

South Carolina Piedmont, Ecoregion 45 Stream Morphology Results

In the South Carolina Piedmont, Ecoregion 45, geomorphic data were collected from 14 streams between October and December 2019 (Figure 1 and Table 1). Seven sites are at USGS gage stations with drainage areas ranging from 9.73 to 94.7 square miles, while the remaining seven are ungaged reference streams in forested watersheds with drainage areas ranging from 0.06 to 4.94 square miles. Several other streams were visited to evaluate their potential for inclusion in this study but were rejected due to local instability or other factors affecting their geomorphic conditions.

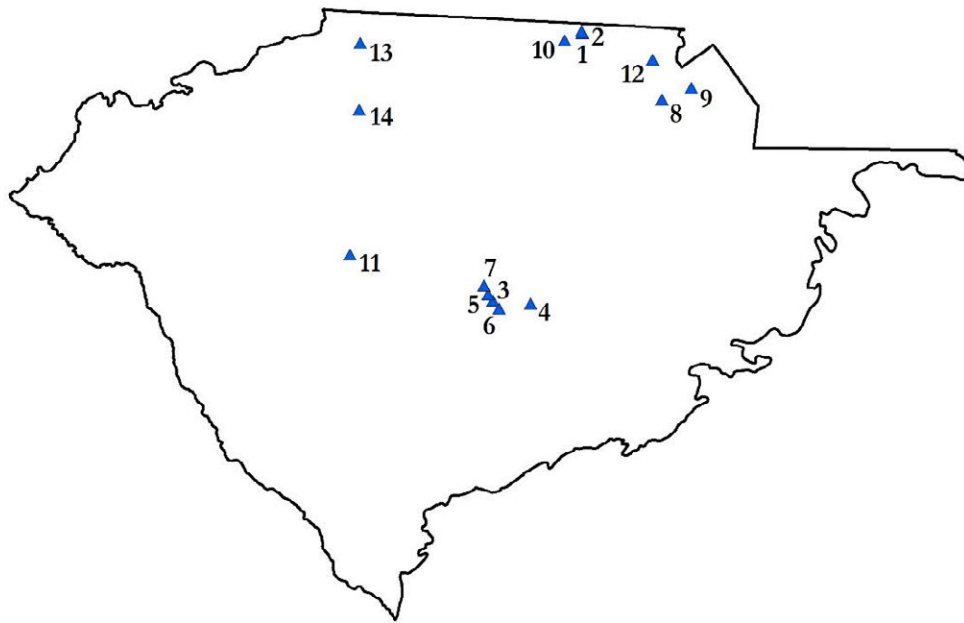


Figure 1. Reference Stream Sites in Ecoregion 45, South Carolina.

Table 1. Reference Stream Sites.

Site	Stream name	Source/Location	Latitude	Longitude	Drainage area (mile ²)
1	UT2 Long Branch	Kings Mountain NMP	35.137778	-81.376944	0.06
2	UT1 Long Branch	Kings Mountain NMP	35.144167	-81.378611	0.18
3	UT Indian Creek	Sumter National Forest	34.393515	-81.673764	0.18
4	UT Kings Creek	Sumter National Forest	34.385354	-81.546552	0.32
5	Pages Creek	Sumter National Forest	34.410620	-81.689626	2.02
6	Joshuas Branch	Sumter National Forest	34.372311	-81.653166	2.98
7	Headleys Creek	Sumter National Forest	34.435460	-81.703539	4.94
8	Tools Fork Creek	USGS Gage	34.954997	-81.106668	9.73
9	Big Dutchman Creek	USGS Gage	34.986998	-81.007374	16.8
10	Kings Creek	USGS Gage	35.118134	-81.437161	27.9
11	South Rabon Creek	USGS Gage	34.517892	-82.155741	30.0
12	Allison Creek	USGS Gage	35.065105	-81.138798	40.4
13	South Pacolet River	USGS Gage	35.106304	-82.129122	55.6
14	South Tyger River	USGS Gage	34.920927	-82.129849	94.7

The USGS gage stations were included in this study because 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 chosen gage sites are at stable stream locations in relatively undisturbed watersheds with field indicators of bankfull stage at riffles near the gages.

The ungaged reference streams in this ecoregion were selected through consultation with SCDNR and other local stream professionals, as well as extensive field reconnaissance. Reference reaches were identified generally based on the following criteria:

- Streams with drainage areas ranging between approximately 0.1 and 10 square miles (with the exception of USGS gage stations)
- Watersheds with stable land use and mostly forested over the past several decades
- Stream channels and floodplains in equilibrium with active bankfull stage indicators (i.e., bank height ratios near 1.0)
- Stream channels with freely-formed meander patterns in low-gradient valleys (less than 2% longitudinal slope)
- 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

Field measurements of stream geomorphological characteristics were collected to establish hydraulic geometry relationships following the methods outlined in the most current version of the North Carolina SQT Field User Manual¹. All stream assessments included collection of bankfull riffle dimension (cross-section) 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
- drainage area (DA)
- bankfull riffle cross-section area (A_{bkr})
- bankfull riffle width (W_{bkr}) and mean depth (d_{bkr}) 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 pattern and profile data included collection of:

- riffle slopes (S_{riffle})
- riffle lengths (L_{riffle})
- pool spacings (p-p)
- pool lengths (L_{pool})
- meander wavelengths ($L_{meander}$)
- belt widths (W_{blt})
- radius of curvature of meander bends (R_c)

Large woody debris (LWD) information was collected in accordance with the most current version of the Application of the Large Woody Debris Index Field User Manual developed by Stream Mechanics and Ecosystem Planning & Restoration².

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 45 are C and E streams, typically with high entrenchment ratios. Width/depth ratios are generally between 9 and 14, with the exception of 7.7 for one of the smaller streams and near 16 for the two largest rivers. Entrenchment ratios are typically high. Six of the valleys were so wide that they precluded exact measurement; in these cases, entrenchment ratios are reported as >10.0.

¹ NC SQT https://stream-mechanics.com/wp-content/uploads/2017/09/Data-Collection-and-Analysis-Manual_NC-SQT-v3.0.pdf; currently under revision.

² Large Woody Debris Assessment https://stream-mechanics.com/wp-content/uploads/2017/12/LWDI-Manual_V1.pdf

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	0.06	0.0118	4.7	7.0	0.7	10.5	3.3	E4
2	0.18	0.0143	4.6	7.2	0.6	11.3	>10.0	E4
3	0.18	0.0082	4.0	6.3	0.6	9.9	>10.0	E5
4	0.32	0.0077	6.5	7.1	0.9	7.7	>10.0	E5
5	2.02	0.0028	30.6	19.0	1.6	11.8	>10.0	E5
6	2.98	0.0032	28.9	20.4	1.4	14.4	>10.0	C5
7	4.94	0.0048	25.4	16.6	1.5	10.8	>10.0	E5
8	9.73	0.0019	108.5	35.6	3.0	11.7	6.5	E5
9	16.8	0.0016	116.4	35.7	3.3	11.0	1.4	B5c
10	27.9	0.0026	109.9	34.9	3.1	11.1	2.4	E4
11	30.0	0.0033	106.7	37.7	2.8	13.3	6.6	C5
12	40.4	0.0015	250.2	48.9	5.1	9.5	3.9	E5
13	55.6	0.0025	242.1	62.8	3.9	16.3	5.5	C5
14	94.7	0.0005	388.2	80.3	4.8	16.6	3.2	C5c-

Table 3 summarizes estimated bankfull hydraulic parameters (velocity and discharge) for each stream based on gage station data (if available) or 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 streams, Manning's n values range from 0.045 to 0.054, which match expected values for natural alluvial streams in the Piedmont. Estimated bankfull average velocities for the study streams range from 1.9 to 4.1, with variations due primarily to slope and cross-section dimensions.

Table 3. Estimated Bankfull Hydraulic Parameters.

Site	Drainage area (mile ²)	Manning's n	Estimated Bankfull Velocity (ft/s)	Estimated Bankfull Discharge (cfs)
1	0.06	0.047	2.3	11
2	0.18	0.047	2.5	11
3	0.18	0.045	2.0	7.9
4	0.32	0.052	2.0	13
5	2.02	0.052	1.9	57
6	2.98	0.052	1.9	54
7	4.94	0.052	2.4	60
8	9.73	*	2.1	232
9	16.8	0.045	2.6	300
10	27.9	0.054	2.7	296
11	30.0	0.052	3.0	320
12	40.4	*	3.4	855
13	55.6	*	4.1	993
14	94.7	0.048	1.9	736

* 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 riffle bankfull morphological parameters and estimated discharge related to watershed drainage area (i.e., regional curves). These graphs include data points measured in the Piedmont ecoregion of both South Carolina and North Carolina. North Carolina stream data points are shown for comparison only and should not be used for assessment or design in South Carolina. The North Carolina data represent a combination of nine USGS gages from Harman, et al. (1999) and 16 reference streams from Lowther (2008). North Carolina data are not included in Figure 5 due to minor differences in the methodologies used to estimate bankfull discharge. Figures 2 through 5 also include best-fit regression lines for each data set in addition to the regression equations and coefficients of determination.

Figures 2 through 4 demonstrate that measured bankfull riffle cross-section area, width, and depth are typically slightly smaller in the South Carolina streams than in the assessed North Carolina streams. One reason for this result may be that many of the sites measured in South Carolina were in protected, forested watersheds with little or no impervious surface (e.g., Sumter National Forest, Kings Mountain National Military Park). These undisturbed, forested watersheds tend to dampen peak flow responses to rainfall. Additionally, USGS gage stations are abundant in the Piedmont of South Carolina, which allowed for selection of the highest-quality gaged streams for inclusion in this study. The cross-section dimensions for South Carolina streams are validated by most streams having a bankfull elevation equal to the top of bank (i.e., Bank Height Ratio = 1.0) and gages with a long-term record having a return interval of around 1.30 years for the bankfull discharge.

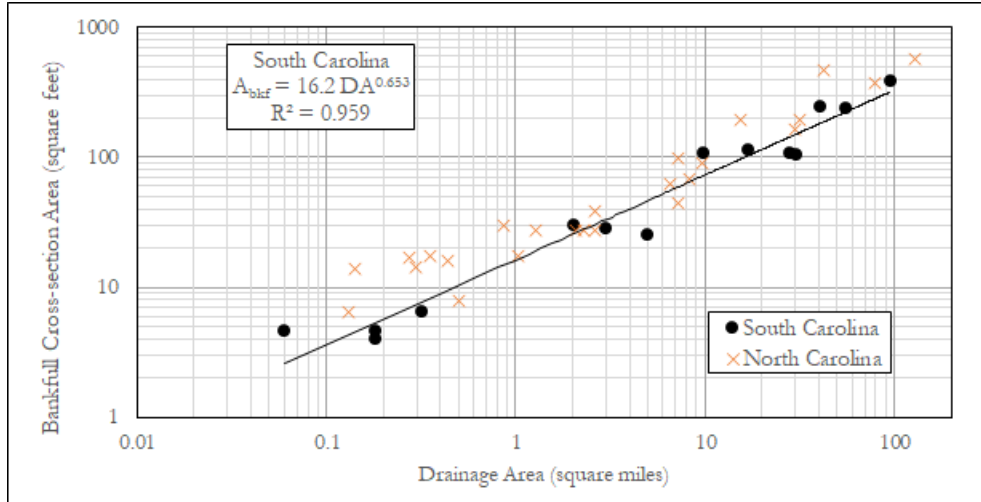


Figure 2. Bankfull riffle cross-section area related to drainage area for Ecoregion 45 streams with best-fit regression equations for South Carolina data. (Note: North Carolina stream data points are shown for comparison only and should not be used for assessment or design in South Carolina.)

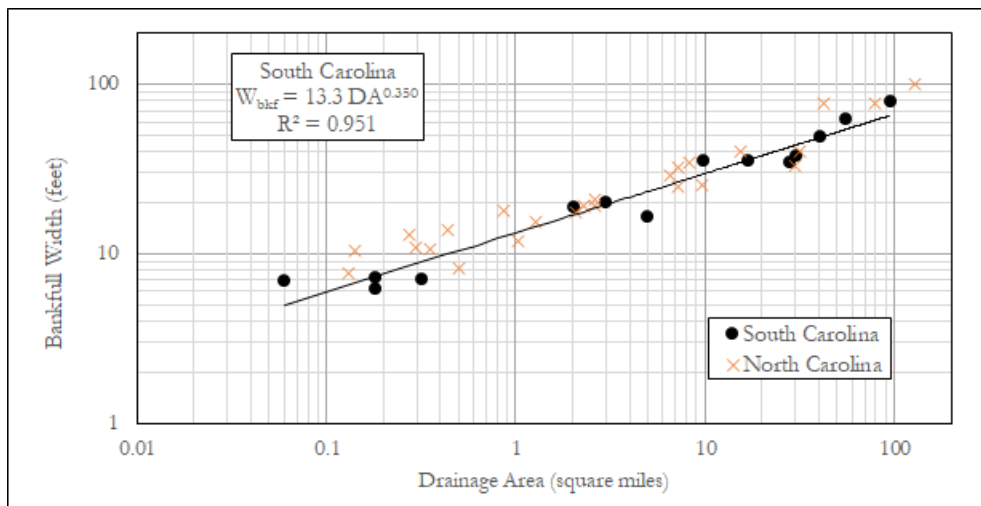


Figure 3. Bankfull riffle cross-section width related to drainage area for Ecoregion 45 streams with best-fit regression equations for South Carolina data. (Note: North Carolina stream data points are shown for comparison only and should not be used for assessment or design in South Carolina.)

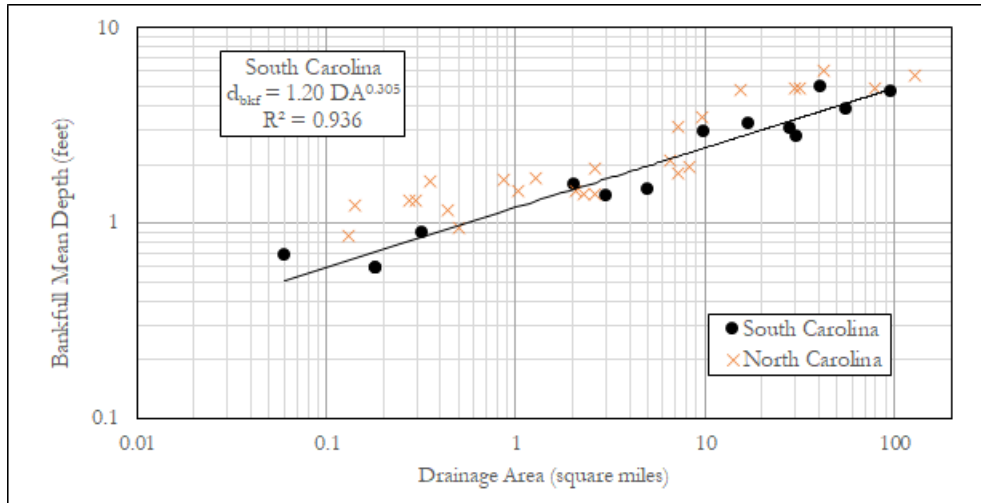


Figure 4. Bankfull riffle mean depth related to drainage area for Ecoregion 45 streams with best-fit regression equations for South Carolina data. (Note: North Carolina stream data points are shown for comparison only and should not be used for assessment or design in South Carolina.)

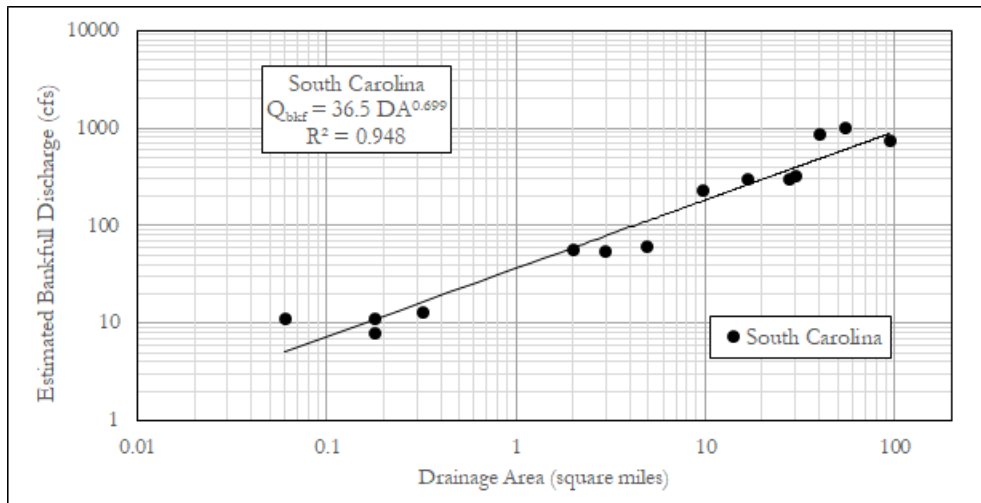


Figure 5. Estimated bankfull discharge related to drainage area for Ecoregion 45 streams.

Table 4 summarizes stream bedform profile data for the reference streams with discernable riffle-pool sequences. Many of the measured streams have low-gradient plane beds dominated by sand, which precludes riffle and pool measurements. For each stream listed, the median profile parameters and the median dimensionless ratios are presented. A wide range of parameters was observed. Median riffle and pool length ratios range from 0.9 to 4.5 for riffles and 1.0 to 4.0 for pools. Median pool spacing ratios range from 2.0 to 8.7. Median riffle slope ratios range from 1.0 to 2.9.

Table 5 summarizes stream pattern data for the meandering reference streams with discernable planform parameters that could be measured in the field. For each stream, the median pattern parameters and the median dimensionless ratios are listed. Median meander wavelength ratios range from 3.3 to 10.5, belt width ratios range from 1.7 to 3.4, and radius of curvature ratios range from 1.4 to 4.1.

Table 6 summarizes Large Woody Debris (LWD) assessments for each stream, including the numbers of LWD pieces and dams and the LWD Index scores.

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])
3	0.18	28.4 [4.5]	25.0 [4.0]	55.1 [8.7]	0.0086 [1.0]
4	0.32	11.0 [1.6]	23.9 [3.4]	21.1 [3.0]	0.0220 [2.9]
5	2.02	47.3 [2.5]	31.1 [1.6]	87.2 [4.6]	0.0050 [1.8]
6	2.98	19.7 [1.0]	21.0 [1.0]	40.9 [2.0]	0.0034 [1.1]
7	4.94	14.4 [0.9]	26.9 [1.6]	43.6 [2.6]	0.0093 [1.9]

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])
3	0.18	1.16	66 [10.5]	18 [2.9]	26 [4.1]
4	0.32	1.33	54 [7.5]	24 [3.4]	17 [2.4]
5	2.02	1.29	110 [5.8]	45 [2.4]	46 [2.4]
6	2.98	1.29	89 [4.4]	34 [1.7]	44 [2.2]
7	4.94	1.34	55 [3.3]	30 [1.8]	24 [1.4]

Table 6. Large Woody Debris Assessment Results.

Site	Number of Pieces	Number of Dams	Piece Score	Dam Score	LWDI
1	7	0	118	0	118
2	5	0	93	0	93
3	6	0	99	0	99
4	6	0	109	0	109
5	8	0	142	0	142
6	5	0	83	0	83
7	7	0	115	0	115
8	10	1	185	16	265
9	10	0	190	0	190
10	12	0	214	0	214
11	7	0	139	0	139
12	10	1	174	15	249
13	9	0	173	0	173
14	7	0	135	0	135

APPENDIX

ECOREGION 45, SOUTH CAROLINA

1. UT2 Long Branch Ecoregion 45, South Carolina

Latitude: 35.137778

Longitude: -81.376944

Drainage area: 0.06 square miles

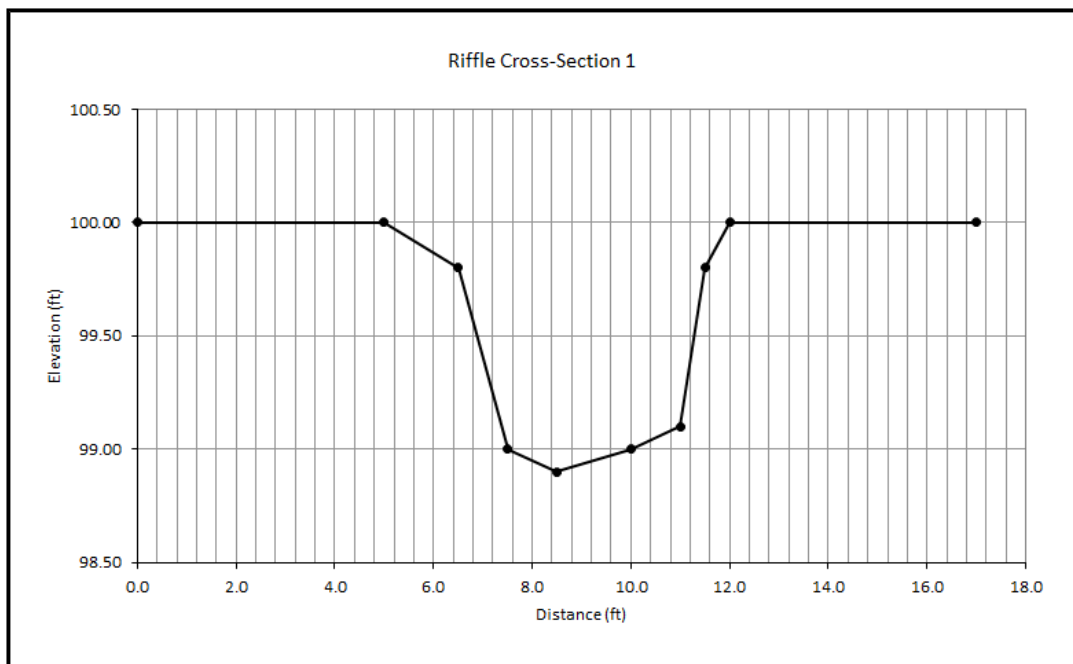
Median particle size: gravel

Longitudinal slope: 0.0118 feet/foot

Stream classification: E4



Area (square feet) =	4.7
Width (feet) =	7.0
Mean depth =	0.7
Max depth =	1.1
Width/depth ratio =	10.5
Entrenchment ratio =	3.3



2. UT1 Long Branch Ecoregion 45, South Carolina

Latitude: 35.144167

Longitude: -81.378611

Drainage area: 0.18 square miles

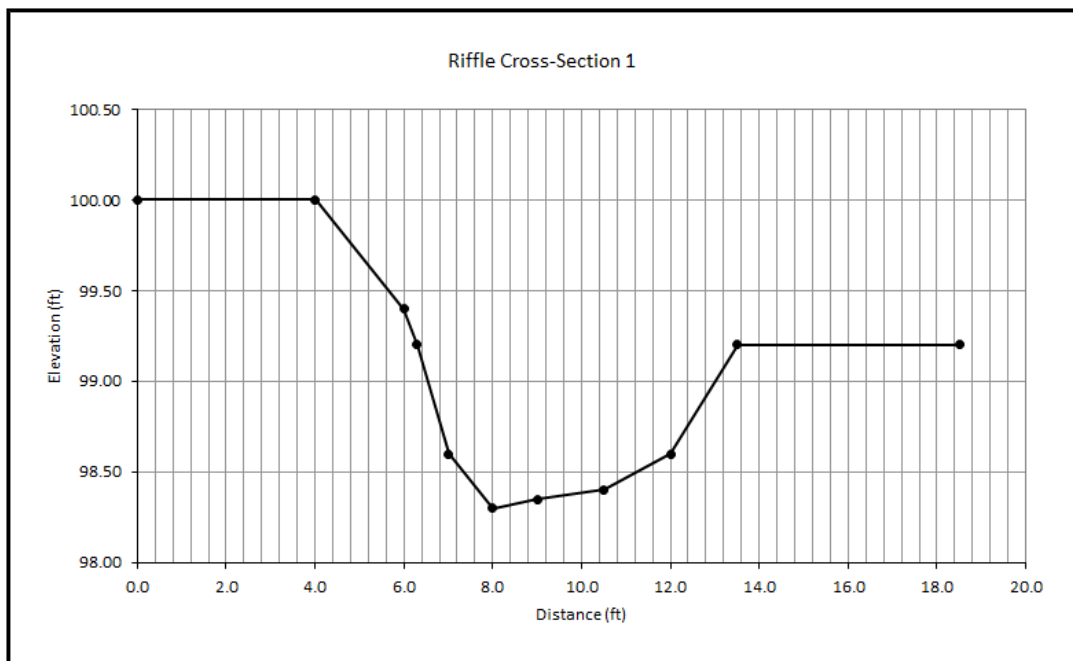
Median particle size: gravel

Longitudinal slope: 0.0143 feet/foot

Stream classification: E4



Area (square feet) =	4.6
Width (feet) =	7.2
Mean depth =	0.6
Max depth =	0.9
Width/depth ratio =	11.3
Entrenchment ratio =	>10



3. UT Indian Creek Ecoregion 45, South Carolina

Latitude: 34.393515

Longitude: -81.673764

Drainage area: 0.18 square miles

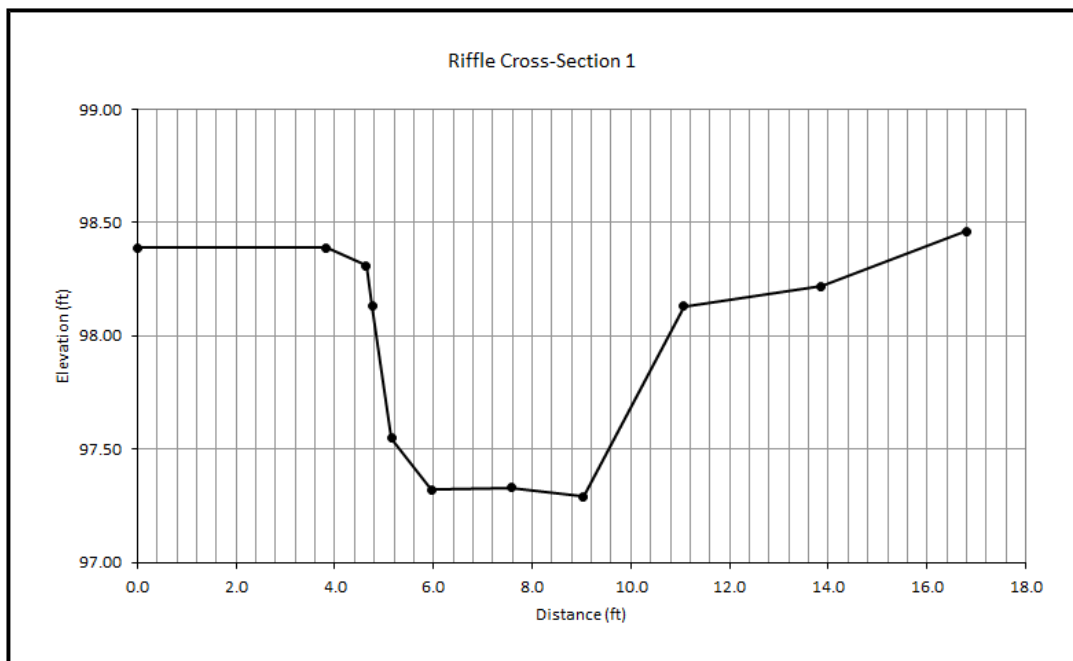
Median particle size: sand

Longitudinal slope: 0.0082 feet/foot

Stream classification: E5



Area (square feet) =	4.0
Width (feet) =	6.3
Mean depth =	0.6
Max depth =	0.8
Width/depth ratio =	9.9
Entrenchment ratio =	>10



4. UT Kings Creek Ecoregion 45, South Carolina

Latitude: 34.385354

Longitude: -81.546552

Drainage area: 0.32 square miles

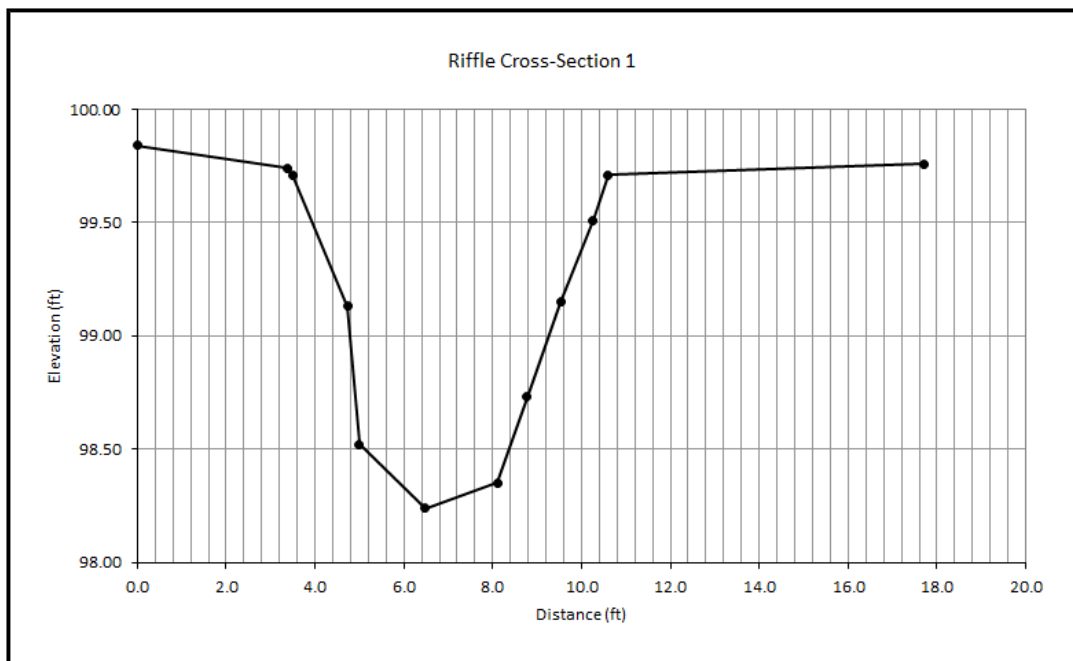
Median particle size: sand

Longitudinal slope: 0.0077 feet/foot

Stream classification: E5



Area (square feet) =	6.5
Width (feet) =	7.1
Mean depth =	0.9
Max depth =	1.5
Width/depth ratio =	7.7
Entrenchment ratio =	>10

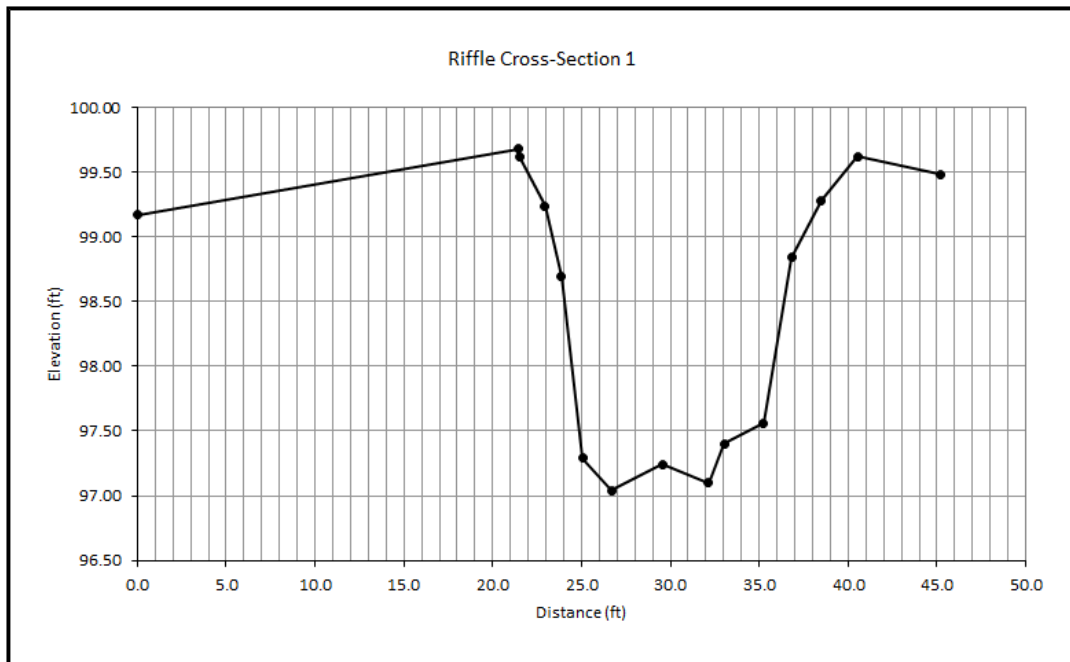


5. Pages Creek Ecoregion 45, South Carolina

Latitude: 34.410620
Longitude: -81.689626
Drainage area: 2.02 square miles
Median particle size: sand
Longitudinal slope: 0.0028 feet/foot
Stream classification: E5



Area (square feet) =	30.6
Width (feet) =	19.0
Mean depth =	1.6
Max depth =	2.6
Width/depth ratio =	11.8
Entrenchment ratio =	>10



6. Joshuas Branch Ecoregion 45, South Carolina

Latitude: 34.372311

Longitude: -81.653166

Drainage area: 2.98 square miles

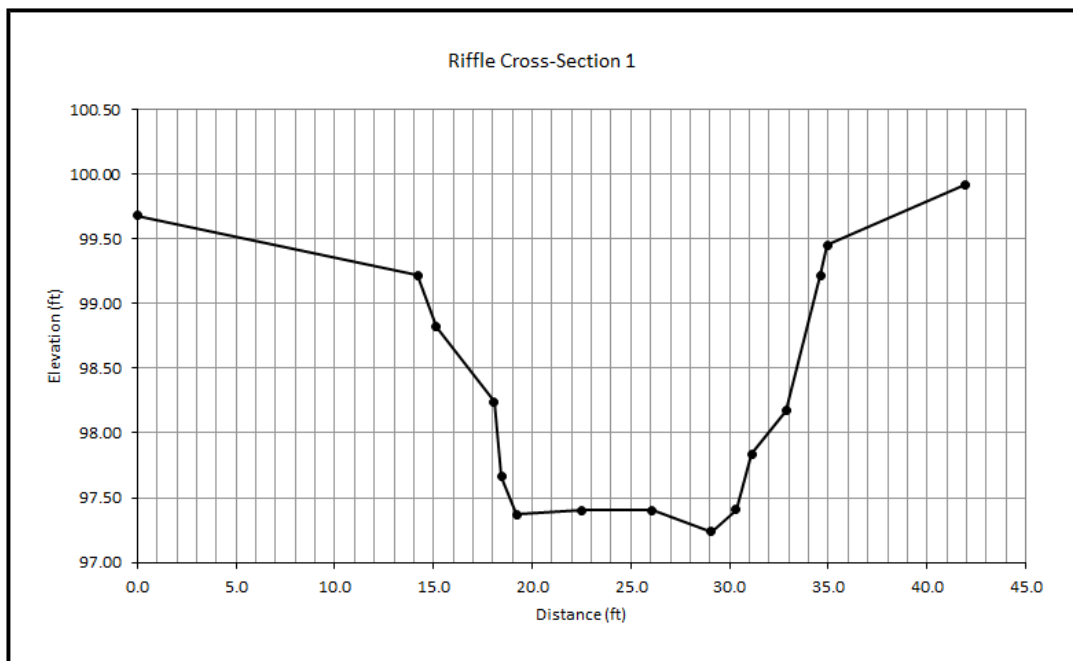
Median particle size: sand

Longitudinal slope: 0.0032 feet/foot

Stream classification: C5



Area (square feet) =	28.9
Width (feet) =	20.4
Mean depth =	1.4
Max depth =	2.0
Width/depth ratio =	14.4
Entrenchment ratio =	>10



7. Headleys Creek Ecoregion 45, South Carolina

Latitude: 34.435460

Longitude: -81.703539

Drainage area: 4.94 square miles

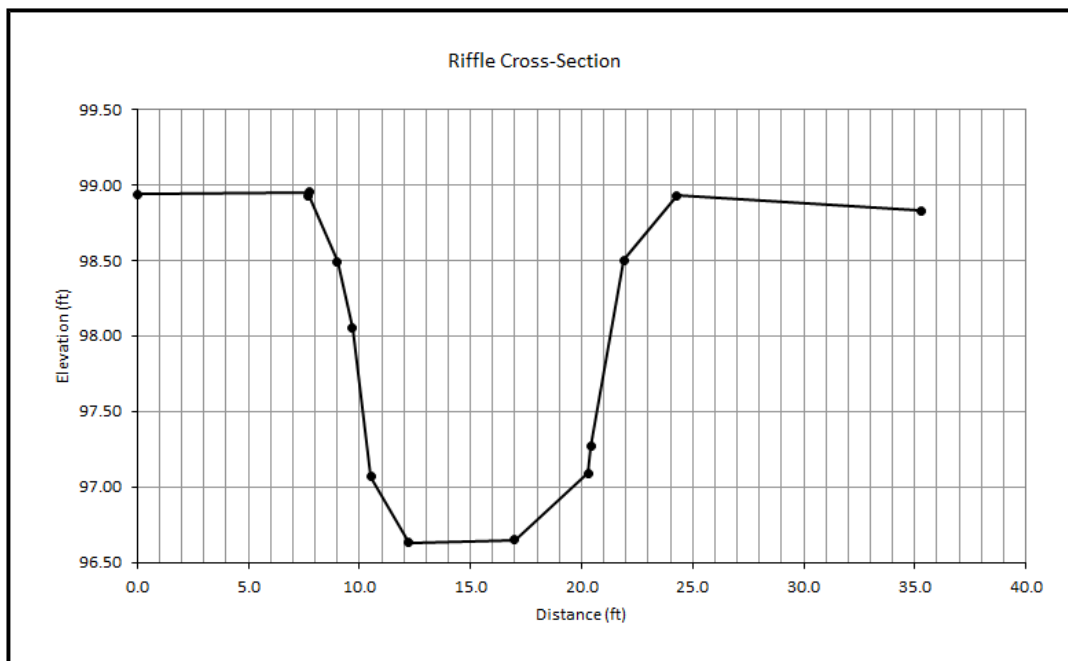
Median particle size: sand

Longitudinal slope: 0.0048 feet/foot

Stream classification: E5



Area (square feet) =	25.4
Width (feet) =	16.6
Mean depth =	1.5
Max depth =	2.3
Width/depth ratio =	10.8
Entrenchment ratio =	>10



8. Tools Fork Creek Ecoregion 45, South Carolina

Latitude: 34.954997

Longitude: -81.106668

Drainage area: 9.73 square miles

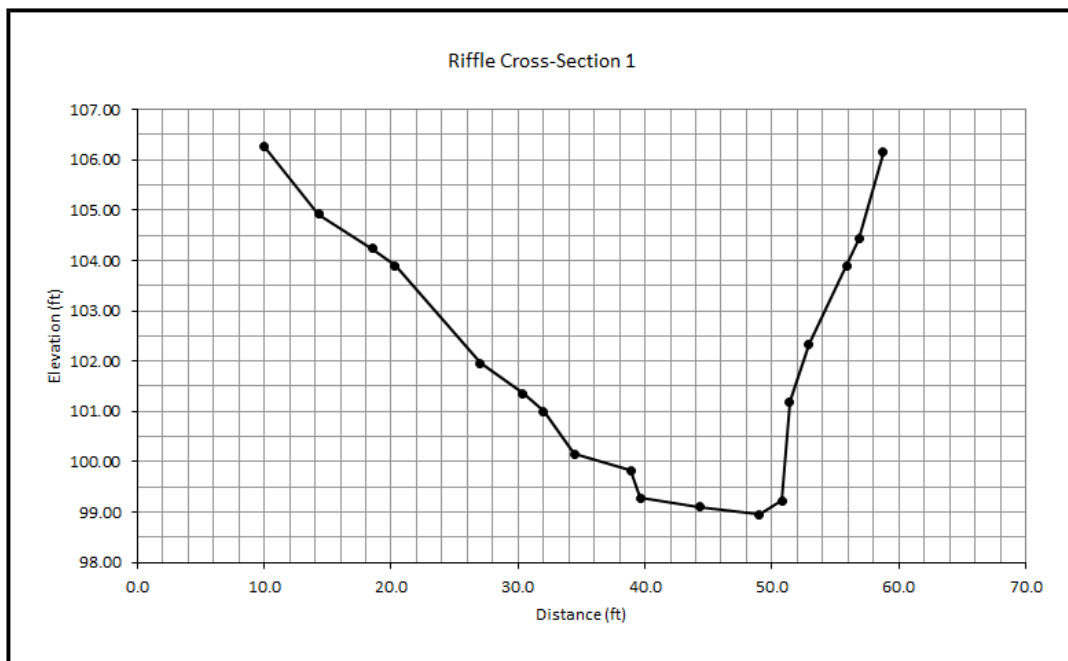
Median particle size: sand

Longitudinal slope: 0.0019 feet/foot

Stream classification: E5



Area (square feet) =	108.5
Width (feet) =	35.6
Mean depth =	3.0
Max depth =	5.0
Width/depth ratio =	11.7
Entrenchment ratio =	6.5



9. Big Dutchman Creek Ecoregion 45, South Carolina

Latitude: 34.986998

Longitude: -81.007374

Drainage area: 16.8 square miles

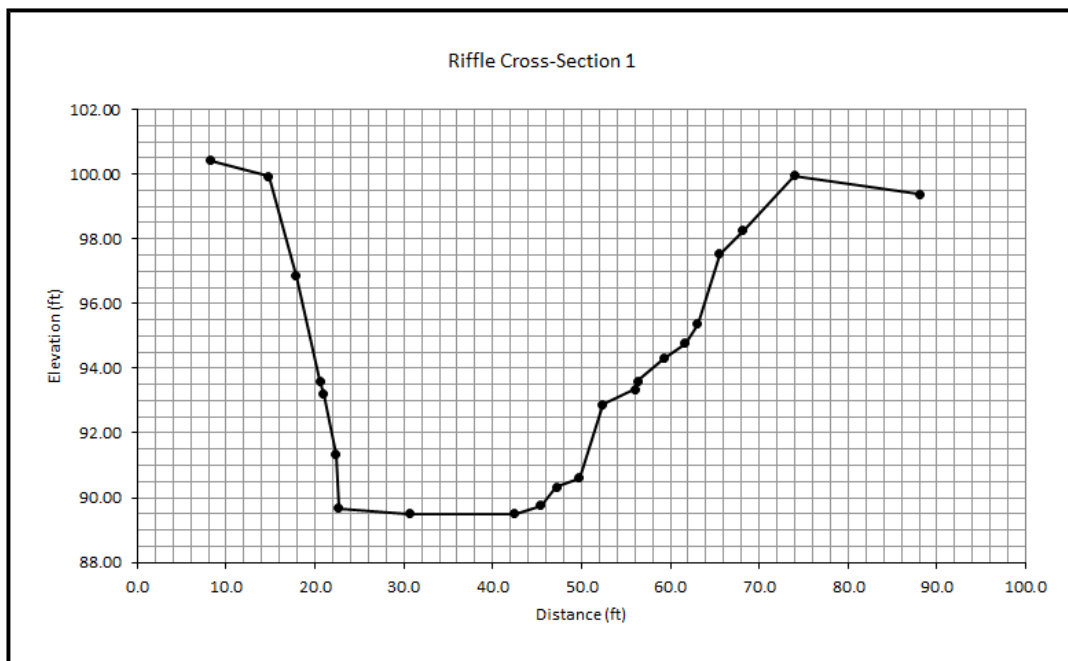
Median particle size: sand

Longitudinal slope: 0.0016 feet/foot

Stream classification: B5c



Area (square feet) =	116.4
Width (feet) =	35.7
Mean depth =	3.3
Max depth =	4.1
Width/depth ratio =	11.0
Entrenchment ratio =	1.4

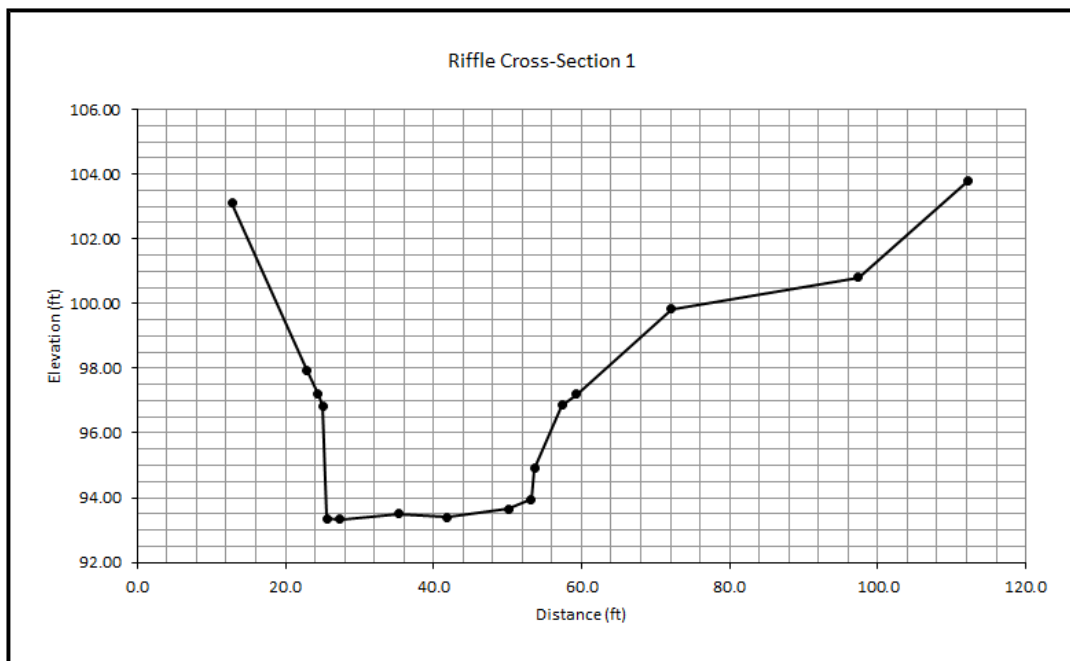


10. Kings Creek Ecoregion 45, South Carolina

Latitude: 35.118134
Longitude: -81.437161
Drainage area: 27.9 square miles
Median particle size: gravel
Longitudinal slope: 0.0026 feet/foot
Stream classification: E4



Area (square feet) =	109.9
Width (feet) =	34.9
Mean depth =	3.1
Max depth =	3.9
Width/depth ratio =	11.1
Entrenchment ratio =	2.4



11. South Rabon Creek Ecoregion 45, South Carolina

Latitude: 34.517892

Longitude: -82.155741

Drainage area: 30.0 square miles

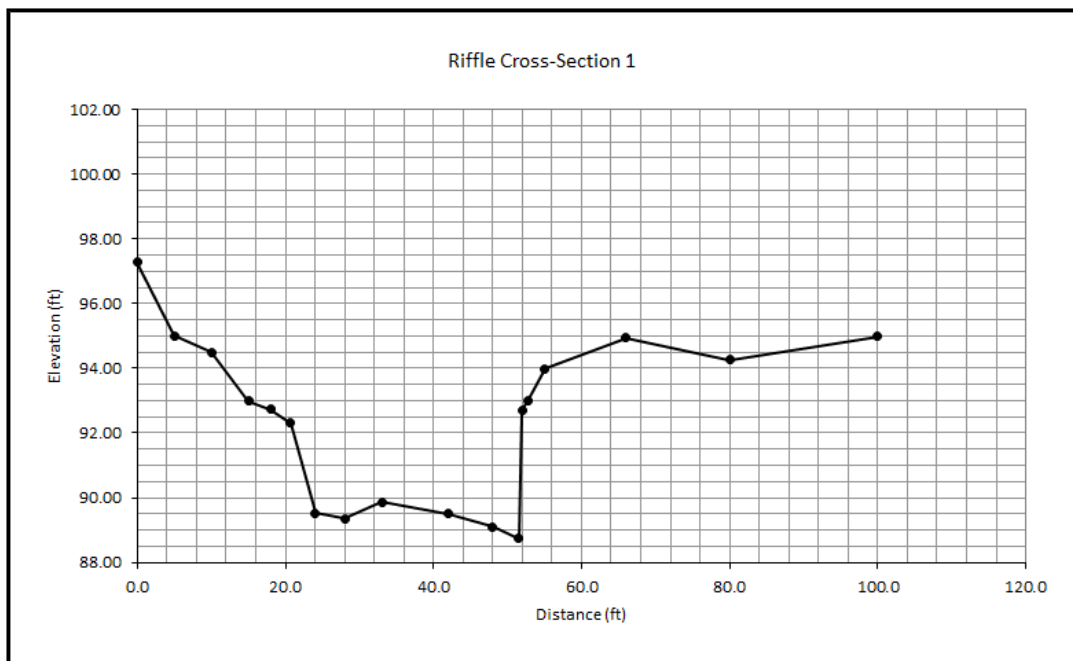
Median particle size: sand

Longitudinal slope: 0.0033 feet/foot

Stream classification: C5



Area (square feet) =	106.7
Width (feet) =	37.7
Mean depth =	2.8
Max depth =	4.2
Width/depth ratio =	13.3
Entrenchment ratio =	6.6



12. Allison Creek Ecoregion 45, South Carolina

Latitude: 35.065105

Longitude: -81.138798

Drainage area: 40.4 square miles

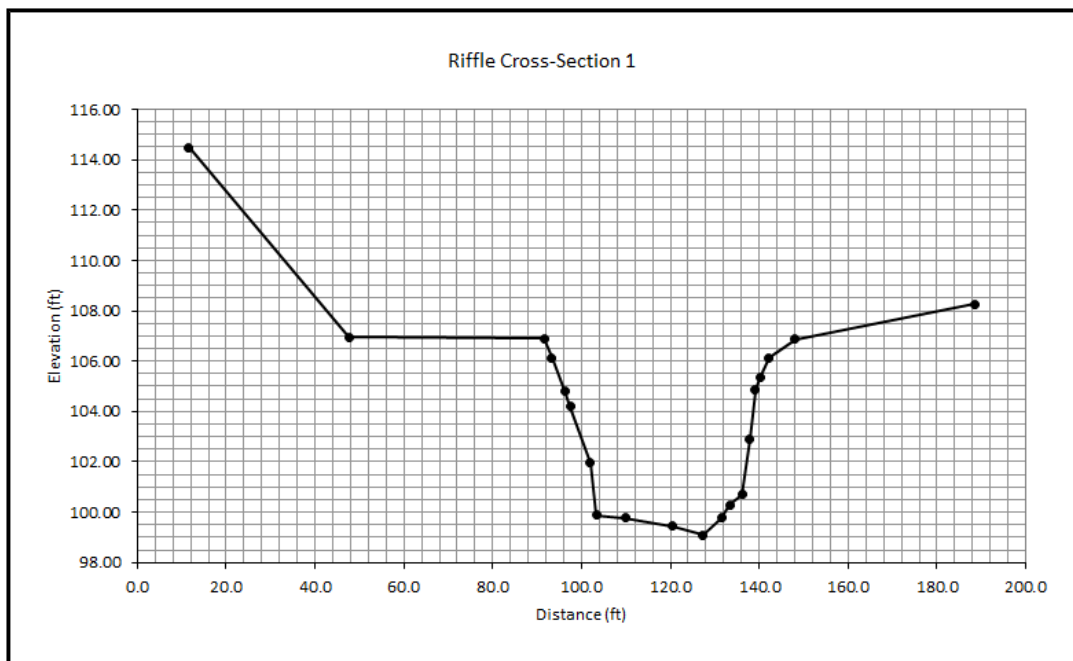
Median particle size: sand

Longitudinal slope: 0.0015 feet/foot

Stream classification: E5



Area (square feet) =	250.2
Width (feet) =	48.9
Mean depth =	5.1
Max depth =	7.1
Width/depth ratio =	9.5
Entrenchment ratio =	3.9



13. South Pacolet River Ecoregion 45, South Carolina

Latitude: 35.106304

Longitude: -82.129122

Drainage area: 55.6 square miles

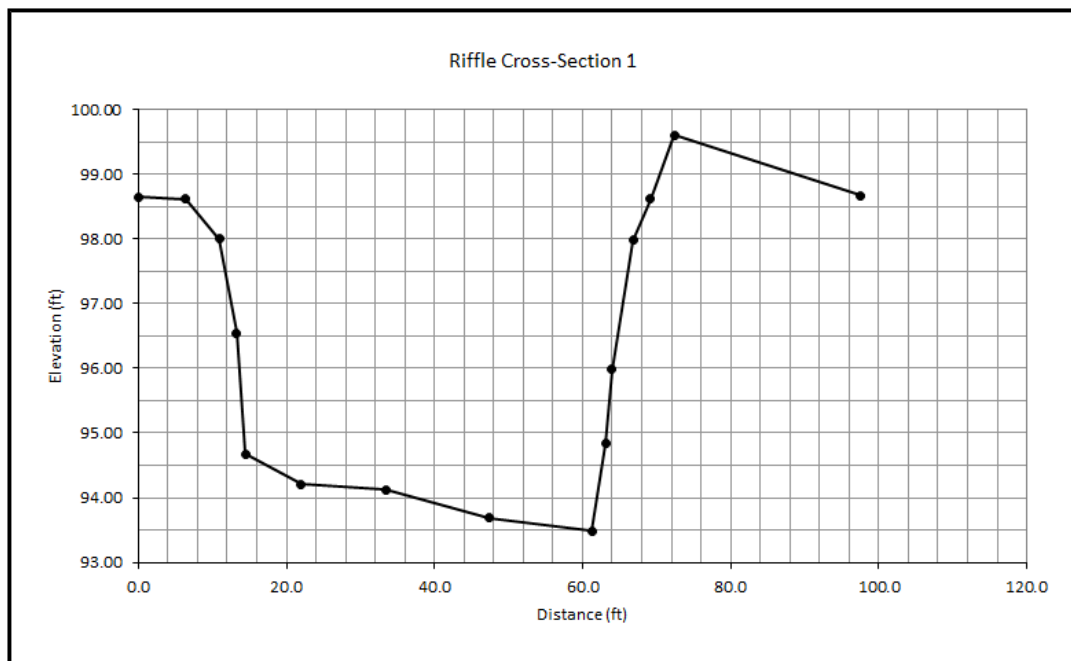
Median particle size: sand

Longitudinal slope: 0.0025 feet/foot

Stream classification: C5



Area (square feet) =	242.1
Width (feet) =	62.8
Mean depth =	3.9
Max depth =	5.1
Width/depth ratio =	16.3
Entrenchment ratio =	5.5



14. South Tyger River Ecoregion 45, South Carolina

Latitude: 34.920927

Longitude: -82.129849

Drainage area: 94.7 square miles

Median particle size: sand

Longitudinal slope: 0.0005 feet/foot

Stream classification: C5c-



Area (square feet) =	388.2
Width (feet) =	80.3
Mean depth =	4.8
Max depth =	6.0
Width/depth ratio =	16.6
Entrenchment ratio =	3.2

