Appendix F2 – Assessment of Controls (Stormwater Management Assessment)

Wexford Annual Physical Assessment 2018

November 2019

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1 INTRODUCTION

Harford County Department of Public Works initiated physical geomorphic monitoring at the tributary to Church Creek in the Wexford community in 2005. Monitoring has been performed by KCI Technologies, Inc. (KCI) and URS Corporation (URS) at the Wexford site from 2005-2018 to meet criteria in the County's NPDES MS4 permit. The site consists of a 2,400 linear foot reach, located downstream of MD Route 7 (Philadelphia Rd) in Aberdeen, Maryland on an unnamed tributary to Church Creek (Figure 1). Within the survey reach, two extended detention stormwater facilities were built in 2006. The first drains all of Antrim Ct. and a portion of Ashford Dr. totaling 7.55 acres. The second pond drains Tralee Cir. and Kerry Ct. totaling 26.41 acres.

The goal of the project is to evaluate the effectiveness of Maryland's 2000 Stormwater Regulations design criteria for controlling the channel protection volume (Cpv) and to assess the geomorphic stability of the stream channel in the assessment reach. This is accomplished through geomorphic monitoring and fulfills the conditions of the County's MS4 permit listed under section IV.F.2 – Stormwater Management Assessment in the Assessment of Controls portion of the County's current permit.

Assessment techniques include an annual survey of permanently monumented channel cross-sections and longitudinal profiles. Cross-sectional and longitudinal profile surveys were conducted in 2005 to establish baseline conditions of channel geometry and slope. Baseline surveys were conducted to enable comparisons with subsequent annual assessments to determine whether lateral or vertical migration of the channel has occurred. Methods, data, and results from the 2018 monitoring period are detailed in this report along with comparisons to previous year's results to investigate changes in channel geometry and stability over time.

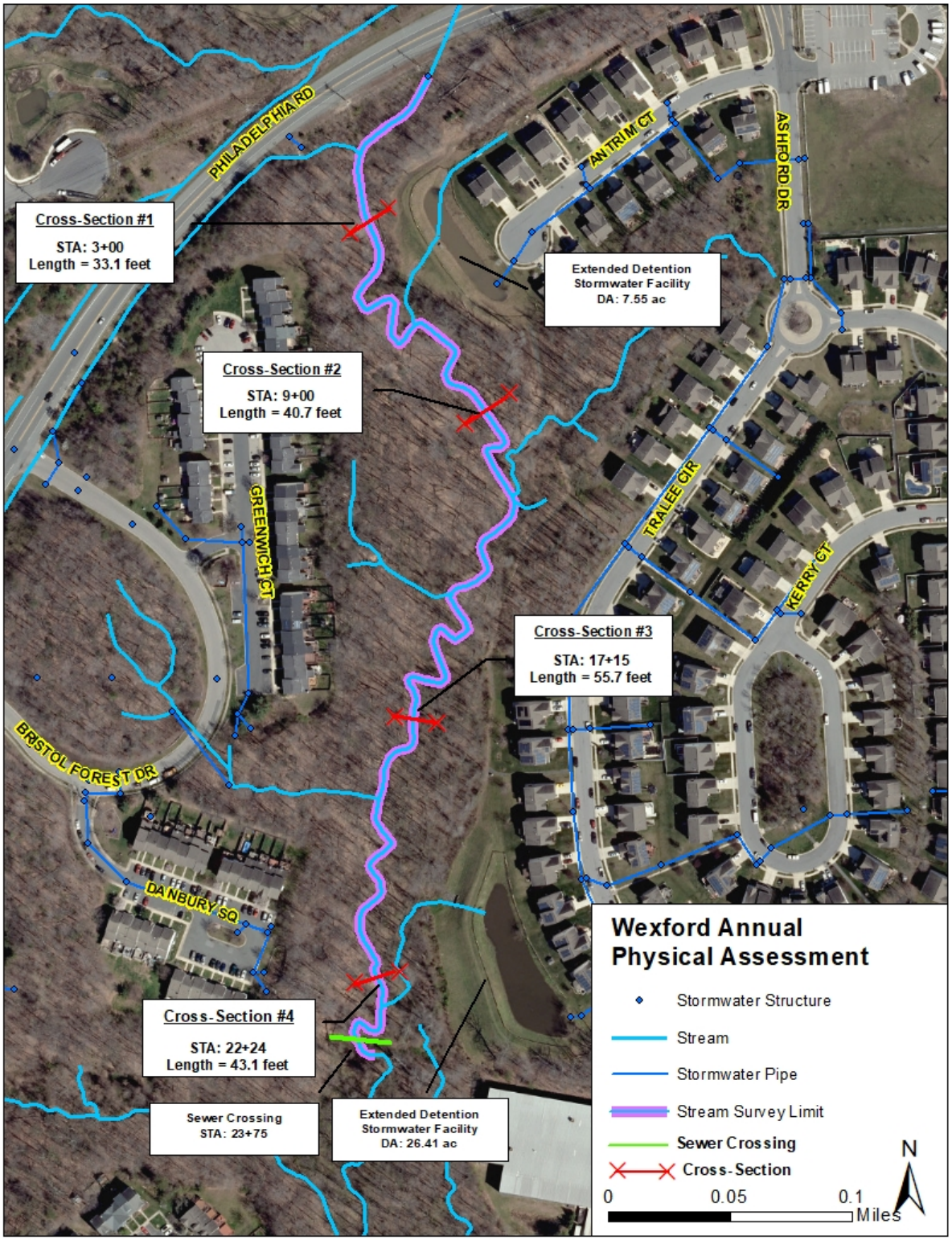


Figure 1 - Stream Survey Limits and Cross-Section Locations

2 METHODS

2.1 GEOMORPHIC ASSESSMENT METHODS

A longitudinal profile of the assessment reach was surveyed in 2005 and annually through 2018 using a laser level, calibrated stadia rod, and 300-foot measuring tape. The profile was established along the channel thalweg and included a survey of breakpoints in and between bed features and delineation of riffles, runs, pools, and glides. A survey of the bankfull elevation (where discernible), top of bank, and water surface was also performed. The longitudinal profile from 2005 was plotted to serve as the baseline for comparison during subsequent years. The profile from 2018 and previous surveys were also plotted and used to track changes that occurred in the bed sequences and channel slope (Figure 2). Profile data can be found in Appendix B.

To establish locations where fluvial geomorphic characteristics of the channel could be measured and compared over time for assessing bed and bank stability, permanent cross-sections were established during the 2005 monitoring effort at four locations within the assessment reach. Rebar monuments were established on either side of the channel to mark the cross-section locations and to maintain repeatable elevation controls. The location of each monument was recorded using a GPS unit capable of sub-meter accuracy. Cross-sections were surveyed annually from 2005 through 2018 using a laser level, calibrated stadia rod, and measuring tape. The cross- sectional surveys captured features of the floodplain, monuments, and all pertinent channel features including:

- Top of bank
- Bankfull elevation
- Edge of water
- Limits of point bar and instream depositional features
- Thalweg
- Floodprone elevation

Longitudinal profile and cross-section data were entered into The Reference Reach Spreadsheet version 4.3L (Mecklenberg 2006) for data analysis and graphical interpretation. Profile and cross-section data collected during 2005 provided the baseline conditions to which subsequent monitoring events were overlaid and compared to assess whether any measureable changes occurred.

Bankfull elevations were selected based upon field observed bankfull indicators and used to calculated measures of channel geometry. Because bankfull indicators are not always easily discernible from year to year and best professional judgment is often required to determine bankfull elevations in incised channels, top of bank features were also measured. Top of low bank cross-sectional areas were also calculated and used to generate values that are directly comparable between each monitoring effort.

3 RESULTS AND CONCLUSIONS

3.1 FLUVIAL GEOMORPHIC ASSESSMENT - 2018

The fourteenth year of longitudinal profile and cross-sectional surveys was completed on October 18 and October 19, 2018. Photographs depicting the overall site conditions are presented in Appendix A. The longitudinal profile data was used to calculate the water surface slope for the channel (Table 1) and can be found in Appendix B. In addition, the profile surveyed during 2018 was plotted and superimposed on the 2005-2017 surveyed profile data (Section 3.2).

Table 1 - Results of longitudinal profile survey- 2018

Reach	Slope
Wexford	1.5%

Cross-sectional surveys were analyzed at each of the four permanent monitoring locations to determine bankfull width, mean depth, width/depth ratio, and overall cross-sectional area. Assessments conducted during 2018 represented the fourteenth annual survey of channel conditions. Results of the cross-sectional measurements are included in

Table 2. Appendix B presents the 2018 cross-section data. All four cross-sections classify as unstable F4 type channels.

Table 2 - Results of cross-sectional survey analysis- 2018

Cross-section	Bankfull Width (ft)	Mean Depth (ft)	Width/ Depth Ratio	Entrench -ment ratio	Bankfull Velocity (ft/s)	Bankfull Discharge (cfs)	Shear Stress (lb/ ft^2)	Flood Prone Area (ft^2)	Bank-full Area (ft^2)	Top of Bank Area (ft^2)
XS 1	11.4	1.1	10.4	2.9	3.1	39.0	0.93	32.8	12.4	81.5
XS 2	21.4	0.8	26.3	1.1	2.7	46.9	0.74	23.2	17.4	70.3
XS 3	15.7	1.0	16.4	1.3	2.9	43.8	0.84	20.5	14.9	90.6
XS 4	16.1	1.0	15.8	1.5	3.4	56.1	0.92	23.4	16.5	51.4

3.2 COMPARISON OF LONGITUDINAL PROFILE 2005-2018

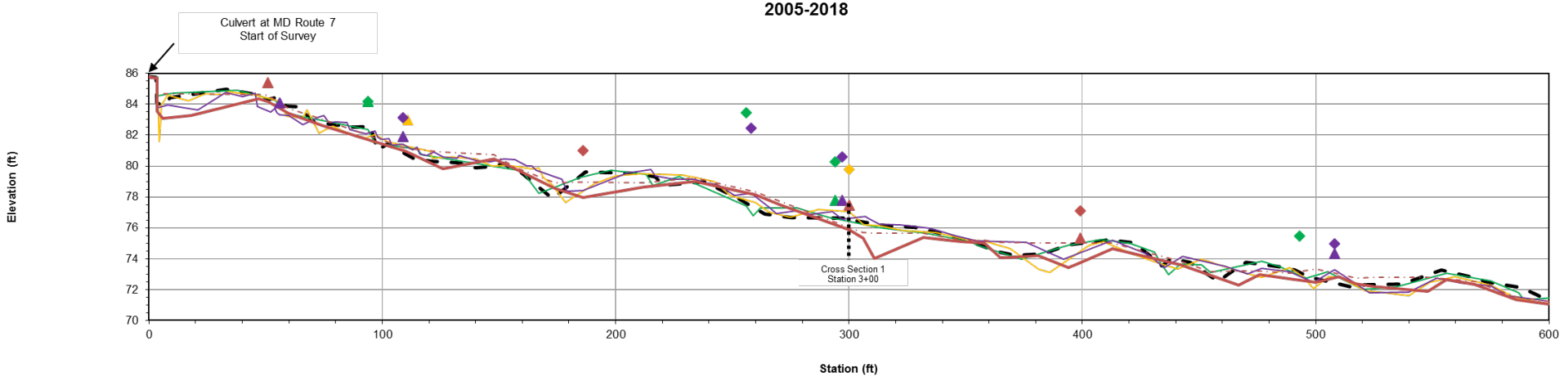
The longitudinal profile data from the 2018 survey was analyzed to calculate the slope of the reach for the fourteenth year of monitoring. As during previous monitoring efforts, the channel slope from 2005 to 2018 has remained constant from 1.44% in 2005 to 1.5% in 2018. Small fluctuations are normal as differences can occur in the calculated slope due to changes in stationing and measurement error over the survey reaches and likely reflect only minor changes in slope over time.

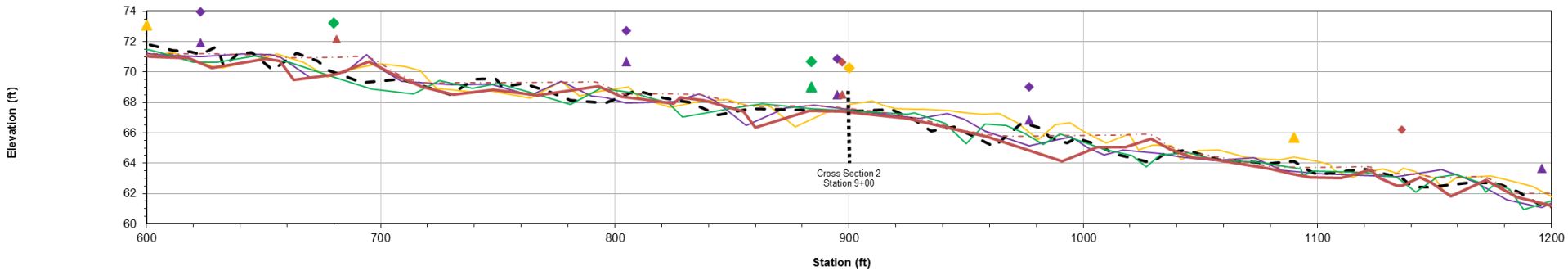
In addition to the slope comparisons, the profile surveyed during 2018 was plotted and superimposed on the plots of prior year profiles surveyed from 2005 through 2018 (Figure 2). In an effort to better graphically present the data, years 2005, 2009, 2013, 2017, and 2018 are

plotted to better distinguish changes. Bed features exhibited evidence of the continually shifting and dynamic nature of this system, including deposition in some pools and bars, deepening of other pools, and shifting locations of riffle crests. There is a trend of channel thalweg incision and pool deepening, especially in the downstream 1,200 linear feet. The channel appears unable to transport the sediment load that results in large mid-channel and lateral bar formation comprised of loose sand and gravel, which overwhelms the channel and causes frequent shifts in bedform. These depositional features increase near bank stresses that result in erosion of the bank and bed. The stream banks and bed near the sewer encasement at station 23+75 continue to degrade and the area should continue to be monitored (Photo on pg. 28 of Appendix A). The most notable changes in channel bed between 20017 and 2018 are:

- Plunge pool depth increased by 0.3 ft. at the MD 7 culvert, STA 0+00 to 0+35
- A 0.8 ft. long pool created at STA 1+26
- A downstream shift of 15 ft. and lengthening 17 ft. of the pool at STA 1+75 to 2+12
- Bed erosion of 2.2 ft. downstream of XS-1 at STA 3+13
- Pool depth increased by 0.5 ft. and lengthening by 30 ft. at STA 3+90
- Pool depth increased by 1.0 ft. and shifted 14 ft. STA 9+91
- Shifting of pool material downstream creating new riffle crest at STA 10+29
- A 1.2 ft. deep pool created at STA 11+57
- Riffle crest shifts of 12 ft. at STA 12+26, 12+61, and 12+95
- Pool depth increased by 1.0 ft. from STA 16+86 to 17+15
- Bed incision of approximately 0.75 ft. from STA 18+00 to 22+60
- Bed incision of 1.4 ft. downstream of the sewer crossing from STA 23+83 to 24+24

Longitudinal Profile Station 0+00 to 12+00
2005-2018





Thalweg 2005 | Thalweg 2009 | Thalweg 2013 | Thalweg 2017 | Thalweg 2018 | Water Surface 2018 | Bankfull 2009

Bankfull 2013 | Bankfull 2017 | Bankfull 2018 | Top of Bank 2009 | Top of Bank 2013 | Top of Bank 2017 | Top of Bank 2018

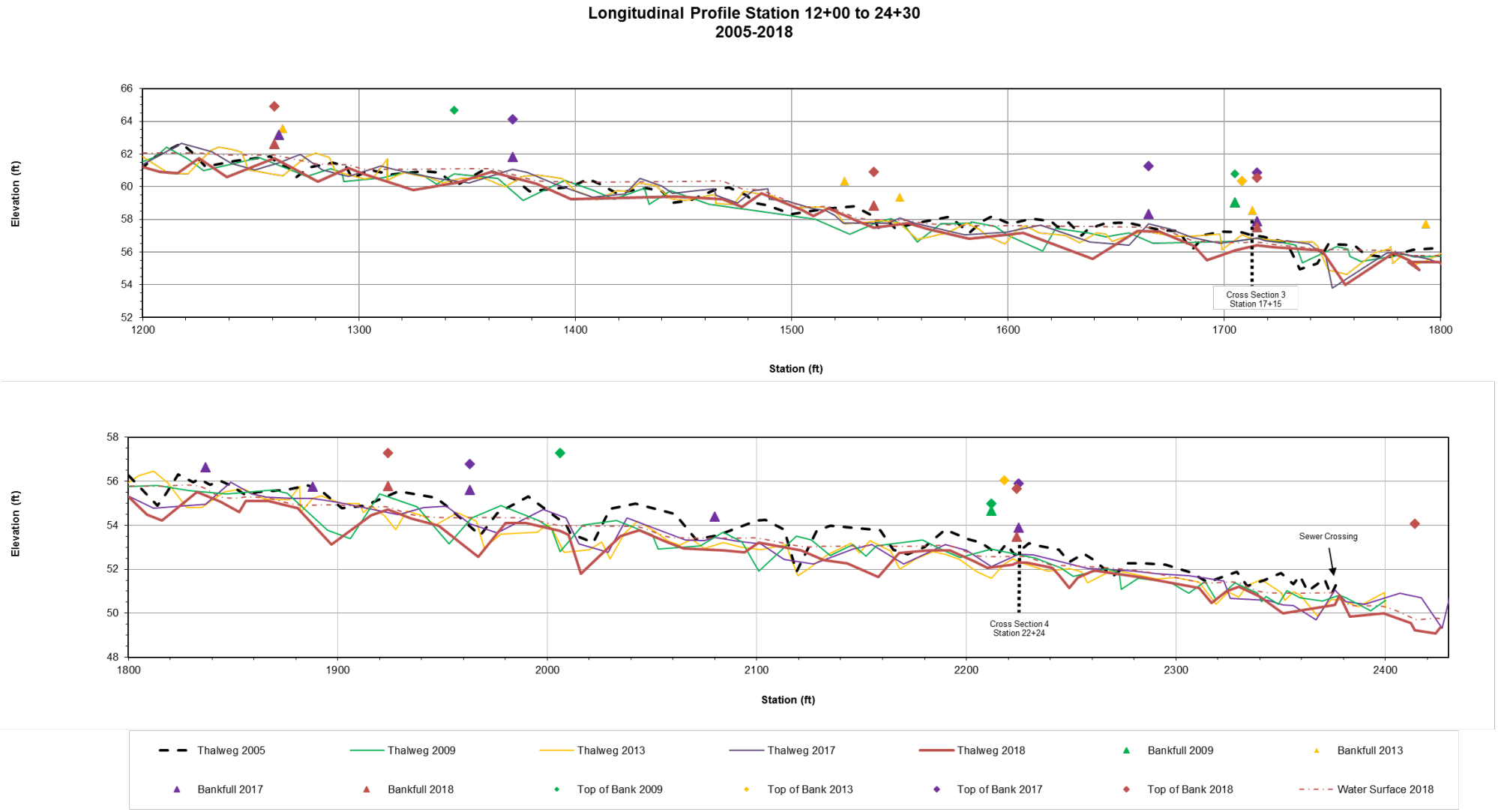


Figure 2 - Longitudinal Profile Overlays 2005-2018

3.3 COMPARISON OF CROSS-SECTIONS 2005-2018

Cross-section surveys from 14 years of monitoring were analyzed at each of the four permanent monitoring locations to determine bankfull width, mean depth, width/depth ratio, and overall cross-sectional area. Since field determination of bankfull elevation in incised systems is difficult to identify and repeat over time, top-of-bank elevation was used to track changes in the cross-sectional dimensions listed below. To compare the stability of reaches over time, the percent increase in top of bank cross-sectional area from 2005 through 2018 is shown in Figure 3. The greatest changes in top of bank cross-sectional area occurred at Cross-section 2 and Cross-section 4, which are located at station 9+00 and 22+24.

Each cross-section is described in detail below. Cross-section survey data can be found in Appendix B of this report. In an effort to better graphically present the data, years 2005, 2009, 2013, 2017, and 2018 are plotted to better distinguish changes over time.

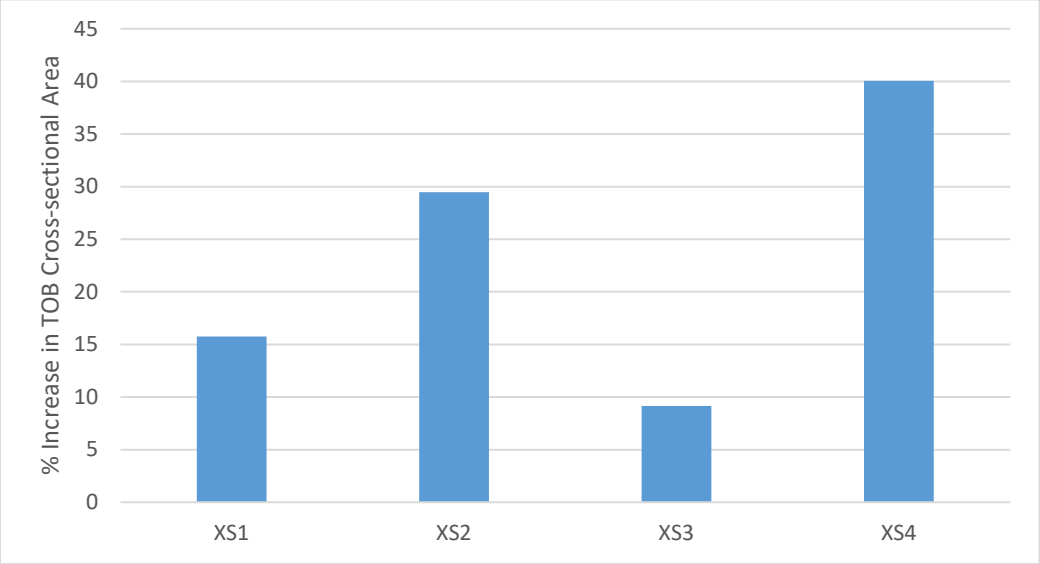


Figure 3 - Percent increase in top of bank cross-sectional area from 2005-2018

CROSS-SECTION 1: STATION 3+00

Cross-section 1 had previously been the most stable, but saw significant changes between 2017 and 2018. A large amount deposition on the left side of the channel along with bed incision on the right side are visible in the survey. (Table 3, Figure 4). Photos facing downstream between 2017 and 2018 below help visualize how much this cross-section has changed in a matter of a year are located in Figure 5. About 0.75 ft. of large material has been deposited on the left side of the channel while about 1 ft. of erosion has scoured out the right side of the channel. (Figure 5). A large pool has also developed directly downstream of the cross-section. The bankfull width has decreased in 2018 as a result of the deposition on the left bank and major incision of the right side of the bed.

Table 3 - Cross-section 1 Measurements

Year	Bankfull Width (ft)	Mean Depth (ft)	Width/ Depth Ratio	Entrench-ment ratio	Bankfull Velocity (ft/s)	Bankfull Discharge (cfs)	Shear Stress (lb/ ft^2)	Flood Prone Area (ft^2)	Bankfull Area (ft^2)	Top of Bank Area (ft^2)
2005	11.3	0.6	30.0	1.2	3.8	42.9	0.52	21.2	11.3	70.4
2009	18.3	0.7	26.5	1.2	4.1	54.6	0.59	21.6	12.6	73.7
2013	17.0	0.6	28.5	1.2	3.7	37.6	0.50	20.9	10.1	75.4
2017	18.0	0.6	28.1	1.2	3.9	44.9	0.54	21.6	11.5	72.7
2018	11.4	1.1	10.4	2.9	3.1	39.0	0.93	32.8	12.4	81.5

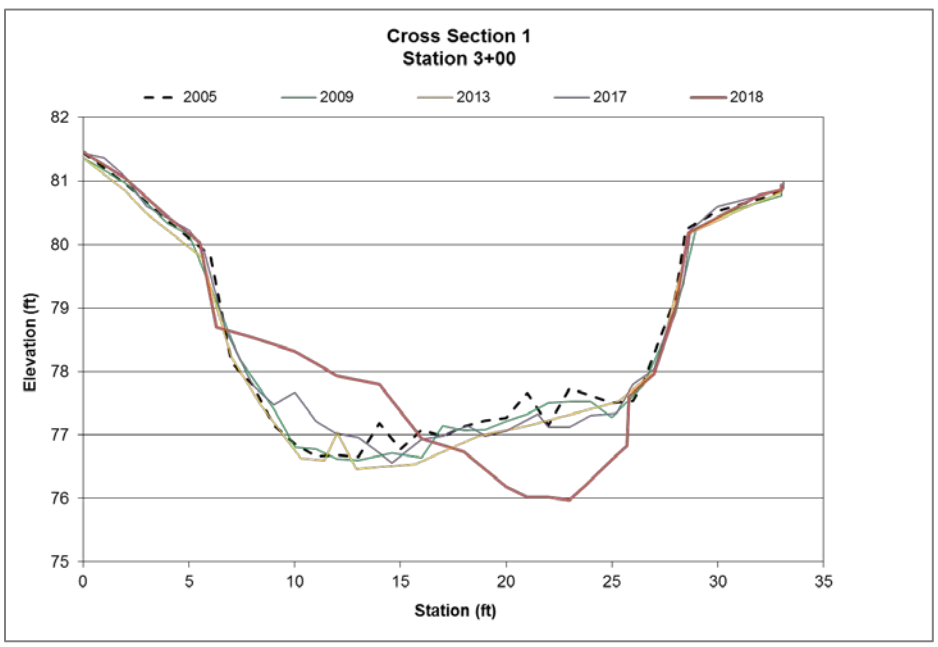


Figure 4 - Cross-section 1 Overlay 2005-2018

Figure 5 - Cross-section 1 facing downstream, 2017 (above), 2018 (below)

CROSS-SECTION 2: STATION 9+00

In the vicinity of Cross-section 2, approximately 0.46 ft. of bed erosion occurred between 2005 and 2018. Additionally, approximately 2.65 ft. amount of bank erosion has occurred on the left bank. The left bank and bed erosion have caused an increase in the bankfull area by 8.7 ft^2 and an increase in the top of bank area of 16 ft^2 (Table 4, Figure 6). The greatest increase in the left bank erosion takes place between 2009 and 2013. There was no significant change between 2017 and 2018 with only a small amount of bed erosion occurring around station 25.

Table 4 - Cross-section 2 Measurements

Year	Bankfull Width (ft)	Mean Depth (ft)	Width/ Depth Ratio	Entrench-ment ratio	Bankfull Velocity (ft/s)	Bankfull Discharge (cfs)	Shear Stress (lb/ ft^2)	Flood Prone Area (ft^2)	Bankfull Area (ft^2)	Top of Bank Area (ft^2)
2005	18.3	0.5	38.4	1.2	3.2	28.0	0.41	21.9	8.7	54.3
2009	19.7	0.9	22.6	1.2	4.7	80.6	0.72	23.5	17.1	54.1
2013	19.9	0.6	33.8	1.1	3.6	42.7	0.49	22.5	11.8	60.0
2017	20.4	0.7	29.2	1.1	4.1	58.6	0.59	22.5	14.2	63.5
2018	21.4	0.8	26.3	1.1	2.7	46.9	0.74	23.2	17.4	70.3

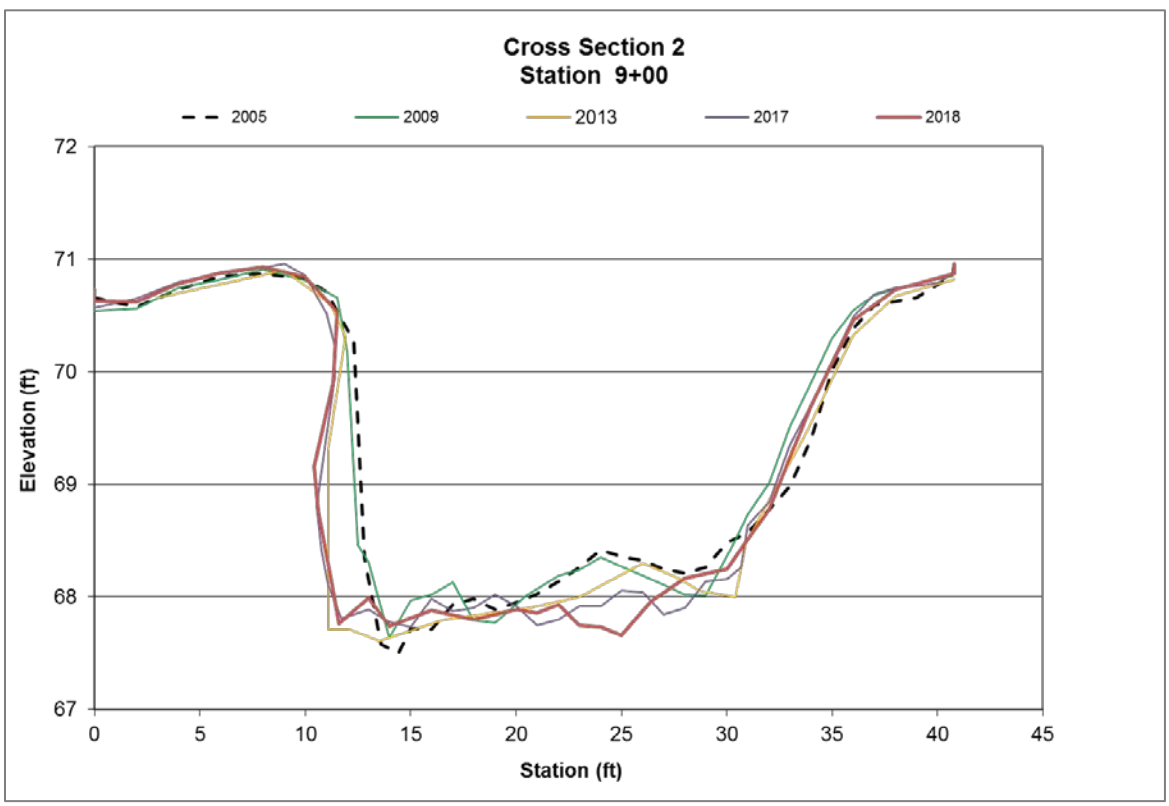


Figure 6 - Cross-section 2 Overlay 2005-2018

CROSS-SECTION 3: STATION 17+15

Cross-section 3 was moderately stable with signs of both aggradation and erosion prior to 2018 when considerable bed erosion occurred between 2017 and 2018 along the left side of the channel. The most evident change is the shift of the thalweg from the right side of the channel to the left (Table 5, Figure 7). Photos facing downstream between 2017 and 2018 below help visualize how much this cross-section has changed in a matter of a year are located in Figure 8. Approximately 1 ft. of bed erosion has occurred on the left side of the channel while 0.6 ft. of deposition has occurred on the right side of the channel. The banks have remained stable between 2017 and 2018.

Table 5 - Cross-section 3 Measurements

Year	Bankfull Width (ft)	Mean Depth (ft)	Width/ Depth Ratio	Entrench-ment ratio	Bankfull Velocity (ft/s)	Bankfull Discharge (cfs)	Shear Stress (lb/ ft^2)	Flood Prone Area (ft^2)	Bankfull Area (ft^2)	Top of Bank Area (ft^2)
2005	13.2	0.7	18.1	1.7	4.1	39.3	0.58	22.2	9.6	80.8
2009	14.0	0.7	21.0	1.4	3.9	36.7	0.55	19.8	9.3	84.0
2013	15.8	0.9	18.5	1.3	4.7	63.7	0.72	19.8	13.5	91.1
2017	15.0	0.7	21.1	1.2	4.2	44.1	0.60	17.6	10.6	85.2
2018	15.7	1.0	16.4	1.3	2.9	43.8	0.84	20.5	14.9	90.6

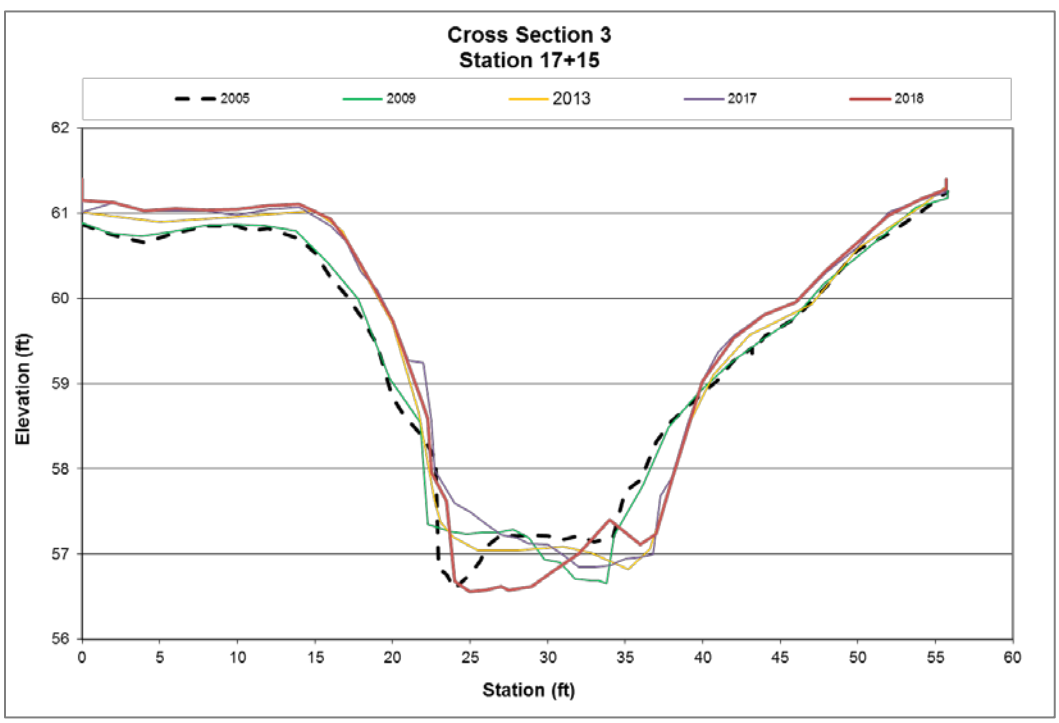


Figure 7 - Cross-section 3 Overlay 2005-2018

Figure 8 - Cross Section 3 facing downstream, 2017 (above), 2018 (below)

CROSS-SECTION 4: STATION 22+24

Cross-section 4 has experienced the most change throughout the 14 monitoring years with significant bed incision and bank erosion on both banks (Table 6, Figure 9). Similar to the other cross-sections, the greatest bed erosion took place between 2009 and 2013. Between the 2013 and 2018 surveys, 1.5 ft. of left bank erosion occurred and approximately 0.45 ft. of bed aggradation occurred. While the channel bed material contains more cobble material in the upstream portions of the channel, the bed material of Cross-section 4 consists of sand and gravel, which is easily transported during high flows. The difference in materials could be a contributor to the instability of this cross-section.

Table 6 - Cross-section 4 Measurements

Year	Bankfull Width (ft)	Mean Depth (ft)	Width/ Depth Ratio	Entrench-ment ratio	Bankfull Velocity (ft/s)	Bankfull Discharge (cfs)	Shear Stress (lb/ ft^2)	Flood Prone Area (ft^2)	Bankfull Area (ft^2)	Top of Bank Area (ft^2)
2005	12.4	0.5	23.5	1.3	3.4	22.2	0.44	16.3	6.6	36.7
2009	13.8	0.4	31.6	1.1	3.0	18.2	0.37	14.5	6.0	41.1
2013	13.7	0.7	20.0	1.2	4.0	37.6	0.57	17.0	9.4	47.5
2017	15.0	0.9	16.5	1.3	4.9	67.0	0.77	20.2	13.7	50.6
2018	16.1	1.0	15.8	1.5	3.4	56.1	0.92	23.4	16.5	51.4

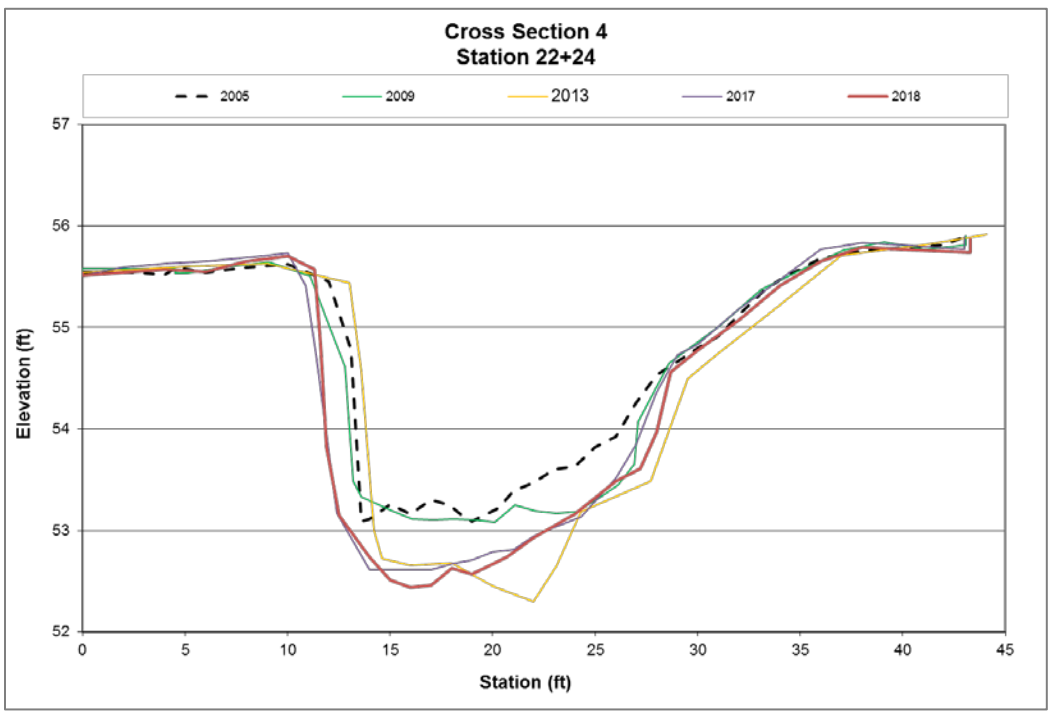


Figure 9 - Cross-section 4 Overlay 2005-2018

3.5 CONCLUSIONS

The fourteenth year of monitoring results indicate that the Wexford site continues to degrade over time. The upstream half of the reach, station 0+00 to 12+00, is relatively stable with a moderate increase in bar formation and the bed material is comprised of larger cobble substrate. Cross-section 1, located at station 3+00, was previously the most stable, but this year large amounts of bed deposition and incision have occurred while the banks have remained stable. As the survey continues downstream, a change to smaller gravel and sand substrate is noticeable along with an increase in bar formation and transverse riffles. Pools in this part of the reach continue to both deepen and fill in, in addition to movement of riffle crests. Cross-section 3 was also actively changing between 2017 and 2018 monitoring years with the thalweg migrating from the right side of the channel to the left. Cross-section 4 in the past has been the most unstable but remained stable this year in comparison to the 2017 survey. Overall Cross-section 4 is the most actively eroding over time, having increased in cross-sectional area significantly in the 14 years of monitoring. Performing cross-section pebble counts in future surveys will help identify bed material changes and if that has any effect on stability of each cross-section. Continued monitoring will help identify areas of increased degradation and help further enhance the long-term data set allowing for more concrete answers of geomorphological change.

It is important to note that the changes in channel cross-section dimension that occurred between the 2017 and 2018 surveys may be due to two factors. First, 2018 was a very wet year with rainfall amounts well above normal. Average annual rainfall in the Baltimore area is near 42 inches. Data through the end of September, just prior to the 2018 field survey at Wexford was 53.5 inches. A higher frequency of storm events and total discharge can have an impact on channel geometry. In addition to the total rainfall, a major flood event occurred on August 31, 2018 that likely resulted in much of the channel erosion and bed down-cutting and shifting observed in the cross-section results in October 2018. The USGS stream gage on James Run, located just to the southwest of the Wexford study area, recorded a gage height near 11 feet, compared to typical storms resulting in maximum stage between 4-5 feet. Likewise the peak discharge recorded at the gage was near 9,000 cfs compared to typical storm peaks between 50-1,000 cfs.

4 REFERENCES

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Rosgen, D.L. 2006. Watershed Assessment of River Stability & Sediment Supply (WARSSS).Wildland Hydrology. Pagosa Springs, CO.

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

Appendix A

Photographic Log 2018 Longitudinal Profile

STA 0+00 - Upstream

STA 0+00 - Downstream

STA 0+50 - Upstream

STA 0+50 - Downstream

STA 1+00 - Upstream

STA 1+00 - Downstream

STA 1+50 - Upstream

STA 1+50 - Downstream

STA 2+00 - Upstream

STA 2+00 - Downstream

STA 2+50 - Upstream

STA 2+50 - Downstream

XS-1 STA 3+00

XS-1 Upstream

XS-1 Downstream

XS-1 Right Bank

XS-1 Left Bank

STA 3+00 - Upstream

STA 3+00 - Downstream

STA 3+50 - Upstream

STA 3+50 - Downstream

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XS-2 STA 9+00

XS-2 Upstream

XS-2 Downstream

XS-2 Right Bank

XS-2 Left Bank

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XS-3 Upstream

XS-3 Downstream

XS-3 Right Bank

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STA 21+50 - Upstream

STA 21+50 - Downstream

XS-4 STA 22+24

XS-4 Upstream

XS-4 Downstream

XS-4 Right Bank

XS-4 Left Bank

STA 22+00 - Upstream

STA 22+00 - Downstream

STA 22+50 - Upstream

STA 22+50 - Downstream

STA 23+00 - Upstream

STA 23+00 - Downstream

STA 23+50 - Upstream

STA 23+50 - Downstream

STA 24+00 - Upstream

STA 24+00 - Downstream

STA 24+25 - Upstream

STA 24+25 - Downstream

Appendix B

Longitudinal Profile and Cross-section 2018 Data

Station	Bed Surface	Water Surface	Bankfull	Top of Bank	Description
0+00	85.77	85.83			culvert invert
0+3.5	85.68	85.69			culvert apron
0+3.6	83.52	84.68			pool
0+6.0	83.07	84.67			pool
1+8.0	83.26	84.66			BOP/TOG
4+7.0	84.37	84.63			BOG/TOR
0+51.0	84.19	84.57	85.40	86.11	H&H XS-11
0+60.0	83.42	83.72			mid riffle
0+74.0	82.63	83.05			mid riffle
1+10.0	80.97	81.13			BOR/TOP
1+26.0	79.82	80.90			mid pool
1+48.0	80.46	80.73			BOP/TOR
1+57.0	79.83	79.93			mid riffle
1+74.0	78.54	78.93			BOR/TOP
1+86.0	77.97	78.94		81.02	mid pool
2+12.0	78.63	78.89			BOP/TOR
2+34.0	79.01	79.23			mid riffle
2+60.0	78.13	78.31			mid riffle
2+71.0	77.44	77.71			mid riffle
3+00.0	75.89	76.02	77.44		XS-1 H&H XS-10
3+06.0	75.35	75.67			BOR/TOP
3+11.0	74.03	75.63			mid pool
3+32.0	75.36	75.64			BOP/TOR
3+48.0	75.09	75.19			mid riffle
3+58.0	75.01	75.18			BOR/TOP
3+65.0	74.06	75.06			mid pool, US/debris jam
3+81.0	74.20	74.99			mid pool
3+94.0	73.44	75.02			mid pool
3+99.0	73.73	75.03	75.33	77.08	H&H XS-9
4+13.0	74.66	75.03			BOP/TOR
4+42.0	73.59	73.81			mid riffle
4+55.0	72.92	73.16			BOR/TOP
4+67.0	72.28	73.20			mid pool, fallen tree
4+76.0	72.97	73.19			BOP/TOR
4+89.0	72.68	73.04			BOR/TOP
5+00.0	72.46	73.32			mid pool
5+10.0	72.84	73.02			BOP/TOR
5+17.0	72.40	72.75			BOR/TOP
5+25.0	72.18	72.78			mid pool
5+48.0	71.89	72.77			mid pool
5+56.0	72.67	72.72			BOP/TOR
5+68.0	72.34	72.52			mid riffle
5+86.0	71.36	71.53			mid riffle
6+02.0	71.00	71.21			BOR/TOP
6+18	70.92	71.20			mid pool
6+28.0	70.26	71.20			mid pool
6+51	70.88	71.08			BOP/TOR
6+57	70.75	70.97			
6+63	69.48	70.94			mid pool
6+81	69.86	70.96	72.15		mid pool
6+95	70.67	70.94			BOP/TOR
7+07	69.71	69.89			mid riffle
7+18	69.03	69.31			BOR/TOP
7+31	68.53	69.30			mid pool
7+48	68.82	69.30			mid pool
7+67	68.48	69.32			mid pool
7+83	68.86	69.33			mid pool
7+93	69.08	69.30			BOP/TOR
8+03	68.37	68.58			BOR/TOP
8+13	68.18	68.57			mid pool
8+25	67.91	68.56			mid pool
8+28	68.31	68.54			BOP/TOR
8+38	68.13	68.47			mid riffle
8+55	67.42	67.82			BOR/TOP
8+60	66.36	67.74			mid pool
8+83	67.44	67.77			mid pool
8+97	67.39	67.64	68.51	70.66	XS-2, H&H XS-8
9+25	66.93	67.08			mid riffle
9+59	65.76	65.88			BOR/TOP
9+91	64.12	65.81			mid pool
10+06	65.07	65.83			mid pool
10+18	65.03	65.85			mid pool
10+29	65.61	65.86			BOP/TOR
10+37	64.90	65.11			mid riffle
10+47	64.38	64.61			BOR/TON
10+53	64.32	64.53			BON/TOR
10+80	63.62	63.78			mid riffle
10+89	63.28	63.74			BOR/TOP
10+97	63.09	63.71			mid pool
11+10	63.03	63.73			mid pool
11+23	63.58	63.73			BOP/TOR
11+26	63.09	63.29			BOR/TOP
11+34	62.51	63.29			mid pool
11+36	62.50	63.29		66.22	H&H XS-7
11+44	63.07	63.23			TOR/BOP
11+49	62.68	63.09			BOR/TOP, US debris jam
11+57	61.84	63.04			mid pool
11+72	62.86	63.04			TOR/BOP

Station	Bed Surface	Water Surface	Bankfull	Top of Bank	Description
11+85	61.77	62.07			BOR/TOP
12+08	60.91	62.06			mid pool
12+16	60.82	62.04			mid pool
12+26	61.74	62.04			BOP/TOR
12+39	60.57	61.94			mid pool
12+61	61.74	61.94	62.62	64.91	BOP/TOR, H&H XS-6
12+81	60.31	61.37			
12+95	61.14	61.34			BOP/TOR
13+02	60.78	61.06			BOR/TOP
13+25	59.78	61.08			mid pool
13+46	60.27	61.11			mid pool
13+61	60.89	61.09			BOP/TOR
13+82	60.21	60.35			BOR/TOP
13+98	59.22	60.26			mid pool
14+21	59.40	60.30			mid pool
14+43	59.25	60.34			mid pool, US log weir
14+52	58.76	59.88			mid pool
14+61	59.61	59.80			BOP/TOR
14+80	58.57	58.77			BOR/TOP
14+85	58.22	58.78			mid pool
14+92	58.67	58.79			BOP/TOR
15+05	57.93	58.07			BOR/TOP
15+13	57.51	57.95	58.84	60.90	H&H XS-5
15+29	57.75	57.93			TOR/BOP
15+38	57.41	57.72			BOR/TOP
15+57	56.80	57.60			mid pool
15+82	57.19	57.61			mid pool
16+14	55.57	57.57			mid pool
16+35	57.29	57.54			BOP/TOG
16+45	57.27	57.49			BOG/TOR
16+61	56.39	56.66			BOR/TOP
16+67	55.52	56.67			mid pool
16+80	56.09	56.59			BOP/TOG
16+90	56.41	56.62	57.53	60.56	XS-3, H&H XS-4
16+98	56.29	56.47			mid riffle
17+20	56.12	56.19			BOR/TOP
17+27	54.77	56.13			mid pool
17+31	54.00	56.13			US of fallen tree
17+53	55.93	56.11			BOP/TOR
17+61	55.46	55.80			BOR/TOP
17+65	54.93	55.78			mid pool
17+75	55.40	55.78			BOP/TOG
17+89	55.39	55.79			BOG/TOP
17+99	54.48	55.78			mid pool
18+06	54.21	55.78			mid pool
18+23	55.51	55.80			BOP/TOR
18+34	55.06	55.30			BOR/TOP
18+43	54.60	55.25			mid pool
18+46	55.09	55.29			BOP/TOG
18+57	55.09	55.23			BOG/TOR
18+71	54.78	54.93			BOR/TOP
18+87	53.13	54.93			mid pool
19+06	54.46	54.84			BOP/TOG
19+14	54.72	54.83	55.77	57.28	H&H XS-3
19+25	54.29	54.49			BOR/TON
19+38	53.98	54.36			BON/TOP
19+57	52.56	54.36			mid pool
19+70	54.11	54.35			BOP/TOG
19+80	54.10	54.31			BOG/TOR
19+96	53.73	53.98			BOR/TON
20+00	53.58	53.98			BON/TOP
20+06	51.81	53.97			mid pool
20+25	53.51	53.96			BOP/TOG
20+34	53.77	53.92			BOG/TOR
20+47	53.23	53.49			BOR/TON
20+55	52.94	53.43			BON/TOP
20+74	52.87	53.42			mid pool
20+84	52.76	53.42			mid pool
20+91	53.20	53.41			BOP/TOR
21+11	52.85	53.05			BOR/TOP
21+22	52.43	53.05			mid pool
21+33	52.26	53.06			mid pool
21+48	51.64	53.08			mid pool
21+58	52.74	53.05			mid pool
21+72	52.87	53.07			BOP/TOG
21+82	52.87	53.07			BOG/TOR
21+94	52.37	52.65			BOR/TOP
22+00	52.06	52.58			mid pool
22+12	52.21	52.59			BOP/TOG
22+14	52.30	52.60	53.49	55.67	XS-4, H&H XS-2
22+22	52.31	52.55			BOG/TOR
22+41	52.05	52.18			BOR/TON
22+44	51.73	52.17			BON/TOP
22+49	51.16	52.17			mid pool
22+53	51.61	52.15			BOP/TOG
22+61	51.94	52.11			BOG/TOR
22+84	51.61	51.91			mid riffle
23+11	51.14	51.42			BOR/TOP

Station	Bed Surface	Water Surface	Bankfull	Top of Bank	Description
23+17	50.46	51.38			mid pool
23+24	51.01	51.42			BOP/TOG
23+30	51.20	51.38			BOG/TOR
23+40	50.77	50.99			BOR/TOP
23+51	49.99	50.92			mid pool
23+76	50.38	50.93			US sewer casing
23+78	50.83	50.88			on sewer casing
23+83	49.86	50.38			pool DS sewer casing
23+99	50.01	50.31			TOR/BOP
24+12	49.56	49.82			BOR/TOP
24+14	49.22	49.71		54.08	H&H XS-1
24+24	49.07	49.78			mid pool
24+26	49.34	49.76			BOP/TOG

Cross Section 1 at Profile Station 3+00

Surveyed on October 18, 2018

HI
83.61

Station	Rod	Bed Surface	Description
0.0	2.32	81.29	LTOP
0.0	2.32	81.29	ground at pin
2.0	2.74	80.87	
4.0	3.34	80.27	
5.5	3.75	79.86	
6.3	5.08	78.53	start of deposition bar
8.0	5.24	78.37	deposition
10.0	5.46	78.15	deposition
12.0	5.85	77.76	deposition
14.0	5.98	77.63	deposition
16.0	6.84	76.77	deposition
18.0	7.05	76.56	deposition
20.0	7.60	76.01	LEW
21.0	7.76	75.85	
22.0	7.76	75.85	
23.0	7.80	75.81	wd: 0.22
23.7	7.59	76.02	REW
25.0	7.17	76.44	slope
25.7	6.95	76.66	slope
25.8	6.17	77.44	RBKFL
27.0	5.82	77.79	slope
28.0	4.82	78.79	btw roots
28.6	3.60	80.01	
32.0	3.00	80.61	
33.0	2.92	80.69	ground at pin
33.0	2.84	80.77	RTOP

Description key: L=left, R=right, B=bank, BKF=bankful,
HI = height of instrument, EW=edge of water, TO=top

Cross Section 2 at Profile Station 9+00
Surveyed on October 18, 2018

HI
76.29

Station	Rod	Bed Surface	Description
0.0	5.83	70.46	LTOP
0.0	5.93	70.36	ground @ pin
2.0	5.94	70.35	
4.0	5.78	70.51	
6.0	5.68	70.61	
8.0	5.63	70.66	LTOB
10.0	5.72	70.57	
11.5	6.03	70.26	edge of bank
11.3	6.66	69.63	undercut
10.4	7.40	68.89	undercut
10.6	7.80	68.49	undercut
11.3	8.50	67.79	undercut
11.6	8.80	67.49	LBOB
13.0	8.57	67.72	on rock
14.0	8.82	67.47	
16.0	8.68	67.61	
18.0	8.76	67.53	
20.0	8.67	67.62	
21.0	8.70	67.59	
22.0	8.63	67.66	
23.0	8.81	67.48	
24.0	8.83	67.46	
25.0	8.90	67.39	wd = 0.25
26.4	8.60	67.69	REW
28.0	8.39	67.90	
30.0	8.31	67.98	
31.0	8.05	68.24	
32.0	7.78	68.51	RBKFL
33.0	7.32	68.97	slope
34.0	6.86	69.43	slope
36.0	6.10	70.19	
38.0	5.83	70.46	
40.8	5.69	70.6	ground @pin
40.8	5.6	70.69	RTOP

Description key: L=left, R=right, B=bank, BKF=bankful,
HI = height of instrument, EOW=edge of water, TO=top

Cross Section 3 at Profile Station 17+15
Surveyed on October 19, 2018

HI
64.51

Station	Rod	Bed Surface	Description
0.0	3.24	61.27	LTOP
0.0	3.49	61.02	ground @ pin
2.0	3.51	61.00	
4.0	3.61	60.90	
6.0	3.58	60.93	
8.0	3.60	60.91	
10.0	3.59	60.92	
12.0	3.55	60.96	
14.0	3.53	60.98	
16.0	3.71	60.80	
17.0	3.95	60.56	LTOB
18.0	4.25	60.26	
20.0	4.90	59.61	
22.0	5.89	58.62	
22.3	6.05	58.46	
22.5	6.68	57.83	
23.5	7.02	57.49	
24.0	7.96	56.55	LEW
25.0	8.08	56.43	
26.0	8.06	56.45	
27.0	8.02	56.49	
27.5	8.06	56.45	WD: 0.16
29.0	8.02	56.49	
30.2	7.86	56.65	REW
32.0	7.63	56.88	
34.0	7.24	57.27	
36.0	7.53	56.98	
37.0	7.40	57.11	
38.0	6.77	57.74	
40.0	5.61	58.90	
42.0	5.10	59.41	
44.0	4.83	59.68	
46.0	4.68	59.83	
48.0	4.30	60.21	
50.0	3.98	60.53	
52.0	3.66	60.85	
54.0	3.48	61.03	
55.7	3.36	61.15	ground @ pin
55.7	3.24	61.27	RTOP

Description key: L=left, R=right, B=bank, BKF=bankful,
HI = height of instrument, EOW=edge of water, TO=top

Cross Section 4 at Profile Station 22+24
Surveyed on October 19, 2018

HI
60.37

Station	Rod	Bed Surface	Description
0.0	3.30	57.07	LTOP
0.0	3.32	57.05	ground @ pin
2.0	3.29	57.08	
4.0	3.26	57.11	
6.0	3.28	57.09	
8.0	3.18	57.19	
10.0	3.13	57.24	LTOB
11.3	3.26	57.11	
11.6	4.00	56.37	erosion
11.9	5.01	55.36	
12.5	5.68	54.69	
14.0	6.09	54.28	LEW
15.0	6.32	54.05	
16.0	6.39	53.98	
17.0	6.37	54.00	
18.0	6.20	54.17	
19.0	6.26	54.11	
20.7	6.09	54.28	REW
22.0	5.90	54.47	
24.0	5.67	54.70	
26	5.35	55.02	
27.2	5.22	55.15	RBKFL
28.0	4.86	55.51	
28.7	4.27	56.10	
30.0	4.06	56.31	
32.0	3.76	56.61	
34.0	3.42	56.95	
36.0	3.18	57.19	
38.0	3.04	57.33	RTOB
40.0	3.06	57.31	
43.3	3.09	57.28	ground @ pin
43.3	2.96	57.41	RTOP

Description key: L=left, R=right, B=bank, BKF=bankful,
HI = height of instrument, EOW=edge of water, TO=top