

South Carolina Blue Ridge, Ecoregion 66 Stream Morphology Results

In the South Carolina Blue Ridge, Ecoregion 66, six streams were visited in April 2019, to collect geomorphic data for comparison to hydraulic geometry regional curves available for the Blue Ridge Ecoregion in North Carolina and Tennessee (Figure 1 and Table 1). Site 6 is an active USGS gage on the Middle Saluda River with a watershed drainage area of 20.8 square miles. The other five sites are reference streams in forested watersheds with drainage areas ranging from 0.11 to 2.01 square miles.

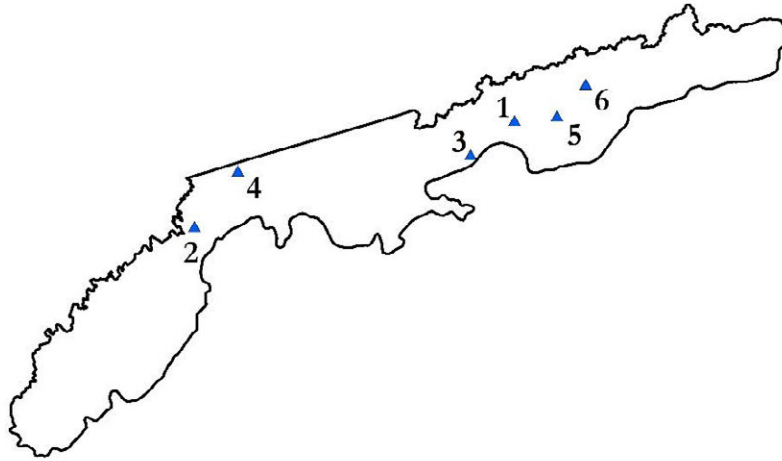


Figure 1. Reference Stream Sites in Ecoregion 66, South Carolina.

Table 1. Reference Stream Sites.

Site	Stream name	Source/Location	Latitude	Longitude	Drainage area (mile ²)
1	UT Matthews Creek	Asbury Hills Camp	35.075628	-82.638887	0.11
2	Crane Creek	Sumter National Forest	34.943975	-83.095603	0.27
3	Green Creek	Table Rock State Park	35.034476	-82.701337	0.35
4	Howard Creek	Sumter National Forest	35.010530	-83.034919	0.56
5	Wattacoo Creek	Naturaland Trust	35.081739	-82.578104	2.01
6	Middle Saluda River	USGS gage	35.120115	-82.537465	20.8

The Middle Saluda River USGS gage station was included in this study because the long-term records for flow stage and discharge can be used to quantify the specific channel-forming discharge exceedance probability for bankfull conditions. Discharge can be reported in terms of exceedance probability (or return period) to assist in determining channel-forming discharges and morphological indicators in ungaged watersheds. The Middle Saluda gage site is at a stable stream location in a relatively undisturbed watershed with field indicators of bankfull stage near a riffle downstream of the gage.

The reference streams in this Ecoregion were selected in consultation with SCDNR and other local stream professionals to identify reference reaches generally based on the following criteria:

- Watersheds with drainage areas ranging between approximately 0.1 and 10 square miles (with the exception of the USGS gage station)
- Watersheds with stable land use, mostly forested, over the past several decades
- Stream channels and floodplains in equilibrium with active bankfull stage indicators (bank height ratios near 1.0)
- Stream channels with freely-formed meander patterns in low-gradient valleys and natural step-pool bedforms in high-gradient valleys
- No valley restrictions throughout the reference reach or upstream/downstream that may influence channel form
- Healthy riparian forest buffers
- Accessible for data collection and protected for future access

For each stream site, field data on stream geomorphological characteristics were collected to establish hydraulic geometry relationships, in addition to collecting large woody debris (LWD) information¹. The geomorphological characteristics were collected following the methods outlined in the most revised version of the North Carolina SQT Field User Manual² and the LWD assessment was in accordance with the most revised version of the Application of the Large Woody Debris Index Field User Manual developed by Stream Mechanics and Ecosystem Planning & Restoration. All reference stream assessments included collection of dimension (cross-sectional) data. As conditions allowed, pattern and profile data were collected for a subset of the reference sites.

Data collected at all reference sites included:

- Rosgen stream type
- valley type
- drainage area (DA)
- bankfull riffle cross-section area (A_{bkf})
- bankfull riffle width (W_{bkf}) and mean depth (d_{bkf}) for calculating width-to-depth ratio (WDR)
- width of floodprone area (W_{fpa}) for calculating entrenchment ratio (ER)
- maximum depth at top of bank and bankfull stage for calculating bank height ratio (BHR)
- channel water surface slope (S)
- sinuosity (k)
- median substrate size classification
- estimated Manning roughness coefficient (n)

The subset of reference sites with profile data included collection of:

- riffle slopes (S_{riffle})
- riffle lengths (L_{riffle})
- pool spacings (p-p)
- pool lengths (L_{pool})

¹ Large Woody Debris Assessment https://stream-mechanics.com/wp-content/uploads/2017/12/LWDI-Manual_V1.pdf

² NC SQT https://stream-mechanics.com/wp-content/uploads/2017/09/Data-Collection-and-Analysis-Manual_NC-SQT-v3.0.pdf; currently under revision.

The subset of reference sites with pattern data included collection of:

- meander wavelengths (L_{meander})
- belt widths (W_{belt})
- radius of curvature of meander bends (R_c)

Field measurement results are presented in the appendix and in the tables and graphs below. Table 2 summarizes riffle cross-section dimension geomorphic parameters used for Rosgen stream classification. Most of the streams in Ecoregion 66 are B streams with typical entrenchment ratios of about 2. One reference stream is an E stream with a wider valley and entrenchment ratio exceeding 3. Width/depth ratios are highly variable, ranging from 8 to 16.

Table 2. Morphology Dimensions.

Site	Drainage area (mile ²)	Channel slope (ft/ft)	Cross-section area (ft ²)	Bankfull width (ft)	Bankfull mean depth (ft)	Width/depth ratio	Entrenchment ratio	Rosgen Stream Class
1	0.11	0.0350	6.0	9.9	0.6	16.2	2.0	B4
2	0.27	0.0171	6.0	8.4	0.7	11.8	1.8	B4c
3	0.35	0.0555	10.7	11.2	1.0	11.7	2.5	B3a
4	0.56	0.0136	13.4	11.2	1.2	9.3	3.6	E4
5	2.01	0.0066	36.1	17.7	2.0	8.7	1.8	B4c
6	20.8	0.0067	166.8	50.4	3.3	15.2	2.0	B3c

Table 3 summarizes estimated bankfull hydraulic parameters (velocity and discharge) for each stream based on gage station data if available and the Manning equation for ungaged streams. The Manning equation, in English units, is:

$$v = \frac{1.486 * (R^{2/3}) * (S^{1/2})}{n}$$

where v is average velocity (feet/second), R is the hydraulic radius (feet), S is average water surface slope (feet/feet), and n is a dimensionless coefficient describing channel roughness, known as Manning's n , which ranges from 0.033 to 0.150 for natural channels. The Cowan (1956) method was used to estimate the Manning's n values based on sediment size, irregularity within a cross-section, variation among cross-sections, obstructions, vegetation, and sinuosity. The bankfull discharge is estimated as the product of average velocity and riffle bankfull cross-section area.

For these six streams, Manning's n values range from 0.047 to 0.060, which match expected values for natural mountain streams. Estimated bankfull average velocities for the study streams range from 2.6 to 5.1, with variations due primarily to slope and bankfull depth.

Table 3. Estimated Bankfull Hydraulic Parameters.

Site	Drainage area (mile ²)	Manning's n	Estimated Bankfull Velocity (ft/s)	Estimated Bankfull Discharge (cfs)
1	0.11	0.047	4.0	24
2	0.27	0.054	2.6	16
3	0.35	0.060	5.1	55
4	0.56	0.054	3.2	43
5	2.01	0.047	3.6	131
6	20.8	*	4.8	794

* Bankfull velocity and discharge were determined using the USGS gage stage-discharge relationship for the field-measured bankfull stage, rather than the Manning equation.

The graphs in Figures 2 through 5 show relationships of measured riffle bankfull morphological parameters and estimated discharge to watershed drainage area (i.e. regional curves). The six data points representing South Carolina streams are plotted along with reference data from Ecoregion 66 in North Carolina and Tennessee. The best fit regression lines represent the combination of data from all three states.

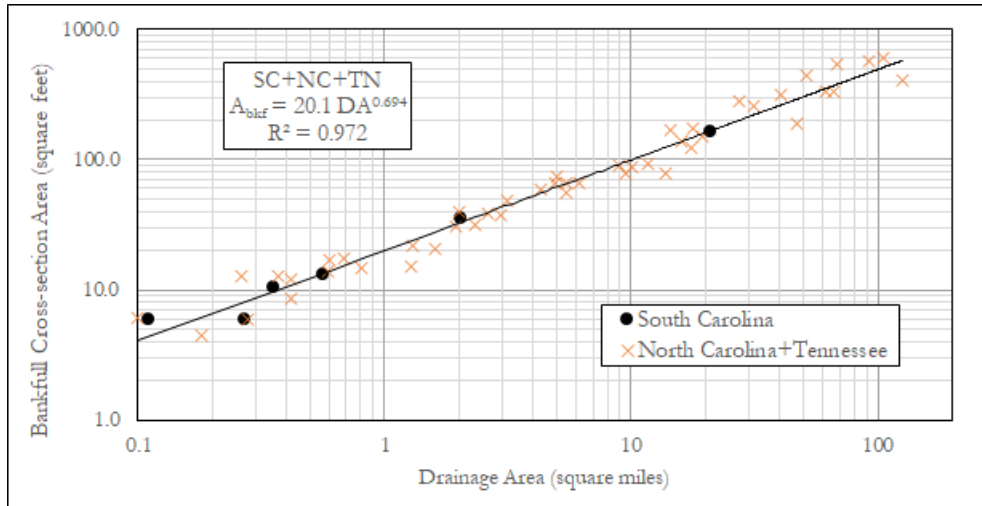


Figure 2. Bankfull riffle cross-section area related to drainage area for Ecoregion 66 streams with best-fit regression equations for SC+NC+TN.

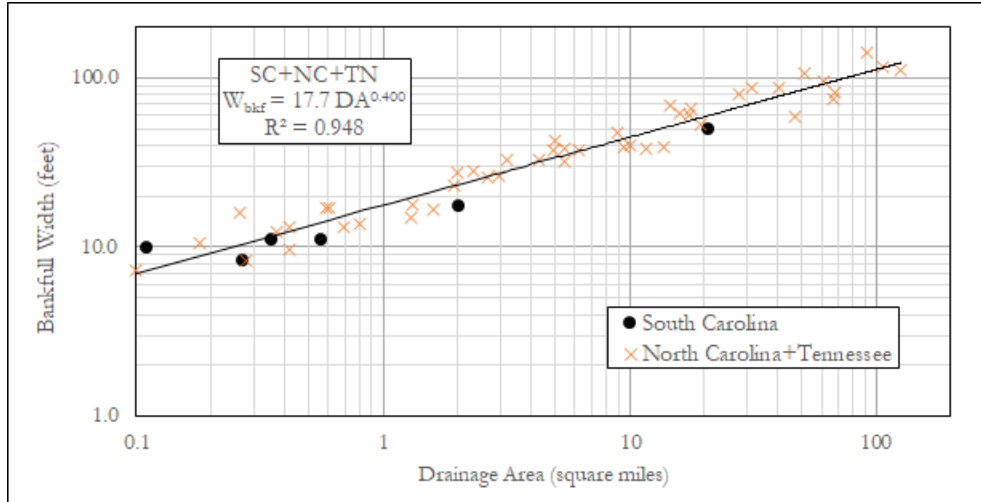


Figure 3. Bankfull riffle cross-section width related to drainage area for Ecoregion 66 streams with best-fit regression equations for SC+NC+TN.

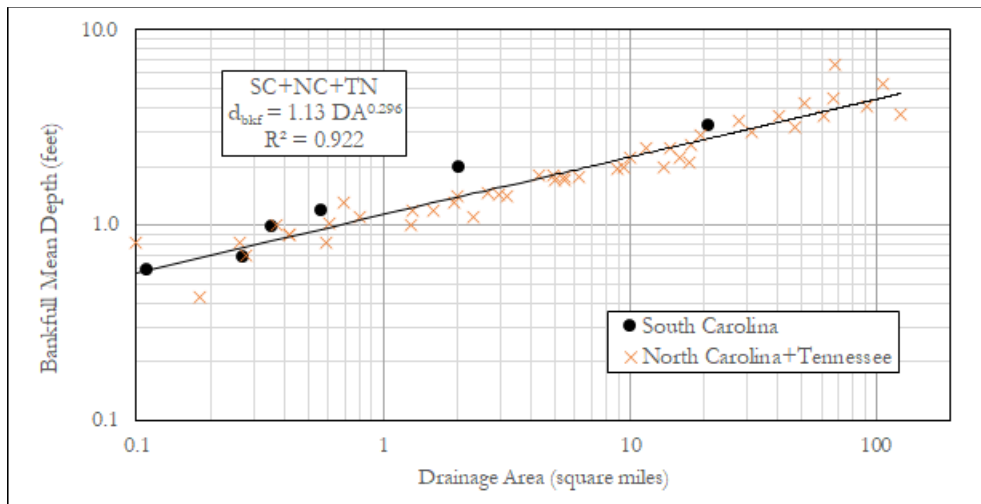


Figure 4. Bankfull riffle mean depth related to drainage area for Ecoregion 66 streams with best-fit regression equations for SC+NC+TN.

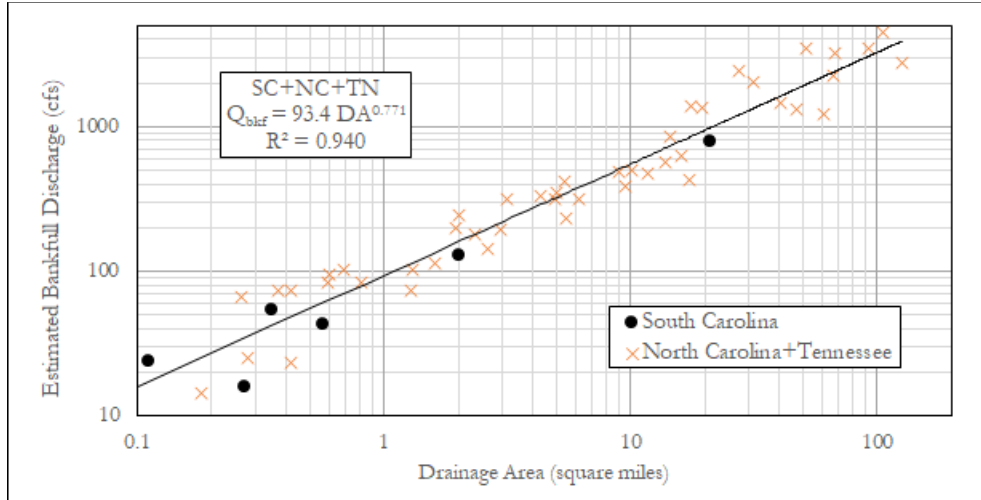


Figure 5. Estimated bankfull discharge related to drainage area for Ecoregion 66 streams with best-fit regression equations for SC+NC+TN.

The South Carolina stream parameters generally fit within the variability measured within this ecoregion in North Carolina and Tennessee. Overall, the South Carolina stream information matches well with North Carolina and Tennessee data, suggesting that the composite South Carolina + North Carolina + Tennessee regional curves are appropriate for use in Ecoregion 66 in South Carolina.

Table 4 summarizes stream bedform profile data for the reference streams with discernable riffle-pool sequences. Median riffle and pool length ratios range from 1.7 to 3.3 for riffles and 1.2 to 2.0 for pools. Median pool spacing ratios range from 2.4 to 3.5. Median riffle slope ratios range from 1.0 to 1.7. Median step height ratios for the two reference streams with discernable steps range from 0.06 to 0.10. For each stream, the median profile parameters and the median dimensionless ratios are listed. These profile parameter ratios are similar to those measured in reference streams within Ecoregion 66 in North Carolina and Tennessee.

Table 5 summarizes stream pattern data for the 2 meandering reference streams with discernable planform parameters. Median meander wavelength ratios for this small sample size range from 4.7 to 6.3, belt width ratios are 2.6, and radius of curvature ratios are 2.1. For each stream, the median pattern parameters and the median dimensionless ratios are listed. These pattern parameter ratios are similar to those observed in reference streams within Ecoregion 66 in North Carolina and Tennessee.

Table 4. Stream Morphology Bedform Profile Parameters.

Site	Drainage area (mile ²)	Median riffle length [ratio to bankfull width] (ft [none])	Median pool length [ratio to bankfull width] (ft [none])	Median pool spacing [ratio to bankfull width] (ft [none])	Median riffle slope [ratio to channel slope] (ft/ft [none])	Median step height [ratio to bankfull width] (ft [none])
1	0.11	16.5 [1.7]	11.5 [1.2]	24.0 [2.4]	0.0348 [1.0]	0.64 [0.06]
2	0.27	16.0 [1.9]	13.0 [1.5]	20.0 [2.4]	0.0280 [1.6]	-
3	0.35	37.0 [3.3]	17.7 [1.6]	35.5 [3.2]	0.0668 [1.2]	1.13 [0.10]
4	0.56	30.0 [2.7]	20.0 [1.8]	39.0 [3.5]	0.0220 [1.6]	-
5	2.01	55.0 [3.1]	36.0 [2.0]	58.0 [3.3]	0.0114 [1.7]	-

Table 5. Stream Morphology Pattern Parameters.

Site	Drainage area (mile ²)	Sinuosity (ft/ft)	Median meander wavelength [ratio to bankfull width] (ft [none])	Median belt width [ratio to bankfull width] (ft [none])	Median radius of curvature [ratio to bankfull width] (ft [none])
2	0.27	1.30	53 [6.3]	22 [2.6]	18 [2.1]
4	0.56	1.30	53 [4.7]	29 [2.6]	24 [2.1]

Table 6 summarizes Large Woody Debris (LWD) assessments for each stream, including the numbers of LWD pieces and dams and the LWD Index scores. The LWDI is 74 at the USGS gage and ranges from 123 to 275 at the five reference streams.

Table 6. Large Woody Debris Assessment Results for Reference Streams, Ecoregion 66.

Site	Number of Pieces	Number of Dams	Piece Score	Dam Score	LWDI
1	14	0	275	0	275
2*	7	0	135	0	135
3	10	0	187	0	187
4*	6	1	124	18	214
5	7	0	123	0	123
6	4	0	74	0	74

* The United States Forest Service indicated that LWD has historically been added to Crane Creek (Site 2) and Howard Creek (Site 4). The LWD assessment results may be affected by this manipulation.

APPENDIX

ECOREGION 66, SOUTH CAROLINA

1. UT Matthews Creek Ecoregion 66, South Carolina

Latitude: 35.075628

Longitude: -82.638887

Drainage area: 0.11 square miles

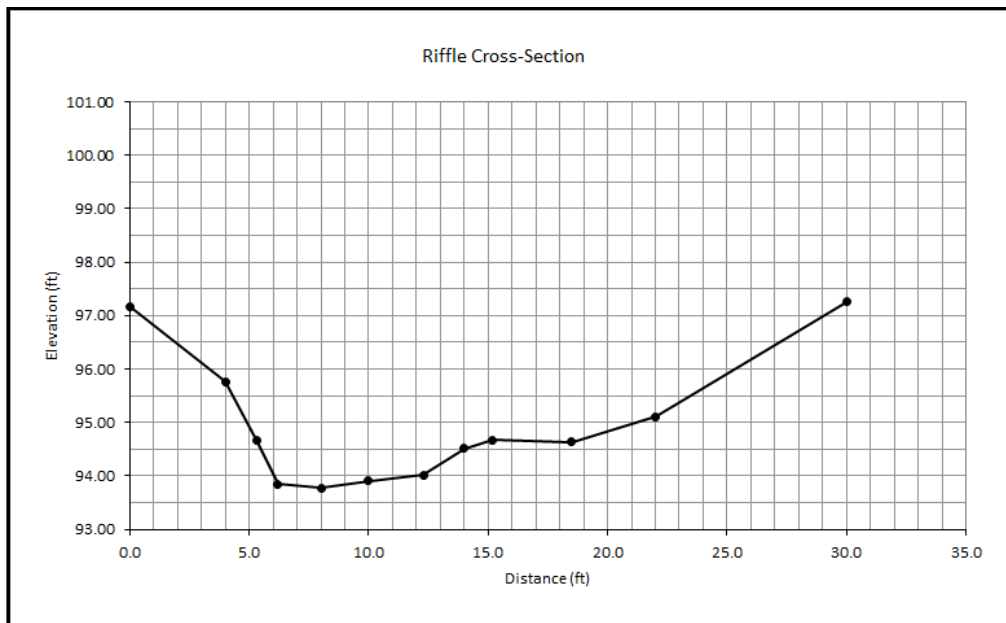
Median particle size: gravel

Longitudinal slope: 0.0350 feet/foot

Stream classification: B4



Area (square feet) =	6.0
Width (feet) =	9.9
Mean depth =	0.6
Max depth =	0.9
Width/depth ratio =	16.2
Entrenchment ratio =	2.0



2. Crane Creek Ecoregion 66, South Carolina

Latitude: 34.943975

Longitude: -83.095603

Drainage area: 0.27 square miles

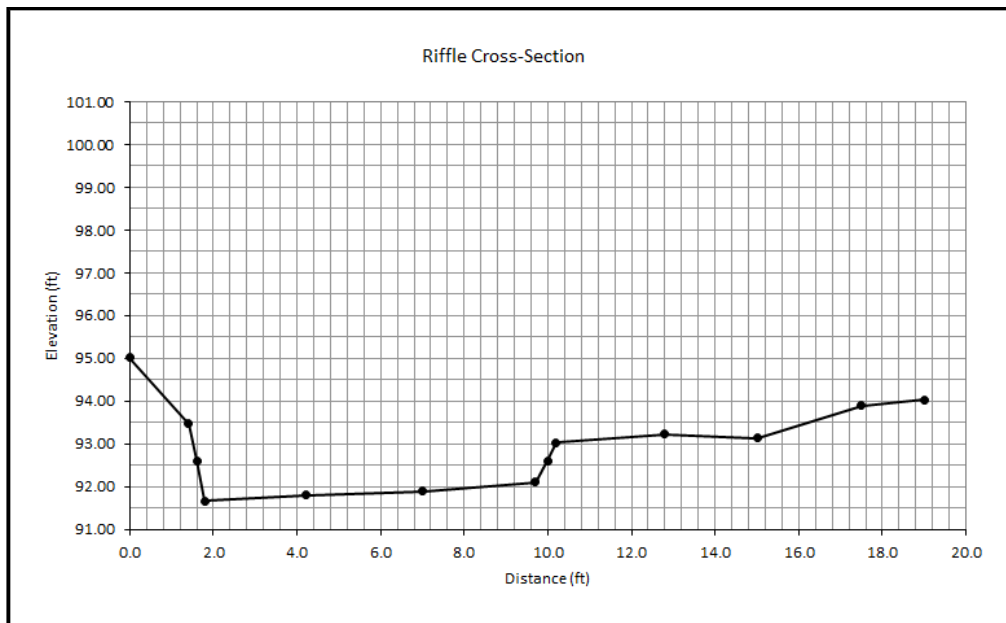
Median particle size: gravel

Longitudinal slope: 0.0171 feet/foot

Stream classification: B4c



Area (square feet) =	6.0
Width (feet) =	8.4
Mean depth =	0.7
Max depth =	0.9
Width/depth ratio =	11.8
Entrenchment ratio =	1.8



3. Green Creek Ecoregion 66, South Carolina

Latitude: 35.034476

Longitude: -82.701337

Drainage area: 0.35 square miles

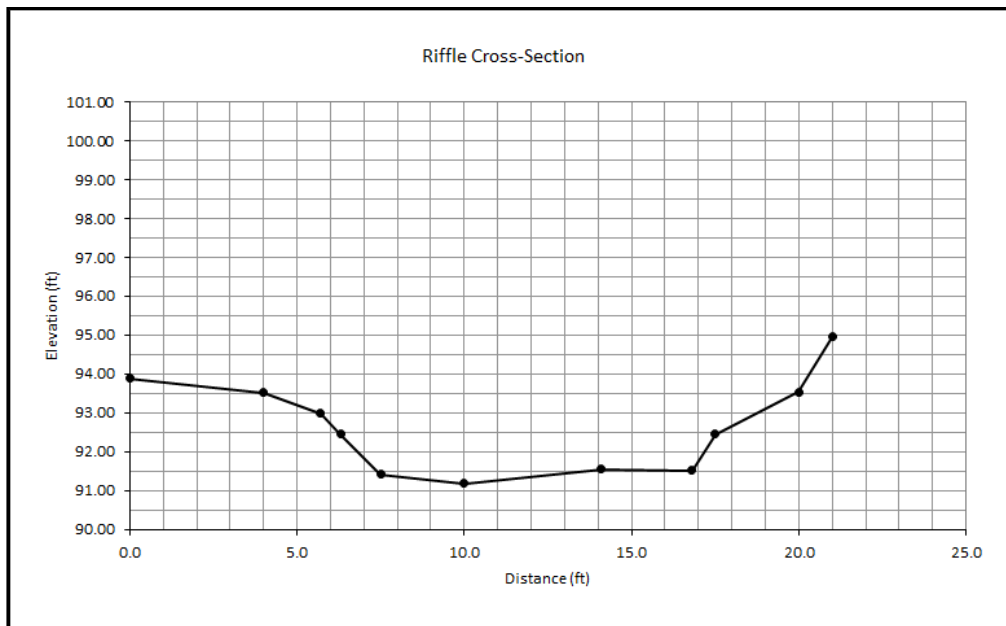
Median particle size: cobble

Longitudinal slope: 0.0555 feet/foot

Stream classification: B3a



Area (square feet) =	10.7
Width (feet) =	11.2
Mean depth =	1.0
Max depth =	1.3
Width/depth ratio =	11.7
Entrenchment ratio =	2.5

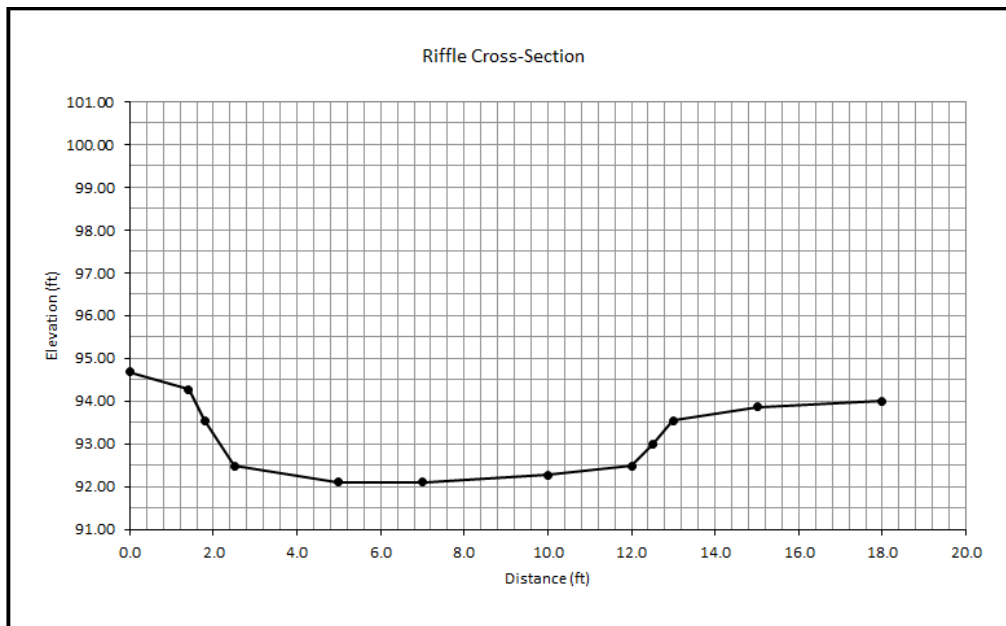


4. Howard Creek Ecoregion 66, South Carolina

Latitude: 35.010530
Longitude: -83.034919
Drainage area: 0.56 square miles
Median particle size: gravel
Longitudinal slope: 0.0136 feet/foot
Stream classification: E4



Area (square feet) =	13.4
Width (feet) =	11.2
Mean depth =	1.2
Max depth =	1.5
Width/depth ratio =	9.3
Entrenchment ratio =	3.6

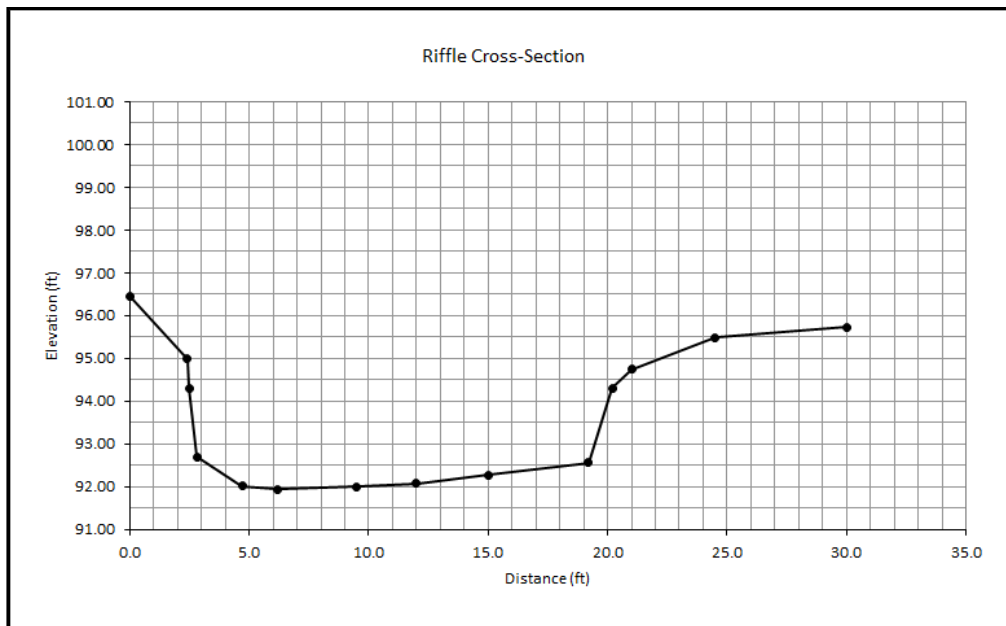


5. Wattacoo Creek Ecoregion 66, South Carolina

Latitude: 35.081739
Longitude: -82.578104
Drainage area: 2.01 square miles
Median particle size: gravel
Longitudinal slope: 0.0066 feet/foot
Stream classification: B4c



Area (square feet) =	36.1
Width (feet) =	17.7
Mean depth =	2.0
Max depth =	2.4
Width/depth ratio =	8.7
Entrenchment ratio =	1.8



6. Middle Saluda River Ecoregion 66, South Carolina

Latitude: 35.120115

Longitude: -82.537465

Drainage area: 20.8 square miles

Median particle size: cobble

Longitudinal slope: 0.0067 feet/foot

Stream classification: B3c



Area (square feet) =	166.8
Width (feet) =	50.4
Mean depth =	3.3
Max depth =	4.0
Width/depth ratio =	15.2
Entrenchment ratio =	2.0

