Switzer Canyon Wash Final Report

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List of Abbreviations

A	Area
Appx	Appendix
ArcGIS	Aeronautical Reconnaissance Coverage Geography Info System
AutoCAD	Automatical Computer Aided Design
BS	Back Sight
C	Antecedent Precipitation Factor/Constant
C_f	Coefficient of Roughness
CCDDM	Coconino Country Design Drainage Manual
COF	City of Flagstaff
D	Diameter
Elev	Elevation
FEMA	Federal Emergency Management Agency
FS	Fore Sight
HEC-RAS	Hydrologic Engineering Centers River Analysis System
HI	Height of Instrument
I	Rainfall Intensity
L	Length
LID	Low impact design
n	Manning's Coefficient
NOAA	National Oceanic and Atmospheric Administration
NRCS	Natural Resources Conservation Service
OM	Operation and Maintenance
Q	Flow Rate
Q_i	Flow Rate In
Q_o	Flow Rate Out
S	Slope
T_c	Time of Concentration
T_i	Duration of Storage
T_t	Sheet Flow Travel Time
V	Velocity
CS, XS	Cross-Section

Table of Appendices

Acknowledgements

The team would like to thank Gary Miller and Douglas Slover for their professional guidance throughout this project.

1.0 Project Introduction

The upper reach of the Switzer Canyon Wash has drawn the attention of the City of Flagstaff for its lack of flood protection. Historically, the Hospital Hill neighborhood often floods due to design flaws of the wash. The Switzer Canyon Wash Drainage Design Project aims to provide a drainage plan that reduces flooding by exploring multiple different design alternatives. The cost of each alternative will be considered; however, the goal is to find the most effective solution.

This project is in Flagstaff, Arizona in the northeast corner of the Hospital Hill neighborhood and extends north along N San Francisco Street. Buffalo Park is to the east of the site and Elk's Lodge is directly west of the wash. Figure 1.1 below is a map of the project location in respect to Flagstaff.

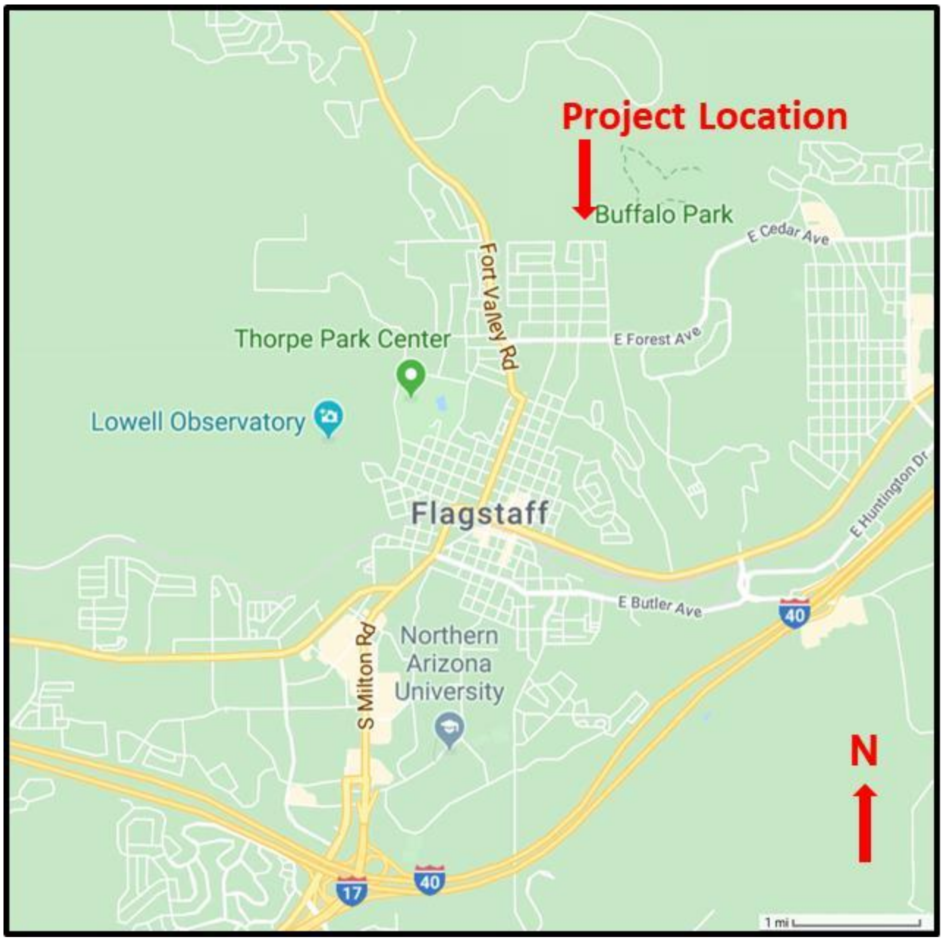

Figure 1.1.1 Project location in respect to Flagstaff, AZ [1]

Figure 1.2 is an aerial map showing how the floodplain runs through the project location. From north of Elk's Lodge, the wash continues south into the neighborhood and a wall redirects it eastward. A double barrel culvert carries storm water under Silver Spruce Avenue and discharges it on the east side of N Turquoise Drive. The wash then continues south toward downtown Flagstaff.

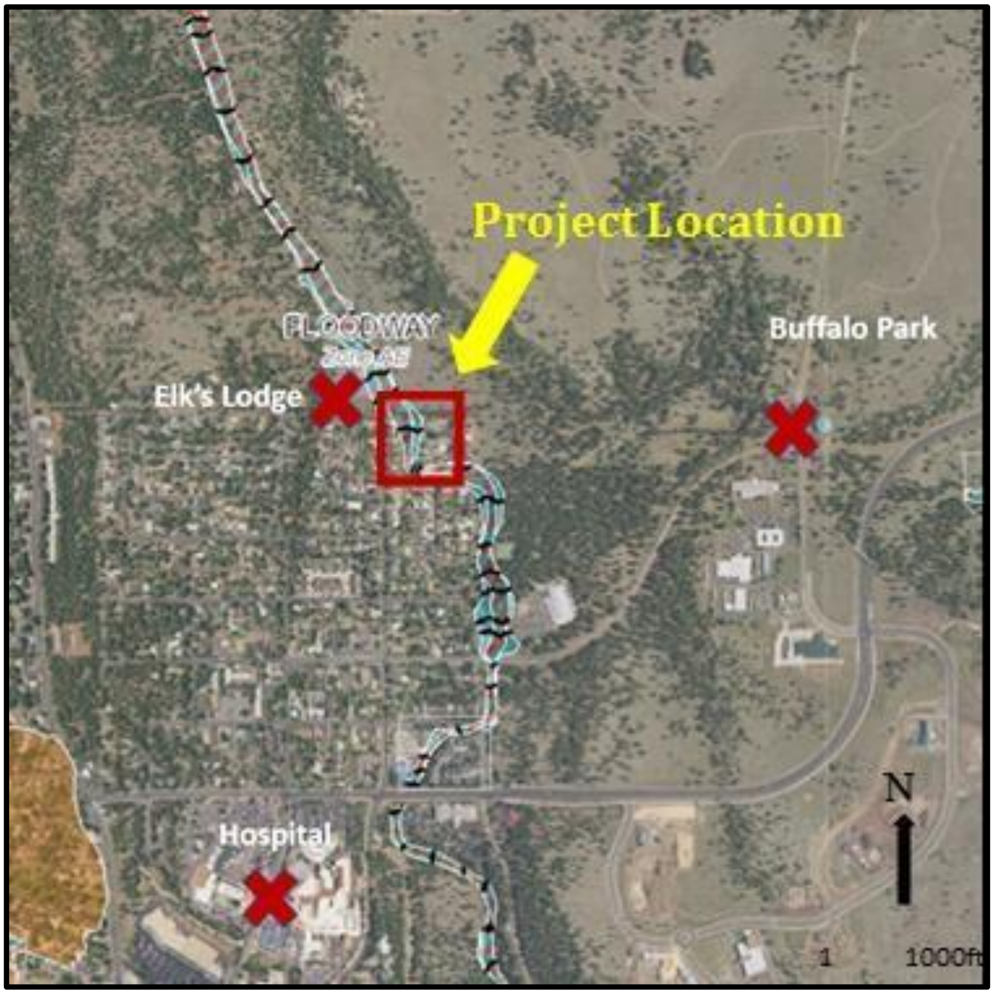

Figure 1.2.2 Aerial map of project location and floodplain ct. FEMA [2]

Figure 1.3 shows a closer look at the area of concern in the Hospital Hill neighborhood (denoted by the red box).

Figure 1.3.3 Aerial Map of the Problematic Flooding Area

1.1 Exclusions

While part of a full project, the following will be excluded from this project due to time constraints and lack of proficiency: construction management, construction plans, geotechnical engineering, traffic analysis, and roadway design. Much of this work would require the use of a third-party company.

2.0 Site Investigation

2.1 Field visit and Preliminary Assessment

A visit to the site was done to take note of the current conditions of the wash and get an understanding of how it flows and where potential problem areas are. Overall, the wash is well covered with short grass. The area around Elk's Lodge is rockier. Starting from the north, there is a mostly clear wash. This can be seen north of point A on Figure 2.1. Southwest of point A is a somewhat flat, open field where storm water dissipates to. Another part of the wash juts off from the original at A and moves eastward. This part is not well defined until point B.

Figure 2.1.4 Aerial of Wash Near Elk's Lodge [3]

Figure 2.2 below shows the newly formed wash (right side) as it angles toward N San Francisco Street. The photo was taken facing northwest toward the open field seen in Figure 2.1. On the left is a secondary channel that contributes to the wash.

Figure 2.2.5 Wash Near Elk's Lodge

After the secondary channel connects with the wash, they drain through the culvert seen in Figure 2.3.6. This culvert runs under N San Francisco Street. The outlet of the culvert is armored similarly to the inlet.

Figure 2.3.6 Inlet of the Culvert Under North San Francisco Street

All site relevant information was summarized and inputted into a stream reach field inventory form. This form was used to document soils, vegetation, and channel descriptions of the reaches. This form allowed the team to categorize the overall condition of the reaches. It was determined that all reaches were in the fair to poor conditions range. To view the stream reach field inventory form, see (Appx A).

2.2 Land Surveying and Data Processing

Using an auto-level and rod (Figures 2.4 and 2.5), the team measured cross-sections of the wash. Cross-sections were measured starting north of point A seen in Figure 2.4. This was designated as Reach 1. Reach 2 starts where the wash reestablishes itself at point B. Cross-sections were measured until the culvert under North San Francisco Street was reached. Reach 3 starts at the outlet of the culvert and ends near where the wash crosses W Fir Avenue.

Figure 2.4.7 Auto level

Figure 2.5.8 Example of a cross-section from Reach 2

Cross-sections were measured wherever the wash experiences a shape change (ex. widened, shrunk, or changed direction). Before starting the cross-sections for each reach, a BS was shot. This was done to establish a known elevation or, in this case, an estimated elevation. The benchmark elevation (original BS) was estimated using Google Earth. While out surveying for Reaches 2 and 3, the team was informed of a benchmark elevation that is the same elevation as the estimated one. The estimated benchmark was slightly lower than the other, but the team determined the estimated value was usable for the purposes of the project.

For each cross-section, a measuring tape was laid perpendicular to the wash and staked at both sides to keep it as straight as possible. Readings were taken from the auto level at about every foot across the wash while holding the rod perpendicular to the ground. Some feet were skipped if the slope appeared to be the same. Each reading was recorded in a field notebook as the FS. In Reach 2, cross-sections around where the secondary channel meets up with the main channel were measured across both channels. Pink flags were placed at what were determined to be the left of bank, right of bank, and thalweg (lowest point of the channel). Figure 2.8 shows the team taking a cross-section in Reach 2. The entire catalog of cross sections for reach 1 through 3 can be found in (Appx B)

By using Equation 2.1, the HI was calculated with the BS and the elevation at the BS. This is then used in Equation 2.2 with the foresight reading to find the rod elevation.

Equation 2.1.1: Height of Instrument [4]

$$HI = BS + Elev$$

Equation 2.2.2: Rod Elevation [4]

$$Elev = HI - FS$$

2.3 Existing Infrastructure

The main infrastructure found on site was three culverts, riprap, berms. Table 2.1 summarizes the culverts size and location in relationship to the reach it lies in.

Table 2.1.1 Culvert Summary from Site Investigation

Reach #	Culverts	Dimensions (ft)
Reach 1	Three Barrel	3
Reach 2	Single Barrel	1.5
Reach 3	N/A	N/A
Reach 4 Section 1	N/A	N/A
Reach 4 Section 2	Double Barrel	2.5

3.0 Hydrology

3.1 Master Drainage Studies

No master drainage studies were found for the site of interest. "The Phase 1 Report North East Area Master Drainage Study" was used as a benchmark to compare the FEMA 100-year flow rate "at the confluence with Silver Spruce Ave. Wash" versus the teams calculated 100-year flow rate at the same location.

3.2 Major Basin Delineation

Sub-basins were delineated using Stream Stats and ArcGIS. Using the watershed delineation tool on Stream Stats, a concentration point was chosen to determine how large the area was contributing to the flow in the channel. The sub-basin was estimated to be about 1.27mi^2 (Appx A.1). Figure 3.1 displays the extent of the area in yellow as well as the concentration point, which is indicated by the blue marker.

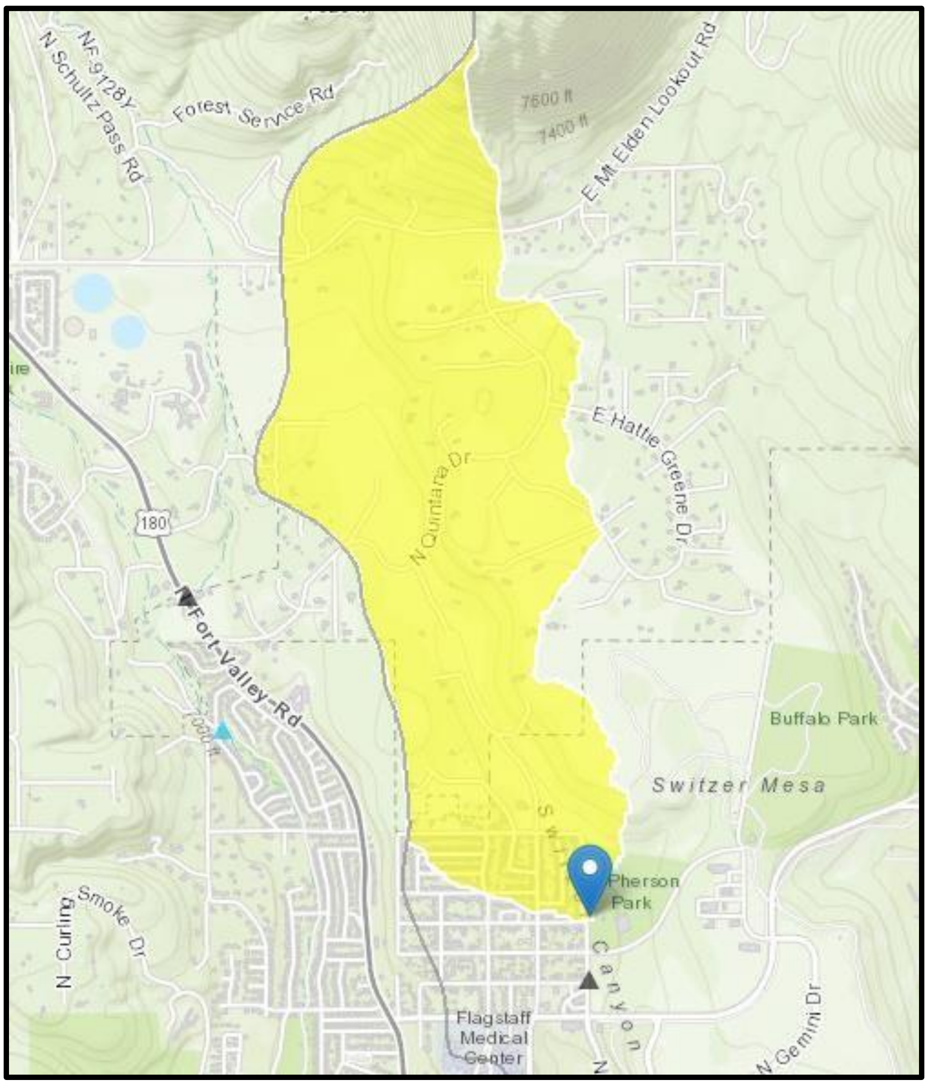

Figure 3.1.9 Stream Stats Major Sub-Basin [5]

This was not used for the true sub-basin delineation but rather a reference for a manual delineation. Using this figure, a true major basin containing 23 sub-basins was created using ArcGIS contour data layered into AutoCAD. The results of this are displayed below in Figure 3.2.

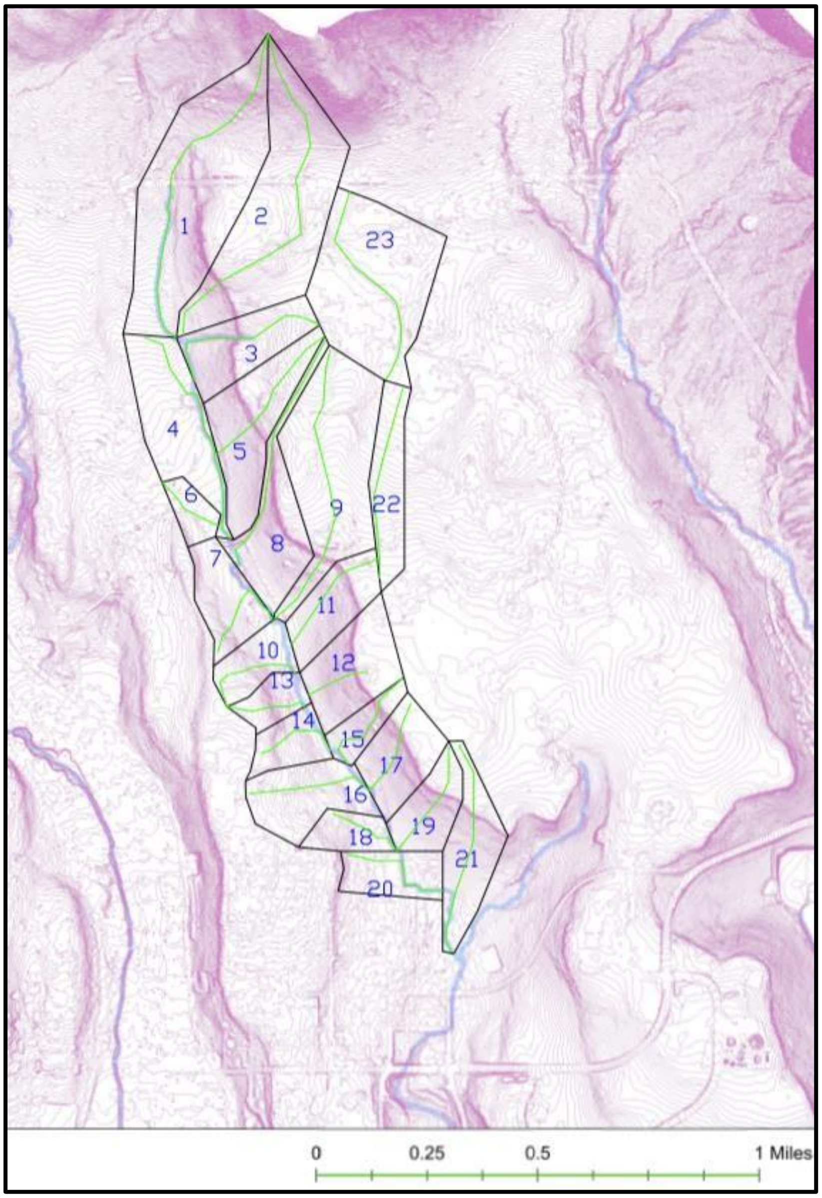

Figure 3.2.10 Final Sub-Basin Delineation

3.3 Sub-Basin Variables

Sub-basin variables were determined by terrain type as viewed on Google Earth. A weighted average approach was used to determine the runoff coefficients of each sub basin (Appx E.1). AutoCAD and Google Earth were used to precisely determine specific terrain, and how large the area was. These terrains had different runoff coefficient and were used accordingly for calculations (Appx E.3-E.4).

3.4 Rational Method

The rational method equation was the basis for flow estimation. The rational method was chosen as the sub-basins within the COF limits were at or beneath 20 acres in size. The other reason this method was chosen was its ability to aid in the estimating the size of a drainage structure. Rainfall intensity, area, and roughness coefficients were necessary for using this method. These variables are displayed in the equation below.

Equation 3.1.3 Rational Equation [6]

$$Q = C_f CIA$$

The roughness coefficients were determined using the City of Flagstaffs Stormwater Management Design Manual's Mannings Coefficient table (Appx D.2) and the antecedent precipitation factors with its respective table (Appx D.1). The sub basin areas were determined using the area command in AutoCAD. Rainfall intensity was found by determining the time of concentration in each basin and matching the found tc values to the corresponding rainfall intensity found in NOAA Atlas 14 (Appx C.2). The time of concentration was determined by flow types which changed with terrain and slope values. The City of Flagstaff ArcGIS contour maps were used in AutoCAD to find these types of flows. The respective data was then inserted into the equations below to find the time of concentration for each basin (Appx E.3-E.4). Values were calculated with respect to City of Flagstaff Stormwater Management Design Manual.

Equation 3.2.4: Sheet Flow Travel Time [7]

$$T_t = [0.007(nL)^{0.8}/(2.0)^{0.5}(S)^{0.4}]$$

Equation 3.3.5: Shallow Concentration Flow Unpaved [7]

$$V = 16.1345(S)^{0.5}$$

Equation 3.4.6: Shallow Concentration Flow Paved [7]

$$V = 20.3282(S)^{0.5}$$

Equation 3.5.7: Street Gutter Flow for 6" Gutter Diameter [7]

$$V = 54(S)^{0.5}$$

Equation 3.6.8: Time of Concentration [7]

$$T_c = L/V$$

Table 3.1.2 below shows the calculated 100-year flow rate at the confluence with Silver Spruce Ave. Wash verses the FEMA 100-year flow rate at the same location.

Table 3.1.2: Calculated 100-yearFlow Rate verses 100-year FEMA Flow Rate

Stream	Location	FEMA	Team	Percent Error
		Q100 (cfs)	Q 100 (cfs)	%
Switzer	at confluence with Spruce Ave. Wash	800	829	3.50

As can be seen in the table above the calculated flow rate was found to be 829 cubic feet per second. The percent error between the calculated flow rate and FEMA flow rate was 3.5 percent.

4.0 Design Alternatives

Six design alternatives were discussed and analyzed in a decision matrix. These were created from five different options for stormwater control: natural channel, detention basin, extended detention basins, wetland, and permeable pavement and dry wells. Permeable pavement and dry wells were proposed to be installed at two spots: at the culvert going across N San Francisco Street and where the channel crosses W Fir Avenue into the neighborhood. This option would allow stormwater to trickle into the underground dry wells to ultimately reduce flow volume and potentially recharge local aquifers. Ultimately, this option did not become an alternative due to a wastewater pipe running under W Fir Avenue which will not allow room underground for a dry well. All other options became parts of alternatives and are explained below. The designs selected for the decision matrix were selected from case studies [8], EPA new development runoff treatment [9], COF stormwater controls measure [10], and COF Master Drainage Phase 1 Report [11].

4.1 Natural Channel Modifications

The first two alternatives were completing and modifying the natural channel and the natural channel with the culvert bypass system. These alternatives would include adding the missing 275 feet of channel (shown in red in Figure 4.1 below), enlarging it to be able to convey the 100-year storm event, and revegetating Reaches 1, 2, and 4.

Figure 4.1.11: Adding in 275ft of Missing Channel

The second alternative bypasses the neighborhood by extending Reach 3 east along W Fir Avenue with a culvert and then south along N Turquoise Drive to the existing culvert outlet. The goal of this is to reroute the floodplain so almost none of the houses are in it. Figure 4.2 below demonstrates this option in red.

Figure 4.2.12: Channel Bypass Alternative

The volume of channel needed to be dredged was calculated using the cross-sectional area found by an online open channel calculator (Appx J.1) and the required length of the channels which were found using Google Earth's measurement tool.

Table 4.1.3: Open Channel CS Specs

Open Channel			
Channel	A (ft^2)	L (ft)	V (ft^3)
Reach 1.5	60.42	275	16615.50
Reach 1.5 + Bypass	60.42	3000	181260.00

The volumes determined for these modifications were later used to calculate expenses for these designs. These costs can be found in Section 4.5.

4.2 Detention/LID Basins

The third and fourth alternatives were extended detention basins and the detention/LID basin. Both alternatives would incorporate a detention basin just north of Elks Lodge. The extended basins alternative also would have a basin further north where a small pond area already exists and an underground detention tank. The extended detention basins would be designed to hold back stormwater for longer than a regular detention basin. Logistically, both alternatives could be LID basins. Figure 4.3 below shows the locations of the extended detention basins. The detention/LID basin would be where Basin 2 is shown.

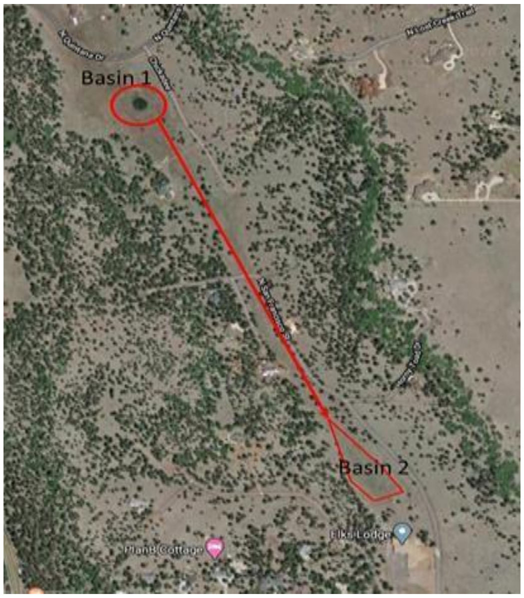

Figure 4.3.13: Extended Basin Alternative

Calculations for area and volume, which was then used to calculate expenses, was done with the Triangular Hydrograph Method and City of Flagstaff Stormwater Management Design Manual standards [17]. This involves converting the T_c to T_i using Equation 4.1 and the T_c of the contributing sub basins (Appx K.1).

Equation 4.1.9: Time of Concentration Conversion [7]

$$T_i = 1.78T_c$$

The new T_i (Appx K.2) value was then inputted into Equation 4.2 along with the target flow reduction to estimate the volume needed for the detention basin. Flow reduction was decided to be 100 cfs leading to a 730 cfs outflow instead of 830 cfs (Appx K.3).

Equation 4.2.10: Triangular Hydrograph Method [7]

$$V = 0.5T_i(Q_i - Q_o)$$

After the volume was computed, the COF Stormwater Management Design Manual was consulted for depth, slope, and configuration standards to determine the area needed for the basin. The recommended depth is 3 ft for detention basins, but other depths were considered to reduce surface area required for implementation [17].

Table 4.2.4: Volume and Area Required for a Detention Basin

Detention Basin					
Depth	V (ft^3)	V (acre-ft)	A (ft^2)	(acres)	(mi^2)
D (3ft)	1219871	28.00	406623.6	9.33	0.0146
D (6ft)	1219871	28.00	203311.8	4.67	0.0073
D (12ft)	1219871	28.00	101655.9	2.33	0.0036

Although different depths were used for estimates, the 6ft depth was used for modelling the detention basin. The outlet structure in the form of a culvert is also required and is to be at least 12 inches in diameter and to be at a slope of at least 2% [17]. Culvert sizing for this basin was tabulated using Manning's equation.

Equation 4.3.11: Manning's [12]

$$5/8\ (C\ \pi n\ \ SQ_{1/2})3/8$$

$$D_{min} = 4$$

The input values generated the size of the culvert at minimum needed. This value is well above the required 12 inches.

Table 4.3.5: Culvert Specs

Culvert Sizing Calculator	
Inputs	
Q (ft^3/s)	730
S (ft/ft)	0.02
n	0.013
Find	
D_{min} (ft)	6.46
D_{min} (in)	77.5

These detention basin and culvert specs were used to estimate cost for two detention basins and the single detention basin with the LID of the same size. The results of such are discussed in line with other design alternatives in Section 4.5.

4.3 Wetlands

The fifth alternative was to create a wetland. The channel area from N Quintana Drive to W Fir Avenue would be transformed to be densely vegetated and to retain water. This would effectively act similar to a detention basin in that the hydrograph would be extended. The red line around Basin 1 shown in Figure 4.3 showcases which area would be turned into a wetland for this design alternative.

A gravel-based wetland was modeled for this design as this surface type has no set requirement for surface area [13]. They also do not require a set seasonal water level to function which pairs well with the drastic change in seasonal precipitation the Flagstaff area has. The volume for the wetland is required to be the same as the design volume runoff. As this volume has already been calculated with detention basins, the wetland will also follow that value along with its surface area and depth. Differing from the detention basin the outlet control is to be in the form of a weir rather than a culvert (Appx L.1) [13].

Table 4.4.6: Wetlands Specs

Wetlands					
Depth	V (ft^3)	V (acre-ft)	A (ft^2)	(acres)	(mi^2)
D (6ft)	1219871	28.00	203311.8	4.67	0.0073

Cost calculations related to this design can be found in Section 4.5.

4.4 Detention Basin and Natural Channel Modifications

The last alternative was the upper basin and the natural channel which would incorporate a detention basin where the existing pond is with the natural channel plans explained above. Ideally, with the detention basin holding back water, the channel would only need minimal modifications. See Figure 4.4 for a visual of the design.

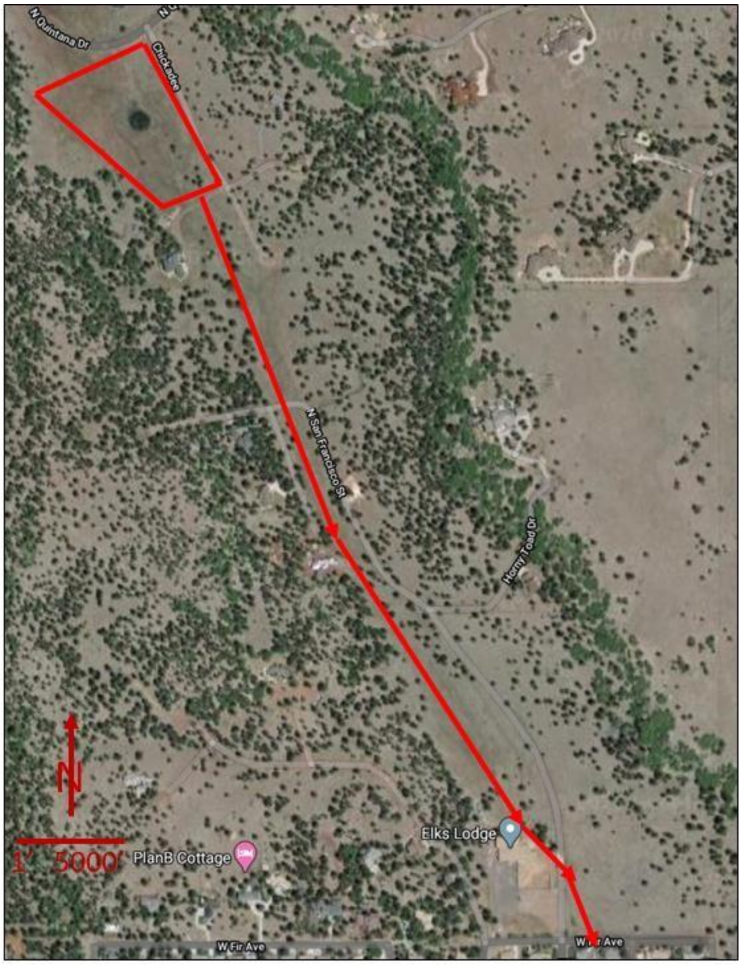

Figure 4.4.1: Northern Detention Basin and Natural Channel Modifications

Refer to previous volume calculations of the single detention basin and Reach 1.5 open channel to understand where the volume of this alternative originated.

Table 4.5.7: Detention Basin and Channel Specs

Detention Basin and Channel	
Feature	V (ft^3)
Detention Basin	1219871
Reach 1.5	16616
Total	1236487

Costs related to this design can be found in Section 4.5.

4.5 Decision Matrix

A decision matrix was used to select the best design based on five different criteria: cost/benefit, environmental/social impacts, operation and maintenance, area needed, and appeal. The team, with the guidance of Gary Miller and Doug Slover, discussed and came up with criteria and the metrics for each. Each category received the same weighting as each of the criteria's is of equal importance to the COF. A score of 1-5 was given to each design with five being best and one being poor. The WLB basin design was included in the decision matrix as a baseline for scoring.

Table 4.6.8: Cost Estimates

	Storage Volume (ft^3) Needed for 100yr Storm Event	Cost ($/^{3})	Adjustment Factor	Assumptions	Relocate Utilities Possibility
Natural Channel	374940	$2,748,310.20	1.5	Based on 3000 ft of channel and a wetted perimeter of 21ft	Medium
Natural Channel/Culvert Bipass	324948	$2,913,068.84	1	Based on 2600 ft of channel and a wetted perimeter of 21. 72" Culvert $830 ft from WLB	High
Extended Basins	2090880	$16,826,150.40	1	Two 4 Acres Basins at 6 ft Deep	Low
Detention Basin/LID basin	2090880	$19,779,724.80	1		
Wetlands	1600000	$18,136,000.00	1.5	Area of 400,000 ft^3	3 Million in Culvert Addition
Upper Basin+ Natural Channel	1045440	$11,911,385.40	1.5		Low
WLB Basin (Control)		$8,000,000.00			

The metrics used for environmental/social impacts were aesthetics of the design, ease for wildlife to move through the area, sediment control, erosion control, and minimal impact to the rural floodplain. It is important to note that all designs will impact the flood zone. By changing the flood zone COF will have to request a FEMA map revision. Performing a map revision requires an expensive up-front cost, but overall can decreases COF residents flood insurance premiums after a community rating system audit is performed.

The metrics for OM were how much money would the COF spending on maintenance for a design per year as well as the ease of maintenance. The metrics for area needed was how much area would a design take to convey a 100-year flood event.

The triangular hydrograph method was used to size all basins designs. Flow master was used to size all designs with a natural channel. Points were awarded to designs that need smaller amounts of area, as well as minimal need to move utilities.

The final category, Appeal, was scored on a designs ability to teach the team several different design aspects of an engineered stormwater solution. This category was added based on the recommendation of Doug Solver. Table 4.7 below shows the decision matrix used.

Table 4.7.9: Decision Matrix

	Cost/Benefit		Environmental/Social Impact		OM		Area Needed		Appeal		Total
Weight	0.2	Score	0.2	Score	0.2	Score	0.2	Score	0.2	score	
Natural Channel	2	0.4	4	0.8	5	1	3	0.6	3	0.6	3.4
Natural Channel/culvert bipass	4	0.8	3	0.6	4	0.8	4	0.8	4	0.8	3.8
Extended Basins	1.5	0.3	2	0.4	2	0.4	1	0.2	2	0.4	1.7
Detention Basin/LID basin	2	0.4	3	0.6	2	0.4	1	0.2	3	0.6	2.2
Wetlands	1	0.2	4	0.8	1	0.2	2	0.4	2	0.4	2
Upper Basin+ Natural Channel	4	0.8	3	0.6	3	0.6	3	0.6	4	0.8	3.4
WLB basin and small Basin North of Fir	3	0.6		0		0		0		0	
WLB basin	3	0.6	2	0.4	3	0.6	3	0.6	0	0	2.2

4.5.1 Cost/Benefit

All costs were compared to the $8 million WLB standard as seen in Table 4.6 [16]. Costs that exceeded that standard lost a point. The metrics for cost and benefit were based upon the upfront cost of each design. The upfront cost of each design was determined using the EPA stormwater Opti-tool [15], as well as the WLB basin designs cost for moving utilities and earthwork costs (Appx M.1-M.2). Both were adjusted for inflation (Appx M.3).

Equation 4.4.12: General Cost Function Formula [15]

$$Cost\ (\$) = Storage\ Volume\ of\ BMP^{*}(ft^3)\ X\ Cost\ Estimate\ for\ BMP\ \left(\frac{\$}{ft^3}\right)\ X\ Adjustment\ Factor$$

Design alternatives were given points if the design was cheaper than the WLB basin design when adjusted for inflation. The WLB basin was given a score of three, if a design was the same cost as the WLB basin it was also given a three. Benefits were measured as the ability for a design to convey a 100-year storm or higher.

For the benefit relative to cost, the natural channel earned a score of two. This was due to a high cost for reshaping the entire channel to handle a 100-year storm event. It was determined during the meeting with COF that the channel bottom width would have to be increased to over 20 ft to accommodate a 100-year storm event. This alternative also fails to address the channel capacity problems in the neighborhood.

The natural channel/culvert bypass earned a score of four due to a moderate amount of earth work to place the 200 ft culvert bypass. A web soil survey was done in the area of interest. The results showed after one foot the soil is all clay (Appx I.2). This design scored higher than the natural channel due to no earth work needed in reach 4.

Both the detention basins and the LID basin were given low scores of 1.5 and 2 respectively. The expense of creating a detention basin/LID was found to be more expensive relative to the natural channels because of the need to purchase private land.

Wetlands received the lowest score due to high costs of reshaping the channel, revegetating the channel, and inputting necessary perforated piping. All which have high construction costs and could not be tabulated by the scope of this project.

Upper detention basin and natural channel received a four due to its relative low cost having one channel and one basin dredged. However, the COF would still need to buy the land for the detention basin from the landowner otherwise it would be ranked higher.

4.5.2 Environmental/Social Impact

The natural channel earned a score of four as this design has very minimal negative environmental or social impacts. The top part can be stripped and reapplied to the site after the channel is dredged, limiting the disturbance of vegetation. Wildlife is also encouraged with this minimal disturbance and is aesthetically pleasing to the residents in the area as they walk by it.

The natural channel/culvert bypass received a score of three as the design contained the benefits of the natural channel as previously stated, but instead required more earthwork that would disturb that natural area. This design also has potential to impact the rural floodplain. Impacting this area could cause COF to lose points with FEMA meaning COF's flood insurance premiums would increase.

The extended basins received a score of two due to the earthwork needed to create each basin as well as the negative aesthetics of the detention basins earth walls. It would also require removing some trees.

The detention basin/LID basin and upper basin and natural channel both received scores of three due to positive environmental impacts of ground water recharge and improving the natural channel.

Wetlands received a four due to its multiple environmental impacts (increasing water quality and habitat formation) as well it being aesthetically pleasing. It was not given a five since it would change the view at Elk's Lodge, the extensive earthwork required, and the traffic delays the construction could cause in the area.

4.5.3 Operation and Maintenance

Refer to Appx M.1 for estimated costs for the first year.

The natural channel design earned the highest score for OM at a five due to very low maintenance frequency and costs. Landscaping, debris and trash removal, and erosion control maintenance also must occur, but that required of all other designs. The neutral channel only needs this maintenance while other designs require additional measures.

The culvert bypass with natural channel received a four while the upper basin and natural channel received a three. Both designs utilize the natural channel which requires minimal maintenance. The increase in OM expense comes from culverts as they require a yearly clear out and inspection. Compared to the detention basin, the culverts were found to be less expensive leading to the natural channel and bypass receiving a higher score.

The extended basins received a score of two in as a reflection of the these high detention basin OM costs. A score of two was also given to the detention basin/LID as LID basins require equally high amounts of maintenance as detention basins to ensure the perforated pipe is clear and functioning properly.

The wetlands received the lowest score due to continual landscaping maintenance, clearing out perforated pipes, and providing continuous flow through the wetland.

4.5.4 Area Needed

The natural channel received a score of three due to how large the natural channel is needed to convey a 100-year storm event with no flooding. The entire area north of the

Elks lodge would be needed to be converted into a channel from preliminary calculations causing additional earthwork costs and disturbance.

The natural channel/culvert bypass received a score of four due to the majority of the design being underground even though the natural channel part would still need a significant amount of space.

The extended basins and detention/LID basin both received scores of one due to eight acres being needed for each design. This is significantly larger than the area needed for the open channel design.

Wetlands received a score of two due to the design needing half the area than the extended basins and detention/LID basin.

The upper basin and natural channel received a three. The idea behind this design is that the basin would discharge water slower to the natural channel. Instead of requiring the channel bottom to be 20ft across.

4.5.5 Appeal

The last category was appeal. The natural channel and LID detention basin both received scores of three. This score was given to these designs as all the designs based on the overall interest of the team members, Gary Miller, and Doug Slover. Wetlands and extended basins received the lowest scores since the interest in implementing these designs was low. The natural channel/culvert bypass and the upper basin and natural channel designs received the most interest from all participating members as the designs effectively protect the neighborhood from flooding and offered the team design experience for different kinds of stormwater infrastructure.

4.5.6 Chosen Design

Ultimately, the natural channel/culvert bypass alternative was chosen as the best design. The natural channel and upper basin and natural channel alternatives tied for second. What made the culvert bypass alternative better than the upper basin alternative was that it requires less area and maintenance compared to the other options while holding the most appeal.

5.0 Hydraulics

5.1 Existing Open Channel Modeling

Using the surveying data previously collected (Appx B.1-B.64), a hydraulic model was created by inputting said data into HEC-RAS. These were modelled by reach and by cross section (APPX G.). The HEC-RAS model runs on the rational equation which requires roughness coefficients. These coefficients were determined using the HEC-RAS manual (APPX H.1-H.3) and aerial images of the site. Though HEC-RAS can have induvial coefficients for each cross-section’s channel and banks, it was assumed these coefficients were the same across each cross-section. The previously estimated flow data for the 100-yr storm (830 cfs) was then put into the model to determine channel conditions and was used for all reaches. The results of the model show that under 10, 25, 50, and 100-year storm events the channel cannot convey the water without flooding.

These results are tentative as the model is not fully finished. The following figures showcase all the reaches modeled in HEC-RAS. The HEC-RAS model file will be included with the final design document. Figure 5.1.14 shows the general geometry of this model.

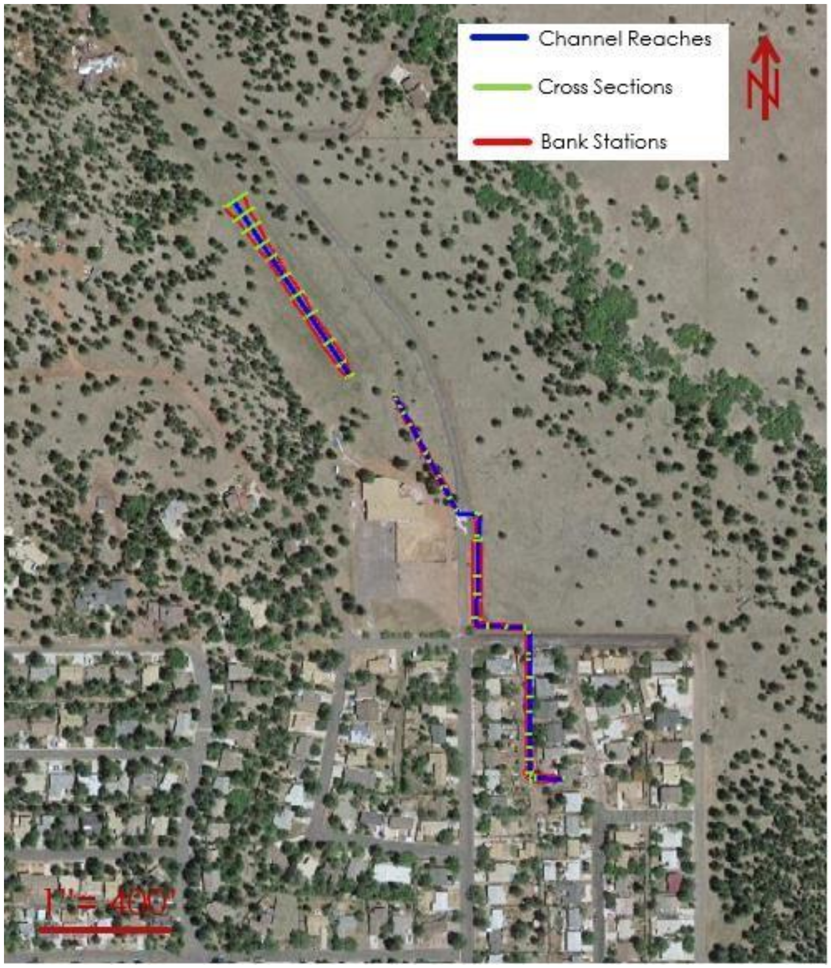

Figure 5.1.14: HEC-RAS Cross Stations

As seen in Figure 5.1.14 there is not channel between reaches 1 and 2. Due to the complexity of determining how much water will flow into reach 2 the team decided to assume the same flow rate through reach 2 as reach 1. Figures 5.2.15, 5.3.16, and 5.4.17 show cross-sections analyzed using HEC-RAS for reaches 1, 3, and 4 respectively. The dark blue lines show the 10, 25, 50, and 100-year storm events with the 100-year on top. Red lines indicate critical depths.

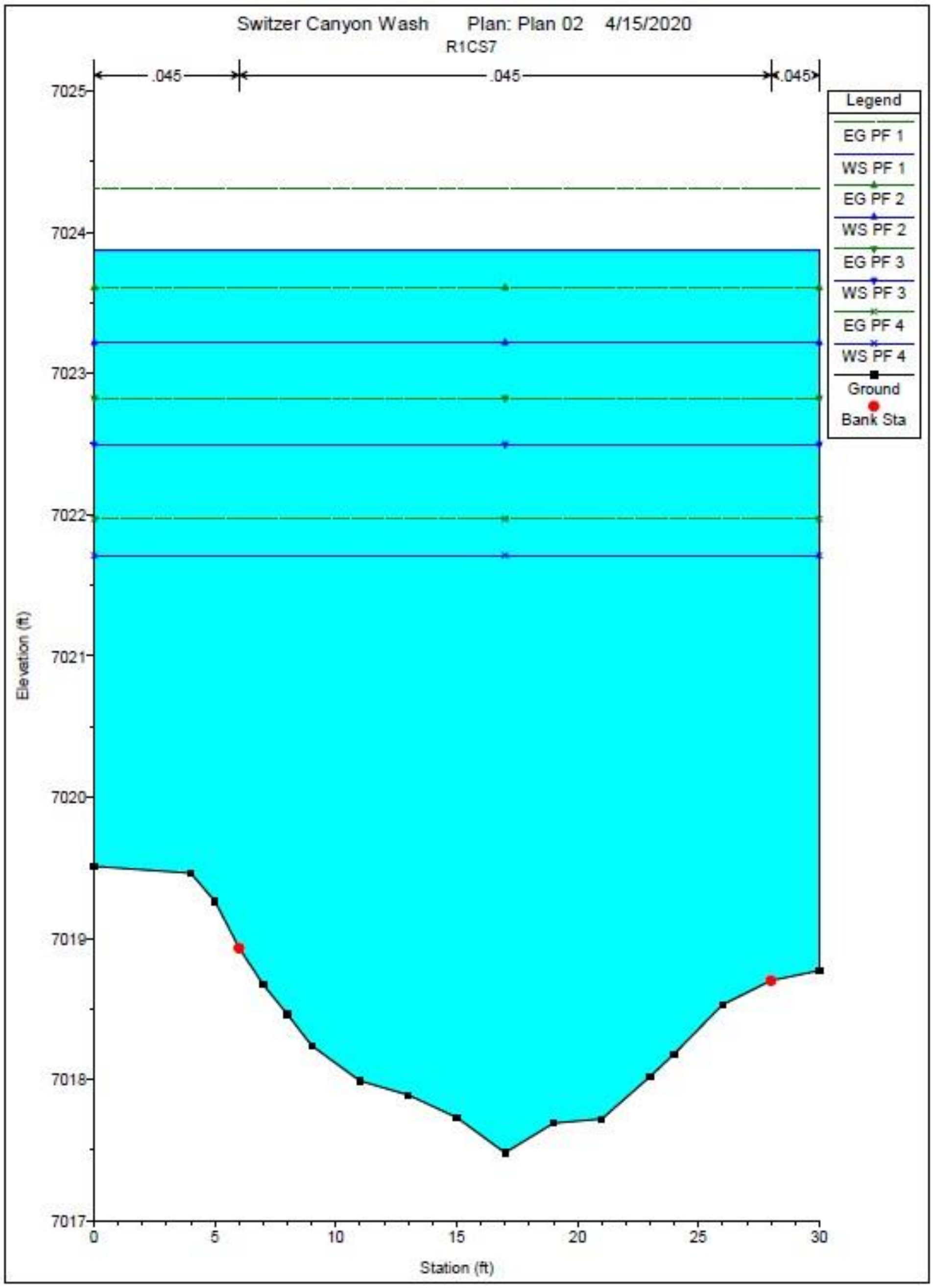

Figure 5.2.15: HEC-RAS Reach 1 Cross-Section

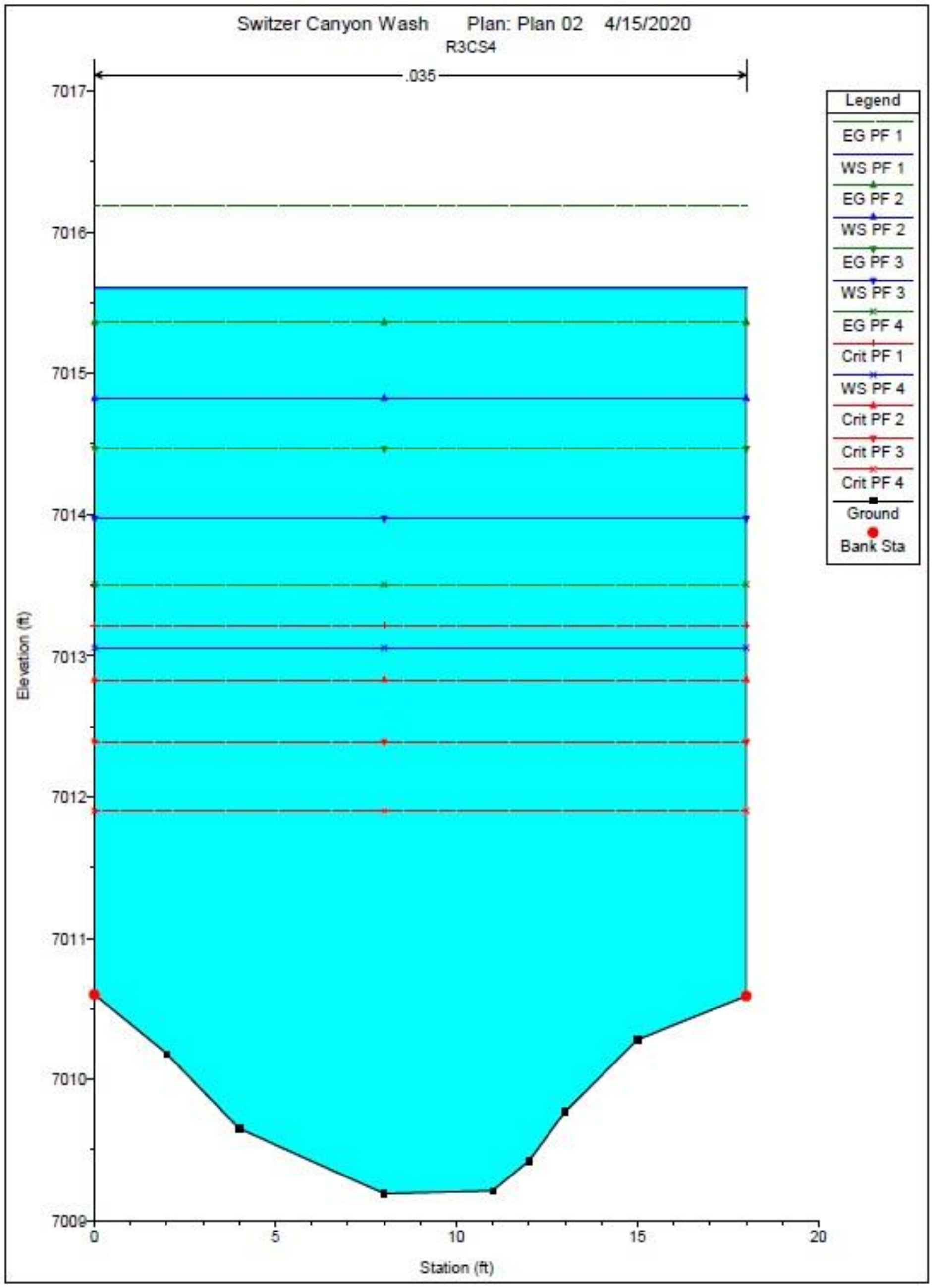

Figure 5.3.16: HEC-RAS Reach 3 Cross-Section

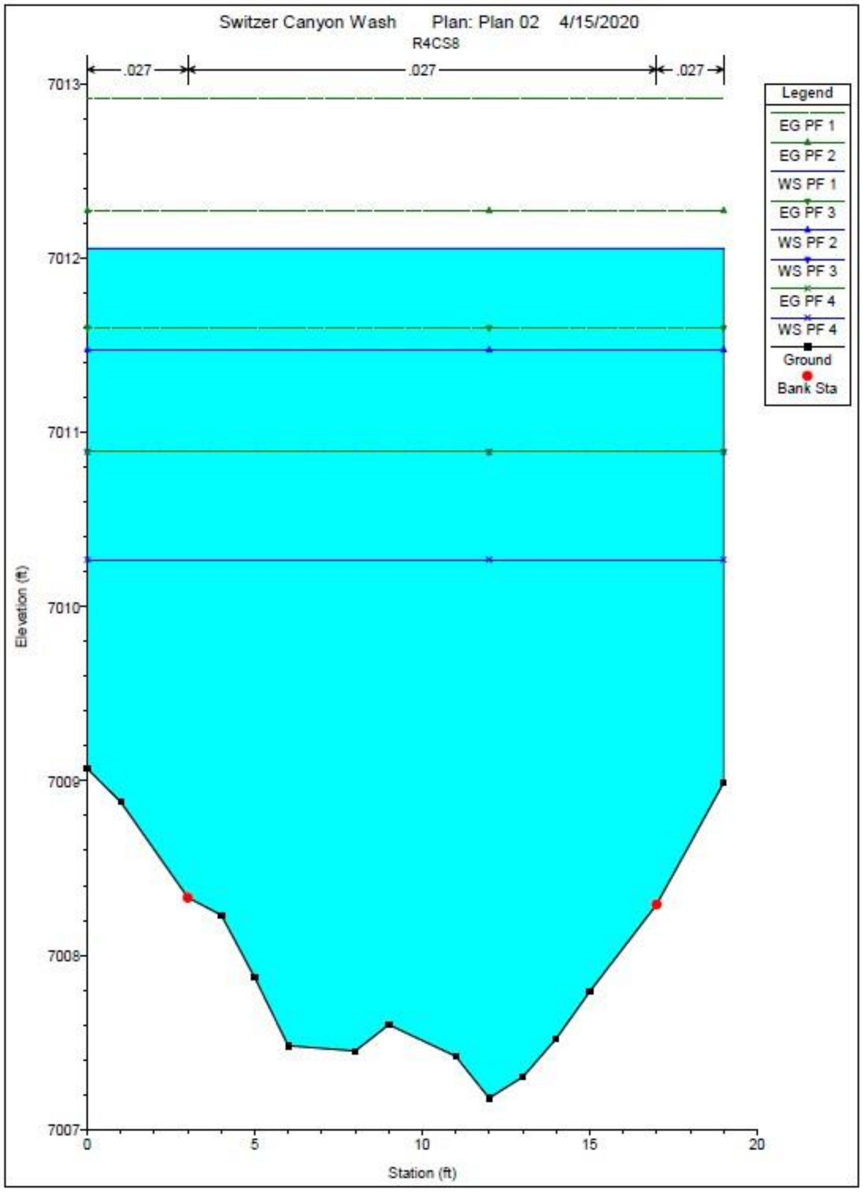

Figure 5.4.17: HEC-RAS Reach 4 Cross-Section

5.2 Proposed Open Channel Modeling

Part of the chosen solution includes reshaping the open channel. The cross-section dimensions decided upon are shown in Figure 5.5.18. Per guidance from the City of Flagstaff Stormwater Management Design Manual, the side slopes of the cross-section are no steeper than 2:1 and the channel slope was designed to be greater than 0.5% [17].

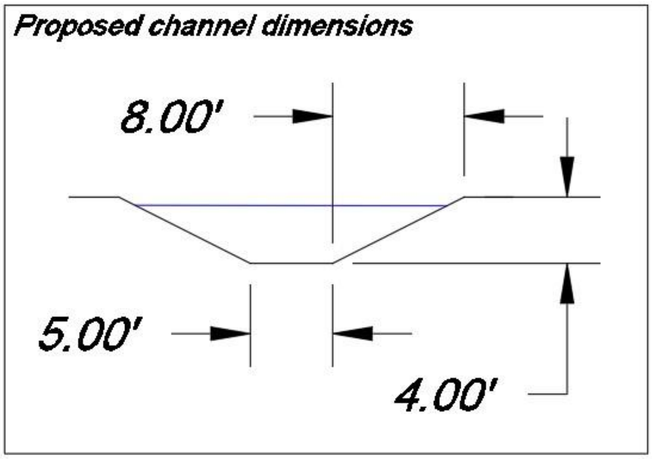

Figure 5.5.18: Proposed Channel Cross-Section Dimensions

6.0 Final Design Recommendation

The culvert bypass option was chosen as the final design. This design involves the reshaping of 3000 feet of channel located in reaches 1 through 3 to the dimensions seen in Figure 5.5.18. The reshaped channel is designed to convey a 100-year flood event without overtopping while meeting COF stormwater codes. The channel side walls will be created from removed dirt from the site with no additional concrete reinforcement. Specifically, the cut from the reshaping of the channel will be used for the right side of the channel. As stated in section 5.2 the channel will have side slopes of 2:1. This steep side slope was chosen to minimize the area needed for the channel considering the site's space limitations due to the Elks Lodge and preexisting water mains. The next step of the natural channel culvert bypass design is constructing a 924-foot culvert spanning from the end of reach 3 to 15 feet southeast of N Turquoise Dr. This culvert will be made up of two 96-inch round reinforced concrete class 3 pipes. Due to the size of the culvert, the entrance will have a concrete head wall as well as 45-degree concrete wing walls to meet COF stormwater code. The downstream end of the culvert will have a rip rap apron around it. The apron will be 57-feet long and 53-feet wide to meet COF stormwater code. Four manholes will be installed at the two 30-degree bends in the culvert. The bends in the culvert are located directly underneath N. Turquoise Dr, in order to simplify operation and maintenance over the life span of the culvert. The culvert will require the removal of 16,500 cubic yards of dirt. Much of this dirt will be used as backfill over the culvert. The rest of the cut will be used in creating a 6-foot by 4-foot tall berm located at the end of reach 3. This berm will serve to direct the water straight into the culvert, as well as take the culvert out of the public eye for safety and scenery reasons. This berm will also be rip-rapped to protect it during an overflow situation. Overflow from the culvert will spill onto W. Fir Ave then into the preexisting channel (reach 4) located perpendicular to the berm. The hydraulic analysis of both the channel and culvert can be found in (Appx N.1-N.2). Figure 6.1.19 below models the hydraulic performed of the culvert during a 100-year storm event. The figure also includes the energy grade line and hydraulic grade line of the water during this storm event.

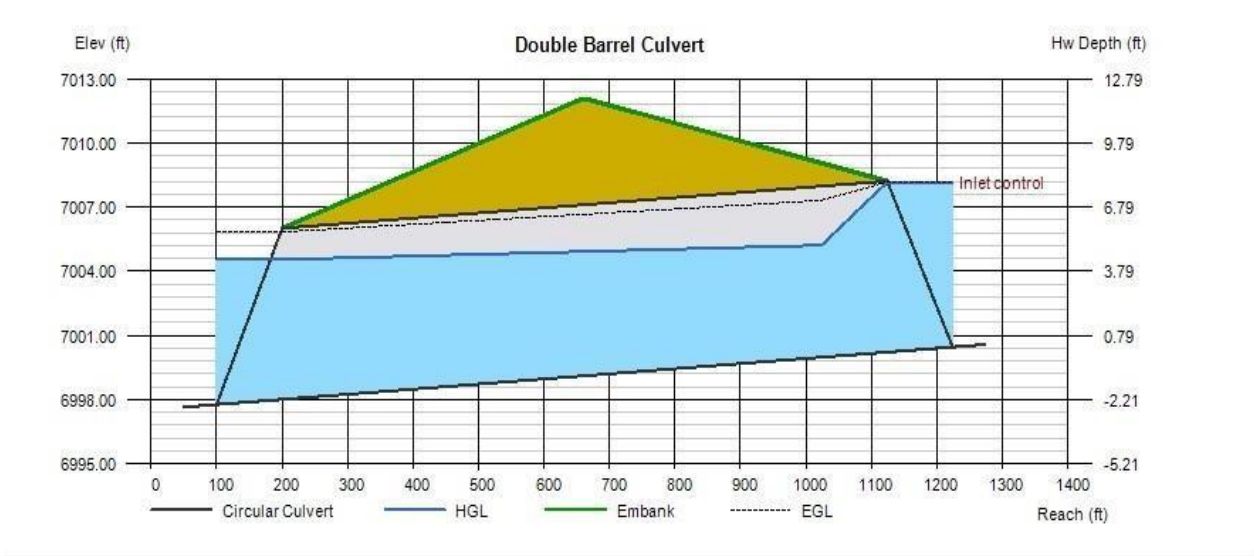

Figure 6.1.19

Figure 6.2.20 below shows the hydraulic model used for the channel. In the figure the channel is conveying a 100-year storm event

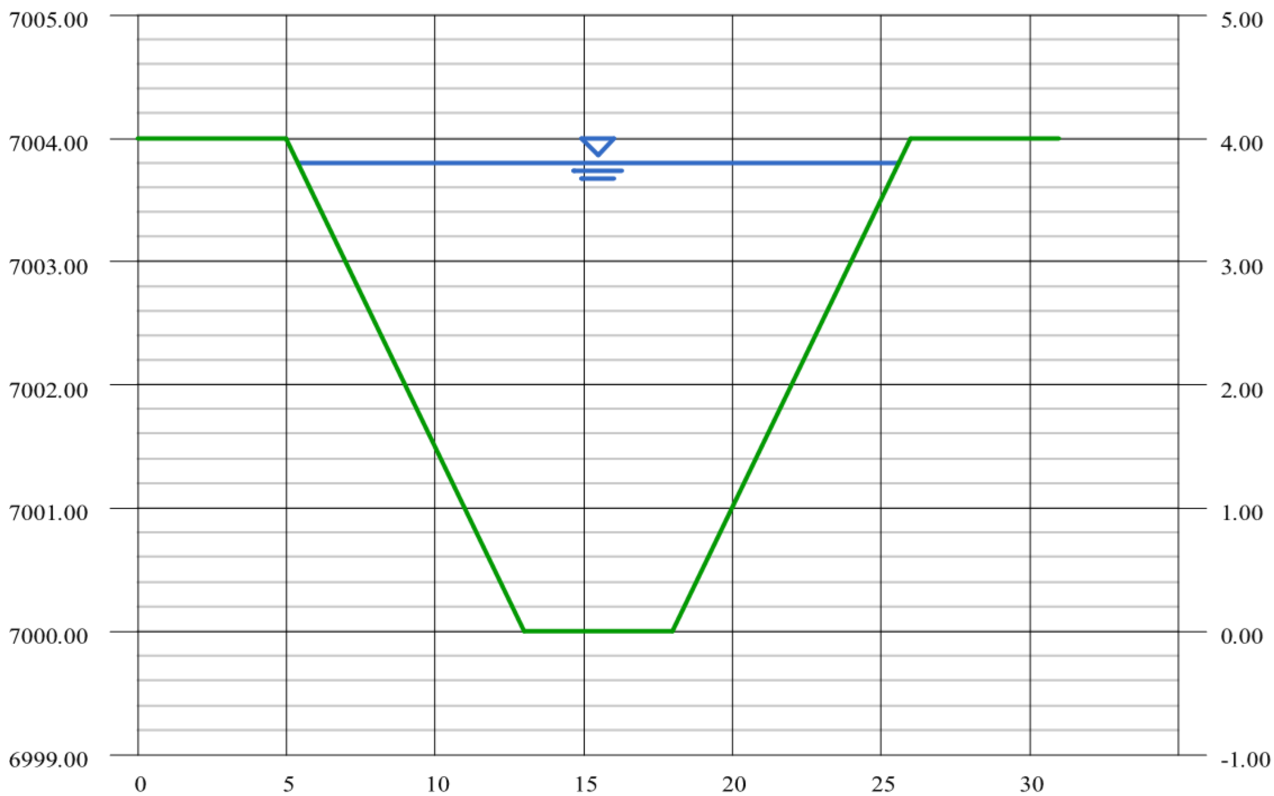

Figure 6.2.20

6.1 Impacts

The natural channel culvert bypass option was chosen for several reasons. One of these reasons is that the design would have very minimal long-lasting negative environmental impacts to the area. By reshaping the natural channel, the design will create a larger protected nature corridor for deer and other animals in the area. This project also provides an opportunity to remove invasive plant species from the area. The channel will also minimize impact to the rural floodplain as water draining from the northeast side of the watershed will not be impacted. The initial construction of the channel will require a considerable amount of earthwork but once the vegetation recovers the area will still look and function the same way as before the project. All the dirt excavated from the site will remain on the site but will be used to shape the right side of the channel. This means no dump trucks will be needed to haul dirt away from the site. This will decrease the amount of noise, wear and tear on the roads, and air pollution for the surrounding area. The same can be said for the culvert design of this project. Most of the excavated dirt will remain on site as back fill and the creation of berms. There is a negative environmental impact of using concrete pipe as the process to make the pipe is energy intensive and creates large amounts of greenhouse gases. The other negative impact of the pipe is that it will have to be brought in on large semi-trucks to the site. These trucks will also have to be used to bring in the excavation equipment as well. The environmental impacts are important to be aware of, but most are temporary. The most important environmental impact of this design is its very small impact to the upstream and downstream flow patterns of the wash.

This project will have major social impacts for the people living in the existing floodplain. Forcing stormwater to move around the neighborhood instead of through it will lower the risk of flooding for many homes. These people won't have to worry as much about property damage during storm events. This design will also allow for people on W Fir Ave to use this road even during large storm events without worries of the road being flooded. The construction of the project will cause negative impacts to the people of Hospital Hill as well as Elks Lodge. These impacts will be loud noises, air pollution, and temporary visual impacts.

The economic impacts of this project are yet to be fully understood. The design would reduce the amount of standing stormwater on W Fir Ave. This would increase the life of the road and cost the COF less money for repairs. As stated in the social impacts the project would effectively take the hospital hill area out of the 100-year floodplain. This would reduce flood insurance for all residents and give the COF flood points with FEMA. The residents of the neighborhood would see the COF working to help the people. This in turn would make residents more likely to stay in Flagstaff which would help the city economically.

6.2 Cost of Implementing the Design

The cost to implement/construct the natural channel culvert bypass design will roughly cost the COF $4,762,018. Most of this cost is due to the large culvert pipes needed. The following tables will show how this estimate was calculated. It's important to note that the tables below do not include any cost for relocating utilities nor the cost for renting two excavators. The estimate does include a crew of eight workers all the culvert materials needed, and the costs for the equipment and permits for all the earth work in both the channel and culvert. Table 6.5.14 shows the total estimated cost and earth work volume to be excavated.

Table 6.1.10: Earth Work Cost - Culvert

Culvert Earth Work Cost		
Deep (ft)	Wide (ft)	Length (ft)
24	20	924
Volume	Cubic yards of Dirt	$ per Cubic Yard
443520	16427	2
Total Cost	$	32,853.33

Table 6.2.11: Additional Costs

Additional Cost (per 3000 ft)			
Equipment/Personnel	Hourly Rates/One Time Rate	Hours Needed	Cost per Item
Bulldozer	37.5	1050	$ 39,375.00
Workers (8)	60	1350	$ 81,000.00
Mobilization Fees	15000		$ 5,000.00
Inspection Fees	15000	0	$ 5,000.00
Compaction Machine	25	1050	$ 26,250.00
Compaction Tests	6000	0	$ 2,000.00
Total Cost	$ 749,625.00		

Table 6.3.12: Earth Work Cost - Channel

Channel Earth Work Cost			
Bottom Width	Top Width	Length	Height
5	20	3000	5
Volume	Cubic yards of dirt	$ per Cubic Yard	
187500	6944	2	
Total Cost	$	13,888.89	

Table 6.4.13: Culvert Materials Cost

Cost of Culvert Materials			
Material	Unit Cost per ft/per part	# of Units	Cost per Item
96" Round Reinforced Concrete Pipe Class 3	2000	1848	$ 3,696,000.00
96" Manhole-Rubber Joint	435	4	$ 1,740.00
96" Intergral Base	624	4	$ 2,496.00
96" x 1'-5' to 48" MH Reducer	1270	4	$ 5,080.00
96" x 8 Manhole Base	365	4	$ 1,460.00
Wing Wall	4000	1	$ 4,000.00
Rip-rap	50	100	$ 5,000.00
Total Cost	$ 3,715,776.00		

Table 6.5.14: Total Project Cost and Earth Work Volume

Totals	
Total Cost of Construction Project (with 30% contingency)	**$ 5,865,786.19**
Cubic Yards of Earthwork	**23371**

As can be seen from Tables 6.1.10 through 6.4.13 many price estimations had to be made for the cost of the piping and earth work fees. These estimates for the piping came from online bid sheets. The earth work costs came from a conversation about the project with a professional construction engineer working for Todd construction based in Portland, OR. Due to the nature of how these costs were found the exact project construction costs was not determined. Due to this project being a 30% design, the final cost has a thirty percent contingency on it. This contingency brings the cost to $5.8 million to construct.

7.0 Summary of Engineering Work

Some changes to the scope of work occurred while performing the tasks. For the surveying portion, only a survey of the channel north of West Fir Avenue was done. The original proposal tasked the team with using a robotic total station for this area to create a point cloud. An auto level survey was performed instead to meet budget and cost constraints. Data for the wash within the neighborhood was found from multiple plan drawings which made performing an auto level survey of reach 4 unnecessary for the 30% draft. The methodology used for data gathering and processing for this project is laid out in Section 2.2.

Changes to the hydrology task included not looking at site specific master drainage studies. None were found for the area. Flow routing was done using a topographic map on ArcGIS provided by the City of Flagstaff instead of survey data from the team. The team decided to utilize the rational method for hydrograph development.

Initially, the plan was to have four design alternatives. The team ended up researching five stormwater control options and using them to create six design alternatives. The hours the team worked on this project can be seen in the table below. The team originally estimated the project to take 603 hours, and due to the scope changing and the team working effectivity the total hours for the project was 616 hours. The breakdown of these hours is shown in the table below.

Table 7.1.15: Hours Breakdown

Hours						
Task	**SENG**	**ENG**	**EIT**	**TECH**	**Total**	**Original total hours**
1.0 Site Investigation	3	2	19	17	41	47
2.0 Hydrology	3.5	4.5	16	13	37	41
3.0 Develop Conceptual Stormwater Management Approaches	10	18	18	10	56	56
4.0 Hydraulics	10	32	44	42	128	52
5.0 Impacts	3	6	12	6	27	23
6.0 Deliverables	37	65	71	65	238	192
7.0 Project Management	22	23	22	22	89	192
Total	88.5	150.5	202	175	616	603

8.0 Summary of Engineering Costs

The number of hours needed for tasks 1, 2, and 7 was overestimated in the proposal. Tasks 4 and 6 hours were significantly underestimated in the proposal. The cost of engineering services, in turn, becomes more expensive for this part of the work. The total cost of engineering work for this project was approximately 66,000 dollars. The breakdown of this cost can be seen in the table below.

Table 8.1.16: Cost breakdown

	Classification	Hours	Rate, $/hr	Cost
Personnel	SENG	88.5	200.00	17700
	ENG	150.5	135.00	20318
	EIT	202	80.00	16160
	TECH	175	60.00	10500
	Total personnel	616		64678
Travel	12 meetings	20 miles	0.58 $/mile	11.6
Supplies	Surveying equipment	18	100 $/hr	1800
TOTAL				**66489**

9.0 Conclusion

The team has been successful in gathering the necessary data to be able to analyze the floodplain, creating and analyzing design alternatives, and modeling the chosen design. The team has been able to note and provide data on problems with channel conveyance between Reaches 1 and 2 via the auto level survey. The team was able to determine an accurate flow rate of 800 cubic feet per second at the concentration point (Silver Spruce Avenue Wash). Design alternatives were created and analyzed. A design alternative that effectively relieves flooding in the Hospital Hill neighborhood was chosen and designed. The cost of the design was kept below the WLB detention basin found in Phase 3 of the City of Flagstaff's Master Drainage Study.

10.0 References

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Appendix

APPX A: Field Assessment

Appx A.1.1: Stream Reach Field Inventory Form Part 1

Flagstaff Area Stream Team - F.A.S.T.

Stormwater Management Section – Utilities Division

Stream Reach Field Inventory Form

Stream Name: Switzer Canyon Wash Upper Reach Reach No.: 1-4

Optional Location Description: Near Elk's Lodge

Inspector(s): Celine Bannourah, Kara Coffel, Gindiri Paul, and Noah Tison Date of Inspection: 1/17/20

Time: 12:15 pm

Reach Photo #s: See Report

Average Channel Reach Conditions: (Check below as applicable and describe below)

1. ___ **No signs of disturbance, good stable natural condition.**
2. ___ **Disturbed, but mostly good stable condition/some localized unstable areas.**
3. _X_ **Fair to poor condition, unstable with indicators of active erosion and/or deposition.**
4. ___ **Disturbed, very poor unstable conditions, active erosion and/or deposition.**
5. ___ **No unique or unusual characteristics or resource values.**
6. ___ **Has unique, or high resource values, or unusual characteristics.**
7. ___ **Historically disturbed reach, no longer natural, but in good stable condition.**

Describe: The channel has many smaller channels connecting to it. All of the reaches have grass, but the last reach has more bouldering. Pooling is also occurring along the channel and in the floodplain between reach 1 and 2. The main channel ends (reach 1) and then starts again at reach 2 after a couple hundred feet. There is also another channel that forms in the area before Elk's lodge that meets up with the main channel. Reach 3 has been excavated a little so the channel is more normalized. The end of reach 3 has some pooling, and reach 4 goes between houses and connects to a culvert at the end. That water is carried all the way underneath Turquoise Drive. There is a lot of build-up at those culverts.

Recommendations: ___ **No Action Needed.** _X_ **Additional detailed examination needed,**
Circle specialty areas: Erosion/Channel Morphology; Riparian/Wetland Vegetation; Archaeology; Recreation/Trails; Wildlife; Other: ______

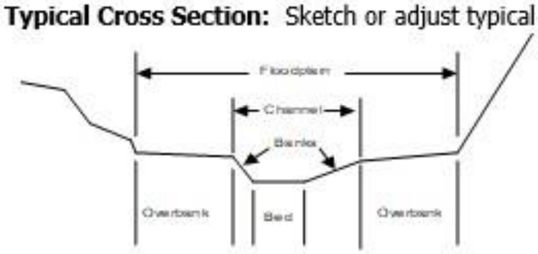
Action Needed For: ___ Cleanup; _X_ Maintenance; _X_ Restoration; ___ Preservation; _X_ Stabilization/Erosion Control; **Priority:** ___ High; ___ Low; _X_ Moderate; ___ Don't Know.

Comments: The channel is not stable enough to convey all of the water so there is a flooding problem in the neighborhood.

Appx A.2.2: Stream Reach Field Inventory Form Part 2

Average Reach Descriptive Data (Use: B=Bed; BK=Bank; OB=Overbank or A=Same all Areas)
__BK, OB__ Dry; _B_ Wet, Type:__ Flowing Stream;__ Spring; ___ Seep; __B__ Pond; Other: _________
Describe: The soil was muddy in some parts of the bed of the channel, and some ponds formed in the floodplain due to the channel disappearing. The rest of the channel was dry, and no water was flowing.
Soil Material: _A_Soil; ___ Sand; _A_ Gravel; _B, Reach 4__ Boulders; ___ Bedrock; Other: _________
Describe: There was soil in all of the reaches, the last reach had bouldering and there was gravel throughout all of the reaches.
Vegetation: Type: _A_ Grass; ___ Pond. Pine; ___ Cottonwood; ___Cattails/Water Lilies; ___Sedges; ___Willows; ___ Wild Rose; ___ NM Locust; Other: _________
Describe: There was a lot of grass throughout the channel reaches.
Noxious (Invasive) Species Observations (Use: P=Present; A=Absent; C=Common; D=Dominant)
___ Dalmatian Toadflax; ___ Yellow Starthistle; __P__ Scotch/Bull Thistle; ___ Diffuse Knapweed;
___ Cheatgrass/Brome; ___ Russian Olive; ___ Siberian Elm; Other: Russian Thistle
Describe: The invasive species are very present and dominating the non-invasive vegetation.
Disturbed Channel Condition Indicators: ___ Unnatural Activity within the Bed, Banks or Floodplain;
___ Bare Ground; _X_ Erosion; _X_ Deposition; ___ Vertical Banks; _X_ Head Cutting; _X_ Excav;___ Fill;
___ Gullies; ___ Grading; ___ Discharge: ___________; Adjacent land use:_____________________
Describe: There was a lot of erosion in the beginning of reach one, and where the first reach ends there is a lot of deposition. There are head cuts that created smaller channels that enter the main channel. Reach 3 has been excavated a little to start with helping the flooding problem.
Possible Causes:
Natural: _X_ Flood Event; ___ Debris Dam; _X_ Wildfire; ___ Unknown; ___ Other: _______________
Describe: There was the Museum Fire over the summer of 2019 that has increased flooding in the area.
Unnatural: ___ Road; ___ Trail; ___ Railroad; ___ Sewer line, _X_ Waterline; ___ Gas Line;___ Dumping;
__ Channelization; ___ Runoff from Adjacent Development; ___ Excavation; ___ Fill; ___ Outlet Pipe;
_X_ Devegetation in Watershed; _X_ Residential; ___ Commercial; ___ Other: __________________
Describe: There is a waterline that is going to be moved in the channel, there is devegetation (less trees) and the addition of residential buildings could contribute to the current state of the channel.
Possible Solution(s): _X_ Erosion Stabilization; _X_ Restoration: ___ Cleanup; _X_ Maint.; ___ Other;
Describe: Design alternatives to restore the channel or allow the channel to no longer flood need to be looked into.
Recommended Follow-up: ___ Detailed Field Inspection; ___ Enforcement Action __ Cleanup;
___ Historical Analysis; _X_ Other; Describe: Surveying the channel and designing solutions to improve channel conditions in order to prevent flooding in the area

Typical Cross Section: Sketch or adjust typical cross section as applicable (looking downstream):



Floodplain = 45′
Channel = 14′
Bed = 4′
Bank Left = 5.15′
Bank Right = 5.12′
Overbank Left = 7′
Overbank Right = 26′

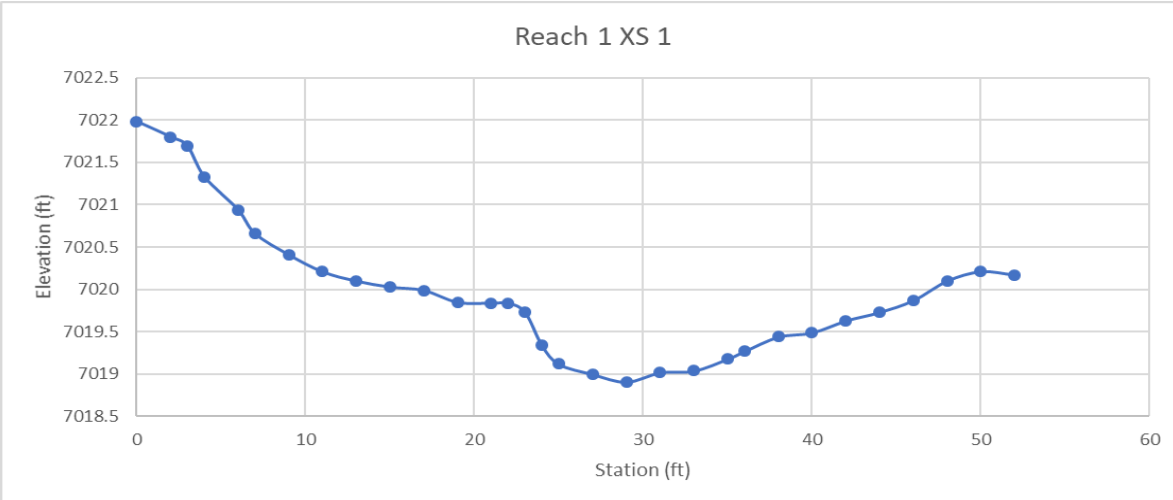
Wildlife Observations (list species or describe)
Animals: Deer, Coyotes
Birds: Crows
Insects: _Y_ Y/N; ___ Terrestrial; ___ Aquatic; ________________________
Amphibians/Reptiles: N/A
Recreation and Trails Observations
Describe Types of Recreation Activity: _X_ Hiking; _X_ Biking; ___ Birding; Other: _______________
Type of Trail: ___ None; ___ FUTS; __ AZ TRL; ___ Social; ___ USFS; ___ Other: Buffalo Park Loop
Condition of Trail: _X_ Good; ___ Poor; ___ Needs Maint/Repair: ________________________
Describe: Buffalo Park loop is on the outskirts of the area of focus.

APPX B: Survey Data Processing

Appx B.1.3: Reach 1 Cross Section 1 Surveying Data

Station (ft)	BS	HI	FS	Elevation (ft)
BM	5.21	7025.21		7020
0		7025.21	3.23	7021.98
2		7025.21	3.41	7021.8
3		7025.21	3.52	7021.69
4		7025.21	3.88	7021.33
6		7025.21	4.27	7020.94
7		7025.21	4.55	7020.66
9		7025.21	4.8	7020.41
11		7025.21	5	7020.21
13		7025.21	5.11	7020.1
15		7025.21	5.18	7020.03
17		7025.21	5.22	7019.99
19		7025.21	5.36	7019.85
21		7025.21	5.37	7019.84
22		7025.21	5.37	7019.84
23		7025.21	5.48	7019.73
24		7025.21	5.87	7019.34
25		7025.21	6.09	7019.12
27		7025.21	6.21	7019
29		7025.21	6.3	7018.91
31		7025.21	6.19	7019.02
33		7025.21	6.17	7019.04
35		7025.21	6.03	7019.18
36		7025.21	5.94	7019.27
38		7025.21	5.77	7019.44
40		7025.21	5.72	7019.49
42		7025.21	5.58	7019.63
44		7025.21	5.48	7019.73
46		7025.21	5.34	7019.87
48		7025.21	5.11	7020.1
50		7025.21	5	7020.21
52		7025.21	5.04	7020.17

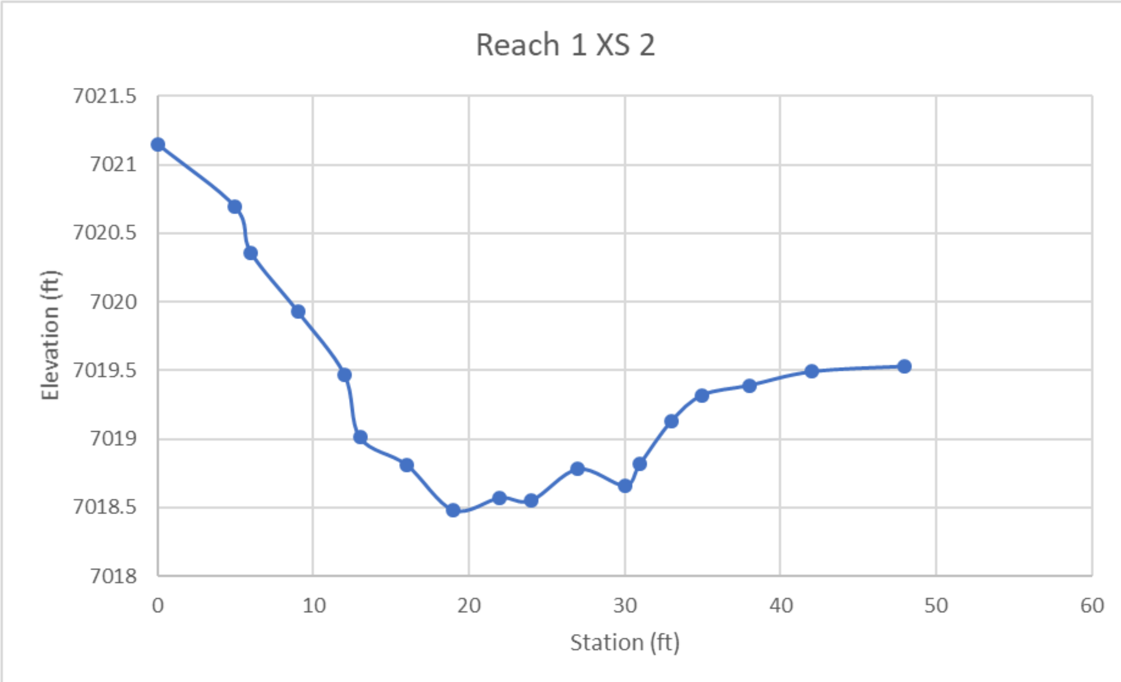
Appx B.2.4: Reach 1 Cross Section 1 Graph



Appx B.3.5: Reach 1 Cross Section 2 Surveying Data

Station (ft)	BS	HI	FS	Elevation (ft)
BM	5.21	7025.21		7020
0		7025.21	4.06	7021.15
5		7025.21	4.52	7020.69
6		7025.21	4.85	7020.36
9		7025.21	5.28	7019.93
12		7025.21	5.74	7019.47
13		7025.21	6.2	7019.01
16		7025.21	6.4	7018.81
19		7025.21	6.73	7018.48
22		7025.21	6.64	7018.57
24		7025.21	6.66	7018.55
27		7025.21	6.43	7018.78
30		7025.21	6.55	7018.66
31		7025.21	6.39	7018.82
33		7025.21	6.08	7019.13
35		7025.21	5.89	7019.32
38		7025.21	5.82	7019.39
42		7025.21	5.72	7019.49
48		7025.21	5.68	7019.53

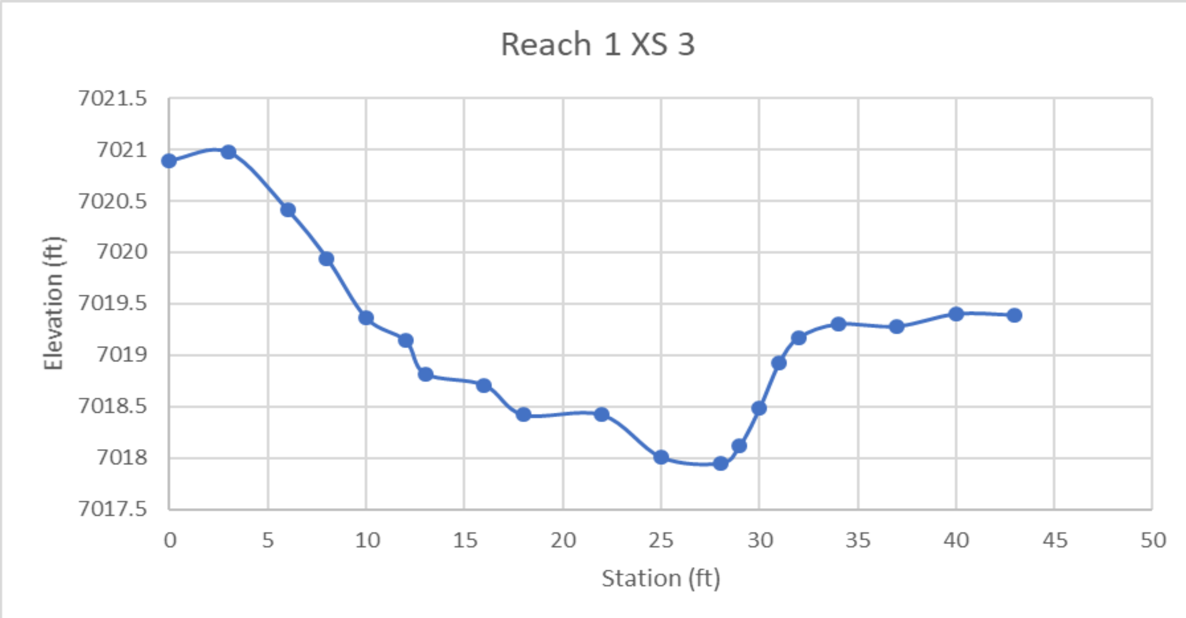
Appx B.4.6: Reach 1 Cross Section 2 Graph



Appx B.5.7: Reach 1 Cross Section 3 Surveying Data

Station (ft)	BS	HI	FS	Elevation (ft)
BM	5.21	7025.21		7020
0		7025.21	4.32	7020.89
3		7025.21	4.24	7020.97
6		7025.21	4.8	7020.41
8		7025.21	5.27	7019.94
10		7025.21	5.85	7019.36
12		7025.21	6.07	7019.14
13		7025.21	6.39	7018.82
16		7025.21	6.5	7018.71
18		7025.21	6.79	7018.42
22		7025.21	6.79	7018.42
25		7025.21	7.2	7018.01
28		7025.21	7.26	7017.95
29		7025.21	7.09	7018.12
30		7025.21	6.73	7018.48
31		7025.21	6.29	7018.92
32		7025.21	6.04	7019.17
34		7025.21	5.91	7019.3
37		7025.21	5.93	7019.28
40		7025.21	5.81	7019.4
43		7025.21	5.82	7019.39

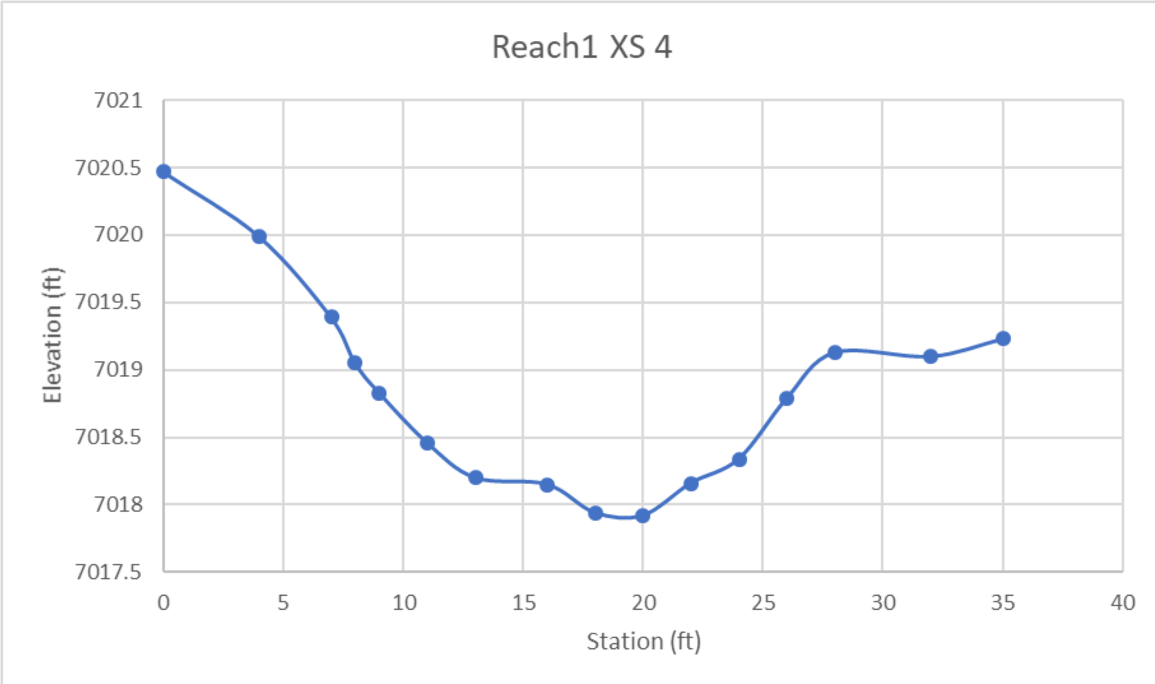
Appx B.6.8: Reach 1 Cross Section 3 Graph



Appx B.7.9: Reach 1 Cross Section 4 Surveying Data

Station (ft)	BS	HI	FS	Elevation (ft)
BM	5.21	7025.21		7020
0		7025.21	4.74	7020.47
4		7025.21	5.22	7019.99
7		7025.21	5.82	7019.39
8		7025.21	6.16	7019.05
9		7025.21	6.38	7018.83
11		7025.21	6.75	7018.46
13		7025.21	7.01	7018.2
16		7025.21	7.06	7018.15
18		7025.21	7.27	7017.94
20		7025.21	7.29	7017.92
22		7025.21	7.05	7018.16
24		7025.21	6.87	7018.34
26		7025.21	6.42	7018.79
28		7025.21	6.08	7019.13
32		7025.21	6.11	7019.1
35		7025.21	5.98	7019.23

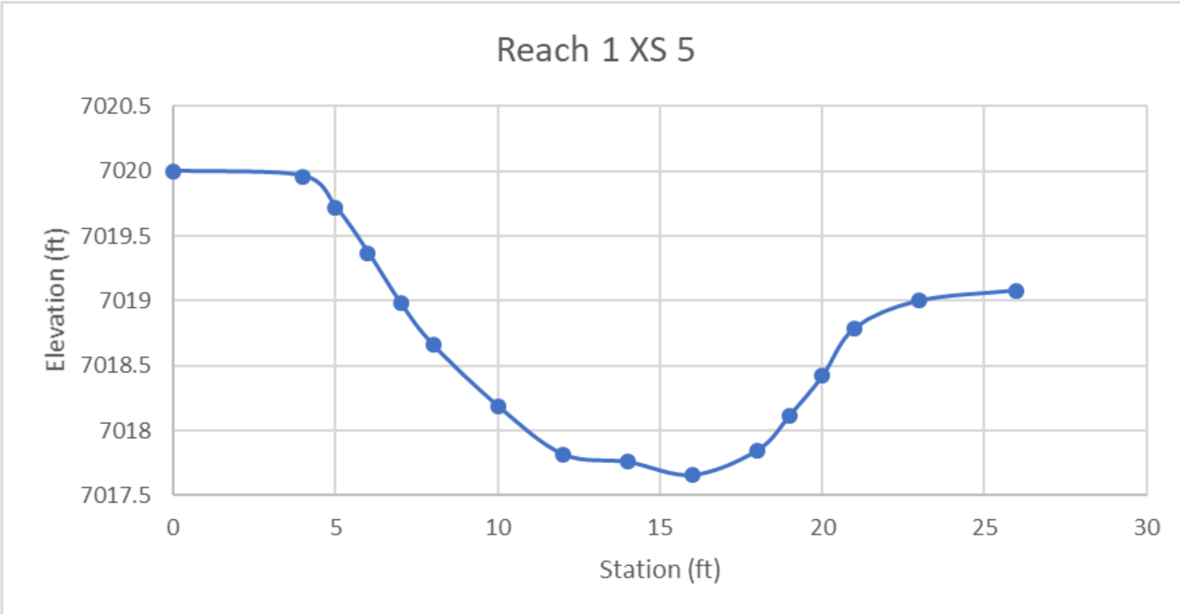
Appx B..8.10: Reach 1 Cross Section 4 Graph



Appx B.9.11: Reach 1 Cross Section 5 Surveying Data

Station (ft)	BS	HI	FS	Elevation (ft)
BM	5.21	7025.21		7020
0		7025.21	5.21	7020
4		7025.21	5.25	7019.96
5		7025.21	5.49	7019.72
6		7025.21	5.84	7019.37
7		7025.21	6.23	7018.98
8		7025.21	6.55	7018.66
10		7025.21	7.02	7018.19
12		7025.21	7.39	7017.82
14		7025.21	7.45	7017.76
16		7025.21	7.55	7017.66
18		7025.21	7.36	7017.85
19		7025.21	7.09	7018.12
20		7025.21	6.79	7018.42
21		7025.21	6.42	7018.79
23		7025.21	6.21	7019
26		7025.21	6.13	7019.08

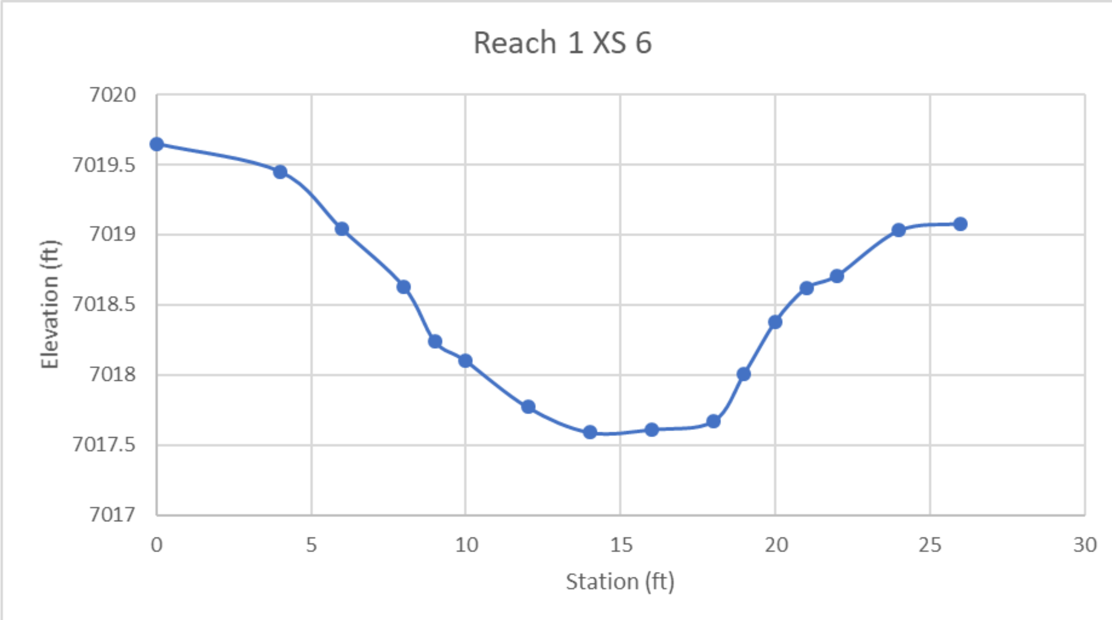
Appx B.10.12: Reach 1 Cross Section 5 Graph



Appx B.11.13: Reach 1 Cross Section 6 Surveying Data

Station (ft)	BS	HI	FS	Elevation (ft)
BM	5.21	7025.21		7020
0		7025.21	5.56	7019.65
4		7025.21	5.76	7019.45
6		7025.21	6.17	7019.04
8		7025.21	6.58	7018.63
9		7025.21	6.97	7018.24
10		7025.21	7.11	7018.1
12		7025.21	7.44	7017.77
14		7025.21	7.62	7017.59
16		7025.21	7.6	7017.61
18		7025.21	7.54	7017.67
19		7025.21	7.2	7018.01
20		7025.21	6.83	7018.38
21		7025.21	6.59	7018.62
22		7025.21	6.5	7018.71
24		7025.21	6.18	7019.03
26		7025.21	6.13	7019.08

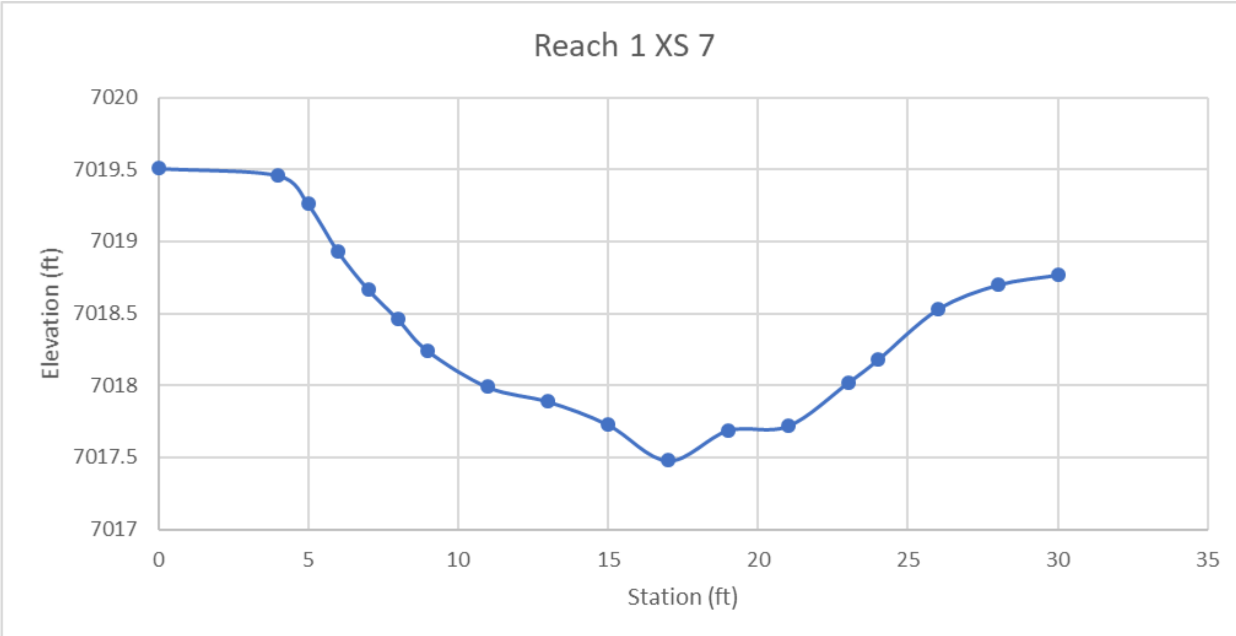
Appx B.12.14: Reach 1 Cross Section 6 Graph



Appx B.13.15: Reach 1 Cross Section 7 Surveying Data

Station (ft)	BS	HI	FS	Elevation (ft)
BM	5.21	7025.21		7020
0		7025.21	5.7	7019.51
4		7025.21	5.75	7019.46
5		7025.21	5.95	7019.26
6		7025.21	6.28	7018.93
7		7025.21	6.54	7018.67
8		7025.21	6.75	7018.46
9		7025.21	6.97	7018.24
11		7025.21	7.22	7017.99
13		7025.21	7.32	7017.89
15		7025.21	7.48	7017.73
17		7025.21	7.73	7017.48
19		7025.21	7.52	7017.69
21		7025.21	7.49	7017.72
23		7025.21	7.19	7018.02
24		7025.21	7.03	7018.18
26		7025.21	6.68	7018.53
28		7025.21	6.51	7018.7
30		7025.21	6.44	7018.77

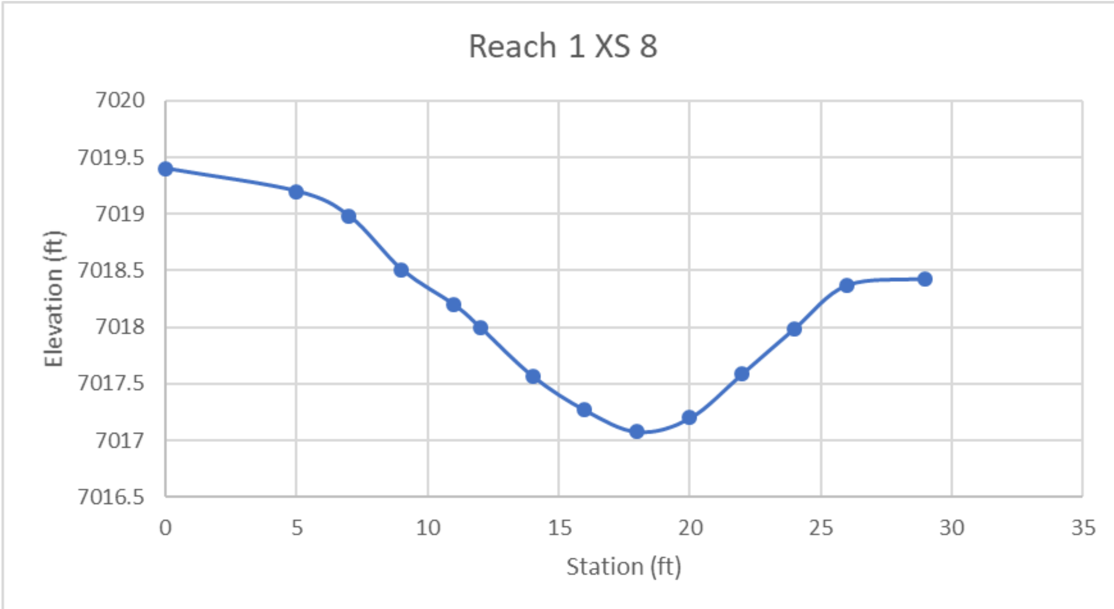
Appx B.14.16: Reach 1 Cross Section 7 Graph



Appx B.15.17: Reach 1 Cross Section 8 Surveying Data

Station (ft)	BS	HI	FS	Elevation (ft)
BM	5.21	7025.21		7020
0		7025.21	5.81	7019.4
5		7025.21	6.01	7019.2
7		7025.21	6.23	7018.98
9		7025.21	6.7	7018.51
11		7025.21	7.01	7018.2
12		7025.21	7.21	7018
14		7025.21	7.64	7017.57
16		7025.21	7.94	7017.27
18		7025.21	8.13	7017.08
20		7025.21	8.01	7017.2
22		7025.21	7.62	7017.59
24		7025.21	7.22	7017.99
26		7025.21	6.84	7018.37
29		7025.21	6.78	7018.43

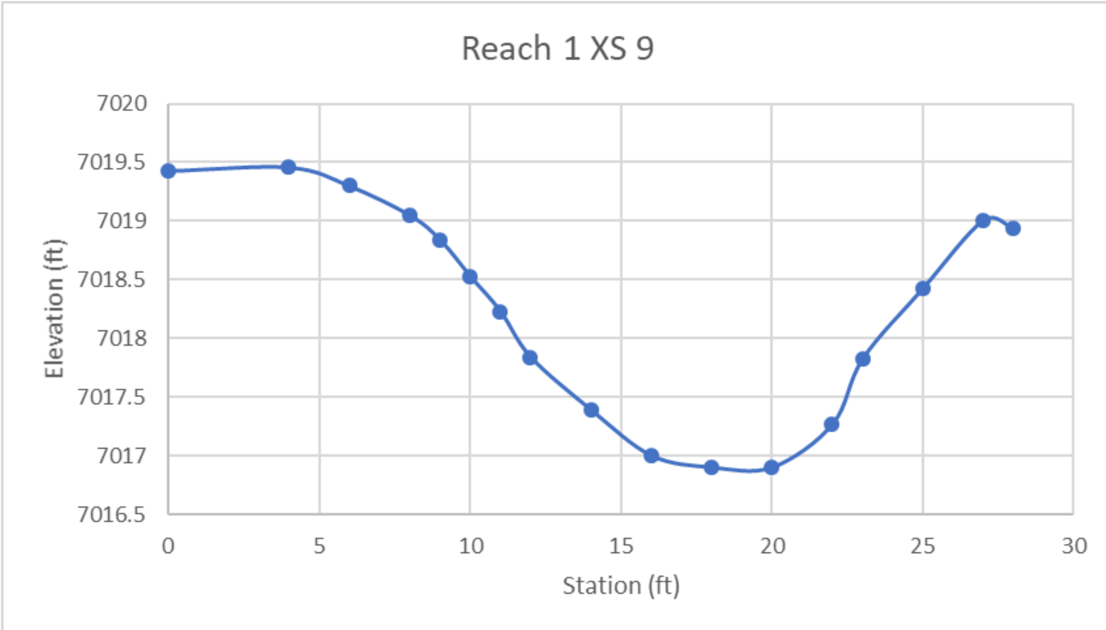
Appx B.16.18: Reach 1 Cross Section 8 Graph



Appx B.17.19: Reach 1 Cross Section 9 Surveying Data

Station (ft)	BS	HI	FS	Elevation (ft)
BM	5.21	7025.21		7020
0		7025.21	5.78	7019.43
4		7025.21	5.75	7019.46
6		7025.21	5.91	7019.3
8		7025.21	6.16	7019.05
9		7025.21	6.37	7018.84
10		7025.21	6.68	7018.53
11		7025.21	6.98	7018.23
12		7025.21	7.37	7017.84
14		7025.21	7.82	7017.39
16		7025.21	8.21	7017
18		7025.21	8.31	7016.9
20		7025.21	8.31	7016.9
22		7025.21	7.94	7017.27
23		7025.21	7.38	7017.83
25		7025.21	6.78	7018.43
27		7025.21	6.2	7019.01
28		7025.21	6.27	7018.94

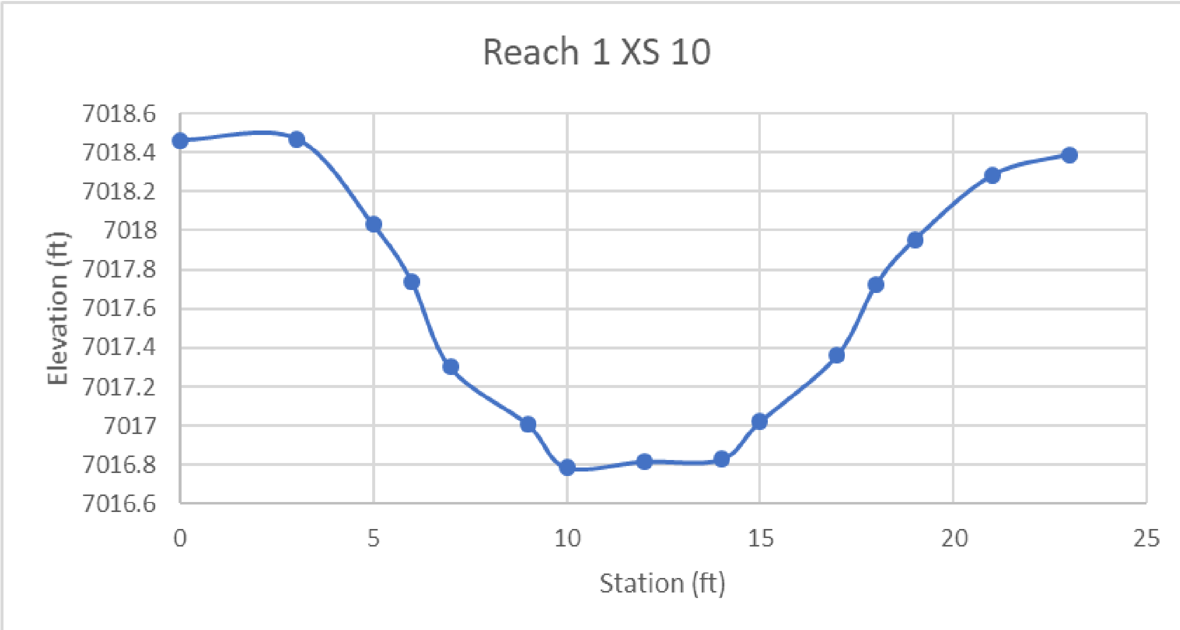
Appx B.18.20: Reach 1 Cross Section 9 Graph



Appx B.19.21: Reach 1 Cross Section 10 Surveying Data

Station (ft)	BS	HI	FS	Elevation (ft)
BM	5.21	7025.21		7020
0		7025.21	6.75	7018.46
3		7025.21	6.74	7018.47
5		7025.21	7.18	7018.03
6		7025.21	7.47	7017.74
7		7025.21	7.91	7017.3
9		7025.21	8.2	7017.01
10		7025.21	8.42	7016.79
12		7025.21	8.39	7016.82
14		7025.21	8.38	7016.83
15		7025.21	8.19	7017.02
17		7025.21	7.85	7017.36
18		7025.21	7.49	7017.72
19		7025.21	7.26	7017.95
21		7025.21	6.93	7018.28
23		7025.21	6.82	7018.39

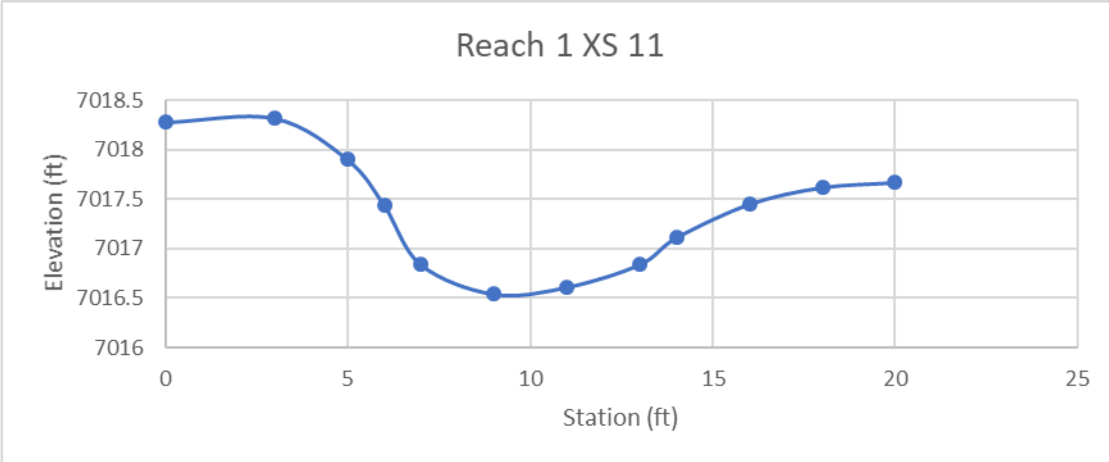
Appx B.20.22: Reach 1 Cross Section 10 Graph



Appx B.21.23: Reach 1 Cross Section 11 Surveying Data

Station (ft)	BS	HI	FS	Elevation (ft)
BM	5.21	7025.21		7020
0		7025.21	6.93	7018.28
3		7025.21	6.89	7018.32
5		7025.21	7.31	7017.9
6		7025.21	7.77	7017.44
7		7025.21	8.37	7016.84
9		7025.21	8.67	7016.54
11		7025.21	8.6	7016.61
13		7025.21	8.37	7016.84
14		7025.21	8.1	7017.11
16		7025.21	7.76	7017.45
18		7025.21	7.59	7017.62
20		7025.21	7.54	7017.67

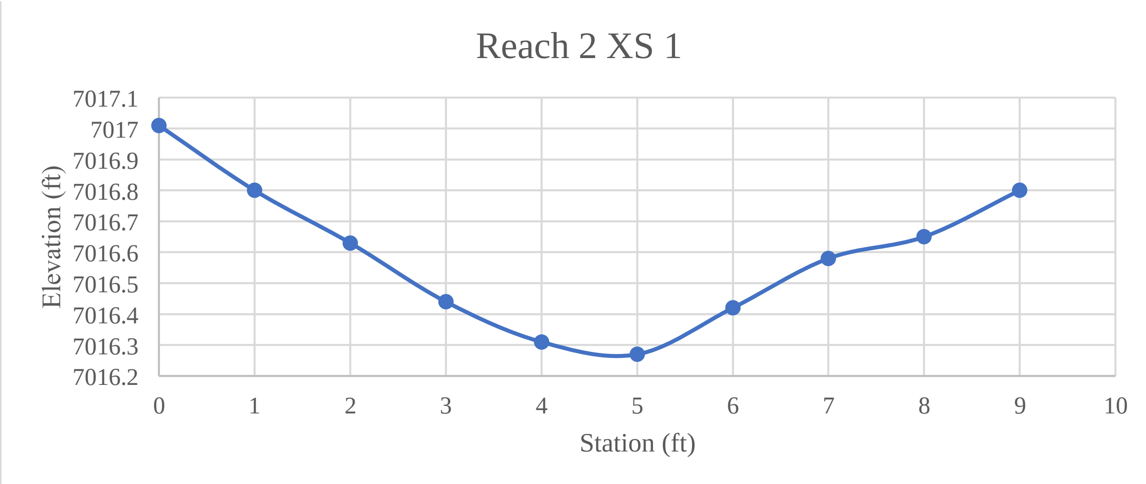
Appx B.22.24: Reach 1 Cross Section 11 Graph



Appx B.23.25: Reach 2 Cross Section 1 Surveying Data

Station (ft)	BS	HI	FS	Elevation (ft)
BM	9.3	7024.3		7015
0		7024.3	7.29	7017.01
1		7024.3	7.5	7016.8
2		7024.3	7.67	7016.63
3		7024.3	7.86	7016.44
4		7024.3	7.99	7016.31
5		7024.3	8.03	7016.27
6		7024.3	7.88	7016.42
7		7024.3	7.72	7016.58
8		7024.3	7.65	7016.65
9		7024.3	7.5	7016.8

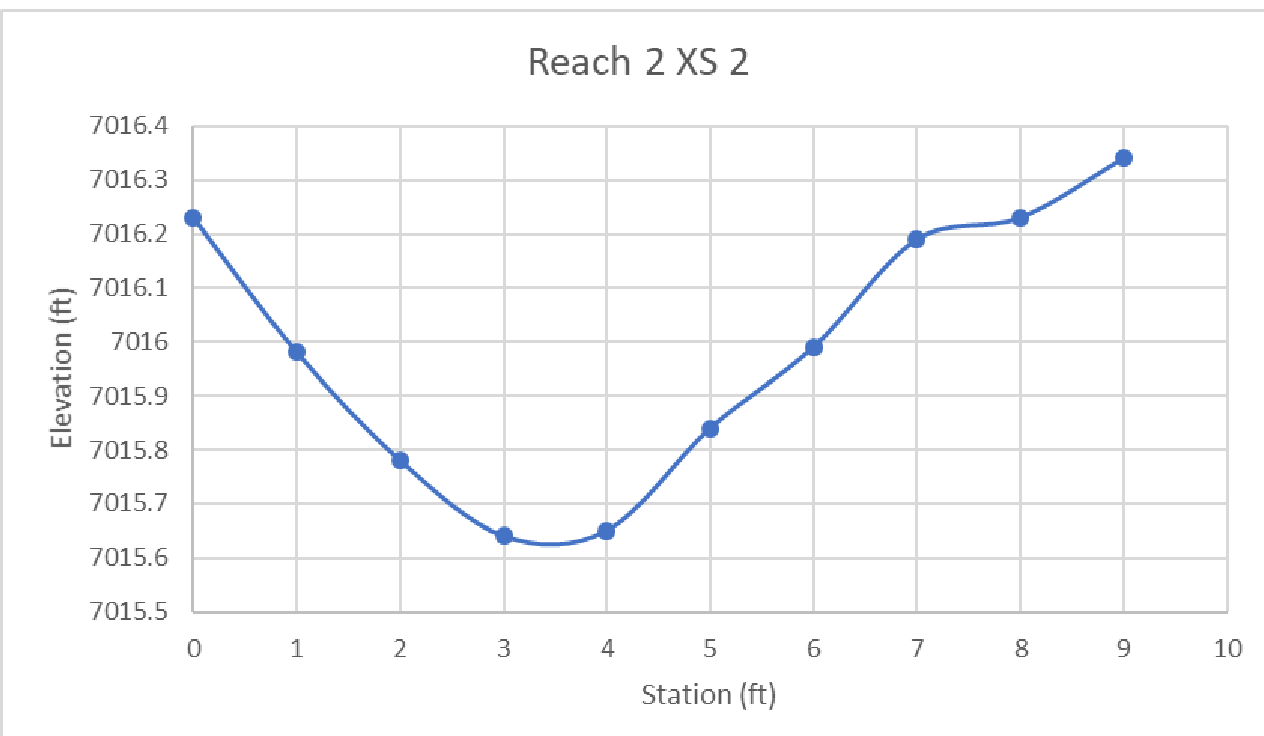
Appx B.24.26: Reach 2 Cross Section 1 Graph



Appx B.25.27: Reach 2 Cross Section 2 Surveying Data

Station (ft)	BS	HI	FS	Elevation (ft)
BM	9.3	7024.3		7015
0		7024.3	8.07	7016.23
1		7024.3	8.32	7015.98
2		7024.3	8.52	7015.78
3		7024.3	8.66	7015.64
4		7024.3	8.65	7015.65
5		7024.3	8.46	7015.84
6		7024.3	8.31	7015.99
7		7024.3	8.11	7016.19
8		7024.3	8.07	7016.23
9		7024.3	7.96	7016.34

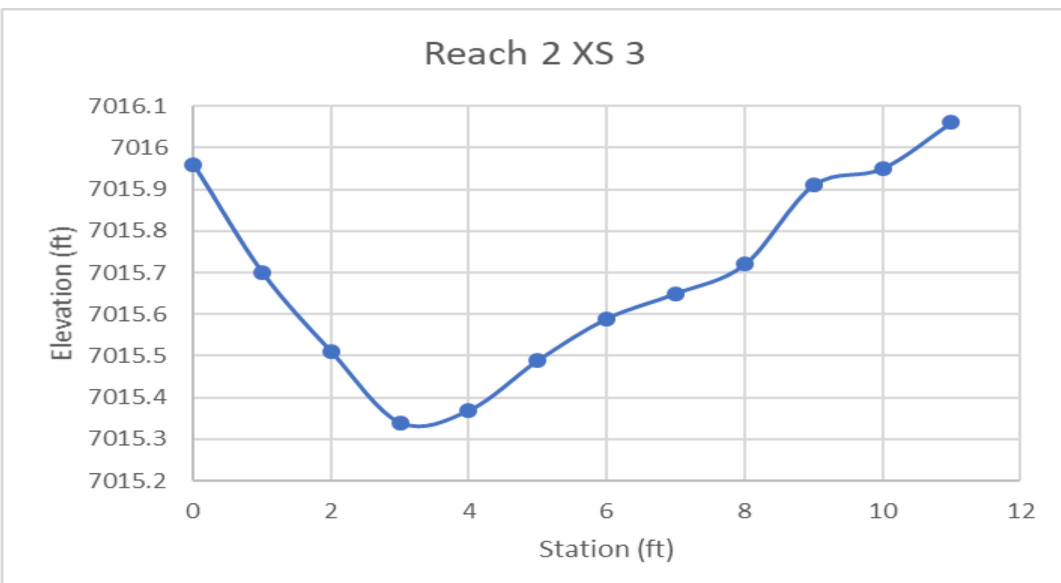
Appx B.26.28: Reach 2 Cross Section 2 Graph



Appx B.27.29: Reach 2 Cross Section 3 Surveying Data

Station (ft)	BS	HI	FS	Elevation (ft)
BM	9.3	7024.3		7015
0		7024.3	8.34	7015.96
1		7024.3	8.6	7015.7
2		7024.3	8.79	7015.51
3		7024.3	8.96	7015.34
4		7024.3	8.93	7015.37
5		7024.3	8.81	7015.49
6		7024.3	8.71	7015.59
7		7024.3	8.65	7015.65
8		7024.3	8.58	7015.72
9		7024.3	8.39	7015.91
10		7024.3	8.35	7015.95
11		7024.3	8.24	7016.06

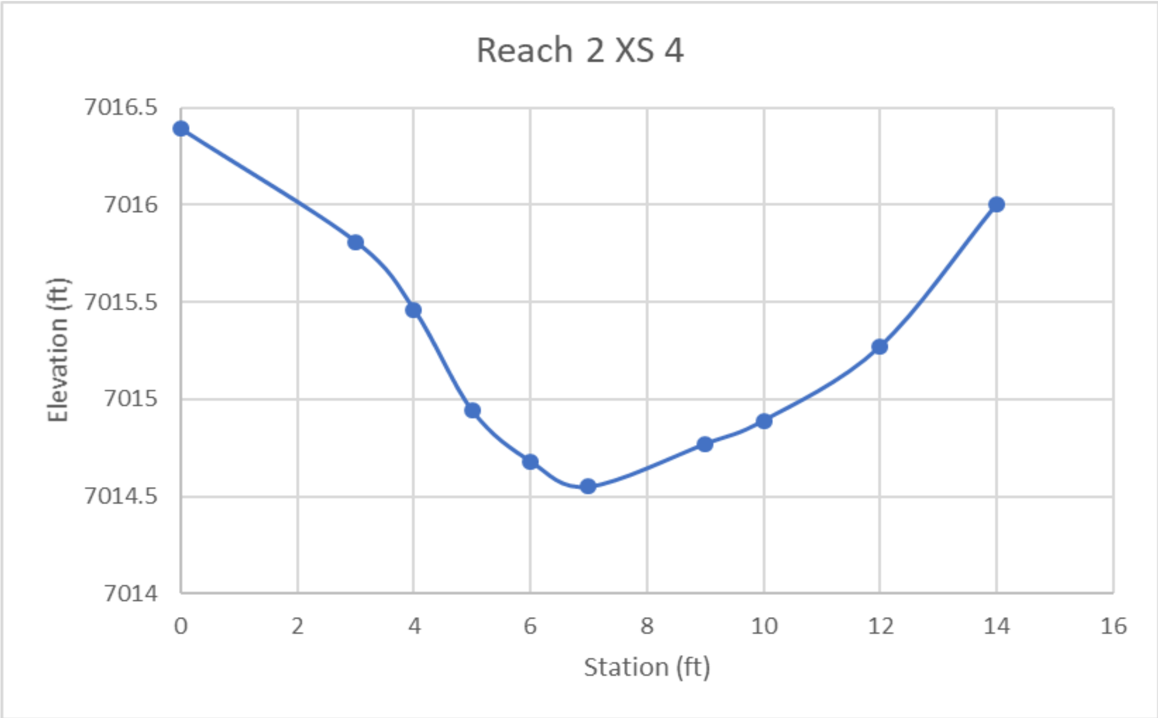
Appx B.28.30: Reach 2 Cross Section 3 Graph



Appx B.29.31: Reach 2 Cross Section 4 Surveying Data

Station (ft)	BS	HI	FS	Elevation (ft)
BM	9.3	7024.3		7015
0		7024.3	7.91	7016.39
3		7024.3	8.49	7015.81
4		7024.3	8.84	7015.46
5		7024.3	9.36	7014.94
6		7024.3	9.62	7014.68
7		7024.3	9.75	7014.55
9		7024.3	9.53	7014.77
10		7024.3	9.41	7014.89
12		7024.3	9.03	7015.27
14		7024.3	8.3	7016

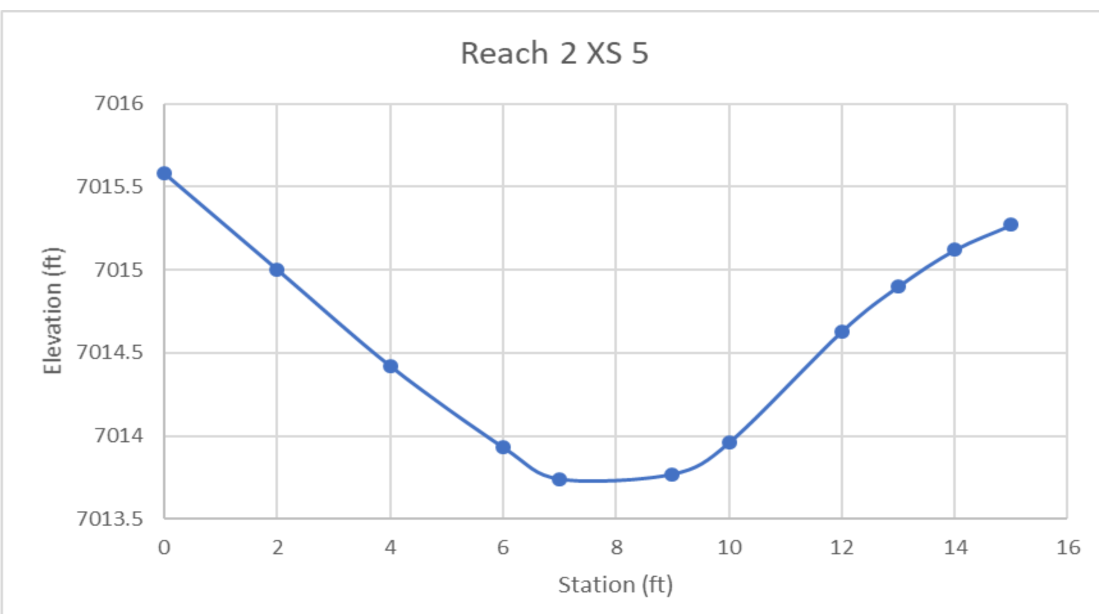
Appx B.30.32: Reach 2 Cross Section 4 Graph



Appx B.31.33: Reach 2 Cross Section 5 Surveying Data

Station (ft)	BS	HI	FS	Elevation (ft)
BM	9.3	7024.3		7015
0		7024.3	8.72	7015.58
2		7024.3	9.3	7015
4		7024.3	9.88	7014.42
6		7024.3	10.37	7013.93
7		7024.3	10.56	7013.74
9		7024.3	10.53	7013.77
10		7024.3	10.34	7013.96
12		7024.3	9.67	7014.63
13		7024.3	9.4	7014.9
14		7024.3	9.18	7015.12
15		7024.3	9.03	7015.27

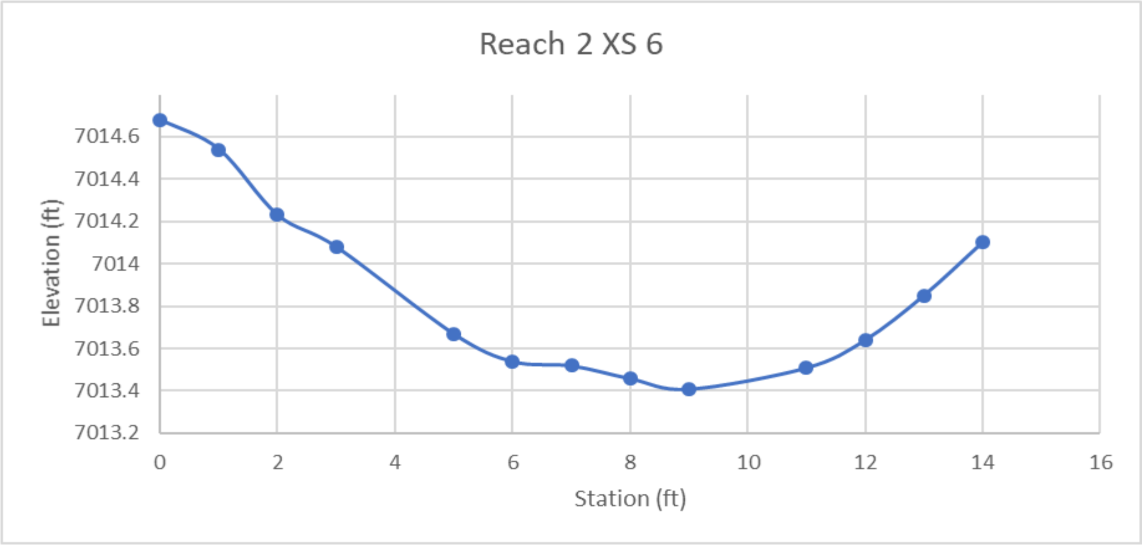
Appx B.32.34: Reach 1 Cross Section 5 Graph



Appx B.33.35: Reach 2 Cross Section6 Surveying Data

Station (ft)	BS	HI	FS	Elevation (ft)
BM	9.3	7024.3		7015
0		7024.3	9.62	7014.68
1		7024.3	9.76	7014.54
2		7024.3	10.07	7014.23
3		7024.3	10.22	7014.08
5		7024.3	10.63	7013.67
6		7024.3	10.76	7013.54
7		7024.3	10.78	7013.52
8		7024.3	10.84	7013.46
9		7024.3	10.89	7013.41
11		7024.3	10.79	7013.51
12		7024.3	10.66	7013.64
13		7024.3	10.45	7013.85
14		7024.3	10.2	7014.1

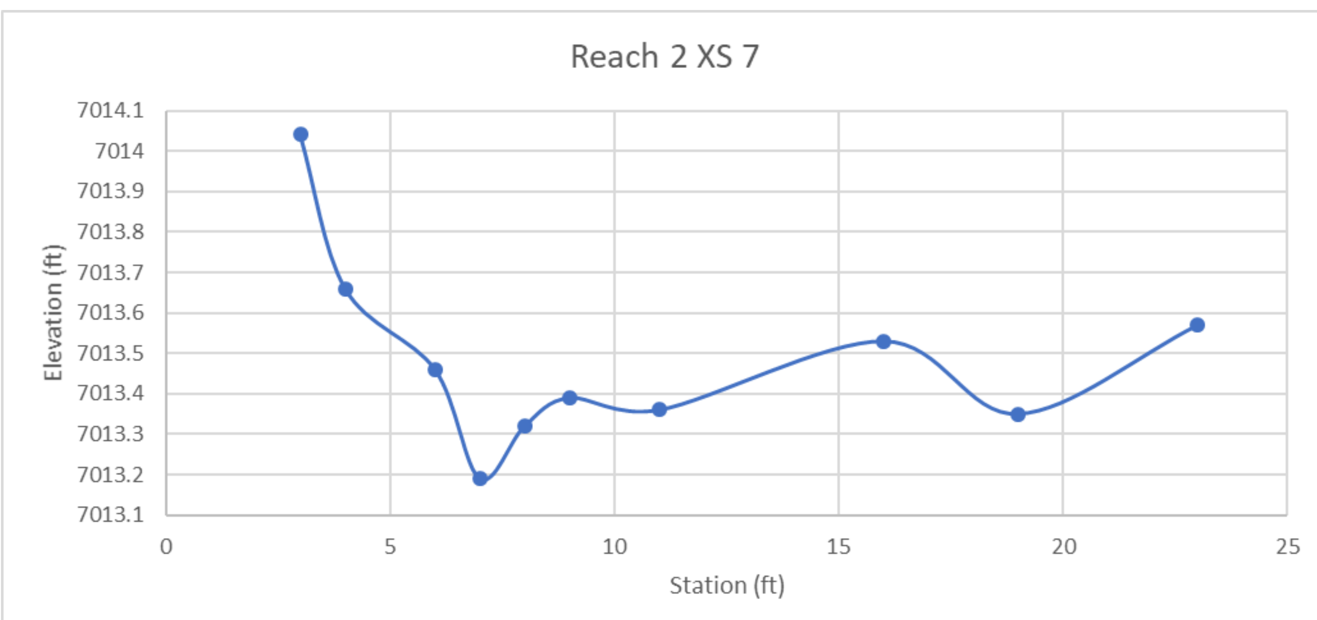
Appx B.34.36: Reach 2 Cross Section 6 Graph



Appx B.35.37: Reach 2 Cross Section 7 Surveying Data

Station (ft)	BS	HI	FS	Elevation (ft)
BM	4.68	7018.78		7014.1
3		7018.78	4.74	7014.04
4		7018.78	5.12	7013.66
6		7018.78	5.32	7013.46
7		7018.78	5.59	7013.19
8		7018.78	5.46	7013.32
9		7018.78	5.39	7013.39
11		7018.78	5.42	7013.36
16		7018.78	5.25	7013.53
19		7018.78	5.43	7013.35
23		7018.78	5.21	7013.57

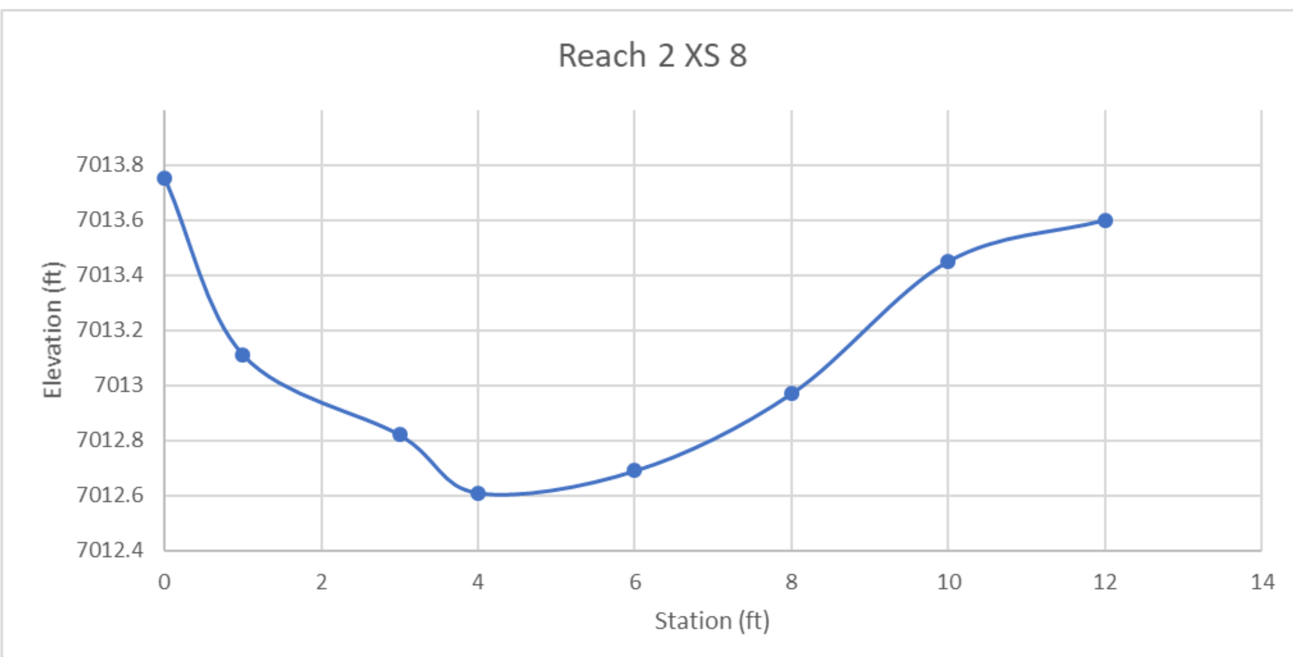
Appx B.36.38: Reach 2 Cross Section 7 Graph



Appx B.37.39: Reach 2 Cross Section 8 Surveying Data

Station (ft)	BS	HI	FS	Elevation (ft)
BM	4.68	7018.78		7014.1
0		7018.78	5.03	7013.75
1		7018.78	5.67	7013.11
3		7018.78	5.96	7012.82
4		7018.78	6.17	7012.61
6		7018.78	6.09	7012.69
8		7018.78	5.81	7012.97
10		7018.78	5.33	7013.45
12		7018.78	5.18	7013.6

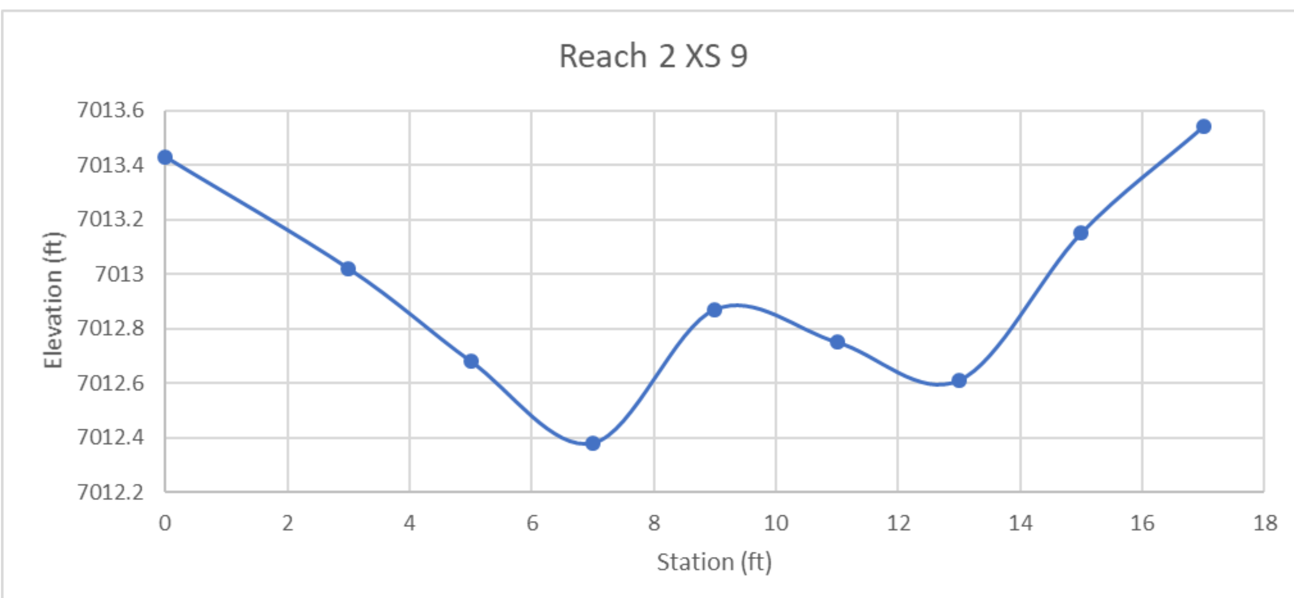
Appx B.38.40: Reach 2 Cross Section 8 Graph



Appx B.39.41: Reach 2 Cross Section 9 Surveying Data

Station (ft)	BS	HI	FS	Elevation (ft)
BM	4.68	7018.78		7014.1
0		7018.78	5.35	7013.43
3		7018.78	5.76	7013.02
5		7018.78	6.1	7012.68
7		7018.78	6.4	7012.38
9		7018.78	5.91	7012.87
11		7018.78	6.03	7012.75
13		7018.78	6.17	7012.61
15		7018.78	5.63	7013.15
17		7018.78	5.24	7013.54

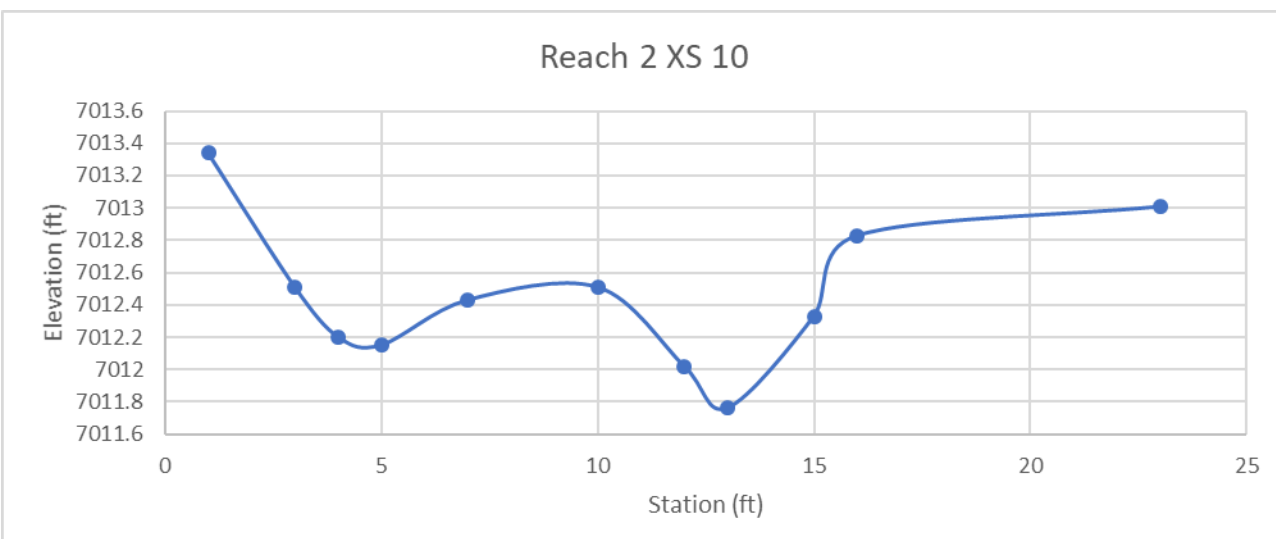
Appx B.40.42: Reach 2 Cross Section 9 Graph



Appx B.41.43: Reach 2 Cross Section 10 Surveying Data

Station (ft)	BS	HI	FS	Elevation (ft)
BM	4.68	7018.78		7014.1
1		7018.78	5.44	7013.34
3		7018.78	6.27	7012.51
4		7018.78	6.58	7012.2
5		7018.78	6.63	7012.15
7		7018.78	6.35	7012.43
10		7018.78	6.27	7012.51
12		7018.78	6.76	7012.02
13		7018.78	7.02	7011.76
15		7018.78	6.45	7012.33
16		7018.78	5.95	7012.83
23		7018.78	5.77	7013.01

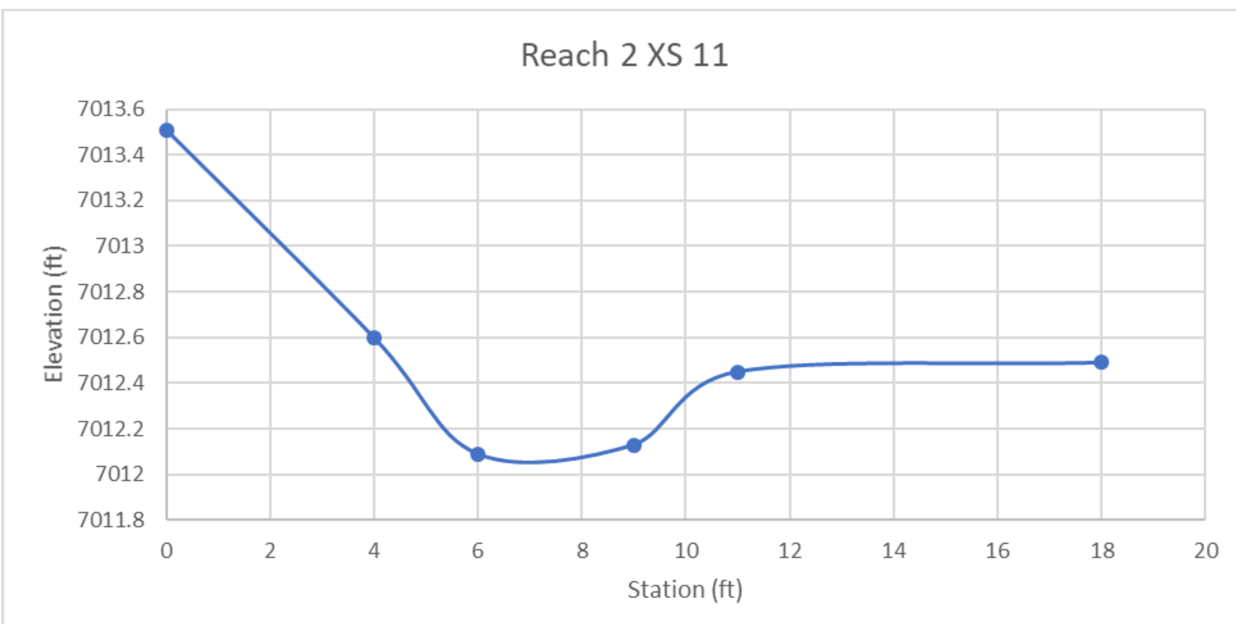
Appx B.42.44: Reach 2 Cross Section 10 Graph



Appx B.43.45: Reach 2 Cross Section 11 Surveying Data

Station (ft)	BS	HI	FS	Elevation (ft)
BM	4.68	7018.78		7014.1
0		7018.78	5.27	7013.51
4		7018.78	6.18	7012.6
6		7018.78	6.69	7012.09
9		7018.78	6.65	7012.13
11		7018.78	6.33	7012.45
18		7018.78	6.29	7012.49

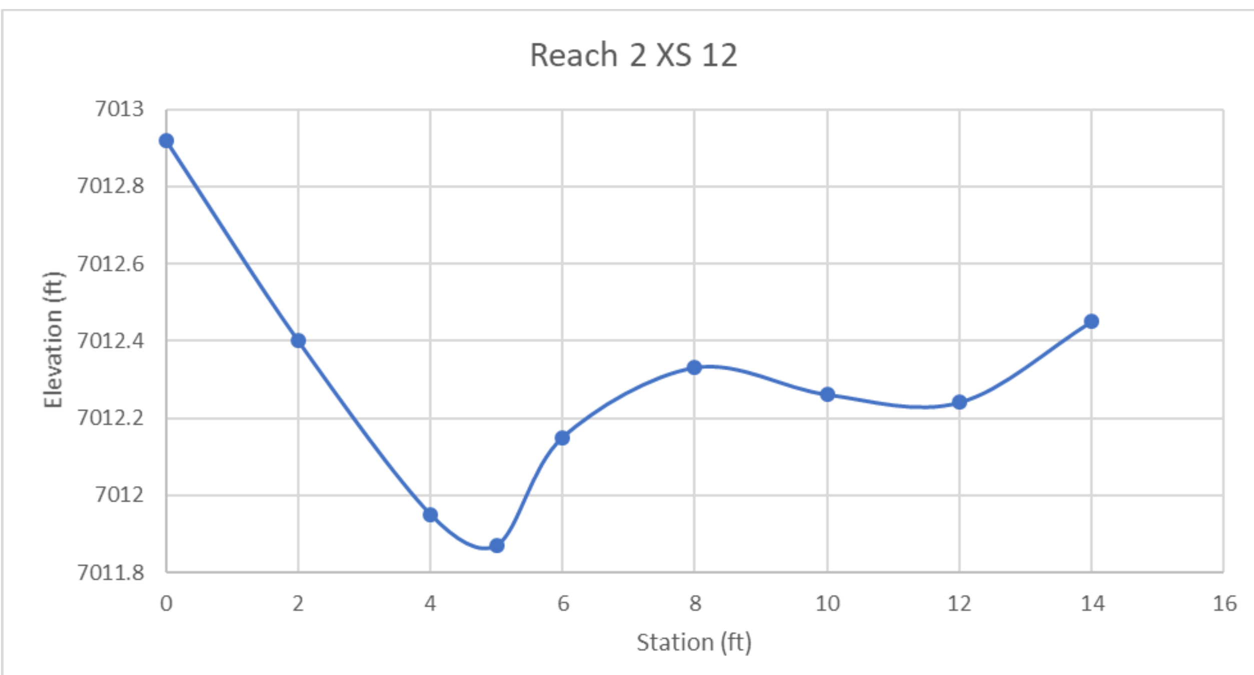
Appx B.44.46: Reach 2 Cross Section 11 Graph



Appx B.45.47: Reach 2 Cross Section 12 Surveying Data

Station (ft)	BS	HI	FS	Elevation (ft)
BM	4.68	7018.78		7014.1
0		7018.78	5.86	7012.92
2		7018.78	6.38	7012.4
4		7018.78	6.83	7011.95
5		7018.78	6.91	7011.87
6		7018.78	6.63	7012.15
8		7018.78	6.45	7012.33
10		7018.78	6.52	7012.26
12		7018.78	6.54	7012.24
14		7018.78	6.33	7012.45

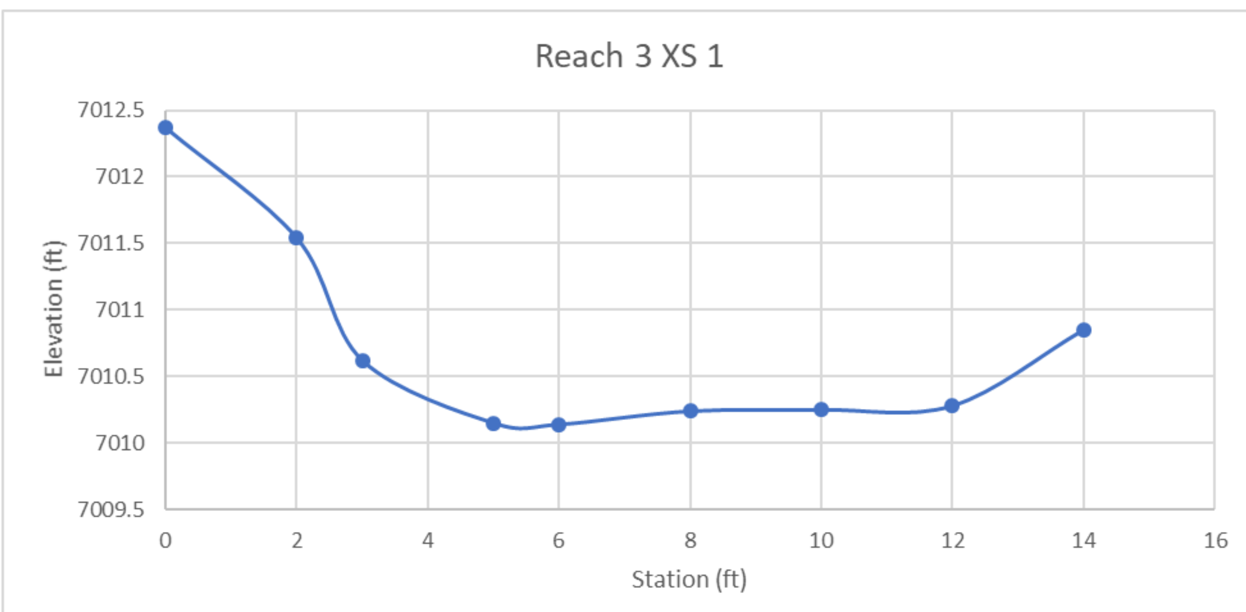
Appx B.46.48: Reach 2 Cross Section 12 Graph



Appx B.47.49: Reach 3 Cross Section1 Surveying Data

Station (ft)	BS	HI	FS	Elevation (ft)
BM	0.69	7016.69		7016
0		7016.69	4.32	7012.37
2		7016.69	5.15	7011.54
3		7016.69	6.07	7010.62
5		7016.69	6.54	7010.15
6		7016.69	6.55	7010.14
8		7016.69	6.45	7010.24
10		7016.69	6.44	7010.25
12		7016.69	6.41	7010.28
14		7016.69	5.84	7010.85

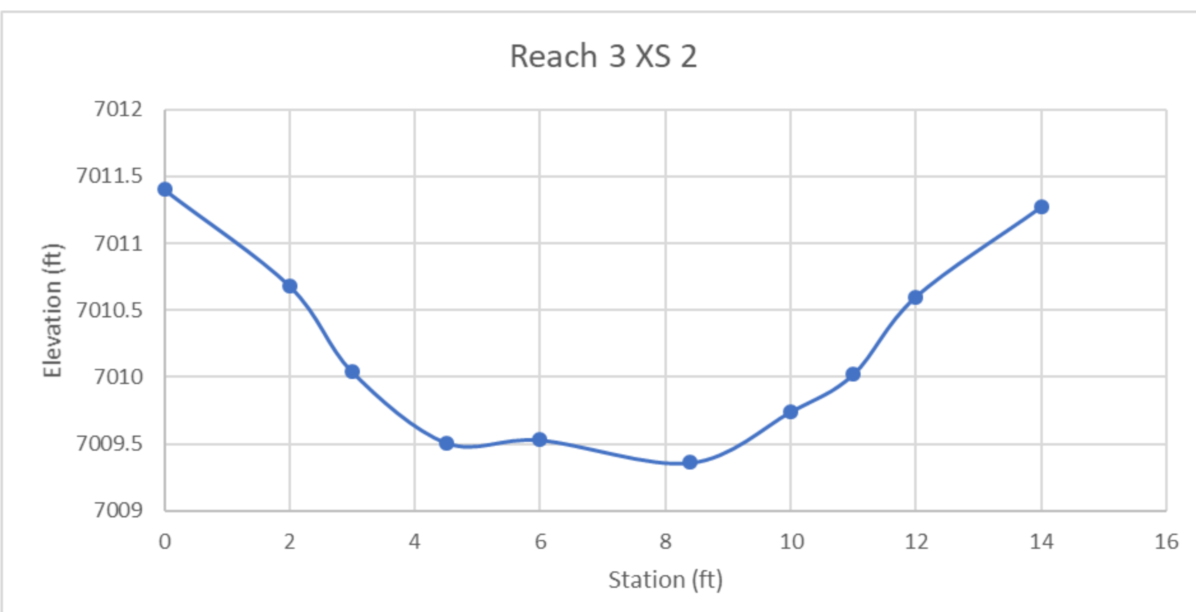
Appx B.48.50: Reach 3 Cross Section 1 Graph



Appx B.49.51: Reach 3 Cross Section 2 Surveying Data

Station (ft)	BS	HI	FS	Elevation (ft)
BM	0.69	7016.69		7016
0		7016.69	5.29	7011.4
2		7016.69	6.01	7010.68
3		7016.69	6.65	7010.04
4.5		7016.69	7.18	7009.51
6		7016.69	7.16	7009.53
8.4		7016.69	7.33	7009.36
10		7016.69	6.95	7009.74
11		7016.69	6.67	7010.02
12		7016.69	6.09	7010.6
14		7016.69	5.42	7011.27

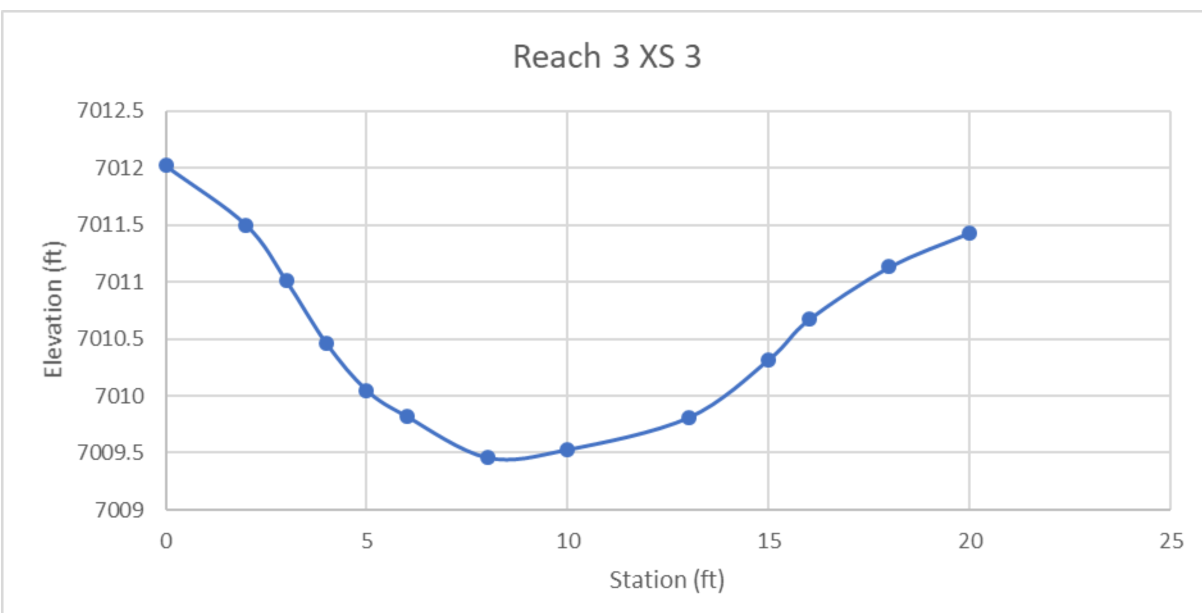
Appx B.50.52: Reach 3 Cross Section 2 Graph



Appx B.51.53: Reach 3 Cross Section3 Surveying Data

Station (ft)	BS	HI	FS	Elevation (ft)
BM	0.69	7016.69		7016
0		7016.69	4.67	7012.02
2		7016.69	5.19	7011.5
3		7016.69	5.68	7011.01
4		7016.69	6.23	7010.46
5		7016.69	6.64	7010.05
6		7016.69	6.87	7009.82
8		7016.69	7.23	7009.46
10		7016.69	7.16	7009.53
13		7016.69	6.88	7009.81
15		7016.69	6.37	7010.32
16		7016.69	6.02	7010.67
18		7016.69	5.56	7011.13
20		7016.69	5.26	7011.43

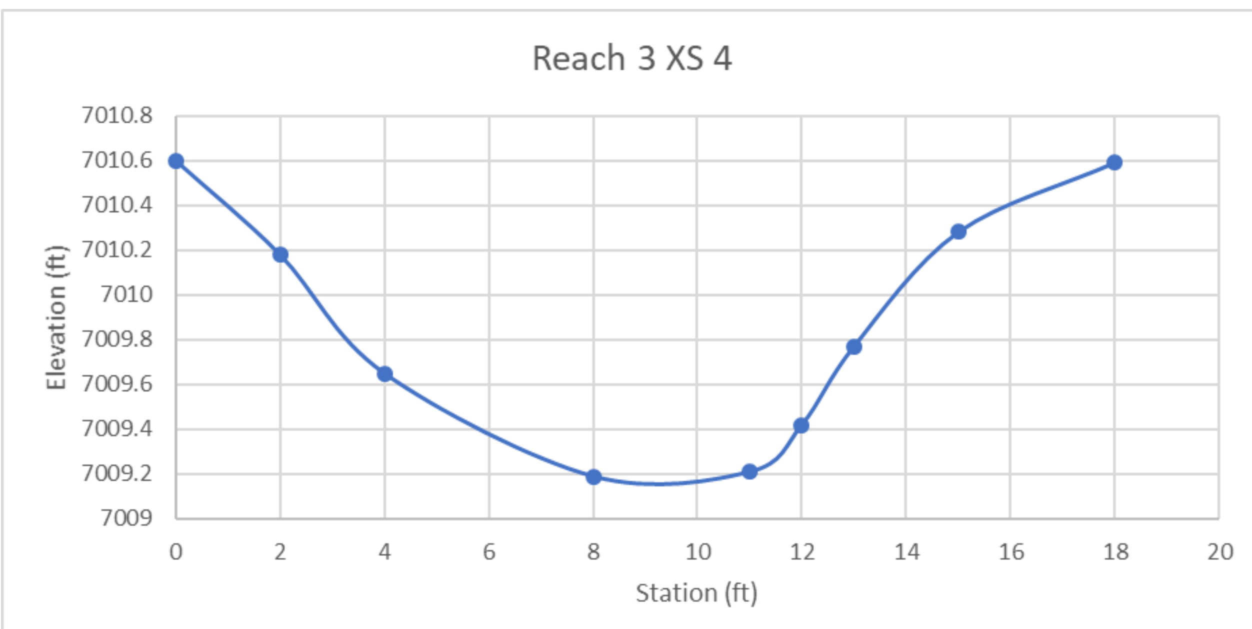
Appx B.52.54: Reach31 Cross Section 3 Graph



Appx B.53.55: Reach 3 Cross Section4 Surveying Data

Station (ft)	BS	HI	FS	Elevation (ft)
BM	0.69	7016.69		7016
0		7016.69	6.09	7010.6
2		7016.69	6.51	7010.18
4		7016.69	7.04	7009.65
8		7016.69	7.5	7009.19
11		7016.69	7.48	7009.21
12		7016.69	7.27	7009.42
13		7016.69	6.92	7009.77
15		7016.69	6.41	7010.28
18		7016.69	6.1	7010.59

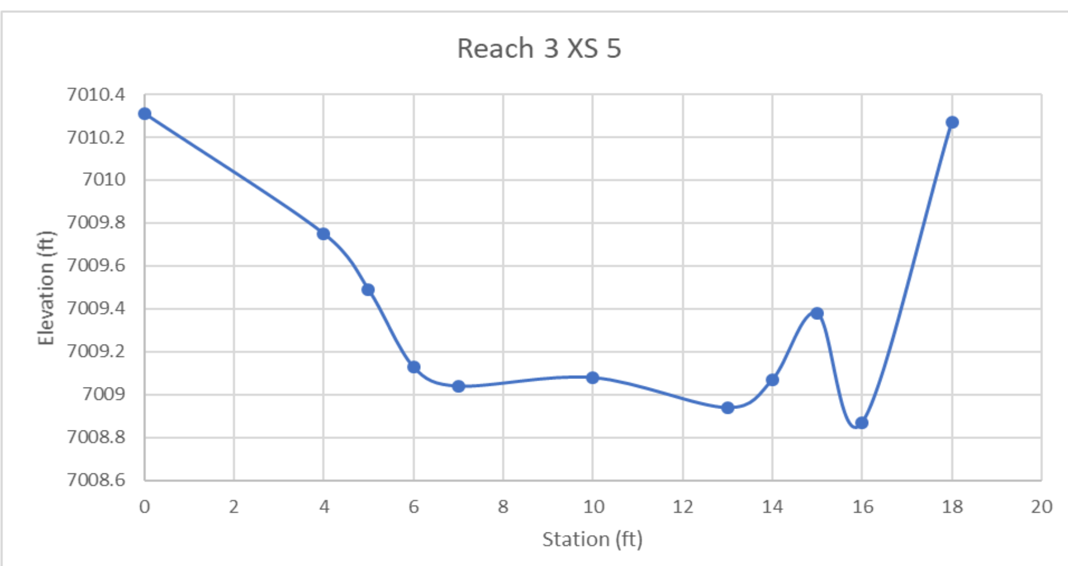
Appx B.54.56: Reach 3 Cross Section 4 Graph



Appx B.55.57: Reach 3 Cross Section5 Surveying Data

Station (ft)	BS	HI	FS	Elevation (ft)
BM	0.69	7016.69		7016
0		7016.69	6.38	7010.31
4		7016.69	6.94	7009.75
5		7016.69	7.2	7009.49
6		7016.69	7.56	7009.13
7		7016.69	7.65	7009.04
10		7016.69	7.61	7009.08
13		7016.69	7.75	7008.94
14		7016.69	7.62	7009.07
15		7016.69	7.31	7009.38
16		7016.69	7.82	7008.87
18		7016.69	6.42	7010.27

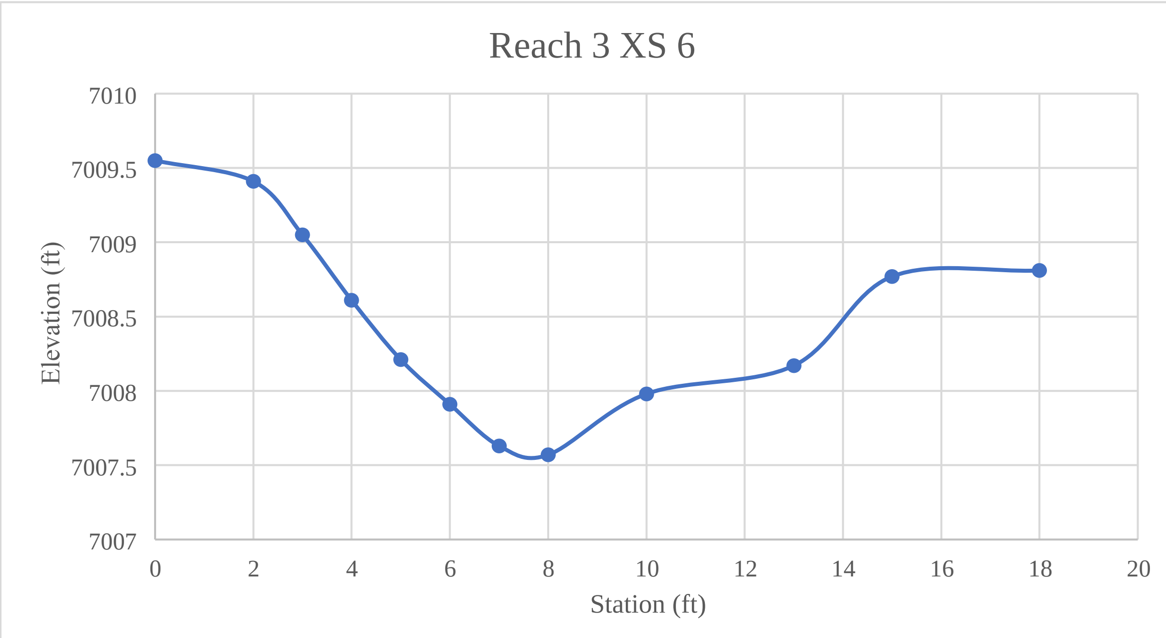
Appx B.56.58: Reach 3 Cross Section 5 Graph



Appx B.57.59: Reach 3 Cross Section 6 Surveying Data

Station (ft)	BS	HI	FS	Elevation (ft)
BM	0.16	7016.16		7016
0		7016.16	6.61	7009.55
2		7016.16	6.75	7009.41
3		7016.16	7.11	7009.05
4		7016.16	7.55	7008.61
5		7016.16	7.95	7008.21
6		7016.16	8.25	7007.91
7		7016.16	8.53	7007.63
8		7016.16	8.59	7007.57
10		7016.16	8.18	7007.98
13		7016.16	7.99	7008.17
15		7016.16	7.39	7008.77
18		7016.16	7.35	7008.81

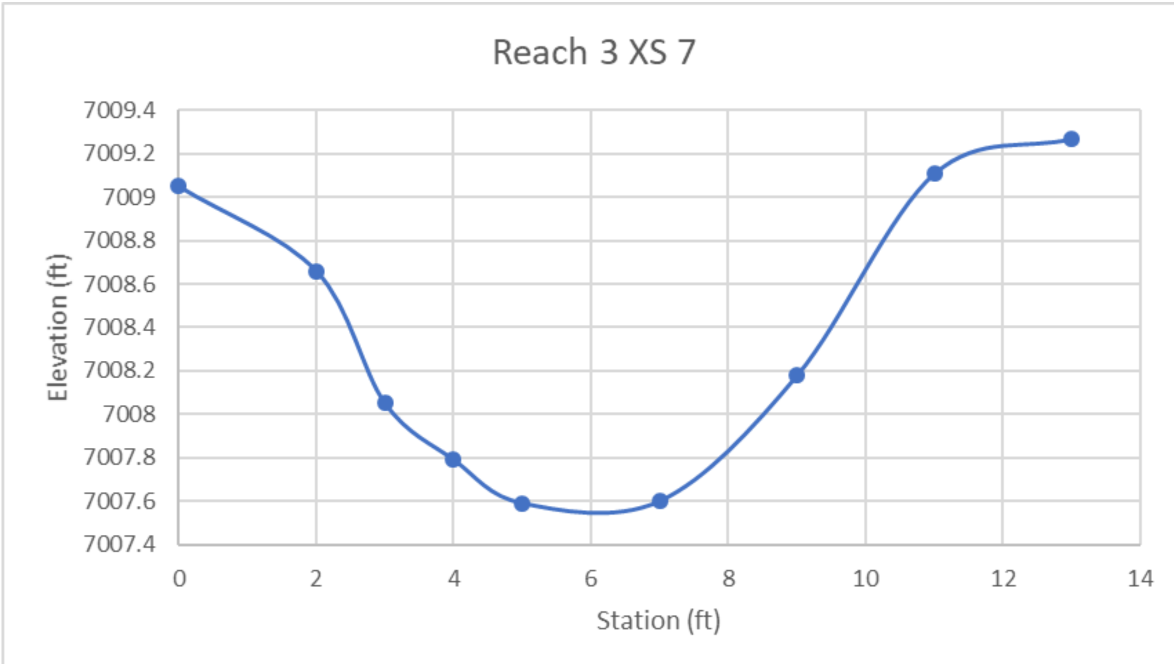
Appx B.58.60: Reach 3 Cross Section 6 Graph



Appx B.59.61: Reach 3 Cross Section7 Surveying Data

Station (ft)	BS	HI	FS	Elevation (ft)
BM	0.69	7016.69		7016
0		7016.69	7.64	7009.05
2		7016.69	8.03	7008.66
3		7016.69	8.64	7008.05
4		7016.69	8.9	7007.79
5		7016.69	9.1	7007.59
7		7016.69	9.09	7007.6
9		7016.69	8.51	7008.18
11		7016.69	7.58	7009.11
13		7016.69	7.42	7009.27

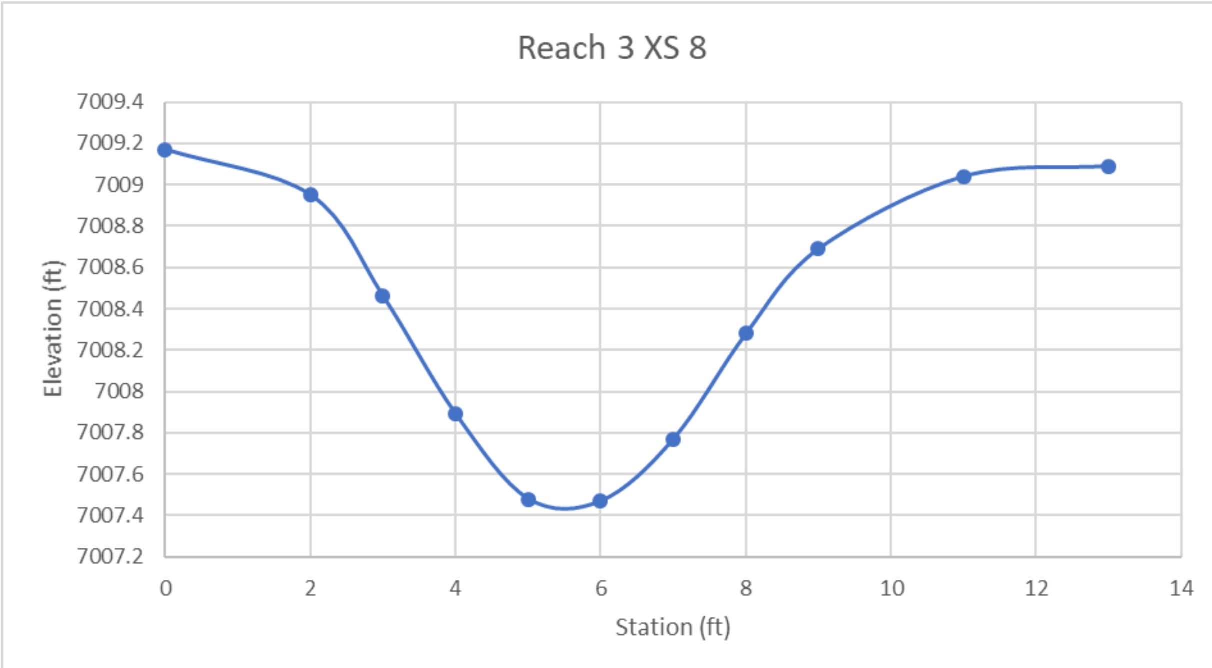
Appx B.60.62: Reach 3 Cross Section 7 Graph



Appx B.61.63: Reach 3 Cross Section 8 Surveying Data

Station (ft)	BS	HI	FS	Elevation (ft)
BM	0.69	7016.69		7016
0		7016.69	7.52	7009.17
2		7016.69	7.74	7008.95
3		7016.69	8.23	7008.46
4		7016.69	8.8	7007.89
5		7016.69	9.21	7007.48
6		7016.69	9.22	7007.47
7		7016.69	8.92	7007.77
8		7016.69	8.41	7008.28
9		7016.69	8	7008.69
11		7016.69	7.65	7009.04
13		7016.69	7.6	7009.09

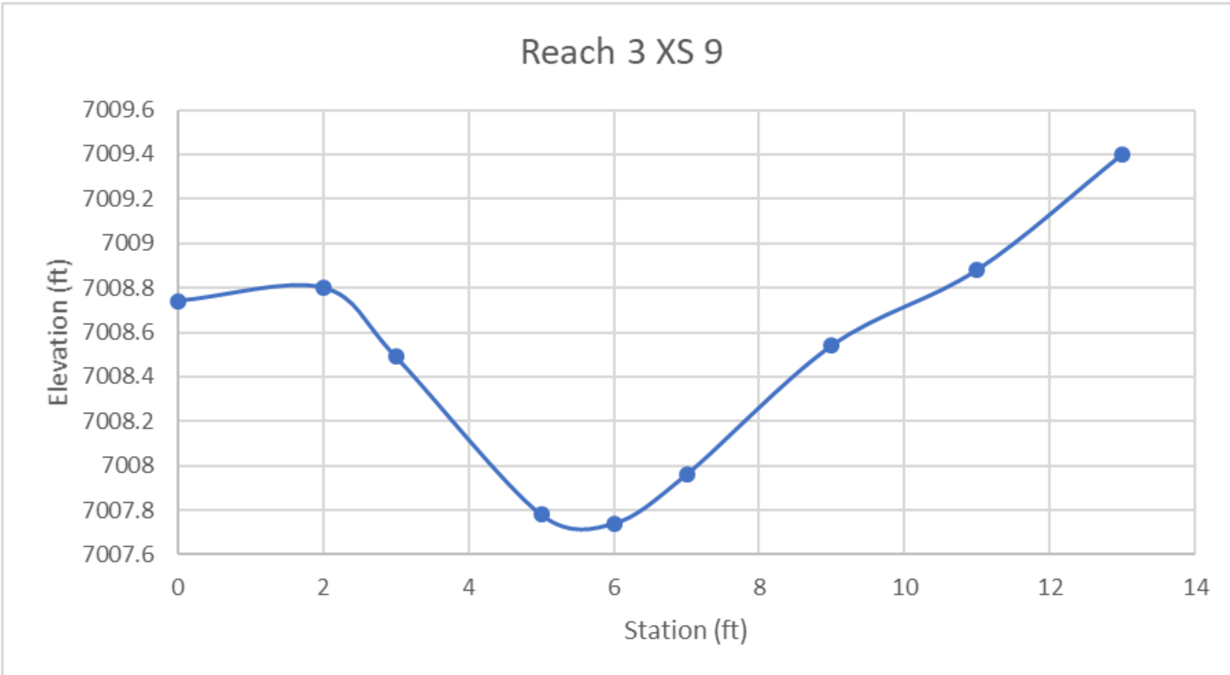
Appx B.62.64: Reach 3 Cross Section 8 Graph



Appx B.63.65: Reach 3 Cross Section 9 Surveying Data

Station (ft)	BS	HI	FS	Elevation (ft)
BM	0.69	7016.69		7016
0		7016.69	7.95	7008.74
2		7016.69	7.89	7008.8
3		7016.69	8.2	7008.49
5		7016.69	8.91	7007.78
6		7016.69	8.95	7007.74
7		7016.69	8.73	7007.96
9		7016.69	8.15	7008.54
11		7016.69	7.81	7008.88
13		7016.69	7.29	7009.4

Appx B.64.66: Reach 3 Cross Section 9 Graph

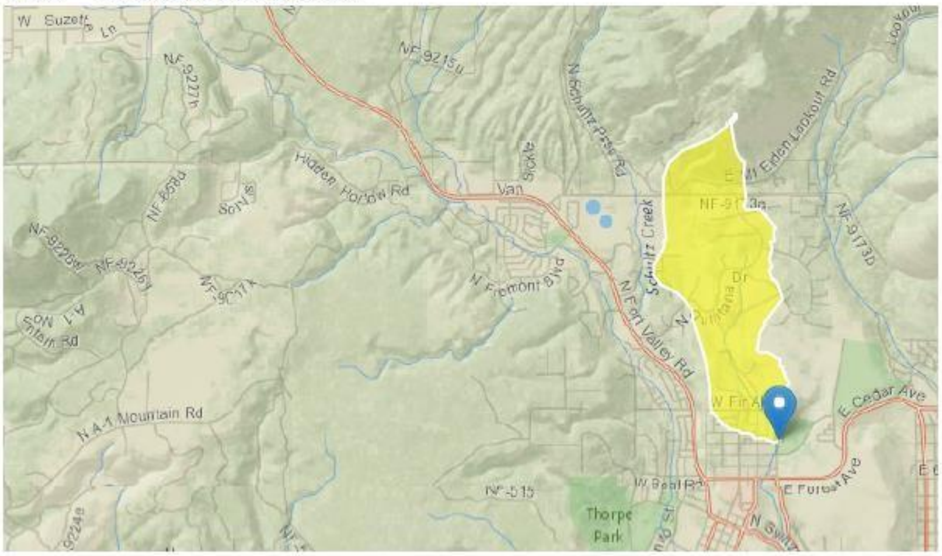


APPX C: Software Results

Appx C.1.67: Stream Stats Report Partial [5]

StreamStats Report

Region ID: AZ
Workspace ID: AZ20200123234824070000
Clicked Point (Latitude, Longitude): 35.21446, -111.63983
Time: 2020-01-23 16:48:41 -0700



Basin Characteristics

Parameter Code	Parameter Description	Value	Unit
APRAVTMP	Mean AprilTemperature	42.7	degrees F
AUGAVPRE	Mean August Precipitation	2.3	inches
AUGAVTMP	Mean August Temperature	64.2	degrees F
AZ_HIPERMA	Percent basin surface area containing high permeability aquifer units as defined for Arizona in SIR 2014-5211	100	percent
AZ_HIPERMG	Percent basin surface area containing high permeability geologic units as defined for Arizona in SIR 2014-5211	100	percent

Appx C.2.68: NOAA Rainfall Intensity [18]

PF tabular

PDS-based point precipitation frequency estimates with 90% confidence intervals (in inches)[1]										
Duration	Average recurrence interval (years)									
	1	2	5	10	25	50	100	200	500	1000
5-min	0.213 (0.186-0.247)	0.277 (0.241-0.320)	0.374 (0.325-0.431)	0.454 (0.391-0.523)	0.569 (0.488-0.652)	0.665 (0.564-0.761)	0.769 (0.644-0.883)	0.882 (0.726-1.01)	1.05 (0.844-1.21)	1.19 (0.938-1.39)
10-min	0.325 (0.284-0.377)	0.422 (0.367-0.487)	0.569 (0.495-0.656)	0.691 (0.596-0.795)	0.866 (0.743-0.993)	1.01 (0.858-1.16)	1.17 (0.979-1.34)	1.34 (1.11-1.54)	1.59 (1.28-1.85)	1.81 (1.43-2.12)
15-min	0.403 (0.352-0.467)	0.523 (0.456-0.603)	0.705 (0.614-0.813)	0.857 (0.738-0.985)	1.07 (0.920-1.23)	1.25 (1.06-1.44)	1.45 (1.21-1.67)	1.66 (1.37-1.91)	1.98 (1.59-2.29)	2.24 (1.77-2.63)
30-min	0.543 (0.474-0.628)	0.704 (0.613-0.813)	0.949 (0.826-1.10)	1.15 (0.994-1.33)	1.45 (1.24-1.66)	1.69 (1.43-1.93)	1.95 (1.64-2.24)	2.24 (1.84-2.58)	2.66 (2.14-3.09)	3.02 (2.38-3.54)
60-min	0.671 (0.586-0.778)	0.871 (0.759-1.01)	1.18 (1.02-1.36)	1.43 (1.23-1.64)	1.79 (1.53-2.05)	2.09 (1.77-2.39)	2.42 (2.02-2.78)	2.77 (2.28-3.19)	3.29 (2.65-3.82)	3.74 (2.95-4.38)
2-hr	0.790 (0.701-0.901)	1.00 (0.886-1.14)	1.32 (1.17-1.50)	1.59 (1.39-1.80)	1.98 (1.72-2.24)	2.31 (1.98-2.61)	2.66 (2.26-3.02)	3.06 (2.55-3.47)	3.63 (2.96-4.15)	4.11 (3.28-4.73)
3-hr	0.889 (0.795-1.01)	1.12 (1.00-1.27)	1.44 (1.28-1.62)	1.71 (1.52-1.93)	2.11 (1.86-2.38)	2.43 (2.12-2.74)	2.79 (2.40-3.16)	3.18 (2.70-3.61)	3.77 (3.13-4.31)	4.26 (3.47-4.91)
6-hr	1.07 (0.970-1.19)	1.33 (1.21-1.48)	1.65 (1.49-1.83)	1.92 (1.74-2.13)	2.33 (2.08-2.58)	2.66 (2.35-2.95)	3.02 (2.64-3.34)	3.40 (2.94-3.79)	3.97 (3.35-4.46)	4.44 (3.68-5.01)
12-hr	1.38 (1.26-1.52)	1.71 (1.56-1.89)	2.09 (1.90-2.30)	2.40 (2.18-2.65)	2.83 (2.55-3.12)	3.16 (2.84-3.49)	3.51 (3.12-3.88)	3.88 (3.41-4.30)	4.41 (3.82-4.92)	4.84 (4.14-5.44)
24-hr	1.71 (1.56-1.88)	2.13 (1.94-2.35)	2.66 (2.41-2.93)	3.08 (2.79-3.40)	3.67 (3.31-4.04)	4.13 (3.71-4.54)	4.62 (4.12-5.07)	5.11 (4.54-5.63)	5.79 (5.09-6.39)	6.32 (5.51-7.01)
2-day	2.04 (1.86-2.25)	2.54 (2.32-2.81)	3.17 (2.89-3.50)	3.68 (3.35-4.05)	4.39 (3.97-4.83)	4.95 (4.46-5.45)	5.54 (4.96-6.09)	6.14 (5.47-6.77)	6.97 (6.14-7.71)	7.63 (6.66-8.47)
3-day	2.21 (2.02-2.43)	2.76 (2.52-3.04)	3.46 (3.15-3.81)	4.03 (3.66-4.43)	4.82 (4.37-5.30)	5.46 (4.92-6.00)	6.13 (5.49-6.75)	6.83 (6.07-7.53)	7.80 (6.86-8.62)	8.57 (7.46-9.51)
4-day	2.38 (2.18-2.62)	2.98 (2.72-3.28)	3.74 (3.41-4.12)	4.37 (3.98-4.80)	5.26 (4.76-5.78)	5.97 (5.38-6.56)	6.73 (6.02-7.40)	7.52 (6.68-8.28)	8.62 (7.58-9.53)	9.51 (8.27-10.6)
7-day	2.88 (2.64-3.14)	3.59 (3.29-3.92)	4.47 (4.10-4.87)	5.20 (4.76-5.66)	6.23 (5.67-6.79)	7.05 (6.38-7.69)	7.92 (7.13-8.64)	8.82 (7.89-9.65)	10.1 (8.92-11.1)	11.1 (9.72-12.2)
10-day	3.28 (3.01-3.58)	4.09 (3.74-4.47)	5.05 (4.63-5.52)	5.82 (5.32-6.35)	6.87 (6.25-7.50)	7.68 (6.96-8.39)	8.51 (7.68-9.31)	9.35 (8.39-10.2)	10.5 (9.33-11.5)	11.4 (10.0-12.5)
20-day	4.40 (4.05-4.80)	5.47 (5.03-5.96)	6.64 (6.10-7.23)	7.53 (6.90-8.19)	8.69 (7.95-9.46)	9.55 (8.71-10.4)	10.4 (9.45-11.3)	11.2 (10.2-12.2)	12.3 (11.1-13.4)	13.1 (11.7-14.3)
30-day	5.38 (4.93-5.88)	6.66 (6.11-7.28)	8.05 (7.38-8.79)	9.11 (8.32-9.94)	10.5 (9.54-11.4)	11.4 (10.4-12.5)	12.4 (11.2-13.6)	13.3 (12.0-14.6)	14.5 (13.0-15.9)	15.4 (13.8-16.9)
45-day	6.45 (5.91-7.10)	8.00 (7.33-8.80)	9.68 (8.87-10.6)	11.0 (10.0-12.1)	12.7 (11.5-13.9)	13.9 (12.6-15.3)	15.2 (13.7-16.7)	16.4 (14.7-18.0)	17.9 (16.0-19.8)	19.1 (17.0-21.1)
60-day	7.58 (6.93-8.31)	9.39 (8.59-10.3)	11.3 (10.3-12.4)	12.7 (11.6-13.9)	14.5 (13.2-15.9)	15.8 (14.3-17.3)	17.0 (15.4-18.7)	18.2 (16.4-20.0)	19.7 (17.7-21.7)	20.7 (18.6-22.9)

[1] Precipitation frequency (PF) estimates in this table are based on frequency analysis of partial duration series (PDS).

Numbers in parenthesis are PF estimates at lower and upper bounds of the 90% confidence interval. The probability that precipitation frequency estimates (for a given duration and average recurrence interval) will be greater than the upper bound (or less than the lower bound) is 5%. Estimates at upper bounds are not checked against probable maximum precipitation (PMP) estimates and may be higher than currently valid PMP values.

Please refer to NOAA Atlas 14 document for more information.

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APPX D: CCDDM Tables

Appx D.1.69: CCDDM Antecedent Precipitation Factor [7]

TABLE 3-1: ANTECEDENT PRECIPITATION FACTORS

Storm Frequency	Factor
25 Year	1.1
50 Year	1.2
100 Year	1.25

Appx D.2.70: CCDDM Manning's Coefficients [7]

TABLE 3-3: MANNING'S "n" FOR SHEET FLOW[1]

Surface Description		'n' value
Concrete		0.012
Asphalt		0.011
Fallow (no residue)		0.05
Cultivated soils:	Residue cover ≤ 20%	0.06
	Residue cover > 20%	0.17
Grass:	Short grass, prairie	0.15
	Dense grasses	0.24
	Bermuda grass[1]	0.41
	Bluegrass sod	0.45
Range (natural)		0.13
Woods[2]:	Light underbrush	0.40
	Dense underbrush	0.80

APPX E: Sub Basin Information

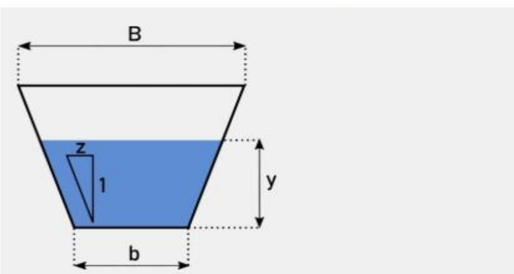
Appx E.1.71: Sub Basin Parameters

Sub-Basin	Area (sq ft)	Area (acre)	Area (sq mi)	Weighted C
1	3268882.61	75.0432188	0.117255029	0.16
2	2983454.97	68.4907018	0.107016722	0.16
3	1132449.6	25.9974655	0.04062104	0.17
4	1442652.29	33.1187395	0.051748031	0.13
5	1376796.55	31.6068998	0.049385781	0.18
6	321759.112	7.38657282	0.01154152	0.13
7	790981.256	18.158431	0.028372548	0.14
8	1163636.09	26.7134089	0.041739701	0.25
9	238244.219	5.46933469	0.008545835	0.19
10	563810.616	12.9433107	0.020223923	0.17
11	804516.51	18.4691577	0.028858059	0.17
12	1078704.35	24.7636444	0.038693194	0.16
13	390780.993	8.97109717	0.014017339	0.17
14	504841.234	11.58956	0.018108688	0.17
15	389435.383	8.94020622	0.013969072	0.32
16	1008336.86	23.1482291	0.036169108	0.13
17	880583.055	20.2154053	0.031586571	0.16
18	421413.41	9.67432071	0.015116126	0.12
19	675575.405	15.5090772	0.024232933	0.16
20	637898.323	14.6441305	0.022881454	0.64
21	1034299.22	23.7442428	0.037100379	0.19
22	829529.027	19.0433661	0.02975526	0.17
23	2547081.54	58.4729463	0.091363979	0.22

Sub-Basin	Raw Input (ACLA)
1	4.1298
2	3.7692
3	1.4307
4	1.8226
5	1.7394
6	0.4065
7	0.9993
8	1.4701
9	0.30099
10	0.7123
11	1.0164
12	1.3628
13	0.4937
14	0.6378
15	0.492
16	1.2739
17	1.1125
18	0.5324
19	0.8535
20	0.8059
21	1.3067
22	1.048
23	3.2179

Appx E.2.72: Sub Basin Modelling

Shape	trapezoidal channel



Height (y)	2 ft
Top width (B)	6 ft
Bottom width (b)	4 ft
Slope (z)	0.5
Area	10 ft²
Wetted perimeter	8.472 ft
Hydraulic radius	1.1803 ft

Appx E.3.73: Sub Basin Flow Data (Sheet and Shallow Concentrated)

Sub basin	Sheet flow						Shallow Conc. Flow (Unpaved)					
	n	L (ft)	Start Elevation (ft)	End Elevation (ft)	S (ft/ft)	T (min)	Start Elevation (ft)	End Elevation (ft)	S (ft/ft)	V (ft/s)	L (ft)	T (min)
1	0	0	0	0	0	0	7600	7150	0.1975	7.1696	2278.9	5.2976
2	0	0	0	0	0	0	7600	7150	0.0999	5.1008	4502.5	14.712
3	0	0	0	0	0	0	7200	7090	0.0696	4.2572	1580	6.1855
4	0	0	0	0	0	0	7095	7070	0.025	2.5497	1001.1	6.5437
5	0	0	0	0	0	0	7200	7070	0.0673	4.1848	1932.5	7.6965
6	0	0	0	0	0	0	7080	7050	0.0348	3.0079	863.17	4.7827
7	0	0	0	0	0	0	7080	7040	0.0399	3.2239	1001.9	5.1794
8	0	0	0	0	0	0	7200	7170	0.0219	2.39	1367.2	9.5339
9	0	0	0	0	0	0	7200	7037	0.0467	3.4885	3486.8	16.659
10	0	0	0	0	0	0	7080	7040	0.0359	3.0563	1114.8	6.0791
11	0	0	0	0	0	0	7140	7040	0.1013	5.1356	987.01	3.2032
12	0	0	0	0	0	0	7110	7030	0.1053	5.2351	759.88	2.4192
13	0	0	0	0	0	0	7080	7030	0.0829	4.6449	603.29	2.1647
14	0	0	0	0	0	0	7090	7025	0.0818	4.6145	794.66	2.8702
15	0.15	203.293	7150	7145	0.0246	20.1263	0	0	0	0	0	0
16	0	0	0	0	0	0	7070	7019	0.0398	3.2185	1281.7	6.6371
17	0.15	289.147	7142	7135	0.02421	26.8479	7135	7020	0.1283	5.7792	896.36	2.585
18	0	0	0	0	0	0	7070	7015	0.0738	4.382	745.64	2.836
19	0	0	0	0	0	0	7136	7014	0.0843	4.6847	1447.2	5.1486
20	0	0	0	0	0	0	7071	7070	0.0029	0.8656	347.42	6.6893
21	0	0	0	0	0	0	7136	7000	0.0752	4.4246	1808.5	6.8122
22	0	0	0	0	0	0	7205	7160	0.022	2.3906	2049.7	14.29
23	0	0	0	0	0	0	7210	7195	0.0244	2.5194	615.21	4.0699

Appx E.4.74: Sub Basin Flow Data (Open Channel, Street Gutter, and Total)

Sub basin	Open Channel flow										Street Gutter flow (6" curb depth)						Total T (min)
	A (ft2)	WP (ft)	R (ft)	Start Elevation (ft)	End Elevation (ft)	S (ft/ft)	n	V (ft/s)	L (ft)	T (min)	Start Elevation (ft)	End Elevation (ft)	S (ft/ft)	V (ft/s)	L (ft)	T (min)	
1	40	20.9443	1.90983	7150	7080	0.03628	0.15	2.91237	1929.54	11.0422	0	0	0	0	0	0	16.34
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14.71
3	40	20.9443	1.90983	7090	7070	0.04143	0.15	3.11231	482.742	2.58512	0	0	0	0	0	0	8.77
4	40	20.9443	1.90983	7070	7050	0.01097	0.15	1.60182	1822.43	18.962	0	0	0	0	0	0	25.51
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7.70
6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4.78
7	40	20.9443	1.90983	7040	7037	0.00657	0.15	1.23932	456.674	6.14148	0	0	0	0	0	0	11.32
8	40	20.9443	1.90983	7060	7043	0.08642	0.15	4.49508	196.709	0.72935	7170	7060	0.09061	16.2544	1214.06	1.24486	11.51
9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	16.66
10	40	20.9443	1.90983	7040	7037	20.5479	0.15	69.3121	0.146	3.5E-05	0	0	0	0	0	0	6.08
11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3.20
12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2.42
13	10	8.472	1.18036	7030	7029	0.01527	0.15	1.37103	65.4806	0.796	0	0	0	0	0	0	2.96
14	10	8.472	1.18036	7025	7023	0.00764	0.15	0.9698	261.745	4.49828	0	0	0	0	0	0	7.37
15	10	8.472	1.18036	7030	7020	0.05009	0.15	2.48299	199.645	1.34008	7145	7030	0.1192	18.6436	964.772	0.86247	22.33
16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6.64
17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	29.43
18	10	8.472	1.18036	7015	7013	0.01085	0.15	1.1556	184.342	2.65868	0	0	0	0	0	0	5.49
19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5.15
20	10	8.472	1.18036	7010	7000	0.01323	0.15	1.27593	756.052	9.8758	7070	7010	0.18985	23.5286	316.042	0.22387	16.79
21	10	8.472	1.18036	7000	6995	0.00624	0.15	0.87636	801.337	15.2399	0	0	0	0	0	0	22.05
22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14.29
23	0	0	0	0	0	0	0	0	0	0	7195	7180	0.00769	4.73644	1949.73	6.86074	10.93

APPX F: Sub Basin Results

Appx F.1.75: 2-yr Sub Basin Results

2-yr					
Sub-Basin	**Cf**	**C**	**i (in/hr)**	**A (acres)**	**Q (cfs)**
1	1	0.16	1.94	75.04322	**23.54091**
2	1	0.16	2	68.4907	**21.88278**
3	1	0.17	2.61	25.99747	**11.19581**
4	1	0.13	1.54	33.11874	**6.42636**
5	1	0.18	2.77	31.6069	**15.46153**
6	1	0.13	3.19	7.386573	**3.05143**
7	1	0.14	2.27	18.15843	**5.564651**
8	1	0.25	2.42	26.71341	**16.22626**
9	1	0.19	1.93	5.469335	**2.037272**
10	1	0.17	3.02	12.94331	**6.566918**
11	1	0.17	3.19	18.46916	**9.780158**
12	1	0.16	3.19	24.76364	**12.71836**
13	1	0.17	3.19	8.971097	**4.80779**
14	1	0.17	2.83	11.58956	**5.51014**
15	1	0.32	1.675	8.940206	**4.836875**
16	1	0.13	2.94	23.14823	**8.949337**
17	1	0.16	1.35	20.21541	**4.421109**
18	1	0.12	3.19	9.674321	**3.749622**
19	1	0.16	3.19	15.50908	**8.113729**
20	1	0.64	1.94	14.64413	**18.15374**
21	1	0.19	1.675	23.74424	**7.576491**
22	1	0.17	2	19.04337	**6.436658**
23	1	0.22	2.42	58.47295	**31.2725**

Appx F.2.76: 5-yr Sub Basin Results

5-yr					
Sub-Basin	**Cf**	**C**	**i (in/hr)**	**A (acres)**	**Q (cfs)**
1	1	0.16	2.62	75.04322	**31.79236**
2	1	0.16	2.70	68.4907	**29.54175**
3	1	0.17	3.52	25.99747	**15.11383**
4	1	0.13	2.08	33.11874	**8.679759**
5	1	0.18	3.74	31.6069	**20.89706**
6	1	0.13	4.30	7.386573	**4.113213**
7	1	0.14	3.09	18.15843	**7.57479**
8	1	0.25	3.27	26.71341	**21.92556**
9	1	0.19	2.60	5.469335	**2.744512**
10	1	0.17	4.08	12.94331	**8.86647**
11	1	0.17	4.30	18.46916	**13.18328**
12	1	0.16	4.30	24.76364	**17.14387**
13	1	0.17	4.30	8.971097	**6.480721**
14	1	0.17	3.81	11.58956	**7.421711**
15	1	0.32	2.26	8.940206	**6.526172**
16	1	0.13	3.96	23.14823	**12.06078**
17	1	0.16	1.82	20.21541	**5.96031**
18	1	0.12	4.3	9.674321	**5.054349**
19	1	0.16	4.3	15.50908	**10.937**
20	1	0.64	2.61	14.64413	**24.42333**
21	1	0.19	2.26	23.74424	**10.22261**
22	1	0.17	2.7	19.04337	**8.689488**
23	1	0.22	3.27	58.47295	**42.25664**

Appx F.3.77.10- yr Sub Basin Results

10-yr					
Sub-Basin	**Cf**	**C**	**i (in/hr)**	**A (acres)**	**Q (cfs)**
1	1	0.16	3.18	75.04322	**38.64123**
2	1	0.16	3.28	68.4907	**35.88776**
3	1	0.17	4.28	25.99747	**18.34869**
4	1	0.13	2.53	33.11874	**10.55759**
5	1	0.18	4.55	31.6069	**25.36918**
6	1	0.13	5.22	7.386573	**4.993249**
7	1	0.14	3.77	18.15843	**9.241733**
8	1	0.25	3.97	26.71341	**26.61911**
9	1	0.19	3.16	5.469335	**3.335638**
10	1	0.17	4.95	12.94331	**10.76366**
11	1	0.17	5.22	18.46916	**16.00389**
12	1	0.16	5.22	24.76364	**20.81186**
13	1	0.17	5.22	8.971097	**7.867293**
14	1	0.17	4.63	11.58956	**9.009956**
15	1	0.32	2.75	8.940206	**7.941138**
16	1	0.13	4.81	23.14823	**14.6416**
17	1	0.16	2.21	20.21541	**7.237519**
18	1	0.12	5.22	9.674321	**6.135744**
19	1	0.16	5.22	15.50908	**13.27701**
20	1	0.64	3.16	14.64413	**29.57001**
21	1	0.19	2.75	23.74424	**12.43902**
22	1	0.17	3.28	19.04337	**10.55612**
23	1	0.22	3.97	58.47295	**51.30241**

Appx F.4.78: 25-yr Sub Basin Results

25-yr					
Sub-Basin	**Cf**	**C**	**i (in/hr)**	**A (acres)**	**Q (cfs)**
1	1.1	0.16	4.00	75.04322	**53.39175**
2	1.1	0.16	4.12	68.4907	**49.58638**
3	1.1	0.17	5.37	25.99747	**25.3563**
4	1.1	0.13	3.17	33.11874	**14.55112**
5	1.1	0.18	5.71	31.6069	**35.04441**
6	1.1	0.13	6.55	7.386573	**6.892023**
7	1.1	0.14	4.76	18.15843	**12.83547**
8	1.1	0.25	4.99	26.71341	**36.80411**
9	1.1	0.19	3.97	5.469335	**4.609725**
10	1.1	0.17	6.21	12.94331	**14.86112**
11	1.1	0.17	6.55	18.46916	**22.08967**
12	1.1	0.16	6.55	24.76364	**28.72595**
13	1.1	0.17	6.55	8.971097	**10.85897**
14	1.1	0.17	5.81	11.58956	**12.44477**
15	1.1	0.32	3.45	8.940206	**10.95877**
16	1.1	0.13	6.04	23.14823	**20.21866**
17	1.1	0.16	2.77	20.21541	**9.978607**
18	1.1	0.12	6.55	9.674321	**8.468973**
19	1.1	0.16	6.55	15.50908	**18.32584**
20	1.1	0.64	3.97	14.64413	**40.86464**
21	1.1	0.19	3.45	23.74424	**17.16584**
22	1.1	0.17	4.12	19.04337	**14.58547**
23	1.1	0.22	4.99	58.47295	**70.93172**

Appx F.5.79: 50-yr Sub Basin Results

50-yr					
Sub-Basin	**Cf**	**C**	**i (in/hr)**	**A (acres)**	**Q (cfs)**
1	1.2	0.16	4.67	75.04322	**68.00167**
2	1.2	0.16	4.81	68.4907	**63.1537**
3	1.2	0.17	6.27	25.99747	**32.26308**
4	1.2	0.13	3.71	33.11874	**18.57802**
5	1.2	0.18	6.66	31.6069	**44.59082**
6	1.2	0.13	7.64	7.386573	**8.769753**
7	1.2	0.14	5.65	18.15843	**16.62041**
8	1.2	0.25	5.82	26.71341	**46.82818**
9	1.2	0.19	4.64	5.469335	**5.877478**
10	1.2	0.17	7.25	12.94331	**18.9098**
11	1.2	0.17	7.64	18.46916	**28.10799**
12	1.2	0.16	7.64	24.76364	**36.55233**
13	1.2	0.17	7.64	8.971097	**13.8175**
14	1.2	0.17	6.78	11.58956	**15.83491**
15	1.2	0.32	4.03	8.940206	**13.96485**
16	1.2	0.13	7.04	23.14823	**25.72675**
17	1.2	0.16	3.24	20.21541	**12.73279**
18	1.2	0.12	7.64	9.674321	**10.77634**
19	1.2	0.16	7.64	15.50908	**23.3187**
20	1.2	0.64	4.64	14.64413	**52.10311**
21	1.2	0.19	4.03	23.74424	**21.87457**
22	1.2	0.17	4.81	19.04337	**18.57619**
23	1.2	0.22	5.82	58.47295	**90.25089**

Appx F.6.80: 100-yr Sub Basin Results

100-yr					
Sub-Basin	**Cf**	**C**	**i (in/hr)**	**A (acres)**	**Q (cfs)**
1	1.25	0.16	5.41	75.04322	**82.05948**
2	1.25	0.16	5.57	68.4907	**76.17943**
3	1.25	0.17	7.26	25.99747	**38.93611**
4	1.25	0.13	4.29	33.11874	**22.3775**
5	1.25	0.18	7.72	31.6069	**53.83067**
6	1.25	0.13	8.86	7.386573	**10.59392**
7	1.25	0.14	6.52	18.15843	**19.97881**
8	1.25	0.25	6.74	26.71341	**56.49018**
9	1.25	0.19	5.37	5.469335	**7.085591**
10	1.25	0.17	8.40	12.94331	**22.83765**
11	1.25	0.17	8.86	18.46916	**33.95462**
12	1.25	0.16	8.86	24.76364	**44.15544**
13	1.25	0.17	8.86	8.971097	**16.69162**
14	1.25	0.17	7.86	11.58956	**19.11785**
15	1.25	0.32	4.66	8.940206	**16.82077**
16	1.25	0.13	8.16	23.14823	**31.06637**
17	1.25	0.16	3.75	20.21541	**15.35107**
18	1.25	0.12	8.86	9.674321	**13.01789**
19	1.25	0.16	8.86	15.50908	**28.16914**
20	1.25	0.64	5.37	14.64413	**62.81289**
21	1.25	0.19	4.66	23.74424	**26.3481**
22	1.25	0.17	5.57	19.04337	**22.40761**
23	1.25	0.22	6.74	58.47295	**108.8722**
					829.155

APPX G: HEC-RAS Results

Appx G.1.81: HEC-RAS Errors (1/3)

Errors Warnings and Notes for Plan : Plan 01

Location:	River: Switzer Canyon Reach: Reach 2 RS: 2400 Profile: PF 1
Warning:	The cross section had to be extended vertically during the critical depth calculations.
Warning:	The parabolic search method failed to converge on critical depth. The program will try the cross section
	slice/secant method to find critical depth.
Location:	River: Switzer Canyon Reach: Reach 2 RS: 2375 Profile: PF 1
Warning:	The cross-section end points had to be extended vertically for the computed water surface.
Warning:	The velocity head has changed by more than 0.5 ft (0.15 m). This may indicate the need for additional cross
	sections.
Warning:	The cross section had to be extended vertically during the critical depth calculations.
Warning:	The energy loss was greater than 1.0 ft (0.3 m). between the current and previous cross section. This may
	indicate the need for additional cross sections.
Warning:	The parabolic search method failed to converge on critical depth. The program will try the cross section
	slice/secant method to find critical depth.
Note:	Hydraulic jump has occurred between this cross section and the previous upstream section.
Location:	River: Switzer Canyon Reach: Reach 2 RS: 2350 Profile: PF 1
Warning:	The cross-section end points had to be extended vertically for the computed water surface.
Warning:	The velocity head has changed by more than 0.5 ft (0.15 m). This may indicate the need for additional cross
	sections.
Warning:	The conveyance ratio (upstream conveyance divided by downstream conveyance) is less than 0.7 or greater
	than 1.4. This may indicate the need for additional cross sections.
Location:	River: Switzer Canyon Reach: Reach 2 RS: 2325 Profile: PF 1
Warning:	The cross-section end points had to be extended vertically for the computed water surface.
Warning:	The conveyance ratio (upstream conveyance divided by downstream conveyance) is less than 0.7 or greater
	than 1.4. This may indicate the need for additional cross sections.
Location:	River: Switzer Canyon Reach: Reach 2 RS: 2300 Profile: PF 1
Warning:	The cross-section end points had to be extended vertically for the computed water surface.
Location:	River: Switzer Canyon Reach: Reach 2 RS: 2295 Profile: PF 1
Warning:	The cross-section end points had to be extended vertically for the computed water surface.
Location:	River: Switzer Canyon Reach: Reach 2 RS: 2250 Profile: PF 1
Warning:	The cross-section end points had to be extended vertically for the computed water surface.
Warning:	The velocity head has changed by more than 0.5 ft (0.15 m). This may indicate the need for additional cross
	sections.
Warning:	The conveyance ratio (upstream conveyance divided by downstream conveyance) is less than 0.7 or greater
	than 1.4. This may indicate the need for additional cross sections.
Location:	River: Switzer Canyon Reach: Reach 2 RS: 2225 Profile: PF 1
Warning:	The cross-section end points had to be extended vertically for the computed water surface.
Warning:	The velocity head has changed by more than 0.5 ft (0.15 m). This may indicate the need for additional cross
	sections.
Location:	River: Switzer Canyon Reach: Reach 2 RS: 2200 Profile: PF 1
Warning:	The cross-section end points had to be extended vertically for the computed water surface.
Warning:	The conveyance ratio (upstream conveyance divided by downstream conveyance) is less than 0.7 or greater
	than 1.4. This may indicate the need for additional cross sections.
Location:	River: Switzer Canyon Reach: Reach 2 RS: 1957 Profile: PF 1
Warning:	The cross-section end points had to be extended vertically for the computed water surface.
Location:	River: Switzer Canyon Reach: Reach 2 RS: 1935 Profile: PF 1
Warning:	The cross-section end points had to be extended vertically for the computed water surface.
Warning:	The conveyance ratio (upstream conveyance divided by downstream conveyance) is less than 0.7 or greater
	than 1.4. This may indicate the need for additional cross sections.
Location:	River: Switzer Canyon Reach: Reach 2 RS: 1915 Profile: PF 1
Warning:	The cross section had to be extended vertically during the critical depth calculations.
Warning:	The parabolic search method failed to converge on critical depth. The program will try the cross section
	slice/secant method to find critical depth.
Location:	River: Switzer Canyon Reach: Reach 2 RS: 1875 Profile: PF 1 Culv: Culvert #1

Appx G.2.82: HEC-RAS Errors (2/3)

Errors Warnings and Notes for Plan : Plan 01 (Continued)

Warning:	The inlet is submerged and the outlet computations indicate that the culvert would flow full over all or part of its
	length. The program would normally default to the outlet answer. However, the user has requested that the
	inlet answer be used.
Warning:	During the culvert inlet control computations, the program could not balance the culvert/weir flow. The reported
	inlet energy grade answer may not be valid.
Warning:	During the culvert outlet control computations, the program could not balance the culvert/weir flow. The
	reported outlet energy grade answer may not be valid.
Note:	The normal depth exceeds the height of the culvert. The program assumes that the normal depth is equal to the
	height of the culvert.
Note:	Culvert critical depth exceeds the height of the culvert.
Note:	During the supercritical calculations a hydraulic jump occurred inside of the culvert.
Location:	River: Switzer Canyon Reach: Reach 2 RS: 1828 Profile: PF 1
Warning:	The cross-section end points had to be extended vertically for the computed water surface.
Location:	River: Switzer Canyon Reach: Reach 2 RS: 1782 Profile: PF 1
Warning:	The cross-section end points had to be extended vertically for the computed water surface.
Warning:	The velocity head has changed by more than 0.5 ft (0.15 m). This may indicate the need for additional cross
	sections.
Warning:	The conveyance ratio (upstream conveyance divided by downstream conveyance) is less than 0.7 or greater
	than 1.4. This may indicate the need for additional cross sections.
Location:	River: Switzer Canyon Reach: Reach 2 RS: 1774 Profile: PF 1
Warning:	The cross-section end points had to be extended vertically for the computed water surface.
Location:	River: Switzer Canyon Reach: Reach 2 RS: 1705 Profile: PF 1
Warning:	The cross-section end points had to be extended vertically for the computed water surface.
Location:	River: Switzer Canyon Reach: Reach 2 RS: 1670 Profile: PF 1
Warning:	The cross-section end points had to be extended vertically for the computed water surface.
Location:	River: Switzer Canyon Reach: Reach 2 RS: 1624 Profile: PF 1
Warning:	The cross-section end points had to be extended vertically for the computed water surface.
Warning:	The conveyance ratio (upstream conveyance divided by downstream conveyance) is less than 0.7 or greater
	than 1.4. This may indicate the need for additional cross sections.
Location:	River: Switzer Canyon Reach: Reach 2 RS: 1589 Profile: PF 1
Warning:	The cross-section end points had to be extended vertically for the computed water surface.
Warning:	The velocity head has changed by more than 0.5 ft (0.15 m). This may indicate the need for additional cross
	sections.
Location:	River: Switzer Canyon Reach: Reach 2 RS: 1552 Profile: PF 1
Warning:	The cross-section end points had to be extended vertically for the computed water surface.
Location:	River: Switzer Canyon Reach: Reach 2 RS: 1515 Profile: PF 1
Warning:	The cross-section end points had to be extended vertically for the computed water surface.
Location:	River: Switzer Canyon Reach: Reach 2 RS: 1462 Profile: PF 1
Warning:	The cross-section end points had to be extended vertically for the computed water surface.
Location:	River: Switzer Canyon Reach: Reach 2 RS: 1432 Profile: PF 1
Warning:	The cross-section end points had to be extended vertically for the computed water surface.
Warning:	The velocity head has changed by more than 0.5 ft (0.15 m). This may indicate the need for additional cross
	sections.
Warning:	The cross section had to be extended vertically during the critical depth calculations.
Warning:	The parabolic search method failed to converge on critical depth. The program will try the cross section
	slice/secant method to find critical depth.
Location:	River: Switzer Canyon Reach: Reach 2 RS: 1414 Profile: PF 1
Warning:	The energy equation could not be balanced within the specified number of iterations. The program used critical
	depth for the water surface and continued on with the calculations.
Warning:	The cross-section end points had to be extended vertically for the computed water surface.
Warning:	The velocity head has changed by more than 0.5 ft (0.15 m). This may indicate the need for additional cross
	sections.
Warning:	The conveyance ratio (upstream conveyance divided by downstream conveyance) is less than 0.7 or greater

Appx G.3.83: HEC-RAS Errors (3/3)

Errors Warnings and Notes for Plan : Plan 01 (Continued)

	than 1.4. This may indicate the need for additional cross sections.
Warning:	The cross section had to be extended vertically during the critical depth calculations.
Warning:	During the standard step iterations, when the assumed water surface was set equal to critical depth, the
	calculated water surface came back below critical depth. This indicates that there is not a valid subcritical
	answer. The program defaulted to critical depth.
Warning:	The parabolic search method failed to converge on critical depth. The program will try the cross section
	slice/secant method to find critical depth.
Location:	River: Switzer Canyon Reach: Reach 2 RS: 1363 Profile: PF 1
Warning:	The cross-section end points had to be extended vertically for the computed water surface.
Note:	Hydraulic jump has occurred between this cross section and the previous upstream section.
Location:	River: Switzer Canyon Reach: Reach 2 RS: 1309 Profile: PF 1
Warning:	The cross-section end points had to be extended vertically for the computed water surface.
Location:	River: Switzer Canyon Reach: Reach 2 RS: 1270 Profile: PF 1
Warning:	The cross-section end points had to be extended vertically for the computed water surface.
Location:	River: Switzer Canyon Reach: Reach 2 RS: 1206 Profile: PF 1
Warning:	The cross-section end points had to be extended vertically for the computed water surface.
Location:	River: Switzer Canyon Reach: Reach 2 RS: 1190 Profile: PF 1
Warning:	The cross-section end points had to be extended vertically for the computed water surface.
Location:	River: Switzer Canyon Reach: Reach 2 RS: 1175 Profile: PF 1
Warning:	The cross-section end points had to be extended vertically for the computed water surface.
Location:	River: Switzer Canyon Reach: Reach 2 RS: 1150 Profile: PF 1
Warning:	The cross-section end points had to be extended vertically for the computed water surface.
Location:	River: Switzer Canyon Reach: Reach 2 RS: 1110 Profile: PF 1
Warning:	The cross-section end points had to be extended vertically for the computed water surface.
Warning:	The conveyance ratio (upstream conveyance divided by downstream conveyance) is less than 0.7 or greater
	than 1.4. This may indicate the need for additional cross sections.
Location:	River: Switzer Canyon Reach: Reach 2 RS: 1100 Profile: PF 1
Warning:	The cross-section end points had to be extended vertically for the computed water surface.
Warning:	The velocity head has changed by more than 0.5 ft (0.15 m). This may indicate the need for additional cross
	sections.
Warning:	The conveyance ratio (upstream conveyance divided by downstream conveyance) is less than 0.7 or greater
	than 1.4. This may indicate the need for additional cross sections.
Location:	River: Switzer Canyon Reach: Reach 2 RS: 500 Profile: PF 1
Warning:	User specified water surface is not possible for the specified flow regime. The program used critical depth as the
	starting water surface.
Warning:	The cross section had to be extended vertically during the critical depth calculations.
Warning:	The parabolic search method failed to converge on critical depth. The program will try the cross section
	slice/secant method to find critical depth.

APPX H: HEC-RAS Manual

Appx H.1.84: HEC-RAS Manning's Coefficients (1/3) [19]

Chapter 3– Basic Data Requirements

Table 3-1 Manning's 'n' Values

Type of Channel and Description	Minimum	Normal	Maximum
A. *Natural Streams*			
1. **Main Channels**			
a. Clean, straight, full, no rifts or deep pools	0.025	0.030	0.033
b. Same as above, but more stones and weeds	0.030	0.035	0.040
c. Clean, winding, some pools and shoals	0.033	0.040	0.045
d. Same as above, but some weeds and stones	0.035	0.045	0.050
e. Same as above, lower stages, more ineffective slopes and sections	0.040	0.048	0.055
f. Same as "d" but more stones	0.045	0.050	0.060
g. Sluggish reaches, weedy. deep pools	0.050	0.070	0.080
h. Very weedy reaches, deep pools, or floodways with heavy stands of timber and brush	0.070	0.100	0.150
2. **Flood Plains**			
a. Pasture no brush			
1. Short grass	0.025	0.030	0.035
2. High grass	0.030	0.035	0.050
b. Cultivated areas			
1. No crop	0.020	0.030	0.040
2. Mature row crops	0.025	0.035	0.045
3. Mature field crops	0.030	0.040	0.050
c. Brush			
1. Scattered brush, heavy weeds	0.035	0.050	0.070
2. Light brush and trees, in winter	0.035	0.050	0.060
3. Light brush and trees, in summer	0.040	0.060	0.080
4. Medium to dense brush, in winter	0.045	0.070	0.110
5. Medium to dense brush, in summer	0.070	0.100	0.160
d. Trees			
1. Cleared land with tree stumps, no sprouts	0.030	0.040	0.050
2. Same as above, but heavy sprouts	0.050	0.060	0.080
3. Heavy stand of timber, few down trees, little undergrowth, flow below branches	0.080	0.100	0.120
4. Same as above, but with flow into branches	0.100	0.120	0.160
5. Dense willows, summer, straight	0.110	0.150	0.200
3. **Mountain Streams, no vegetation in channel, banks usually steep, with trees and brush on banks submerged**			
a. Bottom: gravels, cobbles, and few boulders	0.030	0.040	0.050
b. Bottom: cobbles with large boulders	0.040	0.050	0.070

Appx H.2.85: HEC-RAS Manning's Coefficients (2/3) [19]

Table 3-1 (Continued) Manning's 'n' Values

Type of Channel and Description	Minimum	Normal	Maximum
B. *Lined or Built-Up Channels*			
1. **Concrete**			
a. Trowel finish	0.011	0.013	0.015
b. Float Finish	0.013	0.015	0.016
c. Finished, with gravel bottom	0.015	0.017	0.020
d. Unfinished	0.014	0.017	0.020
e. Gunite, good section	0.016	0.019	0.023
f. Gunite, wavy section	0.018	0.022	0.025
g. On good excavated rock	0.017	0.020	
h. On irregular excavated rock	0.022	0.027	
2. **Concrete bottom float finished with sides of:**			
a. Dressed stone in mortar	0.015	0.017	0.020
b. Random stone in mortar	0.017	0.020	0.024
c. Cement rubble masonry, plastered	0.016	0.020	0.024
d. Cement rubble masonry	0.020	0.025	0.030
e. Dry rubble on riprap	0.020	0.030	0.035
3. **Gravel bottom with sides of:**			
a. Formed concrete	0.017	0.020	0.025
b. Random stone in mortar	0.020	0.023	0.026
c. Dry rubble or riprap	0.023	0.033	0.036
4. **Brick**			
a. Glazed	0.011	0.013	0.015
b. In cement mortar	0.012	0.015	0.018
5. **Metal**			
a. Smooth steel surfaces	0.011	0.012	0.014
b. Corrugated metal	0.021	0.025	0.030
6. **Asphalt**			
a. Smooth	0.013	0.013	
b. Rough	0.016	0.016	
7. **Vegetal lining**	0.030		0.500

Appx H.3.86: HEC-RAS Manning's Coefficients (3/3) [19]

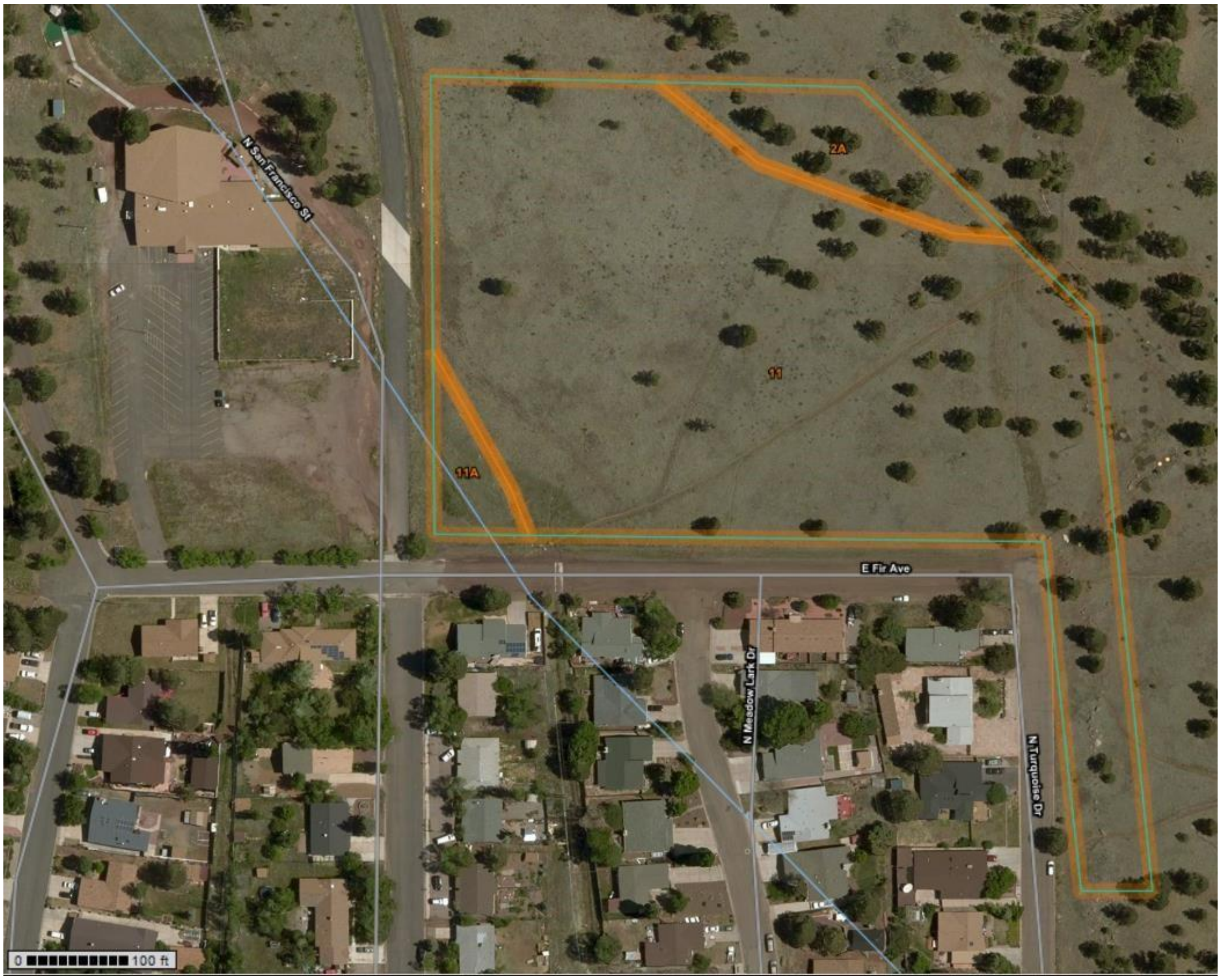
Chapter 3– Basic Data Requirements

Table 3-1 (Continued) Manning's 'n' Values

Type of Channel and Description	Minimum	Normal	Maximum
C. *Excavated or Dredged Channels*			
1. **Earth, straight and uniform**			
a. Clean, recently completed	0.016	0.018	0.020
b. Clean, after weathering	0.018	0.022	0.025
c. Gravel, uniform section, clean	0.022	0.025	0.030
d. With short grass, few weeds	0.022	0.027	0.033
2. **Earth, winding and sluggish**			
a. No vegetation	0.023	0.025	0.030
b. Grass, some weeds	0.025	0.030	0.033
c. Dense weeds or aquatic plants in deep channels	0.030	0.035	0.040
d. Earth bottom and rubble side	0.028	0.030	0.035
e. Stony bottom and weedy banks	0.025	0.035	0.040
f. Cobble bottom and clean sides	0.030	0.040	0.050
3. **Dragline-excavated or dredged**			
a. No vegetation	0.025	0.028	0.033
b. Light brush on banks	0.035	0.050	0.060
4. **Rock cuts**			
a. Smooth and uniform	0.025	0.035	0.040
b. Jagged and irregular	0.035	0.040	0.050
5. **Channels not maintained, weeds and brush**			
a. Clean bottom, brush on sides	0.040	0.050	0.080
b. Same as above, highest stage of flow	0.045	0.070	0.110
c. Dense weeds, high as flow depth	0.050	0.080	0.120
d. Dense brush, high stage	0.080	0.100	0.140

APPX I: USDA Soil Survey

Appx I.1.87: USDA Web Soil Survey Aerial Image [20]



Appx I.2.88: USDA Soil Survey Summary [20]

Map Unit Composition

Collbran and similar soils: 100 percent

Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Collbran

Setting

Landform: Hills
Landform position (two-dimensional): Backslope
Landform position (three-dimensional): Side slope
Down-slope shape: Convex
Across-slope shape: Convex
Parent material: Colluvium and/or alluvium derived from basalt and/or shale

Typical profile

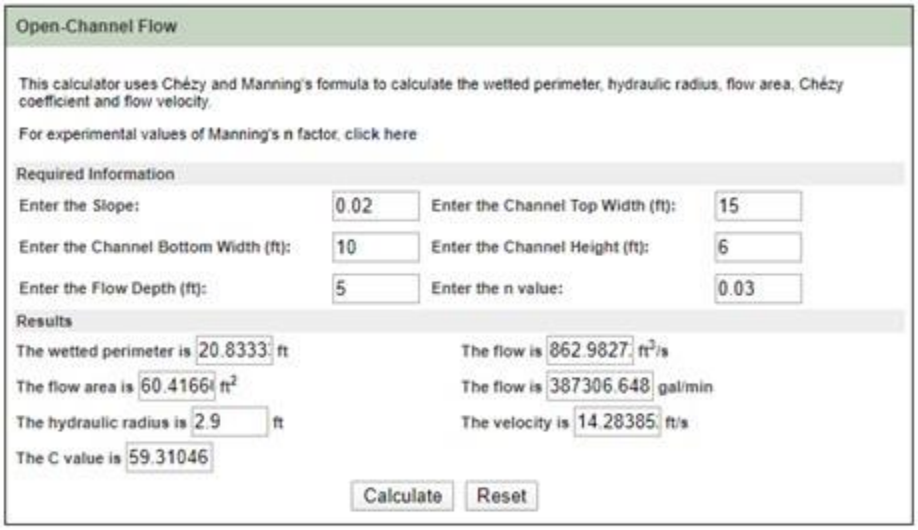
H1 - 0 to 12 inches: stony clay loam
H2 - 12 to 60 inches: clay

Properties and qualities

Slope: 5 to 20 percent
Percent of area covered with surface fragments: 15.0 percent
Depth to restrictive feature: More than 80 inches
Natural drainage class: Well drained
Runoff class: High
Capacity of the most limiting layer to transmit water (Ksat): Moderately low to moderately high (0.06 to 0.20 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum in profile: 5 percent
Salinity, maximum in profile: Nonsaline to very slightly saline (0.0 to 2.0 mmhos/cm)
Available water storage in profile: Moderate (about 8.4 inches)

APPX J: Channel Estimates

Appx J.1.89: Open Channel CS Specs [14]



Open-Channel Flow

This calculator uses Chézy and Manning's formula to calculate the wetted perimeter, hydraulic radius, flow area, Chézy coefficient and flow velocity.

For experimental values of Manning's n factor, click here

Required Information

Enter the Slope:	0.02	Enter the Channel Top Width (ft):	15
Enter the Channel Bottom Width (ft):	10	Enter the Channel Height (ft):	6
Enter the Flow Depth (ft):	5	Enter the n value:	0.03

Results

The wetted perimeter is 20.8333 ft	The flow is 862.9827 ft³/s
The flow area is 60.4166 ft²	The flow is 387306.648 gal/min
The hydraulic radius is 2.9 ft	The velocity is 14.28385 ft/s
The C value is 59.31046	

Calculate Reset

APPX K: Detention Basin Estimates

Appx K.1.90: Time of Concentration for Contributing SBs

Tc (min)	Flow Type				
SB	Sheet	Shallow	Open Chan	Street	Total
1	0	5.297625	11.0422	0	16.34
2	0	14.71189	0	0	14.71
3	0	6.185537	2.585124	0	8.77
4	0	6.543657	18.96199	0	25.51
5	0	7.696513	0	0	7.70
6	0	4.782745	0	0	4.78
7	0	5.179423	6.141478	0	11.32
8	0	9.533865	0.729349	1.244857	11.51
9	0	16.65898	0	0	16.66
10	0	6.079146	3.51E-05	0	6.08
11	0	3.203157	0	0	3.20
12	0	2.419157	0	0	2.42
13	0	2.164719	0.796001	0	2.96
14	0	2.870201	4.498276	0	7.37
15	20.12635	0	1.340082	0.862468	22.33
16	0	6.637064	0	0	6.64
17	26.8479	2.585024	0	0	29.43
18	0	2.836014	2.658684	0	5.49
22	0	14.2901	0	0	14.29
23	0	4.06989	0	6.860742	10.93
Total					228.44

Appx K.2.91: Time of Concentration Conversion to Storage Duration Time

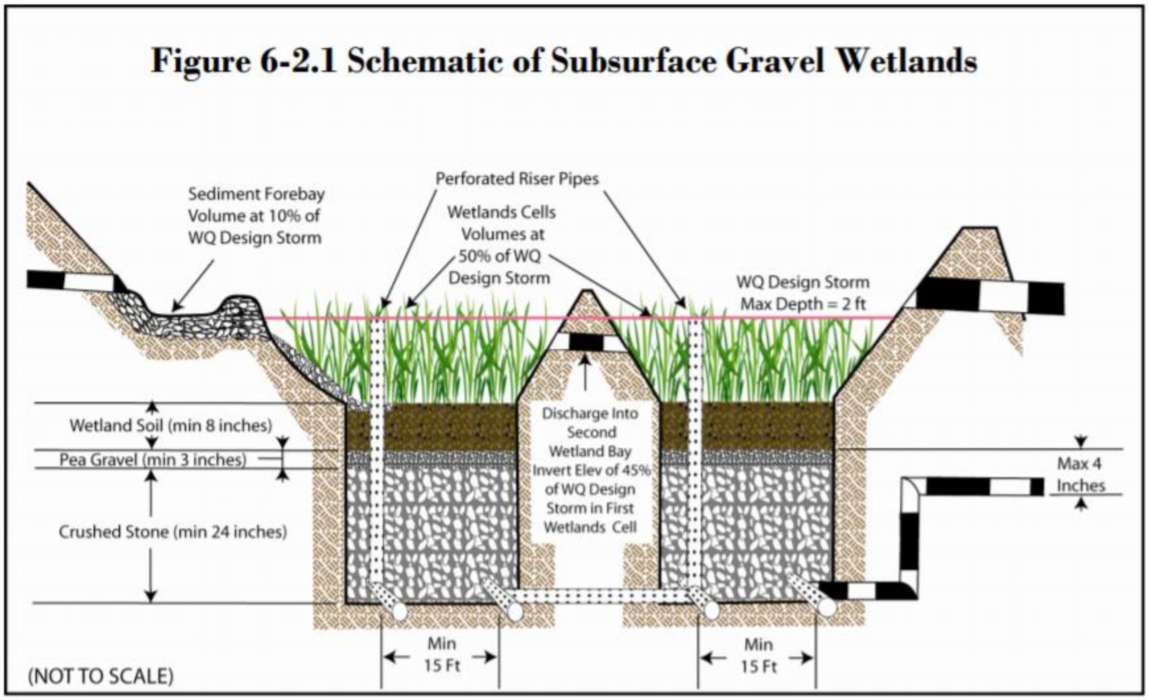
Time		
Tc (min)	Ti (min)	Ti (s)
228.44	406.62	24397.42

Appx K.3.92: Flow Reduction for Detention Basin

Flow		
Qin (cfs)	Qout (cfs)	Qdiff (cfs)
830	730	100

APPX L: Wetland Estimates

Appx L.1.98: Wetlands Criteria [13]



M: Cost Estimations

Appx M.1.93: BMP Cost Estimates [15]

Table 1: Proposed BMP Cost Estimates for Opti-Tool

BMP (From Opti-Tool)	Cost ($/ft³) [1]	Cost ($/ft³) – 2016 dollars[6]
Bioretention (Includes rain garden)	13.37 [2,4]	15.46
Dry Pond or detention basin	5.88 [2,4]	6.80
Enhanced Bioretention (aka-Bio-filtration Practice)	13.5 [2,3]	15.61
Infiltration Basin (or other Surface Infiltration Practice)	5.4 [2,3]	6.24
Infiltration Trench	10.8 [2,3]	12.49
Porous Pavement - Porous Asphalt Pavement	4.60 [2,4]	5.32
Porous Pavement - Pervious Concrete	15.63 [2,4]	18.07
Sand Filter	15.51 [2,4]	17.94
Gravel Wetland System (aka-subsurface gravel wetland)	7.59 [2,4]	8.78
Wet Pond or wet detention basin	5.88 [2,4]	6.80
Subsurface Infiltration/Detention System (aka-Infiltration Chamber)	54.54[5]	67.85

[1] **Footnote: Includes 35% add on for design engineering and contingencies**

[2] **Costs in 2010 dollars**

[3] **From CRWA Cost Estimates**

[4] **From UNHSC Cost Estimates; Most of original costs were from 2004 and converted to 2010 dollars using U.S. Department of Labor (USDOL). (2012). Bureau of Labor Statistics consumer price index inflation calculator.** http://www.bls.gov/data/inflation_calculator.htm

[5] **From Cost Estimate of MA TT Rizzo Project (2008 Dollars)**

[6] **2010 costs were converted to 2016 values to adjust for inflation. The ENR Cost Index Method was used for this conversion.**

Appx M.2.94: Cost Adjustment Factors [15]

Table 2: Example of Cost Adjustment Factors

BMP Type	**EXAMPLE** Cost Adjustment Factor
New BMP in undeveloped area	1
New BMP in partially developed area	1.5
New BMP in developed area	2
Difficult installation in highly urban settings	3

Appx M.3.95: Inflation Adjustment

Cost ($/ft^3)- 2020 Dollars	
16.66	ONE YEARS WORTH OF O&M
7.33	
16.82	
6.73	
13.46	
5.73	
19.48	
19.34	
9.46	
7.33	
80.49	

Appx N.1.96: Culvert Hydraulic Analysis report

Culvert Report

Hydraflow Express Extension for Autodesk® Civil 3D® by Autodesk, Inc. Tuesday, Apr 14 2020

Double Barrel Culvert

Invert Elev Dn (ft)	= 6998.00
Pipe Length (ft)	= 924.00
Slope (%)	= 0.24
Invert Elev Up (ft)	= 7000.21
Rise (in)	= 96.0
Shape	= Circular
Span (in)	= 96.0
No. Barrels	= 2
n-Value	= 0.012
Culvert Type	= Circular Corrugate Metal Pipe
Culvert Entrance	= Mitered to slope (C)
Coeff. K,M,c,Y,k	= 0.021, 1.33, 0.0463, 0.75, 0.7

Embankment

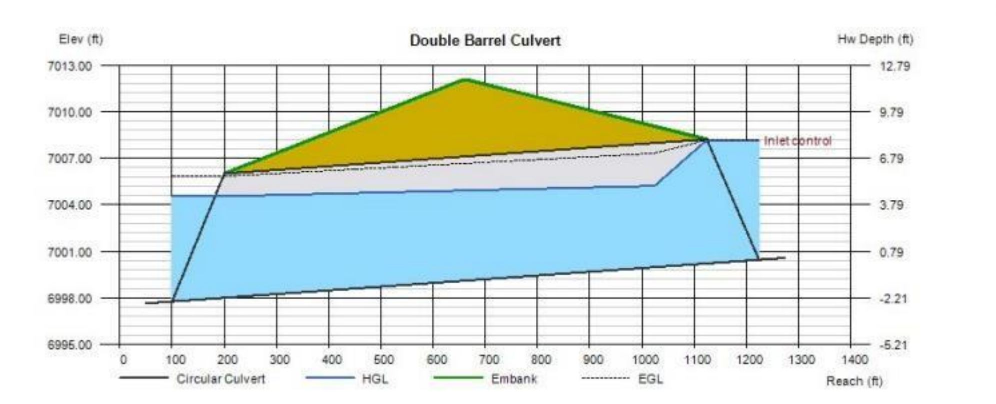
Top Elevation (ft)	= 7012.00
Top Width (ft)	= 15.00
Crest Width (ft)	= 20.00

Calculations

Qmin (cfs)	= 800.00
Qmax (cfs)	= 900.00
Tailwater Elev (ft)	= (dc+D)/2

Highlighted

Qtotal (cfs)	= 800.00
Qpipe (cfs)	= 800.00
Qovertop (cfs)	= 0.00
Veloc Dn (ft/s)	= 9.09
Veloc Up (ft/s)	= 11.88
HGL Dn (ft)	= 7004.54
HGL Up (ft)	= 7005.29
Hw Elev (ft)	= 7008.16
Hw/D (ft)	= 0.99
Flow Regime	= Inlet Control



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Appx N.2.91 Culvert Hydraulic Analysis Report under Various Flow Conditions

Q			Veloc		Depth		HGL			
Total	Pipe	Over	Dn	Up	Dn	Up	Dn	Up	Hw	Hw/D
(cfs)	(cfs)	(cfs)	(ft/s)	(ft/s)	(in)	(in)	(ft)	(ft)	(ft)	
100.00	100.00	0.00	1.56	6.25	58.37	20.75	7002.86	7001.94	7002.55	0.29
200.00	200.00	0.00	2.87	7.59	62.80	29.61	7003.23	7002.68	7003.60	0.42
300.00	300.00	0.00	4.05	8.54	66.26	36.53	7003.52	7003.25	7004.47	0.53
400.00	400.00	0.00	5.15	9.33	69.22	42.43	7003.77	7003.75	7005.25	0.63
500.00	500.00	0.00	6.20	10.03	71.85	47.70	7003.99	7004.19	7005.98	0.72
600.00	600.00	0.00	7.19	10.67	74.23	52.46	7004.19	7004.58	7006.69	0.81
700.00	700.00	0.00	8.16	11.29	76.43	56.86	7004.37	7004.95	7007.40	0.90
800.00	800.00	0.00	9.09	11.88	78.47	60.95	7004.54	7005.29	7008.10	0.99
900.00	900.00	0.00	10.01	12.47	80.39	64.78	7004.70	7005.61	7008.80	1.07

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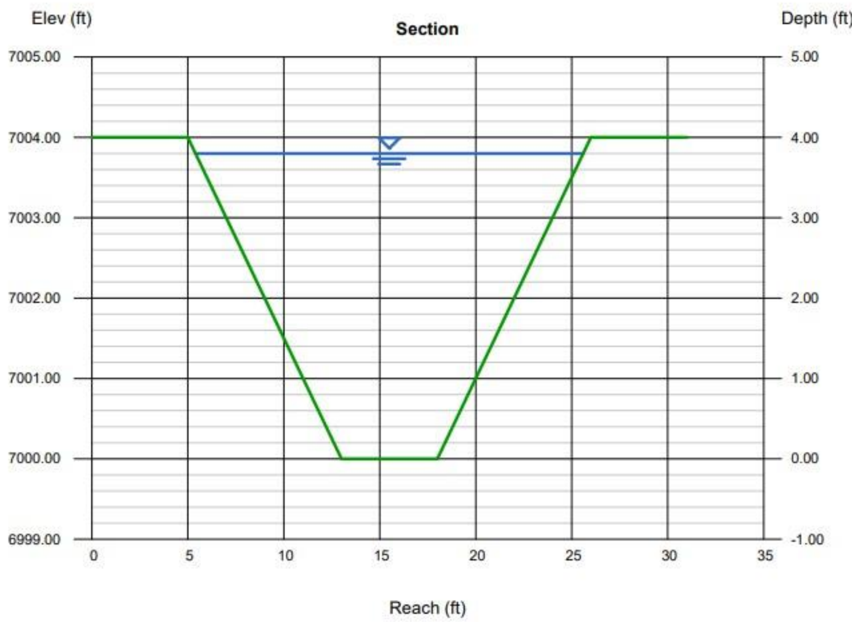
Appx N.3.92 Channel Hydraulic Analysis Report

Channel Report

Hydraflow Express Extension for Autodesk® Civil 3D® by Autodesk, Inc. — Tuesday, Apr 14 2020

<Name>

Trapezoidal		**Highlighted**	
Bottom Width (ft)	= 5.00	Depth (ft)	= 3.80
Side Slopes (z:1)	= 2.00, 2.00	Q (cfs)	= 919.55
Total Depth (ft)	= 4.00	Area (sqft)	= 47.88
Invert Elev (ft)	= 7000.00	Velocity (ft/s)	= 19.21
Slope (%)	= 1.00	Wetted Perim (ft)	= 21.99
N-Value	= 0.013	Crit Depth, Yc (ft)	= 4.00
		Top Width (ft)	= 20.20
Calculations		EGL (ft)	= 9.53
Compute by:	Q vs Depth		
No. Increments	= 20		



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Appx N.4.93 Channel Hydraulic Analysis Report under Various Flow Conditions

Depth	Q	Area	Veloc	Wp	Yc	TopWidth	Energy
(ft)	(cfs)	(sqft)	(ft/s)	(ft)	(ft)	(ft)	(ft)
0.08	0.854	0.413	2.07	5.36	0.10	5.32	0.15
0.16	2.732	0.851	3.21	5.72	0.21	5.64	0.32
0.24	5.419	1.315	4.12	6.07	0.32	5.96	0.50
0.32	8.839	1.805	4.90	6.43	0.44	6.28	0.69
0.40	12.96	2.320	5.59	6.79	0.55	6.60	0.89
0.48	17.76	2.861	6.21	7.15	0.67	6.92	1.08
0.56	23.23	3.427	6.78	7.50	0.79	7.24	1.27
0.64	29.37	4.019	7.31	7.86	0.91	7.56	1.47
0.72	36.18	4.637	7.80	8.22	1.02	7.88	1.67
0.80	43.67	5.280	8.27	8.58	1.14	8.20	1.86
0.88	51.84	5.949	8.71	8.94	1.26	8.52	2.06
0.96	60.70	6.643	9.14	9.29	1.38	8.84	2.26
1.04	70.27	7.363	9.54	9.65	1.50	9.16	2.46
1.12	80.55	8.109	9.93	10.01	1.61	9.48	2.65
1.20	91.55	8.880	10.31	10.37	1.73	9.80	2.85
1.28	103.3	9.677	10.67	10.72	1.85	10.12	3.05
1.36	115.8	10.50	11.03	11.08	1.97	10.44	3.25
1.44	129.0	11.35	11.37	11.44	2.08	10.76	3.45
1.52	143.0	12.22	11.70	11.80	2.20	11.08	3.65
1.60	157.8	13.12	12.03	12.16	2.32	11.40	3.85
1.68	173.4	14.04	12.35	12.51	2.44	11.72	4.05
1.76	189.8	15.00	12.66	12.87	2.55	12.04	4.25
1.84	207.0	15.97	12.96	13.23	2.67	12.36	4.45
1.92	225.1	16.97	13.26	13.59	2.79	12.68	4.65
2.00	244.0	18.00	13.55	13.94	2.90	13.00	4.86
2.08	263.7	19.05	13.84	14.30	3.02	13.32	5.06
2.16	284.3	20.13	14.12	14.66	3.14	13.64	5.26
2.24	305.8	21.24	14.40	15.02	3.26	13.96	5.46
2.32	328.2	22.36	14.68	15.38	3.37	14.28	5.67
2.40	351.5	23.52	14.95	15.73	3.49	14.60	5.87
2.48	375.8	24.70	15.21	16.09	3.61	14.92	6.08
2.56	400.9	25.91	15.48	16.45	3.73	15.24	6.28
2.64	427.1	27.14	15.74	16.81	3.85	15.56	6.49
2.72	454.1	28.40	15.99	17.16	3.96	15.88	6.70
2.80	482.2	29.68	16.25	17.52	4.00	16.20	6.90
2.88	511.2	30.99	16.50	17.88	4.00	16.52	7.11
2.96	541.2	32.32	16.74	18.24	4.00	16.84	7.32
3.04	572.2	33.68	16.99	18.60	4.00	17.16	7.53
3.12	604.3	35.07	17.23	18.95	4.00	17.48	7.74
3.20	637.4	36.48	17.47	19.31	4.00	17.80	7.95
3.28	671.5	37.92	17.71	19.67	4.00	18.12	8.16
3.36	706.7	39.38	17.95	20.03	4.00	18.44	8.37
3.44	742.9	40.87	18.18	20.38	4.00	18.76	8.58
3.52	780.2	42.38	18.41	20.74	4.00	19.08	8.79

Depth	Q	Area	Veloc	Wp	Yc	TopWidth	Energy
(ft)	(cfs)	(sqft)	(ft/s)	(ft)	(ft)	(ft)	(ft)
3.60	818.7	43.92	18.64	21.10	4.00	19.40	9.00
3.68	858.2	45.48	18.87	21.46	4.00	19.72	9.21
3.76	898.8	47.08	19.09	21.82	4.00	20.04	9.43
3.84	940.6	48.69	19.32	22.17	4.00	20.36	9.64
3.92	983.5	50.33	19.54	22.53	4.00	20.68	9.86
4.00	1,028	52.00	19.76	22.89	4.00	21.00	10.07