Silver Creek Flood Examination

Eastern Branch and Elbow Tributary

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Executive Summary

Purpose of the Examination:

This examination evaluates how increased rainfall affects flooding in Silver Creek (East Branch), Bristol, RI, and aims to improve my understanding of natural stream dynamics and hydraulic modeling in HEC RAS. The Town of Bristol hired Beta engineering consultants to conduct a drainage study (*Silver Creek Drainage Study*, Beta Engineers/Scientists, Lincoln, RI, November 2007) to identify the causes of flooding and suggest possible solutions.

In 2010, Rhode Island Department of Environmental Management (RI DEM) presented a new *Rhode Island Design and Installation Standards Manual* (subsequently amended in 2015) that revised the rainfall amounts, particularly for the 100-year storm event. The 100-year storm event rainfall amount increased from the 2007 value of 7.10 inches, to 8.6 inches, which is the current amount.

This examination hypothesizes that increased rainfall will raise runoff amounts, leading to higher flood elevations and larger inundation areas in Silver Creek compared to the Beta Study. To test this, the original model was recreated to calculate runoff and simulate river flow along the East Branch of Silver Creek and Elbow Tributary.

The models were deemed comparable when the recreated hydrology and hydraulic models yielded results similar to the Beta Study's. With this similarity established, the new rainfall amounts can be used in the models to assess their effect on flood elevations and areas.

Results

The updated HEC RAS model indicates that flood elevations along Silver Creek have risen by about 2 inches to 1 foot due to increased rainfall, with an average rise of 0.44 feet. This higher flood elevation results in a larger flooded area, highlighting the persistent flooding issues along Silver Creek and the need for a thorough analysis.

Conclusion

This examination confirms the Beta Study's analysis, indicating increased flood risk between Gooding Avenue and Chestnut Street and within St Mary Cemetery. It supports the Silver Creek Drainage Study's recommendation for additional upstream stormwater storage, especially on vacant land near Gooding Avenue, Naomi Street, and Mount Hope High School. The findings also highlight the crucial role of existing wetlands in mitigating flood elevations and areas.

Declaration:

I conducted this examination independently; it reflects my findings and opinions. No town, regulatory agency, or advocacy group commissioned or funded the study. My neighbors' concerns about potential wetland development and increased flooding prompted this work.

This study does not predict exact flood elevations or the specific extent of a 100-year storm event. It uses the Beta model for comparative purposes and offers a similar confidence level. The goal was to better understand possible rises in flood elevations and inundation area along Silver Creek, highlight current flooding issues, and emphasize wetlands' role in flood mitigation. This supports the need for a comprehensive review of flooding along Silver Creek.

Purpose of Examination:

The purpose of this examination is to evaluate the impact of the increased rainfall amounts on the flooding issues associated with Silver Creek (East Branch) in Bristol, RI. Runoff is excess surface water generated by rainfall. The amount of runoff is determined primarily by the amount of rain that falls. Rainfall creates stromwater runoff that eventually enters a river. Flooding can occur when the quantity of stromwater runoff , entering the river, exceeds the capacity of the river to convey the stromwater by its normal channel area.

The Town of Bristol retained Beta engineering consultants to perform a drainage study of the Silver Creek watershed (*Silver Creek Drainage Study*, Beta Engineers/Scientists, Lincoln, RI, November 2007) (Beta Study). The primary purpose of Beta Study was to determine the cause of the flooding in the Silver Creek watershed and to identify possible remedial actions.

Beta used a hydrology and a hydraulic computer model to simulate stormwater runoff from the watershed into Silver Creek. One models (*HydroCAD*) generate runoff quantities from rainfall amounts from different storm events and the second model (HES RAS) replicate the hydraulic of water flow through the river. Using these two models, the elevation and special delineations of the flood water was determined.

Beta identified the "area from the eastern branch between Gooding Ave and the high school," as one of two areas along Silver Creek that flood periodically (p8. *Silver Creek Drainage Study*). The results of Beta's HEC RAS analysis confirmed this assessment. It also showed that the flood elevations are greater than those that are officially identified in the FEMA Flood Maps (*Flood Insurance Study, Bristol County, Rhode Island,* Federal Emergency Management Agency, February 2013). The hydraulic analysis for the FEMA study: "Hydraulic analysis for the East Branch Silver Creek, Walker Creek and West Branch Silver Creek were obtained from the original FIS for the Town of Bristol (U.S. Department of Urban and Housing Development, 1971) (p11 FEMA Study).

In 2010, Rhode Island Department of Environmental Management (RI DEM) presented a new *Rhode Island Design and Installation Standards Manual* (subsequently amended in 2015) that revised the rainfall amounts, particularly for the 100-year storm event. The 100-year storm event rainfall amount increased from the 2007 value of 7.10 inches, to 8.6 inches, which is the current amount.

Since the rainfall amount have changes, the runoff amounts will increase. The greater volume of water entering and being conveyed by Silver Creek will result in an increase in the flood elevations and size of the area being inundated. The *HydroCAD* and HES RAS models used in the Beta Study were not available. Thus, this examination first had to recreate those models, to produce similar results to the Beta Silver Creek models in order to examine the effect of increased rainfall amounts on the flooding problems along Silver Creek.

This examination replicates the Beta flood study using the new rainfall amount for the 100-year storm event. It recreates the *HydoCAD* and *HEC RAS* models used in the Beta study. The models were considered to be comparable when the recreated hydrology and hydraulic models produced similar results for flood water elevations to the Beta Study's models. With the recreated models providing similar results to the Beta Study models, the new rainfall amounts can be incorporated into this examination's recreated models to examination the impact on the flood elevations and flooding areas from the increased rainfall amounts along Silver Creek (Eastern Branch).

Background:

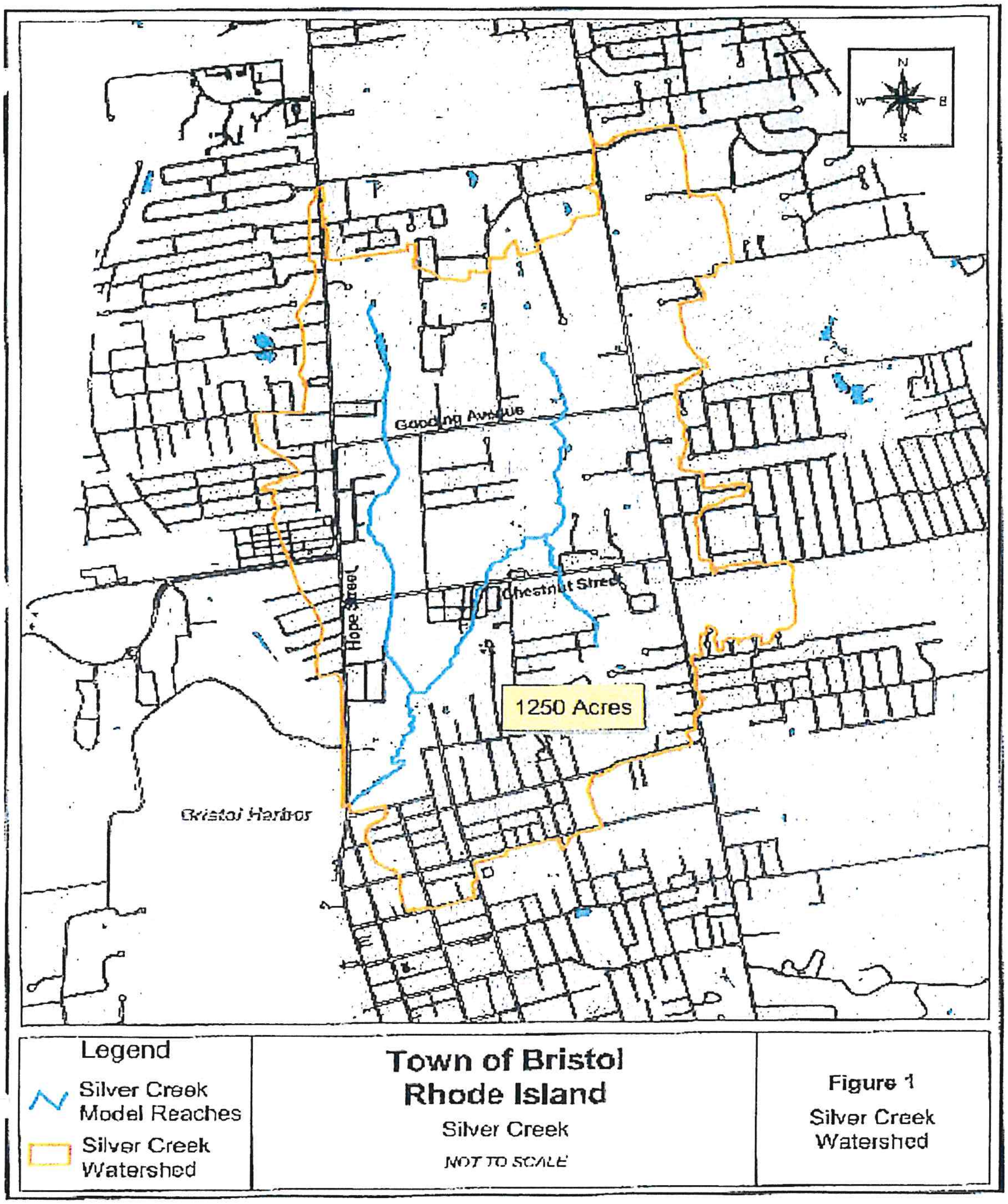
The watershed of the river is identified in order to determine the depth of flood waters and to determine the size or width of floodplains. The watershed will determine the amount of water that will reach a stream and be carried by the stream during normal rainfall and flooding events. A watershed is an area where all the rain that falls within that area, is drained into a common river. The boundaries of the watershed are formed by high areas or ridges along the perimeter of the river. The river is in the low central area of the watershed. The watershed is generally shaped like a bowl.

Figure 1 (from the Beta Study) identifies the boundaries of the Silver Creek watershed. Silver Creek watershed is about 1,250 acres in size. Silver Creek begins as two separate river channels identified as the Eastern Branch and Western Branch that merge into one river that flows into a large marshy area and then discharges into Bristol Harbor. Figure 2 (from the Beta Study) shows the Silver Creek river channel. A third river channel identified as Elbow Street is a tributary that flows into the Eastern Branch. The subject of this examination is the Eastern Branch and Elbow Street tributary of Silver Creek.

Recent Floods

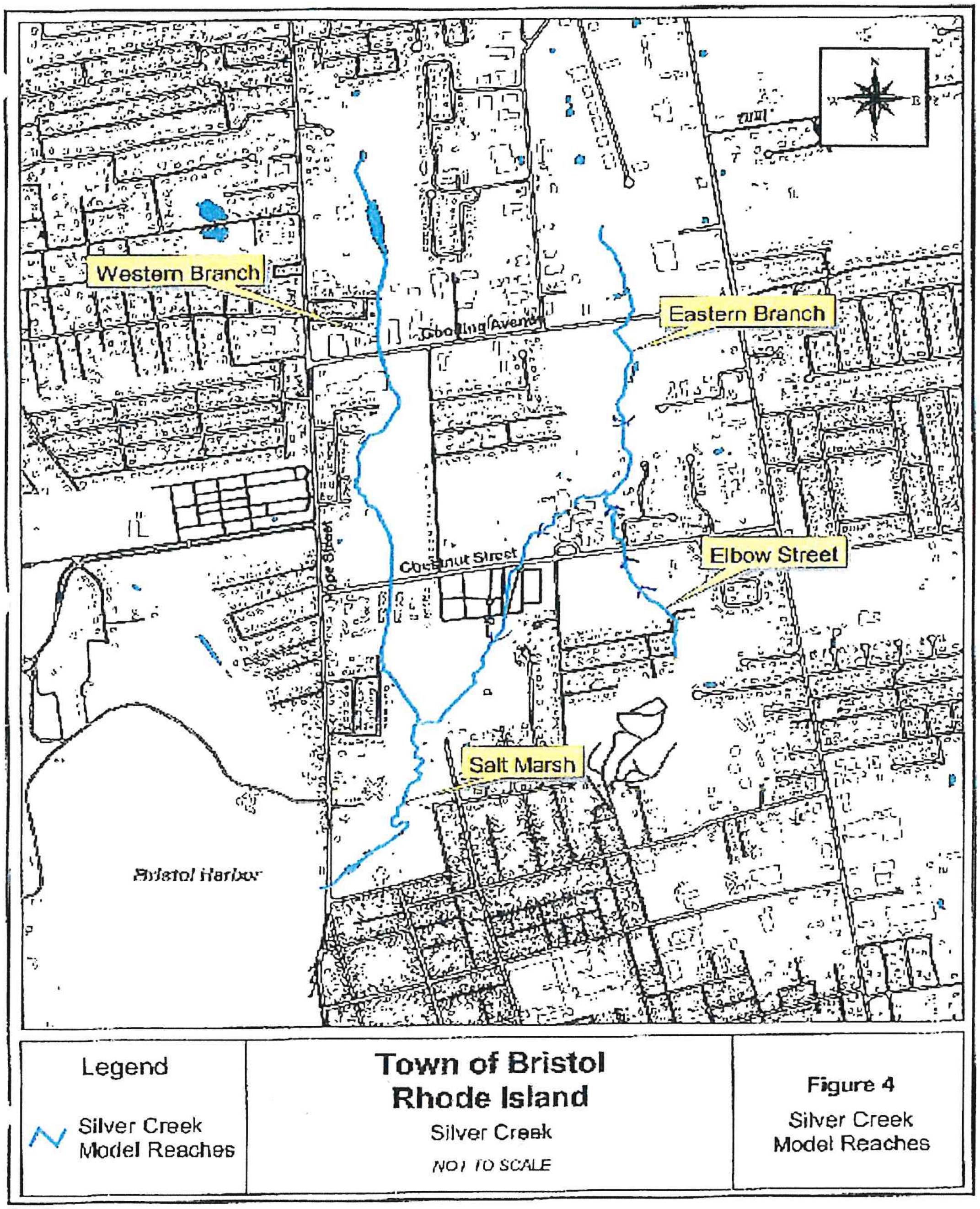
Silver Creek historically has had flooding issues. The photographs on the following pages obtained from the *Bristol Phonic* show Chestnut Street and St Mary Cemetery inundated by flood waters from Silver Creek. The photographs are from April 2010.

Figure 1 …. Silver Creek Watershed



Source : Beta Study p.

Figure 2…. Silver Creek River Channels



Source : Beta Study p.

St. Mary's Cemetery along Chestnut Street was swimming Tues morning. The road was closed to traffic and barricaded for much

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Recreate Beta HEC RAS Model

The first step was to recreate the Beta model with the information provided in the *Silver Creek Drainage Study.* The Beta Study used HEC RAS Version 4.1 to perform the hydraulic analysis for Silver Creek. There are five steps in creating a HEC RAS model:

- Starting a new project
- Entering geometric data
- Entering the flow data
- Performing the hydraulic calculations
- Viewing and printing results

The Beta Study report did not identify the input parameters used for the HEC RAS evaluation. The study did not show cross sections, identify roughness factors or the size and slope of the culverts. The Beta Study did include the results of the HES RAS computations including Flood Profiles and the Profile Summary report. A more in-depth and detail discussion of these input parameters is included in the following sections of this examination.

The Beta Study used the *HydroCAD* model (HydroCAD Software Solutions LLC) which employs the TR-20 and TR-55 method to determine peak runoff rates. TR-55 and TR-20 methods are the accepted procedures for estimating runoff peak rates.

The data used in the Hydraulic Study are usually processed using a computer model, most commonly HEC-RAS, which was developed by the U.S. Army Corps of Engineers' Hydrologic Engineering Center (*HEC-RAS Hydraulic Reference Manual* 5.1, ACOE, 2015). The hydraulic study produces flood water elevations and floodplain areas at each cross section along the river of the watershed areas. These elevations are the primary source of data used to map the area of a floodplain.

The *Silver Creek Drainage Study* included the Summary Profile for Beta's HES RAS model for the 100-year flood using the rainfall amount of 7.1 inches. The profile included information that was used to provide geometric and flow data to recreate the Beta model for this examination. The information included River Stations, flow data (Q), minimum channel elevation and water surface elevation. Appendix A shows Beta's 100-year Summary Profile from the *Silver Creek Drainage Study.* The goal was to use this data to recreate the Beta model and have the recreated model provide similar resulting water surface elevations for the 100-year flood event.

Table 1 provides a comparison between the Original Beta model and the Recreated Model for this examination for the 100-years storm event for the Eastern Section of Silver Creek and the Elbow Tributary. The flood water surface elevations are similar. Appendix A contains the Profile Summary for the Recreated Beta model created for this examination.

Table 1…Comparison between Beta Study Model and This Examination Recreated Model

Beta Study			Recreated Beta Model		
River Station	Min. Channel Elev (feet)	Water Surface Elev (feet)	River Station	Min. Chanel Elev (feet)	Water Surface Elev (feet)
9611	76.00	76.76			
9326	72.00	72.64	9325	72.00	74.27
9081	67.88	68.44	9181	67.88	68.60
8854	64.00	66.97	8692	64.00	66.48
8483	58.85	66.97	8421	58.85	66.47
8483	Gooding Ave Culvert		8371		
8375	58.36	66.96	8341	58.36	66.47
8046	58.14	66.96	7933	58.14	66.47
7473	56.00	66.96	7793	56.00	66.47
6821	56.00	66.96	7414	56.00	66.47
6595	56.00	66.96	7114	56.00	66.47
6359	56.00	66.96	6750	56.00	66.47
5909	56.00	66.96	5847	56.00	66.46
5881	High School Culvert		5819	High School Culvert	
5722	54.00	60.16	5722	54.00	61.75
5498	52.00	60.17	5630	52.00	59.09
5496	High School Road Culvert		5475	High School Road Culvert	
5307	48.00	50.51	5277	48.00	52.79
5158	46.00	47.32	5096	46.00	49.81
45.784975	36.93	45.31	4987	39.93	45.78
	St Mary's Cemetery Culvert		4240	St Mary's Cemetery Culvert	
4219	22.03	26.67	4070	22.03	24.76
3889	14.00	15.99	3933	14.00	15.24
3568	8.00	9.81	3307	8.00	10.44
3263	6.62	7.63	3008	6.44	7.43
2964	3.90	6.09	2607	3.92	5.65
	Elbow Tributary			Elbow Tributary	
2128	99.32	99.68			
1857	92.62	93.25	1935	92.62	93.15
1483	80.58	81.90	1330	80.58	80.91
1369	76.00	77.26	1118	76.00	76.33
1114	69.80	70.53	1052	69.80	69.97
972	66.00	68.15	765	66.00	68.40
829	62.50	68.16	700	62.50	68.38
793	Chestnut Culvert St.		675	Chestnut St. Culvert	
729	62.00	66.96	655	62.00	66.37
479	60.00	66.96	361	60.00	66.45
234	58.00	66.96	54	58.00	66.45

Since the Recreated Model HEC RAS produced similar results for water surface elevations to the Original Beta model, it can be used to form the basic model for examining the impact of the increased rainfall amounts on the flood water level elevations along Silver Creek (Eastern Branch).

The Recreated model used input parameters of flow data and river cross sections geometry from the Original Beta model obtained from Summary Profile contained in the *Silver Creek Drainage Study.* These parameters were not independently created for providing the data inputs into the Recreated Model. For example, the recreated model utilized the topographic data included in the *Map of the Study* area contained in the *Silver Creek Drainage Study.* The cross-section geometry was created by examining the minimum channel elevation identified in the Summary Profile and making a subjective determination of where this cross section may be located on the topographic map. This is one reason why the River Stations on the Original Beta model and the Recreated model are not identical. In order to produce a model that will adequately examine the impact of the increased rainfall amounts, all input parameters must be independently created and consistent with the Original and Recreated models.

Modified Beta Model

The goal of the Modified Beta Model is to independently create all the required input parameters for the HEC RAS Silver Creek examination. The input parameters include flow data, minimum channel depth, cross section geometry, culvert size and inverts. In order to better understand the dynamic of the river flow, additional cross-sections were also created along Silver Creek.

Flood Study Method

There are generally three major phases to a flood study of a river:

- Assess the flow (usually involving a hydrologic study)
- Determine the flood elevations and floodway (usually involving a hydraulic study)
- Map the floodplain and floodway

Hydrologic Study

Runoff is the amount of rainfall that reaches the stream. Any increase in the amount of runoff will, in turn, result in an increase in flood discharge. Discharge, measured in cubic feet per seconds, is the amount of water flowing down a stream channel. Runoff amounts and the resulting discharge rates vary depending on soil type, ground slope and land use. In general, more runoff occurs on non-vegetated land, on paved and built-on urban land, and on steeper slopes. Discharges are estimated by using rainfall and historical stream discharges records. Computer models incorporate numerous watershed characteristics into the hydrologic analyses that when completed show flood discharges for various size rainstorms that are generated along different arears along river.

The Beta Study used the HydroCAD model (HydroCAD Software Solutions LLC) which employs the TR-20 and TR-55 method to determine peak runoff rates. TR-55 and TR-20 methods are the accepted procedures for estimating runoff peak rates. They were developed by the Natural Resources Conservation Service, formerly the Soil Conservation Service that uses the specific watershed parameters to determine the peak runoff rates.

The Beta Study divided the Eastern Branch and the Elbow Street tributary into 16 different subwatersheds. For each subwatershed, their specific subwatershed characteristics of land use, soil types, and topography was entered into the *HydroCAD* model. The model produced the peak runoff rates for each subwatershed. The 16 subwatershed are shown in Appendix B of this examination. The Beta Study Appendix "HydroCAD – 2, 10- and 100-Year Storm Events" shows the specific subwatershed characteristics and the resulting peak flows rates.

This examination used *HydroCAD* (Version 10) to recreate the Beta Study *HydroCAD* model. The same subwatershed parameters used in the Beta Study were used in this examination's recreated *HydroCAD* model. Appendix B of this report includes the recreated *HydroCAD* model that identifies each subwatershed, their specific characteristic and the resulting peak runoff rates for the 100-Year Storm event. Figure 3 shows the routing diagram for the Eastern Branch and the Elbow Street Tributary. Table 2 compares the peak runoff rates from the Beta Study and with this examination's recreated *HydroCAD* model for the 100-Year Storm Event using the 7.10 inches of rainfall. The peak runoff rates are for the Eastern Branch of Silver Creek Upper and Lower Reaches.

Table 2....100 Year Peak Rate Runoff Comparison

Subwatersheds	Beta Study (cfs)	Recreated Model (cfs)
E9611	88.64	88.53
E9326	57.47	57.43
E9081	44.85	44.63
E8497	198.62	198.58
E8046	163.96	163.21
E7473	160.77	160.69
E6821	104.76	104.61
E6369	35.08	34.94
E5909	9.70	9.63
E5498	19.83	19.76
E5158	35.72	35.72
E4975	42.03	42.03
E4219	27.91	27.87
E3889	21.86	21.86
E3568	101.31	101.31
E2964	70.62	70.62

HydroCAD Routing Diagram

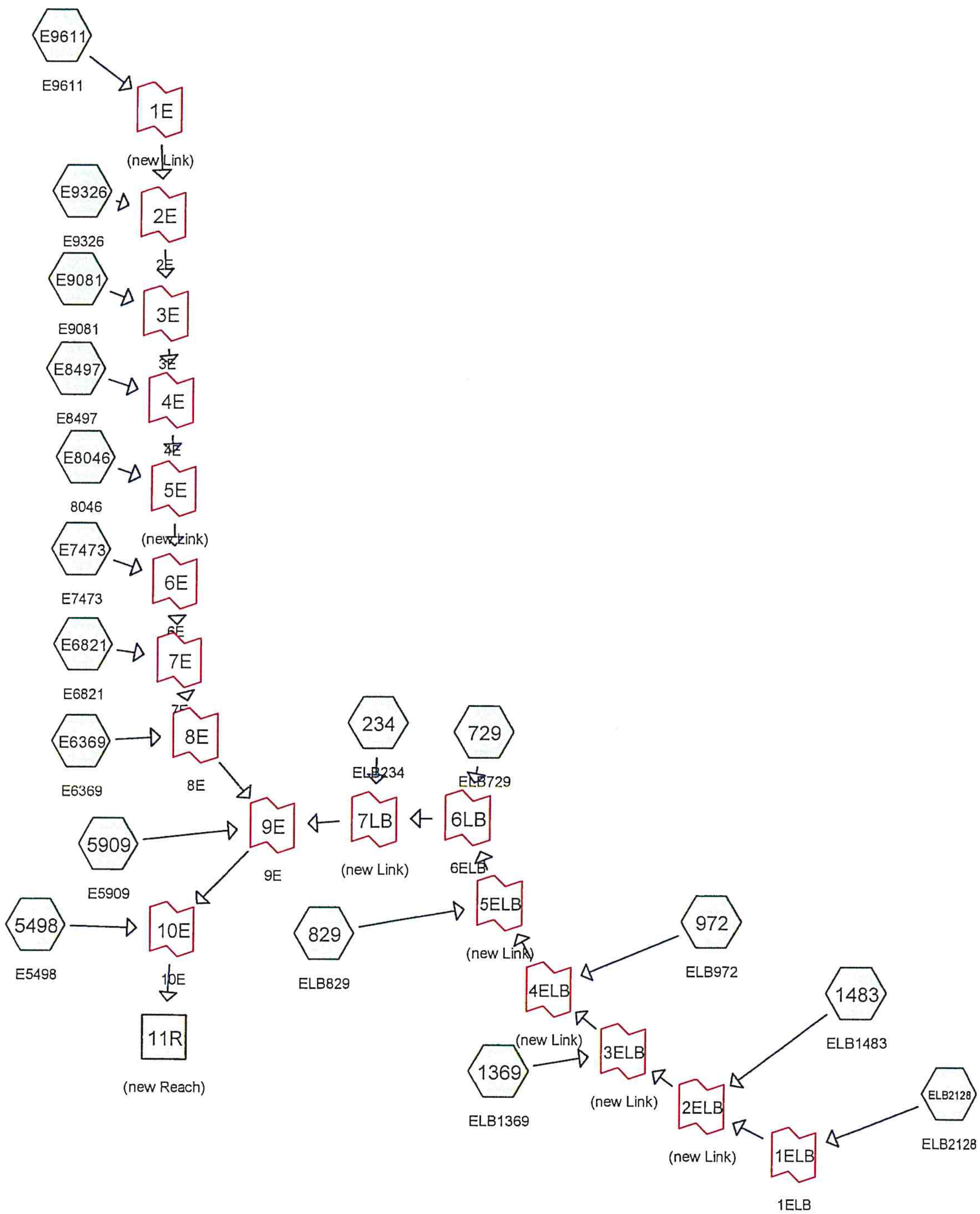


Table 2 shows the peak runoff rates are the same for both studies. The *Hydro CAD* results for Elbow Street Tributary are also the same peak runoff rates. This comparison demonstrates that the recreated *HydroCAD* model has been calibrated to the Beta Study model Thus, the recreated *HydroCAD* model can provide predicable, measurable and reliable results similar to the Beta Study model for this Silver Creek examination.

Hydraulic Study

Hydraulics is the study of fluids in motion. It is used to determine how a quantity of water will flow through a channel or floodplain. Hydraulic analysis combines:

- Flood hydrology, or discharges, (from the Hydrologic Study)
- The cross section data of a river shows how much area there is to carry the water during flooding events, and
- Stream characteristics — roughness, slope, locations and sizes of structures that effect the conveyance of water through the channel.

The data used in the Hydraulic Study are usually processed using a computer model, most commonly HEC-RAS, which was developed by the U.S. Army Corps of Engineers' Hydrologic Engineering Center (*HEC-RAS Hydraulic Reference Manual* 5.1, ACOE, 2015). The hydraulic study produces determinations of flood elevations and floodplain widths at each cross section for a range of river flow discharges. These elevations are the primary source of data used to map the area of the floodplain. The Beta Study used a "A lag time, ranging anywhere from 20 to 60 minutes, was calculated for each watershed based on the amount of time it would take to travel in the creek from the discharge point of the watershed to the next" (p6. Beta Study). The lag time for each watershed was identified in the Appendix of the Bata study and was used in this examination.

Cross-Section

A cross section is a slice through a corridor such as a river. It is perpendicular to the river and provides data on the river's geometry such as on the size and shape of the channel, the area of the floodplain, and the changes in the elevation resulting from watersheds discharges of the flowing water. Cross sections are also taken at areas that are obstructions to water flow such as culverts, buildings and bridges.

Roughness Factor

The roughness factor along the floodplain is used to determine how fast floodwater will flow through the area. Roughness factors are related to ground surface conditions, and they reflect changes in river's velocity due to ground friction. For example, water will flow faster over mowed grass and pavement than it will over an area covered in bushes and trees.

Flood Profile

The hydraulic computer program HEC RAS generates potential flood elevations at each cross section. The flood elevations at locations between the cross sections are determined by plotting the elevations at the cross sections on a graph and connecting the plotted points. The resulting graph is called a flood profile. The bottom of the graph (the horizontal axis or x-axis) shows the distance along the stream. Generally, when profiles are plotted, the slope of the streambed will rise as you read the graph from left to right or downstream to upstream. The left and right sides of the graph (the vertical axis or y-axis) show elevations in feet (NGVD 88).

Beta Study Hydraulic Analysis

The Beta Study used HEC RAS Version 4.1 to perform the hydraulic analysis for Silver Creek. As mentioned previously, the Eastern Branch was divided into 16 subwatersheds and Elbow Street tributary into nine (9) subwatersheds. Elbow Street tributary was included in the Beta Study as it flows under Chestnut Street and joins the Eastern Branch of Silver Creek near the high school. The tributary contributes to flooding problem of Silver Creek.

The Beta Study report did not identify the input parameters used for the HEC RAS evaluation. The study did not show cross sections, identify roughness factors or the size and slope of the culverts. The Beta Study included the results of the HES RAS analysis including Flood Profiles and the Profile Summary report. Appendix A contains the Flood Profile and Profile Summary from the Beta Study for the 100-year storm event using the rainfall amount of 7.10 inches. The goal of the recreated hydraulic examination is to duplicate the flood profile and profile summary data of the Beta Study. Once the recreated HEC-RAS model provides similar results to the Beta Study HEC-RAS analysis, then the new 100-year rainfall amount of 8.6 inches can be studied. Appendix A contains the Flood Profiles and Profile Summary for Eastern Branch of Silver Creek and Elbow Street Tributary for the 100-Year storm event with a rainfall amount of 7.5 inches from the Beta Study.

Recreated Hydraulic Analysis

The Recreated Hydraulic Analysis used HEC RAS Version 5.1 which is the updated computer model for flood plain analysis. The model requires three components to undertake the flood plain analysis. The components are: Geometry data, Flow data and Plan data. The geometry data includes a description of the size, shape and roughness factor for the stream cross sections. The flow data is the discharges rates from the watersheds along the stream (Hydrologic) and the plan data is parameters related to the computations of the model such as topography, cross section locations and culverts.

Cross-Sections

To analyze the Eastern Branch of Silver Creek and the Elbow Street tributary, the channel's geometry needs to be determined. The first step in creating the channel's geometry is obtain topography information along and adjacent to the stream.

For this examination, the topographic data was obtained from *Rhode Island Geographic System (RIGIS)*. RIGIS provides access to a wide variety of location based (geospatial data) for the State. One set of geospatial data is topographic information. "Statewide elevation contour lines (2-ft intervals) derived from a digital elevation model originally produced as part of the Northeast LiDAR Project in 2011." The contours lines for the Silver Creek watershed were obtained from RIGIS. The Beta Study identified the watersheds associated with Eastern Branch and Elbow Street tributary. The watersheds are identified in Appendix B "Silver Creek Watersheds". The Beta study used the same source to obtain topographic information but only an earlier version.

Cross-Sections were created using the RIGIS topographic information. The HEC RAS model can extract detailed cross sections generated by AutoDesk Civil 3D. "AutoDesk Civil 3D is an engineering software application used by civil engineers to plan, design, and manage civil engineering projects. These projects fall under the three main categories; land development, water, and transportation projects and flood plain analysis. Civil 3D is well known in the civil engineering community and widely used on a variety of infrastructure design projects."

The topographic information from RIGIS was imported into Civil 3D and converted into a surface model. The surface model is a 3D representation of the ground surface showing contours line indicating lines of different elevations. The surface model was created with one-foot contour lines by Civil 3D. A topographic and cross-section model was created in Civil 3D and exported into HEC RAS for the flood plain analysis.

The cross sections are created by using Civil 3D to define an alignment and then creating cross sections along the alignment. The alignment is a line that identifies the centerline of the Eastern Branch of Silver Creek and the Elbow Street tributary. Lines were then drawn perpendicular to both alignments crossing the detailed topographic surface model to create cross-sections. The location of the cross-sections was generally in the same place as the Beta Study.

The Beta Study cross-sections locations were identified in the Profile Summary reference as River Stations. These cross-sections represented areas were the flow rate changes along the river as a result of input from the various sub watersheds. Additional cross-sections were produced in this examination to provide a better correlation with the Beta Study and a more detailed understanding of the river flow and flooding dynamics.

Figure 4 shows an example of a cross-section along the Eastern Branch of Silver Creek. The figure shows a photograph of the natural river and the created model image of this cross section. Figure 5 shows an example of the model created cross-section of an existing culvert along Silver Creek. The cross-sections identify the River Station. The axis to the left is the elevations and the bottom axis is the length of the cross-section from left to right looking downstream. The cross-sections are generally in the shape of a V, U or semi-circle with the lowest elevation representing the bottom of the stream and the ascending lines indicating the banks of the stream.

Culverts Along Silver Creek

Culverts are structures that carry water under a road or other manmade structures. They allow vehicles or pedestrians to cross over the stream while allowing water to move through the culvert. There are seven culverts that convey water from Eastern Branch of Silver Creek and the Elbow Street Tributary. Table 3 shows the location of the culverts and their sizes.

Table 3…Culverts

River Reach	Location	Size
Upper Eastern Branch	Gooding Avenue	48" Circular
Lower Eastern Branch	High School	Twin 48" Circular
Lower Eastern Branch	High School	Twin 48" Circular
Lower Eastern Branch	High School Road	Twin 48" Circular
Lower Eastern Branch	Chestnut Street	Twin 48" Circular
Lower Easter Branch	St Mary's Cemetery	48" Circular
Elbow Street Tributary	Chestnut Street	48" Circular

The Beta Study report did not provide information on the culverts. It appears the Study estimated the culverts to be 48" circular in size with a slope of 1 percent. The elevation of the road above the culvert and the inverts of the culvert were obtained from an interpretation of the flood profile included in the Beta Study. The Profile is drawn to scale with elevations on the y axis and distances along the river on the x axis. The Profile showed the culverts and the road or building above the culverts.

Based on this profile, the elevations of the roadways and buildings and the inverts of the culverts was obtained from the Profile. These elevations were correlated with the topographic information. Cross -sections were created immediately before and after the culverts to complete the culvert inputs into the HEC RAS model.

The culvert examination involved interpretation of the Beta culvert information from the profile. This information was verified and supplemented by a plan produced in 2013 for drainage improvements at Mt Hope High School (*Mt Hope High Schools Drainage Improvements*, JMMA, September 2013). The plan set contained an Existing Condition Plan, that was based on a Record Survey Plan, with elevations using NGVD 1929. The existing vertical datum is NVGD 1988.

However, with proper conversion, the plan was useful in obtaining the sizes and inverts of the culverts along the High School section of Silver Creek. The plan corroborated this examination's interpretation of the Beta Study's culvert information.

Figure 4 Cross Section

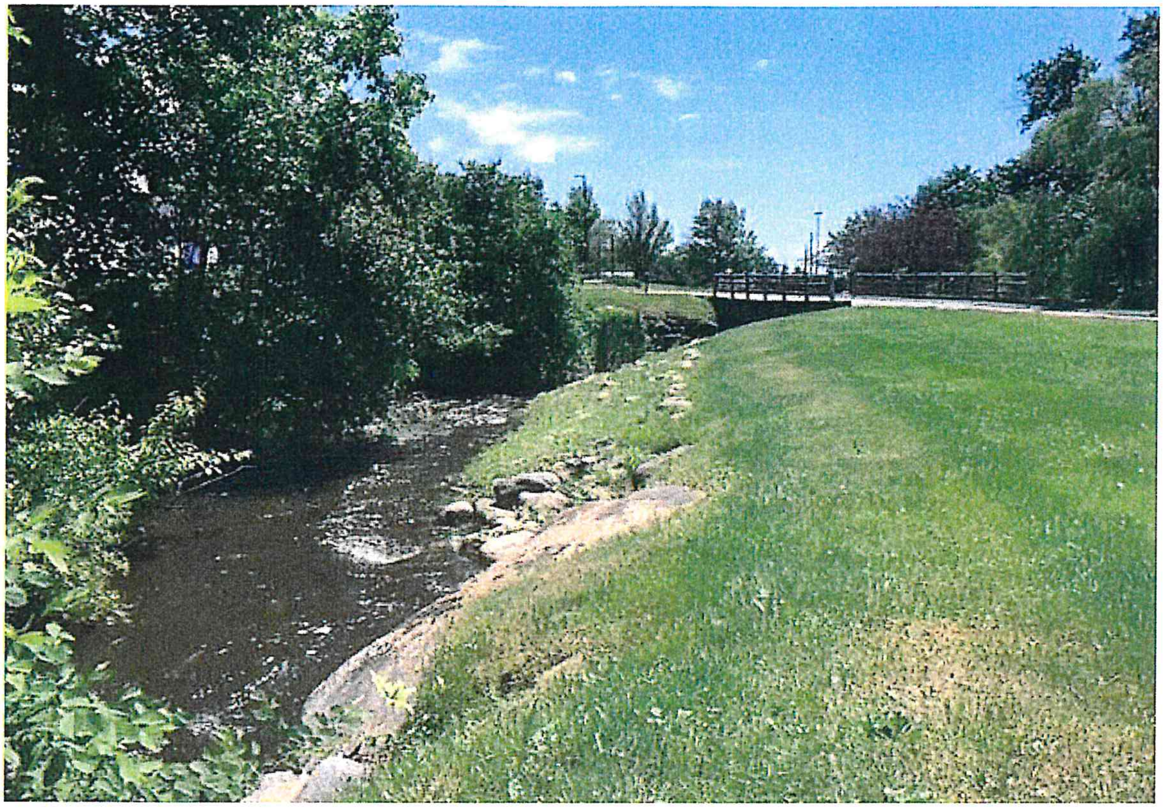


Figure 4...River Section 5551 Near High School Bridge (Looking Downstream)

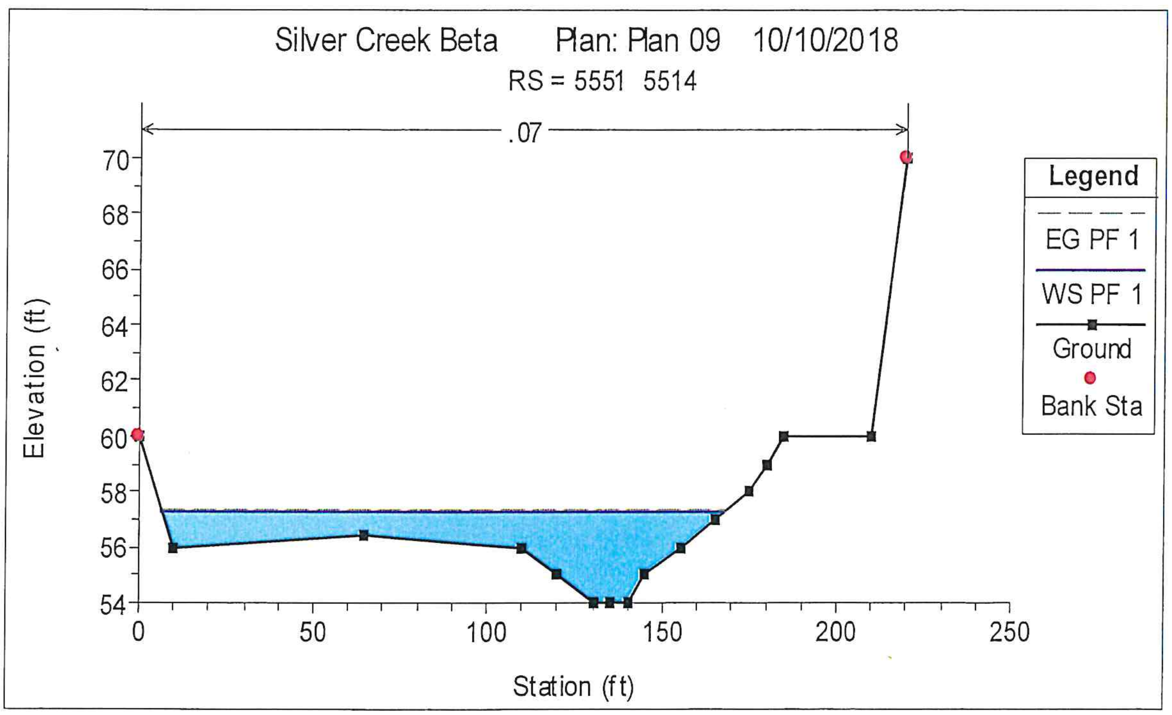
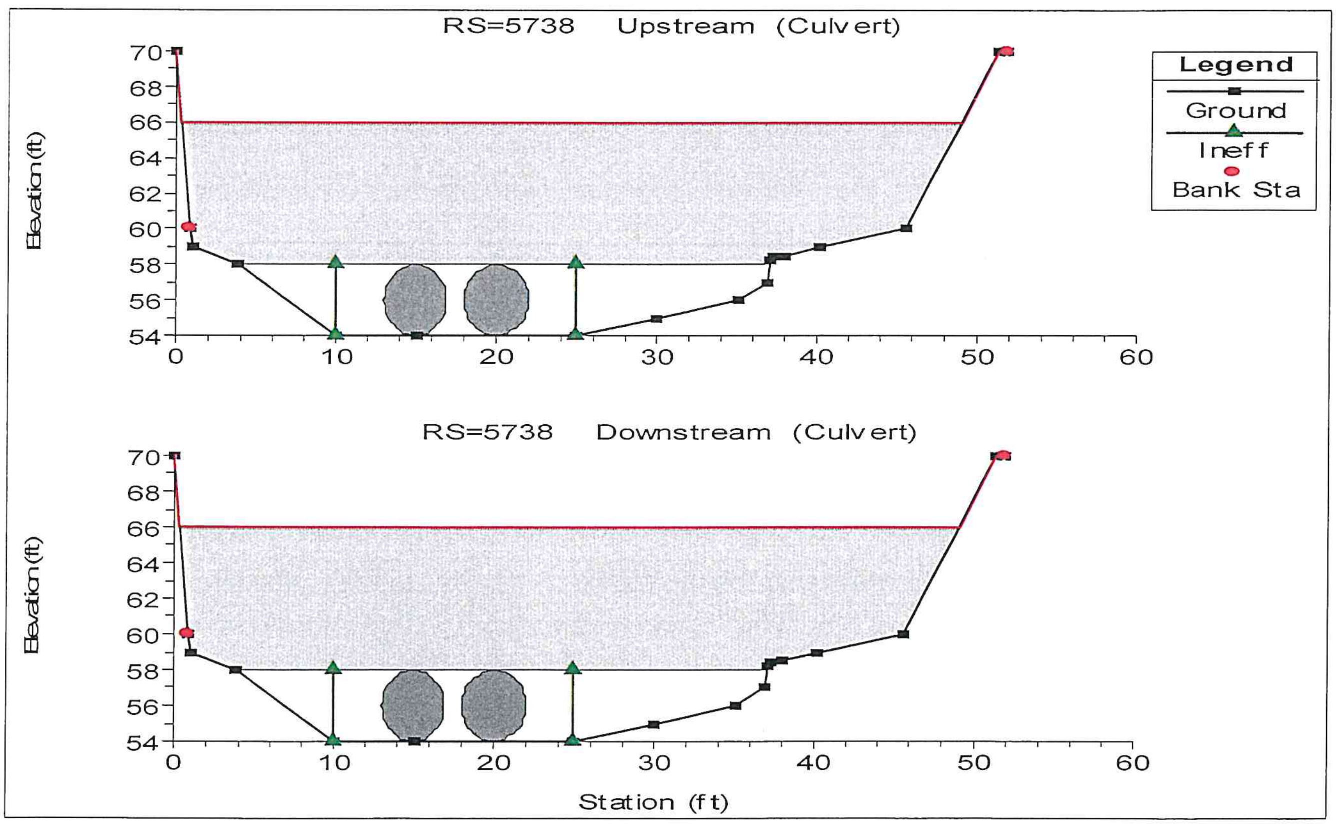


Figure 4...HEC RAS Cross Section Model River Section 5551 Near High School Bridge (Looking Upstream)

Figure 5…River Station 5738 twin 48" Culverts under High School (looking upstream)

Figure 5…HEC RAS Cross-Section Model River Station 5738 twin 48" Culverts under High School



Silver Creek Flood Profile (recreated/modified)

HEC RAS combines the Hydrologic and Hydraulic studies to produce the flood profile. Figure 6 shows the schematic layout of the Eastern Branch of Silver Creek and Elbow Street tributary from HEC RAS recreated model. The layout shows the location of the cross-sections and culverts along the stream.

The Flood Profiles and Profile Summary for the recreated HEC RAS model for the 100-year storm event for this examination is included in Appendix C. Table 4 shows a comparison of the Beta Study HEC RAS model and the recreated HEC RAS model. The two key components the comparison are minimum channel elevation and the resulting water surface elevation. The resulting water surface elevation is considered the flood elevation of the river at each of the identified river stations. Table 4 shows the river stations for the Beta model and the recreated model. It also shows the minimum channel elevation and water surface elevation at each river station. These values were obtained from the computation of the HEC RAS model resulting from the Hydrologic and Hydraulic data inputs. The Profile Summary for the Beta model is in Appendix b and from the Recreated Model in Appendix C.

Figure 6… Schematic Layout Silver Creek and Elbow Street Tributary

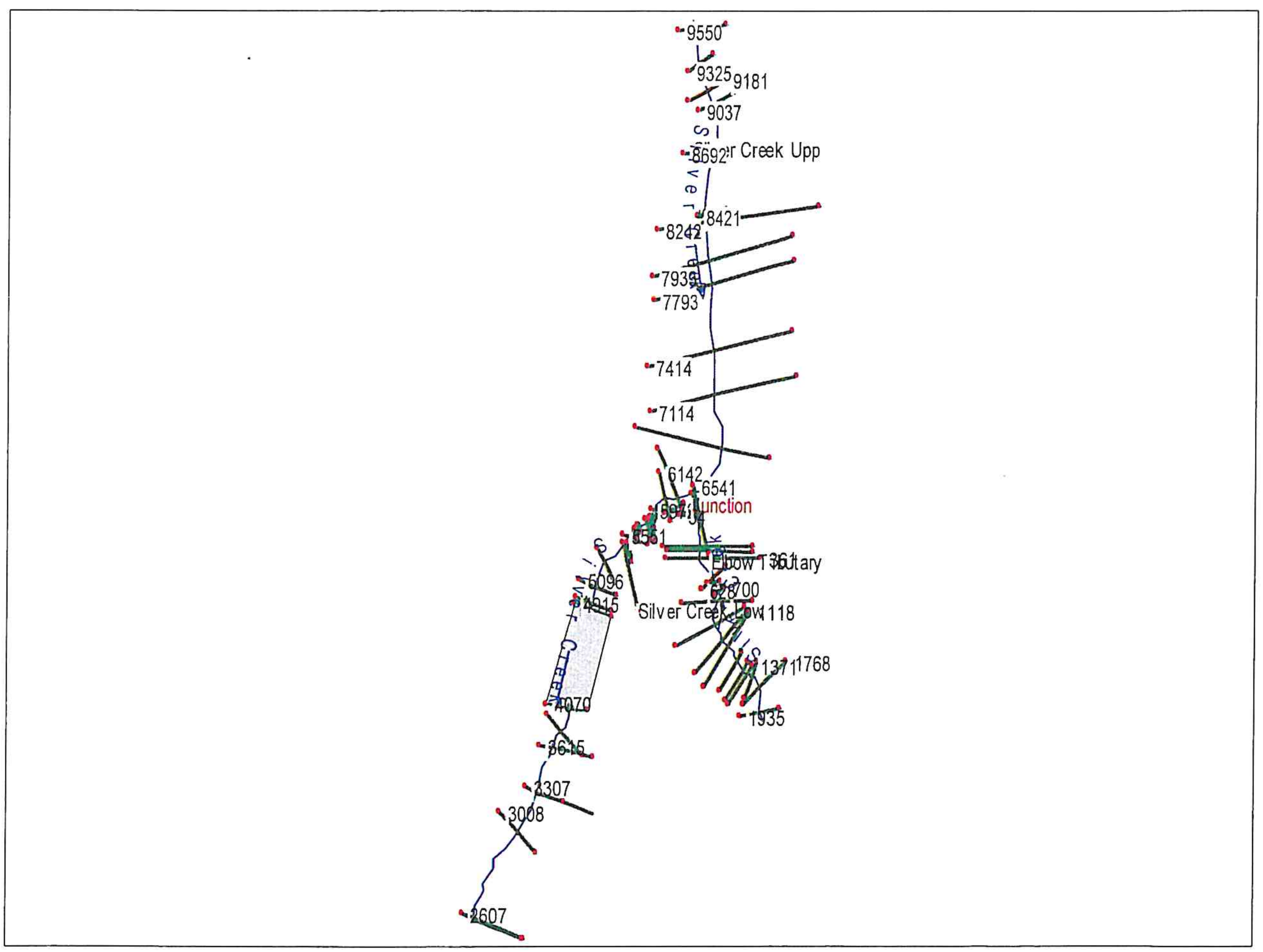


Table 4…Comparison between Beta Study Model and This Examination Recreated Model

Beta Study			Recreated Model		
River Station	Min. Channel Elev (feet)	Water Surface Elev (feet)	River Station	Min. Chanel Elev (feet)	Water Surface Elev (feet)
9611			9550	78.00	79.30
9326	76.00	76.76	9325	75.00	76.16
9081	72.00	72.64	9181	72.00	73.01
	67.88	68.44	9037	69.00	70.07
8854	64.00	66.97	8692	64.00	67.25
			8483	64.00	67.25
8483		58.85	66.97	58.85	67.24
8483	Gooding Ave Culvert		8371	Gooding Ave Culvert	
8375	58.36	66.96	8341	58.26	67.24
			8242	58.26	67.24
8046	58.14	66.96	7933	58.14	67.24
7473	56.00	66.96	7793	57.00	67.24
6821	56.00	66.96	7414	56.00	67.24
6595	56.00	66.96	7114	56.00	67.24
6359	56.00	66.96	6750	56.00	67.24
			6541	55.50	67.24
			6315	55.00	67.24
			6142	55.00	67.24
			5972	55.00	67.24
			5854	55.00	67.23
5909	56.00	66.96	5847	54.00	67.22
5881	High School Culvert		5819	High School Culvert	
			5809	54.00	66.45
			5774	54.00	66.45
			5766	54.00	66.45
			5758	54.00	66.43
			5738	High School Culvert	
5722	54.00	60.16	5722	54.00	59.37
5498	52.00	60.17	5630	54.00	57.95
			5551	54.00	57.40
			5490	51.00	56.85
5496	High School Road Culvert		5475	High School Road Culvert	
			5465	50.00	54.50
			5388	50.00	53.19
5307	48.00	50.51	5277	46.00	49.79
5158	46.00	47.32	5096	43.00	48.70
4975	36.93	45.31	4987	39.93	48.60
4947	Chestnut St/St Mary's Cemetery Culvert		4950	Chestnut Street Culvert	
			4801	36.00	48.58
	St Mary's Cemetery Culvert		4240	St Mary's Cemetery Culvert	
4219	22.03	26.67	4070	22.03	26.93
3889	14.00	15.99	3933	14.00	15.60
			3615	8.00	10.39
3568	8.00	9.81	3307	6.12	7.00
3263	6.62	7.63	3008	3.61	6.04
2964	3.90	6.09	2607	2.50	5.85
			2603	2.00	5.65

Table 4 shows the resulting water surface elevations for each model at the comparable locations of the river stations. The water surface flood elevations created by each model results in essentially the same elevations.

Since the flood water surface elevations for both models are relatively the same, the cross sections and their represented flood elevations for the recreated model are similar to the Beta model. This is one of the more important parameters that must be consistent between the two models in order to confirm the two models produce similar results.

This comparison demonstrates that the recreated HES RAS model, generated for this examination, has been created/calibrated to the original Beta Study model. Thus, the recreated HEC RAS model can be used to provide predicable, measurable and reliable results similar to the HEC RAS Beta Study model.

Change in Condition

Since the Beta Study was completed, the RIDEM has revised the *Rhode Island Design and Installation Standards Manual (*The Manual) specifically the 24-Hour Type III Rainfall Amounts. The Betal model utilized the 2007 rainfall amounts.

However, in 2010, RI DEM presented a new *Rhode Island Design and Installation Standards Manual* (subsequently amended in 2015) that revised the rainfall amounts particularly for the 100-year storm event. The 100-year storm event rainfall amount increased from the 2007 value of 7.10 inches that the Beta used in their study to 8.6 inches. The 8.6 inches is the current value mandated by the regulatory agencies for the 100-year storm. (The Manual, Table 3-1 Rainfall Amounts for Rhode Island, p3-1). "All Rhode Island rainfall values were obtained from the Northeast Regional Climate Center (NRCC) using regional data processed by NRCC from the period through December 2008" (The Manual p.4). All proposed developments must comply with the revised Manual.

Revised Flood Profile

Hydrology

With the recreated HEC RAS models, in this examination, providing similar results to the original Beta Study HEC RAS model, the new rainfall amount for the 100-Year storm event can be incorporated into the recreated model to examine the potential impact on the flood elevations and flooding areas along Silver Creek. The first step in this analysis is to use the recreated *HydroCAD* model to produce the peak runoff rates from a storm with a rainfall amount of 8.6 inches. This examination used *HydroCAD* (Version 10) to recreate the Beta Study *HydroCAD* model. The same subwatershed parameters used in the Beta Study were used in the recreated *HydroCAD* model for the new rainfall amount of 8.6 inches. Appendix B of this report includes the recreated *HydroCAD* that identifies each subwatershed, their specific characteristic and the resulting peak runoff rates for the 100-Year Storm event.

Hydraulic Analysis

The Recreated Hydraulic Analysis used HEC RAS Version 5.1 which is the updated computer model for flood plain analysis. The model requires three components to undertake the flood plain analysis. The components are: Geometry data, Flow data and Plan data. The only parameter that changes is the flow date. The revised peak runoff rates from the recreated *HydroCAD* model were entered into the recreated HEC RAS model.

Table 5 below shows the original peak runoff rates for each of the Beta Study watersheds using the 100-year storm rainfall amount of 7.5 inches. The revised peak runoff rates for each of the watersheds were produced using the 8.5 inches of rainfall. Appendix D contains the revised HydroCAD examination.

Table 5.... Revised 100-Year Peak Runoff Rates

Subwatersheds	Original Recreated Model (cfs) (7.5 inches)	Revised Recreated Model (cfs) (8.5 inches)
E9611	88.6	110.91
E9326	57.43	75.47
E9081	44.63	57.01
E8497	198.58	258.13
E8046	163.21	203.79
E7473	160.69	206.22
E6821	104.61	133.84
E6369	34.94	45.50
E5909	9.63	12.21
E5498	19.76	25.03
E5158	35.72	43.72
E4975	42.03	54.19
E4219	27.87	36.66
E3889	21.86	28.32
E3568	101.31	135.58
E2964		125.65

The next step was to incorporate the revised runoff rates into the recreated HES RAS model. The revised runoff rates, as expected, increase the Q total for water flow along Silver Creek. The higher Q total resulted in a higher flood elevation. Table 6 on the next page shows the higher flow elevations resulting for the higher rainfall amount of 8.5 inches for the 100-Year storm for Silver Creek. Appendix D rainfall 8.6 inches contains the HEC RAS Summary Profile for the new flow rates.

Table 6 … Water Surface Elevation

River Station	Water Surface Elev (feet)	Revised Water Surface Elev (feet)	Difference (feet)
9550	79.30	79.41	0.11
9325	76.16	76.29	0.13
9181	73.01	73.12	0.11
9037	70.07	70.10	0.03
8692	67.25	67.76	0.51
8483	67.25	67.75	0.5
8421	67.24	67.75	0.51
8371	Gooding Ave. Culvert		
8341	67.24	67.75	0.51
8242	67.24	67.75	0.51
7933	67.24	67.75	0.51
7793	67.24	67.75	0.51
7414	67.24	67.75	0.51
7114	67.24	67.75	0.51
6750	67.24	67.75	0.51
6541	67.24	67.75	0.51
6315	67.24	67.75	0.51
6142	67.24	67.75	0.51
5972	67.24	67.75	0.51
5854	67.23	67.74	0.51
5847	67.22	67.71	0.49
5819	High School Culvert		
5809	66.45	67.01	0.56
5774	66.45	67.01	0.56
5766	66.45	67.00	0.55
5758	66.43	66.98	0.55
5738	High School Culvert		
5722	59.37	59.91	0.54
5631	57.95	58.21	0.26
5551	57.40	57.70	0.3
5490	56.85	57.11	0.26
5475	High School Road Culvert		
5465	54.50	54.90	0.4
5388	53.19	53.63	0.44
5277	49.79	50.27	0.48
5096	48.70	49.01	0.31
4987	48.60	48.86	0.26
4950	Chestnut St Culvert		
4915	48.58	48.83	0.25
4240	St Mary Cemetery Culvert		
4070	26.93	27.95	1.02
3933	15.60	15.83	0.23
3615	10.39	10.54	0.15
3307	7.00	7.17	0.17
3008	6.04	6.80	0.76
2607	5.85	6.67	0.82
2603	5.65	6.49	0.84

Potential Floodway Determination

A floodway is a corridor of effective flood area. It usually consists of a stream channel and any adjacent areas that are needed to convey a particular flood event. HEC RAS is used to describe the physical properties of a river and to route flows through the river. Using the peak flows, HEC RAS computes the resulting water surface elevations at each cross-section. These elevations along with distance from the stream center line for each of the cross sections can be plotted on the topographic map. The plotted elevations on the topographic plan potentially shows the boundaries and aerial extent of flood inundation.

The water surface elevations from the HEC RAS Recreated model for each cross section were plotted on the topographic map for Silver Creek. The water surface elevations along Silver Creek and Elbow Tributary were plotted as Spot Elevation using Civil 3D. These spot elevations or points were then connected by a polyline. The polyline represents the potential boundaries and aerial extent of flood inundation.

The fold out map included with this examination shows the potential floodway determination. The most noticeable visual of the map is the extent that the wetland areas mitigate the flood waters. Most of the existing wetland areas are within the boundaries of the flood inundation. It is precisely for this function that wetland areas are protected from development. It is also for this reason that development should not occur within these areas as it will be susceptible to damage caused by flood waters.

The fold out map also shows how the water flow of Silver Creek is constrained by the culverts and buildings as it passes through the high school. This causes the flood waters to back up and spread out in the upstream areas. Most of this inundation areas are wetlands although some private properties are affected. A similar situation occurs within St Mary's Cemetery where the single 48" diameter pipe has insufficient capacity to convey the volume of flood waters. This causes the flood waters to overflow the pipe and flow along the surface.

Conclusion

The revised HEC RAS model showed an increase in flood elevations along Silver Creek ranging from about 2 inches to 1 foot. The average increase in flood water elevation is 0.44 feet or a little over 5 inches. The increase in flood water level elevation should be anticipated as the characteristics of the watersheds have not changed but the rainfall amount has increased. The increase in flood water elevation is not intended to be predictive but to provide a numerical identification of the range of possible flood elevations escalations.

This examination demonstrates that these is a potential increase in flood elevations and flooding areas resulting from the increase rainfall amount. It reinforces Beta's Study's results that the flooding problems along Silver Creek require a thoughtful and comprehensive examination to mitigate the flooding.

The HEC RAS model in this examination seems to shows that flood elevations between Gooding Avenue and Chestnut Street are affected by the culverts under the high school and the high schools' buildings above these culverts. The model shows that the culverts have insufficient capacity to convey the amount of flood waters being generated by the upstream watersheds. The flood water rises above the culverts. The waters are then blocked by the buildings above the culverts causing an increase in flood elevations and the water to flow over the surface. The model calibrations look as if the buildings acts like a dam restricting the flow of the flood water.

The model is very sensitive to the culverts under the high school. The high school's walkway connecting the high schools' buildings can act as dam restricting the flood waters. It appears to be also causing flooding inside some of the high school buildings. This needs to be examine more closely. For a more precise and detail examinations, the HEC RAS model should be supplemented by detail cross sections survey of the culverts and critical cross sections along the river.

This examination confirms and reinforces the analysis of the Beta Study. It shows the potential for increased flooding between Gooding Avenue and Chestnut Street and within St Mary Cemetery as a result of the increased rainfall amount. It supports and reinforces the conclusion of the *Silver Creek Drainage Study* that the existing wetland areas are critical to controlling and mitigating the flood elevations and the resulting extent of flood areas.

The Study's conclusion that "**It is recommended that additional storage be constructed, particularly upstream of the local areas currently experiencing flooding, and on vacant land, to retain stormwater runoff until the peak flows have safety passed….Possible locations include along Gooding Avenue, Naomi Street, within the Mount Hope High School campus ….**" (p.21 The *Silver Creek Drainage Study*).

Declaration

My examination was conducted solely by myself. It represents my work product and my opinions. It was not commissioned or supported financially by the Town, any regulatory agency or any advocatory group. It resulted from concerns expressed by my neighbors that any development within wetland areas could cause increased flooding to their property.

My study was conducted to gain a better understanding of the potential increase of flood water elevations and extent of flooding areas along Silver Creek. It was meant to provide a recognition of the existing flooding issues and the need to recognize the important role that wetland areas have in mitigating flood areas. It provides support, in my opinion, for a comprehensive examination of the flooding issues along Silver Creek. It recognizes that the *Silver Creek Drainage Study* provides a solid basis for such an examination. A supplementary Study should be supported with detail survey data. It should also be integrated with the FEMA maps to provide a better mechanism for controlling flooding along Silver Creek.

The study is not meant to be predicative of the exact flood elevations or flooding areas. It is based on the comparative recreation of the Beta model. An exact recreation of the Beta model is difficult without having access to their cross-section data or their culvert parameters. Yet this examination's recreated and modified models do produces comparative results with the Beta model consistent with the purpose of this examination. It is my opinion, that given the consistency of this examination's modes with the original Beta model, the increase rainfall amount model can be useful in identifying the potential for more severe flooding along Silver Creek and the need for timely response action.

Although the overall results (100-year elevations) will most likely not change significantly, a better understanding and greater confidence levels can be obtained by a more in-depth examination of the HEC RAS model parameters. These include:

- Historic Flood High water Marks - Where the data exists, this floodplain examination could be complemented by comparing the estimated elevations with known high-water marks from actual past floods.

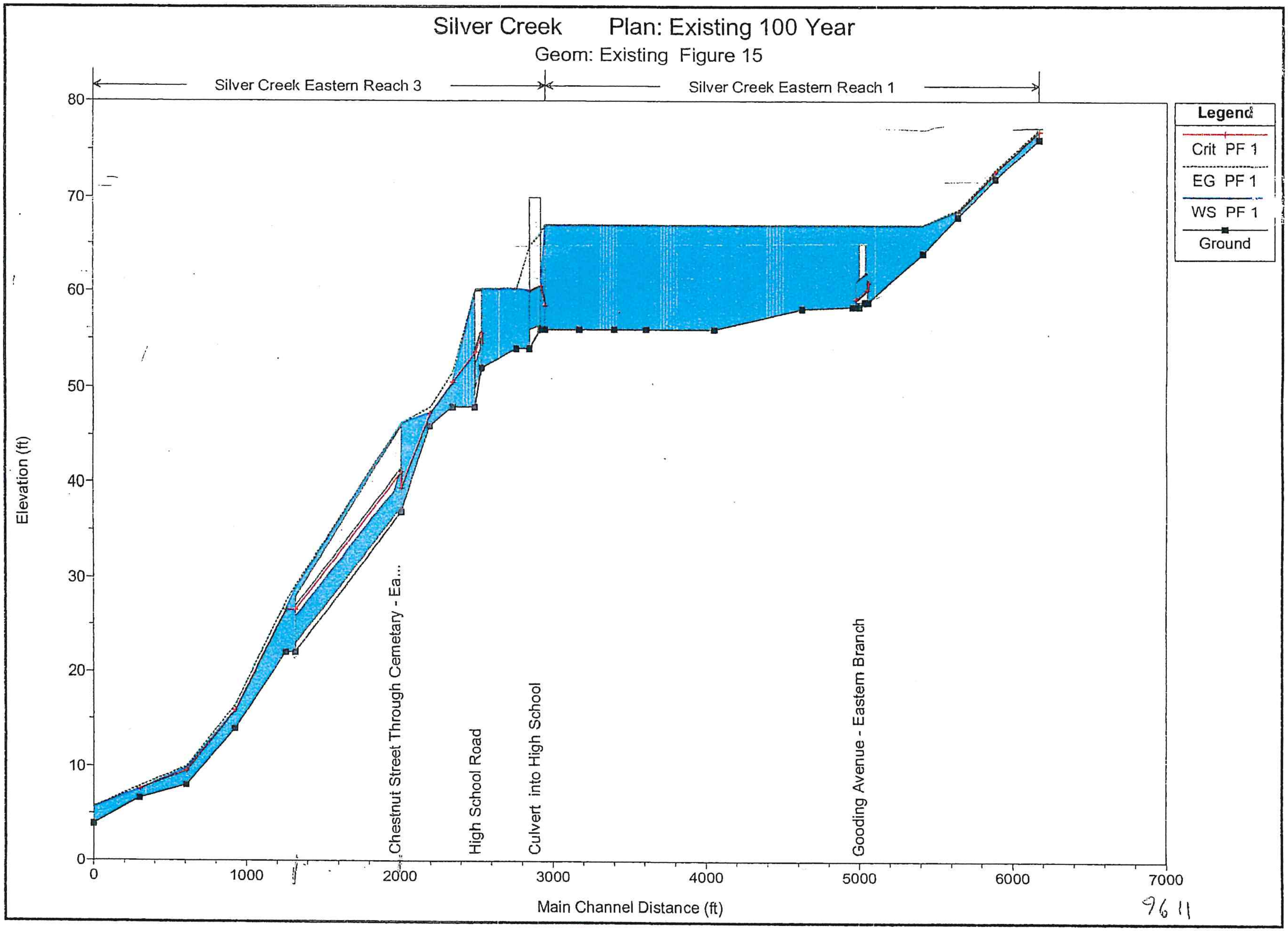
- Roughness coefficients – Specific site examination of the type of surface characteristic for each cross-section. This would include site examination to visually observe and identify specific site characteristics.

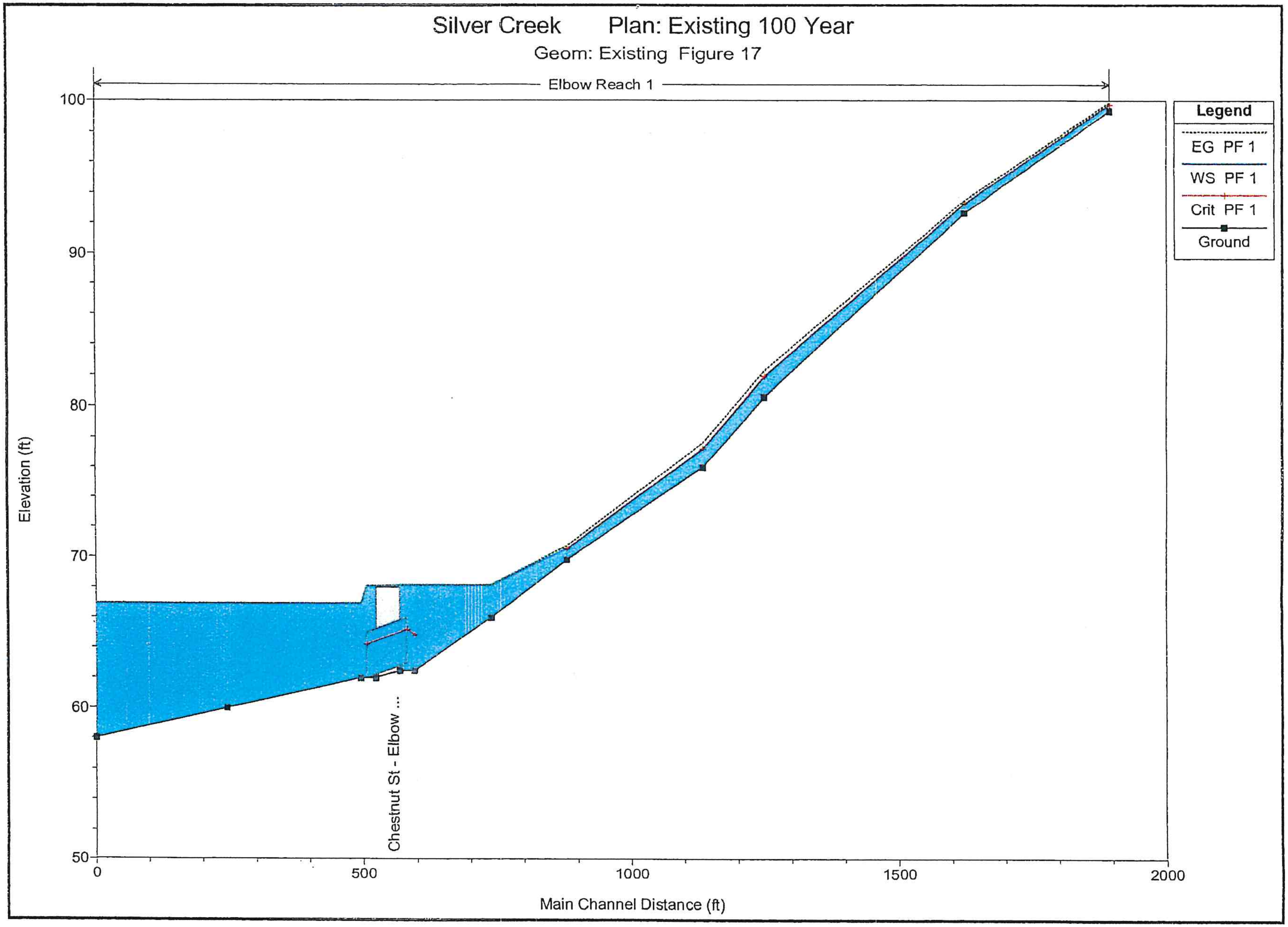
- Survey Culverts – A survey of the culverts will provide the detail information on size, lengths, inverts, material and condition.

- Survey Critical Cross-Sections – A survey, of the critical cross-sections will provide detail information on width, specific point elevations alongg

APPENDIX A

Beta's 100-year Summary Profile from the *Silver Creek Drainage Study*


Silver Creek Plan: Existing 100 Year
Geom: Existing Figure 15
Silver Creek Eastern Reach 3
Silver Creek Eastern Reach 1
Legend
Crit PF 1
EG PF 1
WS PF 1
Ground
Elevation (ft)
80
70
60
50
40
30
20
10
0
Chestnut Street Through Cemetary - Ea...
High School Road
Culvert into High School
Gooding Avenue - Eastern Branch
0
1000
2000
3000
4000
5000
6000
7000
Main Channel Distance (ft)
96 11



Silver Creek Plan: Existing 100 Year
Geom: Existing Figure 17
Elbow Reach 1
Legend
EG PF 1
WS PF 1
Crit PF 1
Ground
Chestnut St - Elbow ...
Elevation (ft)
Main Channel Distance (ft)
100
90
80
70
60
50
0
500
1000
1500
2000

HEC-RAS Plan: Plan 09 River: Silver Creek Reach: Silver Creek Upp Profile: PF 1

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Silver Creek Upp	9325	PF 1	88.64	72.00	73.75	72.84	73.84	0.007318	2.41	36.77	22.07	0.33
Silver Creek Upp	9181	PF 1	88.64	67.88	68.43	68.43	68.64	0.096840	3.68	24.06	57.77	1.01
Silver Creek Upp	8692	PF 1	143.08	64.00	66.52		66.52	0.000022	0.11	1254.35	1014.00	0.02
Silver Creek Upp	8421	PF 1	337.53	58.85	66.50	62.37	66.50	0.000075	0.42	802.37	229.95	0.04
Silver Creek Upp	8371		Culvert									
Silver Creek Upp	8341	PF 1	337.53	58.36	66.45		66.46	0.000099	0.46	739.39	229.55	0.04
Silver Creek Upp	7933	PF 1	337.53	58.14	66.46		66.46	0.000001	0.06	5873.49	1156.58	0.00
Silver Creek Upp	7793	PF 1	337.53	56.00	66.46		66.46	0.000001	0.06	5959.88	1156.39	0.00
Silver Creek Upp	7414	PF 1	361.40	56.00	66.46		66.46	0.000000	0.05	7773.95	1249.51	0.00
Silver Creek Upp	7114	PF 1	361.40	56.00	66.45		66.45	0.000000	0.04	8475.35	1249.51	0.00
Silver Creek Upp	6541	PF 1	373.98	56.00	66.45		66.45	0.000002	0.10	3621.19	456.45	0.01

HEC-RAS Plan: Plan 09 River: Silver Creek Reach: Elbow Tributary Profile: PF 1

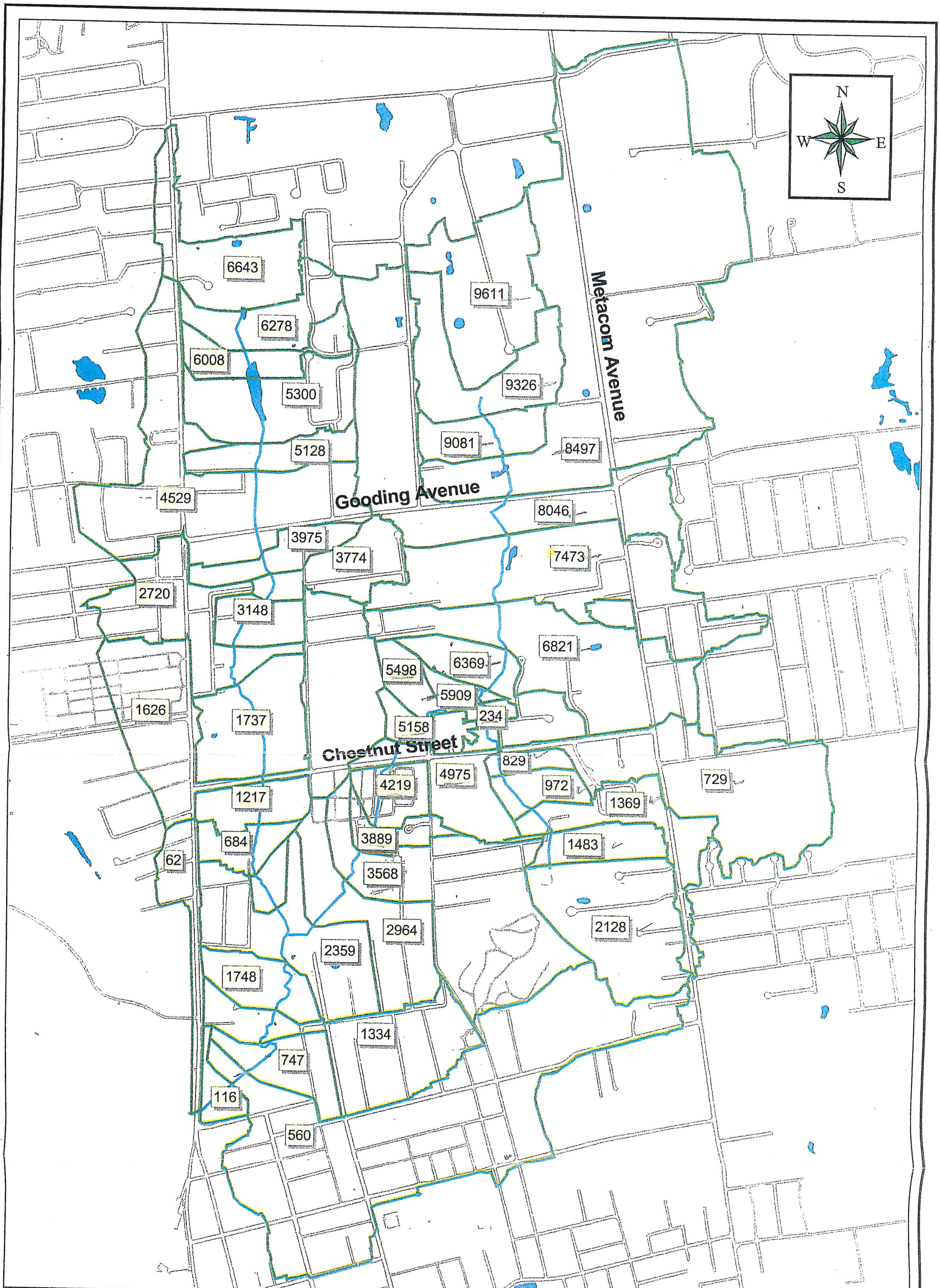
Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Elbow Tributary	1935	PF 1	78.21	92.62	93.15		93.16	0.008027	0.96	81.45	226.89	0.28
Elbow Tributary	1330	PF 1	129.10	80.58	80.91	80.91	80.98	0.152630	2.15	60.05	455.01	1.04
Elbow Tributary	1118	PF 1	129.10	76.00	76.33		76.35	0.014962	1.13	114.26	398.02	0.37
Elbow Tributary	1052	PF 1	133.04	69.80	69.97	69.97	70.04	0.114594	2.16	61.51	372.45	0.94
Elbow Tributary	765	PF 1	134.83	66.00	68.40		68.40	0.000081	0.26	525.32	337.91	0.04
Elbow Tributary	700	PF 1	134.83	62.50	68.38	63.97	68.39	0.000438	0.69	195.82	99.09	0.09
Elbow Tributary	675		Culvert									
Elbow Tributary	655	PF 1	198.89	62.00	66.37		66.52	0.006039	3.06	65.05	75.19	0.34
Elbow Tributary	361	PF 1	198.89	60.00	66.45		66.46	0.000177	0.57	350.48	122.18	0.06
Elbow Tributary	54	PF 1	198.89	58.00	66.45		66.45	0.000002	0.08	2405.60	537.64	0.01

HEC-RAS Plan: Plan 09 River: Silver Creek Reach: Silver Creek Low Profile: PF 1

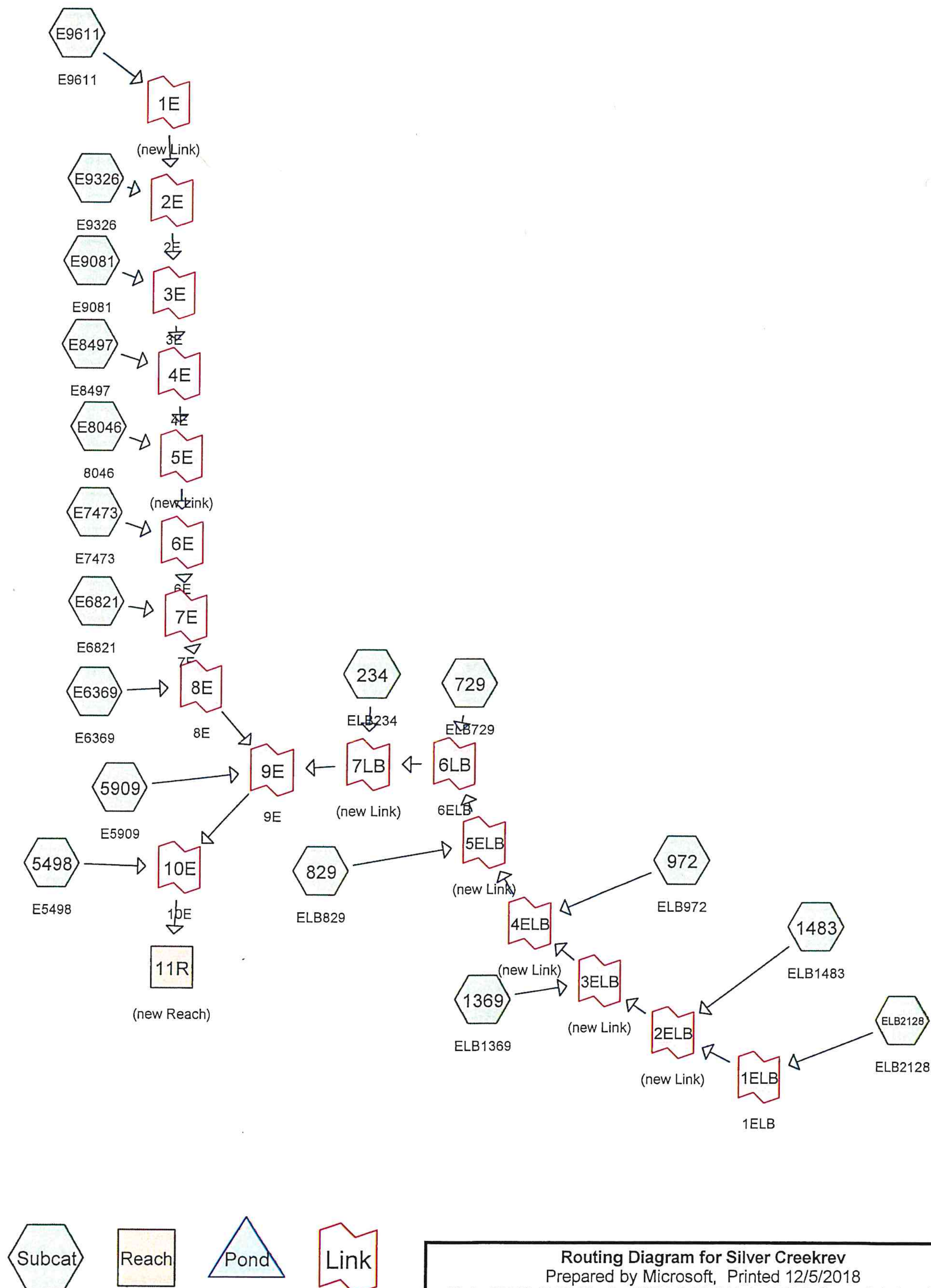
Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Silver Creek Low	5847	PF 1	358.46	56.00	66.44	58.60	66.45	0.000140	0.84	426.78	58.87	0.05
Silver Creek Low	5819		Culvert									
Silver Creek Low	5809	PF 1	358.46	56.00	61.75		61.83	0.003215	2.28	156.89	56.05	0.24
Silver Creek Low	5722	PF 1	358.46	54.00	59.23		59.41	0.008041	3.42	104.84	40.31	0.37
Silver Creek Low	5490	PF 1	429.34	52.00	56.81	54.91	56.90	0.006583	2.47	173.49	98.08	0.33
Silver Creek Low	5475		Culvert									
Silver Creek Low	5388	PF 1	429.34	48.00	52.91		52.98	0.004081	2.09	205.21	105.46	0.26
Silver Creek Low	5277	PF 1	429.34	46.00	49.81	49.81	50.80	0.064603	7.96	53.91	27.44	1.00
Silver Creek Low	4987	PF 1	429.34	36.93	45.78	39.10	45.81	0.000945	1.50	286.97	78.16	0.14
Silver Creek Low	4240		Culvert									
Silver Creek Low	4070	PF 1	435.58	22.00	24.76	24.54	25.74	0.048506	7.95	54.81	21.65	0.88
Silver Creek Low	3933	PF 1	436.44	14.00	15.24	15.24	15.82	0.069461	6.14	71.07	61.37	1.01
Silver Creek Low	3615	PF 1	436.44	8.00	10.44	9.70	10.45	0.002967	1.09	400.67	438.00	0.20
Silver Creek Low	3307	PF 1	443.30	6.44	7.43	7.43	7.67	0.094181	3.99	111.08	231.64	1.02
Silver Creek Low	3008	PF 1	443.30	3.90	5.88		5.90	0.001399	1.15	386.41	221.69	0.15
Silver Creek Low	2607	PF 1	446.09	2.00	5.65	3.08	5.66	0.000500	0.90	498.06	190.06	0.10

APPENDIX B

Eastern Branch and the Elbow Street tributary 16 Subwatersheds



Legend	Town of Bristol Rhode Island	Appendix
Silver Creek	Silver Creek	Silver Creek Watersheds
Silver Creek Watersheds	*NOT TO SCALE*	



Routing Diagram for Silver Creekrev
Prepared by Microsoft, Printed 12/5/2018
HydroCAD® 10.00-22 s/n 09085 © 2018 HydroCAD Software Solutions LLC

Summary for Subcatchment 829: ELB829

Runoff = 14.85 cfs @ 12.42 hrs, Volume= 1.936 af, Depth= 5.47"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-30.00 hrs, dt= 0.05 hrs
Type III 24-hr 100-yearnew Rainfall=8.60"

Area (ac)	CN	Description
0.750	81	1/3 acre lots, 30% imp, HSG C
3.500	73	Woods, Fair, HSG C
4.250	74	Weighted Average
4.025		94.71% Pervious Area
0.225		5.29% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
22.2	150	0.0400	0.11		**Sheet Flow, Sheet** Woods: Light underbrush n= 0.400 P2= 3.30"
10.0	600	0.0400	1.00		**Shallow Concentrated Flow, Concentrated** Woodland Kv= 5.0 fps
32.2	750	Total			

Summary for Subcatchment 972: ELB972

Runoff = 28.03 cfs @ 12.35 hrs, Volume= 3.384 af, Depth= 5.47"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-30.00 hrs, dt= 0.05 hrs
Type III 24-hr 100-yearnew Rainfall=8.60"

Area (ac)	CN	Description
1.000	81	1/3 acre lots, 30% imp, HSG C
6.430	73	Woods, Fair, HSG C
7.430	74	Weighted Average
7.130		95.96% Pervious Area
0.300		4.04% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
14.7	150	0.0400	0.17		**Sheet Flow, Sheet** Grass: Dense n= 0.240 P2= 3.30"
12.5	750	0.0400	1.00		**Shallow Concentrated Flow, Shallow Concentrated** Woodland Kv= 5.0 fps
27.2	900	Total			

Summary for Subcatchment 5498: E5498

Runoff = 25.03 cfs @ 12.49 hrs, Volume= 3.642 af, Depth= 6.55"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-30.00 hrs, dt= 0.05 hrs
Type III 24-hr 100-yearnew Rainfall=8.60"

	Area (ac)	CN	Description
*	2.620	94	
*	4.050	76	
	6.670	83	Weighted Average
	6.670		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
14.7	150	0.0400	0.17		**Sheet Flow,** Grass: Dense n= 0.240 P2= 3.30"
23.9	850	0.0140	0.59		**Shallow Concentrated Flow,** Woodland Kv= 5.0 fps
38.6	1,000	Total			

Summary for Subcatchment 5909: E5909

Runoff = 12.21 cfs @ 12.68 hrs, Volume= 2.108 af, Depth= 6.55"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-30.00 hrs, dt= 0.05 hrs
Type III 24-hr 100-yearnew Rainfall=8.60"

Area (ac)	CN	Description
1.480	94	Urban commercial, 85% imp, HSG C
2.380	76	Woods/grass comb., Fair, HSG C
3.860	83	Weighted Average
2.602		67.41% Pervious Area
1.258		32.59% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
42.2	150	0.0080	0.06		**Sheet Flow, Sheet** Woods: Light underbrush n= 0.400 P2= 3.30"
11.2	300	0.0080	0.45		**Shallow Concentrated Flow, Concentrated** Woodland Kv= 5.0 fps
53.4	450	Total			

Summary for Subcatchment E6369: E6369

Runoff = 45.50 cfs @ 12.83 hrs, Volume= 8.537 af, Depth= 5.83"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-30.00 hrs, dt= 0.05 hrs
Type III 24-hr 100-yearnew Rainfall=8.60"

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
10.8	200	0.0600	0.31		**Sheet Flow, Sheet** Grass: Short n= 0.150 P2= 3.30"
2.9	300	0.0600	1.71		**Shallow Concentrated Flow, Concentrated** Short Grass Pasture Kv= 7.0 fps
22.9	1,065	0.0240	0.77		**Shallow Concentrated Flow, Shallow** Woodland Kv= 5.0 fps
36.6	1,565	Total			

Summary for Subcatchment E8046: 8046

Runoff = 203.79 cfs @ 12.72 hrs, Volume= 37.291 af, Depth= 7.03"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-30.00 hrs, dt= 0.05 hrs
Type III 24-hr 100-yearnew Rainfall=8.60"

Area (ac)	CN	Description
36.960	91	Urban industrial, 72% imp, HSG C
2.300	83	1/4 acre lots, 38% imp, HSG C
10.840	94	Urban commercial, 85% imp, HSG C
13.510	70	Brush, Fair, HSG C
63.610	87	Weighted Average
26.911		42.31% Pervious Area
36.699		57.69% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
17.8	150	0.0250	0.14		**Sheet Flow,** Grass: Dense n= 0.240 P2= 3.30"
15.3	2,275	0.0150	2.49		**Shallow Concentrated Flow, Concentrated** Paved Kv= 20.3 fps
24.4	1,010	0.0190	0.69		**Shallow Concentrated Flow, Concentrated** Woodland Kv= 5.0 fps
57.5	3,435	Total			

Summary for Subcatchment E8497: E8497

Runoff = 258.13 cfs @ 13.73 hrs, Volume= 80.115 af, Depth> 5.95"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-30.00 hrs, dt= 0.05 hrs
Type III 24-hr 100-yearnew Rainfall=8.60"

	Area (ac)	CN	Description
*	161.630	78	Woods
	161.630		100.00% Pervious Area

Summary for Subcatchment E9611: E9611

Runoff = 110.91 cfs @ 12.68 hrs, Volume= 19.417 af, Depth= 6.91"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-30.00 hrs, dt= 0.05 hrs
Type III 24-hr 100-yearnew Rainfall=8.60"

Area (ac)	CN	Description
12.370	72	Woods/grass comb., Good, HSG C
21.330	94	Urban commercial, 85% imp, HSG C
33.700	86	Weighted Average
15.569		46.20% Pervious Area
18.131		53.80% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
16.5	150	0.0300	0.15		**Sheet Flow,** Grass: Dense n= 0.240 P2= 3.30"
37.3	1,500	0.0180	0.67		**Shallow Concentrated Flow,** Woodland Kv= 5.0 fps
53.8	1,650	Total			

Summary for Subcatchment ELB2128: ELB2128

Runoff = 100.23 cfs @ 12.79 hrs, Volume= 18.485 af, Depth= 6.07"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-30.00 hrs, dt= 0.05 hrs
Type III 24-hr 100-yearnew Rainfall=8.60"

Area (ac)	CN	Description
6.960	90	1/8 acre lots, 65% imp, HSG C
4.870	60	Woods, Fair, HSG B
4.870	77	Woods, Poor, HSG C
19.850	81	1/3 acre lots, 30% imp, HSG C
36.550	79	Weighted Average
26.071		71.33% Pervious Area
10.479		28.67% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
50.9	150	0.0200	0.05		**Sheet Flow,** Woods: Dense underbrush n= 0.800 P2= 3.30"
10.3	750	0.0590	1.21		**Shallow Concentrated Flow,** Woodland Kv= 5.0 fps
61.2	900	Total			

Summary for Link 3ELB: (new Link)

Inflow Area = 66.500 ac, 24.72% Impervious, Inflow Depth = 6.00" for 100-yearnew event
Inflow = 166.32 cfs @ 12.92 hrs, Volume= 33.227 af
Primary = 166.14 cfs @ 13.26 hrs, Volume= 33.227 af, Atten= 0%, Lag= 20.1 min

Primary outflow = Inflow delayed by 20.0 min, Time Span= 0.00-30.00 hrs, dt= 0.05 hrs

Summary for Link 4E: 4E

Inflow Area = 231.810 ac, 11.42% Impervious, Inflow Depth > 6.06" for 100-yearnew event
Inflow = 434.13 cfs @ 14.05 hrs, Volume= 117.014 af
Primary = 434.13 cfs @ 14.80 hrs, Volume= 117.008 af, Atten= 0%, Lag= 45.0 min

Primary outflow = Inflow delayed by 45.0 min, Time Span= 0.00-30.00 hrs, dt= 0.05 hrs

Summary for Link 4ELB: (new Link)

Inflow Area = 73.930 ac, 22.64% Impervious, Inflow Depth = 5.94" for 100-yearnew event
Inflow = 171.39 cfs @ 13.25 hrs, Volume= 36.611 af
Primary = 171.22 cfs @ 13.58 hrs, Volume= 36.611 af, Atten= 0%, Lag= 20.0 min

Primary outflow = Inflow delayed by 20.0 min, Time Span= 0.00-30.00 hrs, dt= 0.05 hrs

Summary for Link 5E: (new Link)

Inflow Area = 295.420 ac, 21.38% Impervious, Inflow Depth > 6.27" for 100-yearnew event
Inflow = 463.53 cfs @ 14.79 hrs, Volume= 154.299 af
Primary = 463.53 cfs @ 15.79 hrs, Volume= 154.277 af, Atten= 0%, Lag= 60.0 min

Primary outflow = Inflow delayed by 60.0 min, Time Span= 0.00-30.00 hrs, dt= 0.05 hrs

Summary for Link 5ELB: (new Link)

Inflow Area = 78.180 ac, 21.70% Impervious, Inflow Depth = 5.92" for 100-yearnew event
Inflow = 173.69 cfs @ 13.58 hrs, Volume= 38.546 af
Primary = 173.53 cfs @ 13.91 hrs, Volume= 38.546 af, Atten= 0%, Lag= 20.0 min

Primary outflow = Inflow delayed by 20.0 min, Time Span= 0.00-30.00 hrs, dt= 0.05 hrs

Summary for Link 6E: 6E

Inflow Area = 351.470 ac, 22.53% Impervious, Inflow Depth > 6.25" for 100-yearnew event
Inflow = 479.20 cfs @ 15.79 hrs, Volume= 183.188 af
Primary = 479.20 cfs @ 16.79 hrs, Volume= 183.118 af, Atten= 0%, Lag= 60.0 min

Primary outflow = Inflow delayed by 60.0 min, Time Span= 0.00-30.00 hrs, dt= 0.05 hrs

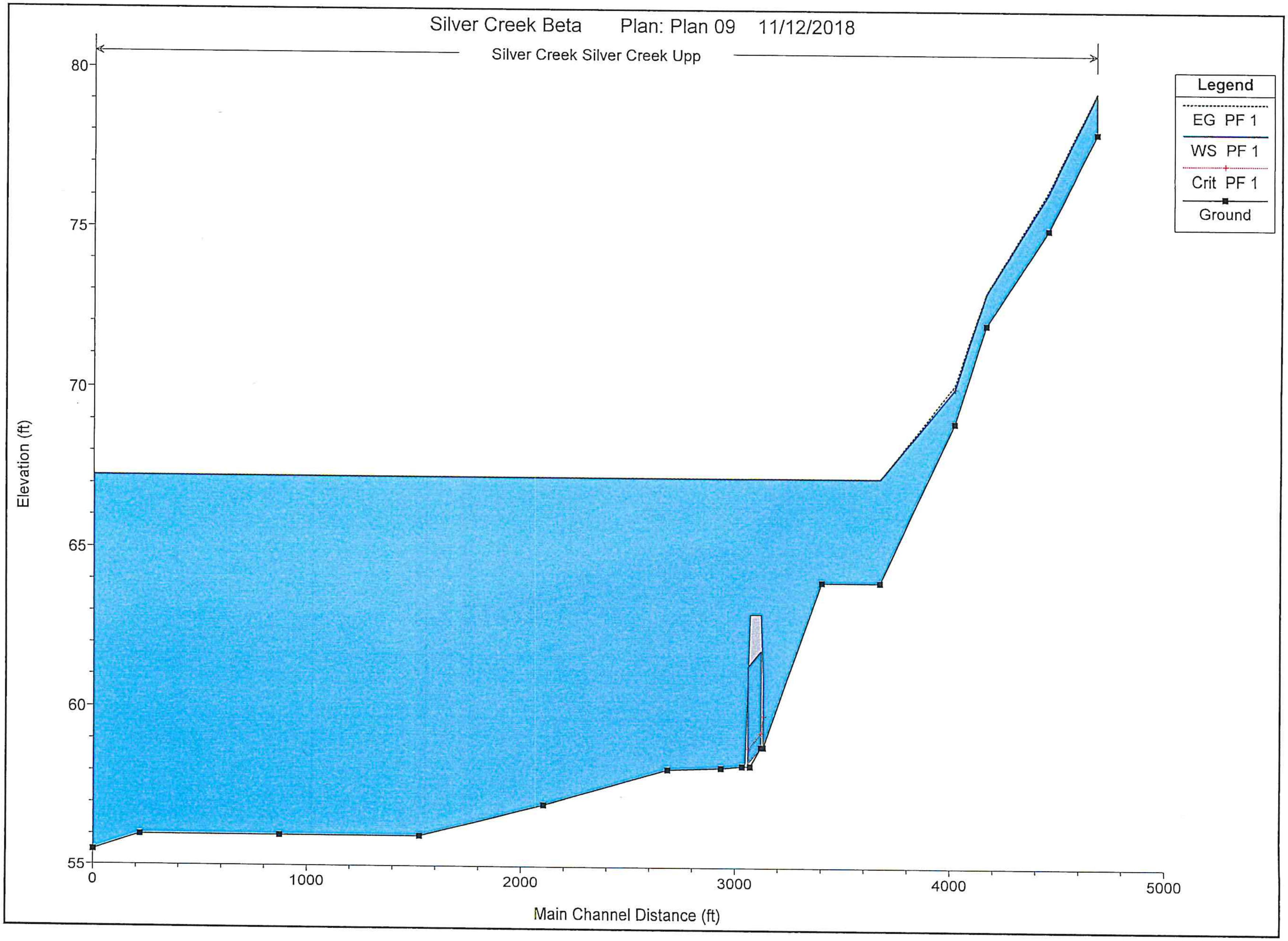
APPENDIX C

Flood Profiles and Profile Summary for the

Recreated HEC RAS Model for the 100-Year Storm Event

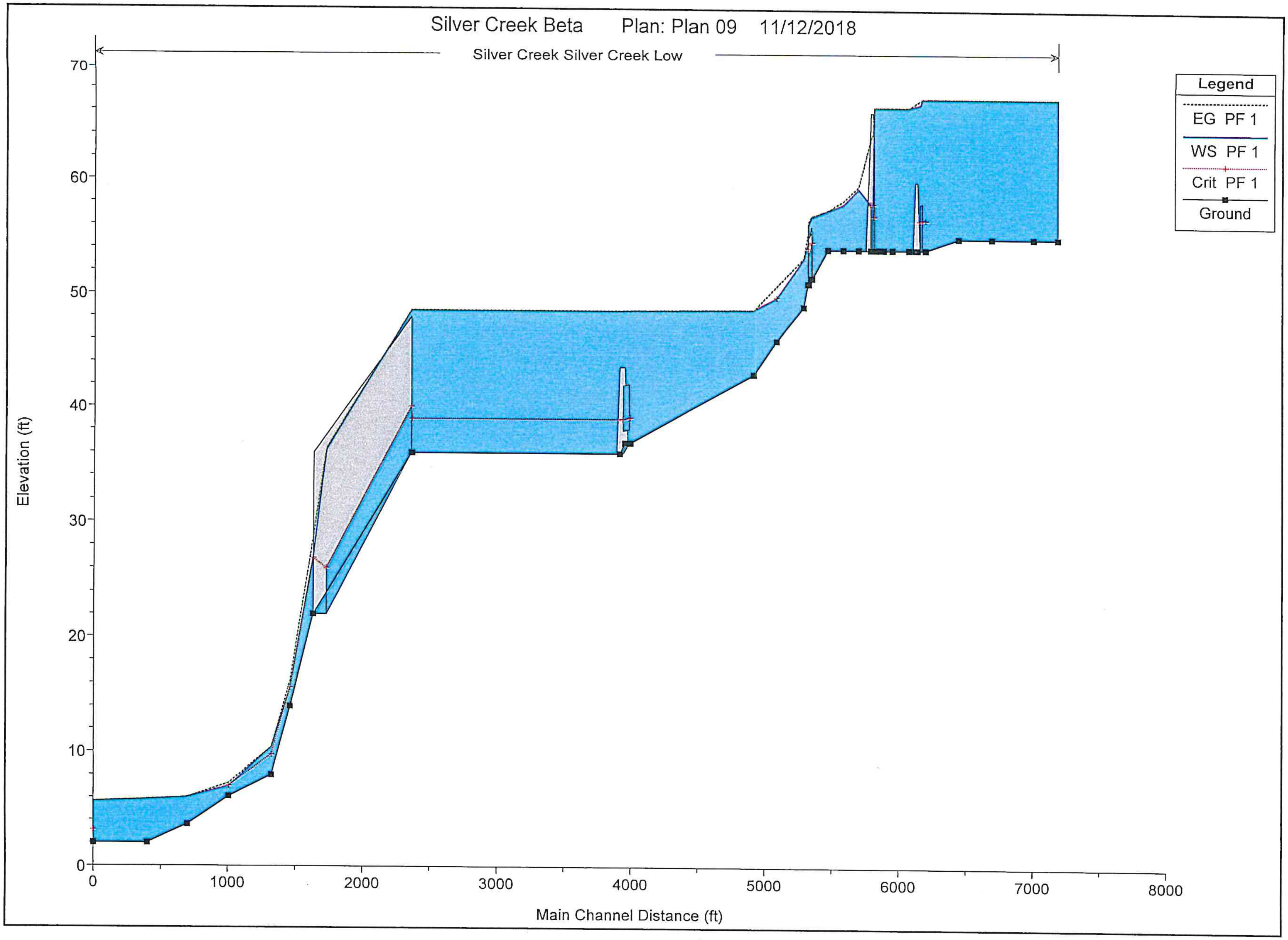
HEC-RAS Plan: Plan 09 River: Silver Creek Reach: Silver Creek Upp Profile: PF 1

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Silver Creek Upp	9550	PF 1	88.64	78.00	79.30		79.33	0.010192	1.47	60.41	106.37	0.34
Silver Creek Upp	9325	PF 1	143.08	75.00	76.16		76.24	0.016940	2.19	65.41	92.61	0.46
Silver Creek Upp	9181	PF 1	143.08	72.00	73.01		73.04	0.007746	1.31	109.35	186.54	0.30
Silver Creek Upp	9037	PF 1	143.08	69.00	70.07	70.07	70.18	0.121157	2.74	52.28	231.78	1.02
Silver Creek Upp	8692	PF 1	143.08	64.00	67.25		67.25	0.000005	0.07	1987.80	1014.00	0.01
Silver Creek Upp	8483	PF 1	143.08	64.00	67.25		67.25	0.000005	0.07	1986.51	1014.00	0.01
Silver Creek Upp	8421	PF 1	149.10	58.85	67.24	59.81	67.24	0.000008	0.15	995.22	250.00	0.01
Silver Creek Upp	8371		Culvert									
Silver Creek Upp	8341	PF 1	149.10	58.26	67.24		67.24	0.000011	0.16	909.99	250.00	0.02
Silver Creek Upp	8242	PF 1	337.53	58.20	67.24		67.24	0.000001	0.06	6064.95	1084.48	0.00
Silver Creek Upp	7933	PF 1	337.53	58.14	67.24		67.24	0.000001	0.05	6822.06	1213.00	0.00
Silver Creek Upp	7793	PF 1	337.53	57.00	67.24		67.24	0.000001	0.05	6870.40	1213.00	0.00
Silver Creek Upp	7414	PF 1	361.40	56.00	67.24		67.24	0.000000	-0.04	8755.56	1249.51	0.00
Silver Creek Upp	7114	PF 1	361.40	56.00	67.24		67.24	0.000000	0.04	9457.06	1249.51	0.00
Silver Creek Upp	6750	PF 1	373.98	56.00	67.24		67.24	0.000000	0.04	8691.22	1161.91	0.00
Silver Creek Upp	6541	PF 1	373.98	55.50	67.24		67.24	0.000001	0.09	3995.25	457.24	0.01


Silver Creek Beta Plan: Plan 09 11/12/2018
Silver Creek Silver Creek Upp
Legend
EG PF 1
WS PF 1
Crit PF 1
Ground
Elevation (ft)
80
75
70
65
60
55
0
1000
2000
3000
4000
5000
Main Channel Distance (ft)

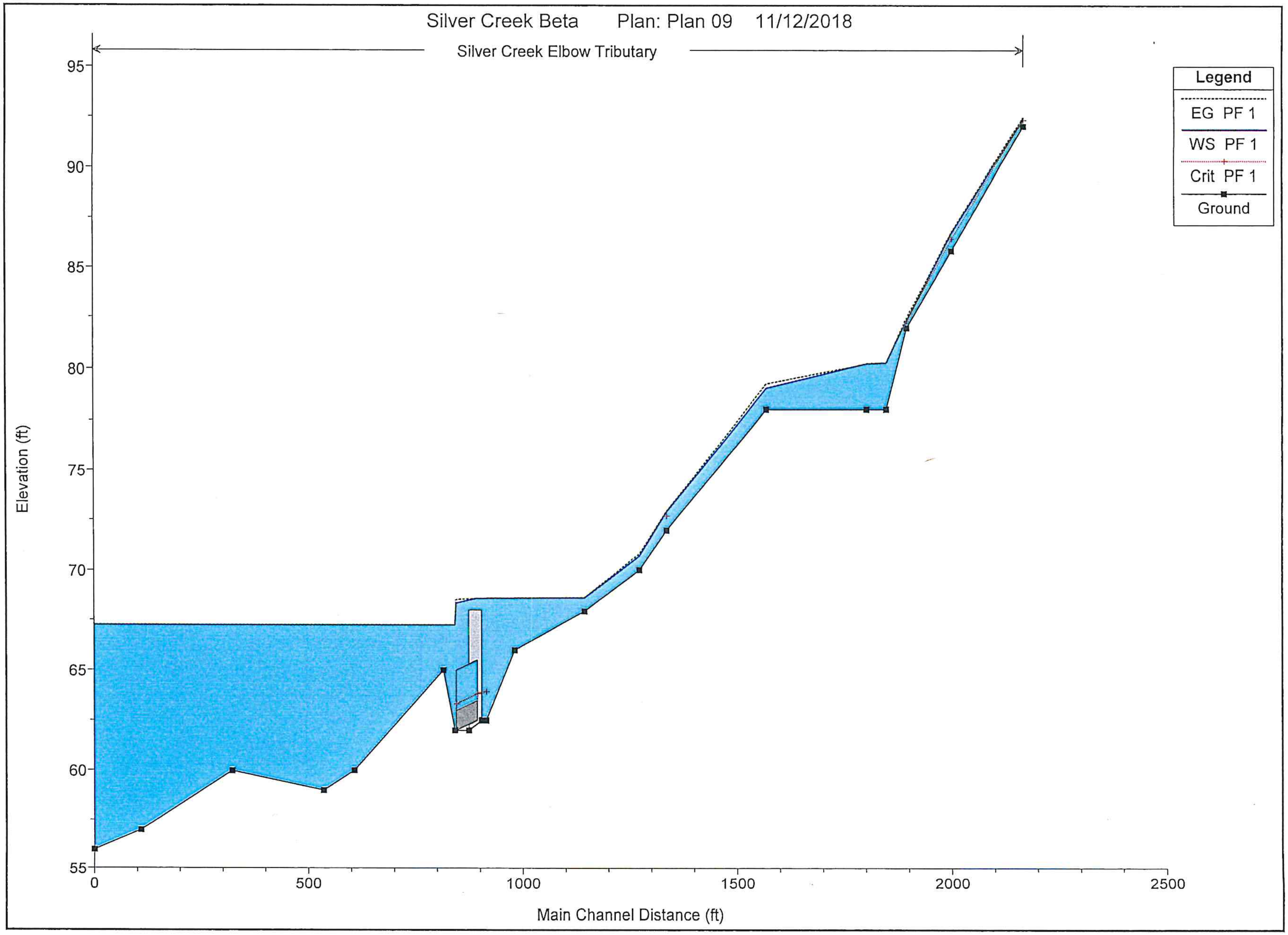
HEC-RAS Plan: Plan 09 River: Silver Creek Reach: Silver Creek Low Profile: PF 1

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Silver Creek Low	6315	PF 1	358.46	55.00	67.24		67.24	0.000001	0.10	3622.33	370.00	0.01
Silver Creek Low	6142	PF 1	358.46	55.00	67.24		67.24	0.000001	0.11	3229.14	330.00	0.01
Silver Creek Low	5972	PF 1	358.46	55.00	67.24		67.24	0.000001	0.11	3145.59	320.00	0.01
Silver Creek Low	5854	PF 1	358.46	55.00	67.23		67.24	0.000058	0.65	552.03	57.92	0.04
Silver Creek Low	5847	PF 1	358.46	54.00	67.22	56.60	67.22	0.000060	0.64	560.55	59.33	0.04
Silver Creek Low	5819		Culvert									
Silver Creek Low	5809	PF 1	358.46	54.00	66.45		66.46	0.000077	0.70	515.35	58.87	0.04
Silver Creek Low	5774	PF 1	358.46	54.00	66.45		66.46	0.000015	0.32	1125.60	139.34	0.02
Silver Creek Low	5766	PF 1	358.46	54.00	66.45		66.45	0.000038	0.50	712.11	77.39	0.03
Silver Creek Low	5758	PF 1	427.56	54.00	66.45		66.45	0.000035	0.45	960.24	133.38	0.03
Silver Creek Low	5748	PF 1	427.56	54.00	66.43	56.92	66.45	0.000138	0.98	438.19	48.92	0.06
Silver Creek Low	5738		Culvert									
Silver Creek Low	5722	PF 1	427.56	54.00	59.37		59.60	0.009892	3.87	110.40	41.06	0.42
Silver Creek Low	5630	PF 1	427.56	54.00	57.95		58.27	0.013489	4.59	93.10	34.66	0.49
Silver Creek Low	5551	PF 1	427.56	54.00	57.40		57.45	0.003759	1.72	248.28	162.54	0.25
Silver Creek Low	5490	PF 1	427.56	51.50	56.85	54.64	56.93	0.005316	2.31	185.16	98.48	0.30
Silver Creek Low	5475		Culvert									
Silver Creek Low	5465	PF 1	429.34	51.00	54.50	54.50	55.41	0.063964	7.65	56.10	31.02	1.00
Silver Creek Low	5388	PF 1	429.34	49.00	53.19		53.26	0.004724	2.11	203.90	116.61	0.28
Silver Creek Low	5277	PF 1	429.34	46.00	49.79	49.79	50.80	0.066173	8.04	53.43	27.32	1.01
Silver Creek Low	5096	PF 1	430.96	43.00	48.70		48.70	0.000088	0.53	810.85	181.87	0.04
Silver Creek Low	4987	PF 1	430.96	36.93	48.60	39.10	48.60	0.000138	0.61	712.18	183.70	0.05
Silver Creek Low	4950		Culvert									
Silver Creek Low	4915	PF 1	430.96	36.00	48.58	38.95	48.59	0.000241	0.72	602.37	182.15	0.07
Silver Creek Low	4240		Culvert									
Silver Creek Low	4070	PF 1	435.58	22.03	26.93	26.88	28.60	0.072394	10.37	42.00	12.31	0.99
Silver Creek Low	3933	PF 1	436.44	14.00	15.60	15.60	16.22	0.069415	6.29	69.36	57.46	1.01
Silver Creek Low	3615	PF 1	436.44	8.00	10.39	9.70	10.41	0.003448	1.14	381.33	433.12	0.22
Silver Creek Low	3307	PF 1	443.30	6.12	7.00	7.00	7.28	0.089989	4.23	104.78	193.06	1.01
Silver Creek Low	3008	PF 1	443.30	3.61	6.04		6.05	0.000900	0.99	449.57	232.87	0.13
Silver Creek Low	2607	PF 1	446.09	2.00	5.85		5.86	0.000483	0.83	539.31	225.75	0.09
Silver Creek Low	2603	PF 1	446.09	2.00	5.65	3.08	5.66	0.000500	0.90	498.06	190.06	0.10


Silver Creek Beta Plan: Plan 09 11/12/2018
Silver Creek Silver Creek Low
Elevation (ft)
Main Channel Distance (ft)
0
10
20
30
40
50
60
70
0
1000
2000
3000
4000
5000
6000
7000
8000
Legend
EG PF 1
WS PF 1
Crit PF 1
Ground

HEC-RAS Plan: Plan 09 River: Silver Creek Reach: Elbow Tributary Profile: PF 1

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Elbow Tributary	1935	PF 1	78.21	92.00	92.34	92.32	92.45	0.086134	2.66	29.45	105.79	0.89
Elbow Tributary	1768	PF 1	78.21	85.81	86.67	86.39	86.73	0.018183	1.83	42.82	83.99	0.45
Elbow Tributary	1422	PF 1	97.00	81.92	82.27	82.27	82.41	0.120101	3.00	32.29	123.36	1.04
Elbow Tributary	1371	PF 1	97.03	78.00	80.25		80.25	0.000998	0.65	148.61	153.93	0.12
Elbow Tributary	1330	PF 1	97.03	78.00	80.20		80.20	0.001162	0.69	141.00	151.22	0.13
Elbow Tributary	1244	PF 1	129.10	78.00	79.02		79.22	0.038706	3.58	36.10	45.23	0.71
Elbow Tributary	1118	PF 1	129.10	71.97	72.88	72.67	72.92	0.019716	1.55	83.50	223.41	0.45
Elbow Tributary	1052	PF 1	133.04	70.00	70.69		70.79	0.065129	2.60	51.13	153.59	0.79
Elbow Tributary	926	PF 1	133.04	67.94	68.60		68.62	0.007466	1.21	109.98	205.34	0.29
Elbow Tributary	765	PF 1	134.83	66.00	68.58		68.59	0.000055	0.20	685.47	486.49	0.03
Elbow Tributary	700	PF 1	134.83	62.50	68.58	63.91	68.58	0.000077	0.41	330.18	99.09	0.04
Elbow Tributary	675		Culvert									
Elbow Tributary	655	PF 1	148.19	62.00	67.24		67.25	0.000096	0.47	312.80	88.34	0.04
Elbow Tributary	628	PF 1	148.19	65.00	67.24		67.24	0.000474	0.49	299.66	270.00	0.08
Elbow Tributary	361	PF 1	148.19	60.00	67.24		67.24	0.000002	0.07	2197.94	538.02	0.01
Elbow Tributary	234	PF 1	148.19	59.00	67.24		67.24	0.000000	0.03	4914.69	725.00	0.00
Elbow Tributary	149	PF 1	198.19	59.98	67.24		67.24	0.000003	0.10	1948.61	454.60	0.01
Elbow Tributary	54	PF 1	198.19	57.00	67.24		67.24	0.000001	0.10	1991.05	200.00	0.01
Elbow Tributary	41	PF 1	199.45	56.00	67.24		67.24	0.000003	0.11	1790.90	172.66	0.01



Silver Creek Beta Plan: Plan 09 11/12/2018
Silver Creek Elbow Tributary
Legend
EG PF 1
WS PF 1
Crit PF 1
Ground
Elevation (ft)
95
90
85
80
75
70
65
60
55
0
500
1000
1500
2000
2500
Main Channel Distance (ft)

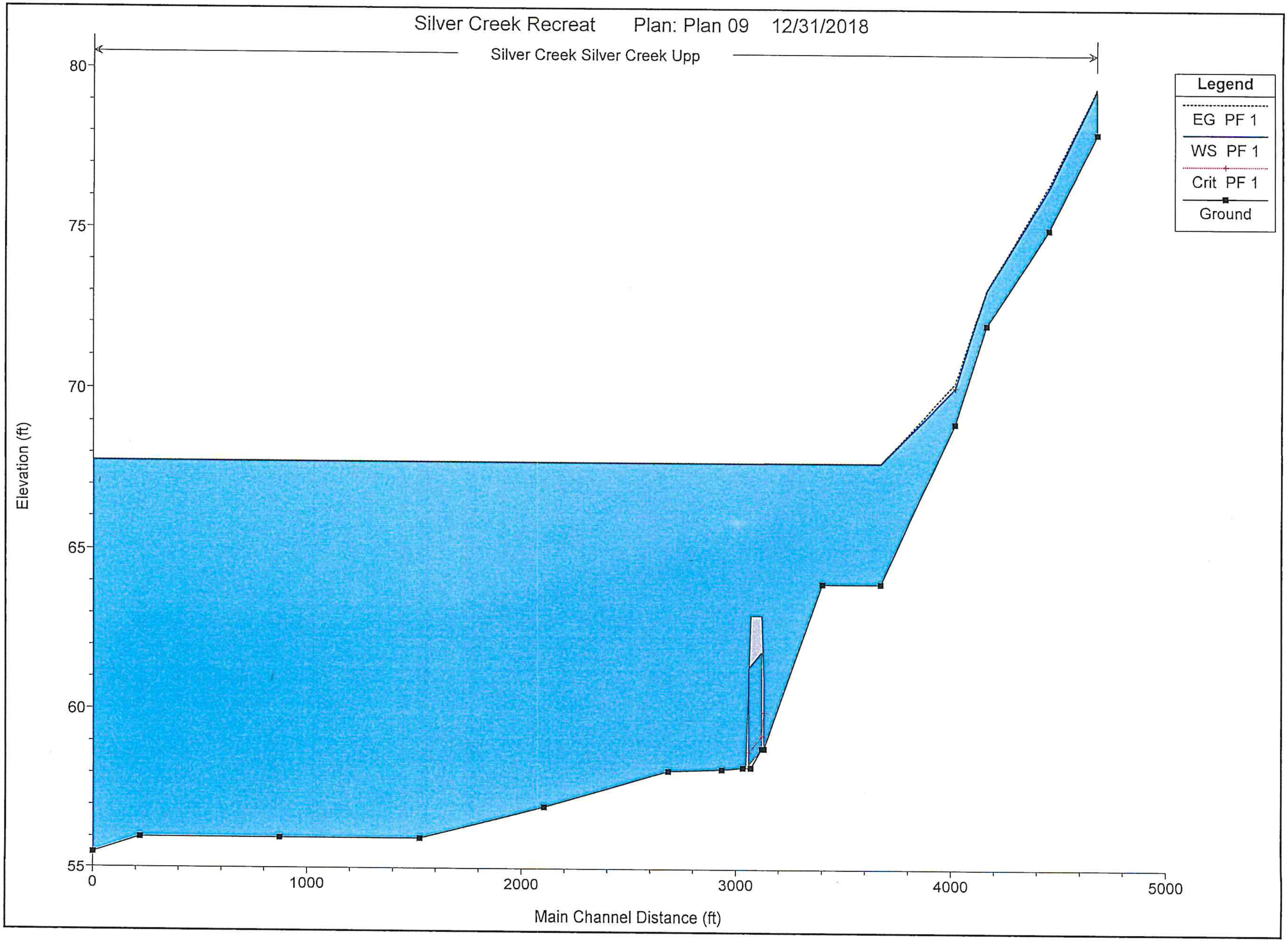
APPENDIX D

Revised Peak Runoff Rates for each of the Watersheds

Produced Using the 8.5 inches of rainfall

HEC-RAS Plan: Plan 09 River: Silver Creek Reach: Silver Creek Upp Profile: PF 1

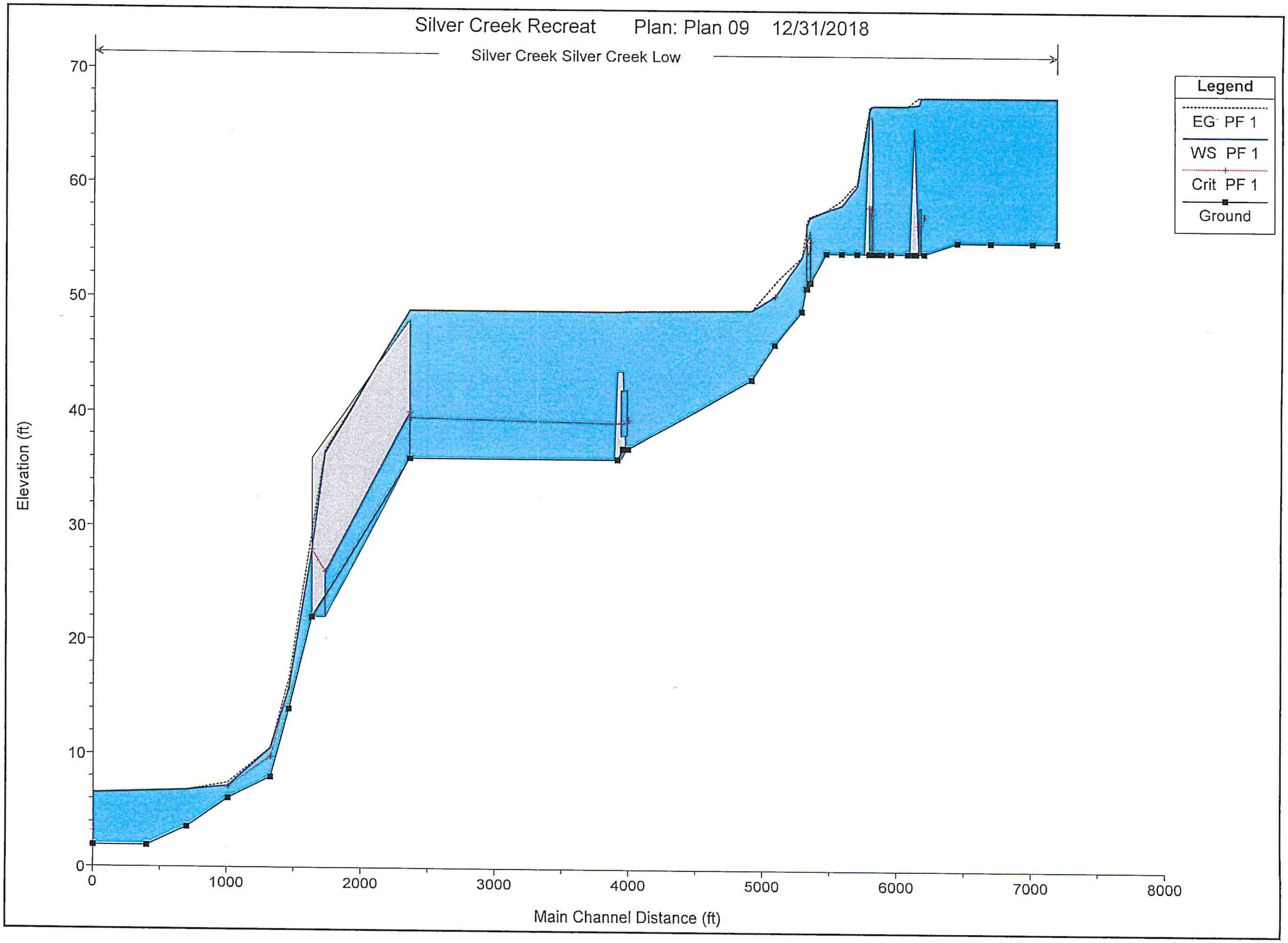
Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Silver Creek Upp	9550	PF 1	110.91	78.00	79.41		79.45	0.009782	1.50	73.92	122.10	0.34
Silver Creek Upp	9325	PF 1	182.65	75.00	76.29		76.38	0.017174	2.34	78.00	100.75	0.47
Silver Creek Upp	9181	PF 1	182.65	72.00	73.12		73.15	0.007798	1.40	130.85	203.63	0.31
Silver Creek Upp	9037	PF 1	182.65	69.00	70.10	70.10	70.24	0.129975	3.05	59.85	237.59	1.07
Silver Creek Upp	8692	PF 1	182.65	64.00	67.76		67.76	0.000004	0.07	2504.24	1014.00	0.01
Silver Creek Upp	8483	PF 1	182.65	64.00	67.76		67.76	0.000004	0.07	2503.27	1014.00	0.01
Silver Creek Upp	8421	PF 1	190.21	58.85	67.75	59.96	67.75	0.000009	0.17	1122.65	250.00	0.01
Silver Creek Upp	8371		Culvert									
Silver Creek Upp	8341	PF 1	190.21	58.26	67.75		67.75	0.000011	0.18	1037.82	250.00	0.02
Silver Creek Upp	8242	PF 1	434.13	58.20	67.75		67.75	0.000001	0.07	6627.30	1115.16	0.00
Silver Creek Upp	7933	PF 1	434.13	58.14	67.75		67.75	0.000001	0.06	7442.24	1213.00	0.00
Silver Creek Upp	7793	PF 1	434.13	57.00	67.75		67.75	0.000001	0.06	7490.48	1213.00	0.00
Silver Creek Upp	7414	PF 1	463.53	56.00	67.75		67.75	0.000000	0.05	9394.23	1249.51	0.00
Silver Creek Upp	7114	PF 1	463.53	56.00	67.75		67.75	0.000000	0.05	10095.68	1249.51	0.00
Silver Creek Upp	6750	PF 1	463.63	56.00	67.75		67.75	0.000000	0.05	9285.01	1161.91	0.00
Silver Creek Upp	6541	PF 1	490.22	55.50	67.75		67.75	0.000002	0.12	4229.01	457.75	0.01



Silver Creek Recreat Plan: Plan 09 12/31/2018
Silver Creek Silver Creek Upp
Legend
EG PF 1
WS PF 1
Crit PF 1
Ground
Elevation (ft)
80
75
70
65
60
55
0
1000
2000
3000
4000
5000
Main Channel Distance (ft)

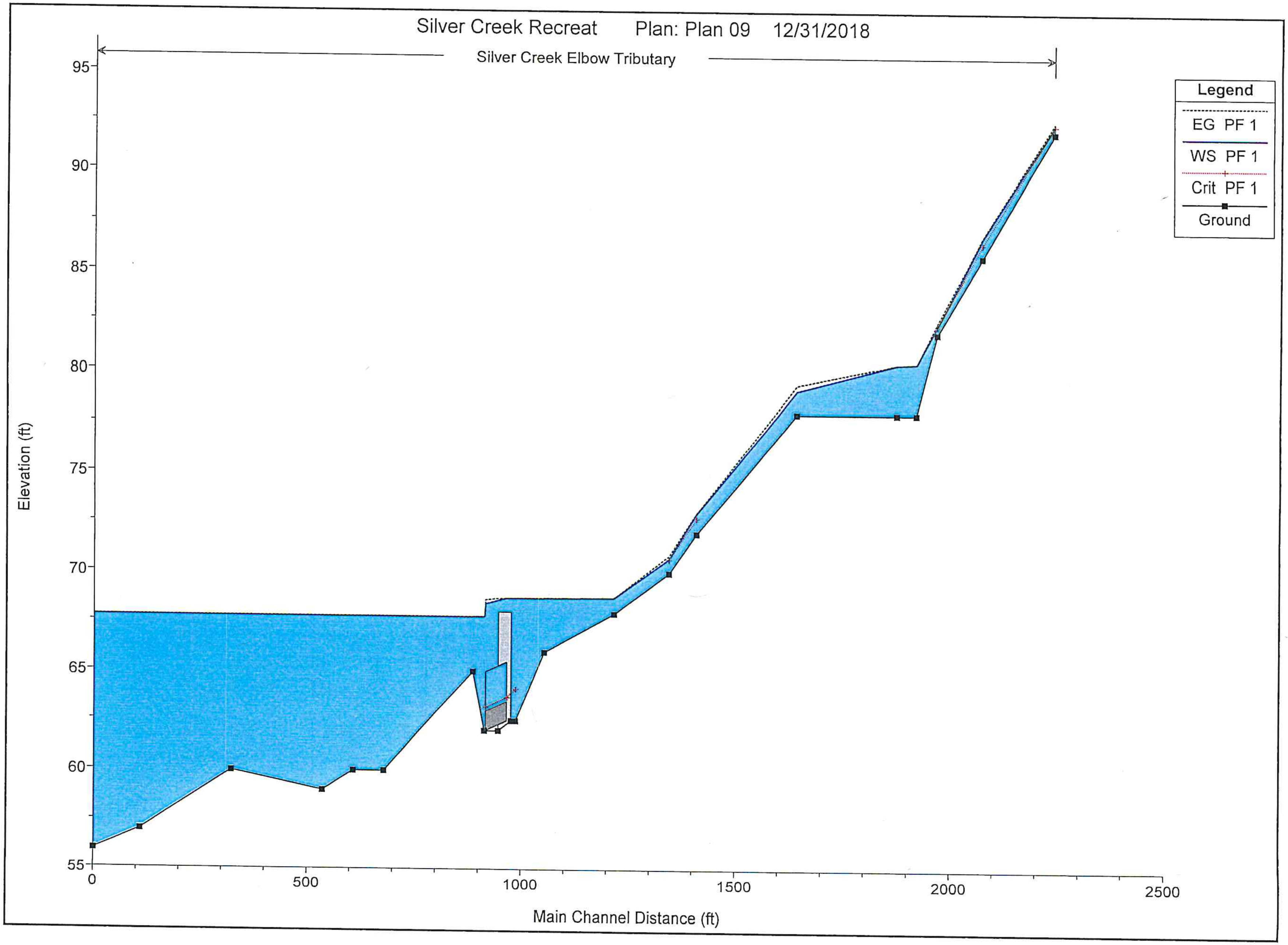
HEC-RAS Plan: Plan 09 River: Silver Creek Reach: Silver Creek Low Profile: PF 1

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Silver Creek Low	6315	PF 1	493.48	55.00	67.75		67.75	0.000002	0.13	3811.36	370.00	0.01
Silver Creek Low	6142	PF 1	493.48	55.00	67.75		67.75	0.000002	0.15	3397.68	330.00	0.01
Silver Creek Low	5972	PF 1	493.48	55.00	67.75		67.75	0.000002	0.15	3308.94	320.00	0.01
Silver Creek Low	5854	PF 1	493.48	55.00	67.74		67.75	0.000095	0.85	581.40	58.41	0.05
Silver Creek Low	5847	PF 1	493.48	54.00	67.71	57.22	67.72	0.000098	0.84	590.03	59.63	0.05
Silver Creek Low	5819		Culvert									
Silver Creek Low	5809	PF 1	493.48	54.00	67.03		67.04	0.000196	1.10	446.67	52.43	0.07
Silver Creek Low	5774	PF 1	493.48	54.00	67.03		67.03	0.000023	0.41	1205.99	139.37	0.02
Silver Creek Low	5766	PF 1	493.48	54.00	67.02		67.03	0.000060	0.65	756.63	77.65	0.04
Silver Creek Low	5758	PF 1	553.24	54.00	67.02		67.03	0.000047	0.53	1037.31	134.86	0.03
Silver Creek Low	5748	PF 1	553.24	54.00	67.00	57.48	67.02	0.000218	1.26	440.47	47.56	0.07
Silver Creek Low	5738		Culvert									
Silver Creek Low	5722	PF 1	553.24	54.00	59.91		60.18	0.009725	4.14	133.57	44.06	0.42
Silver Creek Low	5630	PF 1	553.24	54.00	58.21		58.66	0.018407	5.38	102.75	38.18	0.58
Silver Creek Low	5551	PF 1	553.24	54.00	57.70		57.75	0.003587	1.87	296.60	166.21	0.25
Silver Creek Low	5490	PF 1	553.24	51.50	57.11	55.01	57.22	0.005932	2.62	211.51	101.12	0.32
Silver Creek Low	5475		Culvert									
Silver Creek Low	5465	PF 1	561.63	51.00	54.90	54.90	55.93	0.061220	8.16	68.82	33.39	1.00
Silver Creek Low	5388	PF 1	561.63	49.00	53.61		53.68	0.004456	2.20	255.47	131.18	0.28
Silver Creek Low	5277	PF 1	561.63	46.00	50.27	50.27	51.35	0.062142	8.35	67.22	31.06	1.00
Silver Creek Low	5096	PF 1	563.33	43.00	49.01		49.01	0.000122	0.65	866.95	184.71	0.05
Silver Creek Low	4987	PF 1	563.33	36.93	48.86	39.49	48.87	0.000194	0.74	761.47	187.73	0.06
Silver Creek Low	4950		Culvert									
Silver Creek Low	4915	PF 1	563.33	36.00	48.83	39.52	48.85	0.000332	0.87	648.51	186.01	0.08
Silver Creek Low	4240		Culvert									
Silver Creek Low	4070	PF 1	563.33	22.03	27.95	27.95	29.37	0.068123	9.57	58.89	29.46	1.00
Silver Creek Low	3933	PF 1	563.33	14.00	15.83	15.83	16.56	0.065862	6.83	82.47	57.88	1.01
Silver Creek Low	3615	PF 1	573.19	8.00	10.54	9.78	10.57	0.003691	1.28	446.52	449.37	0.23
Silver Creek Low	3307	PF 1	573.19	6.12	7.17	7.12	7.44	0.069128	4.18	137.19	211.38	0.91
Silver Creek Low	3008	PF 1	573.19	3.61	6.80		6.81	0.000529	0.90	633.53	250.50	0.10
Silver Creek Low	2607	PF 1	576.49	2.00	6.67		6.67	0.000387	0.72	803.73	353.59	0.08
Silver Creek Low	2603	PF 1	576.49	2.00	6.49	3.20	6.50	0.000500	0.78	741.45	350.38	0.09


Silver Creek Recreat Plan: Plan 09 12/31/2018
Silver Creek Silver Creek Low
Legend
EG PF 1
WS PF 1
Crit PF 1
Ground
Elevation (ft)
0
10
20
30
40
50
60
70
0
1000
2000
3000
4000
5000
6000
7000
8000
Main Channel Distance (ft)

HEC-RAS Plan: Plan 09 River: Silver Creek Reach: Elbow Tributary Profile: PF 1

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Elbow Tributary	1935	PF 1	100.23	92.00	92.40	92.37	92.52	0.074960	2.80	35.85	107.36	0.85
Elbow Tributary	1520	PF 1	100.23	85.81	86.76	86.46	86.82	0.019295	1.98	50.66	92.13	0.47
Elbow Tributary	1422	PF 1	125.31	81.92	82.32	82.32	82.48	0.106815	3.20	39.18	124.76	1.01
Elbow Tributary	1371	PF 1	125.31	78.00	80.43		80.44	0.000982	0.71	177.09	160.65	0.12
Elbow Tributary	1330	PF 1	125.31	78.00	80.38		80.39	0.001128	0.74	169.27	159.23	0.13
Elbow Tributary	1244	PF 1	166.32	78.00	79.12		79.38	0.047252	4.09	40.70	48.42	0.79
Elbow Tributary	1118	PF 1	166.32	71.97	72.98	72.72	73.02	0.017467	1.55	107.60	263.00	0.43
Elbow Tributary	1052	PF 1	166.32	70.00	70.70	70.68	70.85	0.089455	3.12	53.39	155.32	0.94
Elbow Tributary	926	PF 1	171.39	67.94	68.72		68.74	0.006622	1.27	135.30	215.43	0.28
Elbow Tributary	765	PF 1	171.39	66.00	68.70		68.70	0.000068	0.23	741.52	488.96	0.03
Elbow Tributary	700	PF 1	171.39	62.50	68.69	64.10	68.69	0.000112	0.50	341.30	99.09	0.05
Elbow Tributary	675		Culvert									
Elbow Tributary	655	PF 1	173.21	62.00	67.75		67.76	0.000094	0.48	360.34	98.27	0.04
Elbow Tributary	628	PF 1	173.21	65.00	67.75		67.75	0.000184	0.40	437.94	270.00	0.05
Elbow Tributary	429	PF 1	173.21	60.00	67.75		67.75	0.000001	0.07	2420.07	500.43	0.01
Elbow Tributary	361	PF 1	173.21	60.00	67.75		67.75	0.000001	0.07	2420.02	500.43	0.01
Elbow Tributary	234	PF 1	173.21	59.00	67.75		67.75	0.000000	0.03	5285.34	725.00	0.00
Elbow Tributary	149	PF 1	255.39	59.98	67.75		67.75	0.000004	0.12	2184.53	468.50	0.01
Elbow Tributary	54	PF 1	255.39	57.00	67.75		67.75	0.000002	0.12	2093.25	200.00	0.01
Elbow Tributary	41	PF 1	255.39	56.00	67.75		67.75	0.000005	0.14	1879.11	172.66	0.01


Silver Creek Recreat Plan: Plan 09 12/31/2018
Silver Creek Elbow Tributary
Legend
EG PF 1
WS PF 1
Crit PF 1
Ground
Elevation (ft)
95
90
85
80
75
70
65
60
55
0
500
1000
1500
2000
2500
Main Channel Distance (ft)