Woodland Drive Drainage Improvement Study

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1.0 Project Summary

1.1 Background

This project included services to prepare a drainage improvement study for potential upgrades to a portion of the existing drainage system in the City of Harrisonburg, VA. The watershed draining to the existing conveyance channel along Woodland Drive was analyzed to evaluate feasible drainage improvement alternatives. A site map has been provided in Figure 1 below.

Figure 1: Woodland Drive Drainage Improvement Site Map

The completed study summarizes the analysis process, findings, and suggestions for potential design improvements to the site, including channel improvements and the configuration of proposed detention basins. The hydrologic and hydraulic analyses described below were performed using PCSWMM (v7.4.3202) utilizing the SWMM 5.1.015 calculation engine.

1.2 Description of Project Limits

The Woodland Drive Drainage Improvement study area sits west of Reservoir Street and north of White Oak Circle, primarily along Woodland Drive in a residential neighborhood in the City of Harrisonburg, VA.

The primary stormwater conveyance system is a riprap-lined channel that extends from east to west, north of Woodland Drive. The channel outfalls to a 10'x6' concrete box culvert under the Sunchase parking lot. The study area is the headwaters of Tributary No. 3 to Blacks Run. Multiple drainage pipes outfall to this channel, as does surface drainage from the Woodland neighborhood and Sunchase Apartment complex.

The conveyance channel is approximately 560 linear feet and is fed by four piped systems, ranging from 24" to 60" in diameter. There are two stormwater detention basins located directly upstream of the channel, southwest and southeast of the Reservoir Street intersection. For reporting purposes, portions of the existing drainage network have been labeled as indicated in Appendix A, EXBT-1, and are described below. EXBT-2 displays the contributing drainage areas that feed each trunkline.

Surface runoff from the Woodland neighborhood is served by curb and gutter, which feeds Trunklines B and C. Drainage discharges into the riprap channel via 36" reinforced concrete pipe (RCP). There is a grass-lined, v-shaped ditch that drains into the Woodland system through a grate inlet at 652 White Oak Circle.

Drainage from the northern development of Sunchase Apartments discharges to the channel via Trunkline D (24" RCP). This trunkline also collects runoff from the area bounded by Neff Avenue, Reservoir Street, and Chase Court.

Surface drainage from Reservoir Street is routed to BMP 1 (southwest of the intersection of Reservoir Street and Lucy Drive) and enters the channel via a 36" steel pipe (Trunkline E). A 60" RCP also discharges to the channel (Trunkline F), which collects drainage from two piped systems. Trunkline F serves as the junction for both a 54" system that runs south to north along Reservoir Street (Trunkline G) and a 36" system that runs east to west along Lucy Drive (Trunkline H). A second BMP (BMP 2) located southeast of the intersection drains into the Lucy Drive system. It should be noted that two additional BMPs exist upstream of Trunkline H, outside of the study limits and were therefore excluded from the analysis.

1.3 Site Visit and Survey

Timmons Group conducted a site visit on March 17th, 2021 to collect site photos and analyze existing conditions in the field. These photos are included in Appendix A. Overall, the existing natural channel was found to be in good operating condition, though woody vegetation was well-established within the channel and portions of the banks displayed signs of scour near the downstream outfall (see Figures 1-14, Appendix A). The grate inlet between 652 and 654 White Oak Circle has been observed to become inundated, causing flooding to occur in this area (Figures 15-18). This information was used to help develop existing hydrologic and hydraulic conditions, summarized below.

2.0 Hydrologic Study Summary

Frequency discharges for the 2-, 10-, 25- and 100-year storm events along the study reach were independently calculated. For this study, hydrology was developed using the SCS Curve Number method. The drainage areas developed for this study were delineated based on 1-ft topography generated from a composite Digital Elevation Model (DEM). The DEM was developed by combining 1-ft contour data from James Madison University and 2-ft contour data from the City of Harrisonburg. Aerial photography streamed from VGIN was also referenced as part of the drainage area delineation. Refer to Appendix B for a map illustrating the drainage areas used to develop the hydrological model evaluated in this study.

2.1 SCS Methodology

Land cover information taken from the VGIN data server was used as the basis for establishing land use classifications within each drainage area. VGIN land cover data was translated into SCS TR-55 land cover types. Soils data defining Hydrologic Soils Groups (HSG) within each drainage area was downloaded from the NRCS Soils Survey website. Based on the Runoff Curve Number tables provided in the NRCS TR-55, a curve number shapefile was generated using each land cover and soils classification, as summarized in Table 1 below. It was assumed that all ground cover types were in "good" hydrologic condition when using the TR-55 tables to estimate curve numbers. Time of concentration was developed for each drainage area using the NRCS methodology for sheet flow, shallow concentrated flow, and channel/pipe reaches, see Section 2.2.1.

Table 1: Runoff Curve Numbers (from NRCS TR-55 Table 2-2)

Cover Type	Hydrologic Soil Group			
	A	B	C	D
Urban				
Open Space - Good	39	61	74	80
Impervious Area - Paved parking	98	98	98	98
Cultivated Agricultural				
Row crops - SR - Good	67	78	85	89
Other Agricultural				
Pasture - Good	39	61	74	80
Woods - Good	30	55	70	77
Arid/Semiarid				
Desert shrub - Good	49	68	79	84

2.2 SWMM Model Parameter Inputs

2.2.1 ARM Subcatchments

Hydrologic data was input into PCSWMM using alternative runoff method (ARM) subcatchments. GIS data and tools were used to develop many of the hydrologic input parameters for the SWMM model. Drainage areas were delineated and directly imported into the model from the supporting GIS layer. Area calculations were performed in ArcMap. As mentioned in Section 2.1, a curve number shapefile was generated in GIS based on land cover and soils classification. This file was imported into PCSWMM and a curve number was calculated for each subcatchment using the *Spatial Weighting* tool. A slope file was generated from the DEM using the *Slope from DEM* tool in PCSWMM, which was used to calculate average percent slope for each subcatchment. The percent impervious parameter was set to zero for all subcatchments because SCS methodology accounts for imperviousness in the curve number calculation.

Flow lengths and time of concentrations were calculated outside of PCSWMM. These were developed based on the TR-55 spreadsheet, see Appendix C. Topography data and aerial photography were used to evaluate the longest flow path from the most remote point to the ultimate discharge point for each subcatchment. Time of concentration was taken as the sum of sheet flow, shallow concentrated flow, and pipe and channel flow travel times. For smaller, majority impervious areas with small time of concentrations, an assumed time of 5 minutes was used to provide a more conservative runoff estimate.

2.2.2 Rainfall Distribution

Rain gages were created for each design storm in PCSWMM using the *Design Storm Creator* tool. The hydrographs for each of the design storms were calculated using an SCS Type II, 24-hr storm. Cumulative rainfall depths were determined in accordance with the NOAA Atlas 14 Precipitation Frequency Data Server for Harrisonburg, Virginia and can be found in Table 2.

Table 2: Frequency and Depth of Analyzed Storm Events

Storm Frequency	24-Hour Rainfall Depth (in.)
2-Year	2.63
10-Year	3.87
25-Year	4.69
100-Year	6.13

2.3 Hydrologic Summary

The site has a contributing drainage area of 371.5 acres. Timmons Group developed flows for subcatchments in accordance with SCS methodology. A drainage area map and hydrology characteristics are presented in EXBT-1, Appendix B. A summary table of the hydrology model has also been included in the exhibit. The channel may experience peak flows of approximately 898 cfs during a 100-yr event and up to 413 cfs during a 10-yr event. Subcatchment 1E was the largest contributing area to the site, and it yielded the largest peak flows for all four design storms.

In Table 3 below, model peak flows are compared to USGS StreamStats flows generated at the influent invert the 10'x6' box culvert, as well as FEMA FIS data. Model flows were similar to USGS data, but greater than FEMA data for the area. Each of the three sources derives flow values using different hydrologic methods, contributing to some of the difference in values.

Table 3: Summary of Hydrologic Parameters and Peak Discharge Rates

Source	Area (Ac.)	100-Yr Peak Flow (cfs)
Model	371.5	898
FEMA FIS (downstream)	640	661
UGS StreamStats (47.52% Developed, 2006 NLCD)	364.8	880
UGS StreamStats (72.5% Developed, 2011 NLCD)	364.8	1090

The flow values reported in the FIS were derived from a larger drainage area. The FEMA model profiles do not account for changes to the floodway immediately downstream of the study area, including the removal of a pond and the installation of the box culvert under the Sunchase Apartments parking lot. These changes may also contribute to the difference in reported peak flows. It should be noted that two FEMA Letter of Map Revisions (LOMRs) exist for Tributary No. 3 to Blacks Run. LOMRs 20-03-1670P and 09-03-0277P for panel 510076 were referenced in this analysis.

3.0 Existing Conditions SWMM Model

3.1 SWMM Model Development

A one-dimensional (1D) unsteady flow hydraulic analysis was completed for the study area in SWMM. In a 1D model, piped system and surface flows interact together and are routed to the outfall. The system consists of nodes representing pipe inlets, outlets, and manholes, and conduits representing pipes, drainage ditches, conveyance channels, and overland flows. Elevation data on the existing drainage infrastructure was obtained from city GIS data and plan sets. To supplement this, city contour data was processed to obtain approximate ground surface elevations for unknown rim elevations.

Entrance and exit loss coefficients were developed to account for bends, pipe diameter changes, pipe confluences, etc. The following table generally details how entrance and exit losses were developed for the model.

Table 4: Entrance and Exit Loss Coefficients Used for Pipe Conduits

ENTRANCE LOSS DESCRIPTION	LOSS COEFFICIENT
SINGLE INFLOW JUNCTIONS	$K_{ENTRANCE}$
Straight thorough manhole junction	0.25
EXIT LOSS DESCRIPTION	**LOSS COEFFICIENT**
Junctions	K_E
No bends	0.35
Bend Angle (degrees)	K_B
15	0.10
20	0.16
25	0.22
30	0.28
40	0.38
50	0.47
60	0.55
70	0.61
80	0.66
90	0.70
K_{Exit} =	$K_E + K_B$
Open Pipe End	1.0

Manning's n roughness coefficients were based on pipe material and channel characteristics. The following values were used for the various conduit materials:

Table 5: Summary Manning's n-Values Used for Conduits

Material	Manning's n
Concrete	0.013
HDPE	0.011
Steel Casing	0.011
Corrugated Metal	0.024
Riprap Channel with Stones and Weeds	0.04 – 0.045
Surface Flow over Impervious Areas	0.020
Surface Flow over Grassy Areas	0.03 - 0.035
Surface Flow over Heavily Vegetated/ Forested Areas	0.06 – 0.09

The hydraulic model incorporates open channel reaches and surface flows caused by flooding drainage structures. The DEM developed for this model (see Section 2.0) was used to digitize surface flow paths and cross sections at key locations along the flow path alignment. Cross sections were cut from the DEM in PCSWMM using the *Transect Creator* tool. Manning's n-values for surface flow and open channel flow were established based on land cover conditions depicted in aerial photography, site photos, and StreetView in Google Maps. For roadway sections not modeled by irregular conduits, rectangular open channels with widths ranging 10 to 20 ft were used to convey surface flow surcharging from drainage structures.

The presence of two existing BMPs within the study area issued the need to include storage nodes in the model. Stage-storage curves were estimated based on existing topographic data. Plans provided by the City were referenced to obtain information on the outlet structures for the BMPs. For each BMP, a series of orifices was used to model the outlets in PCSWMM. Two weirs also were used for each BMP. One weir simulated an emergency spillway, with an assumed elevation two feet below the BMP crest. A second weir was used to simulate flows overtopping the crest of the BMP berm. Existing topographic data was used to approximate weir lengths and heights.

According to existing plans, both BMPs were designed to contain the 100-yr storm without overtopping. However, the model indicates that BMP 1 overtops in the 100-yr event, and that BMP 2 overtops in the 2-yr event. This error may be partially attributed to the use of SCS methodology to produce more conservative peak flows, as well as the omission of two BMPs upstream of Trunkline H. As mentioned in Section 1.2, these BMPs were located outside of the initial study limits and were therefore not included as storage nodes in the model. Plans were not available for these facilities at the time of model development, but some storage volume was accounted for in this area by modeling an irregular conduit with a transect pulled across the basin footprint.

The model's outfall node was set downstream of the system, west of Neff Avenue, to ensure that backwater effects from the 10'x6' box culvert were modeled. The outfall condition was set to normal depth. A 24-hour simulation was created using the Dynamic Wave routing method. The Curve Number method was selected for the infiltration model. A three second routing time step was used, and the reporting time step was set to one minute.

3.2 Findings / Summary of Existing Conditions

The model described above established base flooding along the studied area for existing conditions. Inundation maps and profiles of the existing system were generated for each storm event in PCSWMM. These results are included in Appendix D. This information was used to identify critical flood locations and determine which components of the system would provide the most benefit from upgrades. See Appendix F for detailed SWMM output data for the existing 10-yr model.

As summarized in Section 2.3, the channel outfall north of Woodland Drive collects 371.51 acres of drainage. Model results indicate that the channel passes a peak flow of 413.04 cfs in the 10-yr storm event. Subcatchment 1E contributes most of this drainage, which is collected by Trunkline G along Reservoir Street. In the modeled 10-yr storm event, this subcatchment yields a peak flow of 265.35 cfs. Trunkline G collects a total of 198.05 acres of drainage from five subcatchments. These subcatchments represent drainage east and west of Reservoir Street, as well as the intersection of Reservoir Street and Foley Road (See Appendix A, EXBT-2). Surface runoff from Reservoir Street is primarily collected by Trunkline E and routed to BMP 1.

As seen in the Existing Conditions inundation map in Appendix D.2, roadway flooding occurs in the study area for all events, including the 2-yr storm. This flood mapping, along with a hydraulic grade line (HGL) analysis of the studied trunklines (see Appendices D.2 and D.3), indicates that the existing riprap channel is not the primary source of roadway flooding in the Woodland neighborhood. The inundation exhibit highlights two flood-prone areas: 1) the ditch between 652 and 654 White Oak Circle, and 2) the inlets associated with Trunklines H, F, and BMP 2 at the intersection of Reservoir Street and Lucy Drive.

As seen in the storm profiles in Appendix D.3, in Trunkline F, the HGL spikes in Conduits 78214 and 34066 under all storm events, indicating that these pipes are undersized. This causes Trunkline H to surcharge and flood at the intersection of Reservoir Street and Lucy Drive. As flow backs up Trunkline G, the system demonstrates capacity for the 2-yr event until Structure 3170, at which point surcharging occurs. It should be noted that routed drainage from subcatchments 1D_1 and 1D_3 merge at this structure before entering Trunkline G via Conduit 29039. Figure 2 below displays the configuration of existing drainage infrastructure at Ridgeville Lane and Reservoir Street.

Figure 2: Structure 3170 at Ridgeville Lane and Reservoir Street

Overflow from Structure 3170 then flows north towards Foley Rd, through three city-owned parcels and two residential lots. At 2210 Reservoir Street, a swale runs through the yard that likely conveys this flow (Figure 25, Appendix A,). Drainage is then routed under Foley Road via a concrete pipe and enters a paved channel east of 709 Foley Road. This channel was inaccessible at the time of the site visit due to overgrown vegetation (Figure 26, Appendix A). Channel flow then drains to the Woodland neighborhood through a private, undeveloped parcel before entering the v-ditch on 652 White Oak Circle (Figure 16, Appendix A).

Trunkline E exhibits adequate capacity for the 2-yr event, but portions of Reservoir Street east of the BMP begin to surcharge in the 10-yr event. This was initially causing flood loss in the model because flows were exiting the drainage system and were not accounted for at the end of the simulation. For this reason, the model directs overflow from Reservoir Street to escape the roadway via a driveway entrance, as displayed in Figure 3 below. This flow then merges with surface flows from Foley Road on an undeveloped private parcel and drains to 652 White Oak Circle.

Figure 3: Structure 51639 Surcharge Routing

Findings were presented to city staff on April 28th and June 21st, 2021 and were validated based on prior storm events and complaints received by residents. Potential alternative solutions were discussed and are presented in Section 4.0 below.
As described in Section 3.1, flow simulations indicate BMP1 overtopping during the 100-yr event and BMP2 overtopping in the 2-yr event, which indirectly routes additional flow to the v-ditch and grate inlet via surcharging inlets along Reservoir Street. This is a noted inaccuracy in the model, likely due to the omission of upstream detention facilities along Lucy Drive. Results of the Existing Conditions model may be considered more conservative because the arrival time and volume of peak flows would be dampened by modeling this additional detention.

4.0 Alternatives Analysis

The Existing Conditions model serves as the basis of analysis for each of the proposed alternatives. Five alternatives were analyzed to determine the effectiveness of various flood improvements strategies. Effectiveness was determined by reduction in the existing floodplain and reported peak flow at the outfall for various storm events. Flood improvement strategies considered in this study include:

A. Construction of a BMP on city-owned property.
B. Construction of a BMP on an undeveloped private parcel.
C. Combination of public property and private property BMP footprints in series.
D. Drainage channel improvements.
E. Construction of a BMP on an undeveloped private parcel in addition to channel improvements.

Conceptual layouts of Alternatives A, B, C, and E are presented in Appendix E.1.

4.1 Alternative A: BMP on City-Owned Property

The Existing Conditions hydraulic analysis indicates that flooding in the Woodland neighborhood is caused by flows bypassing the existing drainage infrastructure along Reservoir Street. Flows from two major components of the study basin merge in Trunkline F, creating a spike in the HGL that backs up through Trunkline G and prohibits additional flows from entering the system.

Alternative A seeks to slow down the timing and volume of flows traveling through Trunkline G by redirecting all drainage from subcatchment 1D to a BMP located on city property between Ridgeville Lane and Foley Road. The BMP footprint encompasses a 0.4 ac area and has approximately a 60,000 ft^3 volume. Subcatchment 1D runoff is redirected to the BMP by removal of an existing 27" RCP (Pipe ID 29039 in city GIS database) and replacement with a 27" pipe that routes drainage to the BMP. All drainage from subcatchment 1E is still routed through Trunkline G. Drainage from the BMP is primarily routed into Trunkline E via 24" RCP. Overflow from the BMP in larger events still bypasses the Reservoir Street trunklines and travels north towards Foley Road.

4.2 Alternative B: BMP on Undeveloped Private Parcel

A large BMP is proposed in Alternative B on a privately-owned parcel located between Reservoir Street and the Woodland neighborhood. This BMP footprint encompasses approximately 1.53 ac and has a 495,000 ft^3 volume. Implementation of this alternative may be cost-prohibitive because it requires the City to purchase this parcel prior to BMP construction. Only surface flow from the Foley Road channel (see Section 3.2) and overflow from the Reservoir Street trunklines feed the BMP; there is no piped component to reroute flows from the existing trunklines as presented in Alternative A.

The placement of this BMP impacts the feasibility of rerouting Trunkline G. To redirect the most impactful subcatchments (DA 1D_1, 1D_2, 1D_3), an additional trunkline would need to be installed from the intersection of Ridgeville Lane and Reservoir Street, and outfall at the mouth of the BMP footprint. This would require either: 1) spanning multiple private residential properties, or 2) placing the proposed system within the existing right-of-way and managing spatial conflicts with the two existing trunklines below Reservoir Street. Additionally, the HGL through existing infrastructure along Trunkline E indicates adequate capacity and is already routed to an existing BMP. It is for this reason that Trunklines E and G are not rerouted in this alternative.

The Existing Conditions analysis indicates that excess flows draining to the v-ditch at 652 White Oak Circle are a primary area of flood concern. The BMP placement in this alternative analyzes the effect of detaining flow immediately upstream of this flood-prone area. Though only drainage from the Foley Road channel and overflow from Reservoir Street is detained in this BMP, the model shows that this footprint detains up to the 25-yr event and improves the corresponding floodplains for these storms.

4.3 Alternative C: Combination of City Property BMP and Private Property BMP in Series

The effect of incorporating two BMPs into the drainage system is modeled in Alternative C. Descriptions of the city-owned parcel and private-owned parcel footprints are described in Sections 4.1 and 4.2 above, respectively. The method of flow routing to these BMPs varies slightly from those presented in Alternatives A and B. In this alternative, only drainage from Subcatchment 1D_2 is routed to the city parcel BMP. Subcatchments 1D_1 and 1D_3 are routed to the private parcel BMP via a 24" piped trunkline. Multiple routing combinations were analyzed to direct flow from these subcatchments to the BMPs, and the presented configuration displayed the most effective floodplain reduction. As noted in Alternative B, directing flow to the private parcel footprint through a closed system presents potential design conflicts. Additionally, the feasibility of this alternative is limited because it requires acquisition of a large parcel zoned for future development, in addition to potential easements for a proposed trunkline that directs the most influential flows to the large BMP.

4.4 Alternative D: Drainage channel improvements

Alternative D focuses drainage improvement efforts on the existing conveyance channel only. This alternative represents maintenance of and/or minor upgrades to the existing channel by clearing existing trees and established vegetation. Maintenance would limit disturbance solely to the headwaters of Tributary No. 3 to Blacks Run. Three subalternatives were analyzed for this concept, including clearing only the channel, clearing the channel and overbank areas, and upgrading the channel to a concrete-lined drainage ditch.

The model indicated that channel and overbank clearing does little to improve flooding in the area. Inundation maps for these two subalternatives exhibited negligible differences between the existing and proposed floodplains. However, upgrading the channel to a concrete-lined system and re-grading the channel to establish a more uniform slope produces noticeable effects on the floodplain. For this reason, only this subalternative was pursued and reported upon in the analysis herein.

In this alternative, the channel is regraded to achieve a more uniform longitudinal slope. Ditch geometry is widened to achieve 2:1 side slopes, a 5-ft bottom width, and 6-ft depth. The channel roughness coefficient is changed from 0.045 to 0.013 to simulate a concrete lining. As seen in Figure 4 below, when compared to Existing Conditions, this alternative produces a floodplain increase in the 10-yr storm. Additionally, Alternative D3 increases peak flow at the outfall in the 2-yr event, see Table 7. For these reasons, this alternative was not considered for further evaluation.

Figure 4: Alternative D vs. Existing Conditions, 10-Year Floodplain

4.5 Alternative E: Construction of a BMP on an undeveloped private parcel and channel improvements

This alternative was included in the analysis to evaluate the effect of combined maintenance and mitigation measures on the floodplain. As was observed in the Alternative D results, this alternative also produces a floodplain rise in the 100-yr event. Figure 4 displays an inset of the 100-yr hydrograph for a section of the conveyance channel. Even though overall peak flow is reduced, the timing of the peak is affected, and portions of storm event show a larger volume flowing through the system than under the Existing Conditions model (approximately 30 cfs in some places). As seen in

EXBT-7 and EXBT-8 (Appendix E.2-2), there is no significant floodplain improvement in this alternative over Alternative B in the 10-yr event. In fact, the 25-yr floodplain is slightly higher in Alternative E than in B, and 100-yr floodplain is higher than the Existing Conditions model.

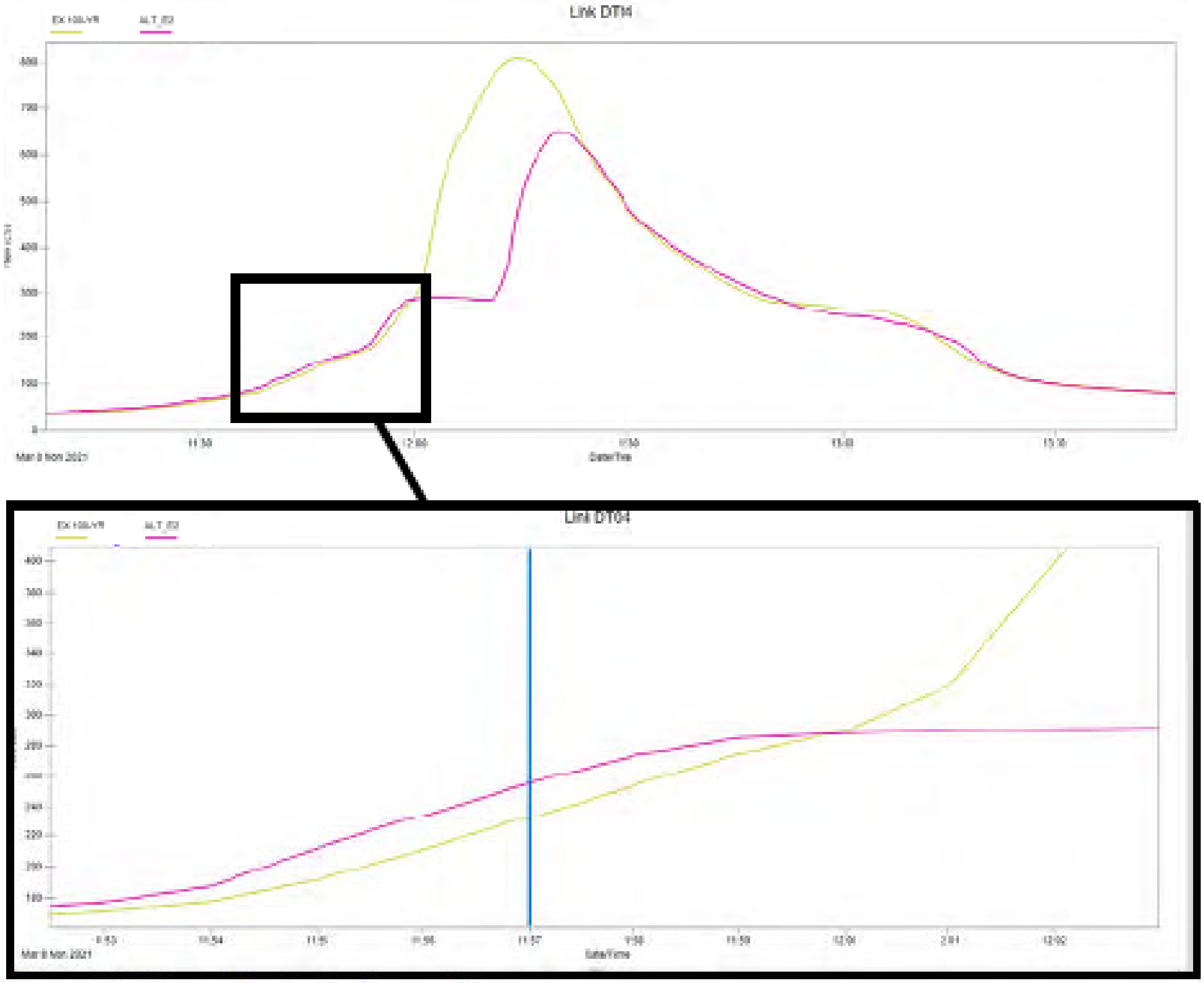


Figure 5: Alternative E Hydrograph

5.0 Summary and Recommendations

5.1 Summary

The 10-yr floodplain was mapped for each alternative and compared to the Existing Conditions results. Of the five presented alternatives, three were selected for detailed analysis. Alternative D exacerbates flooding along Woodland Drive in the 10-yr event and was therefore omitted from further analysis. Alternative C was also removed from the analysis despite providing significant peak flow and floodplain reduction. This alternative provides little benefit over Alternative B for flood attenuation and requires the construction of two basins instead of one. Alternatives A, B, and E have been analyzed under the 2-, 10-, 25-, and 100-yr events. Detailed results and SWMM outputs are presented Appendices E and F. Table 7 below summarizes peak flow reductions by alternative.

Table 7: Comparison of Peak Flows at Outfall by Alternative

	2-YR		10-YR		25-YR		100-YR	
	Q (cfs)	Δ	Q (cfs)	Δ	Q (cfs)	Δ	Q (cfs)	Δ
Ex. Cond.	183.34	-	413.04	-	603.24	-	898.58	-
A		-5.85		-47.09		-21.19		-16.70
B		-4.95		-90.13		-238.74		-58.94
C		-0.96		-90.70		-237.56		-89.00
D		+1.46		-33.49		-72.27		-39.96
E		-3.08		-96.94		-254.03		-136.9

No structures are removed from the 100-yr floodplain under the presented alternatives (see Table 8 below). Alternative E exacerbates flooding and adds an additional structure to the 100-yr floodplain. Both Alternatives B and E remove five structures from the 25-yr floodplain. Alternative A provides relief for three structures in smaller storm events but offers no removal in the 25-yr storm.

Table 8: Comparison of Peak Flows at Outfall by Alternative

Storm Event	No. of Structures in Floodplain	Number of Structures Removed		
	Existing	A	B	E
2-YR	10	3	*	*
10-YR	15	3	3	3
25-YR	19	0	5	5
100-YR*	26	0	0	-1**

* 2-yr inundation was mapped only for Alternative A to determine if the proposed BMP demonstrated capacity for small storm events.

** Alternative E 100-yr floodplain inundates an additional structure rather than removal.

Alternative B demonstrates that even large detention volumes are unable to fully relieve the Woodland neighborhood of flooding issues in large storm events. Further, comparison of Alternatives A, B, and E underscore a key finding of the Existing Conditions analysis: the main conveyance channel is not the primary cause of flooding in this area. Drainage issues first arise further upstream in the existing drainage network and can be attributed to insufficient pipe capacity at key junctions, as well as peak flow augmentation caused by hydrograph overlap.

The construction of a BMP on city-owned property (Alternative A) exhibits the most potential for design, despite its limited effectiveness at flood attenuation. This alternative does not require additional land acquisition by the City. The size of the BMP footprint is much less than that of the private parcel BMP proposed in Alternative B, meaning a smaller footprint of disturbance and few associated construction material quantities.

This analysis demonstrates that the installation of a BMP on the city-owned parcel slightly improves flooding conditions in the Woodland neighborhood. Under this scenario, flows entering the vegetated v-ditch at 652 White Oak Circle are contained within the channel and less flow is allowed to bypass the existing drainage network at the intersection. Though this BMP design only achieves a 2-yr level of service for water quantity benefits in the model, it has the potential to earn credit as water quality BMP as well.

Hydrologic inputs were processed in the Virginia Runoff Reduction Method (VRRM) Re-Development Spreadsheet to determine the feasibility of implementing a constructed wetland per VA BMP Clearinghouse Specifications. The VRRM spreadsheet indicated that a volume of 111,120 ft^3 would be required to treat the contributing drainage area. Though the proposed footprint under Alternative A attempted to maximize treatment volume based on existing spatial constraints, it was only able to achieve a volume of 60,000 ft^3. For this reason, the Chesapeake Bay Program retrofit curves and loading rates were used to calculate estimated load reductions for Total Nitrogen (TN), Phosphorus (TP), and Suspended Solids (TSS). Using Table 3b from the Chesapeake Bay TMDL Special Condition Guidance Memo, loading rates were calculated for each pollutant, see Appendix G. Reduction percentages were calculated using the retrofit equations and load reductions are presented in Table 9 below.

Table 9: Estimated Reduction by Pollutant

Pollutant	Load (lb/yr)	% Reduction	Est. Reduction (lb/yr)
TN	720	29	210
TP	55	45	25
TSS	37,000	58	22,000

It should be noted that the studied reach is sensitive to fluctuations in the arrival times of peak flows from different subcatchments within the study basin. As seen in Alternative E, upgrading the channel from riprap to concrete causes an increase in the 100-yr floodplain due to compounding hydrographs. Drainage design for future developments in the area should ensure that flooding is not exacerbated by allowing the hydrograph of post-developed peak flows to coincide with major peaks in the existing system.

5.2 Recommendations

The alternatives presented in this report analyze designs that seek to mitigate residential flooding impacts in the Woodland neighborhood. Flood inundation maps, hydrographs, and system hydraulics were analyzed using PCSWMM for each alternative.

It is recommended that further studies be conducted upstream of the study area to better inform the design of a stormwater detention system between Ridgeville Lane and Foley Road. Existing infrastructure that outfalls to the conveyance channel should also be further analyzed to demonstrate adequate capacity under small storm events, such as the 2-yr and 10-yr storms.

Future work may include improving and validating the Existing Conditions model developed for this study. Extending the model further south to encompass more of the drainage infrastructure along Reservoir Street would provide a more realistic simulation of true drainage network conditions. Additionally, subdividing the larger subcatchments and routing them through the expanded drainage network would better inform the hydraulic model on the timing of peak flows through the system. Extension of the model eastward along Lucy Drive to encompass upstream BMPs would also improve the model results by accounting for the detention provided by these facilities, especially for smaller storm events.

Inundation mapping may also be improved through the use of a higher resolution DEM, in which curb elevations, inlet sumps, and updated road and channel geometries are included. Mapping may also be improved by utilizing irregular conduits in place of open rectangular conduits to simulate sheet flow on roadways.

Further design and analysis of the proposed BMP outlet control structures would improve the proposed scenarios. The Alternatives Analysis models these structures as pipes with the same geometry as the downstream system. The purpose of this analysis was to provide proof of concept for multiple storm scenarios for these alternatives, rather than fully designed basins. However, detailed information on the outlet control devices in these BMPs would enhance model results, especially for smaller storm events which the small BMP would be capable of detaining.

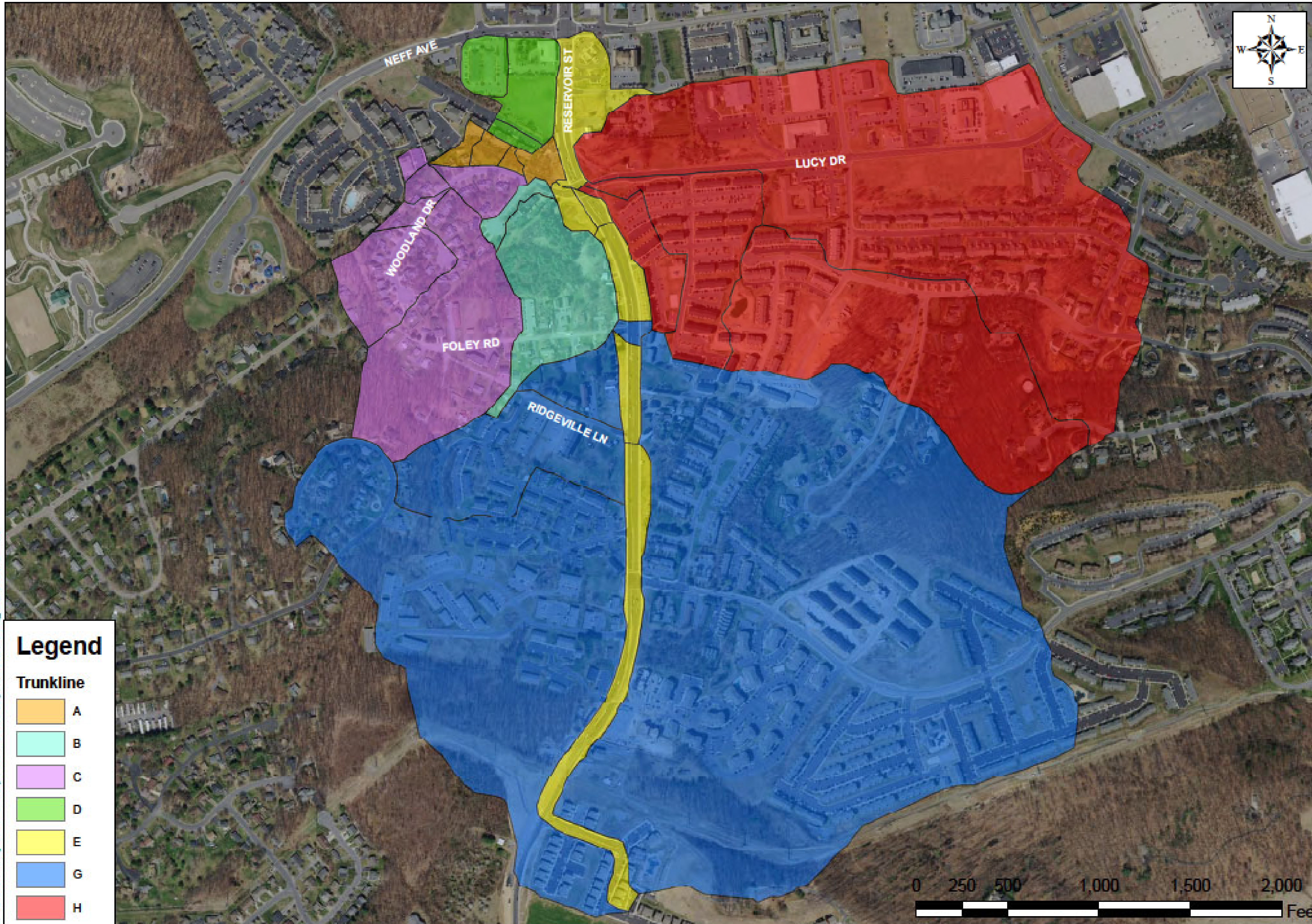
It is important to note that future changes within the studied area as a result of development, redevelopment, or infrastructure changes may cause or contribute to flooding not represented in this report. Hydrologic discharge rates and corresponding base flood elevations may be impacted by further urbanization of the study area. Because of sensitivity to peak flow timing in the existing channel, it is recommended that drainage design for future developments in the area ensure that flooding is not exacerbated by allowing post-developed peak flows to coincide with major peaks in the existing system.

APPENDIX A

Site Map and Photos

EXBT-1
ANNOTATED SITE MAP
WOODLAND DRIVE, HARRISONBURG, VA

TIMMONS GROUP WWW.TIMMONS.COM



TIMMONS GROUP

WOODLAND DRIVE DRAINAGE IMPROVEMENTS

HARRISONBURG, VIRGINIA

TRUNKLINE CONTRIBUTING AREAS

THIS DRAWING PREPARED AT THE CORPORATE OFFICE

YOUR VISION ACHIEVED THROUGH OURS

Site Development | Residential | Infrastructure | Technology | Environmental

DATE	REVISION DESCRIPTION

DATE: 06/25/2021

DRAWN BY: K. REDMAN

DESIGNED BY: K. REDMAN

CHECKED BY: M. CLAUD

SCALE: 1" = 250'

JOB NUMBER: 47305.002

SHEET NO.: EXBT-2

Path: C:\Users\kelsey.redman\Desktop\Woodland Drive Outputs\GIS\47305.002_XPDRAN-TKLN.mxd

SITE PHOTOS

TIMMONS GROUP

EXISTING CONVEYANCE CHANNEL

FIG 1: Trunkline E Outfall (36" SS)

FIG 2: Trunkline F Outfall (60" RCP)

FIG 3: Upstream Terminus of Existing Channel

FIG 4: Existing Conveyance Channel (Facing Upstream)

FIG 5: Existing Conveyance Channel (Facing Upstream)

FIG 6: Existing Conveyance Channel (Facing Downstream)

TIMMONS GROUP

FIG 7: Trunkline B Outfall

FIG 8: Trunkline B Outfall

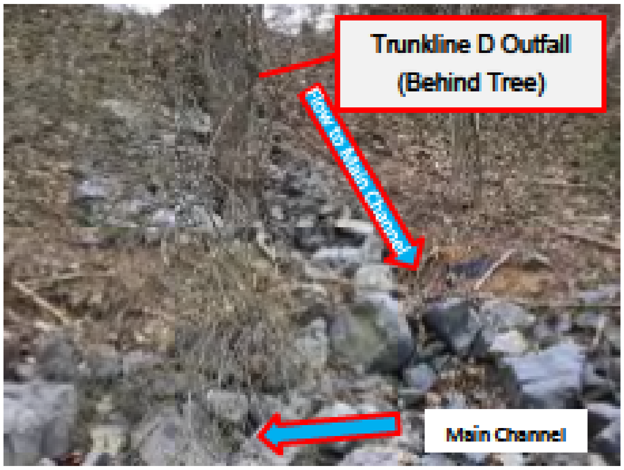


FIG 9: Trunkline D Outfall and Riprap

FIG 10: Trunkline D Outfall

FIG 11: Existing Conveyance Channel, Upstream of Outfall (Facing Downstream)

FIG 12: Erosion of Left Bank (Downstream Terminus of Existing Conveyance Channel, Upstream of Outfall)

FIG 13: Observed Bank Erosion Upstream of Outfall (Facing Upstream)

FIG 14: Ultimate Outfall of Project Limits (10'x6' Box Culvert Under Sunchase Parking)

WOODLAND DRIVE

FIG 15: Intersection of Woodland Drive and White Oak Circle

FIG 16: Yard Inlet and v-ditch at 652 White Oak Circle

FIG 17: Curb Opening to Conveyance Channel at Woodland Drive (Facing West)

FIG 18: Woodland Drive and White Oak Circle (Facing Northeast)

RESERVOIR STREET AND EXISTING BMPs

FIG 19: BMP 1 (Facing South)

FIG 20: Trunkline E2 Outfall into BMP 1

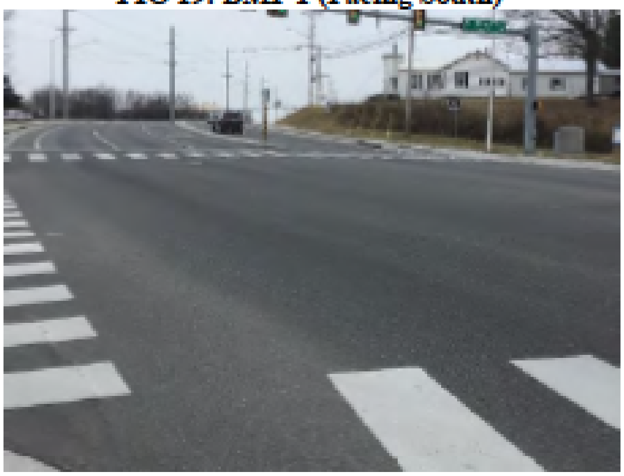


FIG 21: Intersection of Reservoir Street and Woodland Drive (Facing North)

FIG 22: BMP 2 From Top of Berm (Facing East)

FIG 23: BMP 2 at Outlet Structure (Facing South)

FIG 24: BMP 2 Basin and Outlet Structure, Facing Reservoir Street (Facing West)

FOLEY ROAD AND RESERVOIR STREET INTERSECTION

FIG 25: Drainage Ditch on 2210 Reservoir Street (Facing South)

FIG 26: Overgrown Channel at Foley (Unable to Locate Defined Channel)

FIG 27: Intersection of Foley Road and Reservoir Street (Facing East)

FIG 28: Reservoir Street at Foley Road (Facing South)

APPENDIX B

Drainage Areas

Drainage Area ID	Area (Ac.)	Curve Number	Time of Concentration (min.)
1A	0.49	82.32	5.0
1B	0.82	63.67	9.2
1C_1	1.97	81.53	5.0
1C_2	6.76	74.31	16.8
1C_4	1.58	88.45	5.0
1C_5	0.48	81.32	5.0
1D_1	53.97	72.64	24.9
1D_2	3.47	75.41	5.0
1D_3	12.78	77.84	9.0
1E	127.36	74.59	15.2
2	10.31	68.81	8.9
2A	0.96	84.16	8.2
3	16.96	66.61	12.7
3A	6.02	71.25	19.4
3B	0.82	75.42	14.3
3C	0.76	69.29	7.2
3D	0.42	91.06	5.0
3E	1.98	78.15	8.7
4	1.82	95.56	5.0
4A	3.45	72.86	7.7
4B	0.58	93.75	5.0
5	4.52	83.72	10.9
6	66.26	80.05	17.6
7A	3.58	90.45	5.0
7B	10.64	90.08	5.0
7C	30.18	71.48	10.5
8	0.95	72.40	5.0
8A	0.26	65.09	5.0
8B	0.68	66.36	5.0
8C	0.69	73.89	5.0

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TEL 804.200.6500 FAX 804.560.1016 www.timmons.com

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REVISION DESCRIPTION | DATE

TIMMONS GROUP

WOODLAND DRIVE DRAINAGE IMPROVEMENTS

DRAINAGE AREA MAP

DATE: 04/28/2021
DRAWN BY: I. GORDON
DESIGNED BY: K. REDMAN
CHECKED BY: M. CLAUD
SCALE: 1" = 250'
JOB NO.: 47305.002
SHEET NO.: EXBT-1

APPENDIX C

Hydrologic Support Data

TIMMONS GROUP
YOUR VISION ACHIEVED THROUGH OURS.

WORKSHEET FOR SCS HYDROLOGIC PARAMETERS

Land Use:	X	Existing	Project:	Woodland Drive Drainage Improvement
		Proposed	Drainage Area Number:	1A
Off-Site Land Use:	X	Existing	By:	C. REDMAN
		Proposed	Date:	6/17/2021

TIME OF CONCENTRATION (VELOCITY METHOD)

2-Year 24-Hour Precipitation Rainfall Amount (in) =	2.63
County/City:	City of Harrisonburg

Sheet Flow

ID	Type of Flow	n	US Elev.	DS Elev.	Length (ft.)	Avg. Slope (ft/ft)	Travel Time Equation	Velocity (ft/s)	T_t (hrs)	T_t(mins)	Notes
1	Grass - Dense Grasses	0.240				#DIV/0!	$T_t = \frac{0.007\ (nL)0.8}{(P_2)^{0.5}\ S^{0.4}}$	NA			

Shallow Concentrated Flow

ID	Flow Type	n	US Elev.	DS Elev.	Length (ft.)	Avg. Slope (ft/ft)	Velocity Equation	Velocity (ft/s)	T_t (hrs)	T_t(mins)	Notes
2	Pavement and Small Upland Gullies	0.025	1428.0	1427.8	29.67	0.008	V = 20.328(s)^0.5	1.790	0.005	0.276	

Channel Flow

ID	Channel Shape	Channel Type	Channel Description	n	US Elev.	DS Elev.	Length (ft.)	Avg. Slope (ft/ft)	Avg. Normal Depth (ft)	Avg. Bottom Width (ft)	Avg. Side Slopes (ft/ft)	Avg. Top Width (ft)	Equations: Area	Equations: Wetted Perimeter	Equations: Velocity	Average Flow Area (ft^2)	Average Wetted Perimeter (ft^2)	Velocity (ft/s)	T_t (hrs)	T_t(mins)	Notes
13	Circular Pipe	Lined or Built-Up Channel	Clean, straight, full, no rifts or deep pools w/ more stones and weeds	0.060	1427.77	1419.57	153.92	0.053	1.25	NA	NA	NA	A = π(d/2)^2	P = 2π(d/2)	V = (1.49()/(P1/3)()(s)^0.5)()/n	1.23	3.93	3.96	0.011	0.65	
																		Total T_t =	0.015	0.924	
																		T_L =	0.009	0.555	

TIMMONS GROUP
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WORKSHEET FOR SCS HYDROLOGIC PARAMETERS

Land Use:	X	Existing	Project:	Woodland Drive Drainage Improvement
		Proposed	Drainage Area Number:	18
Off-Site Land Use:	X	Existing	By:	C. REDMAN
		Proposed	Date:	6/17/2021

TIME OF CONCENTRATION (VELOCITY METHOD)

2-Year 24-Hour Precipitation Rainfall Amount (in) = 3.43

County/City: City of Harrisonburg

Sheet Flow

ID	Type of Flow	n	US Elev.	DS Elev.	Length (ft.)	Avg. Slope (ft/ft)	Travel Time Equation	Velocity (ft/s)	T_t (hrs)	T_t(mins)	Notes
1	Grass - Dense Grasses	0.240	1430.0	1420.0	101.08	0.099	$T_t = \frac{0.007\ (nL)0.8}{(P_2)^{0.5}\ S^{0.4}}$	NA	0.140	8.376	

Shallow Concentrated Flow

ID	Flow Type	n	US Elev.	DS Elev.	Length (ft.)	Avg. Slope (ft/ft)	Velocity Equation	Velocity (ft/s)	T_t (hrs)	T_t(mins)	Notes
2	Pavement and Small Upland Gullies	0.025	1420.0	1416.0	139.64	0.029	V = 20.328(s)^0.5	3.460	0.011	0.676	

Channel Flow

ID	Channel Shape	Channel Type	Channel Description	n	US Elev.	DS Elev.	Length (ft.)	Avg. Slope (ft/ft)	Avg. Normal Depth (ft)	Avg. Bottom Width (ft)	Avg. Side Slopes (ft/ft)	Avg. Top Width (ft)	Equations: Area	Equations: Wetted Perimeter	Equations: Velocity	Average Flow Area (ft^2)	Average Wetted Perimeter (ft^2)	Velocity (ft/s)	T_t (hrs)	T_t(mins)	Notes
3	Circular Pipe	Lined or Built-Up Channel	Concrete	0.013	1416.00	1413.00	134.48	0.022	3.00	NA	NA	NA	A = π(d/2)^2	P = 2π(d/2)	V = (1.49(((r^2)/3))(s)^0.5))/n	7.07	9.42	14.13	0.003	0.16	Assumed Diameter
																		Total T_c =	0.154	9.211	
																		T_L =	0.092	5.527	

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WORKSHEET FOR SCS HYDROLOGIC PARAMETERS

Land Use:	X	Existing	Project:	Woodland Drive Drainage Improvement
		Proposed	Drainage Area Number:	1C
Off-Site Land Use:	X	Existing	By:	C. REDMAN
		Proposed	Date:	6/17/2021

TIME OF CONCENTRATION (VELOCITY METHOD)

2-Year 24-Hour Precipitation Rainfall Amount (in) = [illegible]

County/City: City of Harrisonburg

Sheet Flow

ID	Type of Flow	n	US Elev.	DS Elev.	Length (ft.)	Avg. Slope (ft/ft)	Travel Time Equation	Velocity (ft/s)	T_t (hrs)	T_t(mins)	Notes
1	Grass - Dense Grasses	0.240	1636.1	1635.0	87.71	0.012	$T_t = \frac{0.007\,(nL)^{0.8}}{(P_2)^{0.5}\,S^{0.4}}$	NA	0.286	17.165	

Shallow Concentrated Flow

ID	Flow Type	n	US Elev.	DS Elev.	Length (ft.)	Avg. Slope (ft/ft)	Velocity Equation	Velocity (ft/s)	T_t (hrs)	T_t(mins)	Notes
2	Pavement and Small Upland Gullies	0.025	1635.0	1592.8	1171.12	0.035	V = 20.328(s)^0.5	3.811	0.085	5.121	

Channel Flow

ID	Channel Shape	Channel Type	Channel Description	n	US Elev.	DS Elev.	Length (ft.)	Avg. Slope (ft/ft)	Avg. Normal Depth (ft)	Avg. Bottom Width (ft)	Avg. Side Slopes (ft/ft)	Avg. Top Width (ft)	Equations: Area	Equations: Wetted Perimeter	Equations: Velocity	Average Flow Area (ft^2)	Average Wetted Perimeter (ft^2)	Velocity (ft/s)	T_t (hrs)	T_t(mins)	Notes
3	Circular Pipe	Lined or Built-Up Channel	Concrete	0.013	1592.58	1580.83	180.74	0.065	1.00	NA	NA	NA	A = π(d/2)^2	P = 2π(d/2)	V = (1.49()(r^2/3)()(s)^0.5)()/n	0.79	3.14	11.60	0.004	0.26	Assumed Diameter
4	Trapezoidal Channel	Lined or Built-Up Channel	Clean, straight, full,no rifts or deep pools	0.080	1580.83	1514.41	336.45	0.197	4.90	10.00	1.00	19.80	A = (b + zh)h	P = b + (2h(SQRT(1 + (z)^2)	V = (1.49()(r^2/3)()(s)^0.5)()/n	73.01	23.86	46.51	0.002	0.12	
5	Circular Pipe	Lined or Built-Up Channel	Concrete	0.013	1514.41	1513.06	194.69	0.007	1.25	NA	NA	NA	A = π(d/2)^2	P = 2π(d/2)	V = (1.49()(r^2/3)()(s)^0.5)()/n	1.23	3.93	4.40	0.012	0.74	
6	Trapezoidal Channel	Lined or Built-Up Channel	Clean, straight, full,no rifts or deep pools	0.080	1513.06	1496.18	106.79	0.158	2.10	23.00	6.00	48.20	A = (b + zh)h	P = b + (2h(SQRT(1 + (z)^2)	V = (1.49()(r^2/3)()(s)^0.5)()/n	74.76	48.55	26.33	0.001	0.07	
7	Circular Pipe	Lined or Built-Up Channel	Concrete	0.013	1496.18	1486.00	184.87	0.055	1.50	NA	NA	NA	A = π(d/2)^2	P = 2π(d/2)	V = (1.49()(r^2/3)()(s)^0.5)()/n	1.77	4.71	13.99	0.004	0.22	
8	Triangular Channel	Lined or Built-Up Channel	Clean, straight, full,no rifts or deep pools	0.080	1486.00	1469.00	313.87	0.054	2.00	NA	4.00	16.00	A = z(h)^2	P = (2h(SQRT(1 + (z)^2)	V = (1.49()(r^2/3)()(s)^0.5)()/n	16.00	16.49	11.33	0.008	0.46	
9	Circular Pipe	Lined or Built-Up Channel	Concrete	0.013	1469.00	1458.15	441.76	0.025	2.00	NA	NA	NA	A = π(d/2)^2	P = 2π(d/2)	V = (1.49()(r^2/3)()(s)^0.5)()/n	3.14	6.28	11.32	0.011	0.65	
10	Trapezoidal Channel	Lined or Built-Up Channel	Clean, straight, full,no rifts or deep pools	0.080	1458.15	1454.59	80.33	0.044	4.00	65.00	6.00	113.00	A = (b + zh)h	P = b + (2h(SQRT(1 + (z)^2)	V = (1.49()(r^2/3)()(s)^0.5)()/n	356.00	113.66	22.38	0.001	0.06	
11	Circular Pipe	Lined or Built-Up Channel	Concrete	0.013	1454.59	1449.98	64.77	0.071	2.25	NA	NA	NA	A = π(d/2)^2	P = 2π(d/2)	V = (1.49()(r^2/3)()(s)^0.5)()/n	3.98	7.07	20.84	0.001	0.05	
12	Trapezoidal Channel	Lined or Built-Up Channel	Clean, straight, full,no rifts or deep pools w/ more stones and weeds	0.060	1449.98	1441.96	266.31	0.030	2.00	3.50	3.50	17.50	A = (b + zh)h	P = b + (2h(SQRT(1 + (z)^2)	V = (1.49()(r^2/3)()(s)^0.5)()/n	21.00	18.06	7.15	0.010	0.62	
13	Circular Pipe	Lined or Built-Up Channel	Clean, straight, full,no rifts or deep pools w/ more stones and weeds	0.060	1441.96	1427.95	1331.32	0.011	3.00	NA	NA	NA	A = π(d/2)^2	P = 2π(d/2)	V = (1.49()(r^2/3)()(s)^0.5)()/n	7.07	9.42	3.15	0.117	7.03	

	T_t (hrs)	T_t(mins)
Total T_t =	0.548	32.552
T_c =	0.326	19.531

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WORKSHEET FOR SCS HYDROLOGIC PARAMETERS

Land Use:	X	Existing	Project:	Woodland Drive Drainage Improvement
		Proposed	Drainage Area Number:	1D_1
Off-Site Land Use:	X	Existing	By:	C. REDMAN
		Proposed	Date:	6/17/2021

TIME OF CONCENTRATION (VELOCITY METHOD)

2-Year 24-Hour Precipitation Rainfall Amount (in) = 3.41

County/City: City of Harrisonburg

Sheet Flow

ID	Type of Flow	n	US Elev.	DS Elev.	Length (ft.)	Avg. Slope (ft/ft)	Travel Time Equation	Velocity (ft/s)	T_t (hrs)	T_t (mins)	Notes
1	Grass - Dense Grasses	0.240	1636.1	1635.0	87.71	0.012	$T_t = \frac{0.007\ (nL)^{0.8}}{(P_2)^{0.5}\ S^{0.4}}$	NA	0.286	17.145	

Shallow Concentrated Flow

ID	Flow Type	n	US Elev.	DS Elev.	Length (ft.)	Avg. Slope (ft/ft)	Velocity Equation	Velocity (ft/s)	T_t (hrs)	T_t (mins)	Notes
2	Pavement and Small Upland Gullies	0.025	1635.0	1591.8	1171.12	0.035	V = 20.328(s)^0.5	3.811	0.085	5.121	

Channel Flow

ID	Channel Shape	Channel Type	Channel Description	n	US Elev.	DS Elev.	Length (ft.)	Avg. Slope (ft/ft)	Avg. Normal Depth (ft)	Avg. Bottom Width (ft)	Avg. Side Slopes (ft/ft)	Avg. Top Width (ft)	Equations: Area	Equations: Wetted Perimeter	Equations: Velocity	Average Flow Area (ft^2)	Average Wetted Perimeter (ft^2)	Velocity (ft/s)	T_t (hrs)	T_t (mins)	Notes
3	Circular Pipe	Lined or Built-Up Channel	Concrete	0.013	1592.58	1580.83	180.74	0.065	1.00	NA	NA	NA	A = π(d/2)^2	P = 2π(d/2)	V = (1.49)((P2/3)((s)^0.5)))/n	0.79	3.14	11.60	0.004	0.26	Assumed Diameter
4	Trapezoidal Channel	Lined or Built-Up Channel	Clean, straight, full,no rifts or deep pools	0.030	1580.83	1514.41	336.46	0.197	4.90	10.00	1.00	19.80	A = (b + zh)h	P = b + (2h(SQRT(1 + (z)^2)	V = (1.49)((P2/3)((s)^0.5)))/n	73.01	23.86	46.51	0.002	0.12	
5	Circular Pipe	Lined or Built-Up Channel	Concrete	0.013	1514.41	1513.06	194.69	0.007	1.25	NA	NA	NA	A = π(d/2)^2	P = 2π(d/2)	V = (1.49)((P2/3)((s)^0.5)))/n	1.23	3.93	4.40	0.012	0.74	
6	Trapezoidal Channel	Lined or Built-Up Channel	Clean, straight, full,no rifts or deep pools	0.030	1513.06	1496.18	106.79	0.158	2.10	23.00	6.00	48.20	A = (b + zh)h	P = b + (2h(SQRT(1 + (z)^2)	V = (1.49)((P2/3)((s)^0.5)))/n	74.76	48.55	26.33	0.001	0.07	
7	Circular Pipe	Lined or Built-Up Channel	Concrete	0.013	1496.18	1486.00	184.87	0.055	1.50	NA	NA	NA	A = π(d/2)^2	P = 2π(d/2)	V = (1.49)((P2/3)((s)^0.5)))/n	1.77	4.71	13.99	0.004	0.22	
8	Triangular Channel	Lined or Built-Up Channel	Clean, straight, full,no rifts or deep pools	0.030	1486.00	1469.00	313.87	0.054	2.00	NA	4.00	16.00	A = z(h)^2	P = (2h(SQRT(1 + (z)^2)	V = (1.49)((P2/3)((s)^0.5)))/n	16.00	16.49	11.33	0.008	0.46	
9	Circular Pipe	Lined or Built-Up Channel	Concrete	0.013	1469.00	1458.15	441.76	0.025	2.00	NA	NA	NA	A = π(d/2)^2	P = 2π(d/2)	V = (1.49)((P2/3)((s)^0.5)))/n	3.14	6.28	11.32	0.011	0.65	
10	Trapezoidal Channel	Lined or Built-Up Channel	Clean, straight, full,no rifts or deep pools	0.030	1458.15	1454.59	80.31	0.044	4.00	65.00	6.00	113.00	A = (b + zh)h	P = b + (2h(SQRT(1 + (z)^2)	V = (1.49)((P2/3)((s)^0.5)))/n	356.00	113.66	22.38	0.001	0.06	
11	Circular Pipe	Lined or Built-Up Channel	Concrete	0.013	1454.59	1449.98	64.77	0.071	2.25	NA	NA	NA	A = π(d/2)^2	P = 2π(d/2)	V = (1.49)((P2/3)((s)^0.5)))/n	3.98	7.07	20.84	0.001	0.05	
																		Total T_c =	0.415	24.896	
																		T_l =	0.249	14.938	

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WORKSHEET FOR SCS HYDROLOGIC PARAMETERS

Land Use:	X	Existing	Project:	Woodland Drive Drainage Improvement
		Proposed	Drainage Area Number:	1D_3
Off-Site Land Use:	X	Existing	By:	C. REDMAN
		Proposed	Date:	6/17/2021

TIME OF CONCENTRATION (VELOCITY METHOD)

2-Year 24-Hour Precipitation Rainfall Amount (in) =	3.43
County/City:	City of Harrisonburg

Sheet Flow

ID	Type of Flow	n	US Elev.	DS Elev.	Length (ft.)	Avg. Slope (ft/ft)	Travel Time Equation	Velocity (ft/s)	T_t (hrs)	T_t(mins)	Notes
1	Smooth Surface (concrete, asphalt, gravel, bare soil)	0.011	1474.7	1473.7	21.28	0.045	$T_t = \frac{0.007\ (nL)^{0.8}}{(P_2)^{0.5}\ S^{0.4}}$	NA	0.005	0.280	

Shallow Concentrated Flow

ID	Flow Type	n	US Elev.	DS Elev.	Length (ft.)	Avg. Slope (ft/ft)	Velocity Equation	Velocity (ft/s)	T_t (hrs)	T_t(mins)	Notes
2	Grassed Waterways	0.050	1473.7	1447.3	290.22	0.091	V = 16.135(s)^0.5	4.870	0.017	0.993	
3	Pavement and Small Upland Gullies	0.025	1447.3	1444.0	78.00	0.043	V = 20.328(s)^0.5	4.194	0.005		

Channel Flow

ID	Channel Shape	Channel Type	Channel Description	n	US Elev.	DS Elev.	Length (ft.)	Avg. Slope (ft/ft)	Avg. Normal Depth (ft)	Avg. Bottom Width (ft)	Avg. Side Slopes (ft/ft)	Avg. Top Width (ft)	Equations: Area	Equations: Wetted Perimeter	Equations: Velocity	Average Flow Area (ft^2)	Average Wetted Perimeter (ft^2)	Velocity (ft/s)	T_t (hrs)	T_t(mins)	Notes
3	Triangular Channel	Natural Stream	Vegetal Lining	0.080	1443.98	1429.79	298.09	0.048	1.00	NA	5.00	10.00	A = z(b)^2	P = (2b)(SQRT(1 + (z)^2)	V = (1.49((r)^2/3))((s)^0.5))/n	5.00	10.20	6.74	0.012	0.74	Assumed Diameter
																		Total T_t =	0.034	2.011	
																		T_L =	0.020	1.206	

TIMMONS GROUP

YOUR VISION ACHIEVED THROUGH OURS.

WORKSHEET FOR SCS HYDROLOGIC PARAMETERS

Land Use:	X	Existing	Project:	Woodland Drive Drainage Improvement
		Proposed	Drainage Area Number:	1D_3
Off-Site Land Use:	X	Existing	By:	C. REDMAN
		Proposed	Date:	6/17/2021

TIME OF CONCENTRATION (VELOCITY METHOD)

2-Year 24-Hour Precipitation Rainfall Amount (in) = 3.43

County/City: City of Harrisonburg

Sheet Flow

ID	Type of Flow	n	US Elev.	DS Elev.	Length (ft.)	Avg. Slope (ft/ft)	Travel Time Equation	Velocity (ft/s)	T_t (hrs)	T_t(mins)	Notes
1	Grass - Dense Grasses	0.240	1600.0	1593.0	34.78	0.201	$T_t = \frac{0.007\ (nL)^{0.8}}{(P_2)^{0.5}\ S^{0.4}}$	NA	0.045	2.685	

Shallow Concentrated Flow

ID	Flow Type	n	US Elev.	DS Elev.	Length (ft.)	Avg. Slope (ft/ft)	Velocity Equation	Velocity (ft/s)	T_t (hrs)	T_t(mins)	Notes
2	Forest w/ Heavy Ground Litter & Hay Meadows	0.202	1593.0	1544.0	224.00	0.219	V = 2.516(s)^0.5	1.177	0.053	3.173	
	Pavement and Small Upland Gullies	0.025	1544.0	1534.9	61.17	0.149	V = 20.328(s)^0.5	7.849	0.002	0.130	
	Forest w/ Heavy Ground Litter & Hay Meadows	0.202	1534.9	1513.4	96.59	0.223	V = 2.516(s)^0.5	1.187	0.023	1.356	
	Pavement and Small Upland Gullies	0.025	1513.4	1496.9	146.34	0.112	V = 20.328(s)^0.5	6.818	0.006	0.358	

Channel Flow

ID	Channel Shape	Channel Type	Channel Description	n	US Elev.	DS Elev.	Length (ft.)	Avg. Slope (ft/ft)	Avg. Normal Depth (ft)	Avg. Bottom Width (ft)	Avg. Side Slopes (ft/ft)	Avg. Top Width (ft)	Equations: Area	Equations: Wetted Perimeter	Equations: Velocity	Average Flow Area (ft^2)	Average Wetted Perimeter (ft^2)	Velocity (ft/s)	T_t (hrs)	T_t(mins)	Notes
3	Circular Pipe	Lined or Built-Up Channel	Concrete	0.013	1493.90	1472.35	175.24	0.123	1.25	NA	NA	NA	A = π(d/2)^2	P = 2π(d/2)	V = [1.49][r^2/3][s^0.5]]/n	1.23	3.93	18.51	0.003	0.16	Assumed Diameter
4	Trapezoidal Channel	Lined or Built-Up Channel	Clean, straight, full,no rifts or deep pools	0.030	1472.35	1466.33	98.28	0.061	3.00	40.00	3.00	58.00	A = (b + zh)h	P = b + (2h(SQRT(1 + (z)^2))	V = [1.49][r^2/3][s^0.5]]/n	147.00	58.97	22.60	0.001	0.07	
5	Circular Pipe	Lined or Built-Up Channel	Concrete	0.013	1466.33	1441.79	719.64	0.034	1.50	NA	NA	NA	A = π(d/2)^2	P = 2π(d/2)	V = [1.49][r^2/3][s^0.5]]/n	1.77	4.71	11.01	0.018	1.09	

	T_t (hrs)	T_t(mins)
Total T_t =	0.150	9.022
T_c =	0.090	5.413

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WORKSHEET FOR SCS HYDROLOGIC PARAMETERS

Land Use:	X	Existing	Project:	Woodland Drive Drainage Improvement
		Proposed	Drainage Area Number:	1E
Off-Site Land Use:	X	Existing	By:	C. REDMAN
		Proposed	Date:	6/17/2021

TIME OF CONCENTRATION (VELOCITY METHOD)

2-Year 24-Hour Precipitation Rainfall Amount (in) = 2.61

County/City: City of Harrisonburg

Sheet Flow

ID	Type of Flow	n	US Elev.	DS Elev.	Length (ft.)	Avg. Slope (ft/ft)	Travel Time Equation	Velocity (ft/s)	T_t (hrs)	T_t(mins)	Notes
1	Grass - Short Grass Prairie	0.150	1727.3	1715.5	101.71	0.116	$T_t = \frac{0.007\ (nL)0.8}{(P_2)^{0.5}\ S^{0.4}}$	NA	0.090	5.425	

Shallow Concentrated Flow

ID	Flow Type	n	US Elev.	DS Elev.	Length (ft.)	Avg. Slope (ft/ft)	Velocity Equation	Velocity (ft/s)	T_t (hrs)	T_t(mins)	Notes
2	Forest w/ Heavy Ground Litter & Hay Meadows	0.202	1715.5	1682.2	148.47	0.225	V = 2.516(s)^0.5	1.193	0.035	2.074	
3	Short-Grass Pasture	0.073	1682.2	1664.0	60.03	0.303	V = 6.962(s)^0.5	3.834	0.004	0.261	
4	Forest w/ Heavy Ground Litter & Hay Meadows	0.202	1664.0	1590.0	253.15	0.292		1.360	0.052	3.102	
5	Pavement and Small Upland Gullies	0.025	1590.0	1586.5	83.04	0.042		4.135	0.006	0.331	

Channel Flow

ID	Channel Shape	Channel Type	Channel Description	n	US Elev.	DS Elev.	Length (ft.)	Avg. Slope (ft/ft)	Avg. Normal Depth (ft)	Avg. Bottom Width (ft)	Avg. Side Slopes (ft/ft)	Avg. Top Width (ft)	Equations: Area	Equations: Wetted Perimeter	Equations: Velocity	Average Flow Area (ft²)	Average Wetted Perimeter (ft²)	Velocity (ft/s)	T_t (hrs)	T_t(mins)	Notes
3	Circular Pipe	Lined or Built-Up Channel	Concrete	0.013	1586.47	1520.63	955.04	0.069	1.25			NA	A = π(d/2)^2	P = 2π(d/2)	V = [1.49()/(^2/3)()(s)^0.5]()/n	1.23	3.93	13.86	0.019	1.15	
4	Trapezoidal Channel	Lined or Built-Up Channel	Clean, straight, full,no rifts or deep pools w/ more stones and weeds	0.040	1520.63	1510.00	124.78	0.085	5.00	12.00	4.00	52.00	A = (b + zh)h	P = b + (2h)(SQRT(1 + (z)^2)	V = [1.49()/(^2/3)()(s)^0.5]()/n	160.00	53.23	22.64	0.002	0.09	
5	Circular Pipe	Lined or Built-Up Channel	Concrete	0.013	1510.00	1477.43	863.38	0.038	1.50			NA	A = π(d/2)^2	P = 2π(d/2)	V = [1.49()/(^2/3)()(s)^0.5]()/n	1.77	4.71	11.58	0.021	1.24	
6	Trapezoidal Channel	Lined or Built-Up Channel	Clean, straight, full,no rifts or deep pools w/ more stones and weeds	0.040	1477.43	1472.56	60.79	0.080	4.00	3.50	3.00	27.50	A = (b + zh)h	P = b + (2h)(SQRT(1 + (z)^2)	V = [1.49()/(^2/3)()(s)^0.5]()/n	62.00	28.80	17.58	0.001	0.06	
7	Circular Pipe	Lined or Built-Up Channel	Concrete	0.013	1472.56	1467.99	659.51	0.007	2.00			NA	A = π(d/2)^2	P = 2π(d/2)	V = [1.49()/(^2/3)()(s)^0.5]()/n	3.14	6.28	6.01	0.030	1.83	

Total T_t =	0.254	15.232
T_L =	0.152	9.139

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WORKSHEET FOR SCS HYDROLOGIC PARAMETERS

Land Use:	X	Existing	Project:	Woodland Drive Drainage Improvement
		Proposed	Drainage Area Number:	2
Off-Site Land Use:	X	Existing	By:	C. REDMAN
		Proposed	Date:	6/17/2021

TIME OF CONCENTRATION (VELOCITY METHOD)

2-Year 24-Hour Precipitation Rainfall Amount (in) = 3.43

County/City: City of Harrisonburg

Sheet Flow

ID	Type of Flow	n	US Elev.	DS Elev.	Length (ft.)	Avg. Slope (ft/ft)	Travel Time Equation	Velocity (ft/s)	T_t (hrs)	T_t(mins)	Notes
1	Grass - Dense Grasses	0.240	1494.6	1489.4	45.90	0.113	$T_t = \frac{0.007\ (nL)0.8}{(P_2)^{0.5}\ S^{0.4}}$	NA	0.071	4.231	

Shallow Concentrated Flow

ID	Flow Type	n	US Elev.	DS Elev.	Length (ft.)	Avg. Slope (ft/ft)	Velocity Equation	Velocity (ft/s)	T_t (hrs)	T_t(mins)	Notes
2	Short-Grass Pasture	0.073	1489.4	1476.0	141.04	0.095	V = 6.962(s)^0.5	2.148	0.018	1.095	
3	Pavement and Small Upland Gullies		1476.0	1471.4	93.27	0.049	V = 20.328(s)^0.5	4.517	0.006	0.345	

Channel Flow

ID	Channel Shape	Channel Type	Channel Description	n	US Elev.	DS Elev.	Length (ft.)	Avg. Slope (ft/ft)	Avg. Normal Depth (ft)	Avg. Bottom Width (ft)	Avg. Side Slopes (ft/ft)	Avg. Top Width (ft)
4	Triangular Channel	Lined or Built-Up Channel	Vegetal Lining	0.080	1471.38	1449.68	270.24	0.080	0.50	NA	4.00	4.00
5	Triangular Channel	Lined or Built-Up Channel	Vegetal Lining	0.080	1449.68	1430.30	323.18	0.060	1.00	NA	3.00	6.00
6	Circular Pipe	Lined or Built-Up Channel	Corrugated Metal	0.025	1430.30	1430.00	56.24	0.005	1.00	NA	NA	NA
7	Trapezoidal Channel	Lined or Built-Up Channel	Vegetal Lining	0.080	1430.00	1412.21	827.47	0.021	7.64	79.00	25.00	461.00
8	Triangular Channel	Lined or Built-Up Channel	Vegetal Lining	0.080	1412.21	1411.38	94.46	0.009	1.50	NA	3.00	9.00

ID	Equations: Area	Equations: Wetted Perimeter	Equations: Velocity	Average Flow Area (ft^2)	Average Wetted Perimeter (ft^2)	Velocity (ft/s)	T_t (hrs)	T_t(mins)	Notes
4	A = z(h)^2	P = (2h)(SQRT(1 + (z)^2))	V = (1.49()(r^2/3))(s)^0.5)()/n	1.00	4.12	5.47	0.014	0.82	Assumed Diameter
5	A = z(h)^2	P = (2h)(SQRT(1 + (z)^2))	V = (1.49()(r^2/3))(s)^0.5)()/n	3.00	6.32	7.40	0.012	0.73	
6	A = π(d/2)^2	P = 2π(d/2)	V = (1.49()(r^2/3))(s)^0.5)()/n	0.79	3.14	1.73	0.009	0.54	
7	A = (b + zh)h	P = b + (2h)(SQRT(1 + (z)^2))	V = (1.49()(r^2/3))(s)^0.5)()/n	2062.80	461.31	19.77	0.012	0.70	
8	A = z(h)^2	P = (2h)(SQRT(1 + (z)^2))	V = (1.49()(r^2/3))(s)^0.5)()/n	6.75	9.49	3.71	0.007	0.42	
						Total T_t =	0.148	8.887	
						T_c =	0.089	5.332	

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WORKSHEET FOR SCS HYDROLOGIC PARAMETERS

Land Use:	X	Existing	Project:	Woodland Drive Drainage Improvement
		Proposed	Drainage Area Number:	2A
Off-Site Land Use:	X	Existing	By:	C. REDMAN
		Proposed	Date:	6/17/2021

TIME OF CONCENTRATION (VELOCITY METHOD)

2-Year 24-Hour Precipitation Rainfall Amount (in) = 3.43

County/City: City of Harrisonburg

Sheet Flow

ID	Type of Flow	n	US Elev.	DS Elev.	Length (ft.)	Avg. Slope (ft/ft)	Travel Time Equation	Velocity (ft/s)	T_t (hrs)	T_t(mins)	Notes
1	Grass - Dense Grasses	0.240	1439.8	1428.1	93.13	0.126	$T_t = \frac{0.007\,(nL)^{0.8}}{(P_2)^{0.5}\,S^{0.4}}$	NA	0.117	7.016	

Shallow Concentrated Flow

ID	Flow Type	n	US Elev.	DS Elev.	Length (ft.)	Avg. Slope (ft/ft)	Velocity Equation	Velocity (ft/s)	T_t (hrs)	T_t(mins)	Notes
2	Pavement and Small Upland Gullies	0.025	1428.1	1410.0	305.83	0.059	V = 20.328(s)^0.5	4.941	0.017	1.032	

Channel Flow

ID	Channel Shape	Channel Type	Channel Description	n	US Elev.	DS Elev.	Length (ft.)	Avg. Slope (ft/ft)	Avg. Normal Depth (ft)	Avg. Bottom Width (ft)	Avg. Side Slopes (ft/ft)	Avg. Top Width (ft)	Equations: Area	Equations: Wetted Perimeter	Equations: Velocity	Average Flow Area (ft^2)	Average Wetted Perimeter (ft^2)	Velocity (ft/s)	T_t (hrs)	T_t(mins)	Notes
4	Circular Pipe	Lined or Built-Up Channel	Concrete	0.013	1401.23	1401.05	37.35	0.005	2.50	NA	4.00	NA	A = π(d/2)^2	P = 2π(d/2)	V = (1.49(r)^2/3)(s)^0.5)/n	4.91	7.85	5.82	0.002	0.11	Assumed Diameter
																		Total T_t =	0.136	8.155	
																		T_c =	0.082	4.893	

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WORKSHEET FOR SCS HYDROLOGIC PARAMETERS

Land Use:	X	Existing	Project:	Woodland Drive Drainage Improvement
		Proposed	Drainage Area Number:	3
Off-Site Land Use:	X	Existing	By:	C. REDMAN
		Proposed	Date:	6/17/2021

TIME OF CONCENTRATION (VELOCITY METHOD)

2-Year 24-Hour Precipitation Rainfall Amount (in) = 3.43

County/City: City of Harrisonburg

Sheet Flow

ID	Type of Flow	n	US Elev.	DS Elev.	Length (ft.)	Avg. Slope (ft/ft)	Travel Time Equation	Velocity (ft/s)	T_t (hrs)	T_t(mins)	Notes
1	Grass - Dense Grasses	0.240	1600.4	1591.3	35.19	0.260	$T_t = \frac{0.007\,(nL)^{0.8}}{(P_2)^{0.5}\,S^{0.4}}$	NA	0.041	2.447	

Shallow Concentrated Flow

ID	Flow Type	n	US Elev.	DS Elev.	Length (ft.)	Avg. Slope (ft/ft)	Velocity Equation	Velocity (ft/s)	T_t (hrs)	T_t(mins)	Notes
2	Forest w/ Heavy Ground Litter & Hay Meadows	0.202	1591.3	1462.2	632.58	0.204	V = 2.516(s)^0.5	1.136	0.155	9.278	
3	Pavement and Small Upland Gullies	0.025	1462.2	1461.0	30.50	0.042	V = 20.328(s)^0.5	4.168	0.002	0.123	

Channel Flow

ID	Channel Shape	Channel Type	Channel Description	n	US Elev.	DS Elev.	Length (ft.)	Avg. Slope (ft/ft)	Avg. Normal Depth (ft)	Avg. Bottom Width (ft)	Avg. Side Slopes (ft/ft)	Avg. Top Width (ft)	Equations: Area	Equations: Wetted Perimeter	Equations: Velocity	Average Flow Area (ft^2)	Average Wetted Perimeter (ft^2)	Velocity (ft/s)	T_t (hrs)	T_t(mins)	Notes
4	Circular Pipe	Lined or Built-Up Channel	Concrete	0.013	1460.97	1434.65	389.65	0.068	1.25	NA	NA	NA	A = π(d/2)^2	P = 2π(d/2)	V = (1.49(r)^(2/3))((s)^0.5)/n	1.23	3.93	13.72	0.008	0.47	Assumed Diameter
5	Trapezoidal Channel	Lined or Built-Up Channel	Clean, straight, full,no rifts or deep pools	0.030	1434.65	1411.96	603.49	0.038	8.00	50.00	5.00	130.00	A = (b + zh)h	P = b + (2h)SQRT(1 + (z)^2)	V = (1.49(r)^(2/3))((s)^0.5)/n	720.00	131.58	29.90	0.006	0.34	
6	Circular Pipe	Lined or Built-Up Channel	Concrete	0.013	1407.00	1403.00	49.55	0.081	2.50	NA	NA	NA	A = π(d/2)^2	P = 2π(d/2)	V = (1.49(r)^(2/3))((s)^0.5)/n	4.91	7.85	23.81	0.001	0.03	

	T_t (hrs)	T_t(mins)
Total T_t =	0.212	12.692
T_c =	0.127	7.615

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WORKSHEET FOR SCS HYDROLOGIC PARAMETERS

Land Use:	X	Existing	Project:	Woodland Drive Drainage Improvement
		Proposed	Drainage Area Number:	3A
Off-Site Land Use:	X	Existing	By:	C. REDMAN
		Proposed	Date:	6/17/2021

TIME OF CONCENTRATION (VELOCITY METHOD)

2-Year 24-Hour Precipitation Rainfall Amount (in) =	2.83
County/City:	City of Harrisonburg

Sheet Flow

ID	Type of Flow	n	US Elev.	DS Elev.	Length (ft.)	Avg. Slope (ft/ft)	Travel Time Equation	Velocity (ft/s)	T_t (hrs)	T_t(mins)	Notes
1	Woods - Light Underbrush	0.400	1500.1	1489.7	71.59	0.145	$T_t = \frac{0.007\ (nL)0.8}{(P_2)^{0.5}\ S^{0.4}}$	NA	0.137	8.212	

Shallow Concentrated Flow

ID	Flow Type	n	US Elev.	DS Elev.	Length (ft.)	Avg. Slope (ft/ft)	Velocity Equation	Velocity (ft/s)	T_t (hrs)	T_t(mins)	Notes
2	Short-Grass Pasture	0.073	1489.7	1462.0	225.31	0.123	V = 6.962(s)^0.5	2.443	0.026	1.537	

Channel Flow

ID	Channel Shape	Channel Type	Channel Description	n	US Elev.	DS Elev.	Length (ft.)	Avg. Slope (ft/ft)	Avg. Normal Depth (ft)	Avg. Bottom Width (ft)	Avg. Side Slopes (ft/ft)	Avg. Top Width (ft)	Equations: Area	Equations: Wetted Perimeter	Equations: Velocity	Average Flow Area (ft²)	Average Wetted Perimeter (ft²)	Velocity (ft/s)	T_t (hrs)	T_t(mins)	Notes
4	Gutter	Lined or Built-Up Channel	Concrete	0.013	1462.0	1425.5	445.78	0.082	0.50	1.00	0.08	1.00	A = 0.5bh	P = h + SQRT((h^2) + (b^2))	V = (1.56/(An))((h)^1.67)((b^2.67))(s)^0.5)	0.25	1.00	0.77	0.160	9.621	vdot 9.4.4.3

	T_t (hrs)	T_t(mins)
Total T_t =	0.323	19.370
T_c =	0.194	11.622

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WORKSHEET FOR SCS HYDROLOGIC PARAMETERS

Land Use:	X	Existing	Project:	Woodland Drive Drainage Improvement
		Proposed	Drainage Area Number:	[illegible]
Off-Site Land Use:	X	Existing	By:	C. REDMAN
		Proposed	Date:	6/17/2021

TIME OF CONCENTRATION (VELOCITY METHOD)

2-Year 24-Hour Precipitation Rainfall Amount (in) = [illegible]

County/City: City of Harrisonburg

Sheet Flow

ID	Type of Flow	n	US Elev.	DS Elev.	Length (ft.)	Avg. Slope (ft/ft)	Travel Time Equation	Velocity (ft/s)	T_t (hrs)	T_t(mins)	Notes
1	Grass - Short Grass Prairie	0.150	1443.1	1438.1	84.74	0.058	$T_t = \frac{0.007\,(nL)^{0.8}}{(P_2)^{0.5}\,S^{0.4}}$	NA	0.103	6.186	

Shallow Concentrated Flow

ID	Flow Type	n	US Elev.	DS Elev.	Length (ft.)	Avg. Slope (ft/ft)	Velocity Equation	Velocity (ft/s)	T_t (hrs)	T_t(mins)	Notes
2	Short-Grass Pasture	0.073	1438.1	1417.0	223.14	0.095	V = 6.962(s)^0.5	2.141	0.029	1.737	

Channel Flow

ID	Channel Shape	Channel Type	Channel Description	n	US Elev.	DS Elev.	Length (ft.)	Avg. Slope (ft/ft)	Avg. Normal Depth (ft)	Avg. Bottom Width (ft)	Avg. Side Slopes (ft/ft)	Avg. Top Width (ft)	Equations: Area	Equations: Wetted Perimeter	Equations: Velocity	Average Flow Area (ft^2)	Average Wetted Perimeter (ft^2)	Velocity (ft/s)	T_t (hrs)	T_t(mins)	Notes
3	Gutter	Lined or Built-Up Channel	Concrete	0.013	1417.0	1410.2	193.34	0.035	0.50	1.00	[illegible]	1.00	A = 0.5bh	P = h + SQRT((h^2) + (b^2))	V = (1.56/(An))((h)^1.67)((b^2.67))(s)^0.5)	0.25	1.00	0.51	0.106	6.348	vdot 9.4.4.3

	T_t (hrs)	T_t(mins)
Total T_t =	0.238	14.271
T_c =	0.143	8.563

TIMMONS GROUP
YOUR VISION ACHIEVED THROUGH OURS.

WORKSHEET FOR SCS HYDROLOGIC PARAMETERS

Land Use:	X	Existing	Project:	Woodland Drive Drainage Improvement
		Proposed	Drainage Area Number:	3C
Off-Site Land Use:	X	Existing	By:	K. REDMAN
		Proposed	Date:	6/17/2021

TIME OF CONCENTRATION (VELOCITY METHOD)

2-Year 24-Hour Percipitation Rainfall Amount (in) =	2.63
County/City:	City of Harrisonburg

Sheet Flow

ID	Type of Flow	n	US Elev.	DS Elev.	Length (ft.)	Avg. Slope (ft/ft)	Travel Time Equation	Velocity (ft/s)	T_t (hrs)	T_t(mins)	Notes
1	Grass - Short Grass Prairie	0.150	1429.8	1422.0	35.19	0.221	$T_t = \frac{0.007\,(nL)^{0.8}}{(P_2)^{0.5}\,S^{0.4}}$	NA	0.030	1.792	

Shallow Concentrated Flow

ID	Flow Type	n	US Elev.	DS Elev.	Length (ft.)	Avg. Slope (ft/ft)	Velocity Equation	Velocity (ft/s)	T_t (hrs)	T_t(mins)	Notes
2	Short-Grass Pasture	0.073	1422.0	1411.9	165.90	0.061	V = 6.962(s)^0.5	1.716	0.027	1.611	

Channel Flow

ID	Channel Shape	Channel Type	Channel Description	n	US Elev.	DS Elev.	Length (ft.)	Avg. Slope (ft/ft)	Avg. Normal Depth (ft)	Avg. Bottom Width (ft)	Avg. Side Slopes (ft/ft)	Avg. Top Width (ft)	Equations: Area	Equations: Wetted Perimeter	Equations: Velocity	Average Flow Area (ft^2)	Average Wetted Perimeter (ft^2)	Velocity (ft/s)	T_t (hrs)	T_t(mins)	Notes
4	Gutter	Lined or Built-Up Channel	Concrete	0.013	1411.9	1410.2	86.66	0.020	0.50	1.00	0.08	1.00	A = 0.5bh	P = h + SQRT((h^2) + (b^2))	V = (1.56/(An))((h)^1.67)((b)^2.67)((s)^0.5)	0.25	1.00	0.38	0.063	3.76	vdot 9.4.4.3
																		Total T_t =	0.119	7.159	
																		T_c =	0.072	4.295	

TIMMONS GROUP
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WORKSHEET FOR SCS HYDROLOGIC PARAMETERS

Land Use:	X	Existing	Project:	Woodland Drive Drainage Improvement
		Proposed	Drainage Area Number:	ID
Off-Site Land Use:	X	Existing	By:	C. REDMAN
		Proposed	Date:	6/17/2021

TIME OF CONCENTRATION (VELOCITY METHOD)

2-Year 24-Hour Precipitation Rainfall Amount (in) = 2.63

County/City: City of Harrisonburg

Sheet Flow

ID	Type of Flow	n	US Elev.	DS Elev.	Length (ft.)	Avg. Slope (ft/ft)	Travel Time Equation	Velocity (ft/s)	T_t (hrs)	T_t(mins)	Notes
1	Smooth Surface (concrete, asphalt, gravel, bare soil)	0.011	1428.5	1421.0	89.93	0.083	$T_t = \frac{0.007\ (nL)^{0.8}}{(P_2)^{0.5}\ S^{0.4}}$	NA	0.012	0.694	

Shallow Concentrated Flow

ID	Flow Type	n	US Elev.	DS Elev.	Length (ft.)	Avg. Slope (ft/ft)	Velocity Equation	Velocity (ft/s)	T_t (hrs)	T_t(mins)	Notes
2	Pavement and Small Upland Gullies	0.025	1421.0	1417.3	80.99	0.046	V = 20.328(s)^0.5	4.380	0.005	0.308	

Channel Flow

ID	Channel Shape	Channel Type	Channel Description	n	US Elev.	DS Elev.	Length (ft.)	Avg. Slope (ft/ft)	Avg. Normal Depth (ft)	Avg. Bottom Width (ft)	Avg. Side Slopes (ft/ft)	Avg. Top Width (ft)	Equations: Area	Equations: Wetted Perimeter	Equations: Velocity	Average Flow Area (ft²)	Average Wetted Perimeter (ft²)	Velocity (ft/s)	T_t (hrs)	T_t(mins)	Notes
4	Circular Pipe	Lined or Built-Up Channel	Concrete	0.013	#REF!	1434.65	189.65	#REF!	1.25	NA	NA	NA	A = π(d/2)^2	P = 2π(d/2)	V = (1.49)(r^(2/3))(s^0.5)/n	1.23	3.93				Assumed Diameter
																		Total T_t =	0.017	1.002	
																		T_c =	0.010	0.601	

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WORKSHEET FOR SCS HYDROLOGIC PARAMETERS

Land Use:	X	Existing	Project:	Woodland Drive Drainage Improvement
		Proposed	Drainage Area Number:	8
Off-Site Land Use:	X	Existing	By:	C. REDMAN
		Proposed	Date:	6/17/2021

TIME OF CONCENTRATION (VELOCITY METHOD)

2-Year 24-Hour Precipitation Rainfall Amount (in) = 2.63

County/City: City of Harrisonburg

Sheet Flow

ID	Type of Flow	n	US Elev.	DS Elev.	Length (ft.)	Avg. Slope (ft/ft)	Travel Time Equation	Velocity (ft/s)	T_t (hrs)	T_t (mins)	Notes
1	Grass - Short Grass Prairie	0.150	1428.0	1424.9	83.99	0.037	$T_t = \frac{0.007\,(nL)^{0.8}}{(P_2)^{0.5}\,S^{0.4}}$	NA	0.121	7.243	

Shallow Concentrated Flow

ID	Flow Type	n	US Elev.	DS Elev.	Length (ft.)	Avg. Slope (ft/ft)	Velocity Equation	Velocity (ft/s)	T_t (hrs)	T_t (mins)	Notes
2	Short-Grass Pasture	0.073	1424.9	1409.3	165.70	0.095	V = 6.962(s)^0.5	2.142	0.021	1.290	

Channel Flow

ID	Channel Shape	Channel Type	Channel Description	n	US Elev.	DS Elev.	Length (ft.)	Avg. Slope (ft/ft)	Avg. Normal Depth (ft)	Avg. Bottom Width (ft)	Avg. Side Slopes (ft/ft)	Avg. Top Width (ft)	Equations: Area	Equations: Wetted Perimeter	Equations: Velocity	Average Flow Area (ft^2)	Average Wetted Perimeter (ft^2)	Velocity (ft/s)	T_t (hrs)	T_t (mins)	Notes
4	Circular Pipe	Lined or Built-Up Channel	Concrete	0.013	1401.5	1399.4	130.31	0.016	3.00	NA	0.08	NA	A = π(d/2)^2	P = 2π(d/2)	V = (1.49((A/P)^2/3)((s)^0.5))/n	7.07	9.42	11.95	0.003	0.18	vdot 9.4.4.3
																		Total T_t =	0.145	8.713	
																		T_L =	0.087	5.228	

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WORKSHEET FOR SCS HYDROLOGIC PARAMETERS

Land Use:	X	Existing	Project:	Woodland Drive Drainage Improvement
		Proposed	Drainage Area Number:	4
Off-Site Land Use:	X	Existing	By:	C. REDMAN
		Proposed	Date:	6/17/2021

TIME OF CONCENTRATION (VELOCITY METHOD)

2-Year 24-Hour Precipitation Rainfall Amount (in) = 2.81

County/City: City of Harrisonburg

Sheet Flow

ID	Type of Flow	n	US Elev.	DS Elev.	Length (ft.)	Avg. Slope (ft/ft)	Travel Time Equation	Velocity (ft/s)	T_t (hrs)	T_t(mins)	Notes
1	Smooth Surface (concrete, asphalt, gravel, bare soil)	0.011	1454.0	1453.5	79.29	0.006	$T_t = \frac{0.007\ (nL)0.8}{(P_2)^{0.5}\ S^{0.4}}$	NA	0.029	1.761	

Shallow Concentrated Flow

ID	Flow Type	n	US Elev.	DS Elev.	Length (ft.)	Avg. Slope (ft/ft)	Velocity Equation	Velocity (ft/s)	T_t (hrs)	T_t(mins)	Notes
2	Pavement and Small Upland Gullies	0.025	1453.5	1444.0	336.23	0.028	V = 20.328(s)^0.5	3.417	0.027	1.640	

Channel Flow

ID	Channel Shape	Channel Type	Channel Description	n	US Elev.	DS Elev.	Length (ft.)	Avg. Slope (ft/ft)	Avg. Normal Depth (ft)	Avg. Bottom Width (ft)	Avg. Side Slopes (ft/ft)	Avg. Top Width (ft)	Equations: Area	Equations: Wetted Perimeter	Equations: Velocity	Average Flow Area (ft^2)	Average Wetted Perimeter (ft^2)	Velocity (ft/s)	T_t (hrs)	T_t(mins)	Notes
3	Triangular Channel	Lined or Built-Up Channel	Vegetal Lining	0.030	1444.00	1443.50	15.78	0.032	2.00	NA	3.00	12.00	A = z(h)^2	P = (2h)(SQRT(1 + (z)^2))	V = (1.49((A/P)^2/3))(s)^0.5)))/n	12.00	12.65	8.54	0.001	0.03	Assumed Diameter
																		Total T_c =	0.057	3.432	
																		T_L =	0.034	2.059	

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WORKSHEET FOR SCS HYDROLOGIC PARAMETERS

Land Use:	X	Existing	Project:	Woodland Drive Drainage Improvement
		Proposed	Drainage Area Number:	6A
Off-Site Land Use:	X	Existing	By:	C. REDMAN
		Proposed	Date:	6/17/2021

TIME OF CONCENTRATION (VELOCITY METHOD)

2-Year 24-Hour Precipitation Rainfall Amount (in) = 2.63

County/City: City of Harrisonburg

Sheet Flow

ID	Type of Flow	n	US Elev.	DS Elev.	Length (ft.)	Avg. Slope (ft/ft)	Travel Time Equation	Velocity (ft/s)	T_t (hrs)	T_t(mins)	Notes
1	Grass - Short Grass Prairie	0.150	1450.0	1447.0	57.07	0.053	$T_t = \frac{0.007\ (nL)0.8}{(P_2)^{0.5}\ S^{0.4}}$	NA	0.078	4.688	

Shallow Concentrated Flow

ID	Flow Type	n	US Elev.	DS Elev.	Length (ft.)	Avg. Slope (ft/ft)	Velocity Equation	Velocity (ft/s)	T_t (hrs)	T_t(mins)	Notes
2	Short-Grass Pasture	0.073	1447.0	1434.0	265.27	0.049	V = 6.962(s)^0.5	1.541	0.048	2.869	

Channel Flow

ID	Channel Shape	Channel Type	Channel Description	n	US Elev.	DS Elev.	Length (ft.)	Avg. Slope (ft/ft)	Avg. Normal Depth (ft)	Avg. Bottom Width (ft)	Avg. Side Slopes (ft/ft)	Avg. Top Width (ft)	Equations: Area	Equations: Wetted Perimeter	Equations: Velocity	Average Flow Area (ft^2)	Average Wetted Perimeter (ft)	Velocity (ft/s)	T_t (hrs)	T_t(mins)	Notes
3	Triangular Channel	Lined or Built-Up Channel	Vegetal Lining	0.030	1434.00	1429.92	88.80	0.046	2.00	NA	3.00	12.00	A = z(h)^2	P = (2h)(SQRT(1 + (z)^2))	V = (1.49((r)^2/3))(s)^0.5))/n	12.00	12.65	10.28	0.002	0.14	Assumed Diameter
																		Total T_c =	0.128	7.701	
																		T_c =	0.077	4.620	

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WORKSHEET FOR SCS HYDROLOGIC PARAMETERS

Land Use:	X	Existing	Project:	Woodland Drive Drainage Improvement
		Proposed	Drainage Area Number:	4B
Off-Site Land Use:	X	Existing	By:	C. REDMAN
		Proposed	Date:	6/17/2021

TIME OF CONCENTRATION (VELOCITY METHOD)

2-Year 24-Hour Precipitation Rainfall Amount (in) = 3.43

County/City: City of Harrisonburg

Sheet Flow

ID	Type of Flow	n	US Elev.	DS Elev.	Length (ft.)	Avg. Slope (ft/ft)	Travel Time Equation	Velocity (ft/s)	T_t (hrs)	T_t(mins)	Notes
1	Smooth Surface (concrete, asphalt, gravel, bare soil)	0.011	1435.9	1434.7	55.33	0.022	$T_t = \frac{0.007\ (nL)^{0.8}}{(P_2)^{0.5}\ S^{0.4}}$	NA	0.013	0.801	

Shallow Concentrated Flow

ID	Flow Type	n	US Elev.	DS Elev.	Length (ft.)	Avg. Slope (ft/ft)	Velocity Equation	Velocity (ft/s)	T_t (hrs)	T_t(mins)	Notes
2	Pavement and Small Upland Gullies	0.025	1434.70	1430.59	259.63	0.016	V = 20.328(s)^0.5	2.550	0.028	1.692	

Channel Flow

ID	Channel Shape	Channel Type	Channel Description	n	US Elev.	DS Elev.	Length (ft.)	Avg. Slope (ft/ft)	Avg. Normal Depth (ft)	Avg. Bottom Width (ft)	Avg. Side Slopes (ft/ft)	Avg. Top Width (ft)	Equations: Area	Equations: Wetted Perimeter	Equations: Velocity	Average Flow Area (ft^2)	Average Wetted Perimeter (ft^2)	Velocity (ft/s)	T_t (hrs)	T_t(mins)	Notes
4	Circular Pipe	Lined or Built-Up Channel	Concrete	0.013	1430.59	1426.13	47.89	0.093	2.00	NA	NA	NA	A = π(d/2)^2	P = 2π(d/2)	V = (1.49[(r)^2/3][(s)^0.5])/n	3.14	6.28	22.03	0.001	0.04	Assumed Diameter
																		Total T_t =	0.042	2.529	
																		T_c =	0.025	1.517	

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WORKSHEET FOR SCS HYDROLOGIC PARAMETERS

Land Use:	X	Existing	Project:	Woodland Drive Drainage Improvement
		Proposed	Drainage Area Number:	5
Off-Site Land Use:	X	Existing	By:	C. REDMAN
		Proposed	Date:	6/17/2021

TIME OF CONCENTRATION (VELOCITY METHOD)

2-Year 24-Hour Precipitation Rainfall Amount (in) = 3.40

County/City: City of Harrisonburg

Sheet Flow

ID	Type of Flow	n	US Elev.	DS Elev.	Length (ft.)	Avg. Slope (ft/ft)	Travel Time Equation	Velocity (ft/s)	T_t (hrs)	T_t(mins)	Notes
1	Grass - Short Grass Prairie	0.150	1464.0	1463.3	57.59	0.012	$T_t = \frac{0.007\ (nL)^{0.8}}{(P_2)^{0.5}\ S^{0.4}}$	NA	0.141	8.482	

Shallow Concentrated Flow

ID	Flow Type	n	US Elev.	DS Elev.	Length (ft.)	Avg. Slope (ft/ft)	Velocity Equation	Velocity (ft/s)	T_t (hrs)	T_t(mins)	Notes
2	Pavement and Small Upland Gullies	0.025	1463.3	1446.4	391.10	0.043	V = 20.328(s)^0.5	4.226	0.026	1.543	

Channel Flow

ID	Channel Shape	Channel Type	Channel Description	n	US Elev.	DS Elev.	Length (ft.)	Avg. Slope (ft/ft)	Avg. Normal Depth (ft)	Avg. Bottom Width (ft)	Avg. Side Slopes (ft/ft)	Avg. Top Width (ft)	Equations: Area	Equations: Wetted Perimeter	Equations: Velocity	Average Flow Area (ft^2)	Average Wetted Perimeter (ft^2)	Velocity (ft/s)	T_t (hrs)	T_t(mins)	Notes
3	Circular Pipe	Lined or Built-Up Channel	Concrete	0.013	1446.40	1421.68	696.15	0.036	2.00	NA	NA	NA	A = π(d/2)^2	P = 2π(d/2)	V = (1.49)(r^(2/3))(s^0.5)/n	3.14	6.28	13.61	0.014	0.85	Assumed Diameter
																		Total T_t =	0.181	10.878	
																		T_c =	0.109	6.527	

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WORKSHEET FOR SCS HYDROLOGIC PARAMETERS

Land Use:	X	Existing	Project:	Woodland Drive Drainage Improvement
		Proposed	Drainage Area Number:	6
Off-Site Land Use:	X	Existing	By:	C. REDMAN
		Proposed	Date:	6/17/2021

TIME OF CONCENTRATION (VELOCITY METHOD)

2-Year 24-Hour Precipitation Rainfall Amount (in) = 3.43

County/City: City of Harrisonburg

Sheet Flow

ID	Type of Flow	n	US Elev.	DS Elev.	Length (ft.)	Avg. Slope (ft/ft)	Travel Time Equation	Velocity (ft/s)	T_t (hrs)	T_t(mins)	Notes
1	Grass - Dense Grasses	0.240	1768.0	1747.8	109.87	0.184	$T_t = \frac{0.007\,(nL)^{0.8}}{(P_2)^{0.5}\,S^{0.4}}$	NA	0.116	6.959	

Shallow Concentrated Flow

ID	Flow Type	n	US Elev.	DS Elev.	Length (ft.)	Avg. Slope (ft/ft)	Velocity Equation	Velocity (ft/s)	T_t (hrs)	T_t(mins)	Notes
2	Pavement and Small Upland Gullies	0.025	1747.8	1746.3	35.27	0.042	V = 20.328(s)^0.5	4.164	0.002	0.141	
3	Forest w/ Heavy Ground Litter & Hay Meadows	0.202	1746.3	1643.6	311.90	0.329	V = 2.516(s)^0.5	1.444	0.060	3.600	
4	Short-Grass Pasture	0.073	1643.6	1598.8	219.90	0.204	V = 6.962(s)^0.5	3.141	0.019	1.167	
5	Pavement and Small Upland Gullies	0.025	1598.8	1555.7	495.63	0.087	V = 20.328(s)^0.5	5.979	0.023	1.390	

Channel Flow

ID	Channel Shape	Channel Type	Channel Description	n	US Elev.	DS Elev.	Length (ft.)	Avg. Slope (ft/ft)	Avg. Normal Depth (ft)	Avg. Bottom Width (ft)	Avg. Side Slopes (ft/ft)	Avg. Top Width (ft)	Equations: Area	Equations: Wetted Perimeter	Equations: Velocity	Average Flow Area (ft²)	Average Wetted Perimeter (ft²)	Velocity (ft/s)	T_t (hrs)	T_t(mins)	Notes
6	Circular Pipe	Lined or Built-Up Channel	Concrete	0.013	1555.67	1504.37	701.00	0.073	1.25	NA	NA	NA	A = π(d/2)^2	P = 2π(d/2)	V = (1.49()/P^2/3)(s)^0.5))/n	1.23	3.93	14.28	0.014	0.82	Assumed Diameter
7	Trapezoidal Channel	Lined or Built-Up Channel	Vegetal Lining	0.030	1504.37	1479.40	871.71	0.029	2.00	20.00	10.00	60.00	A = (b + zh)h	P = b + (2h(SQRT(1 + (z)^2))	V = (1.49()/P^2/3)(s)^0.5))/n	80.00	60.20	10.16	0.024	1.43	
8	Circular Pipe	Lined or Built-Up Channel	Concrete	0.013	1479.40	1448.33	950.94	0.033	3.00	NA	NA	NA	A = π(d/2)^2	P = 2π(d/2)	V = (1.49()/P^2/3)(s)^0.5))/n	7.07	9.42	17.30	0.015	0.93	
9	Pond/Lake/Reservoir	Pond/Lake/Reservoir	Pond/Lake/Reservoir	NA	1448.33	1444.00	252.92	0.016	6.00	NA	NA	NA	NA	NA	V = SQRT(gD)	NA	NA	13.90	0.005	0.32	
10	Circular Pipe	Lined or Built-Up Channel	Concrete	0.013	1444.00	1426.34	727.27	0.024	3.00	NA	NA	NA	A = π(d/2)^2	P = 2π(d/2)	V = (1.49()/P^2/3)(s)^0.5))/n	7.07	9.42	14.74	0.014	0.82	

Total T_t =	0.298	17.599
T_c =	0.176	10.559

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WORKSHEET FOR SCS HYDROLOGIC PARAMETERS

Land Use:	X	Existing	Project:	Woodland Drive Drainage Improvement
		Proposed	Drainage Area Number:	7A
Off-Site Land Use:	X	Existing	By:	C. REDMAN
		Proposed	Date:	6/17/2021

TIME OF CONCENTRATION (VELOCITY METHOD)

2-Year 24-Hour Precipitation Rainfall Amount (in) = 3.60

County/City: City of Harrisonburg

Sheet Flow

ID	Type of Flow	n	US Elev.	DS Elev.	Length (ft.)	Avg. Slope (ft/ft)	Travel Time Equation	Velocity (ft/s)	T_t (hrs)	T_t (mins)	Notes
1	Grass - Dense Grasses	0.240	1768.0	1744.0	113.90	0.211	$T_t = \frac{0.007\ (nL)^{0.8}}{(P_2)^{0.5}\ S^{0.4}}$	NA	0.112	6.718	

Shallow Concentrated Flow

ID	Flow Type	n	US Elev.	DS Elev.	Length (ft.)	Avg. Slope (ft/ft)	Velocity Equation	Velocity (ft/s)	T_t (hrs)	T_t (mins)	Notes
2	Pavement and Small Upland Gullies	0.025	1744.0	1716.5	357.21	0.077	V = 20.328(s)^0.5	5.635	0.018	1.056	
5	Pavement and Small Upland Gullies	0.025	1556.0	1552.6	34.16	0.099	V = 20.328(s)^0.5	6.394	0.001	0.089	

Channel Flow

ID	Channel Shape	Channel Type	Channel Description	n	US Elev.	DS Elev.	Length (ft.)	Avg. Slope (ft/ft)	Avg. Normal Depth (ft)	Avg. Bottom Width (ft)	Avg. Side Slopes (ft/ft)	Avg. Top Width (ft)	Equations: Area	Equations: Wetted Perimeter	Equations: Velocity	Average Flow Area (ft^2)	Average Wetted Perimeter (ft^2)	Velocity (ft/s)	T_t (hrs)	T_t (mins)	Notes
3	Circular Pipe	Lined or Built-Up Channel	Concrete	0.013	1715.29	1699.78	52.22	0.297	1.25	NA	NA	NA	A = π(d/2)^2	P = 2π(d/2)	V = [1.49]/(r^2/3)][(s)^0.5]]/n	1.23	3.93	28.76	0.001	0.03	Assumed Diameter
4	Triangular Channel	Lined or Built-Up Channel	Vegetal Lining	0.080	1699.78	1555.97	630.29	0.228	2.00	NA	8.00	32.00	A = z(h)^2	P = (2h)(SQRT(1 + (z)^2))	V = [1.49]/(r^2/3)][(s)^0.5]]/n	32.00	32.25	23.60	0.007	0.45	
6	Trapezoidal Channel	Natural Stream	Vegetal Lining	0.080	1552.59	1538.00	157.98	0.092	0.75	3.00	6.00	12.00	A = (b + zh)h	P = b + (2h)(SQRT(1 + (z)^2))	V = [1.49]/(r^2/3)][(s)^0.5]]/n	5.63	12.12	9.05	0.005	0.29	
7	Circular Pipe	Lined or Built-Up Channel	Concrete	0.013	1538.00	1512.87	202.48	0.124	1.25	NA	NA	NA	A = π(d/2)^2	P = 2π(d/2)	V = [1.49]/(r^2/3)][(s)^0.5]]/n	1.23	3.93	18.59	0.003	0.18	
8	Triangular Channel	Natural Stream	Clean, straight, full,no rifts or deep pools w/ more stones and weeds	0.040	1512.87	1500.00	343.61	0.037	1.50	NA	5.00	15.00	A = z(h)^2	P = (2h)(SQRT(1 + (z)^2))	V = [1.49]/(r^2/3)][(s)^0.5]]/n	11.25	15.30	5.87	0.016	0.97	
9	Circular Pipe	Lined or Built-Up Channel	Concrete	0.013	1500.00	1443.09	1212.45	0.047	2.00	NA	NA	NA	A = π(d/2)^2	P = 2π(d/2)	V = [1.49]/(r^2/3)][(s)^0.5]]/n	3.14	6.28	15.64	0.022	1.29	
																		Total T_t =	0.185	11.098	
																		T_c =	0.111	6.659	

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WORKSHEET FOR SCS HYDROLOGIC PARAMETERS

Land Use:	X	Existing	Project:	Woodland Drive Drainage Improvement
		Proposed	Drainage Area Number:	79
Off-Site Land Use:	X	Existing	By:	C. REDMAN
		Proposed	Date:	6/17/2021

TIME OF CONCENTRATION (VELOCITY METHOD)

2-Year 24-Hour Precipitation Rainfall Amount (in) = [illegible]

County/City: City of Harrisonburg

Sheet Flow

ID	Type of Flow	n	US Elev.	DS Elev.	Length (ft.)	Avg. Slope (ft/ft)	Travel Time Equation	Velocity (ft/s)	T_t (hrs)	T_t(mins)	Notes
1	Grass - Short Grass Prairie	0.150	1476.3	1463.0	46.26	0.288	$T_t = \frac{0.007\ (nL)^{0.8}}{(P_2)^{0.5}\ S^{0.4}}$	NA	0.033	2.008	

Shallow Concentrated Flow

ID	Flow Type	n	US Elev.	DS Elev.	Length (ft.)	Avg. Slope (ft/ft)	Velocity Equation	Velocity (ft/s)	T_t (hrs)	T_t(mins)	Notes
2	Pavement and Small Upland Gullies	0.025	1463.0	1450.2	218.40	0.059	V = 20.328(s)^0.5	4.921	0.012	0.740	

Channel Flow

ID	Channel Shape	Channel Type	Channel Description	n	US Elev.	DS Elev.	Length (ft.)	Avg. Slope (ft/ft)	Avg. Normal Depth (ft)	Avg. Bottom Width (ft)	Avg. Side Slopes (ft/ft)	Avg. Top Width (ft)	Equations: Area	Equations: Wetted Perimeter	Equations: Velocity	Average Flow Area (ft²)	Average Wetted Perimeter (ft)	Velocity (ft/s)	T_t (hrs)	T_t(mins)	Notes
3	Circular Pipe	Lined or Built-Up Channel	Concrete	0.013	1450.20	1425.61	747.82	0.033	1.25	NA	NA	NA	A = π(d/2)^2	P = 2π(d/2)	V = (1.49()/(^2/3)()s)^0.5()/n	1.23	3.93	9.57	0.022	1.30	Assumed Diameter
																		Total T_t =	0.068	4.050	
																		T_c =	0.041	2.430	

WORKSHEET FOR SCS HYDROLOGIC PARAMETERS

Land Use:	X	Existing	Project:	Woodland Drive Drainage Improvement
		Proposed	Drainage Area Number:	7C
Off-Site Land Use:	X	Existing	By:	C. REDMAN
		Proposed	Date:	6/17/2021

TIME OF CONCENTRATION (VELOCITY METHOD)

2-Year 24-Hour Precipitation Rainfall Amount (in) = 3.43

County/City: City of Harrisonburg

Sheet Flow

ID	Type of Flow	n	US Elev.	DS Elev.	Length (ft.)	Avg. Slope (ft/ft)	Travel Time Equation	Velocity (ft/s)	T_t (hrs)	T_t (mins)	Notes
1	Grass - Dense Grasses	0.240	1768.0	1744.0	112.90	0.213	$T_t = \frac{0.007\,(nL)^{0.8}}{(P_2)^{0.5}\,S^{0.4}}$	NA	0.112	6.718	

Shallow Concentrated Flow

ID	Flow Type	n	US Elev.	DS Elev.	Length (ft.)	Avg. Slope (ft/ft)	Velocity Equation	Velocity (ft/s)	T_t (hrs)	T_t (mins)	Notes
2	Pavement and Small Upland Gullies	0.025	1744.0	1716.5	357.21	0.077	V = 20.328(s)^0.5	5.635	0.018	1.056	
5	Pavement and Small Upland Gullies	0.025	1556.0	1552.6	34.16	0.099	V = 20.328(s)^0.5	6.394	0.001	0.089	

Channel Flow

ID	Channel Shape	Channel Type	Channel Description	n	US Elev.	DS Elev.	Length (ft.)	Avg. Slope (ft/ft)	Avg. Normal Depth (ft)	Avg. Bottom Width (ft)	Avg. Side Slopes (ft/ft)	Avg. Top Width (ft)	Equations: Area	Equations: Wetted Perimeter	Equations: Velocity	Average Flow Area (ft^2)	Average Wetted Perimeter (ft^2)	Velocity (ft/s)	T_t (hrs)	T_t (mins)	Notes
3	Circular Pipe	Lined or Built-Up Channel	Concrete	0.013	1715.29	1699.78	52.22	0.297	1.25	NA	NA	NA	A = π(d/2)^2	P = 2π(d/2)	V = (1.49)(r^2/3)(s^0.5)/n	1.23	3.93	28.76	0.001	0.03	Assumed Diameter
4	Triangular Channel	Lined or Built-Up Channel	Vegetal Lining	0.080	1699.78	1555.97	630.29	0.228	2.00	NA	8.00	32.00	A = z(h)^2	P = (2h)SQRT(1 + (z)^2)	V = (1.49)(r^2/3)(s^0.5)/n	32.00	32.25	23.60	0.007	0.45	
6	Trapezoidal Channel	Natural Stream	Vegetal Lining	0.080	1552.59	1538.00	157.98	0.092	0.75	3.00	6.00	12.00	A = (b + zh)h	P = b + (2h)SQRT(1 + (z)^2)	V = (1.49)(r^2/3)(s^0.5)/n	5.63	12.12	9.05	0.005	0.29	
7	Circular Pipe	Lined or Built-Up Channel	Concrete	0.013	1538.00	1512.87	202.48	0.124	1.25	NA	NA	NA	A = π(d/2)^2	P = 2π(d/2)	V = (1.49)(r^2/3)(s^0.5)/n	1.23	3.93	18.59	0.003	0.18	
8	Triangular Channel	Natural Stream	Clean, straight, full,no rifts or deep pools w/ more stones and weeds	0.040	1512.87	1500.00	343.61	0.037	1.50	NA	5.00	15.00	A = z(h)^2	P = (2h)SQRT(1 + (z)^2)	V = (1.49)(r^2/3)(s^0.5)/n	11.25	15.30	5.87	0.016	0.97	
9	Circular Pipe	Lined or Built-Up Channel	Concrete	0.013	1500.00	1452.21	738.29	0.065	2.00	NA	NA	NA	A = π(d/2)^2	P = 2π(d/2)	V = (1.49)(r^2/3)(s^0.5)/n	3.14	6.28	18.37	0.011	0.67	
																		Total T_c =	0.175	10.476	
																		T_c =	0.105	6.286	

WORKSHEET FOR SCS HYDROLOGIC PARAMETERS

Land Use:	X	Existing	Project:	Woodland Drive Drainage Improvement
		Proposed	Drainage Area Number:	8
Off-Site Land Use:	X	Existing	By:	C. REDMAN
		Proposed	Date:	6/17/2021

TIME OF CONCENTRATION (VELOCITY METHOD)

2-Year 24-Hour Precipitation Rainfall Amount (in) = 2.63

County/City: City of Harrisonburg

Sheet Flow

ID	Type of Flow	n	US Elev.	DS Elev.	Length (ft.)	Avg. Slope (ft/ft)	Travel Time Equation	Velocity (ft/s)	T_t (hrs)	T_t (mins)	Notes
1	Grass - Dense Grasses	0.240	1441.0	1437.0	43.91	0.091	$T_t = \frac{0.007\ (nL)0.8}{(P_2)^{0.5}\ S^{0.4}}$	NA	0.074	4.448	

Shallow Concentrated Flow

ID	Flow Type	n	US Elev.	DS Elev.	Length (ft.)	Avg. Slope (ft/ft)	Velocity Equation	Velocity (ft/s)	T_t (hrs)	T_t (mins)	Notes
2	Pavement and Small Upland Gullies	0.025	1437.0	1434.9	56.80	0.038	V = 20.328(s)^0.5	3.946	0.004	0.240	

Channel Flow

ID	Channel Shape	Channel Type	Channel Description	n	US Elev.	DS Elev.	Length (ft.)	Avg. Slope (ft/ft)	Avg. Normal Depth (ft)	Avg. Bottom Width (ft)	Avg. Side Slopes (ft/ft)	Avg. Top Width (ft)	Equations: Area	Equations: Wetted Perimeter	Equations: Velocity	Average Flow Area (ft^2)	Average Wetted Perimeter (ft^2)	Velocity (ft/s)	T_t (hrs)	T_t (mins)	Notes
3	Triangular Channel	Lined or Built-Up Channel	Vegetal Lining	0.030	1434.87	1406.70	124.09	0.227	1.00	NA	10.00	20.00	A = z(h)^2	P = (2h)SQRT(1 + (z)^2)	V = (1.49)(r^2/3)(s)^0.5)/n	10.00	20.10	14.86	0.002	0.14	Assumed Diameter
4	Trapezoidal Channel	Natural Stream	Clean, straight, full,no rifts or deep pools w/ more stones and weeds	0.060	1406.70	1405.97	24.02	0.030	2.00	5.00	4.00	21.00	A = (b + zh)h	P = b + (2h)SQRT(1 + (z)^2)	V = (1.49)(r^2/3)(s)^0.5)/n	26.00	21.49	7.37	0.001	0.05	
																		Total T_t =	0.081	4.881	
																		T_c =	0.049	2.929	

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WORKSHEET FOR SCS HYDROLOGIC PARAMETERS

Land Use:	X	Existing	Project:	Woodland Drive Drainage Improvement
		Proposed	Drainage Area Number:	8A
Off-Site Land Use:	X	Existing	By:	C. REDMAN
		Proposed	Date:	6/17/2021

TIME OF CONCENTRATION (VELOCITY METHOD)

2-Year 24-Hour Precipitation Rainfall Amount (in) = 2.63

County/City: City of Harrisonburg

Sheet Flow

ID	Type of Flow	n	US Elev.	DS Elev.	Length (ft.)	Avg. Slope (ft/ft)	Travel Time Equation	Velocity (ft/s)	T_t (hrs)	T_t(mins)	Notes
1	Grass - Dense Grasses	0.240	1441.0	1437.0	43.91	0.091	$T_t = \frac{0.007\ (nL)0.8}{(P_2)^{0.5}\ S^{0.4}}$	NA	0.074	4.448	

Shallow Concentrated Flow

ID	Flow Type	n	US Elev.	DS Elev.	Length (ft.)	Avg. Slope (ft/ft)	Velocity Equation	Velocity (ft/s)	T_t (hrs)	T_t(mins)	Notes
2	Pavement and Small Upland Gullies	0.025	1437.0	1434.9	56.80	0.038	V = 20.328(s)^0.5	3.946	0.004	0.240	

Channel Flow

ID	Channel Shape	Channel Type	Channel Description	n	US Elev.	DS Elev.	Length (ft.)	Avg. Slope (ft/ft)	Avg. Normal Depth (ft)	Avg. Bottom Width (ft)	Avg. Side Slopes (ft/ft)	Avg. Top Width (ft)	Equations: Area	Equations: Wetted Perimeter	Equations: Velocity	Average Flow Area (ft^2)	Average Wetted Perimeter (ft^2)	Velocity (ft/s)	T_t (hrs)	T_t(mins)	Notes
3	Triangular Channel	Lined or Built-Up Channel	Vegetal Lining	0.030	1434.87	1406.70	124.09	0.227	1.00	NA	10.00	20.00	A = z(h)^2	P = (2h(SQRT(1 + (z)^2)	V = (1.49()/^2/3)()(s)^0.5)()/n	10.00	20.10	14.86	0.002	0.14	Assumed Diameter
4	Trapezoidal Channel	Natural Stream	Clean, straight, full,no riffs or deep pools w/ more stones and weeds	0.060	1406.70	1398.00	400.40	0.022	4.00	5.00	2.50	25.00	A = (b + zh)h	P = b + (2h(SQRT(1 + (z)^2)	V = (1.49()/^2/3)()(s)^0.5)()/n	60.00	26.54	9.46	0.012	0.71	
																		Total T_t =	0.092	5.532	
																		T_L =	0.055	3.319	

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WORKSHEET FOR SCS HYDROLOGIC PARAMETERS

Land Use:	X	Existing	Project:	Woodland Drive Drainage Improvement
		Proposed	Drainage Area Number:	3B
Off-Site Land Use:	X	Existing	By:	C. REDMAN
		Proposed	Date:	6/17/2021

TIME OF CONCENTRATION (VELOCITY METHOD)

2-Year 24-Hour Precipitation Rainfall Amount (in) =	[illegible]
County/City:	City of Harrisonburg

Sheet Flow

ID	Type of Flow	n	US Elev.	DS Elev.	Length (ft.)	Avg. Slope (ft/ft)	Travel Time Equation	Velocity (ft/s)	T_t (hrs)	T_t(mins)	Notes
1	Grass - Short Grass Prairie	0.150	1408.0	1402.0	51.85	0.116	$T_t = \frac{0.007\ (nL)0.8}{(P_2)^{0.5}\ S^{0.4}}$	NA	0.058	3.160	

Shallow Concentrated Flow

ID	Flow Type	n	US Elev.	DS Elev.	Length (ft.)	Avg. Slope (ft/ft)	Velocity Equation	Velocity (ft/s)	T_t (hrs)	T_t(mins)	Notes

Channel Flow

ID	Channel Shape	Channel Type	Channel Description	n	US Elev.	DS Elev.	Length (ft.)	Avg. Slope (ft/ft)	Avg. Normal Depth (ft)	Avg. Bottom Width (ft)	Avg. Side Slopes (ft/ft)	Avg. Top Width (ft)	Equations: Area	Equations: Wetted Perimeter	Equations: Velocity	Average Flow Area (ft^2)	Average Wetted Perimeter (ft^2)	Velocity (ft/s)	T_t (hrs)	T_t(mins)	Notes
3	Trapezoidal Channel	Lined or Built-Up Channel	Clean, straight, full,no rifts or deep pools w/ more stones and weeds	0.060	1401.98	1399.94	124.09	0.016	2.00	5.00	4.00	21.00	A = (b + zh)h	P = b + (2h)(SQRT(1 + (z)^2)	V = (1.49/(((P1/3)((s)^0.5)))/n	26.00	21.49	5.42	0.006	0.38	Assumed Diameter
																		Total T_c =	0.059	3.542	
																		T =	0.035	2.125	

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WORKSHEET FOR SCS HYDROLOGIC PARAMETERS

Land Use:	X	Existing	Project:	Woodland Drive Drainage Improvement
		Proposed	Drainage Area Number:	3C
Off-Site Land Use:	X	Existing	By:	C. REDMAN
		Proposed	Date:	6/17/2021

TIME OF CONCENTRATION (VELOCITY METHOD)

2-Year 24-Hour Precipitation Rainfall Amount (in) = 2.62

County/City: City of Harrisonburg

Sheet Flow

ID	Type of Flow	n	US Elev.	DS Elev.	Length (ft.)	Avg. Slope (ft/ft)	Travel Time Equation	Velocity (ft/s)	T_t (hrs)	T_t (mins)	Notes
1	Grass - Short Grass Prairie	0.150	1417.3	1410.0	54.19	0.134	$T_t = \frac{0.007\,(nL)^{0.8}}{(P_2)^{0.5}\,S^{0.4}}$	NA	0.052	3.090	

Shallow Concentrated Flow

ID	Flow Type	n	US Elev.	DS Elev.	Length (ft.)	Avg. Slope (ft/ft)	Velocity Equation	Velocity (ft/s)	T_t (hrs)	T_t (mins)	Notes
2	Short-Grass Pasture	0.073	1410.0	1406.0	126.45	0.032	V = 6.962(s)^0.5	1.238	0.028	1.702	

Channel Flow

ID	Channel Shape	Channel Type	Channel Description	n	US Elev.	DS Elev.	Length (ft.)	Avg. Slope (ft/ft)	Avg. Normal Depth (ft)	Avg. Bottom Width (ft)	Avg. Side Slopes (ft/ft)	Avg. Top Width (ft)	Equations: Area	Equations: Wetted Perimeter	Equations: Velocity	Average Flow Area (ft^2)	Average Wetted Perimeter (ft^2)	Velocity (ft/s)	T_t (hrs)	T_t (mins)	Notes
3	Triangular Channel	Lined or Built-Up Channel	Vegetal Lining	0.080	1406.00	1398.00	56.48	0.142	1.00	NA	3.00	6.00	A = z(h)^2	P = (2h)(SQRT(1 + (z)^2))	V = (1.49((r)^2/3))((s)^0.5))/n	3.00	6.32	11.37	0.001	0.08	Assumed Diameter
																		Total T_t =	0.081	4.875	
																		T_c =	0.049	2.925	

APPENDIX D

Modeled Existing Conditions

APPENDIX D.1

Flood Inundation Maps – Existing Storm Events


NEFF AVE.
SUNCHASE CT.
CHASE CT.
RESERVOIR ST.
LUCY DR.
WOODLAND DR.
SCARLET OAK DR.
WHITE OAK CIRCLE
FOLEY RD.
RIDGEVILLE LN.
SCALE 1"=250'
0
250'
500'
NAD 83
LEGEND
2-YEAR FLOODPLAIN
10-YEAR FLOODPLAIN
25-YEAR FLOODPLAIN
100-YEAR FLOODPLAIN
BUILDINGS (GIS)
CITY OF HARRISONBURG PROPERTY LINES (GIS)
CONTOURS (2')
FLOOD VULNERABLE STRUCTURES
2-YEAR FLOODPLAIN
10-YEAR FLOODPLAIN (ADDITIONAL STRUCTURES)
25-YEAR FLOODPLAIN (ADDITIONAL STRUCTURES)
100-YEAR FLOODPLAIN (ADDITIONAL STRUCTURES)
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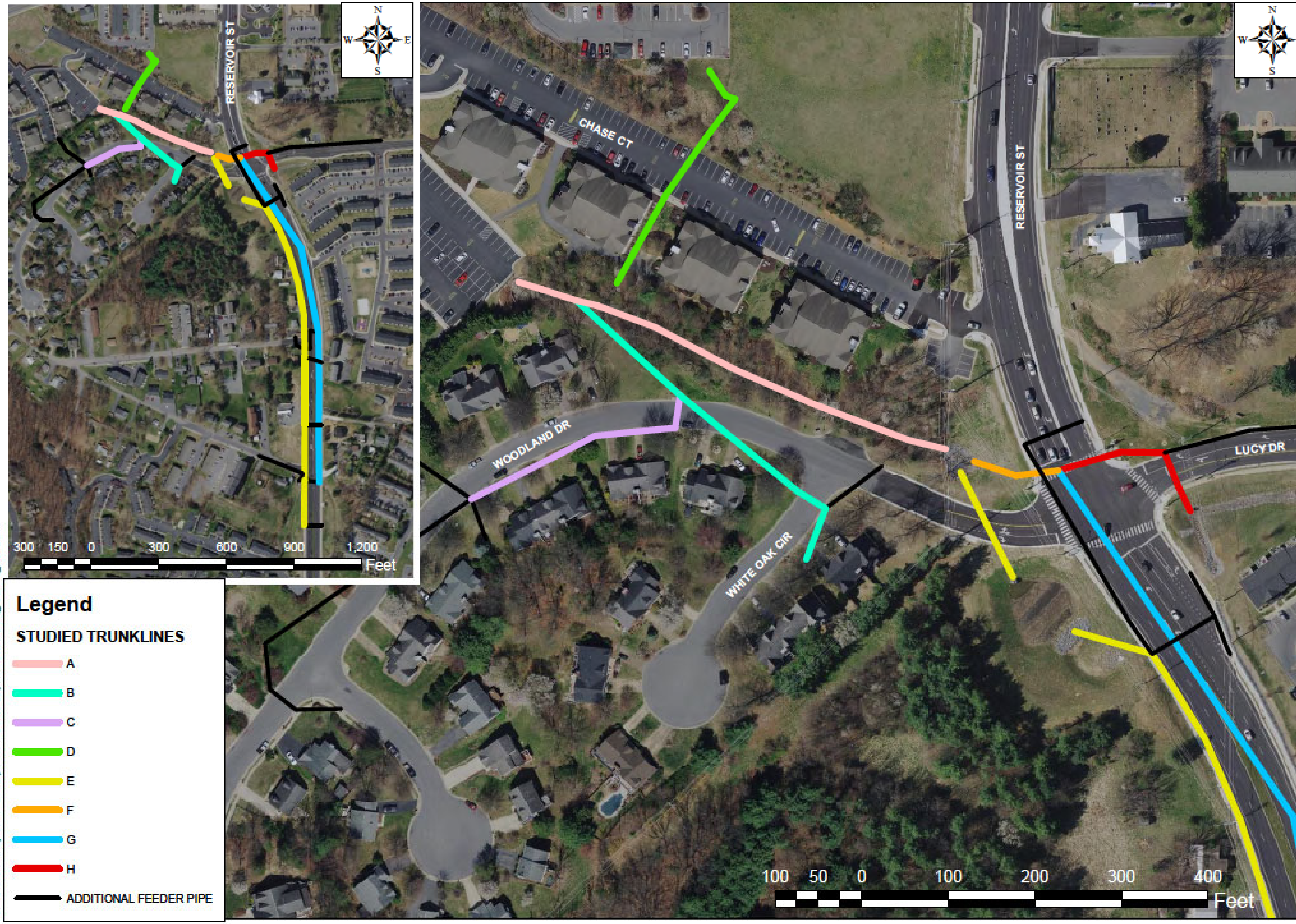
TIMMONS GROUP
REVISION DESCRIPTION
DATE
DATE 06/15/2021
DRAWN BY K. REDMAN
DESIGNED BY K. REDMAN
CHECKED BY M. CLAUD
SCALE 1" = 250'
WOODLAN DRIVE DRAINAGE IMPROVEMENTS
CITY OF HARRISONBURG
EXISTING CONDITIONS FLOODPLAIN MAPPING (RE-STUDY)
JOB NO. 47305.002
SHEET NO. EXBT-1

APPENDIX D.2

Plan View - Trunklines



Path: C:\Users\kelsey.redman\Desktop\Woodland Drive Outputs\GIS\47305.002_XPLAYO_COND.mxd

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Site Development | Residential | Infrastructure | Technology | Environmental

DATE	REVISION DESCRIPTION

DATE 06/25/2021
DRAWN BY K. REDMAN
DESIGNED BY K. REDMAN
CHECKED BY M. CLAUD
SCALE VARIES

TIMMONS GROUP

WOODLAND DRIVE DRAINAGE IMPROVEMENTS

HARRISONBURG, VIRGINIA

STUDIED TRUNKLINES

JOB NUMBER 47305.002
SHEET NO. EXBT-2

APPENDIX D.3

Profiles – Existing Storm Events

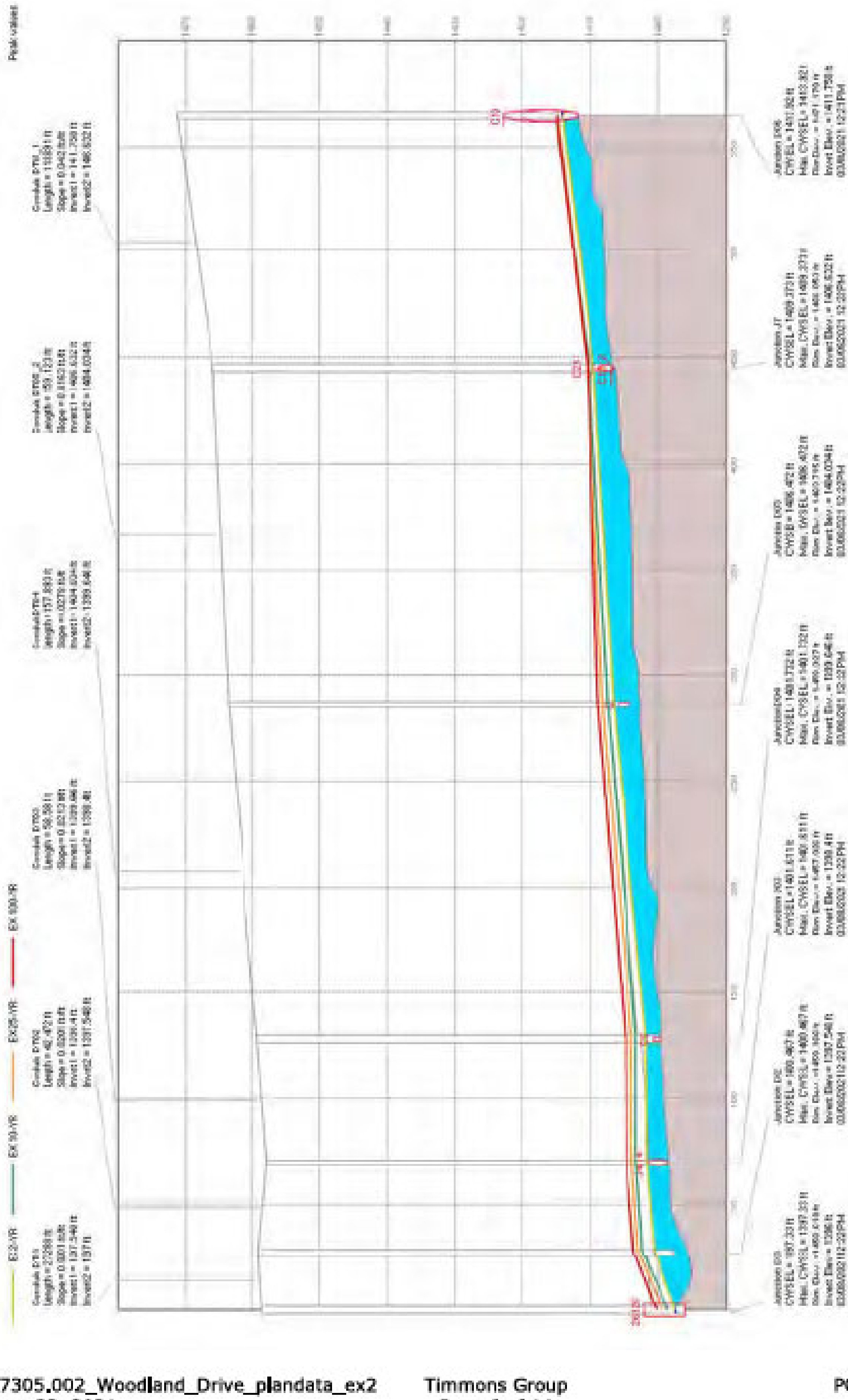

Figure 4: TRUNKLINE A

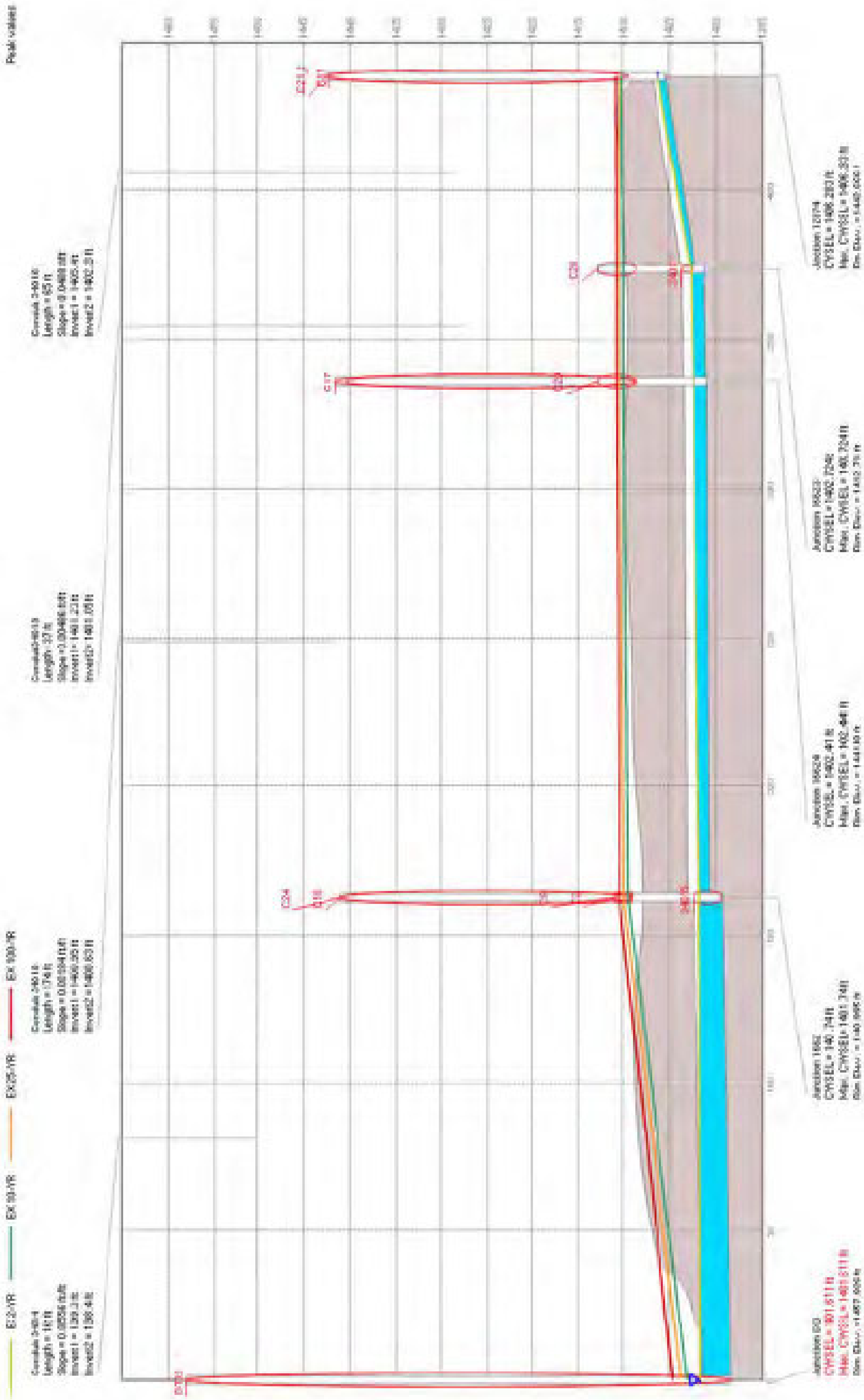

Figure 5: TRUNKLINE B

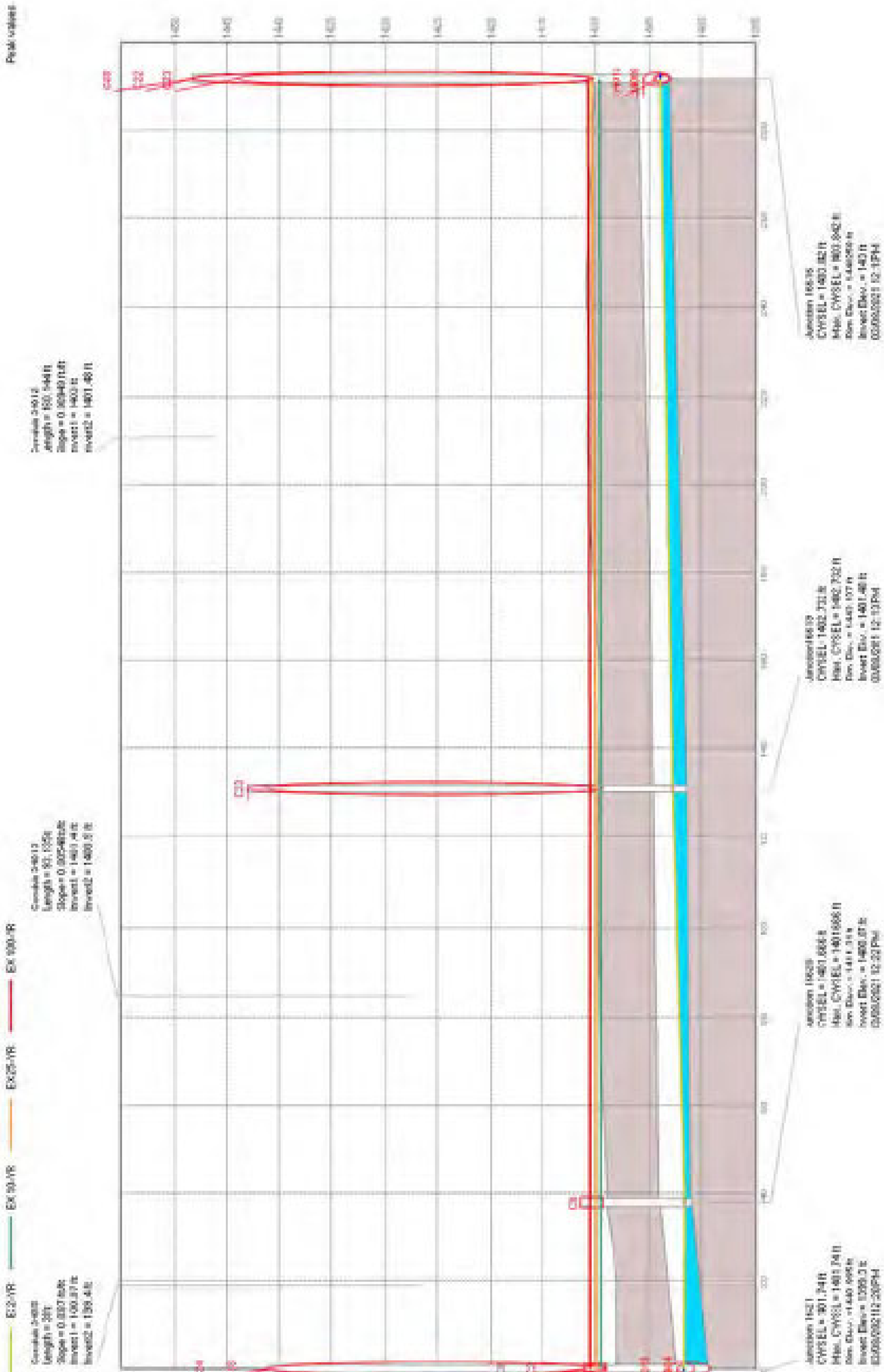

Figure 6: TRUNKLINE C

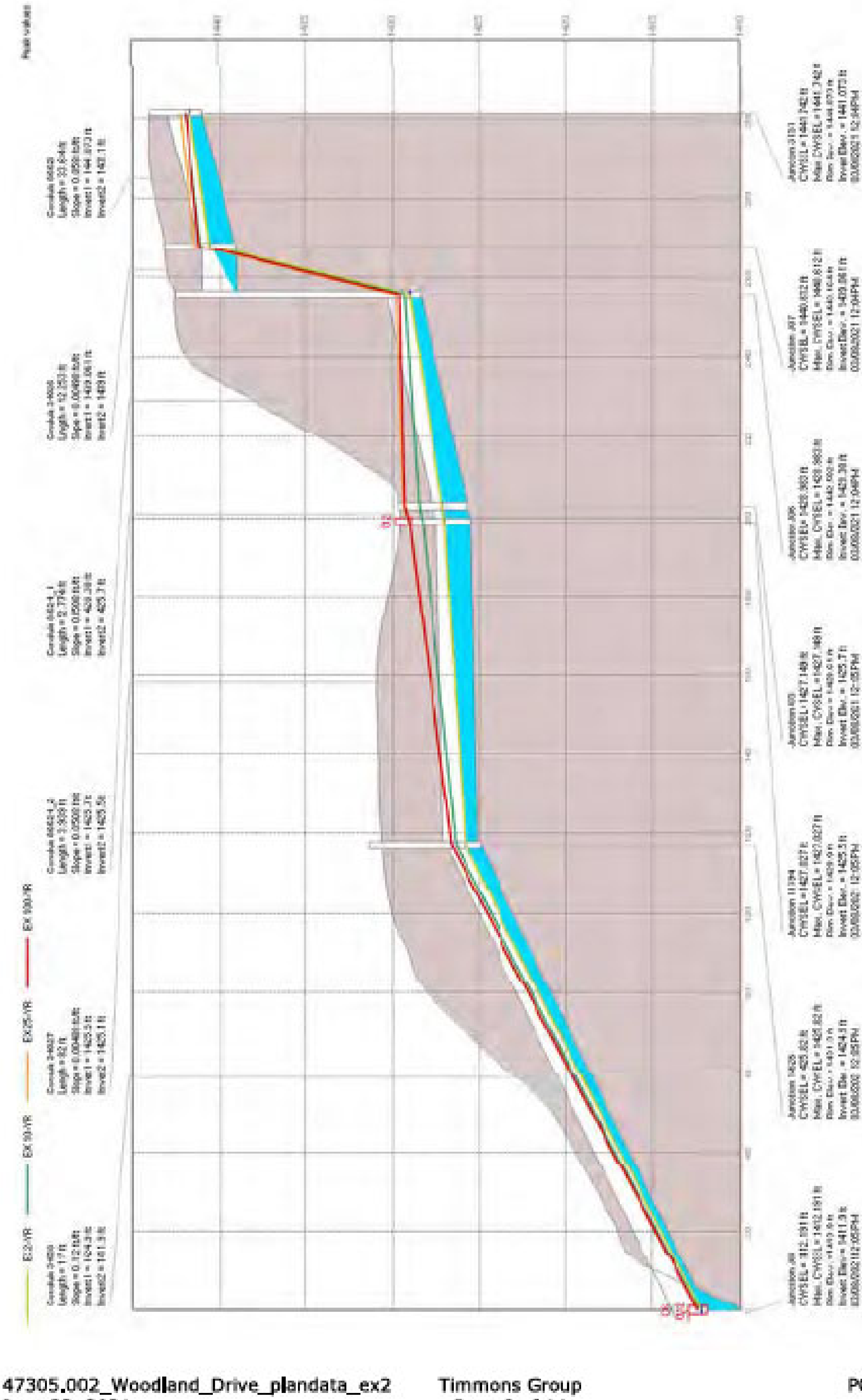

Figure 7: TRUNKLINE D

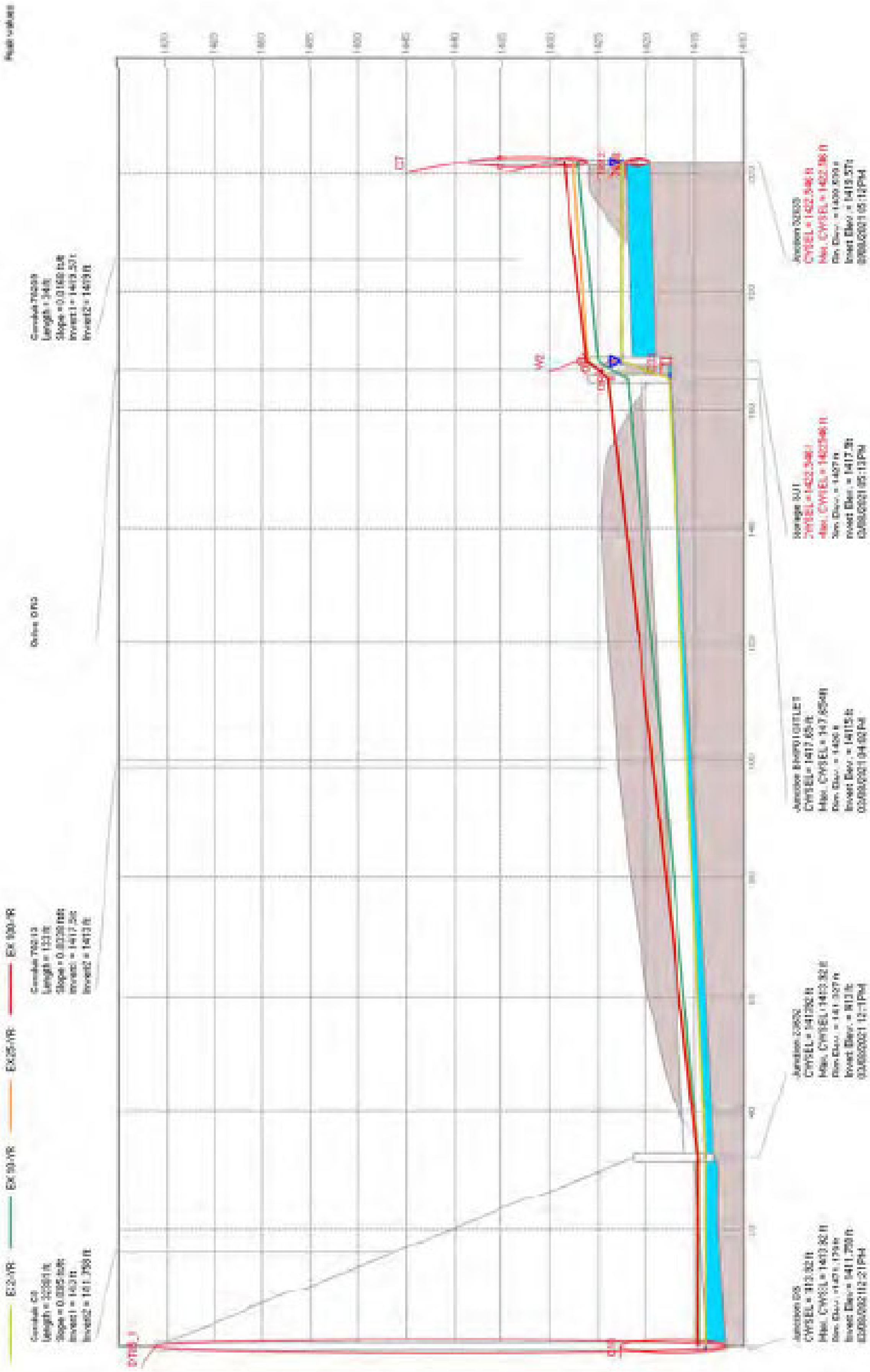

Figure 8: TRUNKLINE E1

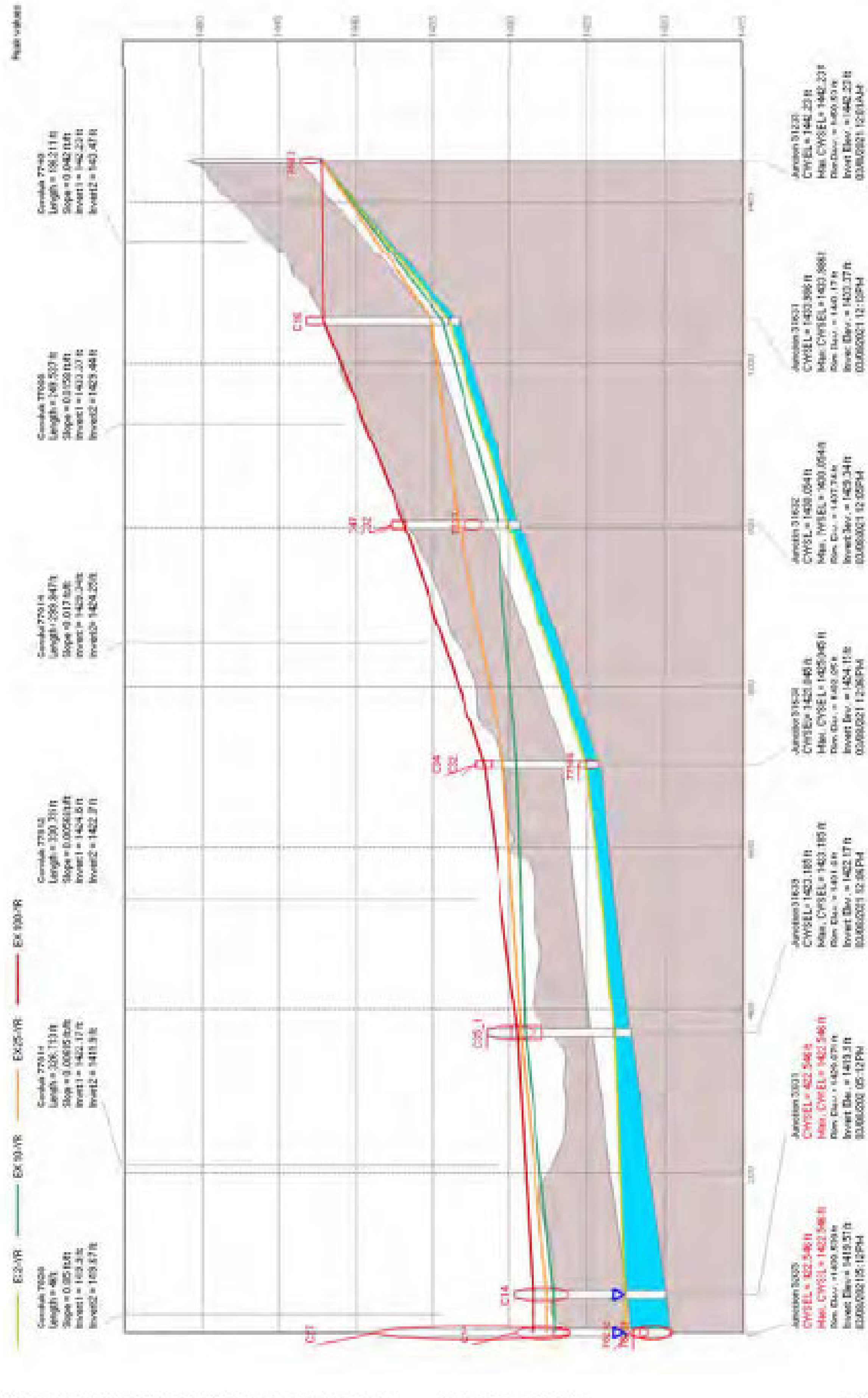

Figure 9: TRUNKLINE E2

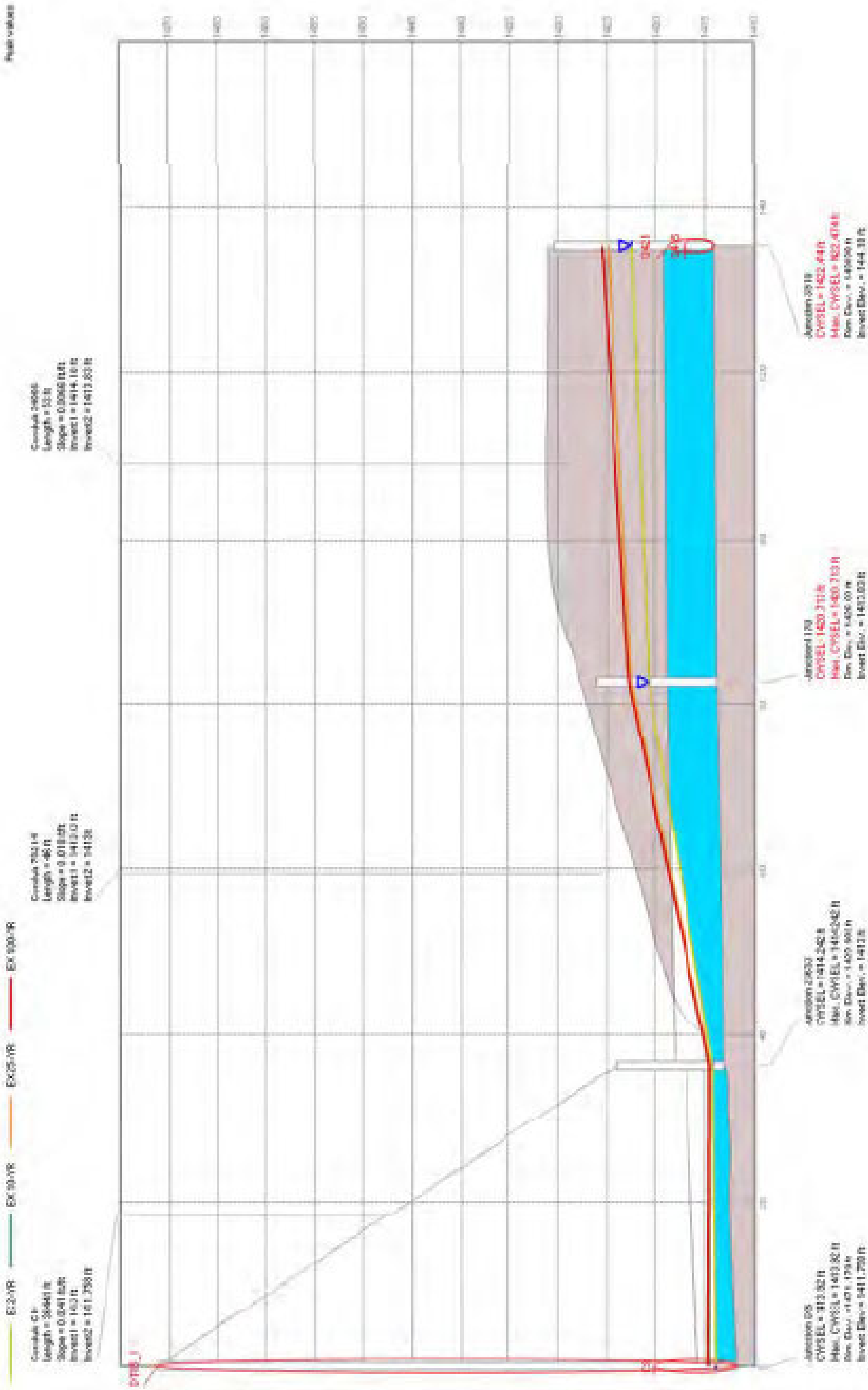

Figure 10: TRUNKLINE F

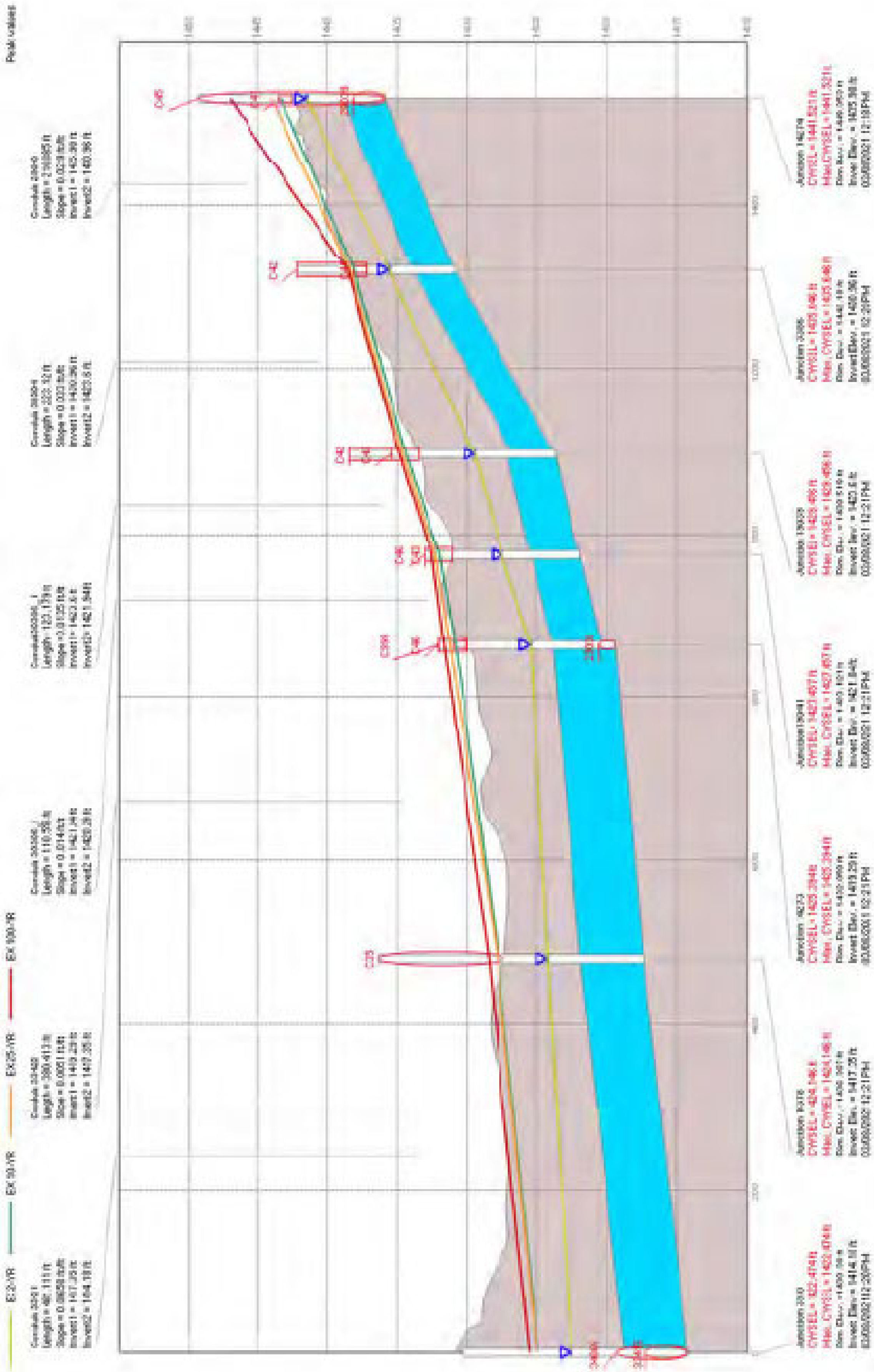

Figure 11: TRUNKLINE G

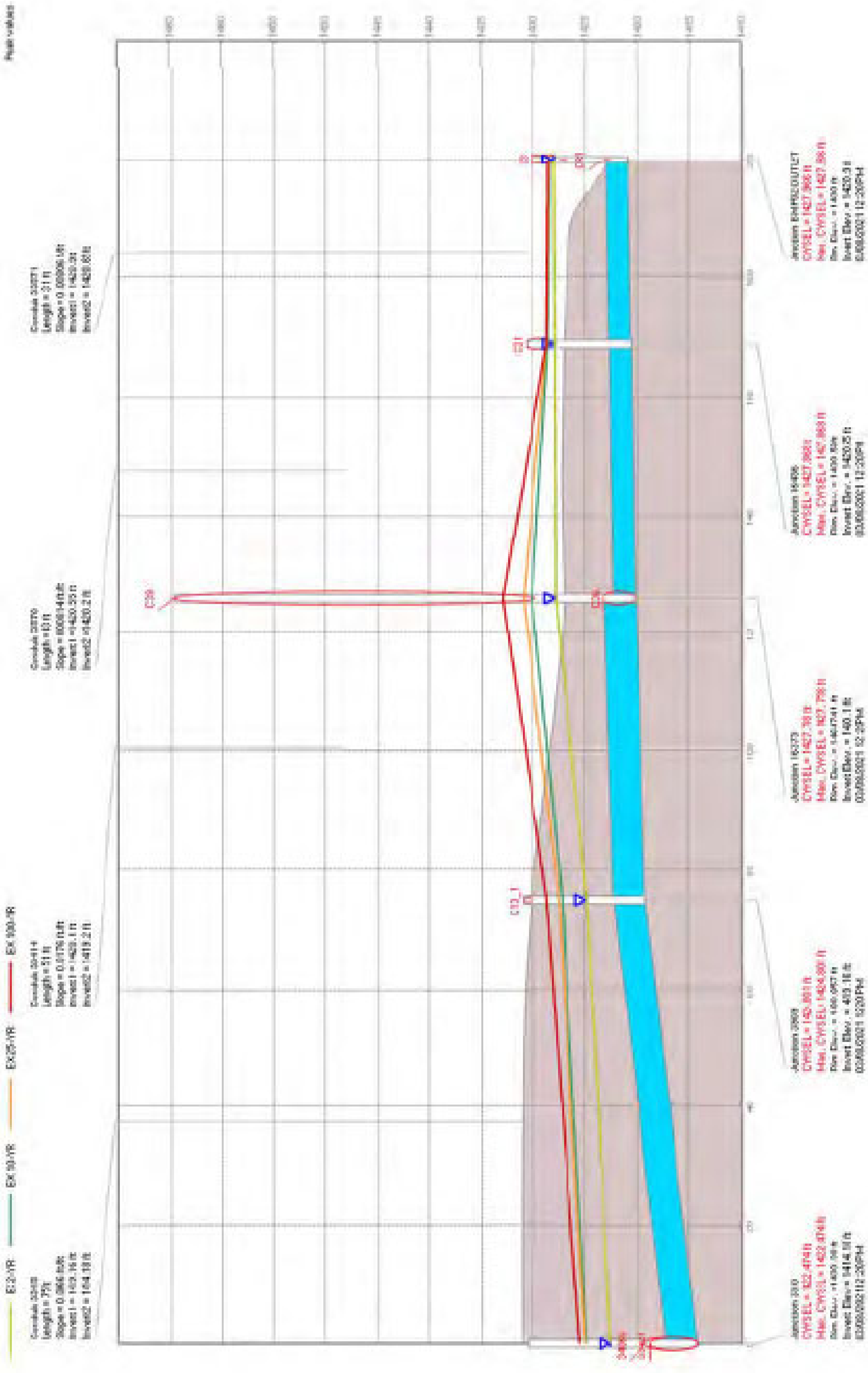

Figure 12: TRUNKLINE H

APPENDIX E

Modeled SWMM Alternatives

APPENDIX E.1

Conceptual Exhibits – Modeled Storm Drainage System

EXBT-1

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EXBT-2

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EXBT-3

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ALTERNATIVE E CONCEPTUAL LAYOUT

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APPENDIX E.2

Flood Inundation Maps – Modeled Storm Drainage System

APPENDIX E.2-1

2-Year Flood Inundation Map

LEGEND

	BUILDINGS (GIS)
	CITY OF HARRISONBURG PROPERTY LINES (GIS)
	CONTOURS (2')
	EX 2-YEAR FLOODPLAIN (RE-STUDY)
	ALTERNATIVE A 2-YEAR FLOODPLAIN

FLOOD VULNERABLE STRUCTURES

	2-YEAR FLOODPLAIN
	2-YEAR FLOODPLAIN (REMOVED STRUCTURES)

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REVISION DESCRIPTION | DATE

DATE 06/10/2021
DRAWN BY K. REDMAN
DESIGNED BY K. REDMAN
CHECKED BY M. DAVIS
SCALE 1" =250'

TIMMONS GROUP

WOODLAN DRIVE DRAINAGE IMPROVEMENTS

CITY OF HARRISONBURG

ALTERNATIVE A 2-YEAR FLOODPLAIN MAPPING (RE-STUDY)

JOB NO. 47305.002
SHEET NO. EXIT-5

APPENDIX E.2-2

10-Year Flood Inundation Maps

Alternative	Description
A	0.4 ac BMP (60,000 ft^3 volume) on city-owned parcel. DA 1D routed to BMP

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REVISION DESCRIPTION

DATE 06/10/2021

DRAWN BY K. REDMAN

DESIGNED BY K. REDMAN

CHECKED BY M. GAUR

SCALE 1" =250'

WOODLAN DRIVE DRAINAGE IMPROVEMENTS

CITY OF HARRISONBURG

ALTERNATIVES ANALYSIS 10-YEAR FLOODPLAIN MAPPING (RESTUDY)

JOB NO. 47305.002

SHEET NO. EXIT-6

\\timmons.com\gis\... 47305.002-Woodland Drive Drainage Improvement\DWG\Sheet\Exhibit\47305.002-EXBT-WUN-ALT52.dwg | Plotted on 6/17/2021 1:22 AM | by Kelsey Redman

Alternative	Description
B	1.53 ac BMP (495,000 ft^3 volume) on privately-owned parcel. Overflow from upstream system routed to BMP

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WOODLAN DRIVE DRAINAGE IMPROVEMENTS

CITY OF HARRISONBURG

ALTERNATIVES ANALYSIS 10-YEAR FLOODPLAIN MAPPING (RESTUDY)

DATE: 06/10/2021

DRAWN BY: K. REDMAN

DESIGNED BY: K. REDMAN

CHECKED BY: M. GAUP

SCALE: 1" =250'

JOB NO.: 47305.002

SHEET NO.: EXIT-7

Alternative	Description
E	Install private BMP and upgrade existing channel to concrete.

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REVISION DESCRIPTION | DATE

DATE 06/11/2021
K. REDMAN
DESIGNED BY K. REDMAN
CHECKED BY M. DAUB
SCALE 1" =250'

WOODLAN DRIVE DRAINAGE IMPROVEMENTS
CITY OF HARRISONBURG

ALTERNATIVES ANALYSIS 10-YEAR FLOODPLAIN MAPPING (RESTUDY)

JOB NO. 47305.002
SHEET NO. EXIT-8

APPENDIX E.2-3

25-Year Flood Inundation Maps

Alternative	Description
A	0.4 ac BMP ($60,000 ft^3$ volume) on city-owned parcel. DA 1D routed to BMP

LEGEND

- BUILDINGS (GIS)
- CITY OF HARRISONBURG PROPERTY LINES (GIS)
- CONTOURS (2')
- EX 25-YEAR FLOODPLAIN (RE-STUDY)
- ALTERNATIVE A

FLOOD VULNERABLE STRUCTURES

- 25-YEAR FLOODPLAIN
- 25-YEAR FLOODPLAIN (REMOVED STRUCTURES) (N/A FOR ALT A 25YR)

TIMMONS GROUP

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TEL 804.200.6500 FAX 804.560.1016 www.timmons.com

DATE	REVISION DESCRIPTION

DATE 06/11/2021 | DRAWN BY K. REDMAN | DESIGNED BY K. REDMAN | CHECKED BY M. GAUD | SCALE 1" =250'

WOODLAND DRIVE DRAINAGE IMPROVEMENTS
CITY OF HARRISONBURG
ALTERNATIVES ANALYSIS 25YEAR FLOODPLAIN MAPPING (RESTUDY)

JOB NO. 47305.002
SHEET NO. EXIT-9

\\timmons.com\gfs\2020\2020\47305- Master Contract City of Harrisonburg 2020\47305.002-Woodland Drive Drainage Improvement\DWG\Sheet\Exhibit\47305.002-EXBT-INUN-ALTS2.dwg | Plotted on 6/17/2021 1:22 AM | by Kelsey Redman

Alternative	Description
B	1.53 ac BMP (495,000 ft^3 volume) on privately-owned parcel. Overflow from upstream systems routed to BMP

LEGEND

- BUILDINGS (GIS)
- CITY OF HARRISONBURG PROPERTY LINES (GIS)
- CONTOURS (2')
- EX 25-YEAR FLOODPLAIN (RE-STUDY)
- ALTERNATIVE B

FLOOD VULNERABLE STRUCTURES

- 25-YEAR FLOODPLAIN
- 25-YEAR FLOODPLAIN (REMOVED STRUCTURES)

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REVISION DESCRIPTION | DATE

DATE 06/11/2021
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DESIGNED BY K. REDMAN
CHECKED BY M. DAVIS
SCALE 1" =250'

WOODLAN DRIVE DRAINAGE IMPROVEMENTS
CITY OF HARRISONBURG

ALTERNATIVES ANALYSIS 25-YEAR FLOODPLAIN MAPPING (RESTUDY)

JOB NO. 47305.002
SHEET NO. EXIT-10

Alternative	Description
E	Install private BMP and upgrade existing channel to concrete.

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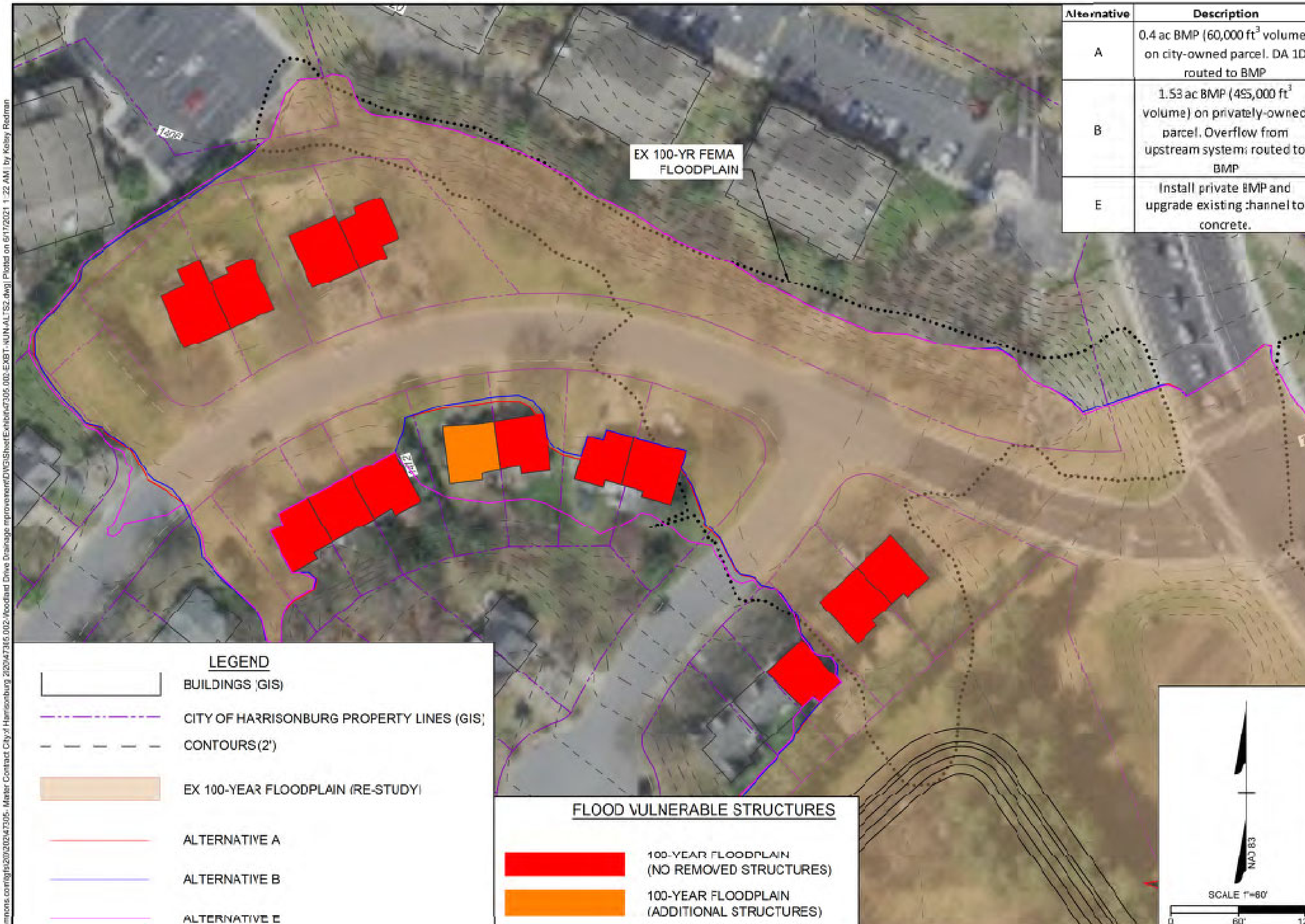
DRAWN BY K. REDMAN
DESIGNED BY K. REDMAN
SCALE 1" =250'

WOODLAN DRIVE DRAINAGE IMPROVEMENTS
CITY OF HARRISONBURG
ALTERNATIVES ANALYSIS 25-YEAR FLOODPLAIN MAPPING (RESTUDY)

JOB NO. 47305.002
SHEET NO. EXIT-11

APPENDIX E.2-4

100-Year Flood Inundation Map



Alternative	Description
A	0.4 ac BMP (60,000 ft^3 volume) on city-owned parcel. DA 1D routed to BMP
B	1.53 ac BMP (455,000 ft^3 volume) on privately-owned parcel. Overflow from upstream system routed to BMP
E	Install private BMP and upgrade existing channel to concrete.

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DATE 06/11/2021

DRAWN BY K. REDMAN

DESIGNED BY K. REDMAN

CHECKED BY M. CLAUD

SCALE 1" =250'

TIMMONS GROUP

WOODLAN DRIVE DRAINAGE IMPROVEMENTS

CITY OF HARRISONBURG

ALTERNATIVES ANALYSIS 100-YEAR FLOODPLAIN MAPPING (RE-STUDY)

JOB NO. 47305.002

SHEET NO. EXIT-12

APPENDIX E.3

Profiles – Modeled Storm Drainage System

APPENDIX E.3-1

SWMM 2 Year Storm Profiles

2-YEAR STORM PROFILES

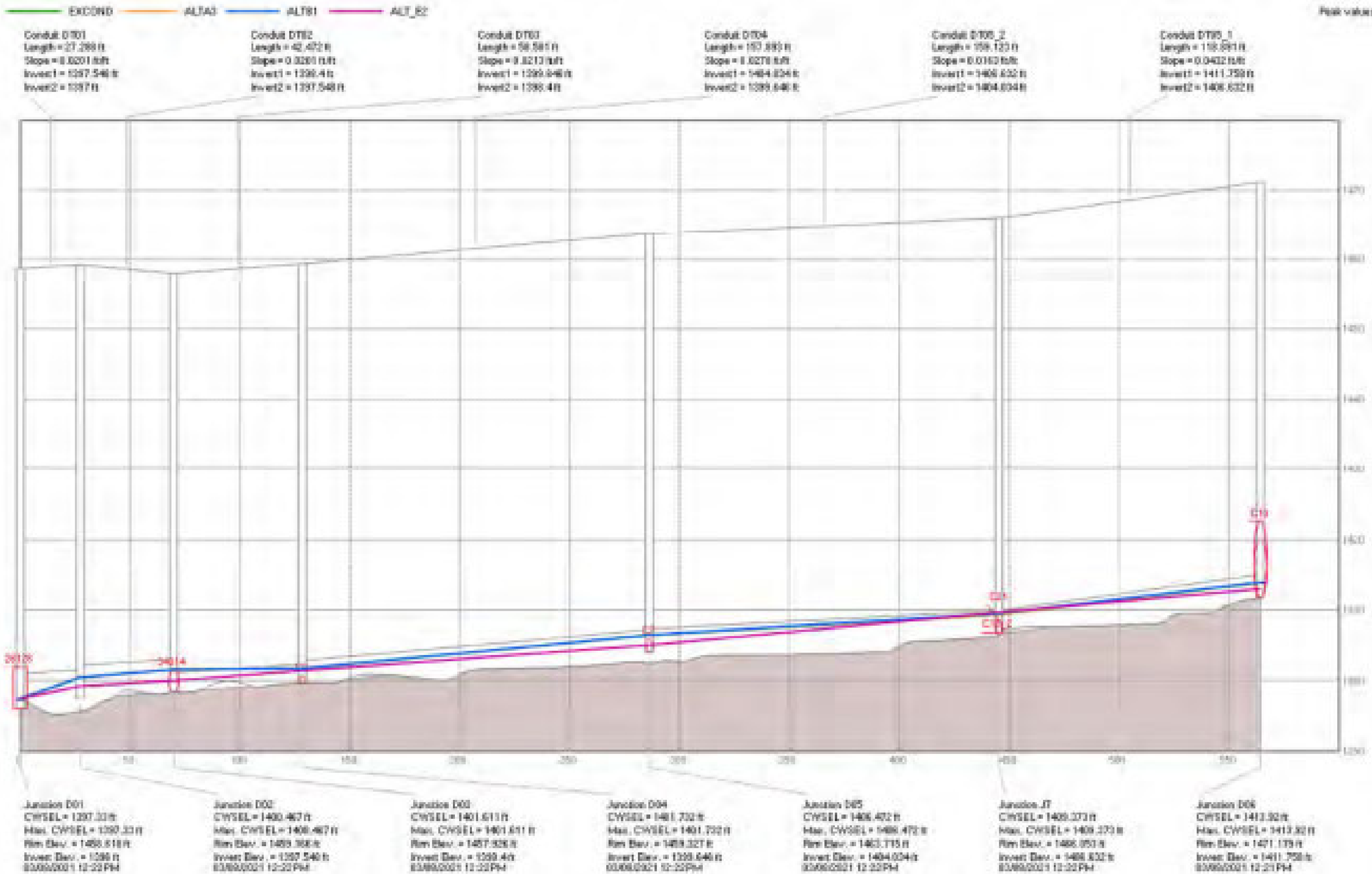

Figure 4: TRUNKLINE A

2-YEAR STORM PROFILES

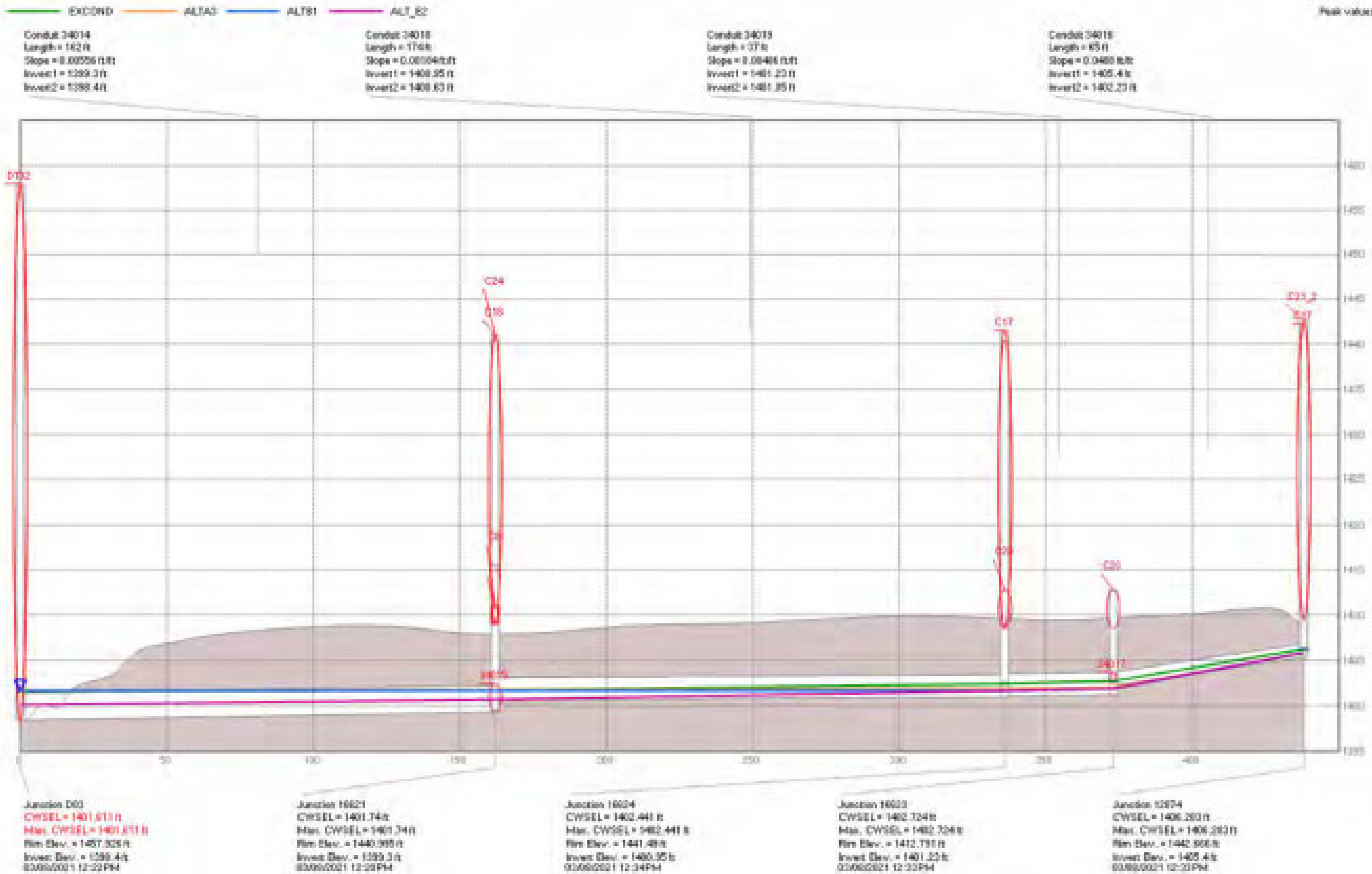

Figure 5: TRUNKLINE B

2-YEAR STORM PROFILES

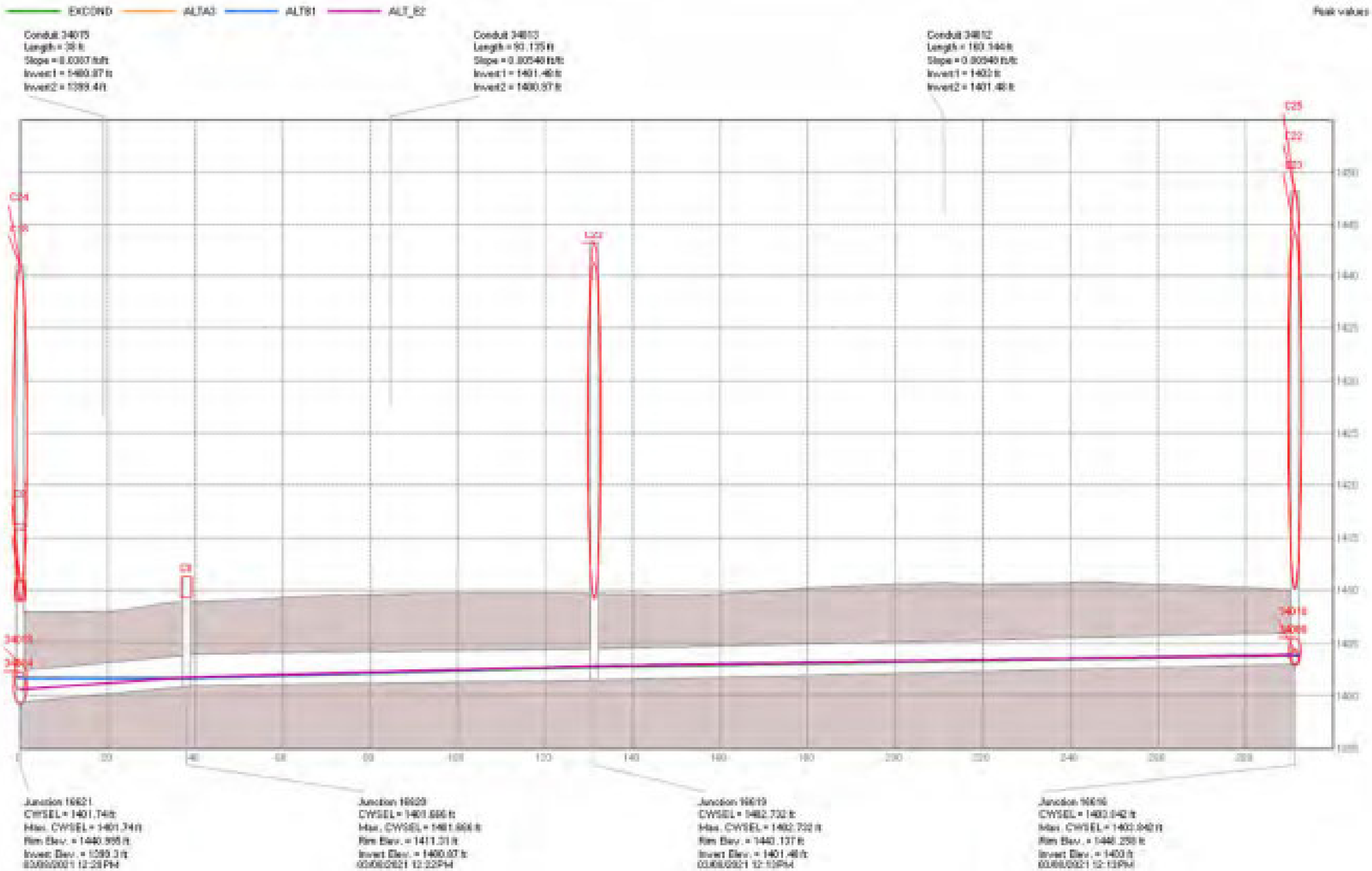

Figure 6: TRUNKLINE C

2-YEAR STORM PROFILES

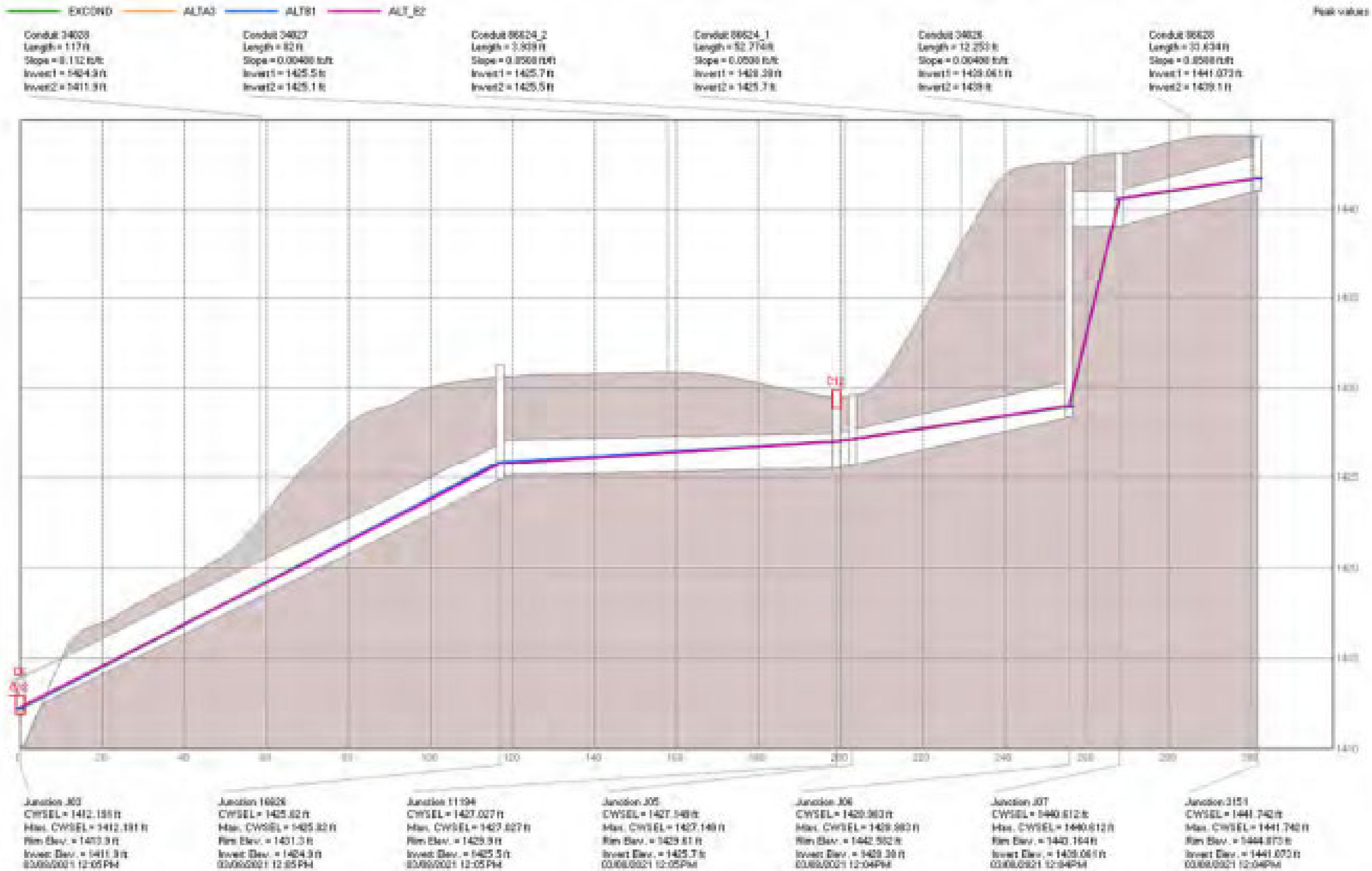

Figure 7: TRUNKLINE D

2-YEAR STORM PROFILES

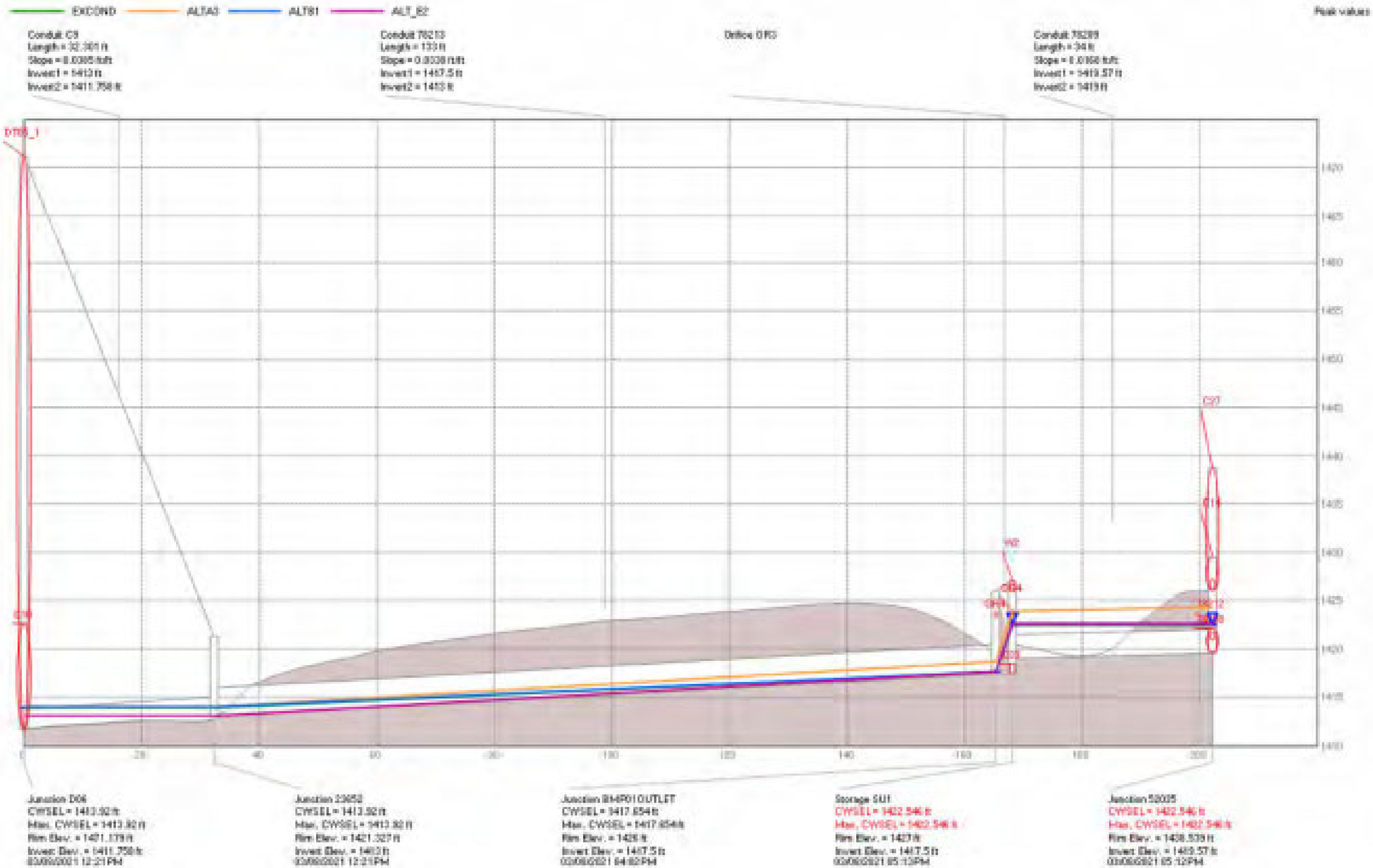

Figure 8: TRUNKLINE E1

2-YEAR STORM PROFILES

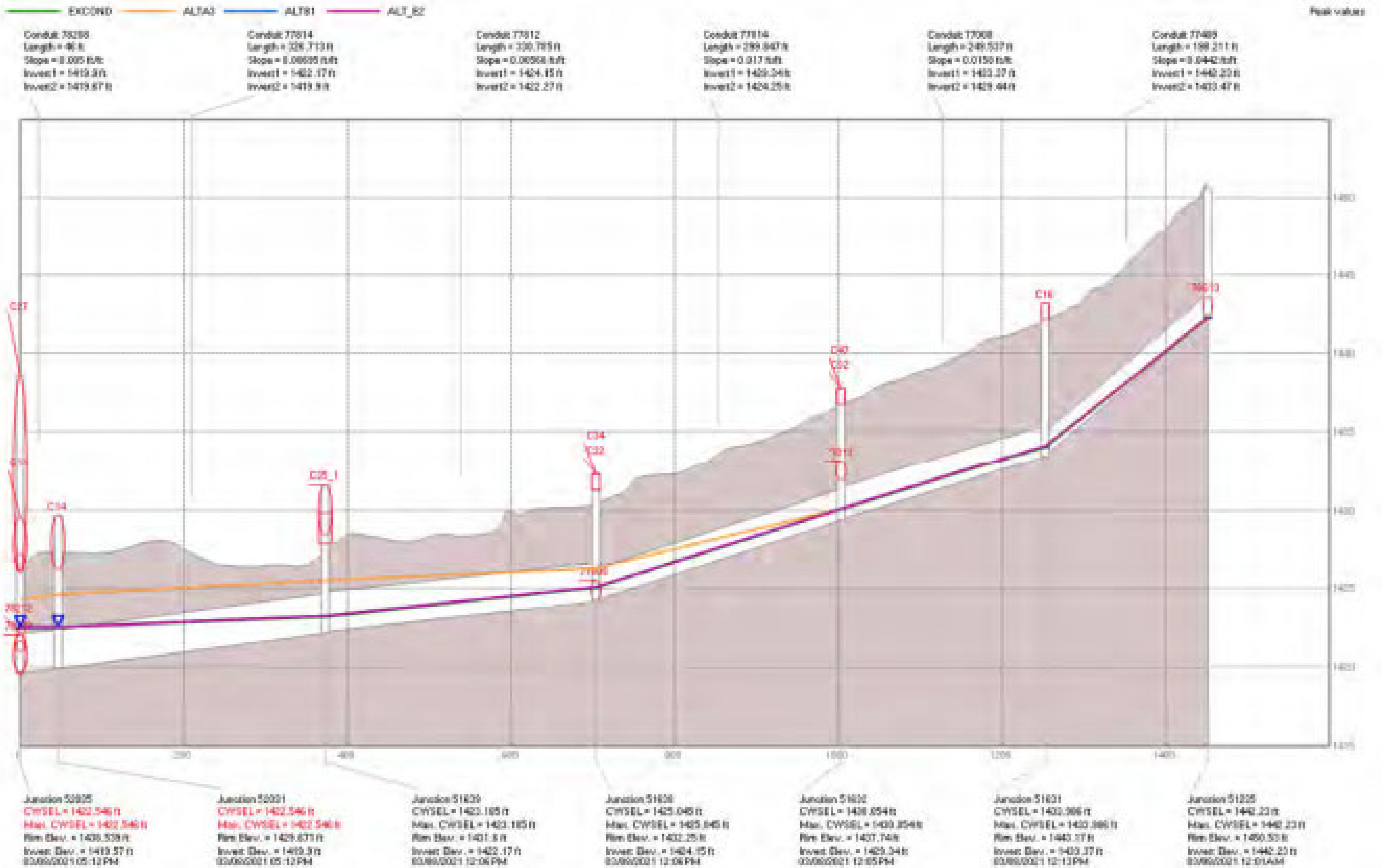

Figure 9: TRUNKLINE E2

47305.002_Woodland_Drive_plandata_ex
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PCSWMM 7.4.3202
SWMM 5.1.015

2-YEAR STORM PROFILES

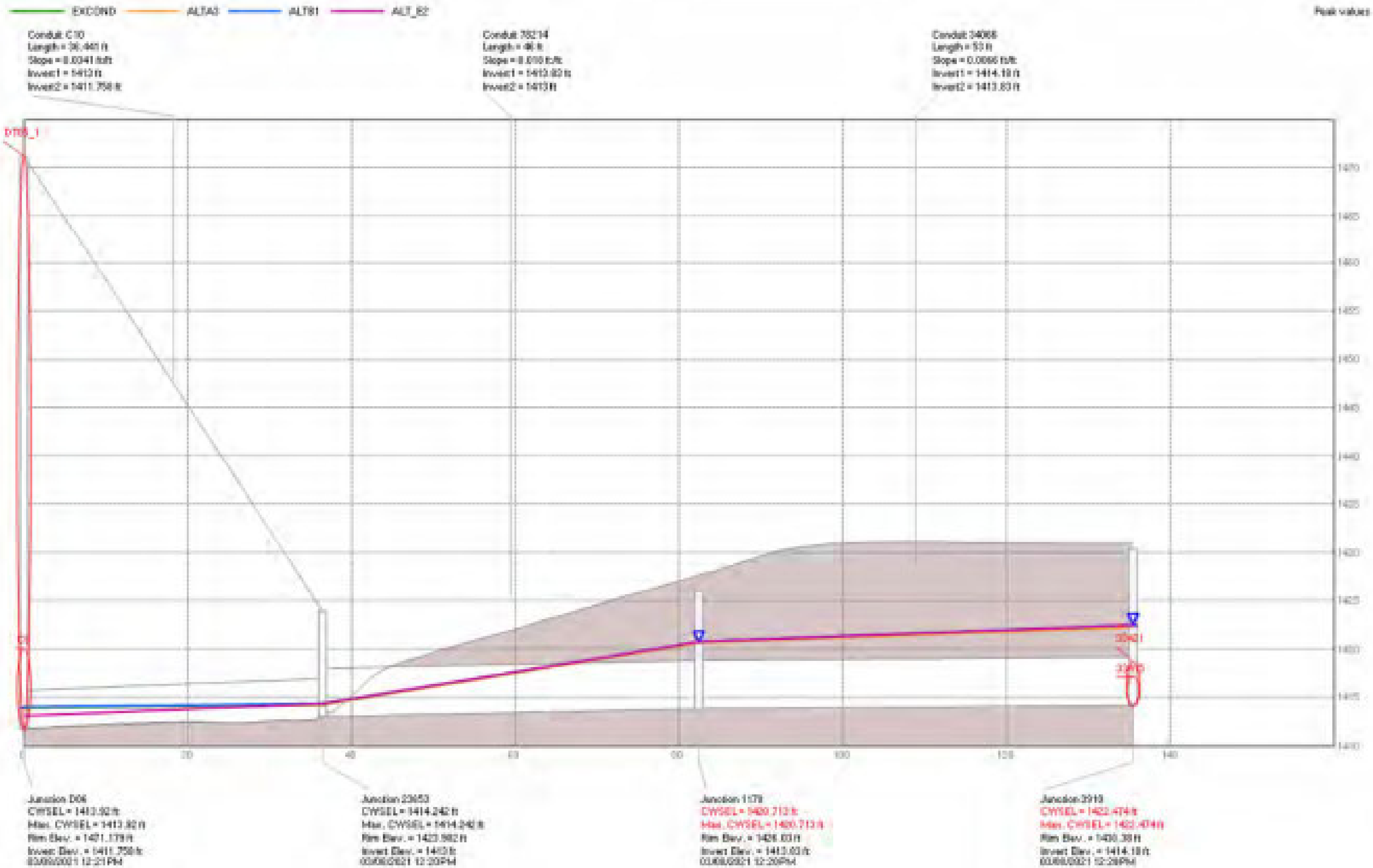

Figure 10: TRUNKLINE F

2-YEAR STORM PROFILES

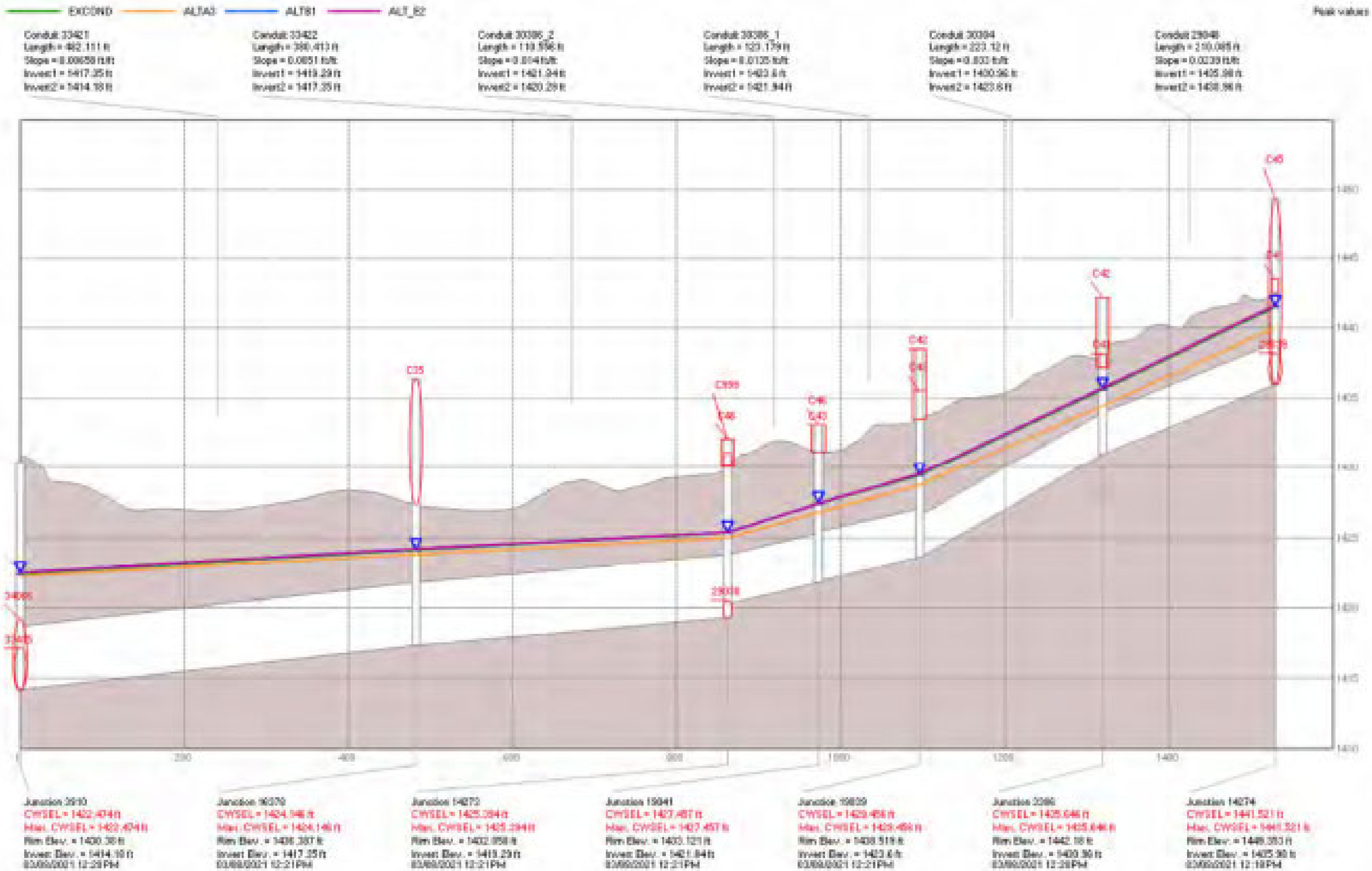

Figure 11: TRUNKLINE G

2-YEAR STORM PROFILES

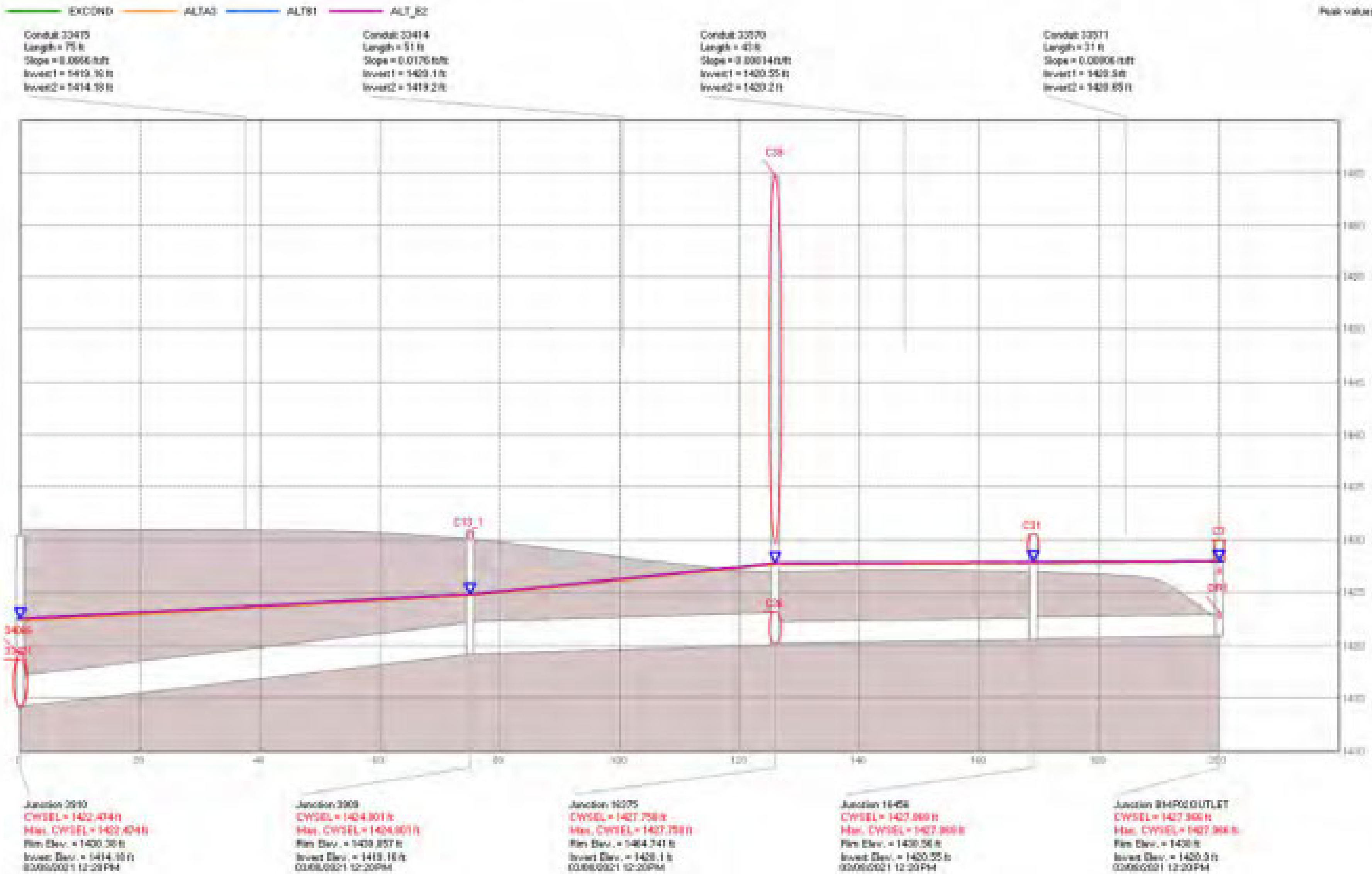

Figure 12: TRUNKLINE H