CulvertCo.
Engineering Firm

11/23/2020

Report

Summit Residential Neighbourhood Earthen Channel/Culvert re-assessment

Sarah Ashkanani- Sa2262@nau.edu
Talal Alameeri- Tra68@nau.edu
Abdullah Alrefaei- Aa3659@nau.edu

Table of Contents

List of Figures

List of Tables

List of Equations

List of Abbreviation

HEC-HMS	Hydrologic engineering centre- Hydrologic Modelling System
AutoCAD	Automatical Computer Aided Design
ArcGIS	Aeronautical Reconnaissance Coverage Geography Info System
CP	Concentration Point
Tc	Time of Concentration
T_t	Travel Time (sheet flow)
n	Manning's Coefficient
L	Flow Length
S	Slope
V	Velocity
r	Radius
CFSMDM	City of Flagstaff Storm Water Management Design Manual
NOAA	National Oceanic and Atmospheric Administration
CMP	Corrugated metal pipe
V	Average velocity of flow, ft/s
g	Acceleration due to gravity (32.2 ft/sec^2)
R	Hydraulic radius
HDPE	High density polyethylene

Acknowledgments

The Team would like to acknowledge our Grader, Technical Advisor and Client Mark Lamer, For all his help and guidance toward this project.

1.0 Project Introduction

The earthen channel located in the summit residential neighbourhood along Pullam Rd in flagstaff is experiencing stability and slope issues. During high flows, debris forms within the channel and causes water to overtop the culvert and due to sedimentation issues, which the 24-inch CMP single pipe is experiencing, the water exits the culvert rapidly causing erosion and floods the backyard of the homeowners located along South Pullam drive. One of the homeowner's backyard is subjected to movement as their backyard's bottom portion is moving towards the channel. The channel was reassessed, and a storm design was built.

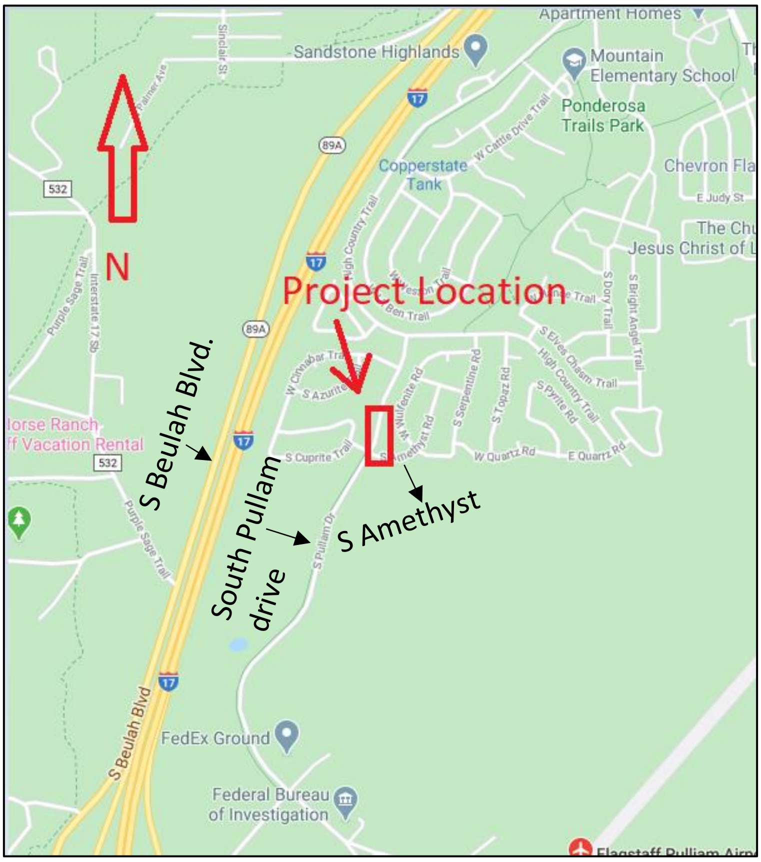


Figure 1. 1:Area of Interest[1].

The area of interest is located around a residential neighbourhood along south Pullam drive in the city of Flagstaff, Arizona as shown in figure 1.1. Displayed on figure 1.2 is the culvert which is located under south Amethyst road which allows water to flow through the culvert under south pullman drive. During the storm, the water overtops the culvert that is located under south Amethyst road and exits the culvert extremely fast causing floods in the backyard of the three houses. The team built a storm drain design to drain the excess rainwater and groundwater from the South Pulliam drive sidewalk along the open channel.

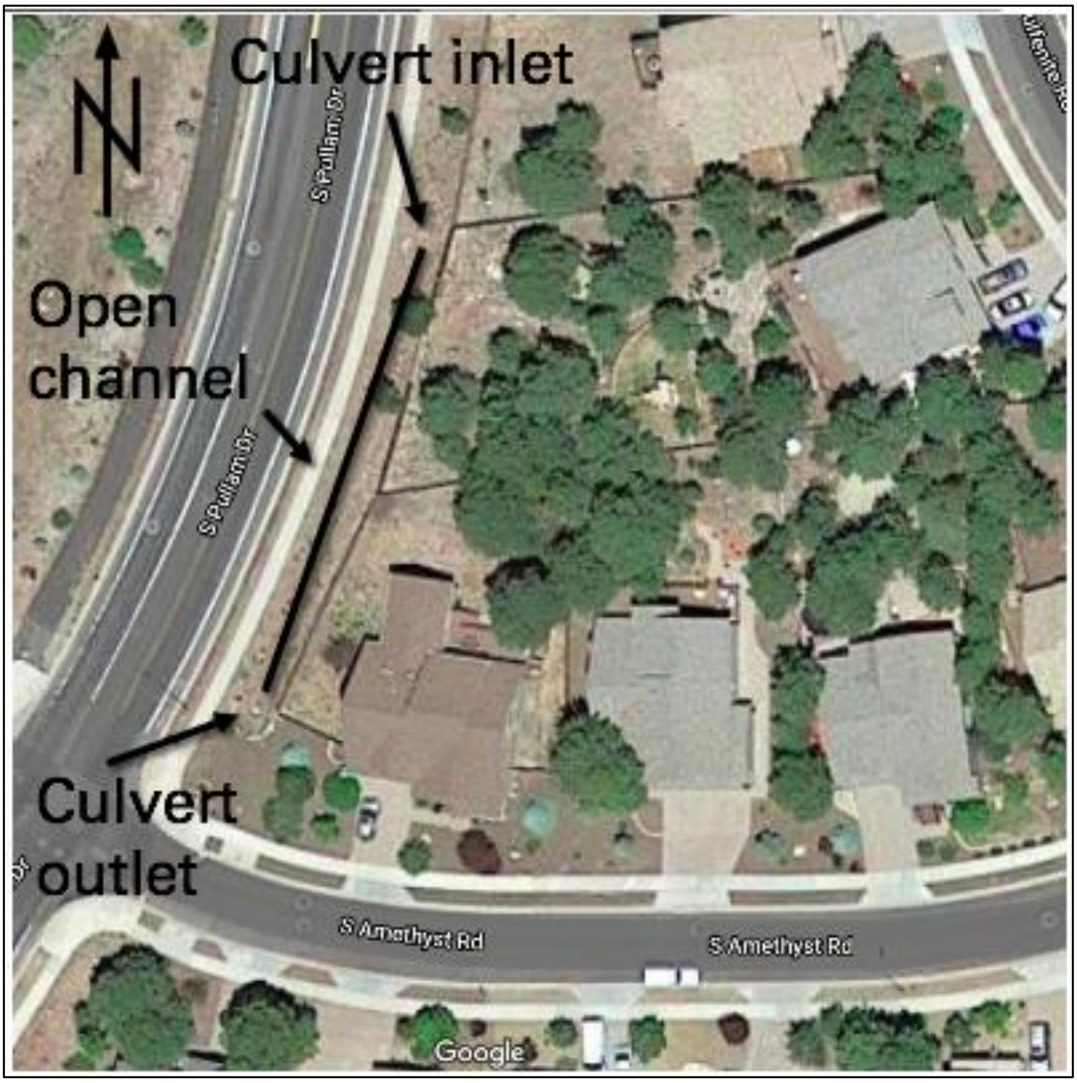


Figure 1. 2:Aerial View of Project Site [2].

2.0 Site Investigation

2.1. Site Visit

The team visited the site on February 7 2020 and gathered a better understanding on the condition of the earthen channel. However, due to the COVID-19 pandemic, in person site visit was no longer an option therefore, the team had to use google earth to identify the current condition of the channel and notify every natural and man-made feature that was used in the hydrology analysis. The soil along the channel was determined to be a mixture of clay and loam. Shortgrass prairie was found between CP5 and CP7 as shown in figure 2.1 Two trees are found between CP5 and 7.

Figure 2. 1 Concentration point Within the open channel [2

The outlet culvert at CP5 shown in figure 2.2 has a wing wall of 45 degrees and a headwall of approximately 2 feet. Medium to large rocks surrounds the culvert outlet at CP5. As Shown in figure 2.3 The culvert inlet that runs under South Pulliam drive at the major concentration point 6 has similar properties to the outlet culvert at CP5.

Figure 2. 3: Open Channel Outlet

Figure 2. 2: Inlet Under Pulliam Dr

2.2 Existing Infrastructure

Table 2. 1: Summary of Culverts Type and Dimensions

Reach No.	Culverts	Dimensions(ft)
Reach 1	CMP Single barrel	2
Reach 2	CMP Single barrel	2
Reach 3	CMP Single barrel	2
Reach 4	CMP Single barrel	2

Figure 2. 4: Aerial image of Earthen channel with reaches identified [3].

Reaches were identified in google earth shown in figure 2.4 above. Reach 1 is an open channel that collects water from the backyard of one of the neighbour's house. Reach 2 starts from an open channel and goes underground through south Amethyst road to the main open channel that was re-assessed and enters an inlet that goes under south Pullam drive. Reach 4 flows under wulfenite road to the main channel and gets collected in the inlet at reach 3. Table 2.1 shows a summary of each reach with its corresponding culvert style, material and dimension.

2.3 Land Survey and Data Processing

The initial plan was to survey the whole area along the channel to collect accurate elevation data points that would be needed to develop a topographic map of the area. However, due to the COVID-19 pandemic, the city of Flagstaff provided the lidar contours data which was collected in 2013 along with the site features.

2.4 Topographic Map

Contours data along with important site features such as roads, buildings, stream reaches, sewer gravity, trails, sewer manholes and water hydrants were extracted from the city of flagstaff GIS map using Arcmap software and was imported into Civil 3D software. The topographic map was then created in Civil 3D software and can be found in appendix-A. The aerial image used that overlays the contours and site features was extracted from google earth.

3.0 Hydrologic Data Derivation

3.1 Major-Basin Delineation

Major basin was delineated using the topographic map obtained from the previous task 2.4. The watershed area was estimated to be 11.8 acers in AutoCAD software which contributes to our channel. This was performed by identifying the high elevation points and following the contours uphill, those high elevation points were then connected to each other and the area was highlighted in yellow (figure 3.1). The concentration point of the major basin was identified as CP6 as a red circle in figure 3.1 below. The major basin contains a total of 7 sub-basins those were created and drawn in AutoCAD software. A fill size map of the major basin can be found in appendix

Figure 3. 1: Major basin Delineation

3.1.1 Sub-Basin & Tc Path Delineation

The sub basin was defined using AutoCAD software with separate concentration points. Sub-basin was defined by terrain type based on the aerial image (google earth) of the watershed area. Each sub-basin is within the major basin split based on similar watershed characteristics with similar drainage rates. The Tc path for each sub-basin was then delineated in AutoCAD by drawing polylines that go downhill to the CP. Time of concentration is known as the time it takes for water to flow from a remote point within a watershed to its concentration/outlet point. Figure 3.2 below shows the results of the sub-basin and TC path delineation.

Figure 3. 2: Sub-Basin and Tc Path

3.1.2 Tc Calculation

Using equations listed in the City of Flagstaff Stormwater design manual [3], the time of concentration was then calculated in an excel file (appendix B). Each time of concentration path was split into parts depending on the type of flow I.e. sheet flow, shallow concentrated flow, street gutter flow and open channel flow. Manning's "n" value for the calculation of sheet flow was used using table 3-3 in appendix C. The break command in AutoCAD was used to split each of the time of concentration path depending on its flow type and was calculated with respect to City of Flagstaff Stormwater Management Design Manual using the following equations:

Equation3. 1: Sheet Flow Travel Time [4]

$$T_t = [0.0007 * (nL)^{0.8} / (2.0)^{0.5} * S^{0.4}]$$

Equation3. 2: Shallow Concentration Flow Unpaved [4]

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

Equation3. 3: Shallow Concentration Flow Paved [4]

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

Equation3. 4: Open Channel Flow[4]

$$V = \frac{1.49 * r^{\frac{2}{3}} * s^{\frac{1}{2}}}{n}$$

Equation3. 5: Street Gutter Flow for 6" Gutter Diameter [4]

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

Equation3. 6: Time of Concentration [4]

$$Tc = L/V$$

Table 3.1 below shows a summary of time of concentration value for each sub-basin. The detailed calculation for each sub-basin that corresponds to the different flow types are shown as tables in appendix-C. Sub-basin information includes area and weighted c values were used in the time of concentration calculation and is shown in appendix-C.

Table 3. 1: Summary of Tc Values

Sub-Basin	Tc(min)
SB1	5.141567
SB2	0.915438
SB3	1.593108
SB4	2.031671
SB5	0.382488
SB6	0.241421

3.1.2.1 Weighted Curve Number Development

Using the runoff coefficients by surface type in table 3-4 and table 3-5 in appendix B, a weighted runoff coefficient value was calculated for different surface types. This was based on different surface type within each sub-basin. The weighted runoff coefficient is the average of all runoff coefficient by surface type depending on the land use, slope and soil type. Equation 3.9 was used to perform this calculation. The summary results of this is given in table3.2 below.

Table 3. 2: Summary of Weighted C

Sub-Basin	Weighted C
SB1	0.14
SB2	0.51
SB3	0.50
SB4	0.24
SB5	0.40
SB6	0.49

The City of Flagstaff Stormwater Design Manual recommended the calculation for the 50- and 100-years storm event within a storm design therefore, runoff value for each sub-basin was calculated in table 3.3 for the 50 years and table 3.4 for the 100 years storm event. Precipitation factor (Cf) was taken from the City of Flagstaff Stormwater Design Manual [4]. Data for partial duration precipitation intensity (i) was collected from NOA Atlas 14 website [5].

Table 3. 3: 50 Years Storm Event

Sub-Basin	Cf	C	Tc	i (in/hr)	A (acres)	Q (cfs)
SB1	1.2	0.14	5.14	7.43	2.997137	**3.60753392**
SB2	1.2	0.51	0.92	7.43	2.609182	**11.9555453**
SB3	1.2	0.50	1.59	7.43	0.722164	**3.19425753**
SB4	1.2	0.24	2.03	7.43	0.434954	**0.9145782**
SB5	1.2	0.40	0.38	7.43	1.300637	**4.62086739**
SB6	1.2	0.49	0.24	7.43	0.847002	**3.68207334**
					Total	**27.9748557**

Table 3. 4: 100 Years Storm Event

Sub-Basin	Cf	C	i (in/hr)	A (acres)	Q (cfs)
SB1	1.25	0.14	8.6	2.997137	**4.349595**
SB2	1.25	0.51	8.6	2.609182	**14.41477**
SB3	1.25	0.50	8.6	0.722164	**3.851309**
SB4	1.25	0.24	8.6	0.434954	**1.102705**
SB5	1.25	0.40	8.6	1.300637	**5.571369**
SB6	1.25	0.49	8.6	0.847002	**4.439467**
				Total	**33.72922**

3.2 HEC-HMS Model

3.2.1 Model Setup

A new basin model was created using HEC-HMS software. Each sub-basin was added in the basin model and connected with reaches that corresponds to our flow network. Data corresponding with each sub-basin such as area, curve number, impervious surface%, and lag time was input for each sub-basin. Downstream direction was also indicated for each sub-basin that corresponds to the reach number. Data for reaches was also input for each reach number. The basin-module setup is shown in appendix-D.

After Finalizing the basin module, a Metrologic model was created to derive the hydrologic simulation. The Metrologic method was created using HEC-HMS software in the Metrologic model manager tap. All sub-basins were added in the Metrologic model. Storm duration, and precipitation intensity duration was specified for our project location Flagstaff Arizona using NOAA Atlas 14 precipitation frequency data table [5].

A control specification model was then created for a specific time period. This will tell HEC-HMS how long the simulation will last. We chose the first simulation to start on January 1st, 2020 and end on January 3rd, 2020 as shown in appendix-D. A time interval of 15 minutes was used for the simulation to make sure we account for all the flow that is coming to our major outlet from the storm event. A simulation run was created, and all the models was used in this run. Using the results tap, a global summary table was obtained which contains peak discharge and volume for the entire model. The global summary table can be found in appendix-D for 10 years, 50 years and 100 years storm events. Table 3.5 below shows the summary results of total discharge for each storm event.

Table 3. 5: Total Discharge Summary For 3 Storm Event

Storm Event:	Peak discharge (Cfs):
100 year storm	36.4
50 year storm	28.4
10 year storm	16.9

3.2.2 Unit Hydrograph

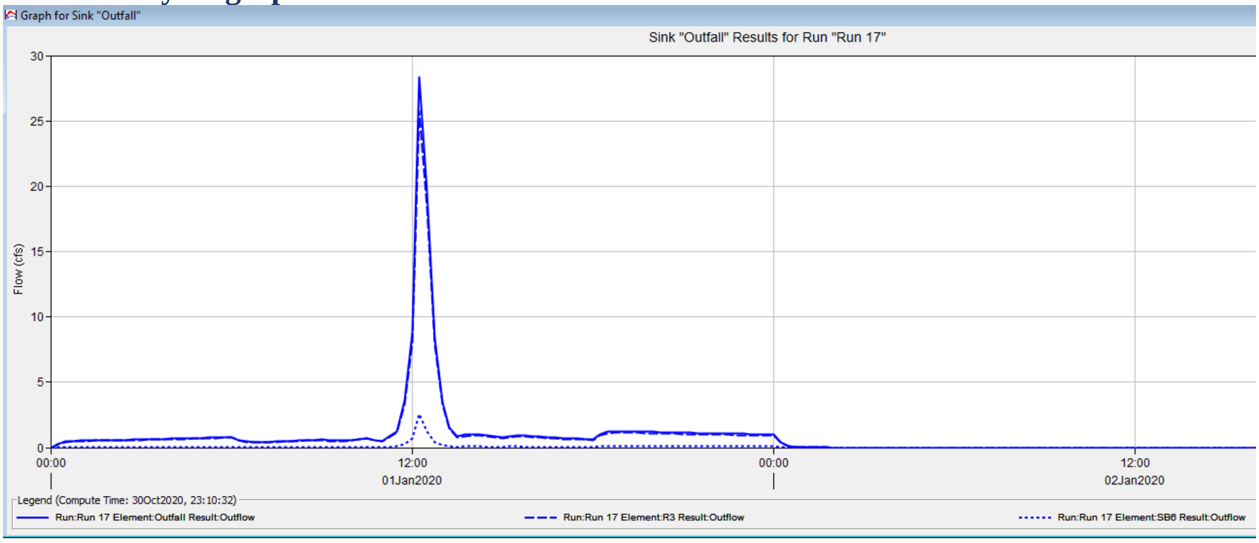


Figure 3. 3:Unit Hydrograph for 50 Yr Storm Event

A unit hydrograph was derived for the outfall which is the total discharge vs time for the whole watershed. As shown in figure 3.4 below, the peak flow for 50 storm event was determined to be approximately 28.4 Cfs and happened around 12:15 pm

3.2.3 Model Optimization

The model was optimized by reviewing the results given in the simulation. After revising the 30% milestones, the flow in HEC-HMS seemed very low due to wrong units of area. This was fixed and the results seems acceptable by comparing the results from HEC-HMS to the rational method. Table 3.6 below shows the summary comparison of the results found in HEC-HMS and Rational Method for peak discharge.

Table 3. 6:Comparison of HEC-HMS and Rational Method Peak Discharges

Storm event	HEC-HMS	Rational Method
100-year storm Discharge (cfs)	36.4	33.7
50-year storm Discharge (cfs)	28.4	27.9
10-year storm Discharge (cfs)	16.9	15.9

4.0 Hydraulic Analysis

4.1 Existing and Proposed Design

Bentley Flow and CulvertMaster software's were used to obtain values that are necessary to re-asses our channel. FlowMaster program was used to solve for normal depth and discharge velocity to ensure that the channel can handle the flow. CulvertMaster software was used to solve for discharge, control type and headwater depth.

4.1.1 CulvertMaster Program
From existing culvert information obtained from the hydrology section, data was inserted in Bentley CulvertMaster program for culvert 1 at CP 5. Those values were, culvert material, diameter, inlet type, length, upstream invert, and downstream invert. The same analysis was then conducted for our major CP6 culvert 2. Flow Runoff of water were obtained, those results can be found in appendix-E. Graphs below shows the results for headwater elevation vs discharge for both culverts.

4.1.2 FlowMaster Model
Existing open channel data was inserted in Bentley FlowMaster software to solve for normal depth and discharge velocity. The data inserted were, roughness coefficient, channel slope, discharge and station along with elevation data for two cross section those were river station 95 and river station 115. The cross sections were preformed using contours from the topographic map shown in appendix-F. Two different discharge were used that were obtained from HEC-HMS modeling Task 3.2, those were the 100-year storm event, and 50-year storm event. Results obtained were checked for 50 year and 100-year storm events. The results obtained can be found in appendix-F.

Proposed open channel data was inserted in Bentley FlowMaster software to solve for pipe diameter for the three pipe materials that was chosen for the alternative storm drain designs based on the 50 years peak discharge. The three pipe materials that were analyzed in Bentley FlowMaster software was smooth wall HDPE, concrete pipe, and corrugated metal pipe. Results for each pipe material can be found in appendix-F.

4.2 Alternatives Designs
Three storm drain design alternatives were analyzed and considered in a decision matrix based on client preference. The three alternatives consist of two parallel pipe designs and one single series pipe as described below. The plan view for each alternative design is shown in appendix-H.

4.2.1 Double 18" smooth wall HDPE pipes
The selection of pipe diameter was based on the 50 years storm. The FlowMaster results for the smooth wall pipe (see appendix F-7) required a diameter of at least 33.7" to handle the 50-year storm event therefore, discharge is divided by two parallel 18" pipes with n value of 0.011 for whole drainage. The two parallel pipes are connected along the existing channel through the CMP culverts.

The current average channel depth is about 3 feet which leaves us with 1.5 feet for the allowable cover. The minimum allowable cover based on the city of flagstaff storm design manual for the HDPE should be one pipe diameter which is 18" and satisfies the requirement. Joints for the HDPE will be spigot type and elastomeric gaskets that will provide a watertight connection between the joints.[4] An excel spreadsheet was used to select the design diameter of the pipe based on the 50 years storm event, the detailed calculation can be shown in appendix-G.

4.2.2 Double 18" reinforced Concrete pipes

The second alternative was similar to the previous one but with two parallel 18" reinforced concrete pipes with an n value of 0.013. The FlowMaster results for the concrete pipe (see appendix F-8) based on the 50 year storm event required a 35.9 inches of diameter therefore, the double concrete pipes is able to handle the peak discharge of 28.4 cfs.
The minimum allowable cover for the concrete pipe is 1 foot and the existing channel has more than enough depth to satisfy the requirement. Bell and spigot ends with O-ring rubber gaskets joints is used to connect the concrete pipes. An excel spreadsheet was used to select the design diameter of the pipe based on the 50 years storm event, the detailed calculation can be shown in appendix-G.

4.2.3 Single 48" Corrugated metal pipes

The third alternative is a single series 48" corrugated metal pipe with n value of 0.024 storm drain. The FlowMaster results for the CMP required a diameter of 58.9 inches and the next available pipe diameter to handle the 50 years storm peak discharge is 48". Since the average existing channel depth is at 3 feet, digging is required to install the 48" corrugated metal pipes. In addition, the current culverts that is within the channel must be replaced to connect the culverts to the storm drain which is very expensive compared to the other alternatives since it requires a lot of work. An excel spreadsheet was used to select the design diameter of the pipe based on the 50 years storm event, the detailed calculation can be shown in appendix- G.

4.3 Decision Matrix

A decision matrix was created to select the best design based on four different criteria's those were, cost of design, efficiency of design, maintenance, and client preference. A score from 1-5 was given for each criteria with 1 being poor and 5 being best as displayed in table 4.1. The cheapest material of pipe is the HDPE pipes at $16.5 per ft hence they were given a 5 in the decision matrix. The concrete pipes are the second cheapest material but almost double the price of the HDPE pipes at $30.5 per ft. The most expensive pipe material is the CMP at $50 per ft. The HDPE pipe is the most efficient material to handle the peak discharge due to the significantly low roughness coefficient value of 0.011. The concrete pipe has a roughness coefficient of 0.013. Even though the CMP has a very high roughness coefficient of 0.024, it was given a rating of 4 similar to the concrete pipes due to the large diameter which can handle up to the 100 year storm event discharge. According to the flagstaff storm design manual, the HDPE has a service life of 75 years highest than the other alternatives at 50 years.[4]

Table 4. 1 Summary of Decision Matrix

Criteria	Double 18” smooth wall HDPE pipes	Double 18” reinforced Concrete pipes	Single 48” Corrugated metal pipes
Material cost per ft	$16.5	$30.5	$50
Construction cost	4	3	1
Material cost	5	3	2
Efficiency of design	5	4	4
Maintenance cost	4	3	3
Client preference	5	4	3
Total	23	17	13

4.4 Final Design

Based on the decision matrix and client preference, the team selected the final design to be a double 18” smooth wall HDPE parallel pipes storm drain. The storm drain is designed based on the 50-year storm event and checked for the 100-year storm event. The cross section of the final storm drain design is shown in Appendix H-4.

4.3.1 Connecting design through existing CMP

Spigot type and elastomeric gaskets joints is used to connect the existing CMP with the storm drain design.[4]

5.0 Final Design Recommendation

The smooth wall HDPE parallel pipes were chosen as the final design. This design consists of two parallel HDPE pipes with a diameter of 18” in which the flow is split along those two pipes. To benefit from the very low n value of 0.011, the HDPE pipe was selected as the material since it can handle the flow more efficiently compared to the other alternatives. This is why it was given a rating of 5 in the decision matrix for the efficiency of design. The HDPE pipes has a service life span of 75 years thus it was given a score of 4 for maintenance cost. The FlowMaster results suggests that the double HDPE pipes can handle up to a maximum discharge of 40 cfs which is above the 50 years storm event peak discharge and is the best alternative to handle the 100 years storm. HDPE pipes are the cheapest to get compared to the other alternatives therefore, it was given a 5 for material cost in the decision matrix.

5.1 Impacts

5.1.1 Social

The project has a significant social impact for the people living in the Summit residential neighborhood. Adding a storm drain to manage the excess water during storm events will lower the risk of flooding for many homes in the neighborhood specially those who are across the channel. People living across the channel won’t need to worry about property damage. People driving across South Pullam Drive will be able to travel on the road without worries of the road being flooded. The negative impacts of this project mainly come from construction. People living around the channel will experience load noises during construction. Having a construction site along a neighborhood where people live will affect the safety of children and adults living around the area. Those negative impacts are temporary since they will only occur during the construction phase.

5.1.2 Environmental

The project will have great impacts on the environment. Air quality will be affected during construction due to excavation and transportation of materials. The pipe material of the final design is made of plastic therefore, it poses a threat to plants and animals since plastic releases harmful chemical into its surrounding soil. Those negative impacts have minimal effects on the environment and wont effect it significantly. Sedimentation and erosion along the channel will be eliminated therefore, this will help the ability of natural plant growth around the area. Trash and debris from stormwater runoff will be collected into the storm drain and go directly to the sewer system which will increase the pollutants from the area.

5.1.3 Economic

The project will impact the economy in many ways. Since the storm drain will decrease the risk of flood along south Pullam drive, the cost for road maintenance and repairs will decrease as the life of the road will increase. The flood insurance rate for all residence around the neighbourhood will decrease since the flood risk will be significantly decreased. There is a short-term negative impact for the home owners association since they are the ones who will pay for the construction cost however, it will save them a couple of thousands in the long run.

5.2 Cost of Implementing the Design

The total approximate cost for the construction of the Smooth wall 18” HDPE storm design is $17240. This factor depends on the length of pipe, labor, concrete manholes, and sand required to construct the design. The length of pipe was measured to be 525.84 ft and costs $75 per 4.6 feet. The labor required to complete the job was estimated to be 62.5 hours and costs $20 per hours. Construction of concrete manholes costs $6000. The sand required to construct this design was overestimated to be 1052 cubic foot at $35 per 37 cubic foot. The table below shows a breakdown on how the cost was calculated. Prices were based on Arizona department of transportation bid website. [7]

Table 5. 1: Implementing cost Breakdown

Item Description	Item unit	Item unit cost	Item quantity	Total item cost
HDPE 18" pipes (526 ft)	4.6 ft	$75	115	$8,625
Concrete manholes	1	$6,000	1	$6,000
Sand (1052 Cu.ft)	27 Cu.ft	$35	39	$1,365
Labor	1 hour	$20	62.5	$1,250
Total				**$17,240**

6.0 Summary of Engineering Work

The scope of work required multiple changes to be done to perform the tasks for this project. The surveying work was eliminated due to COVID-19 pandemic and the city of flagstaff provided lidar data instead. Site investigation hours were decreased also due to the pandemic since most of the site visits were preformed through google earth. The team also lost one team member therefore, the EIT column was set to 0 hours. The table below show the summary of the originally estimated hours of engineering work compared to the actual engineering work. Appendix I shows a full breakdown of engineering work hours estimated in the proposal and the actual work done for each task and sub-task preformed.

Table 6. 1: Summary of staffing hour

Task	SENG	ENG	EIT	TECH	Final Total	Original Total
1.0 Site Investigation	1.15	10.15	0	10.15	21.45	67
2.0 Hydrology	5	7	0	24	36	78
3.0 Hydraulics	23	21	0	36	80	117
4.0 Impacts	4	7	0	11	23	39
5.0 Plan set	5	7.5	0	22	34..5	49.5
6.0 Deliverables	253	266	0	276	795	132
Total	287.15	319.5	0	379.15	986.2	1483.5

7.0 Summary of Engineering Costs

The table below shows the engineering cost estimated in the original proposal. The total cost was calculated to be $44257.5.

Table 7. 1: Proposal engineering cost breakdown

Personnel	Classification	Hours (hr)	Rate ($/hr)	Cost ($)
	SENG	304	50	$15,200
	ENG	320.5	29	$9294.5
	EIT	431	25	$10775
	TECH	428	21	$8988
Travel				
	Meetings	150 Miles	0.60 $/mile	$90 $
Supplies				
	Surveying Equipment	30 hours	90$/hr.	$2,700$
Total				**$44257.5**

Table 7.2 summarises the total engineering cost for the final project after going through many changes of the scope. Most of the changes was due to the COVID-19 pandemic which limited the travel, site visit and supplies.

Table 7. 2 Final engineering cost breakdown

Personnel	Classification	Hours (hr)	Rate ($/hr)	Cost ($)
	SENG	287.15	50	$14357.5
	ENG	319.5	29	$9265.5
	EIT	0	25	-$
	TECH	379.15	21	$7962.15
Travel	N/A	N/A	N/A	-$
Supplies	N/A	N/A	N/A	-$
Total				**$31585.15**

8.0 Conclusion

Based on Hydraulic and hydrology analysis conducted by the team, three storm drain alternatives were considered to re-asses the channel. The team recommends the final design to be the double 18" smooth wall HDPE storm drain pipes since they were capable in handling the 50 years and 100 years storm events more efficiently than the other. The final design selected by the team was the most efficient and economic option and will approximately cost $19,039.65 to construct.

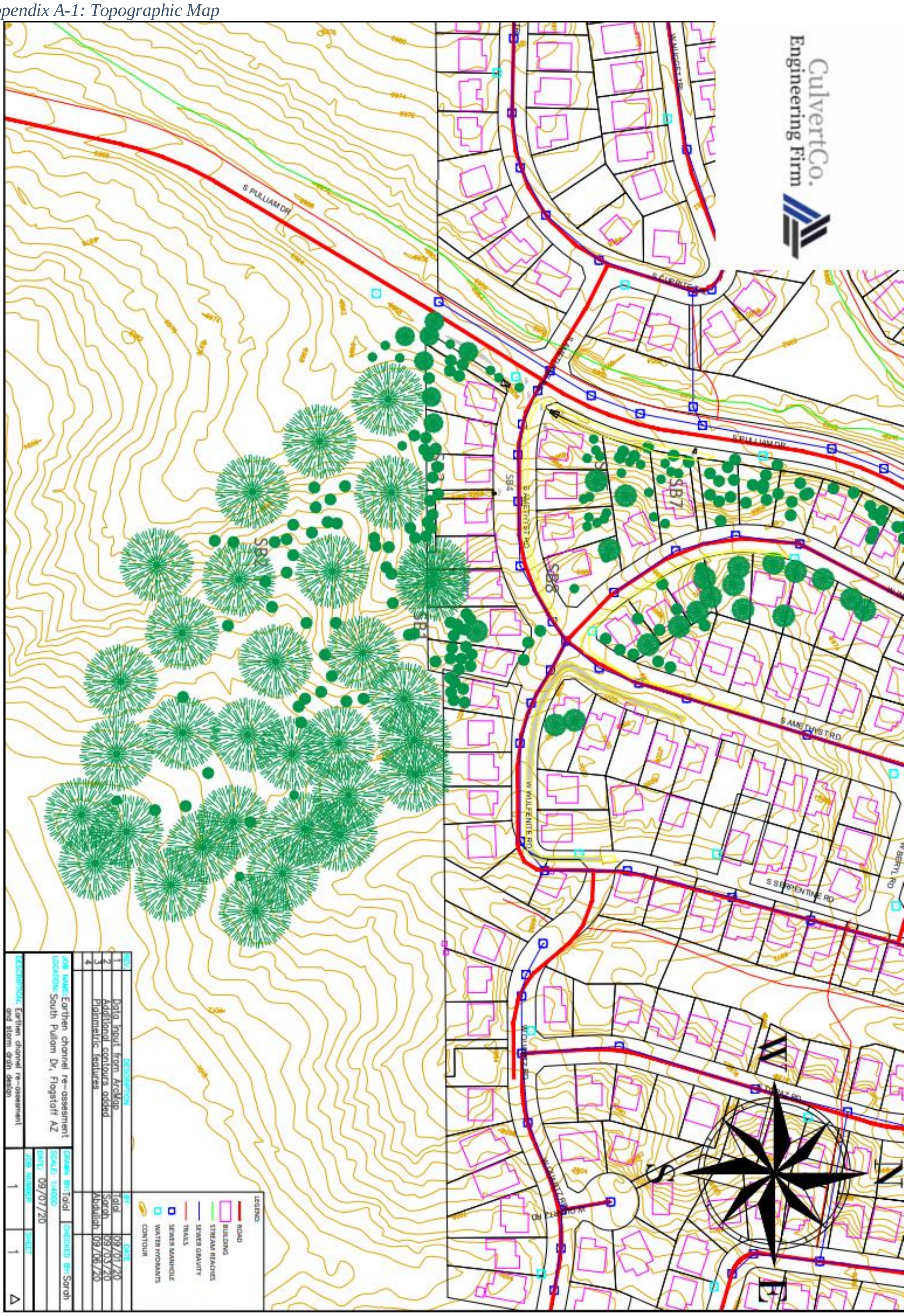
Reference

[1] Google Maps, Google, Flagstaff, AZ, 2020. [Online]. [Accessed: 11-Mar- 2020].
[2] Google Maps, Google, Flagstaff, AZ, 2020. [Online]. [Accessed: 6-Sept- 2020].
[3] Google Earth, *Google*, Flagstaff, AZ, 2020. [Online]. [Accessed: 3-Sept-2020].
[4] Flagstaff.az.gov. 2020. [online] Available at: <https://www.flagstaff.az.gov/DocumentCenter/View/58133/SWMgmtDesignManual-3-09?bidId=> [Accessed 4 September 2020].
[5] "NOAA Atlas 14 Point Precipitation Frequency Estimates: KS," *NOAA Hydrometeorological Design Studies Center*, Apr. 21, 2017. [Online]. Available: https://hdsc.nws.noaa.gov/hdsc/pfds/pfds_map_cont.html. [Accessed: 6-Sept-2020].
[6]. Coconino.az.gov. (2020). [online] Available at: https://coconino.az.gov/DocumentCenter/View/1789/Drainage-Design-Manual_searchable?bidId= [Accessed 25 Feb. 2020].
[7] Apps.azdot.gov. 2020. *E2C2 Historical Unit Price*. [online] Available at: <https://apps.azdot.gov/e2c2/HistoricalPrice.aspx> [Accessed 20 November 2020].

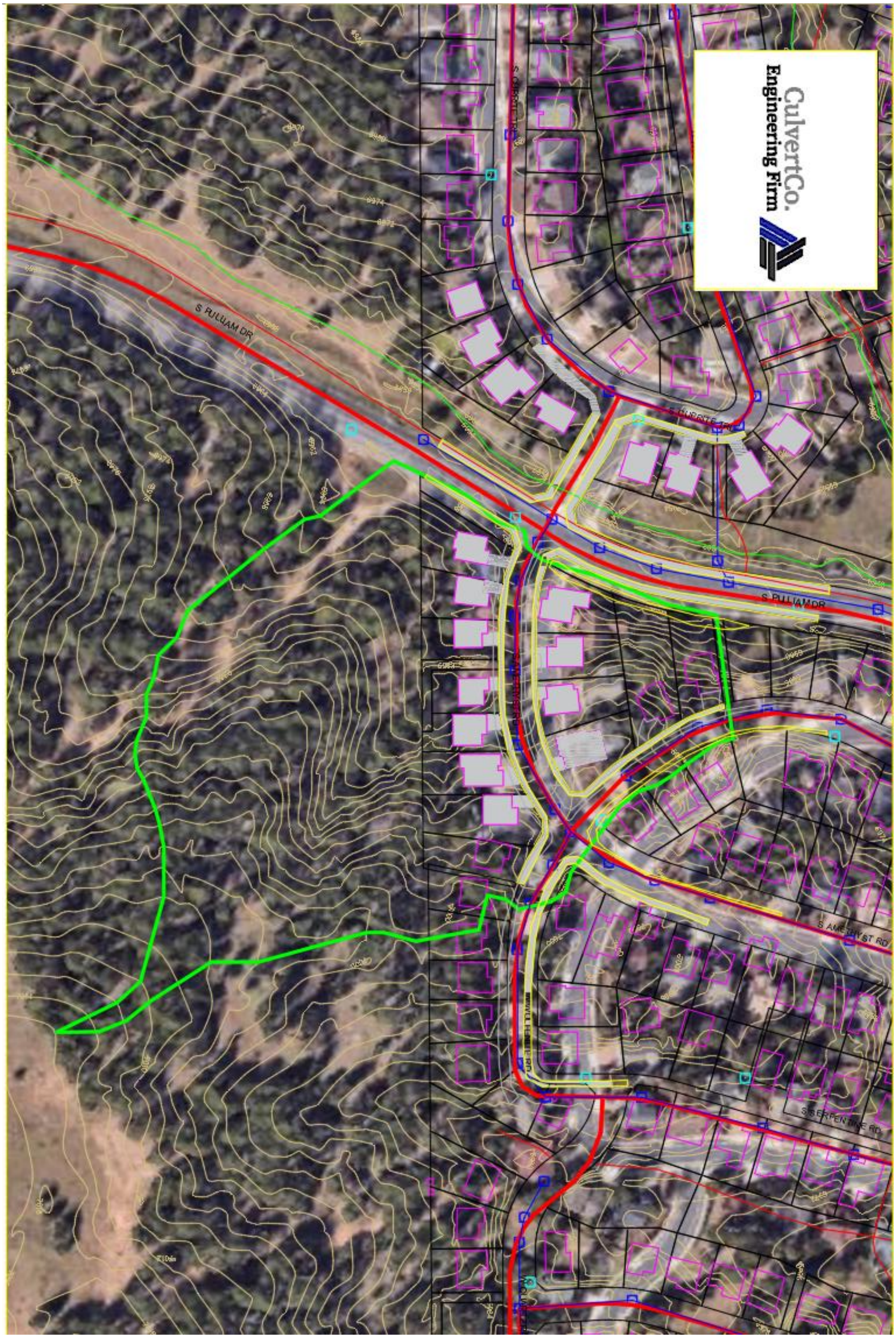
Appendices

Appendix A- Map

Appendix A-1: Topographic Map



Appendix A-2: Major basin



Appendix B- CFSMDM Tables

Appendix B-1: Mannings Values for Sheet [4]

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

Appendix B-2: Runoff Coefficients[4]

TABLE 3-4: RUNOFF COEFFICIENTS (C) BY SURFACE TYPE

Surface Description	**Runoff Coefficients**
Streets	0.95
Asphaltic Concrete	0.95
Concrete	0.95
Brick Pavers	0.90
Compacted ABC roadways/shoulders	0.50 - 0.70
Drives and Sidewalks	0.95
Gravel (open)	0.50
Roofs	0.95

Surface Description	**SLOPE** Flat < 2%	**SLOPE** Avg. 2% - 7%	**SLOPE** Steep > 7%
Lawns			
Sandy Soils	0.10	0.20	0.30
Gravelly Soils	0.15	0.25	0.35
Clay Soils	0.20	0.30	0.40
Dense Vegetation			
Sandy Soils	0.07	0.14	0.20
Gravelly Soils	0.11	0.20	0.27
Clay Soils	0.15	0.25	0.35
Woods			
Sandy Soils	0.05	0.10	0.15
Gravelly Soils	0.07	0.12	0.17
Clay Soils	0.10	0.15	0.20

The coefficients in Table 3-4 are based on the assumption that the design storm does not occur when the surface is frozen. These coefficients are for recurrence intervals less than 25-years, therefore for 25, 50, and 100 year storms, the adjustment factors given in Table 3-1 must be applied to these values. When more than one surface type is present, a composite or weighted runoff coefficient (C_w) value must be used and can be calculated by an area (A) weighted average given in Equation 3.9 below:

$$C_w = (C_1A_1 + C_2A_2 + ... + C_nA_n) / A_{total} \quad (3.9)$$

Appendix B-3: Precipitation Factor [4]

TABLE 3-1: ANTECEDENT PRECIPITATION FACTORS

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

Appendix B-4: NOAA Rainfall Intensity [5]

PF tabular

PDS-based point precipitation frequency estimates with 90% confidence intervals (in inches/hour)[1]

Duration	Average recurrence interval (years)									
	1	2	5	10	25	50	100	200	500	1000
5-min	2.38 (2.11-2.74)	3.10 (2.74-3.54)	4.18 (3.68-4.76)	5.08 (4.43-5.78)	6.36 (5.52-7.21)	7.43 (6.37-8.42)	8.60 (7.27-9.77)	9.86 (8.20-11.2)	11.7 (9.52-13.4)	13.2 (10.6-15.3)
10-min	1.81 (1.60-2.08)	2.36 (2.08-2.69)	3.17 (2.81-3.62)	3.86 (3.37-4.40)	4.84 (4.21-5.49)	5.66 (4.85-6.41)	6.55 (5.54-7.44)	7.50 (6.24-8.52)	8.89 (7.24-10.2)	10.1 (8.05-11.7)
15-min	1.50 (1.32-1.72)	1.95 (1.72-2.23)	2.62 (2.32-3.00)	3.19 (2.78-3.64)	4.00 (3.48-4.54)	4.68 (4.01-5.30)	5.41 (4.58-6.15)	6.20 (5.16-7.04)	7.35 (5.99-8.42)	8.33 (6.65-9.64)
30-min	1.01 (0.892-1.16)	1.31 (1.16-1.50)	1.77 (1.56-2.02)	2.15 (1.87-2.45)	2.70 (2.34-3.06)	3.15 (2.70-3.57)	3.64 (3.08-4.14)	4.18 (3.47-4.74)	4.95 (4.03-5.67)	5.61 (4.48-6.49)
60-min	0.624 (0.552-0.716)	0.812 (0.717-0.928)	1.09 (0.967-1.25)	1.33 (1.16-1.52)	1.67 (1.45-1.89)	1.95 (1.67-2.21)	2.25 (1.91-2.56)	2.58 (2.15-2.94)	3.06 (2.50-3.51)	3.47 (2.77-4.02)
2-hr	0.368 (0.332-0.417)	0.467 (0.418-0.526)	0.616 (0.551-0.694)	0.740 (0.657-0.830)	0.922 (0.810-1.04)	1.07 (0.932-1.21)	1.24 (1.06-1.39)	1.42 (1.20-1.60)	1.68 (1.39-1.92)	1.91 (1.54-2.18)
3-hr	0.269 (0.242-0.304)	0.340 (0.306-0.383)	0.435 (0.391-0.488)	0.517 (0.463-0.581)	0.638 (0.568-0.715)	0.735 (0.646-0.823)	0.843 (0.732-0.948)	0.961 (0.819-1.09)	1.14 (0.950-1.29)	1.29 (1.05-1.47)
6-hr	0.165 (0.151-0.183)	0.204 (0.188-0.226)	0.255 (0.232-0.281)	0.298 (0.271-0.328)	0.360 (0.325-0.396)	0.411 (0.367-0.453)	0.467 (0.412-0.514)	0.527 (0.457-0.581)	0.614 (0.519-0.683)	0.685 (0.569-0.768)
12-hr	0.106 (0.098-0.115)	0.130 (0.121-0.142)	0.160 (0.147-0.174)	0.184 (0.169-0.200)	0.216 (0.198-0.236)	0.242 (0.219-0.263)	0.268 (0.241-0.293)	0.296 (0.263-0.325)	0.334 (0.292-0.369)	0.365 (0.314-0.405)
24-hr	0.072 (0.066-0.078)	0.090 (0.082-0.098)	0.112 (0.102-0.122)	0.129 (0.118-0.141)	0.154 (0.140-0.168)	0.173 (0.157-0.189)	0.194 (0.174-0.211)	0.214 (0.192-0.234)	0.242 (0.215-0.266)	0.265 (0.232-0.291)
2-day	0.043 (0.039-0.047)	0.054 (0.049-0.059)	0.067 (0.061-0.073)	0.078 (0.071-0.085)	0.092 (0.084-0.101)	0.104 (0.094-0.114)	0.116 (0.105-0.127)	0.129 (0.115-0.141)	0.146 (0.129-0.160)	0.160 (0.140-0.176)
3-day	0.031 (0.028-0.034)	0.038 (0.035-0.042)	0.048 (0.044-0.053)	0.056 (0.051-0.061)	0.067 (0.061-0.073)	0.076 (0.069-0.083)	0.085 (0.077-0.093)	0.094 (0.085-0.103)	0.108 (0.095-0.118)	0.118 (0.104-0.130)
4-day	0.025 (0.023-0.027)	0.031 (0.028-0.034)	0.039 (0.035-0.042)	0.045 (0.041-0.049)	0.054 (0.049-0.059)	0.061 (0.056-0.067)	0.069 (0.062-0.075)	0.077 (0.069-0.084)	0.088 (0.078-0.097)	0.098 (0.085-0.107)
7-day	0.017 (0.016-0.018)	0.021 (0.019-0.023)	0.026 (0.024-0.028)	0.030 (0.028-0.033)	0.036 (0.033-0.039)	0.041 (0.037-0.044)	0.046 (0.041-0.050)	0.051 (0.046-0.056)	0.058 (0.052-0.064)	0.064 (0.056-0.070)
10-day	0.013 (0.012-0.015)	0.017 (0.015-0.018)	0.021 (0.019-0.022)	0.024 (0.022-0.026)	0.028 (0.025-0.030)	0.031 (0.028-0.034)	0.034 (0.031-0.037)	0.038 (0.034-0.041)	0.042 (0.038-0.046)	0.046 (0.041-0.050)
20-day	0.009 (0.008-0.010)	0.011 (0.010-0.012)	0.013 (0.012-0.015)	0.015 (0.014-0.016)	0.018 (0.016-0.019)	0.019 (0.018-0.021)	0.021 (0.019-0.023)	0.023 (0.021-0.024)	0.025 (0.023-0.027)	0.026 (0.024-0.029)
30-day	0.007 (0.007-0.008)	0.009 (0.008-0.010)	0.011 (0.010-0.012)	0.012 (0.011-0.013)	0.014 (0.013-0.015)	0.015 (0.014-0.017)	0.017 (0.015-0.018)	0.018 (0.016-0.019)	0.019 (0.018-0.021)	0.021 (0.019-0.022)
45-day	0.006 (0.005-0.006)	0.007 (0.007-0.008)	0.009 (0.008-0.010)	0.010 (0.009-0.011)	0.011 (0.010-0.012)	0.012 (0.011-0.014)	0.014 (0.012-0.015)	0.015 (0.013-0.016)	0.016 (0.014-0.017)	0.017 (0.015-0.019)
60-day	0.005 (0.005-0.006)	0.006 (0.006-0.007)	0.008 (0.007-0.008)	0.009 (0.008-0.009)	0.010 (0.009-0.011)	0.011 (0.010-0.011)	0.011 (0.010-0.012)	0.012 (0.011-0.013)	0.013 (0.012-0.014)	0.014 (0.012-0.015)

[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.

Back to Top

Appendix C- Sub Basin Information

Appendix C-1: Sub-Basin Parameters

Sub-Basin	Area (sq ft)	Area (Acre)	Area (sq mi)	Weighted C
SB1	130555.5	2.997141185	0.004683	0.14
SB2	113638.4	2.608777778	0.0040762	0.51
SB3	31452.46	0.722049128	0.0011282	0.50
SB4	18943.17	0.434875344	0.0006795	0.24
SB5	56645.22	1.300395317	0.0020319	0.40
SB6	36888.88	0.846852158	0.0013232	0.49

Appendix C-2: Sub Basin Shallow Concentrated Flow Data

Street gutter flow								
Sub-Basin	Start Elev	End Elev (ft)	L(ft)	d(ft)	s(ft/ft)	v(ft/s)	Tc(sec)	Tc(min)
SB1	6970	6969	185.79	0.5	0.005382	3.961709	46.89643	0.781607
SB2	7000	6969	648.49	0.5	0.047803	11.80655	54.9263	0.915438
SB3	6970.2	6958	239.43	0.5	0.050954	12.18946	19.64238	0.327373
SB4	6971	6958	206.09	0.5	0.063079	13.56241	15.19567	0.253261
SB5	6988	6956	366.29	0.5	0.087362	15.96086	22.94927	0.382488
SB6	6982	6956	251.5	0.5	0.10338	17.36247	14.48527	0.241421

Appendix C-3: Sub Basin Sheet Flow Data

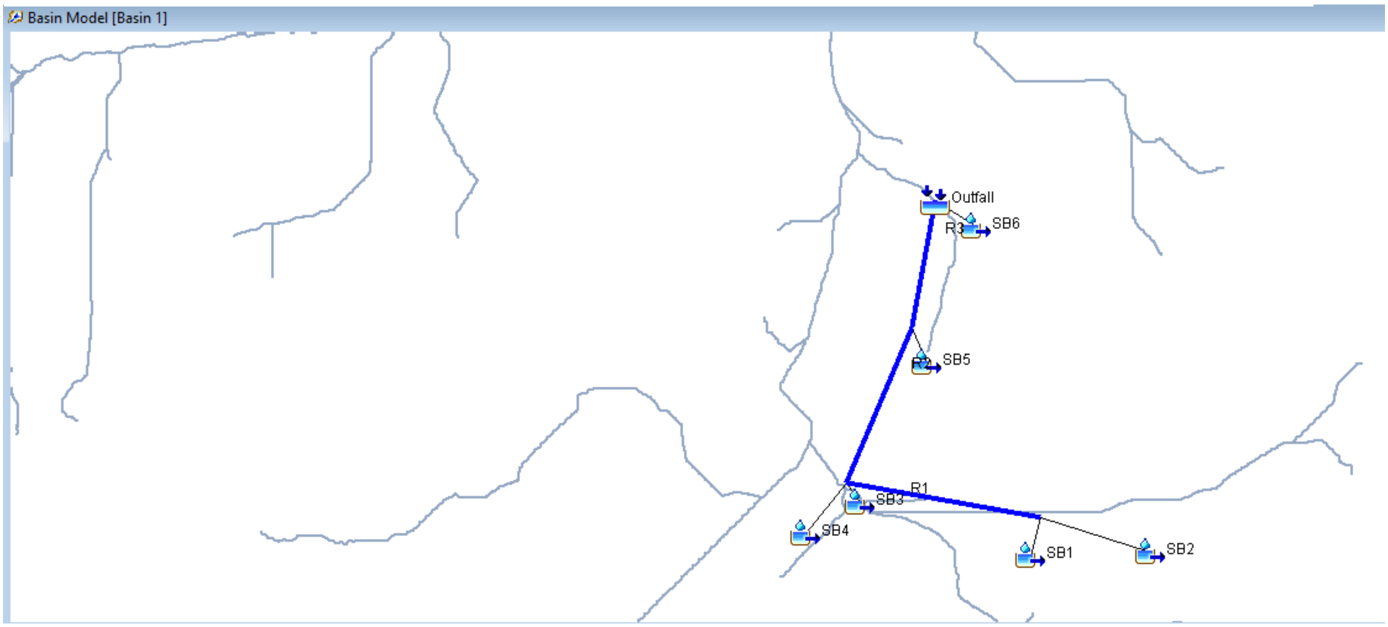
Sheet Flow							
Sub-basin	Start Elev(ft)	End Elev (ft)	n	L(ft)	s (ft/ft)	Tc (hr)	Tc(min)
SB1	7008	6970	0.012	601.77	0.063147	0.072666	4.35996
SB3	6984.5	6970.2	0.012	155	0.092258	0.021096	1.265735
SB4	6984.5	6971	0.012	201.87	0.066875	0.02964	1.77841

Appendix C-4: Runoff Coefficients and Weighted C Value

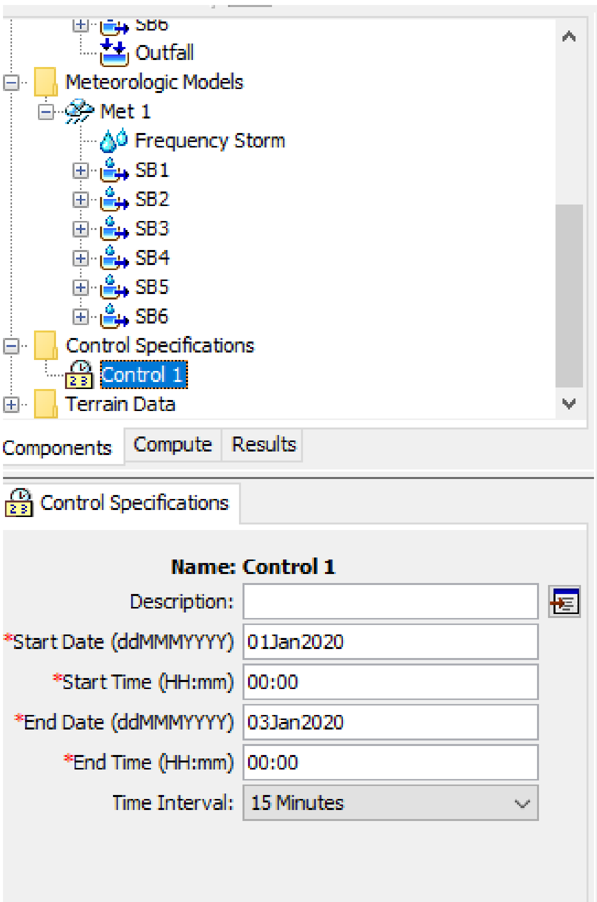
Sub-Basin	**Percentage of Surface Type within Sub-Basin (%)**								**Total Area (Arces)**	**Weighted C**
	Asphaltic Conc	Woods Gravelly Clay Steep	Woods Gravelly Clay Average	Compacted ABC Roadways	Landscaping Flat	Drives and Sidewalks	Dense Vegetation Clay Soils Flat	Roof		
SB1	0%	0%	100%	0%	0%	0%	0%	0%	2.99	0.14
SB2	14%	0%	54%	0%	0%	14%	0%	19%	2.61	0.51
SB3	18%	0%	56%	0%	0%	13%	0%	14%	0.72	0.50
SB4	0%	0%	88%	0%	0%	0%	0%	12%	0.43	0.24
SB5	7%	0%	68%	0%	0%	12%	0%	13%	1.30	0.40
SB6	4%	0%	57%	0%	0%	19%	0%	20%	0.85	0.49
	0.95	0.185	0.135	0.6	0.175	0.95	0.15	0.95		3.17
Runoff Coefficients (C)										

Appendix D- HEC-HMS

Appendix D-1: Basin Model Set up



Appendix D-2: Control Specification Model



Appendix D-3 : Summary result 10 yr storm event

Global Summary Results for Run "Run 3"

Project: project1 Simulation Run: Run 3

Start of Run: 01Jan2020, 00:00 Basin Model: Basin 1
End of Run: 03Jan2020, 00:00 Meteorologic Model: Met 1
Compute Time:05Oct2020, 11:45:29 Control Specifications:Control 1

Show Elements: All Elements Volume Units: ◉ IN ○ ACRE-FT Sorting: Hydrologic

Hydrologic Element	Drainage Area (MI2)	Peak Discharge (CFS)	Time of Peak	Volume (IN)
SB1	0.0046830	10.6	02Jan2020, 00:15	159.14
SB2	0.0040769	4.4	02Jan2020, 00:15	2.38
R1	0.0087599	14.6	02Jan2020, 00:15	86.18
SB3	0.0011282	0.7	02Jan2020, 00:15	1.33
SB4	0.0006795	0.5	02Jan2020, 00:15	1.55
R2	0.0105676	15.2	02Jan2020, 00:15	71.68
SB5	0.0020321	1.8	02Jan2020, 00:15	1.93
R3	0.0125997	16.4	02Jan2020, 00:15	60.43
SB6	0.0013232	0.5	02Jan2020, 00:15	0.82
Outfall	0.0139228	16.9	02Jan2020, 00:15	54.77

Appendix D-4 :Summary result 50 yr storm event

Global Summary Results for Run "Run 8"

Project: project1 Simulation Run: Run 8

Start of Run: 01Jan2020, 00:00 Basin Model: Basin 1
End of Run: 03Jan2020, 00:00 Meteorologic Model: Met 1
Compute Time:05Oct2020, 11:50:37 Control Specifications:Control 1

Show Elements: All Elements Volume Units: ◉ IN ○ ACRE-FT Sorting: Hydrologic

Hydrologic Element	Drainage Area (MI2)	Peak Discharge (CFS)	Time of Peak	Volume (IN)
SB1	0.0046830	19.0	01Jan2020, 12:15	286.27
SB2	0.0040769	6.6	01Jan2020, 12:15	2.69
R1	0.0087599	24.9	01Jan2020, 12:15	154.29
SB3	0.0011282	1.1	01Jan2020, 12:15	1.54
SB4	0.0006795	0.7	01Jan2020, 12:15	1.77
R2	0.0105676	25.9	01Jan2020, 12:15	128.17
SB5	0.0020321	2.7	01Jan2020, 12:15	2.18
R3	0.0125997	27.6	01Jan2020, 12:15	107.85
SB6	0.0013232	0.8	01Jan2020, 12:15	0.96
Outfall	0.0139228	28.4	01Jan2020, 12:15	97.70

Appendix D-5: Summary result 100 yr storm event

Global Summary Results for Run "Run 9"

Project: project1 Simulation Run: Run 9

Start of Run: 01Jan2020, 00:00 Basin Model: Basin 1
End of Run: 03Jan2020, 00:00 Meteorologic Model: Met 1
Compute Time: 05Oct2020, 11:34:12 Control Specifications: Control 1

Show Elements: All Elements Volume Units: IN ACRE-FT Sorting: Hydrologic

Hydrologic Element	Drainage Area (MI2)	Peak Discharge (CFS)	Time of Peak	Volume (IN)
SB1	0.0046830	13.2	01Jan2020, 12:15	191.06
SB2	0.0040762	19.8	01Jan2020, 12:15	222.04
R1	0.0087592	32.2	01Jan2020, 12:15	205.48
SB3	0.0011282	1.3	01Jan2020, 12:15	1.80
SB4	.000679493	0.9	01Jan2020, 12:15	2.04
R2	0.0105669	33.4	01Jan2020, 12:15	170.65
SB5	0.0020319	3.2	01Jan2020, 12:15	2.50
R3	0.0125988	35.5	01Jan2020, 12:15	143.53
SB6	0.0013232	1.0	01Jan2020, 12:15	1.14
Outfall	0.0139220	36.4	01Jan2020, 12:15	130.00

Appendix E- Culvertmaster

Appendix E-1:CulvertMaster results for culvert 1 at CP5

Culvert Analysis Report
Culvert-1

Culvert Summary					
Computed Headwater Eleva	6,959.67	ft	Discharge	8.59	cfs
Inlet Control HW Elev.	6,959.50	ft	Tailwater Elevation	N/A	ft
Outlet Control HW Elev.	6,959.67	ft	Control Type	Entrance Control	
Headwater Depth/Height	0.83				

Grades					
Upstream Invert	6,958.00	ft	Downstream Invert	6,956.00	ft
Length	99.38	ft	Constructed Slope	0.020125	ft/ft

Hydraulic Profile					
Profile	S2		Depth, Downstream	0.99	ft
Slope Type	Steep		Normal Depth	0.99	ft
Flow Regime	Supercritical		Critical Depth	1.05	ft
Velocity Downstream	5.52	ft/s	Critical Slope	0.016952	ft/ft

Section					
Section Shape	Circular		Mannings Coefficient	0.024	
Section Material	CMP		Span	2.00	ft
Section Size	24 inch		Rise	2.00	ft
Number Sections	1				

Outlet Control Properties					
Outlet Control HW Elev.	6,959.67	ft	Upstream Velocity Head	0.42	ft
Ke	0.50		Entrance Loss	0.21	ft

Inlet Control Properties					
Inlet Control HW Elev.	6,959.50	ft	Flow Control	Unsubmerged	
Inlet Type	Headwall		Area Full	3.1	ft²
K	0.00780		HDS 5 Chart	2	
M	2.00000		HDS 5 Scale	1	
C	0.03790		Equation Form	1	
Y	0.69000				

Culvert Analysis Report
Culvert-2

Culvert Summary					
Computed Headwater Eleva	6,959.67	ft	Discharge	19.81	cfs
Inlet Control HW Elev.	6,958.87	ft	Tailwater Elevation	N/A	ft
Outlet Control HW Elev.	6,959.67	ft	Control Type	Outlet Control	
Headwater Depth/Height	1.83				

Grades					
Upstream Invert	6,956.00	ft	Downstream Invert	6,955.00	ft
Length	75.00	ft	Constructed Slope	0.013333	ft/ft

Hydraulic Profile					
Profile	CompositeM2PressureProfile		Depth, Downstream	1.60	ft
Slope Type	Mild		Normal Depth	N/A	ft
Flow Regime	Subcritical		Critical Depth	1.60	ft
Velocity Downstream	7.36	ft/s	Critical Slope	0.027388	ft/ft

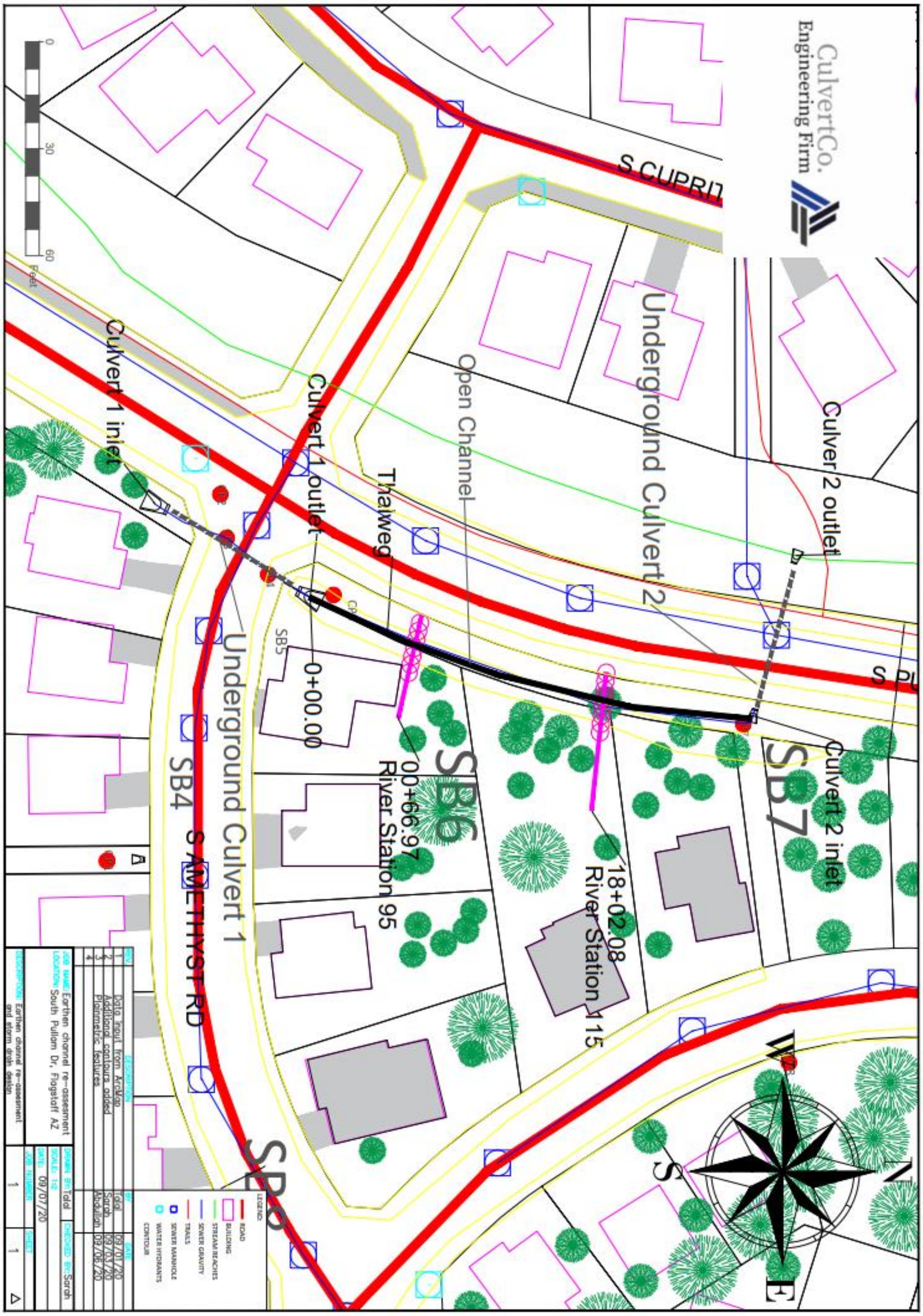
Section					
Section Shape	Circular		Mannings Coefficient	0.024	
Section Material	CMP		Span	2.00	ft
Section Size	24 inch		Rise	2.00	ft
Number Sections	1				

Outlet Control Properties					
Outlet Control HW Elev.	6,959.67	ft	Upstream Velocity Head	0.62	ft
Ke	0.50		Entrance Loss	0.31	ft

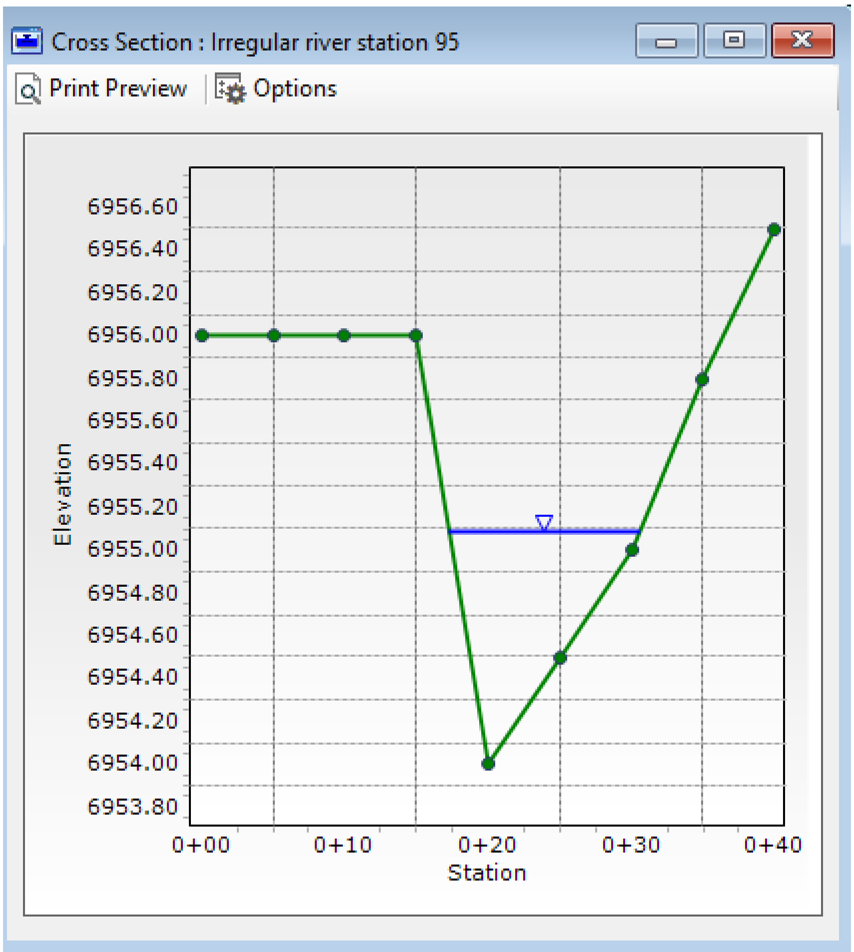
Inlet Control Properties					
Inlet Control HW Elev.	6,958.87	ft	Flow Control	Submerged	
Inlet Type	Headwall		Area Full	3.1	ft²
K	0.00780		HDS 5 Chart	2	
M	2.00000		HDS 5 Scale	1	
C	0.03790		Equation Form	1	
Y	0.69000				

Appendix F- FlowMaster existing and propose

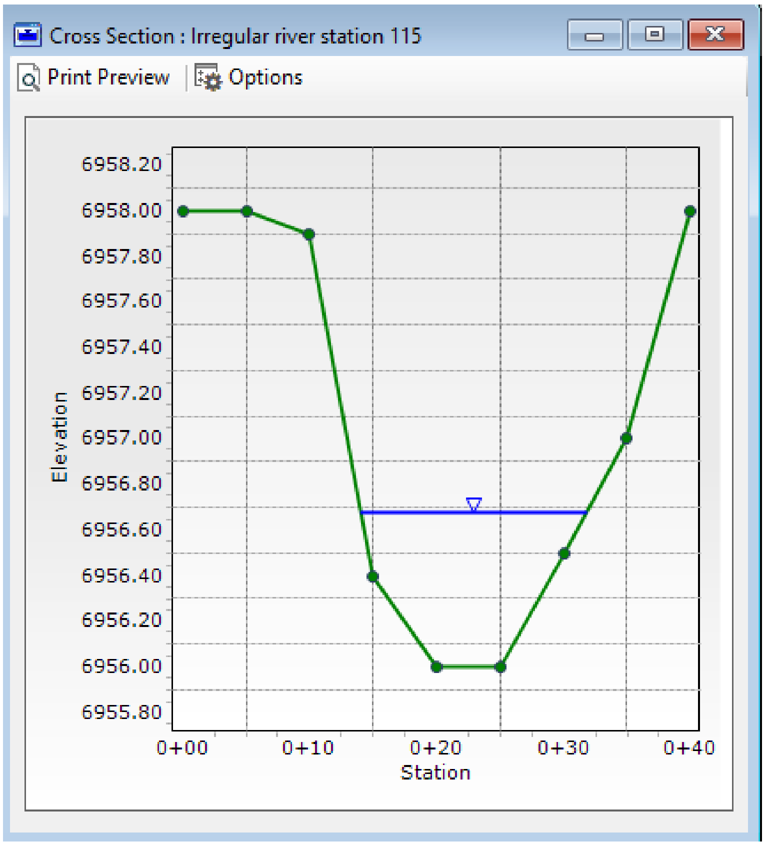
Appendix F-1: Channel of cross section



Appendix F-2: River station 95 Cross section



Appendix F-3::River station 115 Cross section



Appendix F-4: FlowMaster result for existing 50 yr storm for river station 95

Worksheet for existing river station 95 (50 year storm)

Licensed for Academic Use Only

Project Description	
Friction Method	**Manning Formula**
Solve For	**Normal Depth**

Input Data	
Channel Slope	**0.018 ft/ft**
Discharge	**36.40 cfs**

Section Definitions

Station (ft)	Elevation (ft)
0+00	6,956.00
0+05	6,956.00
0+10	6,956.00
0+15	6,956.00
0+20	6,954.00
0+25	6,954.50
0+30	6,955.00
0+35	6,955.80
0+40	6,956.50

Roughness Segment Definitions

Start Station	Ending Station	Roughness Coefficient
(0+00, 6,956.00)	(0+05, 6,956.00)	0.035
(0+05, 6,956.00)	(0+10, 6,956.00)	0.035
(0+10, 6,956.00)	(0+15, 6,956.00)	0.035
(0+15, 6,956.00)	(0+20, 6,954.00)	0.035
(0+20, 6,954.00)	(0+25, 6,954.50)	0.035
(0+25, 6,954.50)	(0+30, 6,955.00)	0.035
(0+30, 6,955.00)	(0+35, 6,955.80)	0.035
(0+35, 6,955.80)	(0+40, 6,956.50)	0.035

Options	
Current Roughness Weighted Method	**Pavlovskii's Method**
Open Channel Weighting Method	**Pavlovskii's Method**
Closed Channel Weighting Method	**Pavlovskii's Method**

Results	
Normal Depth	**14.4 in**
Roughness Coefficient	**0.035**
Elevation	**6,955.20 ft**
Elevation Range	**6,954.0 to 6,956.5 ft**
Flow Area	**8.9 ft²**
Wetted Perimeter	**14.5 ft**
Hydraulic Radius	**7.3 in**

Untitled1.fm8
10/5/2020

Bentley Systems, Inc. Haestad Methods Solution Center
27 Siemon Company Drive Suite 200 W
Watertown, CT 06795 USA +1-203-755-1666
Licensed for Academic Use Only

FlowMaster [10.03.00.03]
Page 1 of 2

Worksheet for existing river station 95 (50 year storm)

Licensed for Academic Use Only

Results	
Top Width	**14.22 ft**
Normal Depth	**14.4 in**
Critical Depth	**13.9 in**
Critical Slope	**0.022 ft/ft**
Velocity	**4.10 ft/s**
Velocity Head	**0.26 ft**
Specific Energy	**1.46 ft**
Froude Number	**0.915**
Flow Type	**Subcritical**

GVF Input Data	
Downstream Depth	**0.0 in**
Length	**0.0 ft**
Number Of Steps	**0**

GVF Output Data	
Upstream Depth	**0.0 in**
Profile Description	**N/A**
Profile Headloss	**0.00 ft**
Downstream Velocity	**0.00 ft/s**
Upstream Velocity	**0.00 ft/s**
Normal Depth	**14.4 in**
Critical Depth	**13.9 in**
Channel Slope	**0.018 ft/ft**
Critical Slope	**0.022 ft/ft**

Appendix F-5 : FlowMaster result for existing 50 yr storm for river station 115

Worksheet for existing river station 115 (50 year storm)

Licensed for Academic Use Only

Project Description

Friction Method	**Manning Formula**
Solve For	**Normal Depth**

Input Data

Channel Slope	**0.018 ft/ft**
Discharge	**28.40 cfs**

Section Definitions

Station (ft)	Elevation (ft)
0+00	6,958.00
0+05	6,958.00
0+10	6,957.90
0+15	6,956.40
0+20	6,956.00
0+25	6,956.00
0+30	6,956.50
0+35	6,957.00
0+40	6,958.00

Roughness Segment Definitions

Start Station	Ending Station	Roughness Coefficient
(0+00, 6,958.00)	(0+05, 6,958.00)	0.035
(0+05, 6,958.00)	(0+10, 6,957.90)	0.035
(0+10, 6,957.90)	(0+15, 6,956.40)	0.035
(0+15, 6,956.40)	(0+20, 6,956.00)	0.035
(0+20, 6,956.00)	(0+25, 6,956.00)	0.035
(0+25, 6,956.00)	(0+30, 6,956.50)	0.035
(0+30, 6,956.50)	(0+35, 6,957.00)	0.035
(0+35, 6,957.00)	(0+40, 6,958.00)	0.035

Options

Current Roughness Weighted Method	**Pavlovskii's Method**
Open Channel Weighting Method	**Pavlovskii's Method**
Closed Channel Weighting Method	**Pavlovskii's Method**

Results

Normal Depth	**8.2 in**
Roughness Coefficient	**0.035**
Elevation	**6,956.68 ft**
Elevation Range	**6,956.0 to 6,958.0 ft**
Flow Area	**8.3 ft²**
Wetted Perimeter	**17.9 ft**
Hydraulic Radius	**5.6 in**

Untitled1.fm8
10/5/2020

Bentley Systems, Inc. Haestad Methods Solution Center
27 Siemon Company Drive Suite 200 W
Watertown, CT 06795 USA +1-203-755-1666
Licensed for Academic Use Only

FlowMaster
[10.03.00.03]
Page 1 of 2

Worksheet for existing river station 115 (50 year storm)

Licensed for Academic Use Only

Results	
Top Width	**17.78 ft**
Normal Depth	**8.2 in**
Critical Depth	**7.7 in**
Critical Slope	**0.024 ft/ft**
Velocity	**3.42 ft/s**
Velocity Head	**0.18 ft**
Specific Energy	**0.87 ft**
Froude Number	**0.882**
Flow Type	**Subcritical**

GVF Input Data	
Downstream Depth	**0.0 in**
Length	**0.0 ft**
Number Of Steps	**0**

GVF Output Data	
Upstream Depth	**0.0 in**
Profile Description	**N/A**
Profile Headloss	**0.00 ft**
Downstream Velocity	**0.00 ft/s**
Upstream Velocity	**0.00 ft/s**
Normal Depth	**8.2 in**
Critical Depth	**7.7 in**
Channel Slope	**0.018 ft/ft**
Critical Slope	**0.024 ft/ft**

Worksheet for existing river station 95 (100 year storm)

Licensed for Academic Use Only

Project Description	
Friction Method	**Manning Formula**
Solve For	**Normal Depth**

Input Data	
Channel Slope	**0.018 ft/ft**
Discharge	**36.40 cfs**

Section Definitions

Station (ft)	Elevation (ft)
0+00	6,956.00
0+05	6,956.00
0+10	6,956.00
0+15	6,956.00
0+20	6,954.00
0+25	6,954.50
0+30	6,955.00
0+35	6,955.80
0+40	6,956.50

Roughness Segment Definitions

Start Station	Ending Station	Roughness Coefficient
(0+00, 6,956.00)	(0+05, 6,956.00)	0.035
(0+05, 6,956.00)	(0+10, 6,956.00)	0.035
(0+10, 6,956.00)	(0+15, 6,956.00)	0.035
(0+15, 6,956.00)	(0+20, 6,954.00)	0.035
(0+20, 6,954.00)	(0+25, 6,954.50)	0.035
(0+25, 6,954.50)	(0+30, 6,955.00)	0.035
(0+30, 6,955.00)	(0+35, 6,955.80)	0.035
(0+35, 6,955.80)	(0+40, 6,956.50)	0.035

Options	
Current Roughness Weighted Method	**Pavlovskii's Method**
Open Channel Weighting Method	**Pavlovskii's Method**
Closed Channel Weighting Method	**Pavlovskii's Method**

Results	
Normal Depth	**14.4 in**
Roughness Coefficient	**0.035**
Elevation	**6,955.20 ft**
Elevation Range	**6,954.0 to 6,956.5 ft**
Flow Area	**8.9 ft²**
Wetted Perimeter	**14.5 ft**
Hydraulic Radius	**7.3 in**

Untitled1.fm8
10/5/2020

Bentley Systems, Inc. Haestad Methods Solution Center
27 Siemon Company Drive Suite 200 W
Watertown, CT 06795 USA +1-203-755-1666
Licensed for Academic Use Only

FlowMaster
[10.03.00.03]
Page 1 of 2

Worksheet for existing river station 95 (100 year storm)

Licensed for Academic Use Only

Results	
Top Width	**14.22 ft**
Normal Depth	**14.4 in**
Critical Depth	**13.9 in**
Critical Slope	**0.022 ft/ft**
Velocity	**4.10 ft/s**
Velocity Head	**0.26 ft**
Specific Energy	**1.46 ft**
Froude Number	**0.915**
Flow Type	**Subcritical**

GVF Input Data	
Downstream Depth	**0.0 in**
Length	**0.0 ft**
Number Of Steps	**0**

GVF Output Data	
Upstream Depth	**0.0 in**
Profile Description	**N/A**
Profile Headloss	**0.00 ft**
Downstream Velocity	**0.00 ft/s**
Upstream Velocity	**0.00 ft/s**
Normal Depth	**14.4 in**
Critical Depth	**13.9 in**
Channel Slope	**0.018 ft/ft**
Critical Slope	**0.022 ft/ft**

Appendix F-7 : FlowMaster result for existing 100 yr storm for river station 115

Worksheet for existing river station 115 (100 year storm)

Licensed for Academic Use Only

Project Description	
Friction Method	**Manning Formula**
Solve For	**Normal Depth**

Input Data	
Channel Slope	**0.018 ft/ft**
Discharge	**36.40 cfs**

Section Definitions

Station (ft)	Elevation (ft)
0+00	6,958.00
0+05	6,958.00
0+10	6,957.90
0+15	6,956.40
0+20	6,956.00
0+25	6,956.00
0+30	6,956.50
0+35	6,957.00
0+40	6,958.00

Roughness Segment Definitions

Start Station	Ending Station	Roughness Coefficient
(0+00, 6,958.00)	(0+05, 6,958.00)	0.035
(0+05, 6,958.00)	(0+10, 6,957.90)	0.035
(0+10, 6,957.90)	(0+15, 6,956.40)	0.035
(0+15, 6,956.40)	(0+20, 6,956.00)	0.035
(0+20, 6,956.00)	(0+25, 6,956.00)	0.035
(0+25, 6,956.00)	(0+30, 6,956.50)	0.035
(0+30, 6,956.50)	(0+35, 6,957.00)	0.035
(0+35, 6,957.00)	(0+40, 6,958.00)	0.035

Options	
Current Roughness Weighted Method	**Pavlovskii's Method**
Open Channel Weighting Method	**Pavlovskii's Method**
Closed Channel Weighting Method	**Pavlovskii's Method**

Results	
Normal Depth	**9.2 in**
Roughness Coefficient	**0.035**
Elevation	**6,956.77 ft**
Elevation Range	**6,956.0 to 6,958.0 ft**
Flow Area	**9.9 ft²**
Wetted Perimeter	**19.0 ft**
Hydraulic Radius	**6.2 in**

Worksheet for existing river station 115 (100 year storm)

Licensed for Academic Use Only

Results	
Top Width	**18.93 ft**
Normal Depth	**9.2 in**
Critical Depth	**8.7 in**
Critical Slope	**0.023 ft/ft**
Velocity	**3.68 ft/s**
Velocity Head	**0.21 ft**
Specific Energy	**0.98 ft**
Froude Number	**0.898**
Flow Type	**Subcritical**

GVF Input Data	
Downstream Depth	**0.0 in**
Length	**0.0 ft**
Number Of Steps	**0**

GVF Output Data	
Upstream Depth	**0.0 in**
Profile Description	**N/A**
Profile Headloss	**0.00 ft**
Downstream Velocity	**0.00 ft/s**
Upstream Velocity	**0.00 ft/s**
Normal Depth	**9.2 in**
Critical Depth	**8.7 in**
Channel Slope	**0.018 ft/ft**
Critical Slope	**0.023 ft/ft**

Appendix F-8 : FlowMaster result for Smooth wall HDPE pipe - 50 yr storm

Smooth Wall HDPE

Licensed for Academic Use Only

Project Description	
Friction Method	Manning Formula
Solve For	Full Flow Diameter

Input Data	
Roughness Coefficient	0.011
Channel Slope	0.002 ft/ft
Normal Depth	33.7 in
Diameter	33.7 in
Discharge	28.00 cfs

Results	
Diameter	33.7 in
Normal Depth	33.7 in
Flow Area	6.2 ft²
Wetted Perimeter	8.8 ft
Hydraulic Radius	8.4 in
Top Width	0.00 ft
Critical Depth	21.0 in
Percent Full	100.0 %
Critical Slope	0.004 ft/ft
Velocity	4.53 ft/s
Velocity Head	0.32 ft
Specific Energy	3.13 ft
Froude Number	(N/A)
Maximum Discharge	30.12 cfs
Discharge Full	28.00 cfs
Slope Full	0.002 ft/ft
Flow Type	Subcritical

GVF Input Data	
Downstream Depth	0.0 in
Length	0.0 ft
Number Of Steps	0

GVF Output Data	
Upstream Depth	0.0 in
Profile Description	N/A
Profile Headloss	0.00 ft
Average End Depth Over Rise	0.0 %
Normal Depth Over Rise	0.0 %
Downstream Velocity	0.00 ft/s
Upstream Velocity	0.00 ft/s
Normal Depth	33.7 in
Critical Depth	21.0 in

Untitled1.fm8
10/30/2020

Bentley Systems, Inc. Haestad Methods Solution Center
27 Siemon Company Drive Suite 200 W
Watertown, CT 06795 USA +1-203-755-1666
Licensed for Academic Use Only

FlowMaster
[10.03.00.03]
Page 1 of 2

Smooth Wall HDPE

Licensed for Academic Use Only

GVF Output Data	
Channel Slope	0.002 ft/ft
Critical Slope	0.004 ft/ft

Appendix F-9 : FlowMaster result for concrete pipe - 50 yr storm

CONCRETE PIPE

Licensed for Academic Use Only

Project Description	
Friction Method	Manning Formula
Solve For	Full Flow Diameter

Input Data	
Roughness Coefficient	0.013
Channel Slope	0.002 ft/ft
Normal Depth	35.9 in
Diameter	35.9 in
Discharge	28.00 cfs

Results	
Diameter	35.9 in
Normal Depth	35.9 in
Flow Area	7.0 ft²
Wetted Perimeter	9.4 ft
Hydraulic Radius	9.0 in
Top Width	0.00 ft
Critical Depth	20.6 in
Percent Full	100.0 %
Critical Slope	0.005 ft/ft
Velocity	3.99 ft/s
Velocity Head	0.25 ft
Specific Energy	3.24 ft
Froude Number	(N/A)
Maximum Discharge	30.12 cfs
Discharge Full	28.00 cfs
Slope Full	0.002 ft/ft
Flow Type	Subcritical

GVF Input Data	
Downstream Depth	0.0 in
Length	0.0 ft
Number Of Steps	0

GVF Output Data	
Upstream Depth	0.0 in
Profile Description	N/A
Profile Headloss	0.00 ft
Average End Depth Over Rise	0.0 %
Normal Depth Over Rise	0.0 %
Downstream Velocity	0.00 ft/s
Upstream Velocity	0.00 ft/s
Normal Depth	35.9 in
Critical Depth	20.6 in

Untitled1.fm8
10/29/2020

Bentley Systems, Inc. Haestad Methods Solution Center
27 Siemon Company Drive Suite 200 W
Watertown, CT 06795 USA +1-203-755-1666
Licensed for Academic Use Only

FlowMaster
[10.03.00.03]
Page 1 of 2

CONCRETE PIPE

Licensed for Academic Use Only

GVF Output Data	
Channel Slope	0.002 ft/ft
Critical Slope	0.005 ft/ft

Corrugated Metal Pipe-0.024
Licensed for Academic Use Only

Project Description	
Friction Method	Manning Formula
Solve For	Channel Diameter

Input Data	
Roughness Coefficient	0.024
Channel Slope	0.002 ft/ft
Normal Depth	29.4 in
Discharge	28.40 cfs

Results	
Diameter	58.9 in
Flow Area	9.4 ft²
Wetted Perimeter	7.7 ft
Hydraulic Radius	14.7 in
Top Width	4.91 ft
Critical Depth	17.8 in
Percent Full	49.9 %
Critical Slope	0.011 ft/ft
Velocity	3.01 ft/s
Velocity Head	0.14 ft
Specific Energy	2.59 ft
Froude Number	0.383
Maximum Discharge	61.38 cfs
Discharge Full	57.06 cfs
Slope Full	0.000 ft/ft
Flow Type	Subcritical

GVF Input Data	
Downstream Depth	0.0 in
Length	0.0 ft
Number Of Steps	0

GVF Output Data	
Upstream Depth	0.0 in
Profile Description	N/A
Profile Headloss	0.00 ft
Average End Depth Over Rise	0.0 %
Normal Depth Over Rise	0.0 %
Downstream Velocity	0.00 ft/s
Upstream Velocity	0.00 ft/s
Normal Depth	29.4 in
Critical Depth	17.8 in
Channel Slope	0.002 ft/ft
Critical Slope	0.011 ft/ft

Untitled1.fm8
10/15/2020

Bentley Systems, Inc. Haestad Methods Solution Center
27 Siemon Company Drive Suite 200 W
Watertown, CT 06795 USA +1-203-755-1666
Licensed for Academic Use Only

FlowMaster
[10.03.00.03]
Page 1 of 1

Appendix G- Diameter selection for alternative design

Appendix G-1: Concrete Pipe

1	2			3	15	10	11	17	12	18	13
Sr No	From manhole to manhole			Length	Storm Water flow						
					Area (ft2)	Area	C	Intensity	Intensity		Q
	Mx	to	Mx	ft		acre			in/h		cusec
1	0	to	1	0	130553.676	2.9971	0.14	3.8773E-06	8.6	0.9923398	1.80425
2	1	to	2	134.61	113652.396	2.6091	0.51	3.8773E-06	8.6	3.146966	5.72176
3	2	to	3	249.189	31459.032	0.7222	0.5	3.8773E-06	8.6	0.8540015	1.55273
4	3	to	4	35.7678	18944.244	0.4349	0.24	3.8773E-06	8.6	0.2468492	0.44882
5	4	to	6	80.6378	56654.136	1.3006	0.4	3.8773E-06	8.6	1.2303676	2.23703
6	5	to	6	25.64	36895.32	0.8470	0.49	3.8773E-06	8.6	0.981546	1.78463

8	9	10	11	12	13	19	20
Design Flow(q)	Design Velocity	Diameter Calculated	Selected Dia	Selected Dia	Discharge flow full(Q_{full})	Slope	Vcheck
cfs	ft/sec	in	in	ft	cfs		ft/sec
1.804254	3	10.50	**0**	0	0.000000	0	0.00000
7.526011	3	10.72	**18**	1.5	5.298750	0.005625	3.00000
9.078741	3	11.78	**18**	1.5	5.298750	0.005625	3.00000
9.527557	3	12.07	**18**	1.5	5.298750	0.005625	3.00000
11.764589	3	13.41	**18**	1.5	5.298750	0.005625	3.00000
13.549218	3	14.39	**18**	1.5	5.298750	0.005625	3.00000

26	27	28	29	30	31	32
Ground Level		Invert Level		Trench Depth		Wall thickness
U/E	D/E	U/E	D/E	U/E	D/E	
6960	6960	6954.956	6954.956	5.04	5.04	0.044
6960	6959.8	6954.956	6954.19888	5.04	5.60	0.044
6959.8	6959.3	6954.1989	6952.79731	5.60	6.50	0.044
6959.3	6959.3	6952.7973	6952.59613	6.50	6.70	0.044
6959.3	6959.2	6952.5961	6952.14258	6.70	7.06	0.044
6959.2	6959.2	6952.1426	6951.99836	7.06	7.20	0.044

Appendix G-2: Corrugated metal pipe (CMP)

1	2			3	15	10	11	17	12	18	13	8
Sr No	From manhole to manhole			Length	Storm Water flow							Design Flow(q)
					Area (ft2)	Area	C	Intensity	Intensity		Q	
	Mx	to	Mx	ft		acre			in/h		cusec	cfs
1	0	to	1	0	130553.676	2.9971	0.14	3.8773E-06	8.6	1.9846796	3.60851	3.608508
2	1	to	2	134.61	113652.396	2.6091	0.51	3.8773E-06	8.6	6.2939319	11.44351	15.052021
3	2	to	3	249.189	31459.032	0.7222	0.5	3.8773E-06	8.6	1.708003	3.10546	18.157481
4	3	to	4	35.7678	18944.244	0.4349	0.24	3.8773E-06	8.6	0.4936985	0.89763	19.055115
5	4	to	6	80.6378	56654.136	1.3006	0.4	3.8773E-06	8.6	2.4607352	4.47406	23.529179
6	5	to	6	25.64	36895.32	0.8470	0.49	3.8773E-06	8.6	1.9630919	3.56926	27.098437

9	10	11	12	13	19	20
Design Velocity	Diameter Calculated	Selected Dia	Selected Dia	Discharge flow full(Q_{full})	Slope	Vcheck
ft/sec	in	in	ft	cfs		ft/sec
3	14.85	**0**	0	0.000000	0	0.00000
3	30.33	**42**	3.5	28.848750	0.003108	3.00000
3	33.31	**42**	3.5	28.848750	0.003108	3.00000
3	34.13	**42**	3.5	28.848750	0.003108	3.00000
3	37.92	**48**	4	37.680000	0.002601	3.00000
3	40.70	**48**	4	37.680000	0.002601	3.00000

26	27	28	29	30	31	32
Ground Level		Invert Level		Trench Depth		Wall thickness
U/E	D/E	U/E	D/E	U/E	D/E	
6960	6960	6954.9792	6954.97917	5.02	5.02	0.02083333
6960	6959.8	6954.9792	6954.56082	5.02	5.24	0.026
6959.8	6959.3	6954.5608	6953.78637	5.24	5.51	0.026
6959.3	6959.3	6953.7864	6953.67521	5.51	5.62	0.026
6959.3	6959.2	6953.6752	6953.46547	5.62	5.73	0.026
6959.2	6959.2	6953.4655	6953.39878	5.73	5.80	0.03125

Appendix G-3: HDPE Pipe

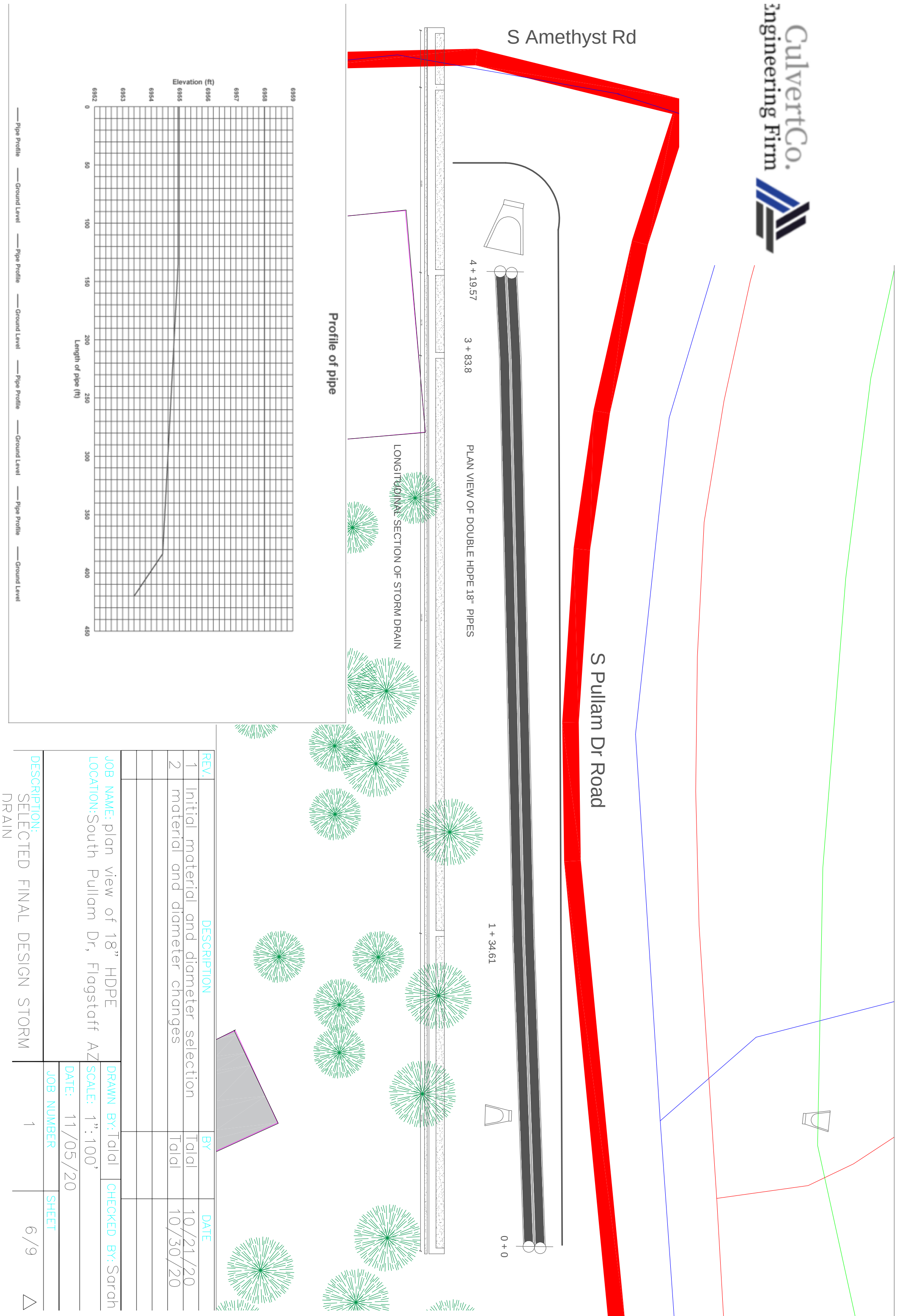
1	2			3	15	10	11	17	12	18	13	8
Sr No	From manhole to manhole			Length	Storm Water flow							Design Flow(q)
					Area (ft2)	Area	C	Intensity	Intensity		Q	
	Mx	to	Mx	ft		acre			in/h		cusec	cfs
1	0	to	1	0	130553.676	2.9971	0.14	3.8773E-06	8.6	0.9923398	1.80425	1.804254
2	1	to	2	134.61	113652.396	2.6091	0.51	3.8773E-06	8.6	3.146966	5.72176	7.526011
3	2	to	3	249.189	31459.032	0.7222	0.5	3.8773E-06	8.6	0.8540015	1.55273	9.078741
4	3	to	4	35.7678	18944.244	0.4349	0.24	3.8773E-06	8.6	0.2468492	0.44882	9.527557
5	4	to	6	80.6378	56654.136	1.3006	0.4	3.8773E-06	8.6	1.2303676	2.23703	11.764589
6	5	to	6	25.64	36895.32	0.8470	0.49	3.8773E-06	8.6	0.981546	1.78463	13.549218

9	10	11	12	13	19	20
Design Velocity	Diameter Calculated	Selected Dia	Selected Dia	Discharge flow full(Q_{full})	Slope	Vcheck
ft/sec	in	in	ft	cfs		ft/sec
3	10.50	**0**	0	0.000000	0	0.00000
3	10.72	**18**	1.5	5.298750	0.004027	3.00000
3	11.78	**18**	1.5	5.298750	0.004027	3.00000
3	12.07	**18**	1.5	5.298750	0.004027	3.00000
3	13.41	**18**	1.5	5.298750	0.004027	3.00000
3	14.39	**18**	1.5	5.298750	0.004027	3.00000

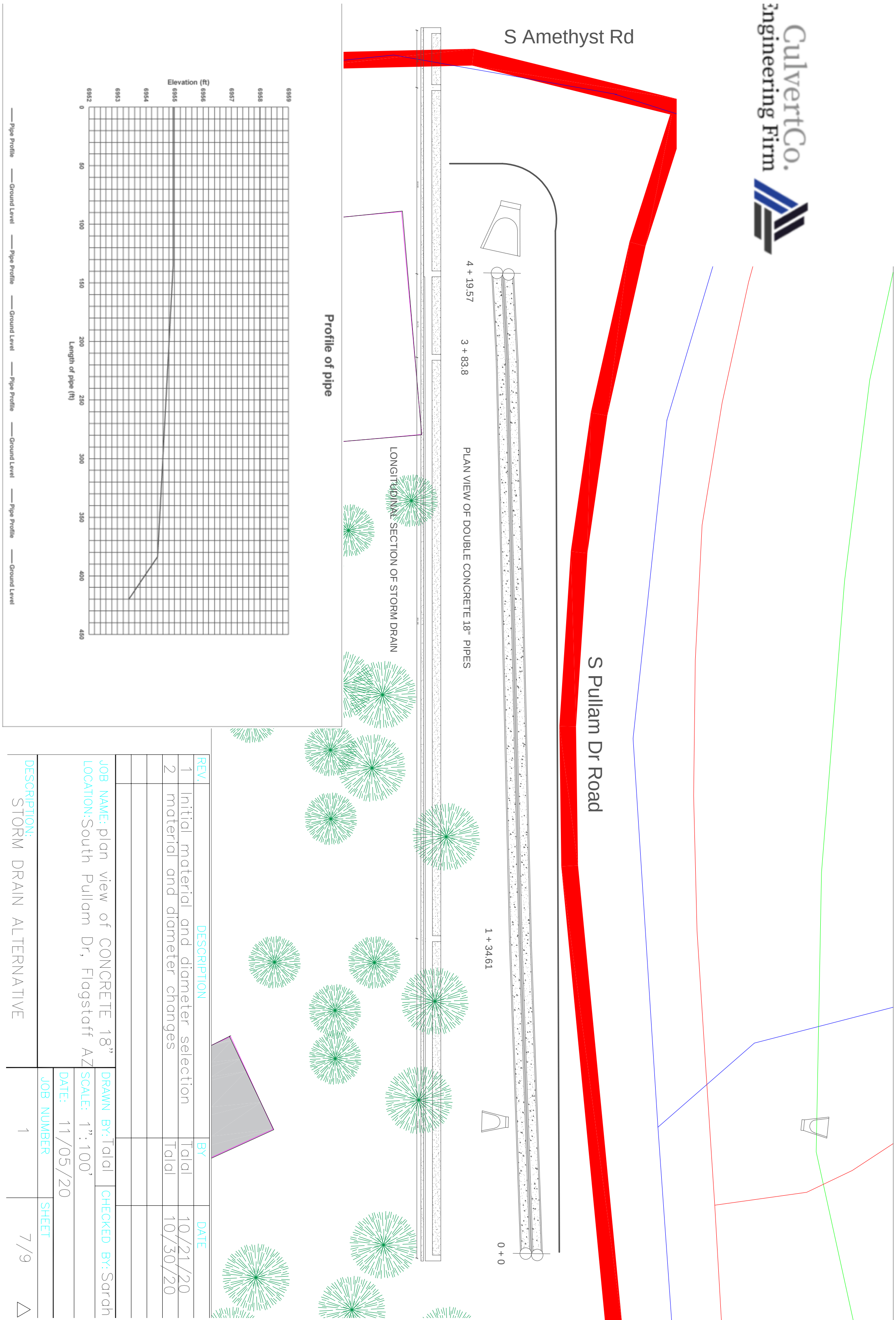
26	27	28	29	30	31	32
Ground Level		Invert Level		Trench Depth		Wall thickness
U/E	D/E	U/E	D/E	U/E	D/E	
6960	6960	6954.956	6954.956	5.04	5.04	0.044
6960	6959.8	6954.956	6954.41392	5.04	5.39	0.044
6959.8	6959.3	6954.4139	6953.41043	5.39	5.89	0.044
6959.3	6959.3	6953.4104	6953.26639	5.89	6.03	0.044
6959.3	6959.2	6953.2664	6952.94166	6.03	6.26	0.044
6959.2	6959.2	6952.9417	6952.8384	6.26	6.36	0.044

Appendix H- Alternative designs

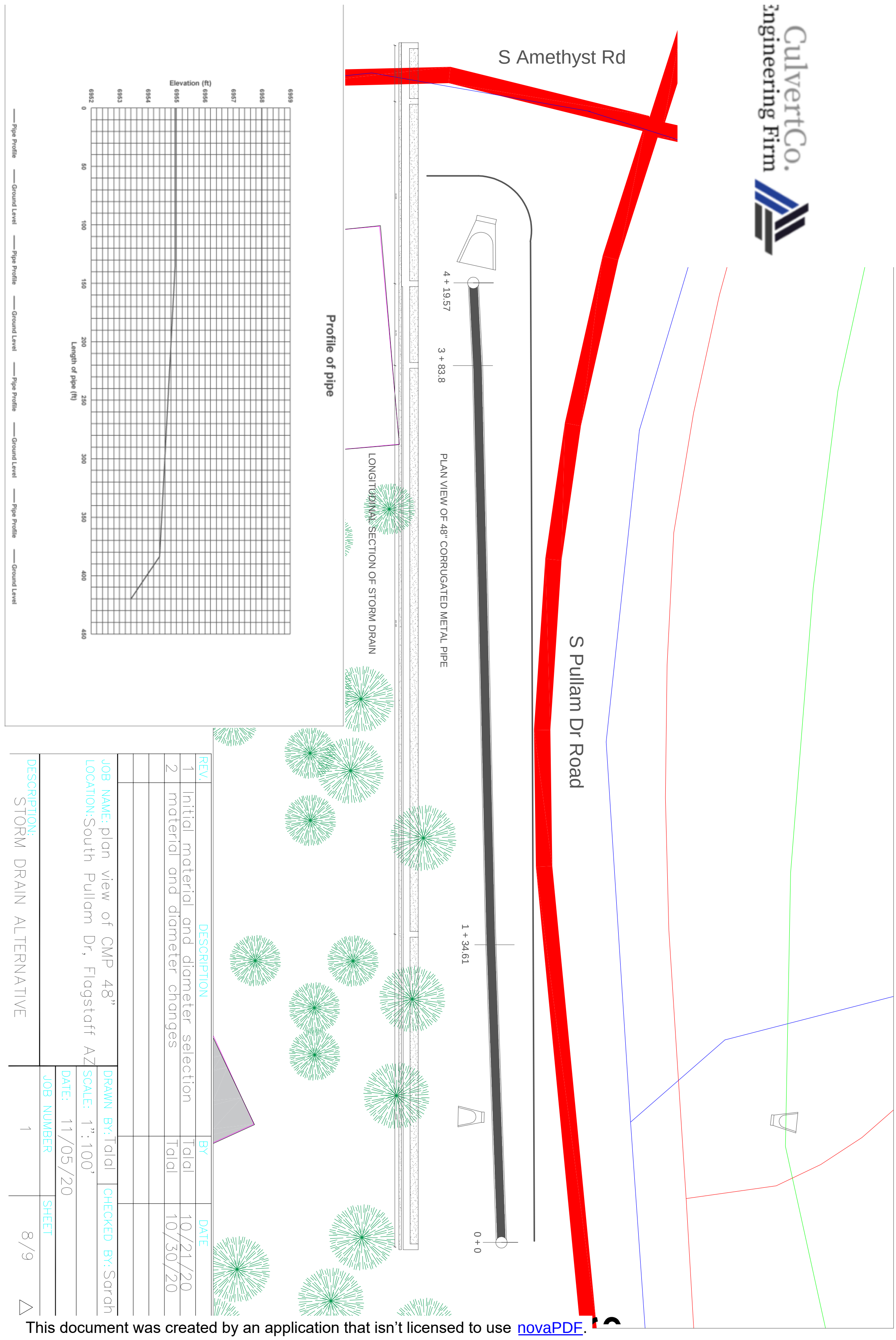
Appendix H- 1: plan and profile view of 18" HDPE pipe



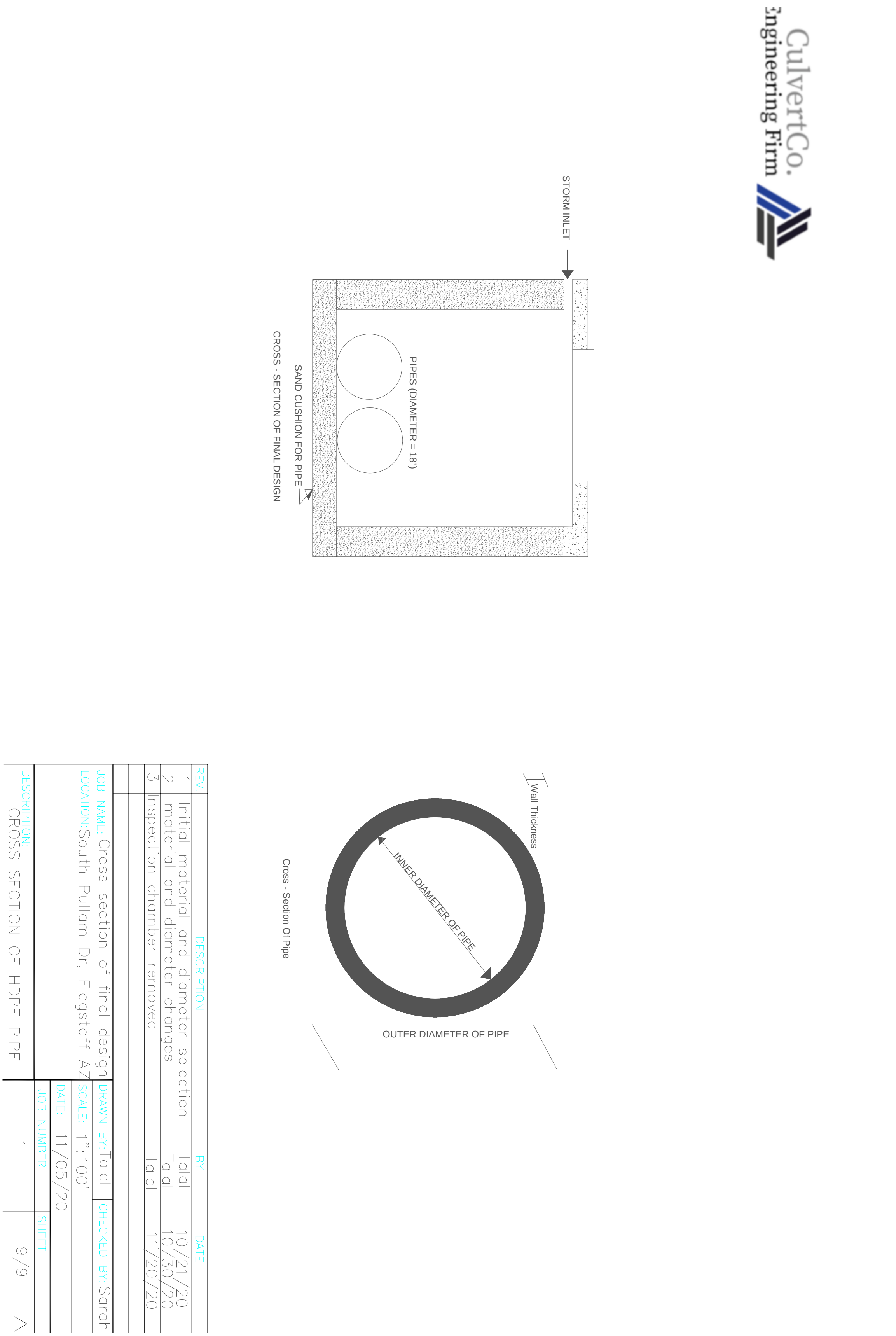
Appendix H- 2: plan and profile view of double 18” concrete pipe



Appendix H- 3: plan and profile view of single 48” CMP pipe



Appendix H- 4: cross section of final double 18" smooth wall HDPE pipe



Appendix I-Engineering work breakdown

Appendix I- 1: Original Proposal staffing hour breakdown

Task	SENG (hr)	ENG (hr)	EIT (hr)	TECH (hr)	Total Hours
Task 1.0 Site investigation	**3**	**3**	**31**	**31**	**67**
1.1 Site visit	1	1	1	1	3
1.2 Land survey	1	1	20	20	42
1.3 Topographic Map	1	1	10	10	21
Task 2.0 Hydrologic analysis	**4**	**8**	**33**	**33**	**78**
2.1 Watershed delineation	1	2	4	4	10
2.1.1 Time of concentration delineation	1	2	5	5	13
2.1.2 Time of concentration calculation	1	2	9	9	21
2.2 HEC-RAS Modelling	1	2	15	15	33
Task 3.0 Hydraulic analysis	**12**	**15**	**45**	**45**	**117**
3.1 Existing and proposed design	1	1	20	20	21
3.1.1 CulvertMaster programming	1	1	5	5	11
3.1.2 FlowMaster modelling	1	1	5	5	11
3.2 Alternatives Storm Drain	3	4	5	5	17
3.3 Final Design	4	5	5	5	19
3.4 Proposed Outlet protection	2	3	5	5	15
Task 4.0 Impacts	**3**	**6**	**15**	**15**	**39**
4.1 Social	1	2	5	5	13
4.2 Environmental	1	2	5	5	13
4.3 Economic	1	2	5	5	13
Task 5.0: Plan Set	**5**	**4.5**	**20**	**20**	**49.5**
5.1 Cover sheet	0.5	0.5	2	2	5

5.1 Survey sheet	1	0	2	2	4
5.1.1 Topographic map	0.5	1	3	3	7.5
5.2 Notes/ Details	1	1	4	4	10
5.3 Demolition sheet	0.5	0.5	3	3	6.5
5.4 Plan sheet	0.5	0.5	2	2	4.5
5.5 Plan Profile of design	1	1	4	4	10
Task 6.0: Deliverables	**277**	**284**	**287**	**284**	**1132**
6.1 30% Submission	5	6	9	9	29
6.2 60% Submission	7	8	8	8	31
6.3 90% Submission	8	11	11	11	41
6.4 Final Submission	10	10	10	10	40
6.5 Website	3	5	5	2	15
6.6 Memo Binder	30	30	30	30	120
6.7 Team Meeting	140	140	140	140	560
6.8 Technical Advisor	32	32	32	32	128
6.9 Grading Instructor	32	32	32	32	128
7.0 Client	10	10	10	10	40
Total	304	320.5	431	428	1483.5

Appendix I- 2: Final staffing hour breakdown

Task	SENG (hr)	ENG (hr)	EIT (hr)	TECH (hr)	Total Hours
Task 1.0 Site investigation	**1.15**	**10.15**	**0**	**10.15**	**21.45**
1.1 Site visit	15 minutes	15 minutes	0	15 minutes	45 minutes
1.2 Land survey (GIS)	0	0	0	0	0
1.3 Topographic Map	1	10	0	10	21
Task 2.0 Hydrologic analysis	**5**	**7**	**0**	**24**	**36**
2.1 Watershed delineation	1	1	0	2	4
2.1.1 Time of concentration delineation	1	1	0	1	3
2.1.2 Time of concentration calculation	1	2	0	6	9
2.2 HEC-HMS Modelling	2	3	0	15	20
Task 3.0 Hydraulic analysis	**23**	**21**	**0**	**36**	**80**
3.1 Existing and proposed design	6	4	0	10	20
3.1.1 CulvertMaster programming	2	2	0	6	10
3.1.2 FlowMaster modelling	3	5	0	7	15
3.2 Alternatives Storm Drain	6	5	0	8	19
3.3 Final Design	6	5	0	5	16
3.4 Proposed Outlet protection	0	0	0	0	0
Task 4.0 Impacts	**5**	**7**	**0**	**11**	**23**
4.1 Social	2	3	0	3	8
4.2 Environmental	1	2	0	5	8
4.3 Economic	2	2	0	3	7
Task 5.0: Plan Set	5	**7.5**	**0**	**22**	**34.5**
5.1 Cover sheet	1	1.5	0	3	5.5
5.1 Survey sheet	1	0	0	2	3

5.1.1 Topographic map	1	3	0	7	11
5.2 Notes/ Details	0	0	0	0	0
5.3 Demolition sheet	0	0	0	0	0
5.4 Plan sheet	1	1	0	3	5
5.5 Plan Profile of design	1	2	0	7	10
Task 6.0: Deliverables	**253**	**266**	**0**	**276**	**795**
6.1 30% Submission	6	7	0	7	20
6.2 60% Submission	7	10	0	10	27
6.3 90% Submission	5	9	0	11	25
6.4 Final Submission	9	11	0	15	35
6.5 Website	1	5	0	3	9
6.6 Memo Binder	10	9	0	15	34
6.7 Team Meeting	140	140	0	140	420
6.8 Technical Advisor	30	30	0	30	90
6.9 Grading Instructor	35	35	0	35	105
7.0 Client	10	10	0	10	30
Total	**287.15**	**319.5**	**0**	**379.15**	**986.2**