GEOMORPHOLOGICAL CONDITION IN THE PICTURE SPRING BRANCH SUBWATERSHED, SEVERN RIVER WATERSHED, ANNE ARUNDEL COUNTY, MARYLAND: FY2021

Prepared for

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1.0 INTRODUCTION

Anne Arundel County is required to perform physical stream monitoring in the Picture Spring Branch Subwatershed in accordance with their National Pollutant Discharge Elimination System (NPDES) Municipal Separate Storm Sewer System (MS4) Discharge Permit (NPDES permit number MD0068306). The goal of this monitoring effort is to assess the implementation of best management practice (BMP) design criteria from the *2000 Maryland Stormwater Design Manual* approved by Maryland Department of the Environment (MDE). The BMP design criteria were applied to the stormwater management system constructed at the West County Library site, located in Odenton, Maryland, just west of the intersection of State Highways 170 (Telegraph Road) and 175 (Annapolis Road). Specifically, bioretention areas and dry swale structural BMPs, and the nonstructural credit "sheetflow to buffer" were incorporated into the library site development in order to mitigate the effects of stormwater runoff on Picture Spring Branch.

There are four additional stormwater BMPs within the watershed that influence the flows through the study reach. These include a dry detention pond, a retention pond, and two other detention ponds with shallow wetlands. Baseline conditions within the watershed, for both land use and BMP functionality, were developed as part of this long-term study. These conditions are monitored periodically to determine if changes within the watershed affect the conditions found in the stream channel.

To monitor the effectiveness of these BMPs on stream channel protection, the County implemented a monitoring program to characterize the biological and geomorphological conditions of the Picture Spring Branch Subwatershed, located within the Severn River Watershed, in the vicinity of the Odenton/West County Library. Physical condition assessments for Picture Spring Branch began in 2003 and is conducted on an annual basis. Biological and habitat monitoring to measure overall stream health has also been performed, but was discontinued after the Spring 2020 assessment.

This report summarizes the results of geomorphological assessments performed in Fall 2020 with comparisons to previous years' conditions and discusses the current watershed conditions.

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2.0 METHODS

2.1 SAMPLING LOCATIONS

The study area is located in the southwestern portion of the Picture Spring Branch Subwatershed, within the Severn River Watershed in Anne Arundel County, Maryland (Figure 2-1). The study area consists of the North Tributary and South Tributary and encompasses approximately 156 acres of drainage. The land use within the study area is dominated by developed land, with approximately 68% in residential, commercial, industrial, and transportation uses (Table 2-1). The paved and impervious surfaces account for approximately 35% of the catchment area. Less than one-third of the subwatershed (31.3%) is open space or wooded land cover, most of which surrounds the stream valley. Note that drainage areas and land use were updated in 2019 using Anne Arundel County LIDAR (2017) data.

Three biological monitoring locations are located within the study area, which were selected by County staff in 2006 (see Figure 2-1). Two sites were placed on the North Tributary and one site was placed downstream of the confluence with the South Tributary and below Piney Orchard Parkway (MD State Highway 170). Sites were marked in the field using silver tree tags labeled with the site name located at the upstream and downstream ends of each 75-meter sampling segment. Biological monitoring was discontinued in FY2021 at these three locations.

Table 2-1. Summary of land use in the Picture Spring Branch study area catchment, Anne Arundel County

Land Use	Acres	% of Watershed Area
Commercial	15.8	10.1
Industrial	16.9	10.8
Open Space	6.0	3.8
Residential	56.3	36.0
Transportation	16.8	10.7
Utility	1.6	1.0
Forest	43.0	27.5
Total	**156.4**	**100.0**

Source: Anne Arundel County Department of Public Works

Five previously established cross-sections were re-measured in Fall 2020 as part of the annual geomorphological assessment. Three cross-sections are located along the North Tributary, one is located on the South Tributary, and another is located downstream of Piney Orchard Parkway (see Figure 2-1). Permanent cross-section monuments are located on each bank and consist of iron bolts set in concrete flush to the ground surface.

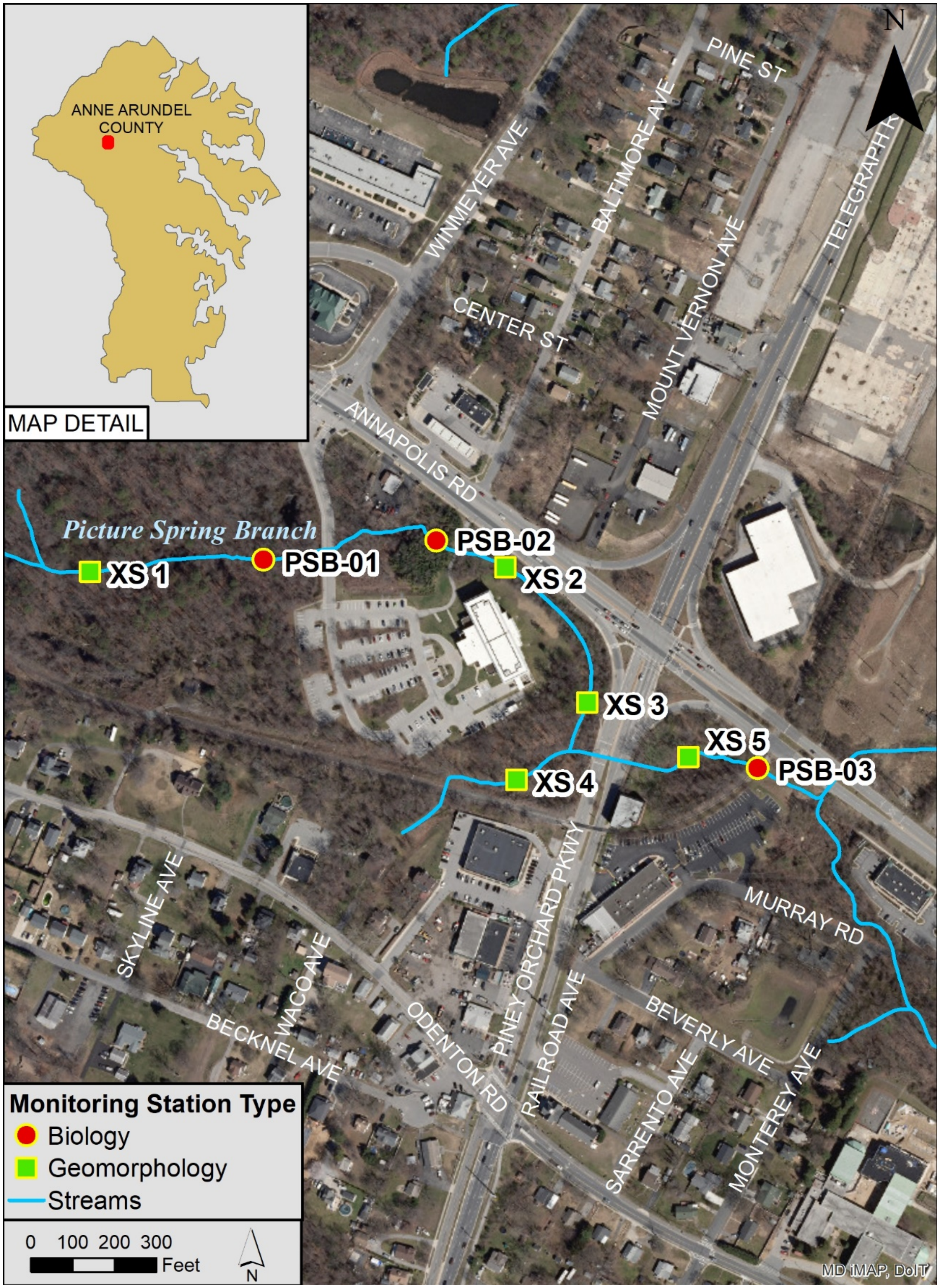

Figure 2-1. Picture Spring Branch study area stream monitoring locations

2.2 FIELD METHODS

Geomorphic assessment data were collected in accordance with the standard operating procedures (SOPs) approved for the County's NPDES Program. All methods are consistent with previous years' methods (with applicable updates) to ensure data comparability between years. Collection methods are summarized below. Field data were collected in 2020 by Versar, Inc.

Geomorphic assessments included a survey of the longitudinal profile, measurement of permanent cross-sections, and representative pebble counts. Data from these measurements were used to determine the stream type of each reach as categorized by the Rosgen Stream Classification (Rosgen 1996), which can be found in Appendix A. Geomorphic assessments were conducted following established quality control measures found in Appendix C.

The longitudinal profile was performed throughout the entire study area, totaling 1,968 linear feet along the North Tributary and continuing below Telegraph Road (Maryland Route 170) and 363 linear feet along the South Tributary. The goal of the longitudinal profile was to identify indicators and elevations of the bankfull discharge (i.e., bankfull indicators) and to determine the bankfull water surface slope throughout the study reach. Once bankfull indicators were identified and elevation measurements made, channel thalweg and water surface elevations were also recorded.

The cross-section surveys were performed at the five permanent cross-section locations (Figure 2-1). Photos were taken of upstream, downstream, left bank, and right bank views at each cross-section location. Photographs are included in Appendix B. Cross-section surveys consisted of measuring the topographic variability of the associated stream bed, floodplains, and terraces, including:

- Monument elevations
- Changes in topography
- Top of each channel bank
- Elevations of bankfull indicators
- Edge of water during the time of survey
- Thalweg or deepest elevation along active channel
- Depositional and erosional features within the channel

During the cross-sectional survey, the following measurements and calculations of the bankfull channel, which are critical for determining the Rosgen stream type of each reach, were also collected:

- Bankfull Width (Wbkf): the width of the channel at the elevation of bankfull discharge or at the stage that defines the bankfull channel.
- Mean Depth (dbkf): the mean depth of the bankfull channel.

- Bankfull Cross-sectional Area (Abkf): the area of the bankfull channel, estimated as the product of bankfull width and mean depth.
- Width Depth Ratio (Wbkf/dbkf): the ratio of the bankfull width to mean depth.
- Maximum Depth (dmbkf): the maximum depth of the bankfull channel, or the difference between the thalweg elevation and the bankfull discharge elevation.
- Width of Floodprone Area (Wfpa): the width of the channel at a stage of twice the maximum depth. If the width of the floodprone area was far outside of the channel, its value was visually estimated or paced off.
- Entrenchment Ratio (ER): the ratio of the width of the floodprone area versus bankfull width.
- Sinuosity (K): ratio of the stream length versus the valley length or the valley slope divided by the channel slope. Sinuosity was visually estimated, or the valley length was paced off so that an estimate could be calculated.

To quantify the distribution of channel substrate particle sizes within the study area, a modified Wolman pebble count (Rosgen 1996) was performed at each cross-section location. Reach-wide proportional counts were used. Each pebble count consists of stratifying the reach based on the frequency of channel features in that reach (e.g., riffle, run, pool, glide) and measuring 100 particles across ten transects (i.e., 10 particles in each of 10 transects). The transects are allocated across all feature types in the proportion at which they occur within the reach. The intermediate axis of each measured pebble is recorded. The goal of the pebble count is to measure 100 particles across the bankfull width of the channel and calculate the median substrate particle size (i.e., D_{50}) of the reach. This value is used for categorizing the sites into the Rosgen Stream Classification (Rosgen 1996). If a channel was clearly a sand or silt bed channel with no distinct variation in material size, the pebble count was not performed, and the D_{50} was visually estimated. However, if the channel did have variation in bed material size from feature to feature, a full pebble count was performed.

2.3 DATA ANALYSIS

Geomorphic field data were compared to regional relationships of bankfull channel geometry developed by the USFWS for streams in the Maryland Coastal Plain (McCandless 2003) and by Anne Arundel County Department of Public Works (AADPW 2002) for urban streams within the County. Estimates of the bankfull channel parameters, the longitudinal profile survey, the cross-section survey, and the pebble count data were entered into *The Reference Reach Spreadsheet* (Mecklenburg 2006) and analyzed for each assessment site. These data were used to identify each stream reach as one of the stream types categorized by the Rosgen Stream Classification (Rosgen 1996). In the Rosgen Classification methodology, streams are categorized based on their measured field values of entrenchment ratio, width/depth ratio, sinuosity, water surface slope, and channel materials according to the table in Appendix A: Rosgen Stream Classification. As illustrated in Appendix A, the Rosgen Stream Classification categorizes streams into broad stream types, which are identified by the letters Aa, A, B, C, D, DA, E, F, and G. Table 2-2 includes general descriptions of each Rosgen stream type. A summary of the stream types identified for the streams in this study is included in Appendix B: Geomorphic Assessment Results.

Table 2-2. Rosgen Stream Classification types

Channel Type	General Description
Aa+	Very steep, deeply entrenched, debris transport, torrent streams.
A	Steep, entrenched, confined, cascading, step/pool streams. High energy/debris transport associated with depositional soils. Very stable if bedrock or boulder dominated channel.
B	Moderately entrenched, moderate gradient, riffle dominated channel with infrequently spaced pools. Moderate width/depth ratio. Narrow, gently sloping valleys. Very stable plan and profile. Stable banks.
C	Low gradient, meandering, slightly entrenched, point-bar, riffle/pool, alluvial channels with broad, well-defined floodplains.
D	Braided channel with longitudinal and transverse bars. Very wide channel with eroding banks. Active lateral adjustment, high bedload and bank erosion.
DA	Anastomosing (multiple channels) narrow and deep with extensive, well-vegetated floodplains and associated wetlands. Very gentle relief with highly variable sinuosities and width/depth ratios. Very stable streambanks.
E	Low gradient, highly sinuous, riffle/pool stream with low width/depth ratio and little deposition. Very efficient and stable. High meander/width ratio.
F	Entrenched, meandering riffle/pool channel on low gradients with high width/depth ratio and high bank erosion rates.
G	Entrenched “gully” step/pool and low width/depth ratio on moderate gradients. Narrow valleys. Unstable, with grade control problems and high bank erosion rates.

Source: Rosgen (1996).

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3.0 RESULTS

The geomorphic assessment field data were compared to both the Maryland Coastal Plain (MCP) regional relationships of bankfull channel geometry (McCandless 2003) and relationships for gauged urban Coastal Plain streams developed specifically for Anne Arundel County (AADPW 2002) to determine how bankfull characteristics observed in the field compared to those predicted by the MCP and urban relationships. Comparisons of bankfull width, bankfull cross-sectional area, and mean bankfull depth are shown in Figures 3-1, 3-2, and 3-3, respectively. In Fall 2020, bankfull width values fell between the MCP and urban curve values at three sites, with two points wider than predicted by either curve. Field data for mean bankfull depth mainly fell between the MCP curve and urban curve predictions, with one site more shallow than predicted by either curve. All bankfull cross-sectional area field data values fell between the MCP curve and urban curve predictions. Overall, most of the field data fell somewhere between the MCP and urban relationships. However, the regional curves were developed using streams with drainage areas ranging from 0.3 to 89.7 square miles, with the majority of data collected in watersheds greater than one square-mile with low (zero to three percent) imperviousness. Thus, it is possible that stream channels with smaller drainage areas and more imperviousness, such as those studied in this assessment (ranging from 0.07 to 0.23 square miles), exhibit greater variability in channel dimensions when compared to the MCP relationships. Additionally, the Rosgen method is best used on streams that are free to adjust their lateral boundaries under the current discharge regime experienced by the system (Rosgen 1996), conditions which do not necessarily exist in the study area. For example, cross-sections 2, 3, and 5 are underlain by concrete trapezoidal channels, possibly making the accurate determination of the bankfull indicators in the field at these locations problematic. Regardless, given the high imperviousness of the study drainage area (35%) and the modified nature of the channel, it is not surprising that the field data deviated in some cases from the MCP curve and were more closely matched to urban curve predictions for bankfull width.

Based on the Rosgen Classification scheme, one site was classified as an E channel, one site as a C channel, one site as a G channel, and two sites as F channels (Table 3-1). Water surface slopes along the study area ranged from 0.0017 ft/ft to 0.037 ft/ft. All five sites had channel substrates dominated by sand; D_{50} values ranged from 0.091 mm to 0.12 mm. Detailed summaries of the geomorphic data and stream types are included in Appendix B: Geomorphic Assessment Results.

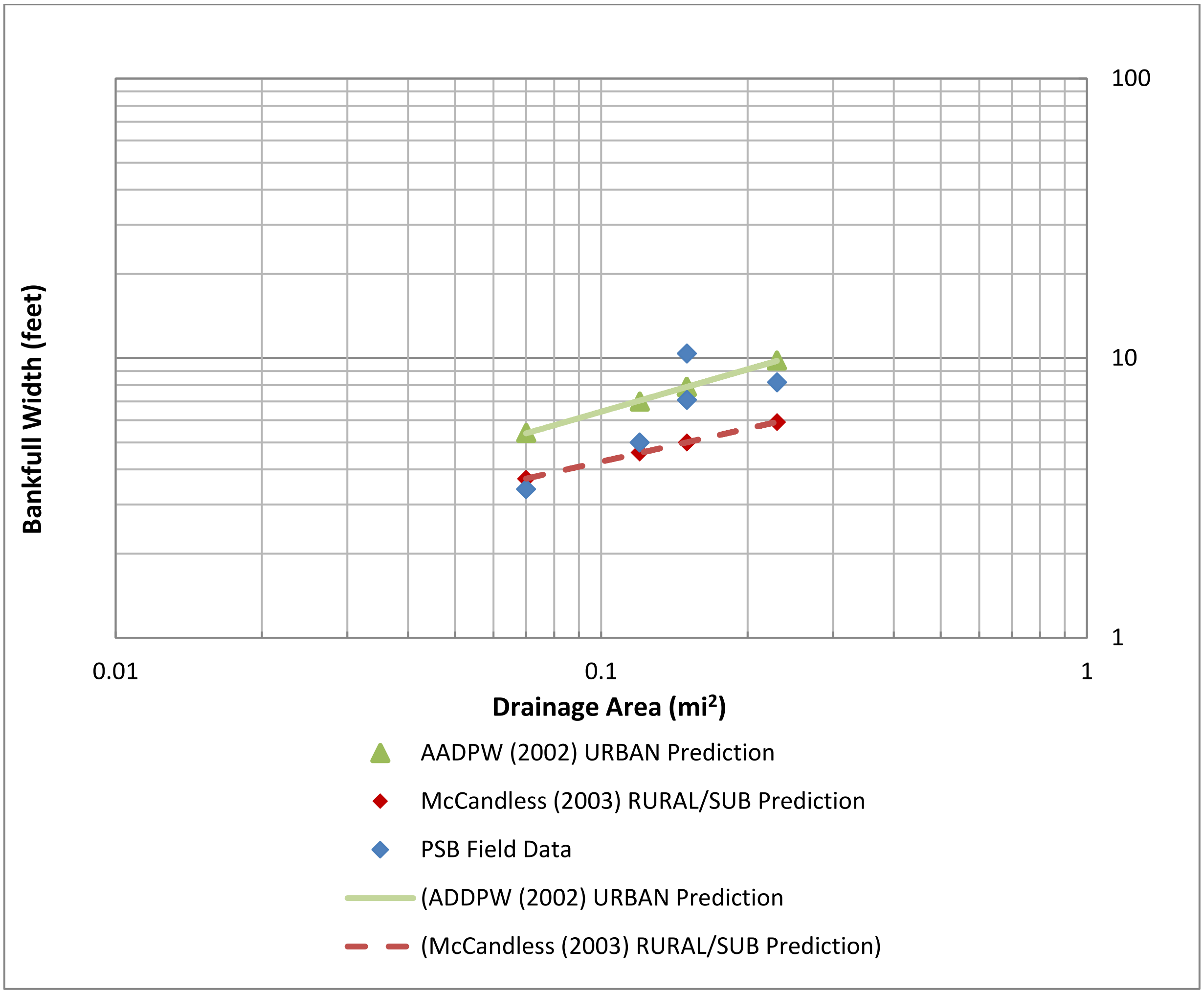

Figure 3-1. Comparison of the bankfull width drainage area relationship between Picture Spring Branch (PSB) Fall 2020 field data and regional relationship curve data

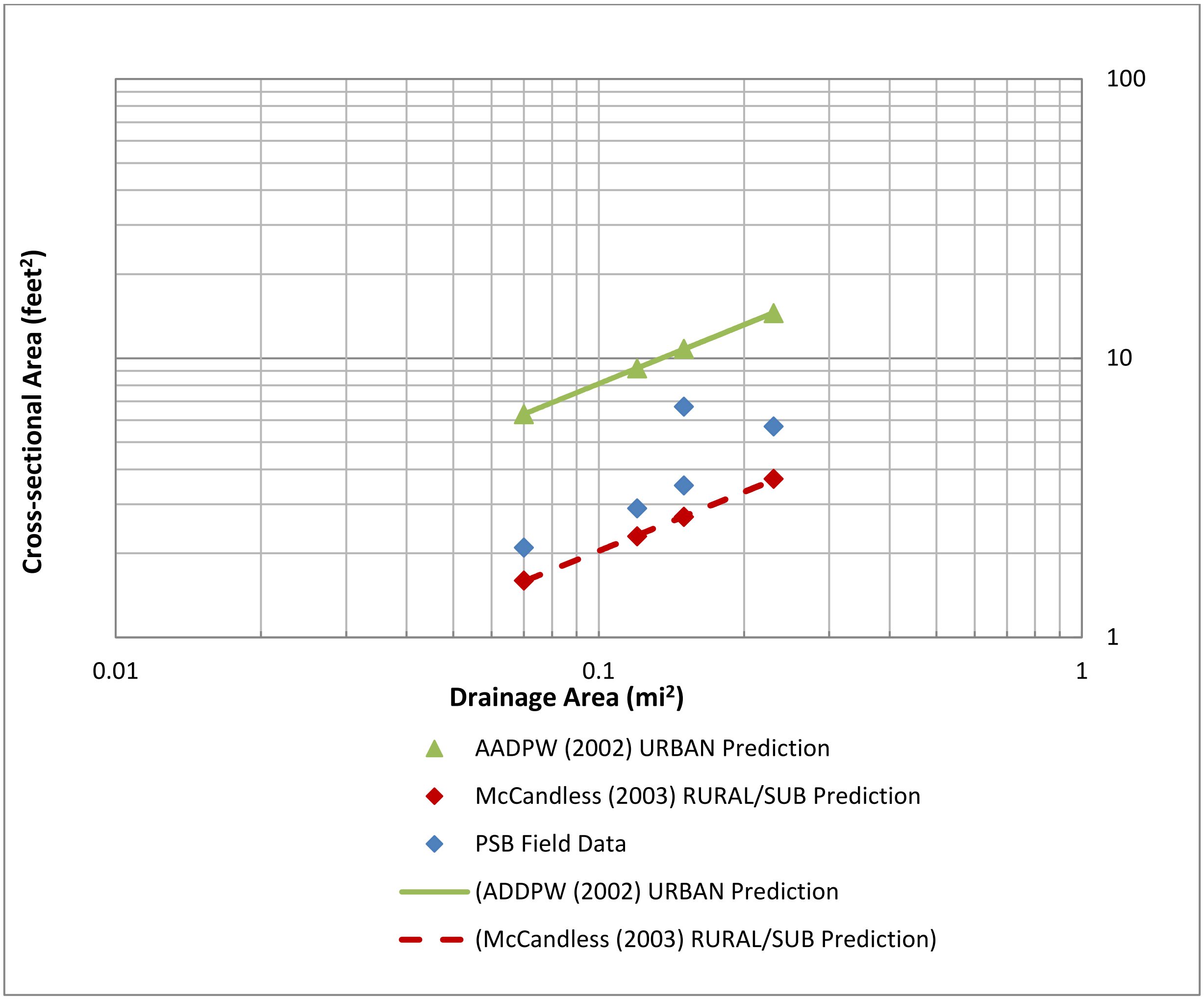

Figure 3-2. Comparison of the bankfull cross-sectional area drainage area relationship between Picture Spring Branch (PSB) Fall 2020 field data and regional relationship curve data

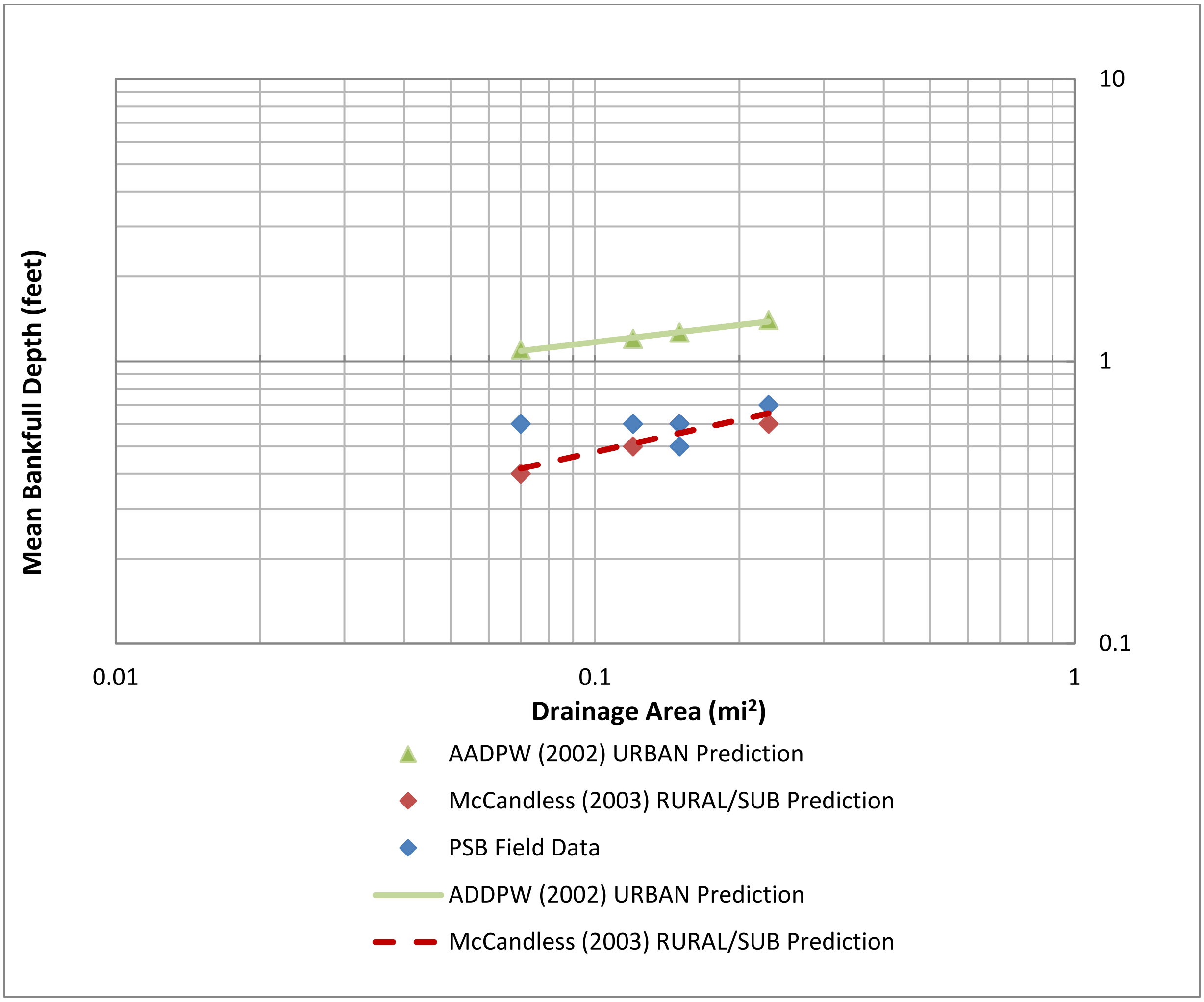

Figure 3-3. Comparison of the mean bankfull depth drainage area relationship between Picture Spring Branch (PSB) Fall 2020 field data and regional relationship curve data

Table 3-1. Rosgen Classification Results – Fall 2020

Cross-section	Classification	D_{50} (mm)	Water Surface Slope (ft/ft)
XS-1	E5	0.093	0.0048
XS-2	F5	0.097	0.0017
XS-3	F5	0.091	0.0054
XS-4	G5	0.12	0.037
XS-5	C5	0.092	0.0042

Cross-section 1, located in the well-forested upper portion of the North Tributary continues to exhibit characteristics typical of both C and E type channels, as well as some characteristics that fit neither. For example, E channels are typically very sinuous; however, this reach had very little sinuosity. Likewise, C channels often have numerous point bars, which were not common along this reach. Based on these characteristics, in 2017 best professional judgment was applied and the classification was changed from a C5 to an E5 given the decreased entrenchment and width/depth ratio. The same conditions were still present in 2018, 2019, and 2020 and the channel remains classified as an E5.

F5 channels were identified at cross-sections 2 and 3 which are located on the North Tributary upstream of Maryland State Highway 170. The stream segment along this portion of the North Tributary was over-widened as a result of past alteration with the installation of a concrete trapezoidal channel. However, it continues to adjust by filling with sediment and woody debris, thus establishing a more “natural” stream channel within the man-made, engineered channel.

Cross-section 5, located downstream of Maryland State Highway 170, was reclassified from a C5 channel to an F5 channel in Spring 2020 due a decrease in entrenchment ratio. The Rosgen classification at this cross-section previously changed from an F5 in 2014 to a C5 in 2015 and remained classified as a C5 channel with similar entrenchment and width/depth ratios from 2016 through 2019. This location was reclassified again in Fall 2020 back to a C5 channel due to an increase in entrenchment ratio.

A G5 channel was maintained at cross-section 4 on the South Tributary, a change from an E5b channel in 2019 to G4 channel in Spring 2020. While it is possible that this reach may exhibit both G and E characteristics along different portions of the reach, it was assigned an E5b classification in 2019, primarily based on the entrenchment and width/depth ratios measured at the cross-section location, as well as the channel slope within the vicinity of the cross-section. However, a reduced entrenchment ratio and increased width/depth ratio observed in 2020 more aligned this site as a G channel. In comparison to the North Tributary, the South Tributary is not over-widened and has a steeper longitudinal gradient than the North Tributary. Indicators were observed that show some limited floodplain connectivity along the upstream portion of the tributary where the cross-section is located. However, just downstream of the cross-section location, the channel is noticeably entrenched and shows signs of active downcutting. Significant changes in the shape of this cross-section were observed during the 2013 survey, as the channel had noticeably deepened and widened since the 2012 survey (Appendix B). Over the next year, aggradation occurred affecting the bed level by raising it approximately 0.5 feet. From 2014 to 2015, the channel shifted slightly but remained stable in terms of aggradation or deepening. Noticeable aggradation occurred again in 2016 with an approximate 0.5-foot rise in bed elevation, but the bed was stable between the 2016 and 2018 surveys. Between 2018 and 2019, the stream experienced downcutting (approximately 0.3 ft) and erosion (slightly less than one foot at the most affected area) at/near the right bank; between 2019 and 2020 the downcutting continued at this location, deepening by approximately 0.5 ft and impacting the left bank, such that the channel edges are now similar and the stream bed is flat across the width of the channel.

Analysis of the South Tributary longitudinal profile overlay from 2007 through Fall 2020 shows considerable downcutting between stations 1+00 and 2+20 (Appendix B). However, during 2014, the pool near station 2+00 had mostly filled in. This trend continued in 2015, with the pool working its way up the reach to station 1+80. In 2016, the pool remained at station 1+80 but deepened by almost a foot with no additional changes occurring in 2017. In 2018, the pool shifted slightly downstream and deepened by about half a foot. In 2019, the pool filled in slightly, losing about 0.3 feet in depth. In Spring 2020, the location of the pool remained the same but showed signs of scouring upstream and aggradation downstream, while deepening of approximately 0.5 feet was seen at this pool in Fall 2020. The headcut and large scour pool between stations 2+68 and 2+90 just downstream from this eroded section have not increased in height nor depth. However, in 2016 this scour pool shifted downstream by several feet. Furthermore, aggradation raised the channel bed by almost a foot between 2017 and 2018. Little change was observed in this area between 2018 and 2019. This headcut was found to have aggraded in the Spring 2020 survey and eroded and widened in the Fall 2020 survey. It is recommended that this area continue to be monitored, as further erosion could eventually lead to undermining of the concrete-lined channel just downstream.

An overlay of North Tributary longitudinal profiles shows little change occurring to this reach from 2007 through Spring 2020; significant aggradation was seen throughout this reach during the Fall 2020 survey (Appendix B). Numerous man-made structures (i.e., culverts, concrete-lined channel) throughout this reach appear to be providing adequate grade control, preventing substantial channel degradation. In one portion of the reach between cross-sections 1 and 2 (profile stations 383 – 454), notable aggradation has occurred particularly between 2016 and 2020. This is the area just above the Winmeyer Avenue culvert. Aggradation also appears to be occurring between stations 1,000 and 1,300, between stations 1,400 and 1,500, as well as between stations 1,800 and 1,950; continued monitoring of these areas is recommended to further determine if they continue to aggrade or return to conditions seen in prior surveys.

4.0 SUMMARY AND CONCLUSIONS

4.1 GEOMORPHIC ASSESSMENT SURVEY SUMMARY

The majority of the streams within the Picture Spring Branch study area have been altered by past channelization and the installation of concrete-lined channels, resulting from modifications made to accommodate runoff from Maryland State Highways 170 and 175, running both perpendicular and parallel to the stream channel, respectively. Consequently, stream reaches in the vicinity of cross-sections 2 and 3 on the North Tributary and mainstem were over-widened and resulted in F channels at these locations. A notable amount of sediment has deposited in these concrete channels in recent surveys and it appears as though these channels have become naturalized. Cross-sections 2 and 3 appeared quite stable during recent years, having shown very little change from previous surveys. Cross-section 5 experienced notable aggradation across its total width between 2011 and 2012. Between 2012 and 2020, the right-side stream bed at cross-section 5 continued to erode while the left side had nominal change from 2014 to 2020. This character has resulted in this channel being classified as either a C or F stream type, rating as a C5 channel in Fall 2020 after an F5 classification in the Spring 2020 survey.

Past channelization also appears to have occurred on the South Tributary in the vicinity of cross-section 4. The slope of the South Tributary is much greater than that of the North Tributary, and the channel showed signs of active downcutting between 2003 and 2013. Between 2018 and 2019, the channel bed downcut approximately 0.3 ft further and the right bank experienced up to one foot of erosion, resulting in increased channel dimensions between 2018 and 2019. Between 2019 and Spring 2020, the stream bed along the left bank downcut approximately 0.3 ft, resulting in a flatter stream bed and further increased channel dimensions, leading to a change in Rosgen stream type classification. Minimal aggradation was noted between Spring 2020 and Fall 2020 surveys but was not enough to change Rosgen classifications between the surveys.

Historically, the stream reach in the Picture Spring Branch study area that appeared least disturbed was in the vicinity of cross-section 1. This section of stream is in a forested upper portion of the North Tributary and had historically been classified as a C stream type during the early years of this study. Due to downcutting and widening, this reach was re-classified as an E5 channel in 2017 and has remained an E5 from 2018 through Fall 2020, as downcutting and widening have continued and stabilized, respectively.

To compare changes over time, the cross-sectional area from 2011 through Fall 2020 was calculated for each cross-section using the top of bank elevation from the baseline survey to standardize comparisons and reduce variability among more subjective bankfull elevation reference points, or even changes that can occur to top of bank elevations from year to year. It is important to note that calculations prior to 2011 did not use this baseline reference elevation; instead, the corresponding year's top of bank elevation was used to calculate cross-sectional area. Consequently, these values are not directly comparable to the cross-sectional areas reported in 2011 through Fall 2020. Comparison of baseline cross-sectional area is, however, comparable from 2011 through Fall 2020 as all calculations are made using the same top of bank elevation.

Channel dimensions appear moderately constant for three of the five cross-sections compared to baseline conditions (Table 4-1). The stream channel at cross-sections 2, 3, and 5 has remained relatively stable, with cross-sectional area decreasing only 7.3% and 8.4%, and 0.6%, respectively, since the beginning of the study in 2003. In contrast, larger increases in cross-sectional areas have occurred at the smaller cross-sections 1 and 4. Partially due to recent channel deepening and also influenced by discrepancies in calculations, cross-sectional area at cross-section 1 increased 79.7% from baseline conditions in 2005. Cross-section 4, which had remained relatively stable during 2016-2018, eroded and downcut between 2018 and 2020, resulting in a cross-sectional area increase of 40.8% from baseline conditions. Unsurprisingly, cross-sections 1 and 4 are located in portions of the stream where there has been no engineering or armoring of the channel, while the other three cross-sections have been channelized. Cross-section 1 is also located upstream of the stormwater BMPs implemented in the watershed as part of the West County Library project, so is therefore unaffected by their presence. These cross-sections are also the smallest of the five, so any changes in cross-sectional area will seem magnified. When examining changes in cross-sectional area since 2011 with calculations standardized as discussed above, the changes in cross-sectional area decrease at all five cross-sections to much lower percentages. Cross-sections 1 and 4 still exhibit the greatest overall percent change using these standardized calculations due to erosion and deepening at these stations (Table 4-1).

4.2 CONCLUSIONS

Based upon the data collected over the course of this study, it appears that the development of the West County Library site has not accelerated the degradation of this system. While geomorphological conditions from prior surveys have fluctuated slightly from year to year, the overall conditions have changed minimally when compared to baseline data. It is likely that the best management practices installed within the watershed have reduced the impact of some stressors affecting the stream (i.e., hydrologic alteration) such that the system has begun to stabilize from past alteration and land use modifications (i.e., extensive channelization).

Table 4-1. Summary of cross-sectional area (square feet) at the five cross-sections and changes over time

Cross-section[a]	XS-1	XS-2	XS-3	XS-4	XS-5
July 2003	ND	146.0	84.5	7.6	35.5
Jan 2005	6.4	164.4	83.2	5.5	35.2
March 2006	7.6	143.9	81.0	7.6	34.0
March 2007	6.8	142.6	81.1	7.6	32.9
May 2008	6.3	141.5	81.5	7.4	34.9
July 2009	6.8	142.8	80.8	8.4	33.4
May 2010	6.0	145.2	80.5	9.7	34.5
July 2011[b]	9.7	143.0	81.9	9.3	34.8
April 2012[b]	8.0	143.1	81.8	9.2	28.4
July 2013[b]	8.6	142.8	80.4	10.5	30.9
June 2014 [b]	8.8	141.9	77.4	10.0	32.6
June 2015 [b]	10.2	143.0	80.9	10.3	31.6
March 2016 [b]	9.8	144.7	75.4	9.6	33.2
February 2017[b]	10.2	143.3	78.6	9.3	32.7
March 2018[b]	10.0	141.3	78.8	9.2	34.2
March 2019[b]	11.2	139.2	78.2	10.6	34.1
March 2020[b]	10.8	138.3	77.1	11.3	35.6
October 2020[b]	11.5	135.4	77.4	10.7	35.3
% Change 2003-2020	79.7[c]	-7.3	-8.4	40.8	-0.6
% Change 2011-2020	18.6	-5.2	-5.5	15.1	1.4

[a] All values listed here are for top of bank area
[b] Values obtained using reference elevations (top of bank) from baseline measurements
[c] % change from 2005
ND = No Data

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5.0 REFERENCES

Anne Arundel County Department of Public Works (AADPW). 2002. Cypress Creek Tributary Assessment and Findings Report. Prepared by Bayland Consultants and Designers, Inc., and Clear Creek Consulting. 32 pp., plus Appendices.

Code of Maryland Regulations (COMAR), Title 26, Department of the Environment, Part 1, Vol. XXIII.

McCandless, T.L. 2003. *Maryland stream survey: Bankfull discharge and channel characteristics of streams in the Coastal Plain hydrologic region*. U.S. Fish and Wildlife Service, Annapolis, MD. CBFO-S03-02.

Mecklenburg, D. 2006. *The Reference Reach Spreadsheet*. Version 4.3 L. Ohio Department of Natural Resources.

Rosgen, D.L. 1996. *Applied River Morphology*. Wildland Hydrology, Pagosa Springs, CO.

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APPENDIX A

ROSGEN STREAM CLASSIFICATION

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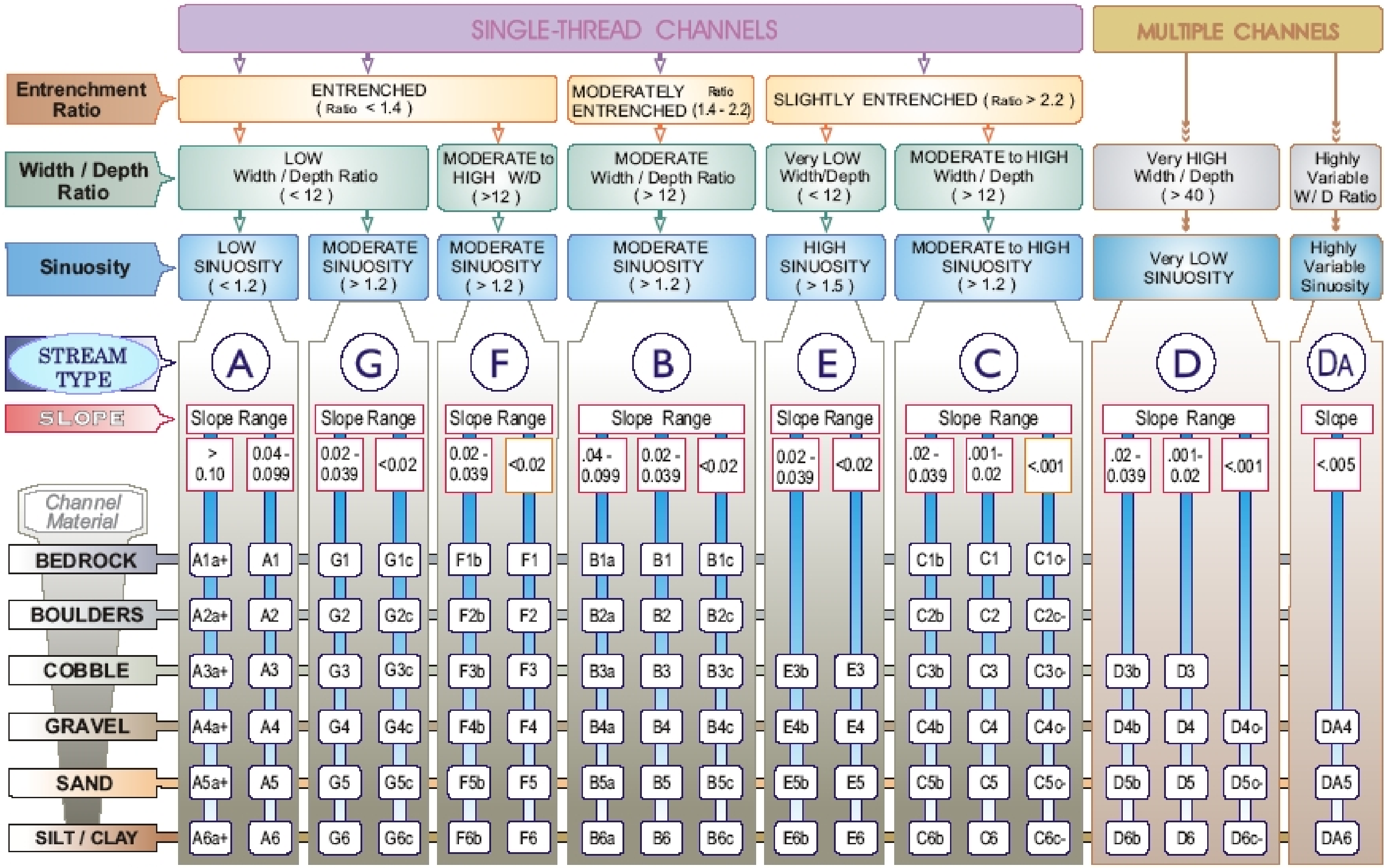
The Key to the Rosgen Classification of Natural Rivers



KEY to the ROSGEN CLASSIFICATION of NATURAL RIVERS. As a function of the *"continuum of physical variables"* within stream reaches, values of ***Entrenchment*** and ***Sinuosity*** ratios can vary by +/- 0.2 units; while values for ***Width / Depth*** ratios can vary by +/- 2.0 units.

Source: Rosgen, D.L. 1996. *Applied River Morphology*. Wildland Hydrology, Pagosa Springs, CO.

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APPENDIX B

GEOMORPHIC ASSESSMENT RESULTS

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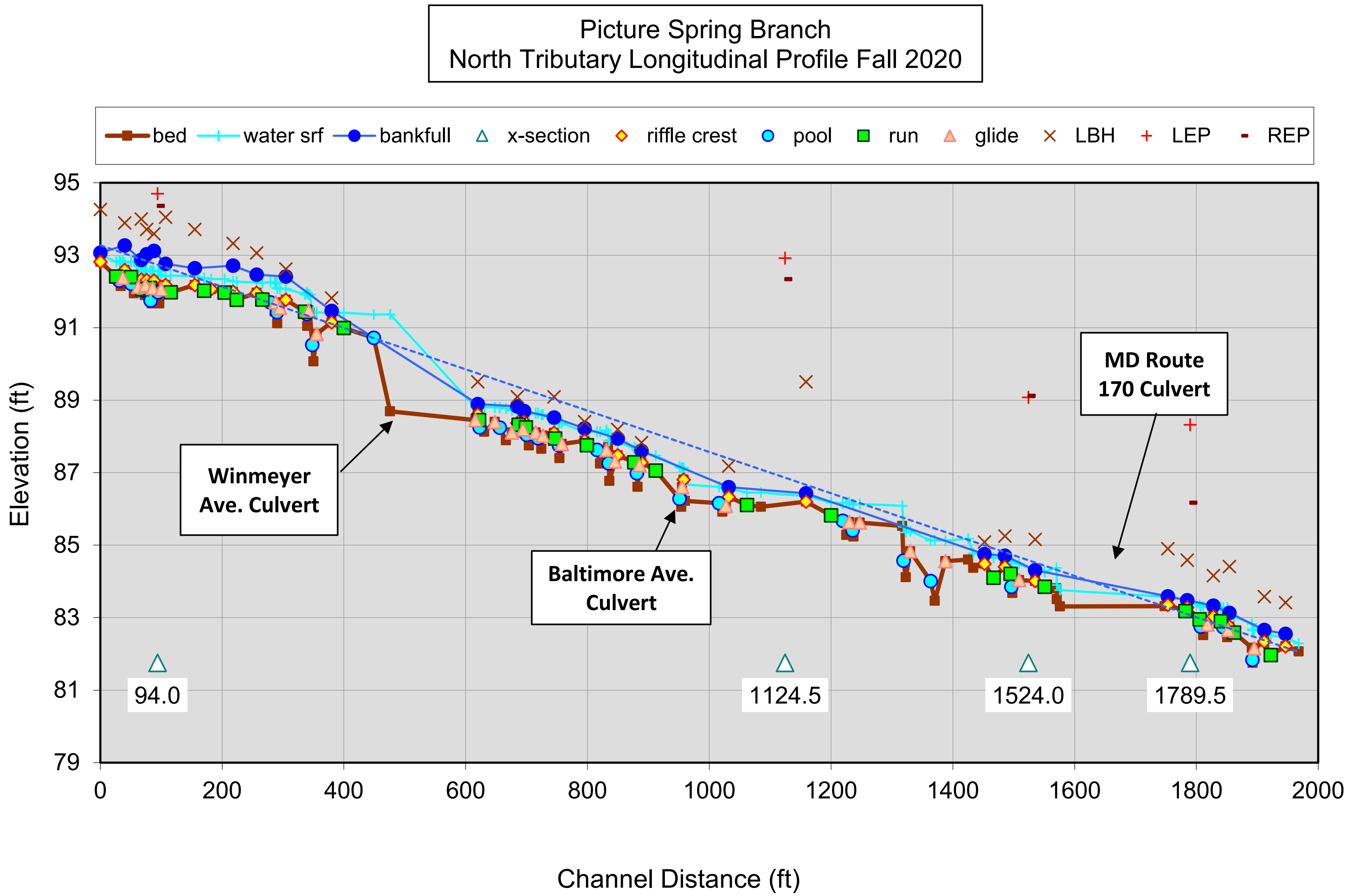
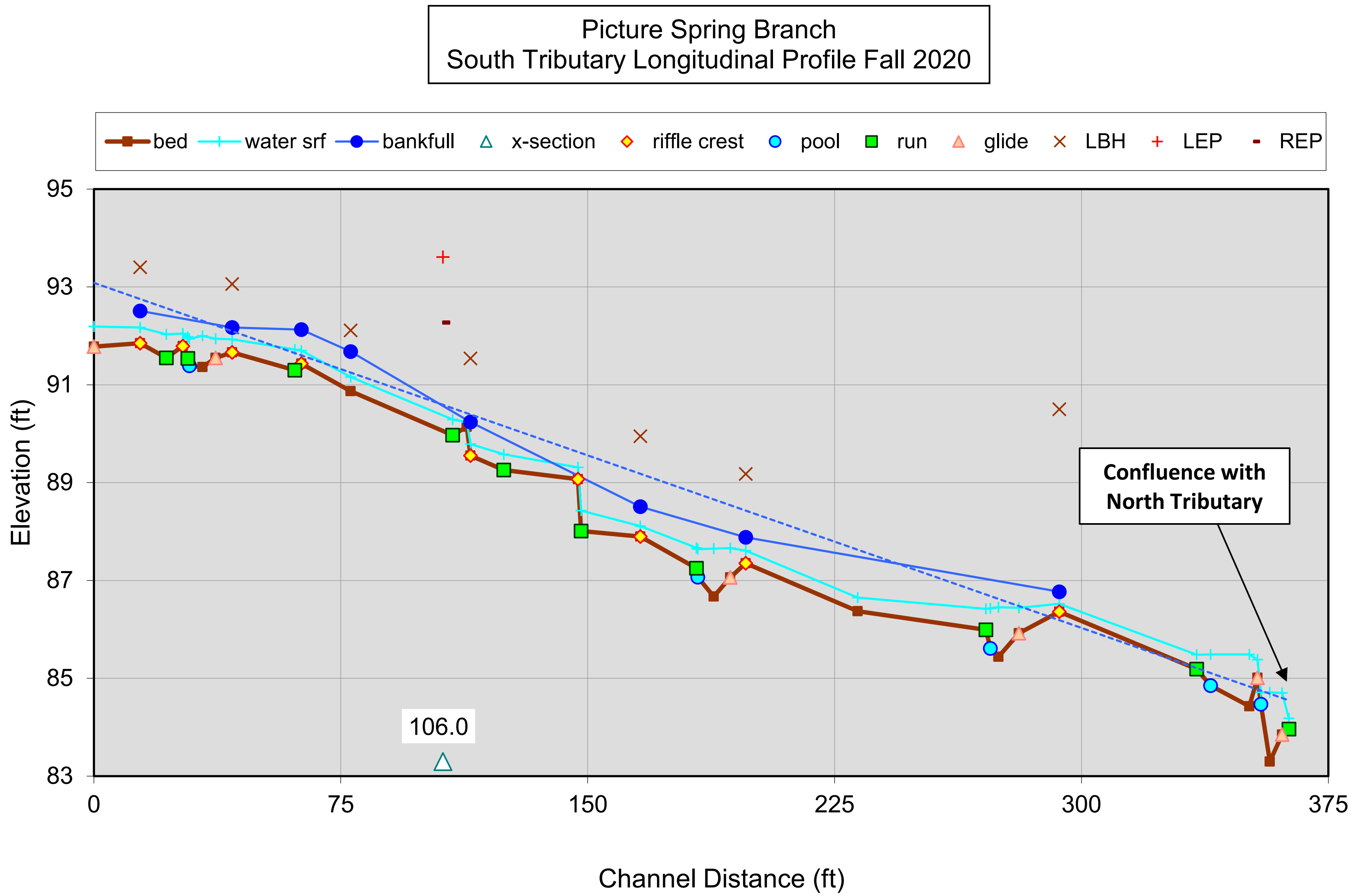
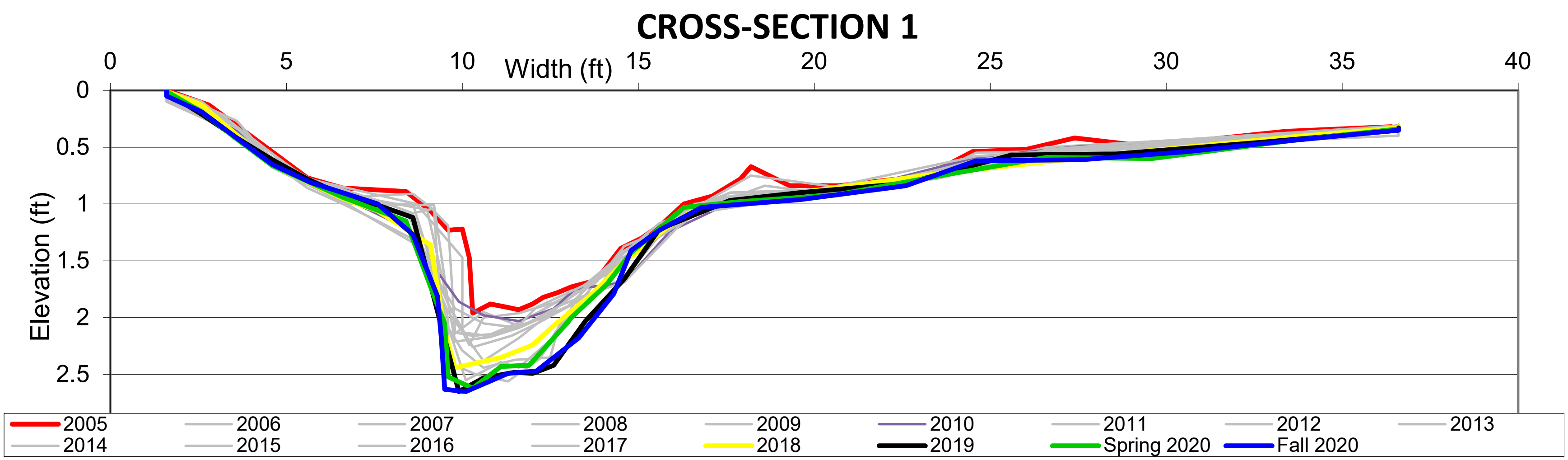
Picture Spring Branch
Fall 2020 Geomorphic Assessment Results Summary

Assessment Parameter	Cross-section				
	XS-1 Pool @ Sta. 0+94	XS-2 Run @ Sta. 11+24.5	XS-3 Pool @ Sta. 15+24	XS-4 Run @ Sta. 1+06 on South Tributary	XS-5 Riffle @ Sta. 17+89.5
Classification	E5	F5	F5	G5	C5
Bankfull Width (ft)	5.0	10.4	7.1	3.4	8.2
Mean Depth (ft)	0.6	0.6	0.5	0.6	0.7
Bankfull X-Sec Area (sq ft)	2.9	6.7	3.5	2.1	5.7
Width: Depth Ratio	8.7	16.2	14.4	5.6	11.8
Flood-Prone Width (ft)	13.4	13.3	13.2	5.0	20.6
Entrenchment Ratio	2.7	1.3	1.5	1.5	2.5
D_{50}(mm)	0.093	0.097	0.091	0.12	0.092
Water Surface Slope (ft/ft)	0.0048	0.0017	0.0054	0.037	0.0042
Sinuosity	<1.2	<1.2	<1.2	<1.2	<1.2
Drainage Area (mi^2)	0.12	0.15	0.15	0.07	0.23
Adjustments?	Sin ↑	Sin ↑	Sin ↑, ER ↓	Sin ↑, ER ↓	Sin ↑, W/D ↑


Picture Spring Branch
North Tributary Longitudinal Profile Fall 2020
bed
water srf
bankfull
x-section
riffle crest
pool
run
glide
LBH
LEP
REP
Elevation (ft)
Channel Distance (ft)
95
93
91
89
87
85
83
81
79
0
200
400
600
800
1000
1200
1400
1600
1800
2000
Winmeyer Ave. Culvert
Baltimore Ave. Culvert
MD Route 170 Culvert
94.0
1124.5
1524.0
1789.5


Picture Spring Branch
South Tributary Longitudinal Profile Fall 2020
bed
water srf
bankfull
x-section
riffle crest
pool
run
glide
LBH
LEP
REP
Elevation (ft)
Channel Distance (ft)
95
93
91
89
87
85
83
0
75
150
225
300
375
106.0
Confluence with North Tributary



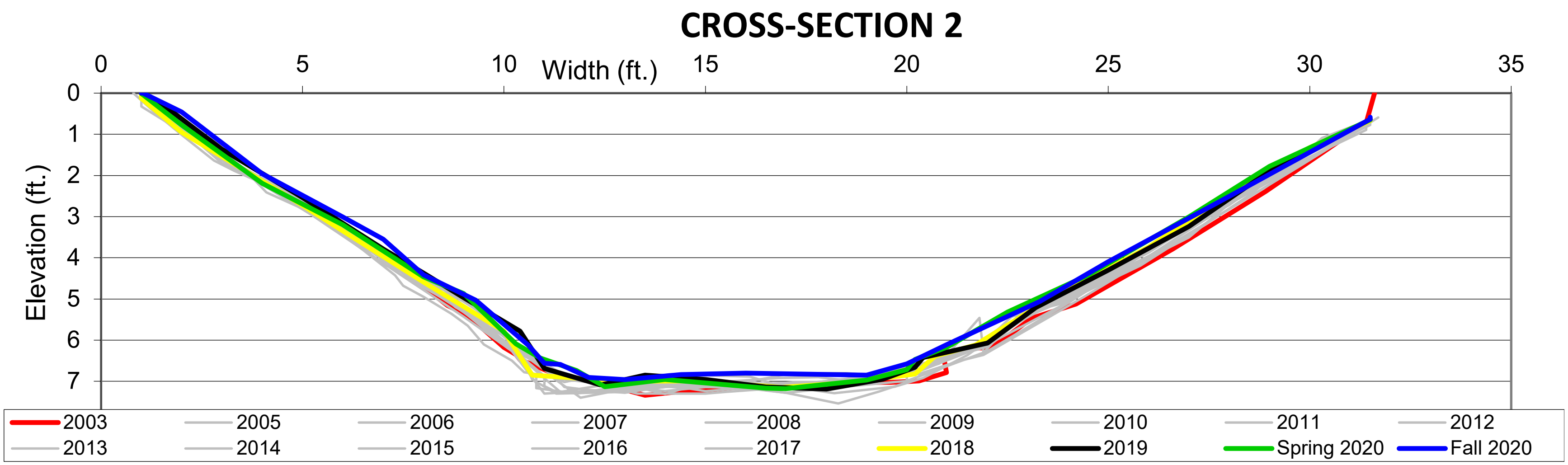
Upstream View

Downstream View

Left Bank View

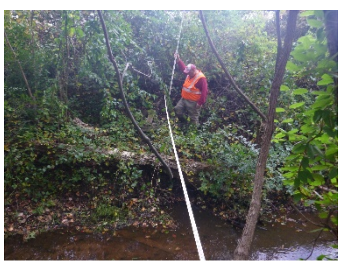
Right Bank View

Fall 2020 Geomorphic Assessment Results	
Bankfull Width (W_{bkf}) (feet)	5.0
Mean Depth (d_{bkf}) (feet)	0.6
Bankfull Cross-sectional Area (A_{bkf}) (feet^2)	2.9
Width/Depth Ratio (W_{bkf}/d_{bkf})	8.7
Width of Flood-prone Area (W_{fpa}) (feet)(feet)	13.4
Entrenchment Ratio (ER) = W_{fpa}/W_{bkf}	2.7
Channel Materials D_{50} (millimeters)	0.093
Water Surface Slope (S)	0.0048
Sinuosity (K) = stream length/valley length	<1.2
Adjustments?	Sin ↑
STREAM TYPE	**E5**

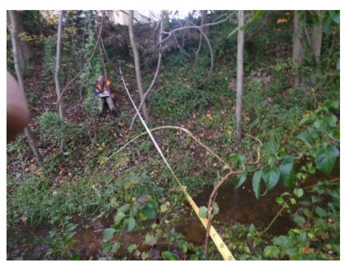


Upstream View

Downstream View



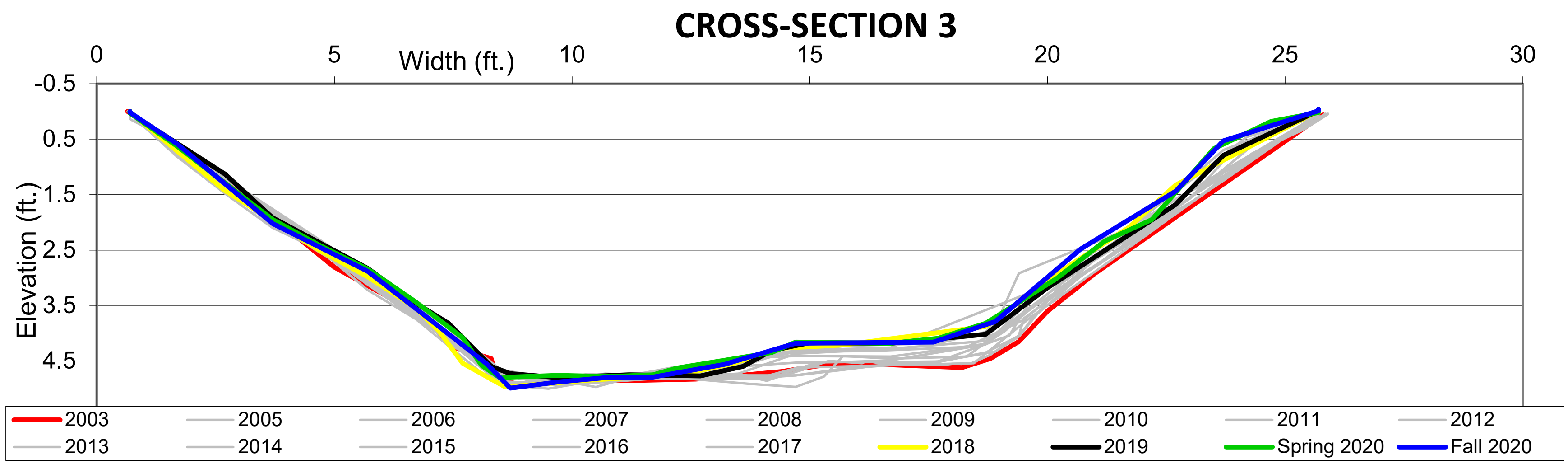
Left Bank View



Right Bank View

Fall 2020 Geomorphic Assessment Results

Bankfull Width (W_{bkf}) (feet)	10.4
Mean Depth (d_{bkf}) (feet)	0.6
Bankfull Cross-sectional Area (A_{bkf}) (feet^2)	6.7
Width/Depth Ratio (W_{bkf}/d_{bkf})	16.2
Width of Flood-prone Area (W_{fpa}) (feet)	13.3
Entrenchment Ratio (ER) = W_{fpa}/W_{bkf}	1.3
Channel Materials D_{50} (millimeters)	0.097
Water Surface Slope (S)	0.0017
Sinuosity (K) = stream length/valley length	<1.2
Adjustments?	Sin ↑
STREAM TYPE	**F5**



Upstream View

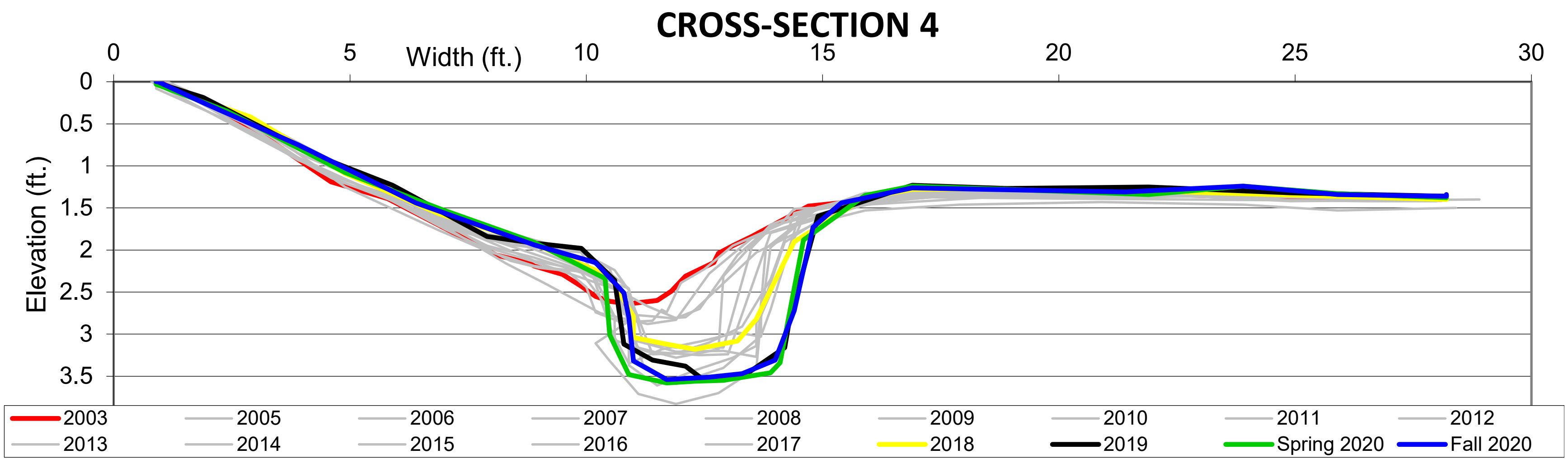
Downstream View

Left Bank View

Right Bank View

Fall 2020 Geomorphic Assessment Results

Bankfull Width (W_{bkf}) (feet)	7.1
Mean Depth (d_{bkf}) (feet)	0.5
Bankfull Cross-sectional Area (A_{bkf}) (feet^2)	3.5
Width/Depth Ratio (W_{bkf}/d_{bkf})	14.4
Width of Flood-prone Area (W_{fpa}) (feet)	13.2
Entrenchment Ratio (ER) = W_{fpa}/W_{bkf}	1.5
Channel Materials D_{50} (millimeters)	0.091
Water Surface Slope (S)	0.0054
Sinuosity (K) = stream length/valley length	<1.2
Adjustments?	Sin ↑, ER ↓
STREAM TYPE	**F5**



Upstream View

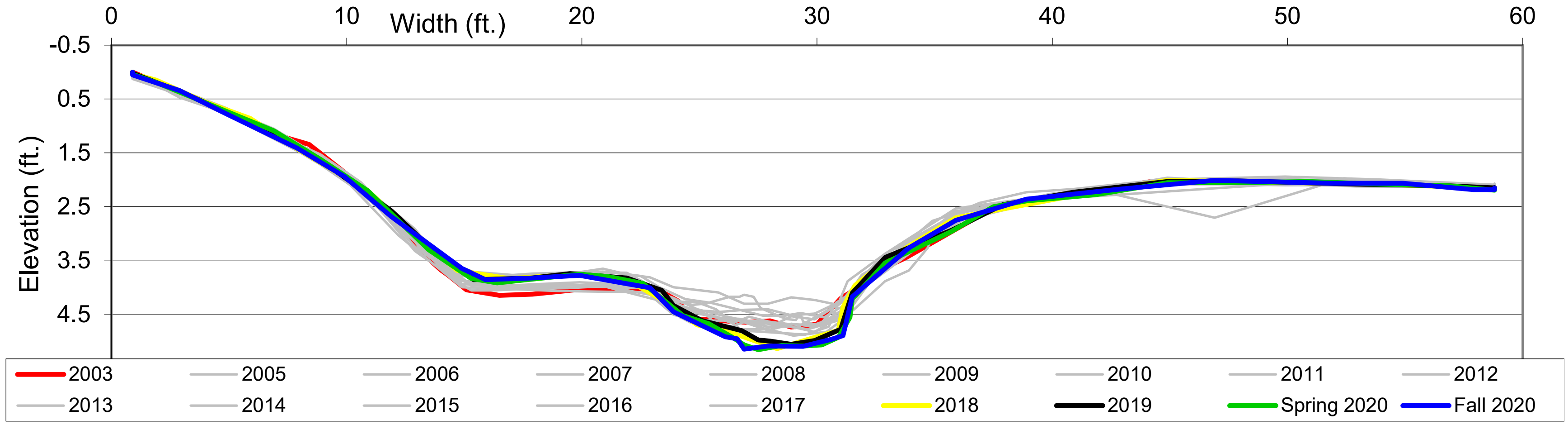
Downstream View

Left Bank View

Right Bank View

Fall 2020 Geomorphic Assessment Results	
Bankfull Width (W_{bkf}) (feet)	3.4
Mean Depth (d_{bkf}) (feet)	0.6
Bankfull Cross-sectional Area (A_{bkf}) (feet^2)	2.1
Width/Depth Ratio (W_{bkf}/d_{bkf})	5.6
Width of Flood-prone Area (W_{fpa}) (feet)	5.0
Entrenchment Ratio (ER) = W_{fpa}/W_{bkf}	1.5
Channel Materials D_{50} (millimeters)	0.12
Water Surface Slope (S)	0.037
Sinuosity (K) = stream length/valley length	<1.2
Adjustments?	Sin ↑, ER ↓
STREAM TYPE	**G5**

CROSS-SECTION 5



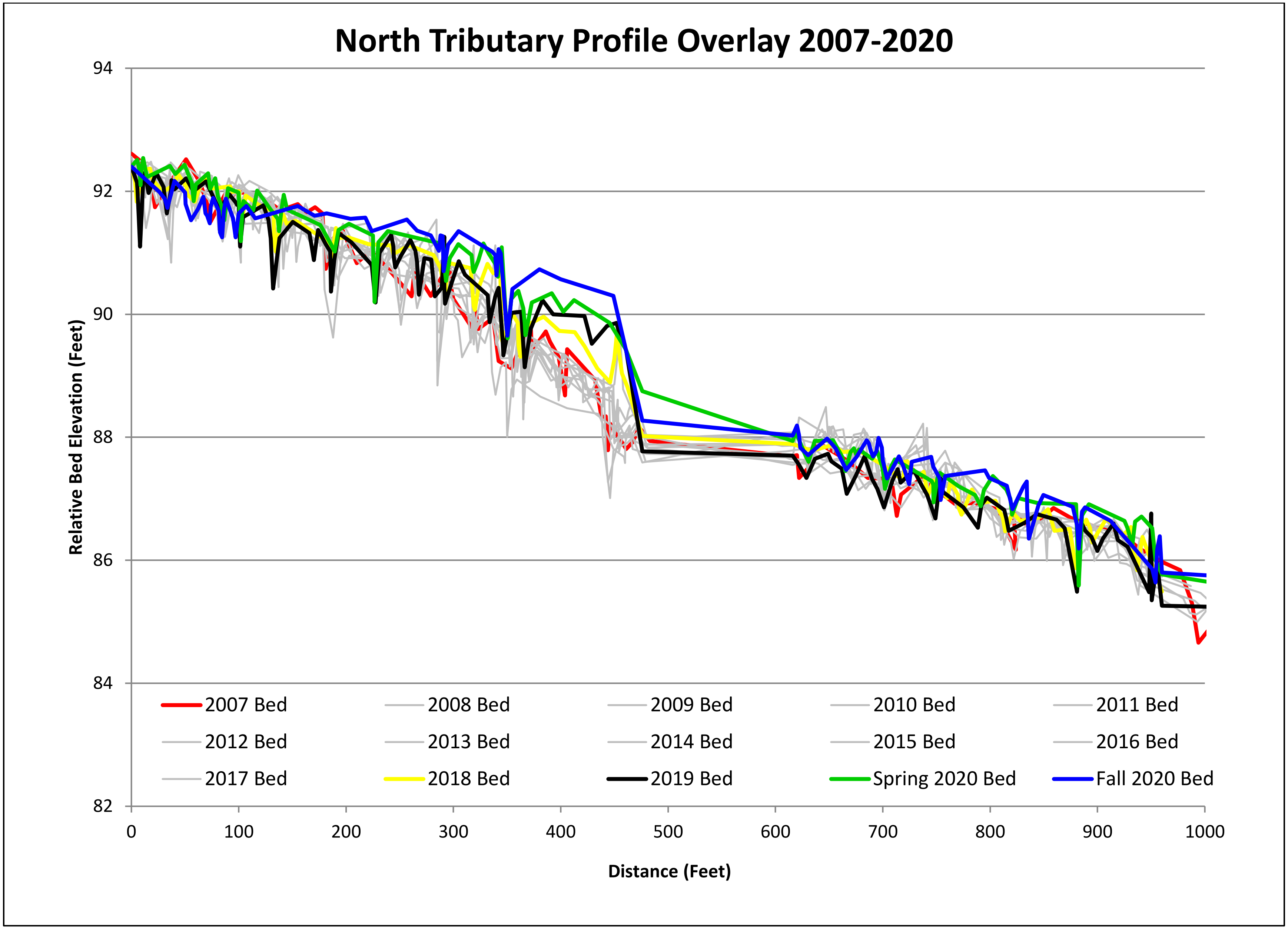

Upstream View

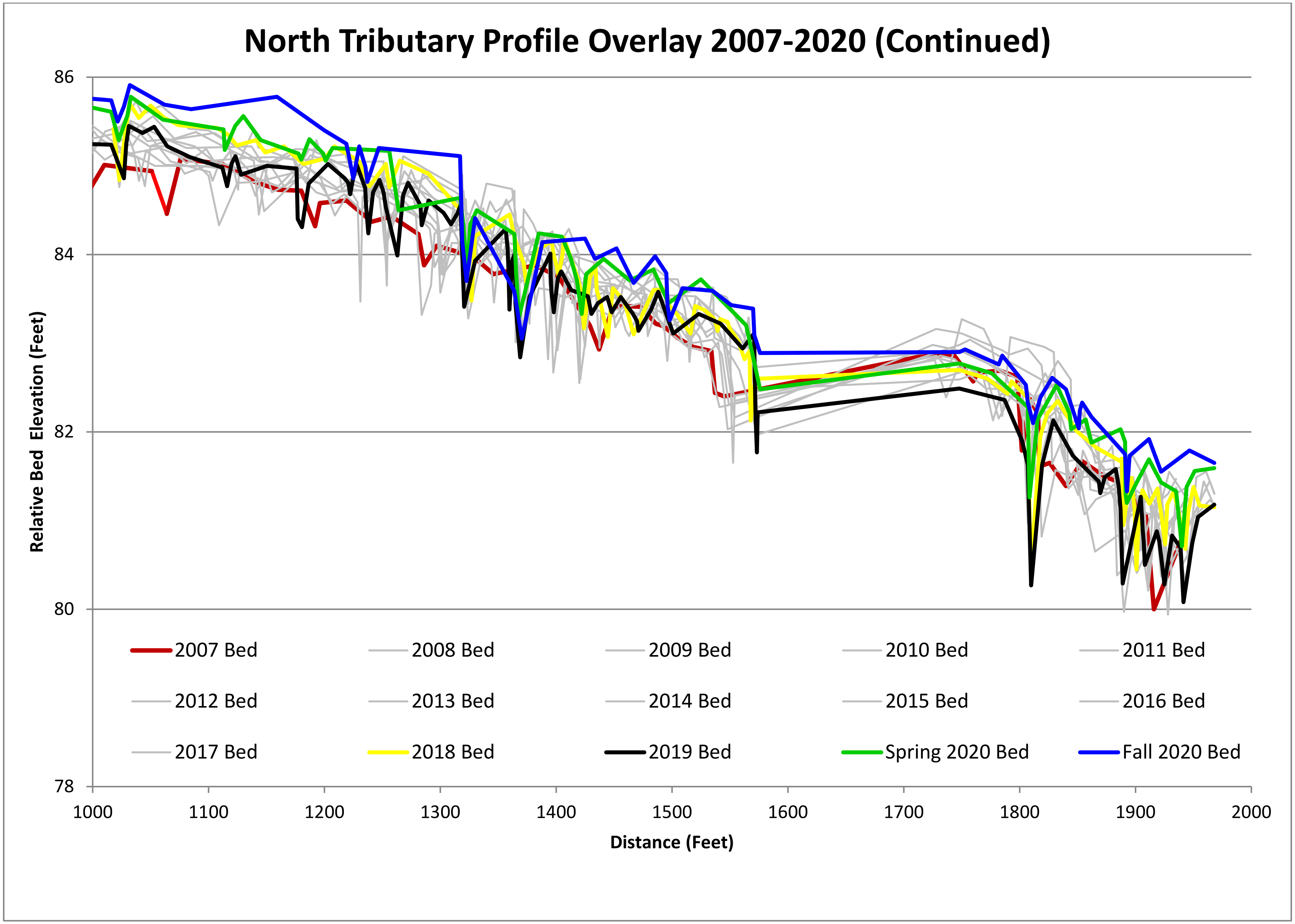

Downstream View

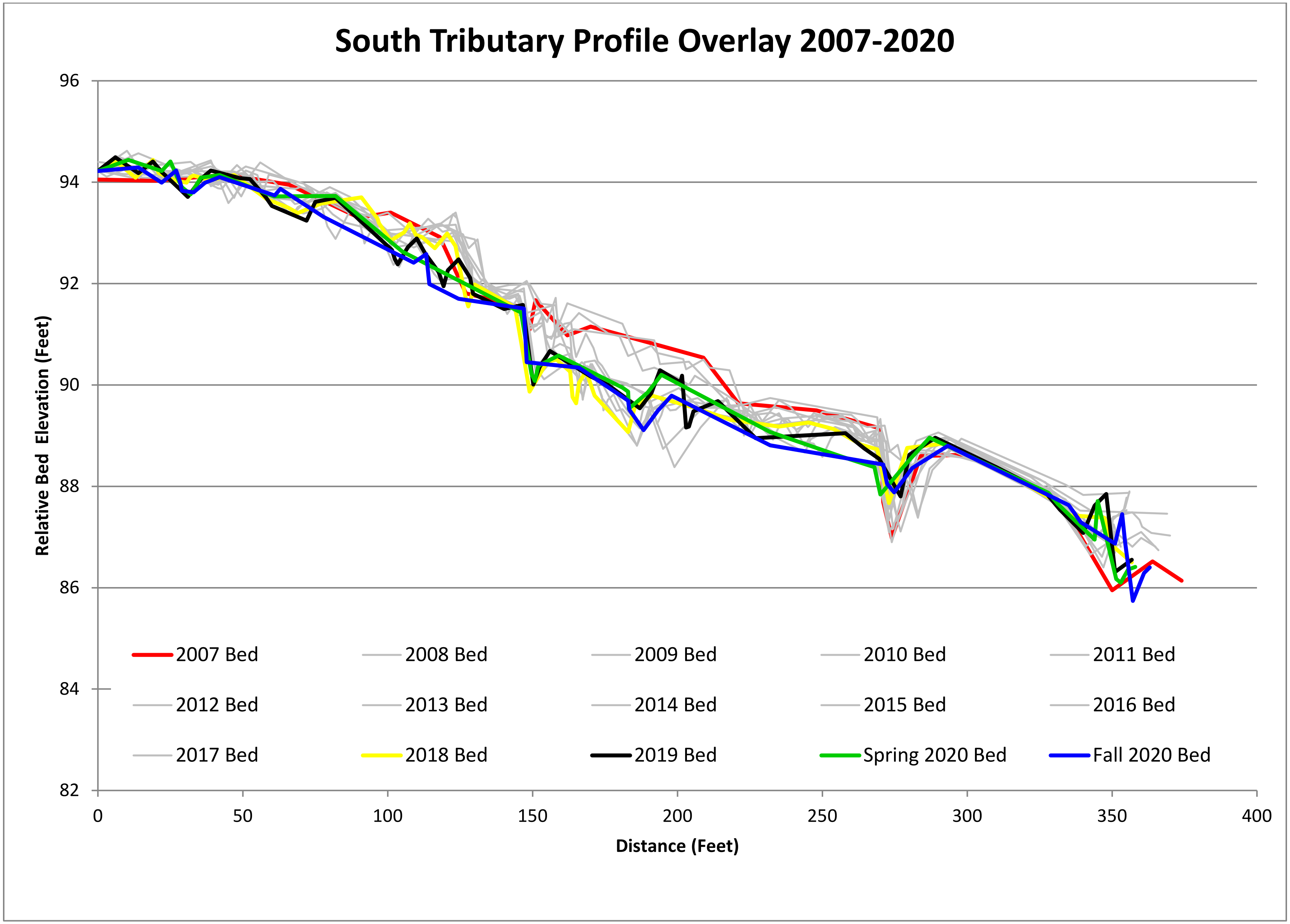

Left Bank View


Right Bank View

Fall 2020 Geomorphic Assessment Results	
Bankfull Width (W_{bkf}) (feet)	8.2
Mean Depth (d_{bkf}) (feet)	0.7
Bankfull Cross-sectional Area (A_{bkf}) ($feet^2$)	5.7
Width/Depth Ratio (W_{bkf}/d_{bkf})	11.8
Width of Flood-prone Area (W_{fpa}) (feet)	20.6
Entrenchment Ratio (ER) = W_{fpa}/W_{bkf}	2.5
Channel Materials D_{50} (millimeters)	0.092
Water Surface Slope (S)	0.0042
Sinuosity (K) = stream length/valley length	<1.2
Adjustments?	Sin ↑, W/D ↑
STREAM TYPE	**C5**


North Tributary Profile Overlay 2007-2020
Relative Bed Elevation (Feet)
Distance (Feet)
94
92
90
88
86
84
82
0
100
200
300
400
500
600
700
800
900
1000
2007 Bed
2008 Bed
2009 Bed
2010 Bed
2011 Bed
2012 Bed
2013 Bed
2014 Bed
2015 Bed
2016 Bed
2017 Bed
2018 Bed
2019 Bed
Spring 2020 Bed
Fall 2020 Bed


North Tributary Profile Overlay 2007-2020 (Continued)
Relative Bed Elevation (Feet)
86
84
82
80
78
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
Distance (Feet)
2007 Bed
2008 Bed
2009 Bed
2010 Bed
2011 Bed
2012 Bed
2013 Bed
2014 Bed
2015 Bed
2016 Bed
2017 Bed
2018 Bed
2019 Bed
Spring 2020 Bed
Fall 2020 Bed


South Tributary Profile Overlay 2007-2020
Relative Bed Elevation (Feet)
96
94
92
90
88
86
84
82
0
50
100
150
200
250
300
350
400
Distance (Feet)
2007 Bed
2008 Bed
2009 Bed
2010 Bed
2011 Bed
2012 Bed
2013 Bed
2014 Bed
2015 Bed
2016 Bed
2017 Bed
2018 Bed
2019 Bed
Spring 2020 Bed
Fall 2020 Bed

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APPENDIX C

QUALITY ASSURANCE/QUALITY CONTROL

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This section describes all Quality Assurance/Quality Control (QA/QC) procedures implemented for this project including geomorphic field sampling, geomorphic data entry, and classification of stream types.

Field Sampling
Geomorphic assessment field crews have more than one year of experience conducting similar assessment using the Rosgen Stream Classification Methodology and final data QA/QC is performed by staff with two or more levels of Rosgen training.

Geomorphic assessment survey equipment is calibrated annually and regularly inspected to ensure proper functioning. Cross-section and profile data were digitally plotted and analyzed in Ohio Department of Natural Resources (ODNR) Reference Reach Spreadsheet Version 4.3L for accuracy.

Data Entry
All data entered were double checked by someone other than the person who performed the initial data entry. Any errors found during QA/QC were corrected to ensure 100% accuracy of the data.

Identification of Stream Types
All stream types were determined by hand based on the methods of the Rosgen Stream Classification (Rosgen 1996). Due to the natural variability, or continuum, of streams, adjustments in the values of Width Depth Ratio (+/- 2.0) and Entrenchment Ratio (+/- 0.2) are allowed, which may result in assigning a different stream type. Therefore, all stream types assigned were checked by a second person and any necessary adjustments were made.

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