version 1.0* (McDonald et al. 2018b).

Reach-Scale Measurements

The reach-scale characteristics of each monitored reach are measured at and between 11 equidistant transects (distance between transects is two times average wetted width; Figure 4). Reach length is 20 times average wetted width (as determined during the initial survey of the reach). Data collected at each of these transects include: vegetative bank cover, presence of eroding banks, bed and bank material, channel widths (e.g., wetted, active, bankfull, and channel-full widths), water depth, and bank heights/angles. In addition to a qualitative description of bed sediment at each transect, a quantitative measure of bed sediment is obtained by conducting a Wolman pebble count on a representative riffle within the reach (Wolman 1954).

These data provide an understanding of the geomorphic/physical characteristics of the survey reach and are used to derive a bank stability score for the reach (Table 1; Fitzpatrick et al. 1998). Many stream banks in the Appalachian Piedmont are scored as “at-risk” or “unstable.” This condition is consistent with expectations, given that many comparable streams in the region are currently reestablishing functional floodplains within their highly entrenched channel systems.

To understand in-stream and near-channel habitats, measurements are also taken between each transect. These between transect measurements include: canopy cover, the amount and type of in-stream habitat (e.g., high-energy riffles vs. low-energy pools), an inventory of large woody debris (LWD; defined as greater than 1 meter (3.3 ft) in length and greater than 10 centimeters (3.9 inches [in]) in diameter as defined in McDonald et al. 2018a), and a description of in-channel features (e.g., sand/cobble bars).

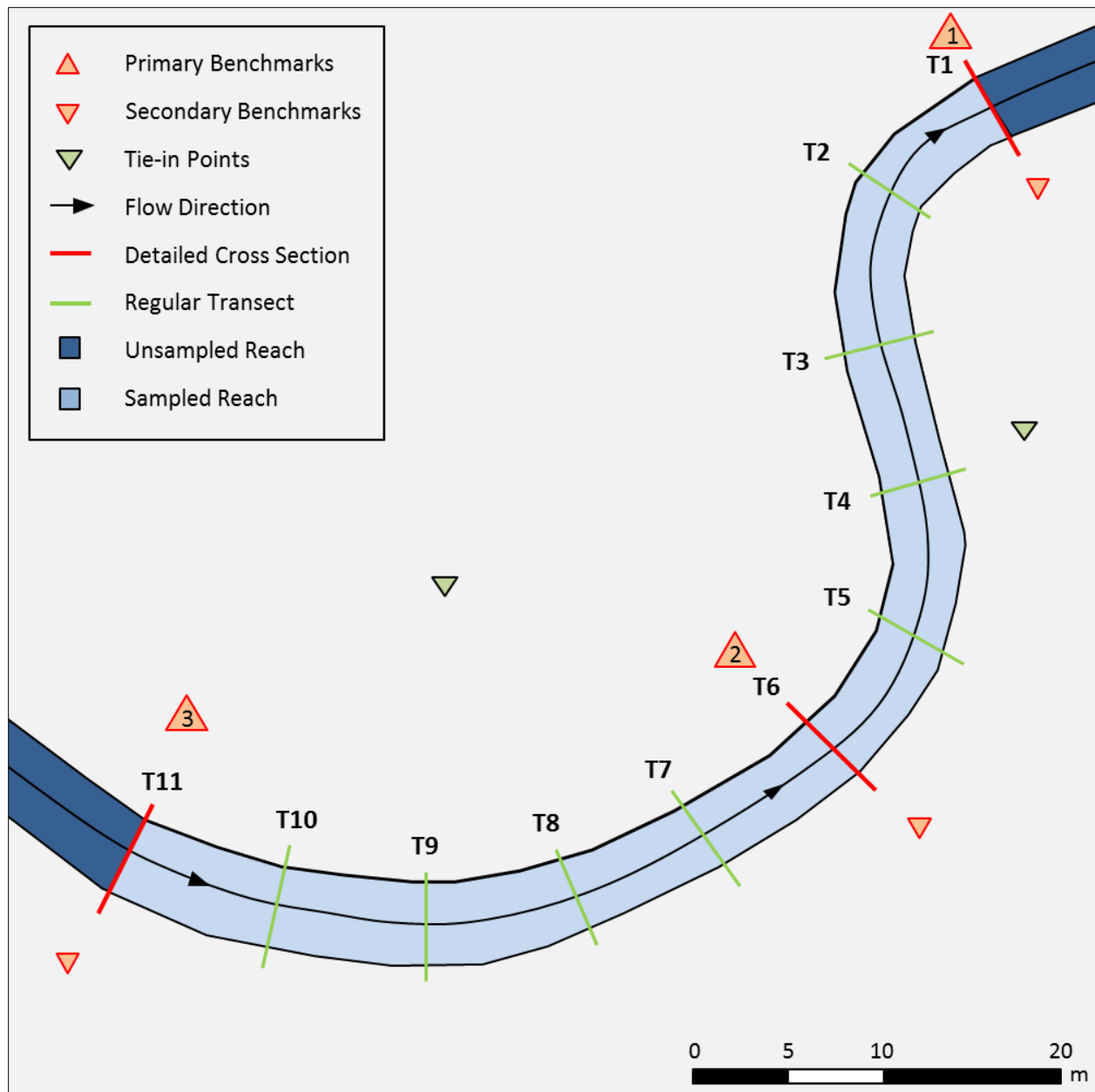


Figure 4. Example layout of stream reach with benchmarks, tie-in points, and transects.

Table 1. Bank Stability Index (BSi) from Fitzpatrick et al. (1998). A BSi score is determined by adding up the bank angle, vegetative cover, bank height, and bank sediment scores for each bank (separate score for left and right banks at each transect)¹.

Bank Stability Factor	Classification	Score
Angle (°)	0–30	1
	31–60	2
	> 60	3
Vegetative cover (%)	> 80	1
	50–80	2
	20–49	3
	< 20	4
Bank Height (meters)	< 1	1
	1–2	2
	2–3	3
	3–4	4
	> 4	5
Type of Bank Sediment	Bedrock, artificial	1
	Boulder, cobble	3
	Clay	4
	Silt	5
	Sand	8
	Gravel/Sand	10

¹ Total score rankings: 4–7 stable; 8–10 at-risk; 11–15 unstable; and 16–22 very unstable

Detailed Transect Cross-Sections

Three of the eleven standard transects (optimally T1, T6, and T11) are surveyed using a survey grade (sub-millimeter accuracy) total station. These surveys allow lateral variability along each transect to be quantified and in- and out-of-channel changes to be monitored through time (Figure 5).

Additionally, repeated surveying of channel cross-sections allows changes in streambed elevation and bank profiles to be quantitatively assessed in relation to a known point (benchmark). These data will be used to calculate bankfull and channel-full areas and will be used along with the bank stability index to assess the condition and stability of the reach.

5. active channel width (meters);
6. channel-full width (meters);
7. channel-full height (meters);
8. bank angle ($^{\circ}$); and
9. vegetative cover of the banks (%).

Bankfull width is not included in the statistical analysis because bankfull was not measured on each transect (due to lack of a floodplain) and the number of bankfull measurements at each reach was not equal. If the ANOVA showed a significant difference, a post hoc Tukey test was used to determine where the difference occurred (i.e. from which site(s) does “Claybed Creek” significantly differ?).

Results

On April 24, 2019, one stream reach (HOBE001, “Claybed Creek”) was surveyed following the methods outlined in SOP 1.2.16 *Wadeable Stream Reach-Scale Field Data Collection—Version 1.0* (McDonald et al. 2018c) and SOP 1.2.18 *Using a Total Station to Conduct a Stream Survey—Version 1.0* (McDonald et al. 2018d). The surveyed reach is on a second-order segment within its stream network. Field surveys, in-office analyses, and statistical comparisons between the surveyed reach and similar monitored reaches are presented in the following sections. Transect-scale results and data summary tables for HOBE001 are provided in Appendix B. A regional context is provided by including survey results from four previously surveyed second-order streams at Chattahoochee River NRA (CHAT004, -008, -010, and -014; McDonald et al. 2019).

HOBE001—“Claybed Creek”

Basin Characteristics

The HOBE001 watershed drains 3.46 square kilometers (1.34 square miles [sq mi]) and is larger than the watersheds draining to the selected streams at Chattahoochee River NRA (1.39–2.67 square kilometers [0.54–1.03 sq mi]; Table 2). Most of “Claybed Creek’s” watershed lies south of the park on private land (Figure 2). The land use/land cover for the watershed draining to HOBE001 is quite different from the watersheds draining to the CHAT streams (Table 3). HOBE001 has far less development (4% versus 56–71%), more forest cover (68% versus 27–40%), and far more pasture/grassland (16% versus 0–5%). Unlike the CHAT watersheds, a large portion of “Claybed Creek’s” watershed is covered in shrubland (11%; Table 3). “Claybed Creek” at HOBE001 is a second-order stream in its stream network. All four of the comparison streams from Chattahoochee River NRA are also second-order streams in their respective stream networks. NPS manages approximately 6.7% of the watershed draining to HOBE001. The drainage density of “Claybed Creek’s” watershed (1.33 km/km²) is second lowest out of the streams compared in this report (Table 3). HOBE001’s watershed had the highest entire stream gradient (0.0311 m/m), the lowest segment gradient (0.0075 m/m), and the second lowest channel gradient (0.0068 m/m; Table 4). HOBE001’s watershed has moderate slope (8°), the lowest variability in watershed slope (CV = 0.61°), the highest drainage shape (0.36), the second highest basin relief ratio (0.028), and the most variability in elevation (elevation standard deviation = 17.64 meters [57.87 ft]; Table 2).

Table 2. Watershed characteristics for HOBE001 compared to four selected reaches from Chattahoochee River NRA. All variables were calculated using the National Elevation Dataset (NED) 10-meter (32.8-ft) digital elevation model [km—kilometers].

Basin Characteristic	HOBE001	CHAT004	CHAT008	CHAT010	CHAT014
Drainage Area (km ²)	3.46	1.39	1.65	2.01	2.67
NPS Managed Area (km ²)	0.23	0.01	0.11	0.29	0.01
NPS Managed Area (%)	6.7%	0%	7%	14%	0%
Total Stream Length (km)	4.59	1.64	2.71	2.72	4.22
Drainage Density	1.33	1.18	1.64	1.36	2.00
Strahler Order	2	2	2	2	2
Bifurcation Ratio	2.00	2.00	1.50	1.50	1.25
Entire Stream Gradient ¹	0.0311	0.0232	0.0264	0.0217	0.0167
Segment Gradient ²	0.0075	0.0135	0.0155	0.0279	0.0145
Slope - Average	8.00	8.30	6.78	5.39	8.05
Slope - Std. Dev.	4.86	5.40	4.64	4.06	4.88
Slope - CV	0.61	0.65	0.68	0.75	0.61
Basin Length (km)	3.08	2.32	2.85	2.86	3.33
Basin Shape ³	0.36	0.26	0.20	0.25	0.24
Basin Relief (meters)	85.45	74.32	70.33	70.14	80.22
Basin Relief Ratio	0.028	0.032	0.025	0.025	0.024
Elevation - Std. Dev. (meters)	17.64	14.41	14.62	12.28	14.45

¹ Entire stream gradient calculated by dividing the difference between the elevations at 10% and 85% stream length by the length of the stream between

² Segment gradient is calculated by dividing the difference in elevations at the top of the stream segment and the bottom of the stream segment by the stream length between

³ Basin shape is calculated by dividing drainage area by squared basin length

Table 3. Land use/land cover characteristics in 2011 for the watersheds draining to HOBE001 compared to four selected reaches from CHAT. The data included in this table are from the National Land Cover Dataset (NLCD).

NLCD Class	HOBE001	CHAT004	CHAT008	CHAT010	CHAT014
Developed Open & Low (%)	4	41	56	69	48
Developed Med. & High (%)	0	15	7	2	12
Forested (%)	68	39	33	27	40
Grassland (%)	16	5	3	2	0
Cultivated (%)	0	0	0	0	0
Shrub (%)	11	0	0	0	0

Table 4. Comparison of average detailed transect characteristics at HOBE001 compared to four selected reaches from CHAT.

Site	n ¹	Slope	Sinuosity	n ²	BF Area (m ²)	BF Width (m)	BF Depth (m)	CF Area (m ²)	CF Width (m)	CF Depth (m)
HOBE001	13	-0.0068	1.02	3	2.03	4.45	0.70	5.58	6.39	1.39
CHAT004	13	-0.0114	1.02	3	1.89	4.44	0.56	7.37	7.05	1.49
CHAT008	12	-0.0142	1.10	3	1.34	5.09	0.34	5.04	7.52	0.78
CHAT010	12	-0.0106	1.36	3	2.04	5.05	0.59	6.35	7.88	1.23
CHAT014	14	-0.0026	1.50	3	1.15	3.92	0.47	2.84	5.73	0.85

¹ Number of measurements taken for slope and sinuosity

² Number of measurements taken for bankfull and channel full area, width, and height

Reach Description

HOBE001 is located on an unnamed second-order stream that flows from south to north into the Tallapoosa River. The stream was nicknamed “Claybed Creek” because of the intermittent exposure of a claybed(s) in the bed of the channel (McDonald 2019). During the 2019 survey, two claybeds were observed; one along river left near T6 and T7 and the other on river right near T9 (Figure 6). A small groundwater seep was observed along river left between T2 and T3. The reach that was surveyed on “Claybed Creek” is approximately 520 meters (1,706 ft) upstream of its confluence with the Tallapoosa River and approximately 40 meters (131.2 ft) downstream from an NPS service road (small bridge) crossing. There are no trails (besides the service road) within the vicinity of the reach. HOBE001 has a moderately coarse bed and its channel has a moderate degree of entrenchment. Some floodplain areas have developed on both rivers left and right inset within the higher valley bottom surface (Figure 6). The reach that was surveyed was 50 meters (164 ft) long with 5 meters

(16.4 ft) between transects. The longitudinal profile has two relatively large increase in slope downstream of the riffle at T3 and at the step between T8 and T9 (Figure 7). Water surface slope for this section of “Claybed Creek” (0.0068 m/m) was lower than all other reaches except for CHAT014 (0.0026 m/m; Table 4). The reach at HOBE001 is less sinuous (1.02) than all CHAT reaches (1.10–1.50), except for CHAT004 (which has the same sinuosity; Table 4). The detailed transects were surveyed on T1 (BM1), T6 (BM2), and T11 (BM3). Detailed transect 1 (T1) has a relatively high degree of entrenchment and the river right bank has slumped into the channel (Figure 8). On detailed transect 2 (T6), a floodplain has developed on river left and a sand and gravel bar has developed along river left on detailed transect 3 (T11; Figure 8).

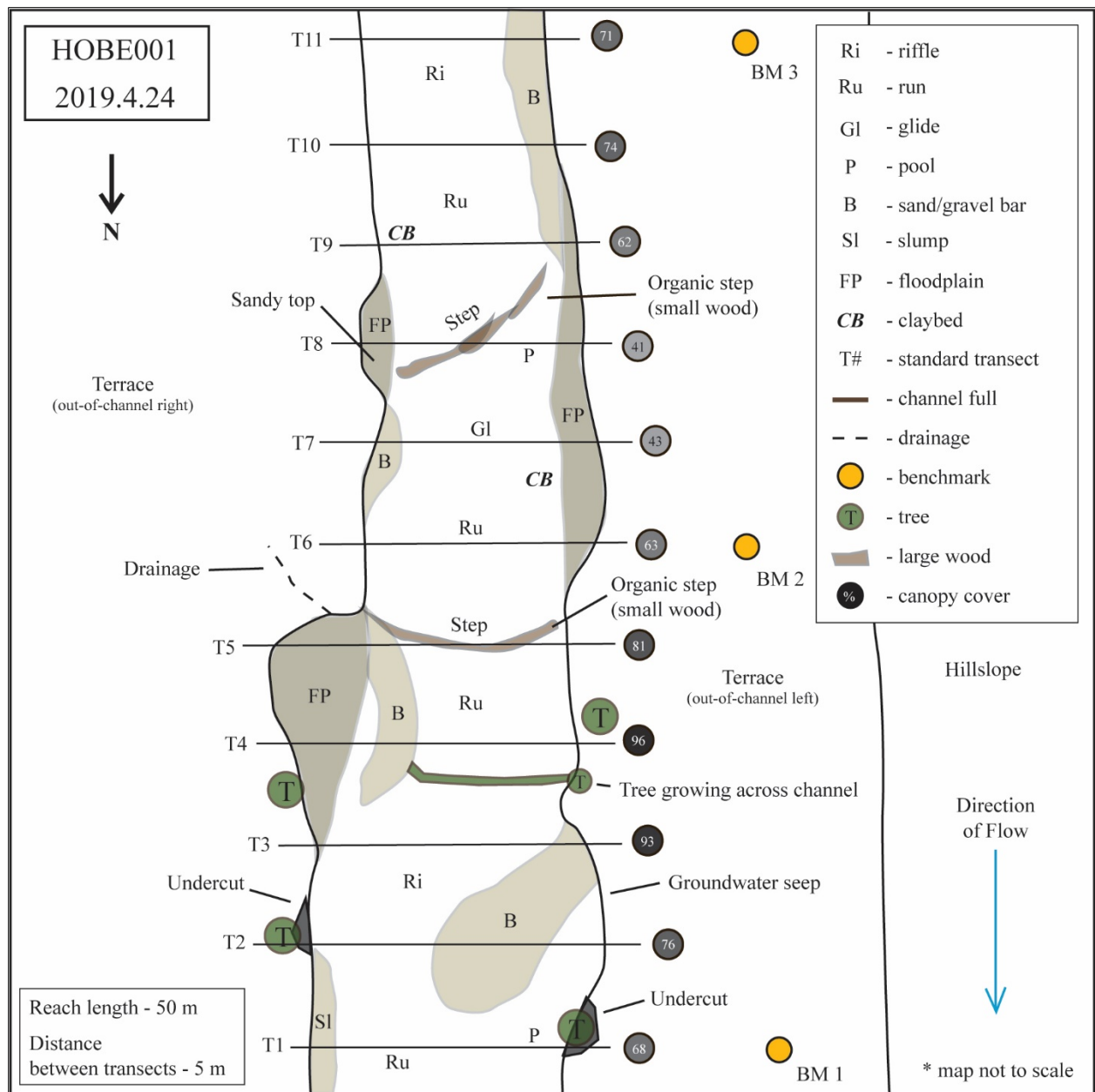


Figure 6. Reach-scale map of HOBE001. Important geomorphic surfaces and in-channel features are labeled to provide a context for the standard and detailed transect information provided in this report. The canopy cover circles are varying shades of grey which indicate the amount of canopy cover at each transect.

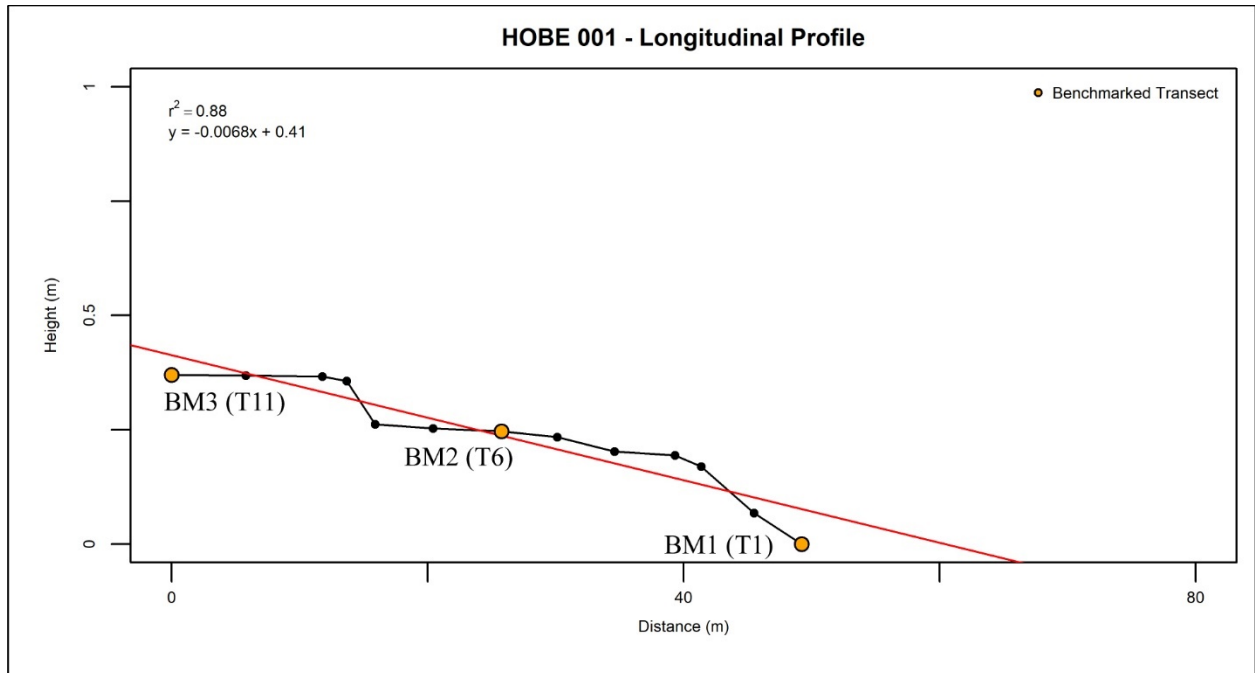


Figure 7. Longitudinal profile for HOBE001. The red line on the graph corresponds to the interpreted slope of the reach. The r^2 value describes the strength of the trend line. The 'T#' in parentheses indicates the standard transect number on which the detailed transects were surveyed. The graph is scaled to the longitudinal profile graphs from the second order CHAT streams (McDonald et al. 2019).

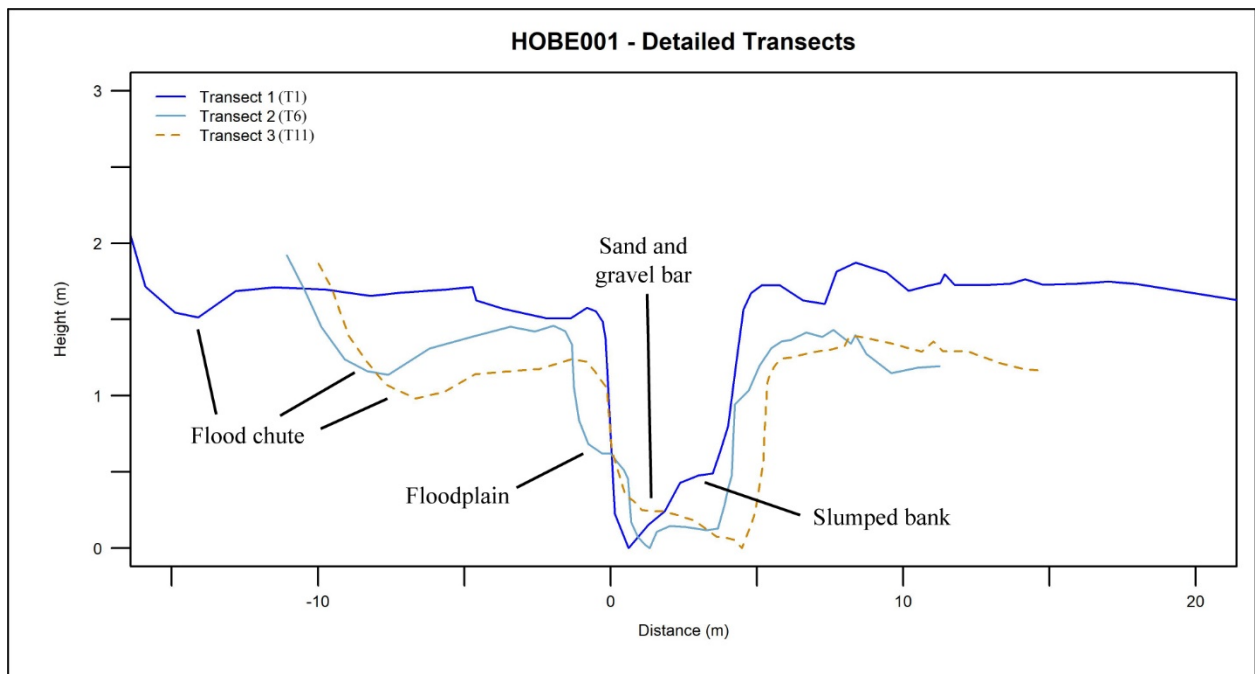


Figure 8. Comparison of the detailed transects at HOBE001. The location of the left channel-full points for each transect are normalized to allow for comparisons between transects. The 'T#' in parentheses indicates the standard transect number on which the detailed transects were surveyed.

Habitat Characteristics

The geomorphic channel units (GCUs) at HOBE001 consisted mostly of runs with a few areas covered by riffles, glides, and pools (Table 5). “Claybed Creek” had only one well-defined riffle within the surveyed reach (between T2 and T3; Figure 6). HOBE001’s GCUs frequency and distribution were unlike any of the selected stream reaches at Chattahoochee River NRA (Table 5). Bed sediment at “Claybed Creek” were mostly gravel-sized (Table 6). The smallest particle measured during the pebble count on HOBE001 was coarser than the smallest pebbles measured at all of the selected CHAT streams. On the other hand, the largest particle measured at HOBE001 (66 millimeters [2.6 in]) was (two to four times) finer than the maximum particle size measured on all of the other streams, except for CHAT014. The results of the post-hoc tukey test indicated that the mean size of bed sediment at HOBE001 (35.32 millimeters [1.39 in]) was statistically significantly finer than at CHAT004 (50.82 millimeters [2.00 in]) and statistically significantly coarser than at CHAT014 (13.87 millimeters [0.55 in]; Tables 6 and 7).

Five pieces of large woody debris (LWD) were measured at HOBE001 (Table 8). The volume of LWD per channel area at HOBE001 ($0.0010 \text{ m}^3/\text{m}^2$) was the lowest out of all of the compared reaches ($0.0011\text{--}0.0067 \text{ m}^3/\text{m}^2$). While the number of pieces of LWD within HOBE001 were low, there was a large number of smaller pieces of wood contributing to the creation of step habitat within the reach (Figure 6). Canopy cover at HOBE001 was the lowest on average (70% compared to 90–94%) and the most variable ($\text{CV} = 0.25$ compared to $0.03\text{--}0.06$; Table 9).

Average thalweg depth at HOBE001 (0.26 meters [0.85 ft]) was slightly shallower than the CHAT010 (0.28 meters [0.92 ft]) and deeper than the other streams ($0.16\text{--}0.25$ meters [0.52–0.82 ft]; Table 10). Though differences in mean thalweg depth were not statistically significant (Table 7). Thalweg position at HOBE001 was more variable ($\text{CV} = 0.63$) than the selected CHAT streams ($0.25\text{--}0.60$; Table 10). Similar to mean thalweg depth, differences in mean thalweg position between sites were not statistically significant (Table 7).

Table 5. Comparison of geomorphic channel units (GCUs) observed in the area between transects at HOBE001 compared to four selected reaches from Chattahoochee River NRA.

GCUs Type	Site	Frequency	Max (%)	Mean (%)	SD (%)
Riffle	HOBE001	3	30	6	11
	CHAT004	8	95	39	36
	CHAT008	7	100	41	39
	CHAT010	5	100	30	37
	CHAT014	3	40	8	15
Run	HOBE001	10	100	81	15
	CHAT004	6	80	27	31
	CHAT008	3	70	11	22
	CHAT010	4	100	20	36
	CHAT014	2	100	16	35
Glide	HOBE001	1	50	5	16
	CHAT004	0	0	0	0
	CHAT008	0	0	0	0
	CHAT010	0	0	0	0
	CHAT014	0	0	0	0
Pool	HOBE001	5	25	6	8
	CHAT004	8	100	35	37
	CHAT008	7	100	49	39
	CHAT010	7	100	50	44
	CHAT014	8	100	76	41
Step	HOBE001	2	20	3	6
	CHAT004	0	0	0	0
	CHAT008	0	0	0	0
	CHAT010	0	0	0	0
	CHAT014	0	0	0	0

Table 6. Particle size distributions of bed sediment (in mm) from the pebble count pebble surveys conducted at HOBE001 compared to four selected reaches from Chattahoochee River NRA. The subscripts indicate the percent of the sample that is smaller than the reported diameter.

Statistic (mm)	HOBE001 (n=100)	CHAT004 (n=100)	CHAT008 (n=100)	CHAT010 (n=100)	CHAT014 (n=100)
Min	8.00	0.06	2.00	2.00	2.00
D ₅	14.05	2.00	2.00	2.00	2.00
D ₁₆	22.00	5.00	9.00	6.84	6.00
D ₅₀	36.00	37.50	34.50	28.00	13.00
Mean	35.32	50.82	40.73	41.82	13.87
D ₈₄	49.00	93.12	76.64	73.00	20.00
D ₉₅	56.95	140.50	100.50	112.75	31.00
Max	66.00	250.00	130.00	190.00	47.00

Table 7. Significance of the differences in the pebble counts, thalweg depths, and thalweg positions of HOBE001 compared to the selected streams from CHAT, based on a post-hoc Tukey analysis. The significance of the differences are indicated by: “–”not significant; “*” p-value <0.05, “**” p-value <0.01, and “***” p-value <0.001. F-value and p-value of ANOVA results are reported as footnotes.

Pairs	n ¹	Pebble Count (mm) ²	P-value	Sig.	n ³	Thalweg Depth (m) ⁴	P-value	Sig.	Thalweg Position (%) ⁵	P-value	Sig.
HOBE001 - CHAT004	100	-15.50	0.006	**	11	0.10	–	–	9.09	–	–
HOBE001 - CHAT008	100	-5.41	0.755	–	11	0.07	–	–	-2.27	–	–
HOBE001 - CHAT010	100	-6.50	0.606	–	11	-0.02	–	–	-19.09	–	–
HOBE001 - CHAT014	100	21.42	< 0.001	***	11	0.02	–	–	-13.18	–	–

¹ Number of pebbles

² F(4,100) = 18.59, p < 0.001

³ Number of measurements taken for thalweg depth and position

⁴ F(4,11) = 1.34, p = 0.267

⁵ F(4,11) = 2.34, p = 0.06

Table 8. Comparison of the summary statistics for the large woody debris measured at HOBE001 compared to four selected reaches from Chattahoochee River NRA [m—meters].

Statistic	Site	n	Length (m)	Diameter (m)	Volume (m³)
Min	HOBE001	5	0.99	0.10	0.03
	CHAT004	10	2.00	0.10	0.02
	CHAT008	6	1.45	0.12	0.02
	CHAT010	12	1.80	0.10	0.01
	CHAT014	2	3.75	0.15	0.09
Mean	HOBE001	5	2.35	0.21	0.08
	CHAT004	10	3.57	0.23	0.30
	CHAT008	6	3.62	0.20	0.18
	CHAT010	12	3.00	0.16	0.07
	CHAT014	2	4.35	0.23	0.18
Max	HOBE001	5	4.00	0.33	0.20
	CHAT004	10	6.63	0.60	1.61
	CHAT008	6	5.53	0.43	0.74
	CHAT010	12	4.02	0.28	0.18
	CHAT014	2	4.95	0.30	0.27

Table 8 (continued). Comparison of the summary statistics for the large woody debris measured at HOBE001 compared to four selected reaches from Chattahoochee River NRA [m—meters].

Statistic	Site	n	Length (m)	Diameter (m)	Volume (m ³)
SD	HOBE001	5	1.20	0.09	0.07
	CHAT004	10	1.89	0.16	0.52
	CHAT008	6	1.83	0.12	0.28
	CHAT010	12	0.89	0.07	0.06
	CHAT014	2	0.85	0.11	0.13
Sum	HOBE001	5	—	—	0.41
	CHAT004	10	—	—	2.96
	CHAT008	6	—	—	1.06
	CHAT010	12	—	—	0.41
	CHAT014	2	—	—	0.35
Per Channel Area (m ³ /m ²)	HOBE001	—	—	—	0.0010
	CHAT004	—	—	—	0.0067
	CHAT008	—	—	—	0.0027
	CHAT010	—	—	—	0.0007
	CHAT014	—	—	—	0.0011

Table 9. Comparison of the variability in canopy cover at HOBE001 compared to four selected reaches from CHAT.

Site	n	Min (%)	Mean (%)	Max (%)	SD (%)	CV
HOBE001	11	41	70	96	17	0.25
CHAT004	11	88	94	99	4	0.04
CHAT008	11	90	93	96	2	0.03
CHAT010	11	79	90	97	6	0.06
CHAT014	11	88	94	99	4	0.04

Table 10. Comparison of reach-scale averaged thalweg conditions at HOBE001 compared to four selected reaches from CHAT.

Thalweg Characteristic	Site	n	Min	Mean	Max	SD	CV
Depth (meters)	HOBE001	11	0.10	0.26	0.48	0.12	0.45
	CHAT004	11	0.09	0.16	0.34	0.08	0.49
	CHAT008	11	0.06	0.19	0.64	0.18	0.94
	CHAT010	11	0.08	0.28	0.61	0.17	0.60
	CHAT014	11	0.03	0.25	0.48	0.16	0.64
Position ¹ (%)	HOBE001	11	10	48	95	30	0.63
	CHAT004	11	5	39	75	24	0.60
	CHAT008	11	10	50	90	24	0.47
	CHAT010	11	25	67	90	17	0.25
	CHAT014	11	25	61	95	24	0.39

¹position is percent distance from left bank

Channel Morphology

The mean wetted width of “Claybed Creek” (3.51 meters [11.52 ft]) was wider and less variable than that of the CHAT channels (2.57–3.30 meters [8.43–10.83 ft]; Table 11). While HOBE001 had a wider mean wetted width than the four CHAT streams, these differences were not statistically significant (Table 12). Mean active channel width at HOBE001 (4.23 meters [13.88 ft]) was also wider than the CHAT reaches (3.46–4.21 meters [11.35–13.81 ft]; Table 11). Though again, these differences in mean active channel width were not statistically significant (Table 12). Variability in active channel widths (CV) at HOBE001 (0.25) was similar to the other reaches (0.23–0.32; Table 11). Mean bankfull width at HOBE001 (5.23 meters [17.12 ft]) was second to CHAT010 (5.4 meters [17.7 ft]; Table 11). Differences in mean bankfull width were not statistically compared because of the inconsistent number of bankfull widths available to measure within each reach. Mean channel-full width at HOBE001 (8.08 meters [26.51 ft]) was again second to CHAT010 (8.77 meters [28.77 ft]; Table 11). Additionally, the differences in mean channel-full between sites was not statistically significant (Table 12). Variability in channel-full width at HOBE001 (0.33) was higher than the CHAT reaches (0.22–0.26; Table 11).

“Claybed Creek’s” mean minimum bank height (1.15 meters [3.77 ft]) was less than the mean minimum bank heights for all of the reaches (1.21–1.67 meters [3.97–5.48 ft]) except for CHAT014 (1.06 meters [3.48 ft]; Table 13). Minimum bank heights were moderately variable at HOBE001. “Claybed Creek” had the highest mean bankfull height (0.74 meters [2.43 ft]) of the reaches compared in this report (0.54–0.69 meters [1.77–2.26 ft]; Table 13). Additionally, the height of the bankfull surface at HOBE001 was the second most variable. Mean channel-full bank height at HOBE001 (1.38 meters [4.53]) was statistically significantly less than CHAT004 (1.67 meters [5.48

ft]; Tables 13 and 14). Channel-full bank heights at HOBE001 were less variable ($CV = 0.13$) than the four CHAT reaches (0.20–0.28; Table 13).

Nine undercuts were observed and measured at HOBE001 which is similar to the number of undercuts observed on the CHAT reaches ($n = 7$ –13; Table 14). The mean depth of the undercuts at HOBE001 (0.29 meters [0.95 ft]) was greater than the other sites included in this report (0.15–0.27 meters [0.49–0.89 ft]). Bank angles at HOBE001 ranged from 11.1° to 81.6° (Table 14). Mean bank angle at HOBE001 was less than all other sites but these differences were not statistically significant (Table 15). Mean bank vegetation cover for HOBE001's banks (62.27%) were statistically significantly greater than all four of the CHAT streams (29.32–39.77%; Table 14). "Claybed Creek" had the lowest mean bank stability score (11.68; "unstable"). The minimum ("best") bank stability score at HOBE001 (9.5) was classified as "at-risk." None of the HOBE001 banks scored higher than 14.5 ("unstable"). Variability in bank stability scores at HOBE001 (0.11) was less than the CHAT reaches (0.12–0.19; Table 14). See Methods section for how to interpret bank stability scores.

Mean bankfull area of the detailed cross-sections at HOBE001 (2.03 square meters [21.85 sq ft]) was second to CHAT010 (2.04 square meters [21.96 sq ft]; Table 2). Bankfull heights on the detailed transects at HOBE001 were higher than on the selected CHAT streams (0.34–0.59 meters [1.12–1.94 ft]; Table 2). Bankfull widths on the detailed transects were moderately wide at HOBE (4.45 meters [14.60 ft]) compared to CHAT (3.92–5.09 meters [12.86–16.70 ft]; Table 2). Channel-full area at HOBE001 (5.58 square meters [60.06 sq ft]) was slightly larger than the mean of the CHAT reaches (5.4 square meters [58.13 sq ft]; Table 2).

Table 11. Comparison of reach-scale averaged width characteristics of HOBE001 compared to four selected reaches from CHAT [m—meters].

Widths	Site	n	Min (m)	Mean (m)	Max (m)	SD (m)	CV
Wetted	HOBE001	11	2.42	3.51	5.13	0.89	0.25
	CHAT004	11	2.03	3.16	4.13	0.65	0.21
	CHAT008	11	1.56	2.57	3.63	0.69	0.27
	CHAT010	11	1.46	3.30	4.70	0.90	0.27
	CHAT014	11	1.10	2.66	4.61	1.19	0.45
Active Channel	HOBE001	11	3.00	4.23	6.02	1.04	0.25
	CHAT004	11	2.03	3.93	7.13	1.26	0.32
	CHAT008	11	3.21	4.21	6.74	1.06	0.25
	CHAT010	11	2.50	4.13	5.46	0.96	0.23
	CHAT014	11	2.63	3.46	5.51	0.93	0.27
Bankfull	HOBE001	6	3.98	5.23	6.00	0.70	0.13
	CHAT004	0	—	—	—	—	—
	CHAT008	6	3.37	4.95	6.38	1.04	0.21
	CHAT010	5	3.41	5.40	8.35	1.97	0.36
	CHAT014	3	3.84	4.18	4.45	0.31	0.07
Channel-Full	HOBE001	11	5.04	8.08	13.70	2.66	0.33
	CHAT004	11	4.65	6.35	9.11	1.66	0.26
	CHAT008	11	5.79	7.96	10.96	1.74	0.22
	CHAT010	11	4.52	8.77	11.78	2.20	0.25
	CHAT014	11	4.75	6.37	8.50	1.39	0.22

Table 12. Significance of the differences in diagnostic channel widths at HOBE001 versus the selected reaches at CHAT, based on a post-hoc Tukey analysis. The significance of the differences are indicated by: “–”not significant; “**” p-value <0.05, “***” p-value <0.01, and “****” p-value <0.001. F-value and p-value of ANOVA results are reported as footnotes.

Pairs	n ¹	Wetted Width (m) ²	P-value	Sig	n ³	Active Channel Width (m) ⁴	P-value	Sig	Channel-full Width (m) ⁵	P-value	Sig
HOBE001 - CHAT004	11	0.35	–	–	11	0.30	–	–	1.73	0.26	–
HOBE001 - CHAT008	11	0.94	–	–	11	0.01	–	–	0.12	1.00	–
HOBE001 - CHAT010	11	0.21	–	–	11	0.10	–	–	-0.69	0.92	–
HOBE001 - CHAT014	11	0.85	–	–	11	0.77	–	–	1.71	0.27	–

¹ Number of measurements for wetted width

² F(4,11) = 2.34, p = 0.07

³ Number of measurements for active and full-channel width

⁴ F(4,11) = 1.01, p = 0.41

⁵ F(4,11) = 3.34, p = 0.02

Table 13. Comparison of average reach-scale bank heights at HOBE001 compared to four selected reaches from Chattahoochee River NRA [m—meters].

Bank Heights	Site	n	Min (m)	Mean (m)	Max (m)	SD (m)	CV
Minimum Bank Height ^{1,2} (m)	HOBE001	22	0.45	1.15	1.64	0.35	0.30
	CHAT004	22	0.84	1.67	2.23	0.45	0.27
	CHAT008	22	0.38	1.21	1.95	0.47	0.39
	CHAT010	22	0.52	1.31	1.94	0.40	0.31
	CHAT014	22	0.43	1.06	1.47	0.29	0.28
Bankfull Height ^{1,3} (m)	HOBE001	7	0.45	0.74	1.17	0.26	0.36
	CHAT004	0	—	—	—	—	—
	CHAT008	6	0.38	0.64	1.03	0.27	0.43
	CHAT010	5	0.52	0.69	0.99	0.18	0.26
	CHAT014	3	0.43	0.54	0.65	0.11	0.21
Channel-full Height ¹ (m)	HOBE001	22	1.06	1.38	1.78	0.18	0.13
	CHAT004	22	0.84	1.67	2.23	0.45	0.27
	CHAT008	22	0.66	1.36	1.95	0.38	0.28
	CHAT010	22	0.80	1.45	1.94	0.29	0.20
	CHAT014	22	0.61	1.13	1.47	0.23	0.20

¹ above thalweg

² this height refers to the lowest bank height on either side (bankfull or channel-full)

³ statistics are based on the transects where feature is present (# in parentheses)

Table 14. Comparison of average reach-scale bank characteristics at HOBE001 compared to four selected reaches from Chattahoochee River NRA.

Bank Characteristics	Site	n	Min (m)	Mean (m)	Max (m)	SD (m)	CV
Bank Undercut ¹ (meters)	HOBE001	9	0.06	0.29	0.66	0.18	0.61
	CHAT004	13	0.11	0.20	0.41	0.09	0.44
	CHAT008	8	0.07	0.24	0.58	0.19	0.78
	CHAT010	7	0.07	0.27	0.52	0.16	0.59
	CHAT014	9	0.05	0.15	0.27	0.08	0.52
Bank Angle (°)	HOBE001	22	11.10	48.41	81.60	19.47	0.40
	CHAT004	22	33.90	67.29	92.40	15.19	0.23
	CHAT008	22	10.60	55.77	90.00	27.64	0.50
	CHAT010	22	8.80	49.92	89.90	31.33	0.63
	CHAT014	22	9.40	59.19	90.90	28.63	0.48
Vegetation Cover (%)	HOBE001	22	30.00	62.27	90.00	20.69	0.33
	CHAT004	22	0.00	39.77	95.00	26.34	0.66
	CHAT008	22	5.00	37.05	80.00	23.89	0.64
	CHAT010	22	5.00	29.55	70.00	20.81	0.70
	CHAT014	22	0.00	29.32	70.00	22.64	0.77
Bank Stability ²	HOBE001	22	9.50	11.68	14.50	1.33	0.11
	CHAT004	22	10.50	13.23	17.00	1.65	0.12
	CHAT008	22	9.00	13.43	16.00	1.61	0.12
	CHAT010	22	8.00	12.36	15.00	2.38	0.19
	CHAT014	22	9.00	13.77	16.00	1.78	0.13

¹ statistics are based on the transects where feature is present (# in parentheses)

² bank stability score rankings: 4–7 stable; 8–10 at-risk; 11–15 unstable; and 16–22 very unstable

Table 15. Significance of the differences of the channel-full heights, bank angles, and vegetative cover at HOBE001 compared to the selected streams at CHAT, based on a post-hoc Tukey analysis. The significance of the differences are indicated by: “–”not significant; “*” p-value <0.05, “**” p-value <0.01, and “***” p-value <0.001. F-value and p-value of ANOVA results are reported as footnotes.

Pairs	n ¹	Channel-full Height (m) ²	P-value	Sig.	Bank Angle (°) ³	P-value	Sig.	Vegetative Cover (%) ⁴	P-value	Sig.
HOBE001 - CHAT004	22	-0.283	0.034	*	-18.88	–	–	22.50	0.013	*
HOBE001 - CHAT008	22	0.018	0.999	–	-7.36	–	–	25.23	0.004	**
HOBE001 - CHAT010	22	-0.066	0.961	–	-1.51	–	–	32.73	< 0.001	***
HOBE001 - CHAT014	22	0.249	0.086	–	-10.78	–	–	32.95	< 0.001	***

¹ Number of measurements for channel-full- height, bank angle and vegetative cover

² F(4,22) = 7.66, p < 0.001

³ F(4,22) = 2.01, p = 0.098

⁴ F(4,22) = 7.58, p < 0.001

Implications and Synthesis of Results

This section describes the processes that were observed at HOBE001 and the potential changes that may occur between surveys (next round of surveys to be completed during spring and summer 2022). The processes that are described will be explained within the context of the objectives of the protocol (i.e., basin characteristics that affect channel morphology and habitat, and the status of channel morphology and habitat characteristics).

HOBE001—“Claybed Creek”

HOBE001’s watershed is relatively large for a second-order stream (3.46 square kilometers [1.34 sq mi], Table 3) and is mostly covered by forested areas (68%), grassland/pasture (16%), and shrubland (11%; Table 4). Approximately 4% of “Claybed Creek’s” watershed is developed and there was no area covered by medium- and/or high-intensity development. Though HOBE001’s watershed has a low percentage of developed land cover (and associated impervious surfaces), the high percentage of the watershed covered by pastured and shrub lands along the stream network may contribute to flashier stormflows than expected based on the high forest cover (Price et al. 2011). HOBE001’s watershed has a high entire stream gradient (0.0311 m/m), a low segment gradient (0.0075 m/m), and a low reach gradient (0.0068 m/m, Tables 2 and 3). HOBE001’s watershed has an intermediate average slope (8.0°), moderately low drainage density (1.33 km/km²), a high basin shape (0.36; more circular watershed), and a moderately high basin relief ratio (0.028; Table 3). Based on the basin/watershed characteristics (i.e., entire stream gradient, watershed slope, basin shape, basin relief ratio, and land use/land cover), the stream likely has a moderately flashy flow regime. The low segment and channel slopes may attenuate the energy available to erode the reach during periods of flooding, but the combination of the rest of the characteristics indicates that the basin is likely influenced by moderately flashy flow. Note that the flow regime at Horseshoe Bend NMP is much less flashy than CHAT streams because of the large differences in land use/land cover and associated impervious surfaces (Table 2). Gage data are needed to confirm these interpretations.

Due to its location on the south side of the Tallapoosa River, visitors are not expected to interact with “Claybed Creek” (HOBE001). In-stream habitat was predominately run habitat with some riffle, pool, and glide habitat mixed in (Table 5). Two organic steps were also observed within the reach (Figure 6). While the mean bed sediment at HOBE001 is not very coarse, the lack of fine and very fine sediment (high D₅ and D₁₆) within the representative riffle (where the pebble count was conducted) indicates that the stream is not being affected by erosion of fine sediments upstream (potentially a result of upstream cyclical forestry). The differences in the upper portions of the particle size distributions between the HOBE and CHAT streams is likely due to differences in geology and the availability of coarse material. A more in-depth study of the stream network and geology upstream of HOBE001 is needed to determine whether there are coarser particles available that are not making it down to this reach.

HOBE001 had the lowest volume of LWD per channel area (0.0010 m³/m²) of all of the stream reaches compared in this report (Table 8). The lack of LWD in “Claybed Creek” is related to the low mean canopy cover (70%) that was observed within the reach (Table 9). The majority of the

vegetation surrounding the stream channel is privet with some areas covered in briar thickets. There are relatively few large trees overhanging the stream (at-the-site, as well as up- and downstream). Combined with the high probability that the stream has a flashy flow regime, the lack of trees available to provide LWD likely contributes to the low volume of LWD observed within the reach. Though the reach lacks fine sediments that are often detrimental to benthic macroinvertebrate habitats, the lack of LWD is a negative benthic macroinvertebrate habitat attribute. This lack of LWD may put the stream at greater risk of habitat degradation for benthic dwelling invertebrates (Allan and Castillo 2007). Additionally, this reach lacked habitat heterogeneity (81% run) thought to promote biodiversity (Allan and Castillo 2007; Palmer et al. 2010). Even though the reach lacked very fine sediment, based on the lower-energy GCUs and the lack of LWD, HOBE001's in-stream habitat was classified as "poor to fair." This classification is a generalized interpretation of in-stream habitat and additional work is needed to determine how flow (e.g., flashiness of flow and baseflow conditions), water quality, and in-stream physical characteristics affect biodiversity and stream health at Horseshoe Bend NMP. Habitat within the reach may degrade to a "poor" rating if fine and/or very fine sediment is added to the reach (potentially from a disturbance upstream). Alternatively, if LWD can become established within the reach, this additional habitat complexity could make the reach more habitable which would result in a "fair" classification of the habitat (Allan and Castillo 2007).

The major defining characteristics of the stream were claybeds in the bed of the stream, the presence of the ground water seep, and the floodplain surfaces that have developed. Claybeds were observed along river left near T6 and T7 and on river right near T9 (Figure 6). These claybeds were not interpreted as contemporary depositional features. Instead, these claybeds are being exposed as the channel bed cuts down through the historic sediment overburden. The age of these claybeds is unknown but one possibility is that these clay-rich features are the original B-horizon of the presettlement landscape. Determining the extent of these claybeds (through stratigraphic analysis) would help to understand the long-term future development of the stream as these features are much less resistant to erosion/downcutting. Related to the claybeds is the ground water seep identified between T2 and T3. One of the survey crew (C. S. Cooper, personal communication) observed that this seep is flowing along the contact between the historical overburden (relatively sandy sediment) and a claybed that had similar characteristics to the claybeds observed upstream. This observation makes sense and is due to the low infiltration rate of the clayey sediment compared to the relatively sandy overburden. In addition to the stratigraphic analysis, a piezometric analysis of the higher terrace surface would help provide an understanding of groundwater flow and help elucidate the extent and topography of the claybeds.

The arcuate shape of the floodplain surfaces on river right (between T3 and T5 and on T8) suggest that these surfaces were not constructed through lateral migration and deposition on the inside of a meander bend, rather, they are the result of stabilization of large rotational slump blocks. The floodplain on river left between T6 and T9 is also interpreted as a stabilized slump. The elevation of this surface (relative to the thalweg) of this surface grades up upstream. This difference in elevation is interpreted as the slow upstream migration of the slump. Similar longitudinally extensive but laterally restricted surfaces were also observed along the streams at Chattahoochee River NRA (McDonald et al. 2019) as well as along the streams at Kennesaw Mountain NBP (McDonald and

Starkey 2019b). The bar surface between T9 and T11 could be an extension of this slump that has been eroded down to its current elevation. A similar process is occurring downstream between T1 and T2, on river right. In this area of the stream, a portion of the channel bank has slumped into the channel. If this slump block becomes stabilized, it could begin to resemble the T6 to T9 floodplain on river left. Alternatively, this slump block could slowly be eroded away and end up resembling the T9 to T11 bar surface.

Conclusion

HOBE001's watershed ("Claybed Creek") has high basin shape and moderate slope/relief and is covered by forest, pasture, and shrubland. The major defining characteristics of the stream were the presence of claybeds in the bed of the stream, a groundwater seep along one side of the stream, and floodplains along both sides of the stream. The stream appears to be developing as expected based on the stream channel evolution model presented at the beginning of this report (Figure 1). Based on the different geomorphic surfaces observed within and immediately surrounding the reach, the stream appears to be in channel evolution model stage III. The floodplain surfaces are interpreted as evidence that the stream is widening through progressive slumping of the stream banks. The presence of the claybeds within the reach could potentially disrupt this progression along the channel evolution continuum due to its high rate of erodability. Should a knickpoint (large change in slope) migrate upstream into the reach, these exposed claybeds would not provide sufficient protection of the channel bed. This knickpoint could migrate upstream relatively quickly and set the stream back in its evolutionary stage. It is suggested that a longitudinal profile of the entire length of stream within the park be completed to determine whether a knickpoint exists that may influence this reach.

With regards to habitat, the distinguishing features of the stream were the homogeneity of in-stream habitat (predominately run) and the lack of LWD within the reach. While the reach lacked fine and very fine sediment in its representative riffle (where the pebble count was conducted), the lack of cobble sized particles within the reach increases the potential for increased bed mobility if a large flood event affects the reach. Due to the lack of coarser sediment, the homogeneity of habitat, and the lack of LWD, habitat within the reach was classified as "poor to fair." These classifications are generalized interpretations of in-stream habitat and additional work is needed to determine how flow (e.g., flashiness of flow and baseflow conditions), water quality, and in-stream physical characteristics affect biodiversity and stream health at Horseshoe Bend NMP. Habitat within the reach may degrade to a "poor" rating if fine and/or very fine sediment is added to the reach (potentially from a disturbance upstream). Alternatively, if LWD can become established within the reach, this additional habitat complexity could make the reach more habitable which would result in a 'fair' classification of the habitat (Allan and Castillo 2007). The stream does not have immediate management concerns, although there is extensive privet growth in the area outside of the channel.

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Appendix A. Explanation of Variables

Table A-1 contains the descriptions of each variable.

Table A-1. Variables and their descriptions.

Variable	Variable Scale	Description
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).
Total Stream Length	Basin	The sum of the length of perennial streams within a watershed.
Drainage Density	Basin	The ratio of total stream length to drainage area.
Basin Length	Basin	The length of the line that bisects a watershed running from outlet to drainage divide.
Basin Shape	Basin	Drainage area divided by basin length squared (Horton 1932)
Average Watershed Slope	Basin	Within watershed, average of the slope values of each pixel of a digital elevation model.
Standard Deviation of Slope	Basin	Within watershed, standard deviation of the slope values of each pixel of a digital elevation model.
Basin Relief	Basin	Within watershed, maximum elevation minus minimum elevation
Standard Deviation of Elevation	Basin	The standard deviation of elevation within a watershed.
Basin Relief Ratio	Basin	A ratio calculated by dividing basin relief by basin length.
Entire Stream Gradient	Basin	The difference in elevation at 85% and 10% of the main stem stream length divided by the stream length between the two points (Fitzpatrick et al. 1998).
Segment Gradient	Basin	The difference in elevation between the upstream extent of the stream segment and the downstream extent of the stream segment, divided by the length of the stream segment.
Strahler Stream Order	Basin	A stream ordering system where order increases when two orders of the same magnitude join.
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).
Land Use/Land Cover	Basin	Land use/land cover is derived from the NLCD dataset.
Geomorphic Channel Units	Reach	Geomorphic channel units are a way to classify in-channel habitat (e.g., riffles and pools)

^a collected at each standard transect (11 measurements)

^b calculated at each detailed transect (three per reach) using survey data collected using a total station

Table A-1 (continued). Variables and their descriptions.

Variable	Variable Scale	Description
Large Woody Debris	Reach	Pieces of woody material that have a diameter greater than 0.1 meters (0.3 ft) and are 1 meter (3.3 ft) or longer.
Pebble Count	Reach	The size and distribution of 100 particles (pebble count) from a representative riffle (Wolman 1954).
Canopy Closure	Reach ^a	The average of four measurements (looking upstream, downstream, and at each bank) taken using a spherical densiometer.
Reach Sinuosity	Reach	Sinuosity is calculated by dividing reach length by valley length.
Longitudinal Profile	Reach	The gradient of the line that connects the tops of the steps and riffles within a reach (channel slope)
Wetted Width	Transect ^a	Wetted channel width is measured where water is flowing (including undercuts)
Active Channel Width	Transect ^a	Active channel width is measured to the beginning of vegetation within the stream channel
Bankfull Width	Transect ^{a,b}	Bankfull widths should only be measured if there is a floodplain (or incipient floodplain) present
Bankfull Height	Transect ^{a,b}	The height of the channel bank where a floodplain is present
Bankfull Area	Transect ^b	The cross-sectional area of a stream channel at bankfull stage (height) measured perpendicular to flow
Bankfull Perimeter	Transect ^b	The length of the contact between the stream of flowing water and its containing channel, measured at a section perpendicular to streamflow at bankfull discharge
Bankfull Hydraulic Radius	Transect ^b	A measure of hydraulic efficiency defined by the ratio between bankfull area and bankfull perimeter
Channel-full Width	Transect ^{a,b}	Channel full widths are measured from the top of the lowest bank that is not a floodplain.
Channel-full Height	Transect ^{a,b}	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)
Channel-full Area	Transect ^b	The cross-sectional area of a stream channel at bankfull stage measured perpendicular to flow
Channel-full Perimeter	Transect ^b	The length of the contact between the stream of flowing water and its containing channel, measured at a section perpendicular to streamflow at channel full discharge
Channel-full Hydraulic Radius	Transect ^b	A measure of hydraulic efficiency defined by the ratio between channel full area and channel full perimeter

^a collected at each standard transect (11 measurements)

^b calculated at each detailed transect (three per reach) using survey data collected using a total station

Table A-1 (continued). Variables and their descriptions.

Variable	Variable Scale	Description
Thalweg Position	Transect ^a	The position of the thalweg as a percent distance of the wetted width from left water's edge
Thalweg Depth	Transect ^a	The greatest depth of water along a transect
Dominant Particle Size	Transect ^a	A visual estimate of the dominant sediment size along a transect
Dominant Habitat	Transect ^a	A visual estimate of the dominant geomorphic channel unit along a transect
In-channel features	Transect ^a	A description of the in-channel features (e.g., bars or islands) that are present along a transect
Floodplain width	Transect ^a	The width(s) of floodplain(s) present along rivers left and/or right
Bank Undercut	Transect ^a	Where the bank overhangs the channel due to lateral erosion at the base of the bank
Bank Angle	Transect ^a	The dominant bank angle from active channel boundary to the top of the bank
Bank Sediment	Transect ^a	The dominant sediment composition of the channel banks
Bank Erosion	Transect ^a	The presence of and type erosion (e.g., lateral or slump) that is observed on the channel banks
Bank Cover	Transect ^a	A visual estimate of the percent of the channel banks that has vegetative cover

^a collected at each standard transect (11 measurements)

^b calculated at each detailed transect (three per reach) using survey data collected using a total station

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Appendix B. Survey Results for HOBE001

Figures B-1 through B-16 and Tables B-1 through B-8 show survey sites and results.

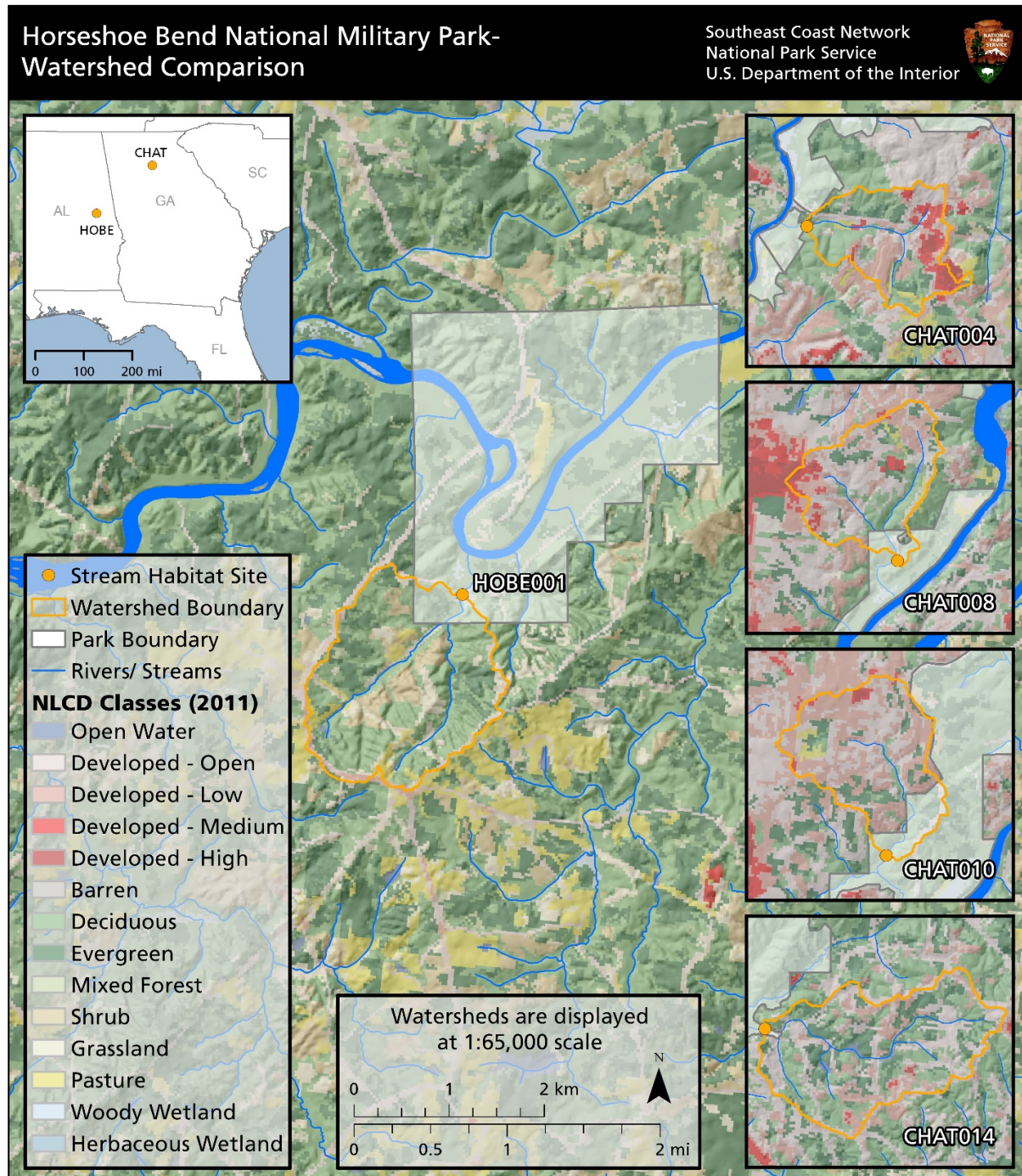


Figure B-1. Map display of watershed size for HOBE001 versus CHAT004, -008, -010, and -014 watersheds. The land use/land cover (NLCD 2011, Homer et al. 2015) and perennial streams (derived from a 10-meter (32.8-ft) digital elevation model; data available from the U.S. Geological Survey) in the vicinity of the park are also shown.



Figure B-2. Photograph taken on HOBE001 looking upstream from T1 (detailed transect 1).



Figure B-3. Photograph taken on HOBE001 looking downstream from T1 (detailed transect 1).



Figure B-4. Photograph taken on HOBE001 facing the left bank on T1 (detailed transect 1).



Figure B-5. Photograph taken on HOBE001 facing the right bank on T1 (detailed transect 1).



Figure B-6. Photograph taken on HOBE001 looking upstream from T6 (detailed transect 2).



Figure B-7. Photograph taken on HOBE001 looking downstream from T6 (detailed transect 2).



Figure B-8. Photograph taken on HOBE001 facing the left bank on T6 (detailed transect 2).



Figure B-9. Photograph taken on HOBE001 facing the right bank on T6 (detailed transect 2).



Figure B-10. Photograph taken on HOBE001 looking upstream from T11 (detailed transect 3).



Figure B-11. Photograph taken on HOBE001 looking downstream from T11 (detailed transect 3).



Figure B-12. Photograph taken on HOBE001 facing the left bank on T11 (detailed transect 3).



Figure B-13. Photograph taken on HOBE001 facing the right bank on T11 (detailed transect 3).

Table B-1. Land use/land cover characteristics for 2001, 2006, and 2011 for HOBE001. The data included in this table are from the National Land Cover Dataset (Homer et al. 2001, Fry et al. 2006; Homer et al. 2015).

NLCD Class	2001 percent of watershed	2006 percent of watershed	2011 percent of watershed
Open Water	0	0	0
Developed - Open ¹	3	3	3
Developed - Low ¹	1	1	1
Developed - Medium ¹	0	0	0
Developed - High ¹	0	0	0
Barren	0	0	0
Deciduous	61	60	53
Evergreen	16	16	15
Mixed Forest	1	1	0
Shrub	1	3	11
Grassland	11	11	11
Pasture	5	5	5
Cultivated	0	0	0
Woody Wetland	0	0	0
Herbaceous Wetland	0	0	0

¹ refers to the intensity or type of development

Table B-2. Geomorphic channel units (GCUs) observed in the area between transects at HOBE001. The data describe the percent coverage of each type of GCU.

Transect	(%) Riffle	(%) Run	(%) Glide	(%) Pool	(%) Step
1–2	0	75	0	25	0
2–3	30	70	0	0	0
3–4	0	100	0	0	0
4–5	0	90	0	5	5
5–6	0	90	0	10	0
6–7	0	90	0	10	0
7–8	0	50	50	0	0
8–9	0	70	0	10	20
9–10	20	80	0	0	0
10–11	10	90	0	0	0
Frequency	3	10	1	5	2
Max (%)	30	100	50	25	20
Mean (%)	6	81	5	6	3
Median (%)	0	85	0	3	0
SD (%)	11	15	16	8	6

Table B-3. Characteristics of the large woody debris observed at HOBE001 [m—meters].

LWD ID	Length (m)	Diameter (m)	Volume (m3)	Transect Interval	Function	Position
1	2.35	0.33	0.20	9	Bank Protection	Buried
2	0.99	0.26	0.05	6	None	Free
3	2.95	0.20	0.09	2	Bank Protection	Ramp
4	1.45	0.16	0.03	2	Organic Trap	Buried
5	4.00	0.10	0.03	1	None	Free

Table B-4. Variability of canopy cover observed at HOBE001.

Transect	Canopy Cover (%)
1	68
2	76
3	93
4	96
5	81
6	63
7	43
8	41
9	62
10	74
11	71
Min (%)	41
Max (%)	96
Mean (%)	70
Median (%)	71
SD (%)	17
CV	0.25

Table B-5. Average reach-scale bank characteristics at HOBE001. 'L' indicates left bank, 'R' indicates right bank, 'SD' is standard deviation, and 'CV' is coefficient of variation [m—meters].

Bank Characteristics	n (L)	n (R)	Min (L)	Min (R)	Max (L)	Max (R)	Mean (L)	Mean (R)	Median (L)	Median (R)	SD (L)	SD (R)	CV (L)	CV (R)
Bank Height ¹ (m)	11	11	0.58	0.45	1.54	1.64	1.15	1.14	1.14	1.31	0.29	0.41	0.25	0.36
Bankfull Height ^{1,2} (m)	3	4	0.58	0.45	1.17	1.01	0.83	0.67	0.75	0.60	0.30	0.25	0.36	0.37
Channel-full Height ^{1,2} (m)	11	11	1.06	1.27	1.71	1.78	1.33	1.43	1.36	1.38	0.20	0.16	0.15	0.11
Water Depth at Base ³ (m)	11	11	-0.19	-0.25	0.00	-0.04	-0.09	-0.09	-0.08	-0.07	0.06	0.06	—	—
Bank Undercut ² (m)	6	3	0.06	0.09	0.66	0.30	0.35	0.18	0.34	0.16	0.19	0.11	0.55	0.58
Bank Angle (°)	11	11	12	11	82	70	51	46	53	56	17	22	0.33	0.48
Vegetation Cover (%)	11	11	30	30	90	90	65	59	65	60	22	20	0.34	0.34
Bank Stability ⁴	11	11	At-Risk	At-Risk	Unstable	Unstable	Unstable	Unstable	Unstable	Unstable	1.38	1.51	0.12	0.13

¹ above thalweg

² statistics are based on the transects where feature is present (# in parentheses)

³ a negative number indicates base of bank is above the water surface

⁴ See Table A-1 for explanation of scores

Table B-6. Cross-sectional characteristics for detailed transect 1 at HOBE001 [m—meters].

Type	Area (m ²)	Perimeter (m)	Hydraulic Radius (m)	Width (m)	Depth (m)	Width/Depth
Bankfull	1.65	4.48	0.37	3.91	0.74	5.31
Channel-full	5.34	6.92	0.77	5.38	1.58	3.41
Ratio	3.24	1.54	2.10	1.38	2.14	0.64

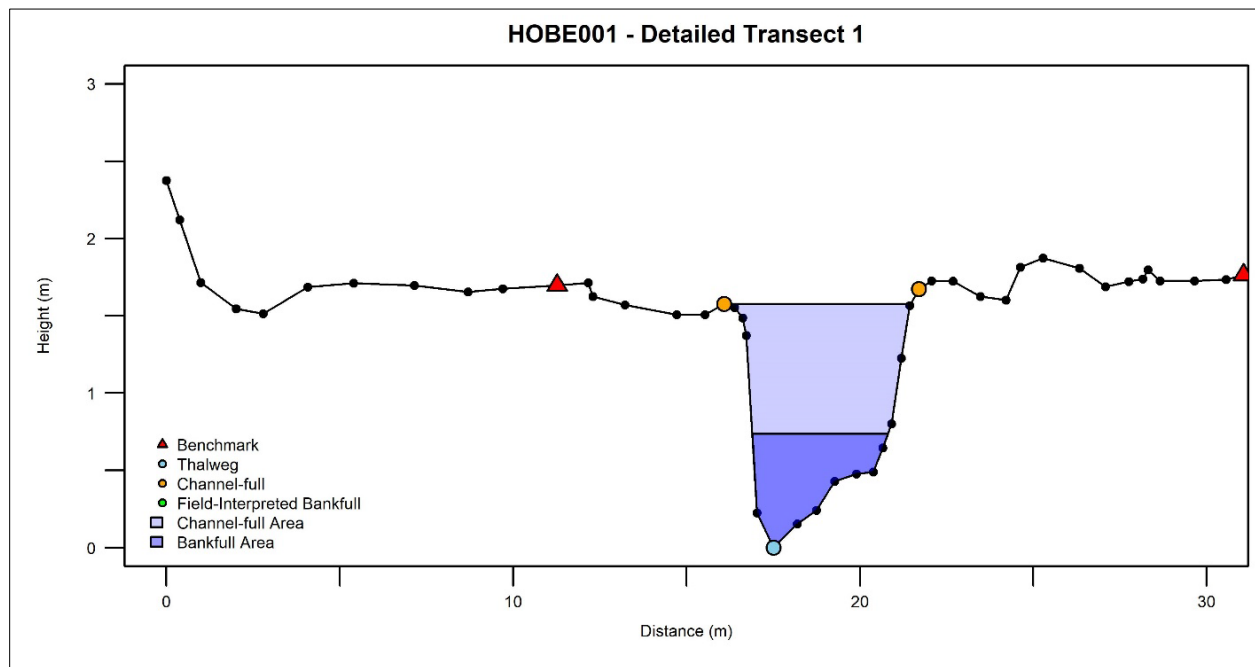


Figure B-14. Detailed transect 1 at HOBE001. The surveyed locations of the left and right benchmarks, channel-full bank-tops, and interpreted bankfull bank height are shown on the figure. Additionally, the channel-full (light blue) and bankfull (dark blue) cross-sectional areas are also included (channel-full cross-sectional area equals light blue plus dark blue). If no bankfull surfaces were present at the cross-section, bankfull area was interpolated by determining hydraulic radius when the water surface is at the reach averaged bankfull height above thalweg.

Table B-7. Cross-sectional characteristics for detailed transect 2 at HOBE001 [m—meters].

Type	Area (m ²)	Perimeter (m)	Hydraulic Radius (m)	Width (m)	Depth (m)	Width/Depth
Bankfull	1.75	4.67	0.37	4.17	0.62	6.71
Channel-full	5.98	8.41	0.71	7.22	1.36	5.33
Ratio	3.43	1.80	1.90	1.73	2.18	0.79

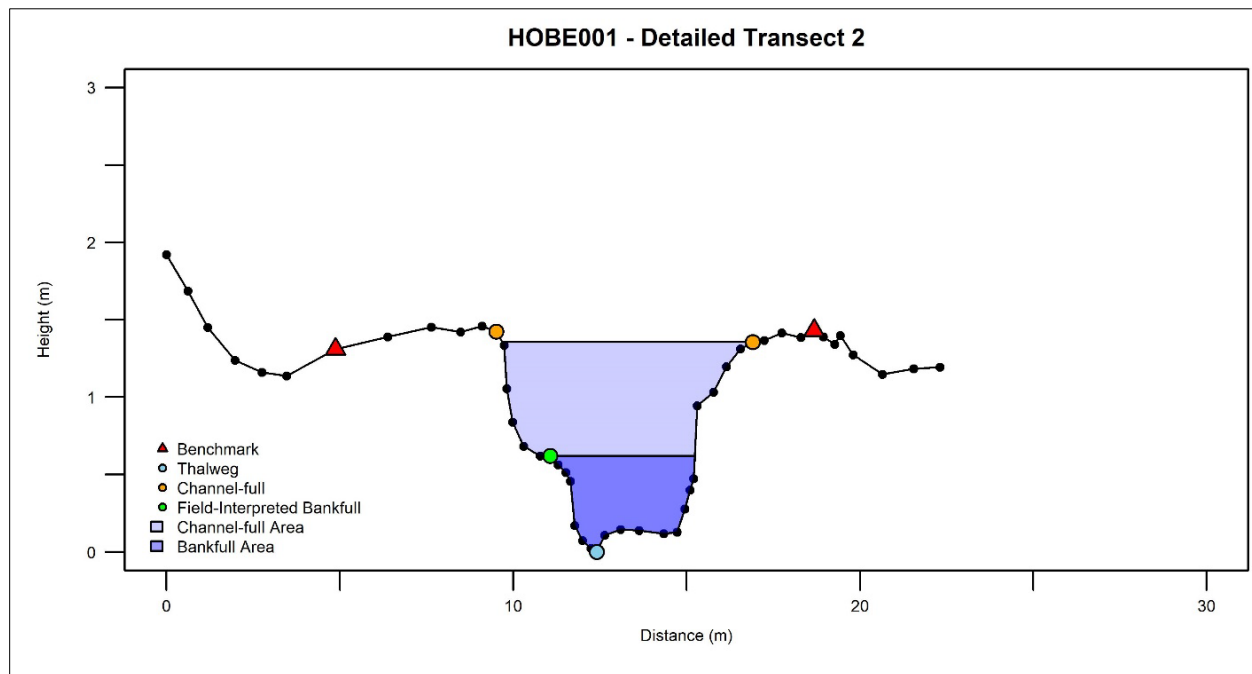


Figure B-15. Detailed transect 2 at HOBE001. The surveyed locations of the left and right benchmarks, channel-full bank-tops, and bankfull bank height are shown on the figure. Channel-full (light blue) and bankfull (dark blue) cross-sectional areas are also included (channel-full cross-sectional area equals light blue plus dark blue). When bankfull height above thalweg was greater than the lowest out-of-channel surface (LooC), bankfull area was interpolated using LooC height to determine the hydraulic radius at this height.

Table B-8. Cross-sectional characteristics for detailed transect 3 at HOBE001 [m—meters].

Type	Area (m ²)	Perimeter (m)	Hydraulic Radius (m)	Width (m)	Depth (m)	Width/Depth
Bankfull	2.71	5.78	0.47	5.26	0.74	7.13
Channel-full	5.41	7.60	0.71	6.57	1.22	5.37
Ratio	2.00	1.32	1.52	1.25	1.66	0.75

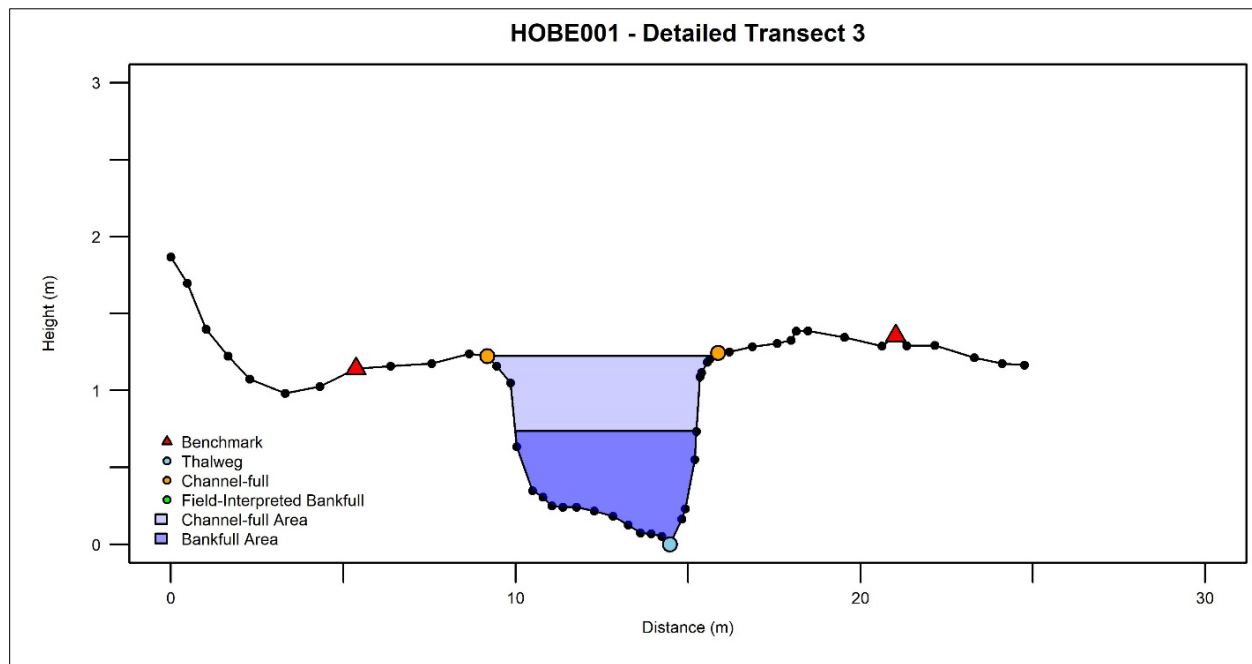


Figure B-16. Detailed transect 3 at HOBE001. The surveyed locations of the left and right benchmarks, channel-full bank-tops, and interpreted bankfull bank height are shown on the figure. Channel-full (light blue) and bankfull (dark blue) cross-sectional areas are also included (channel-full cross-sectional area equals light blue plus dark blue). When bankfull height above thalweg was greater than the lowest out-of-channel surface (LooC), bankfull area was interpolated using LooC height to determine the hydraulic radius at this height.

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