Fanning Wash Low-Water Crossing Design

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- CENE 486C
- 12/3/2021
- Final Presentation

Figure 1: Soliere Ave running adjacent to I-40 Culvert

Project Background

Purpose

- Create design alternatives for the Low-Water Crossing at Fanning Wash & Soliere Ave to mitigate flooding.

Goals

- Improve flooding across Soliere Ave.
- Create an accurate flow model of existing site.
- Propose improved culvert designs.

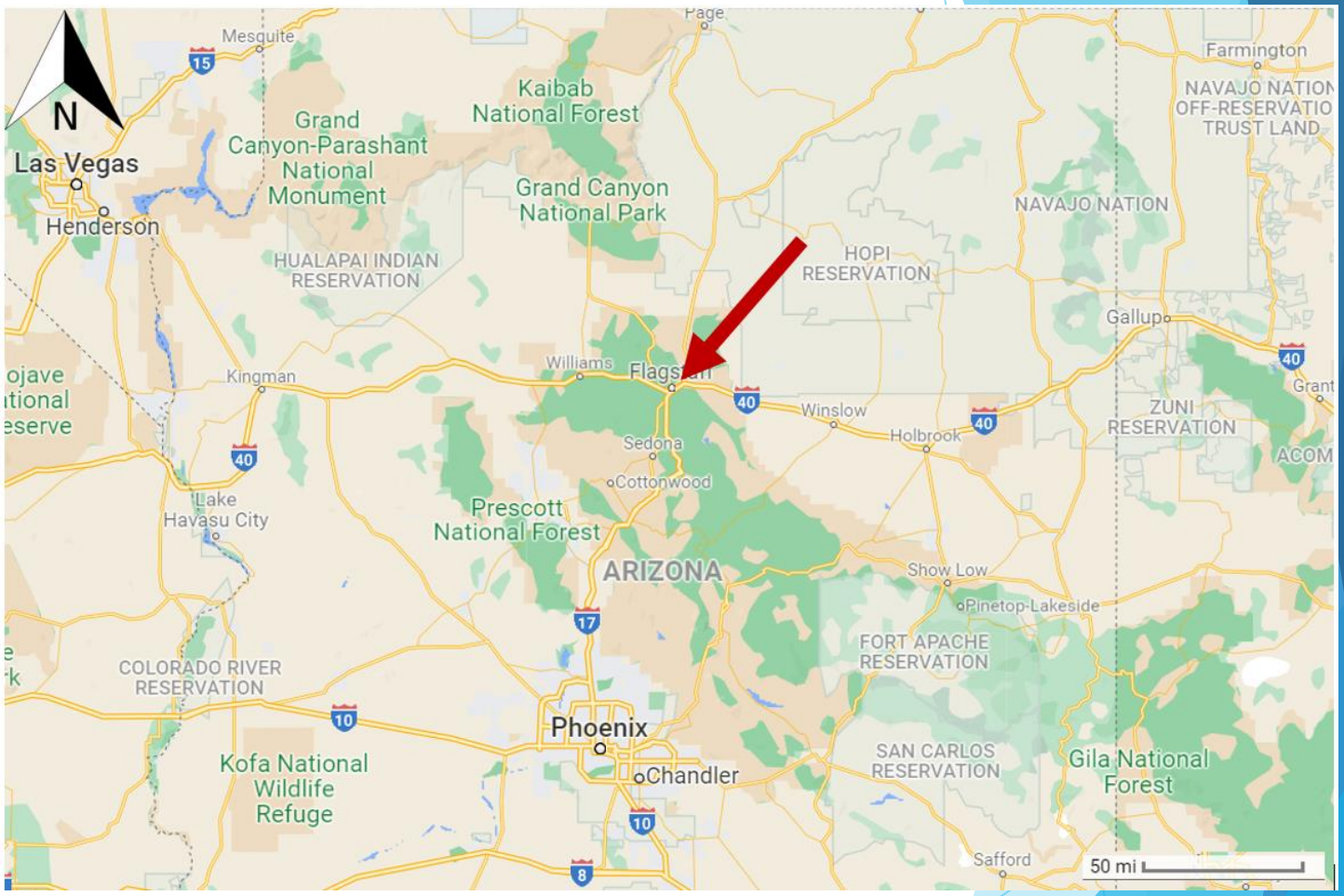

Figure 2: Location Map for the City of Flagstaff

Figure 3: Flow Path of Fanning Wash & Rio de Flag

Figure 4: Location Map of Existing Culvert along I-40

Site Investigation

- Existing I-40 Culvert and Site Research
  - Site map created from survey data and site sketch.
  - Used to illustrate existing structures and land features.

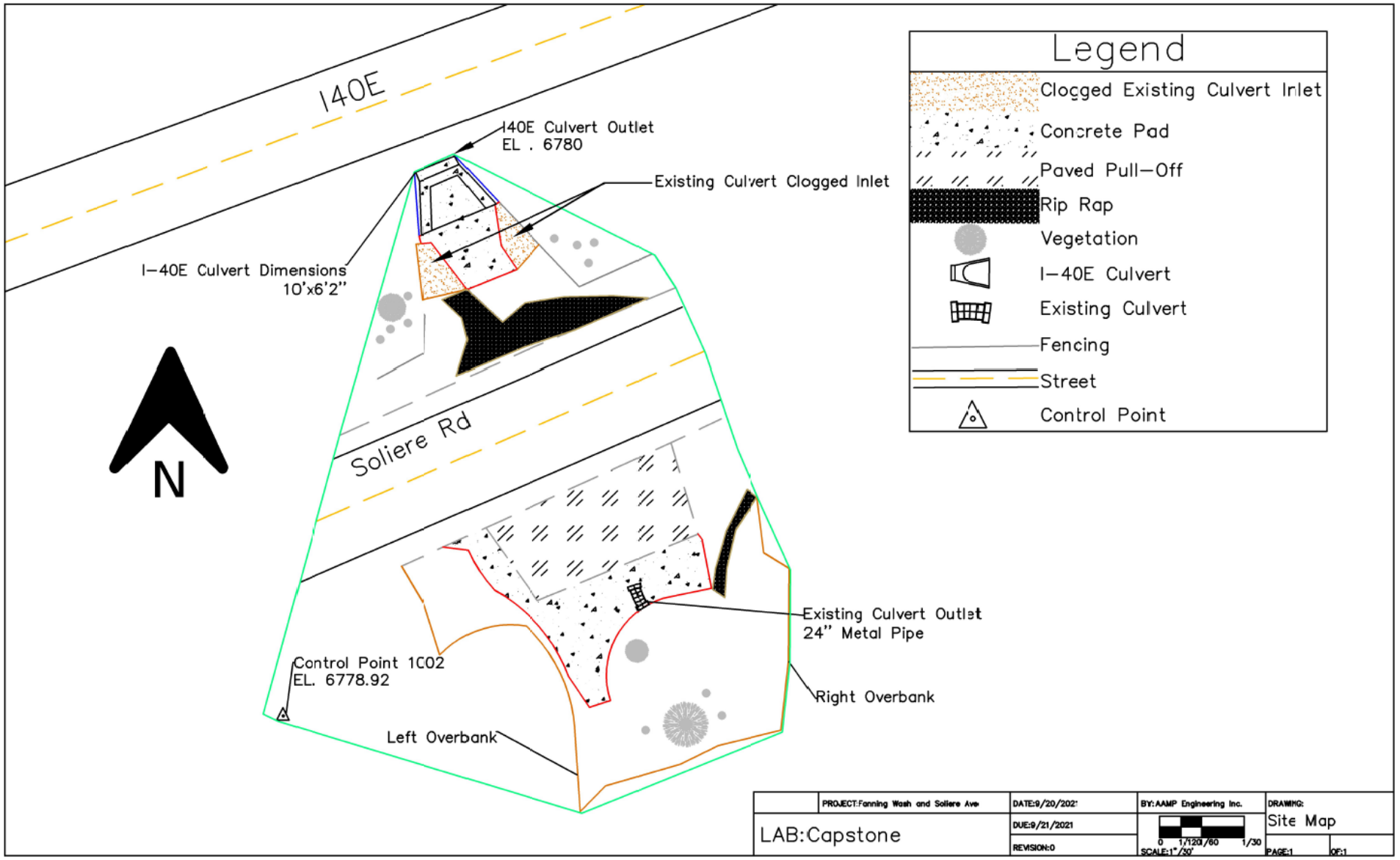

Figure 5: Site Map

Topographic Map

Surveying was conducted to collect these data points (around 125 shots were taken)

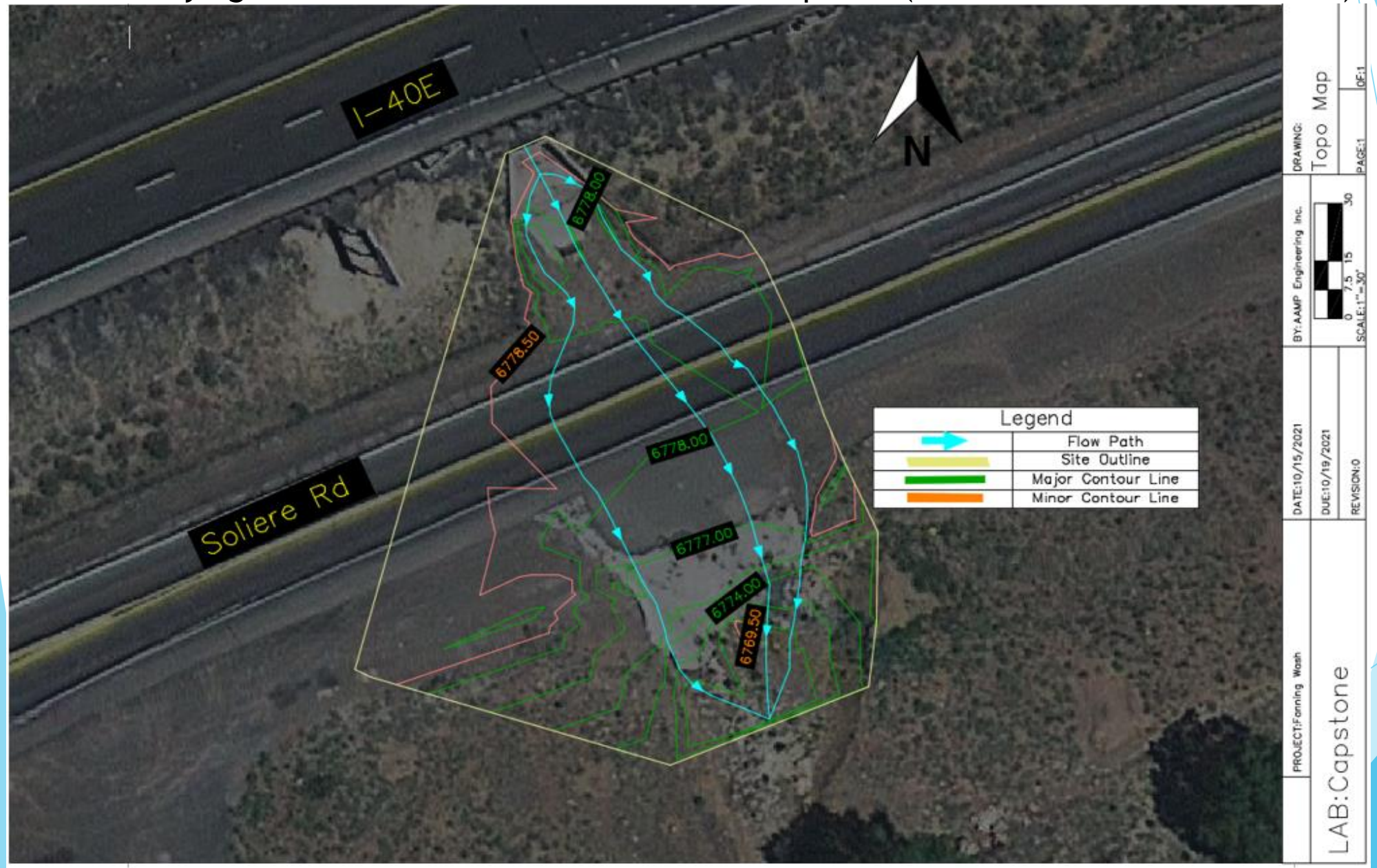

Figure 6: Topographic Map

Station Interval Method

- Placed cross sections where change in geometry and material was found
- Placed 11 Cross Sections
- 2' Station Interval's for large amounts elevation change
- 5' Station Intervals for small amounts of elevation change

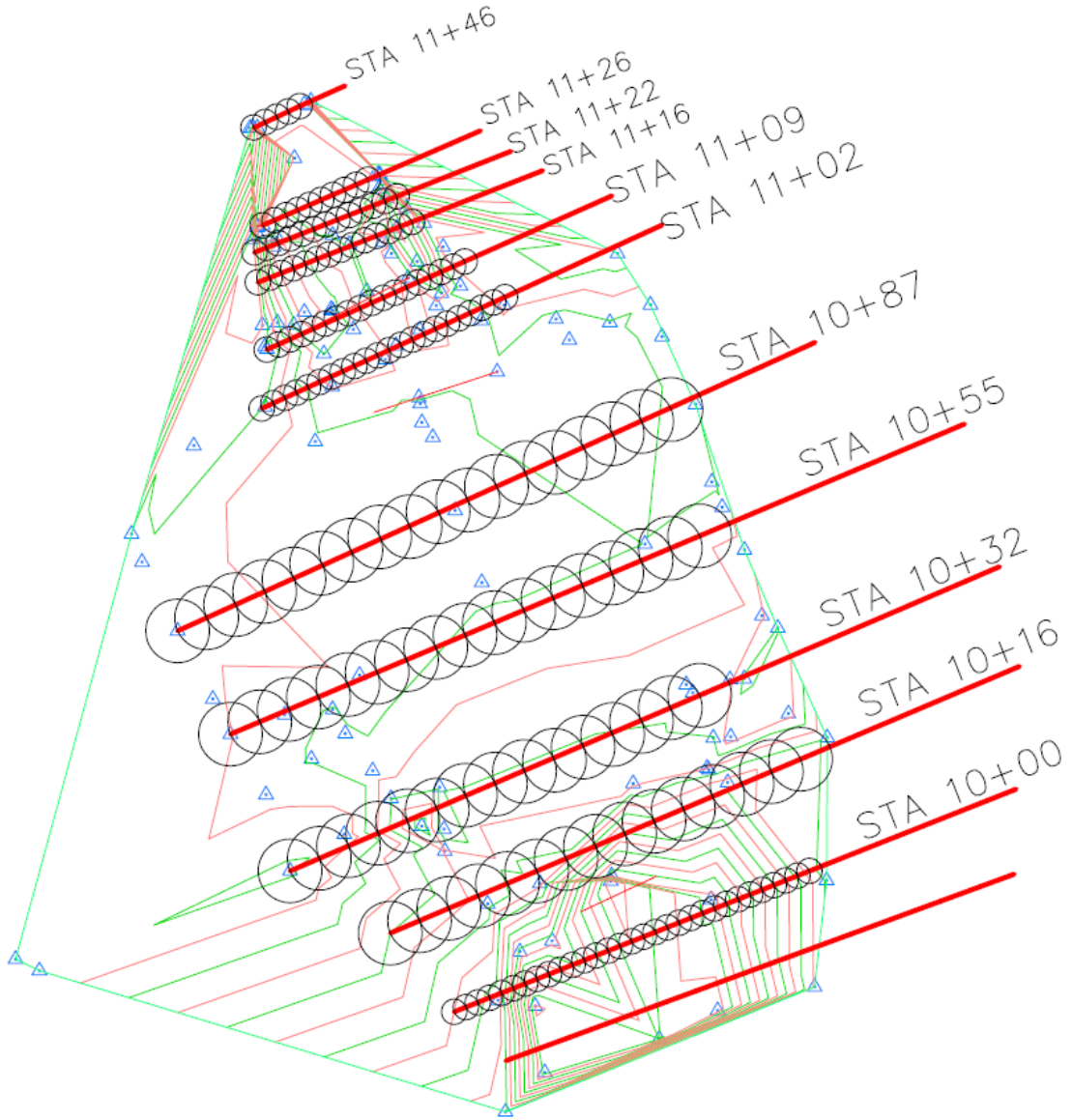

Figure 7: Cross Section Intervals

HEC-RAS Model of Existing Site Location

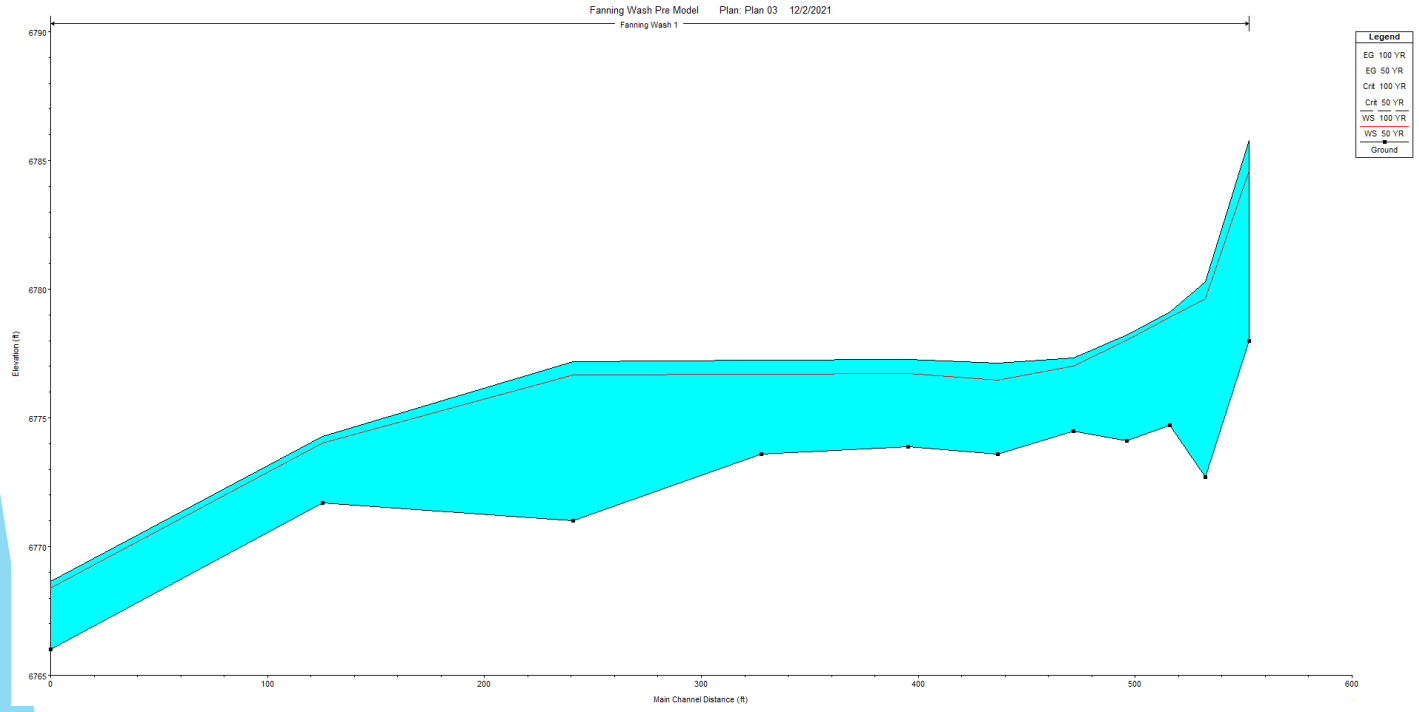

Figure 8: Existing HEC-RAS Model

River Sta	Profile	Q Total (cfs)	Min Ch El (ft)	W.S. Elev (ft)	E.G. Elev (ft)	E.G. Slope (ft/ft)	Vel Chnl (ft/s)	Flow Area (sq ft)
11+46	100 YR	730	6778	6785.77	6789.58	0.006709	15.66	46.6
11+46	50 YR	570	6778	6784.59	6787.82	0.006069	14.42	39.52
11+26	100 YR	730	6772.7	6780.29	6780.37	0.000085	2.45	321.11
11+26	50 YR	570	6772.7	6779.63	6779.71	0.000103	2.38	253.11
11+22	100 YR	730	6774.7	6779.1	6780.26	0.437214	6.36	101.03
11+22	50 YR	570	6774.7	6778.9	6779.64	0.38909	5.88	90.62
11+16	100 YR	730	6774.1	6778.22	6779.01	0.021566	1.28	177.18
11+16	50 YR	570	6774.1	6778.03	6778.61	0.018415	1.15	161.39
11+09	100 YR	730	6774.48	6777.33	6778.25	0.04833	1.92	170.02
11+09	50 YR	570	6774.48	6777.01	6777.83	0.065516	2.03	140.44
11+02	100 YR	730	6773.6	6777.14	6777.42	0.004105	4.64	177.75
11+02	50 YR	570	6773.6	6776.45	6776.95	0.010931	5.94	108.17
10+87	100 YR	730	6773.88	6777.27	6777.34	0.000131	2.19	328.26
10+87	50 YR	570	6773.88	6776.73	6776.8	0.000145	2.04	273.18
10+55	100 YR	730	6773.6	6777.25	6777.33	0.000135	2.34	312.38
10+55	50 YR	570	6773.6	6776.71	6776.78	0.000155	2.22	257.2
10+32	100 YR	730	6771	6777.18	6777.29	0.005721	1.12	515.56
10+33	50 YR	570	6771	6776.65	6776.74	0.00503	0.97	462.17
10+16	100 YR	730	6771.7	6774.28	6774.91	1.321229	6.45	117.5
10+16	50 YR	570	6771.7	6774.03	6774.61	1.421334	6.16	94.14
10+00	100 YR	730	6766	6768.66	6771.11	0.008422	12.56	58.1
10+00	50 YR	570	6766	6768.39	6770.58	0.008995	11.87	48.01

Table 1: Existing HEC-RAS Data

HEC-RAS Existing 3D Model

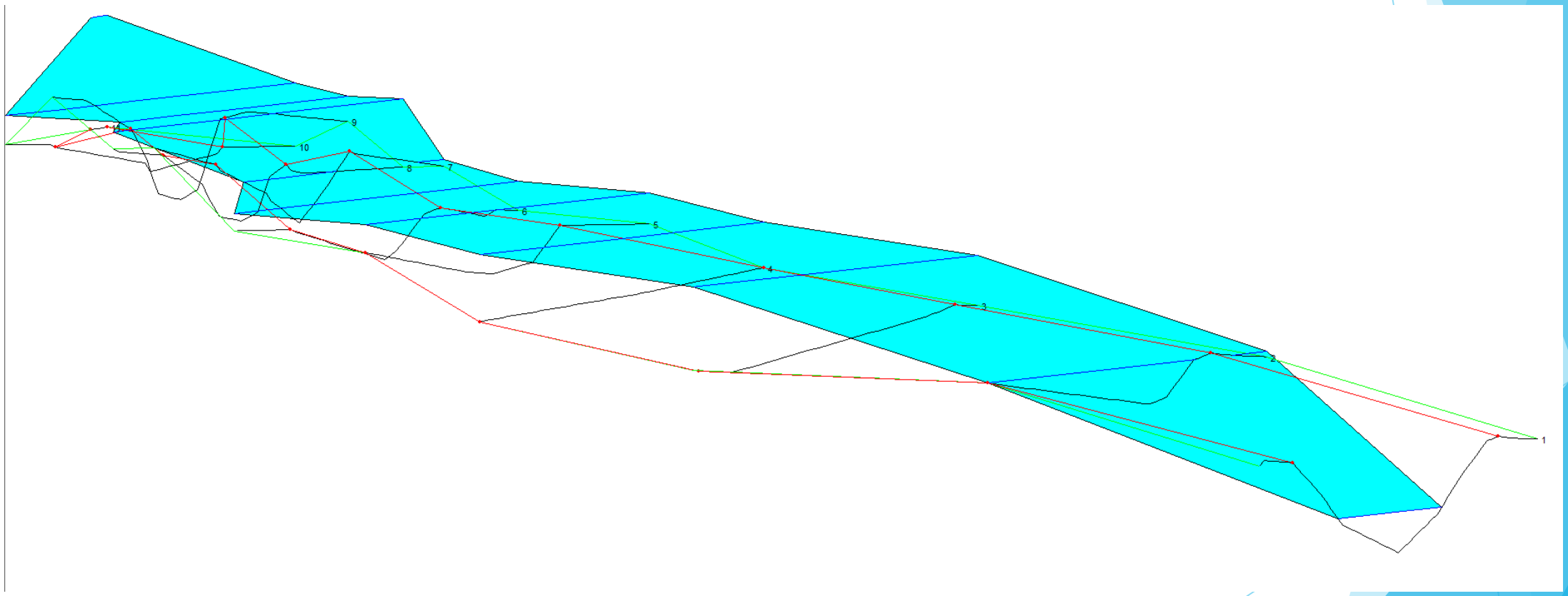

Figure 9: HEC-RAS Existing 3D Model

Design Alternatives

Potential Design:				
Description:	Three 6’ Diameter Corrugated Metal Pipes (CMP)	Three 6' Diameter Concrete Pipes	Two 12’x 7’ Box Culverts	Two 5.9’(W) x 4.5'(H) Arched Culverts

Table 2: Design Alternatives

Alternative #1: Triple Barrel Corrugated Metal Pipes

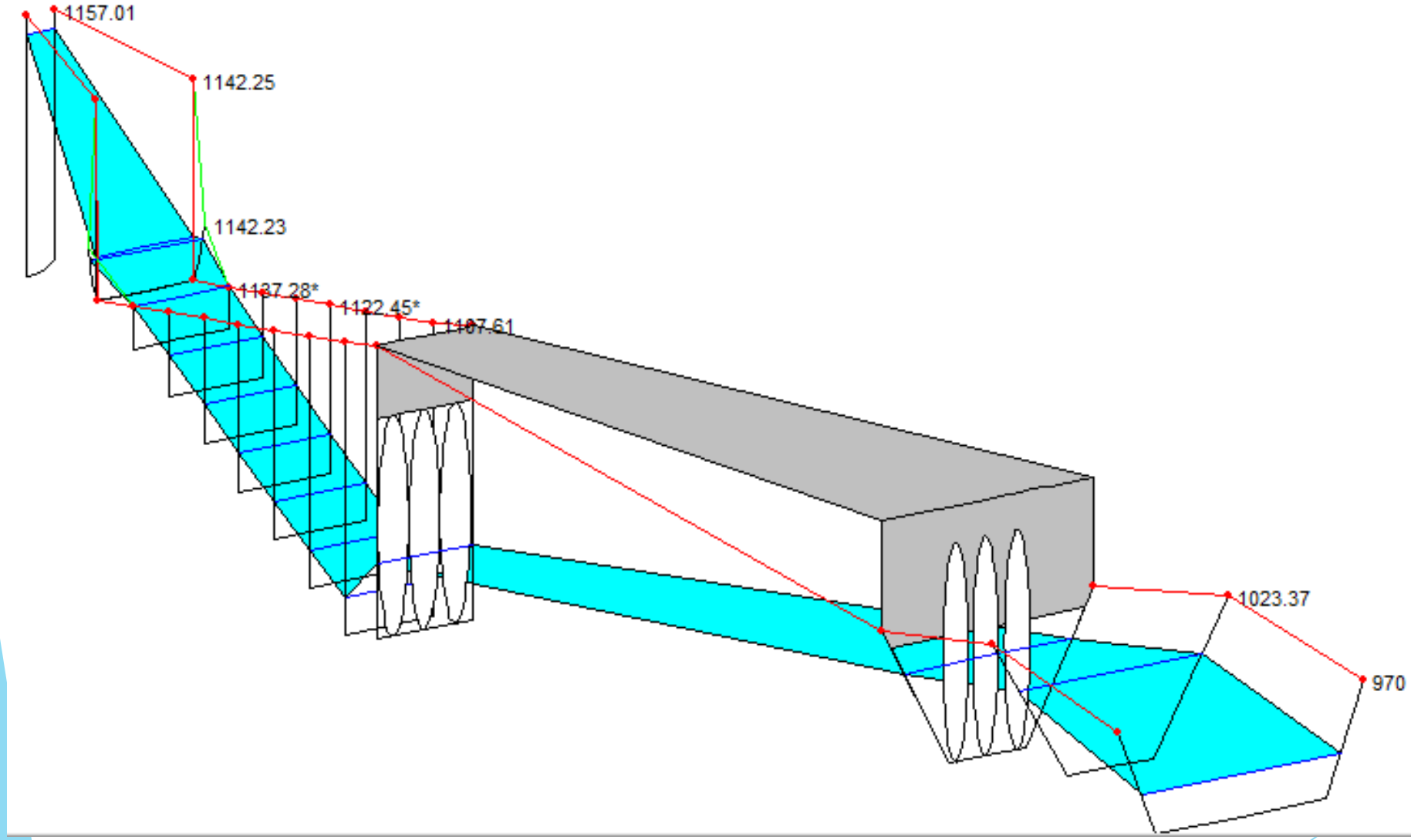

Figure 10: Alternative #1 3D Flow Model

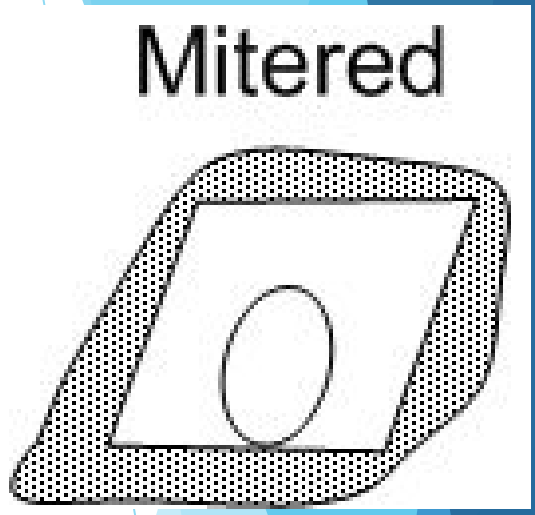

Figure 11: Inlet Type [3]

Alternative #2: Triple Barrel Concrete Pipes

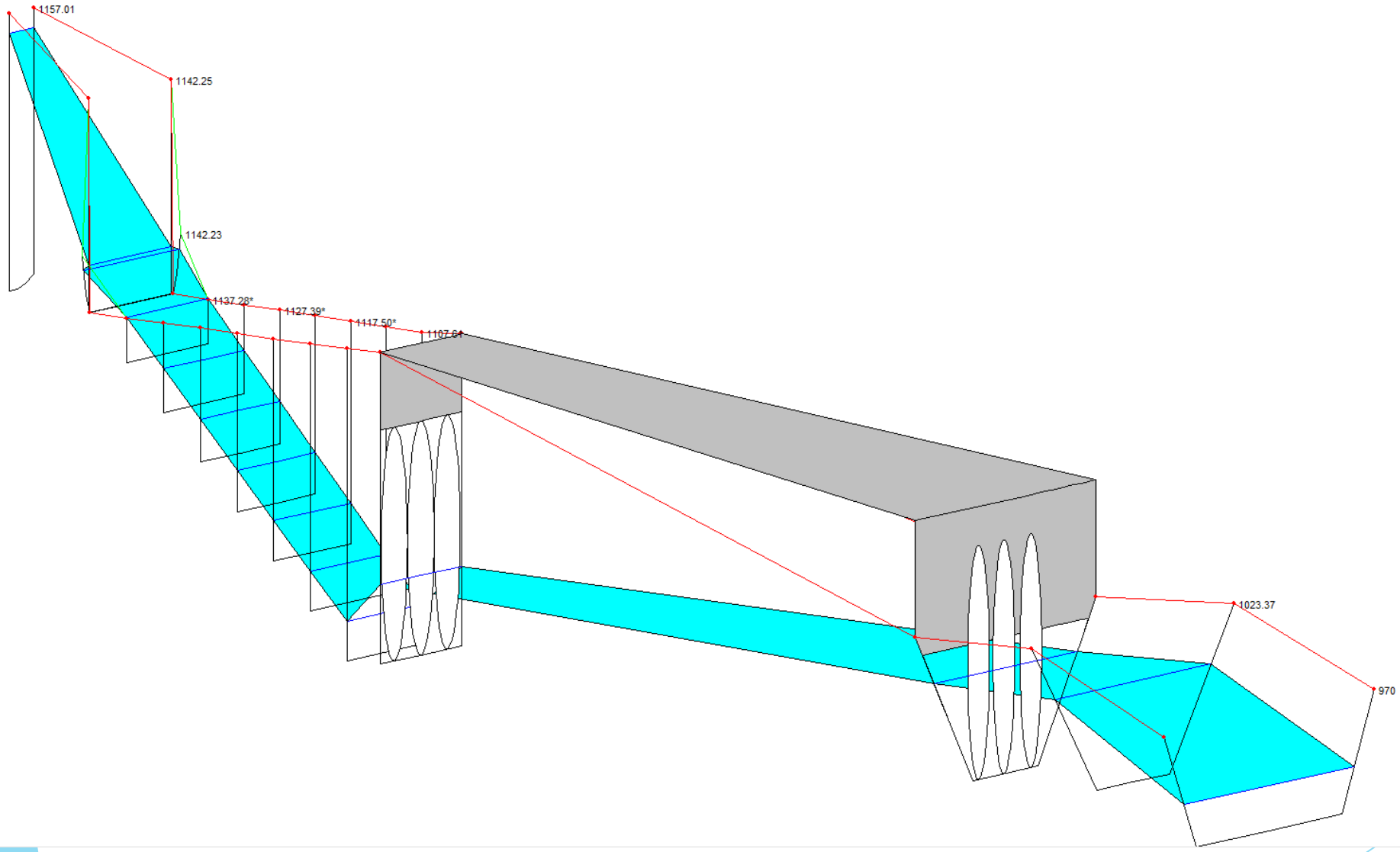

Figure 12: Alternative #2 3D Flow Model

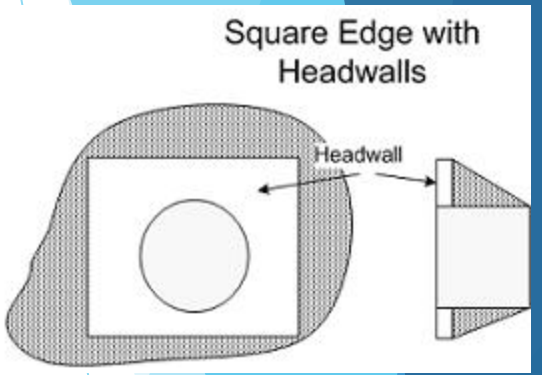

Figure 13: Inlet Type [3]

Alternative #3: Double Box Culverts

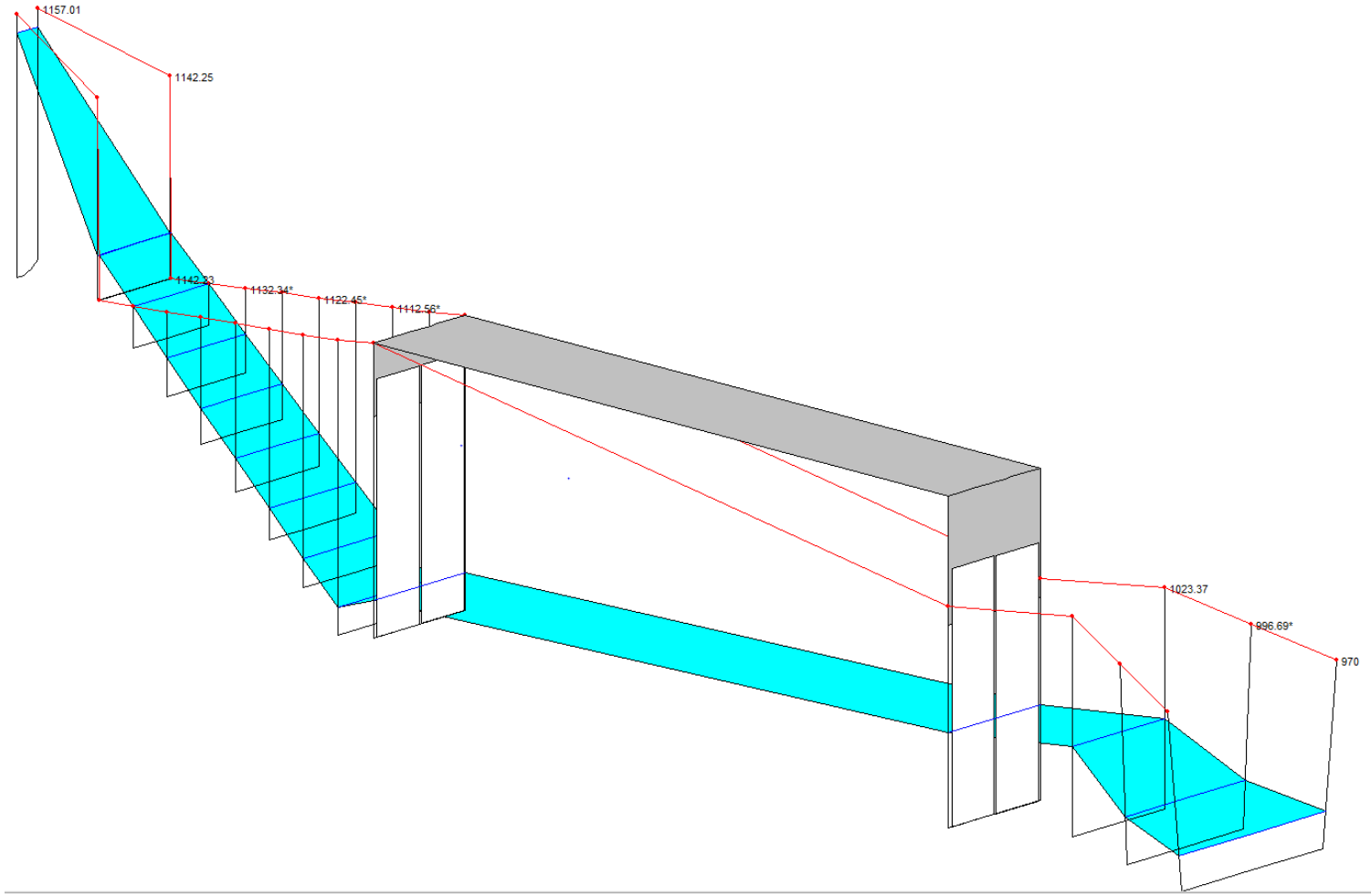

Figure 14: Alternative #3 3D Flow Model

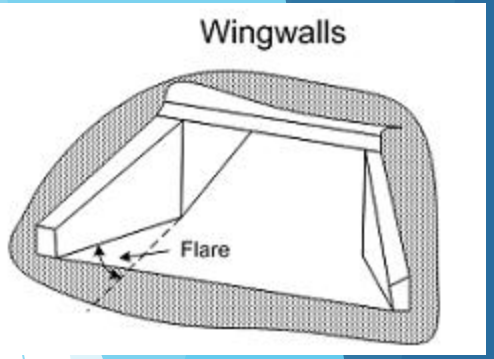

Figure 15: Inlet Type [3]

Alternative #4: Double Arched Culverts

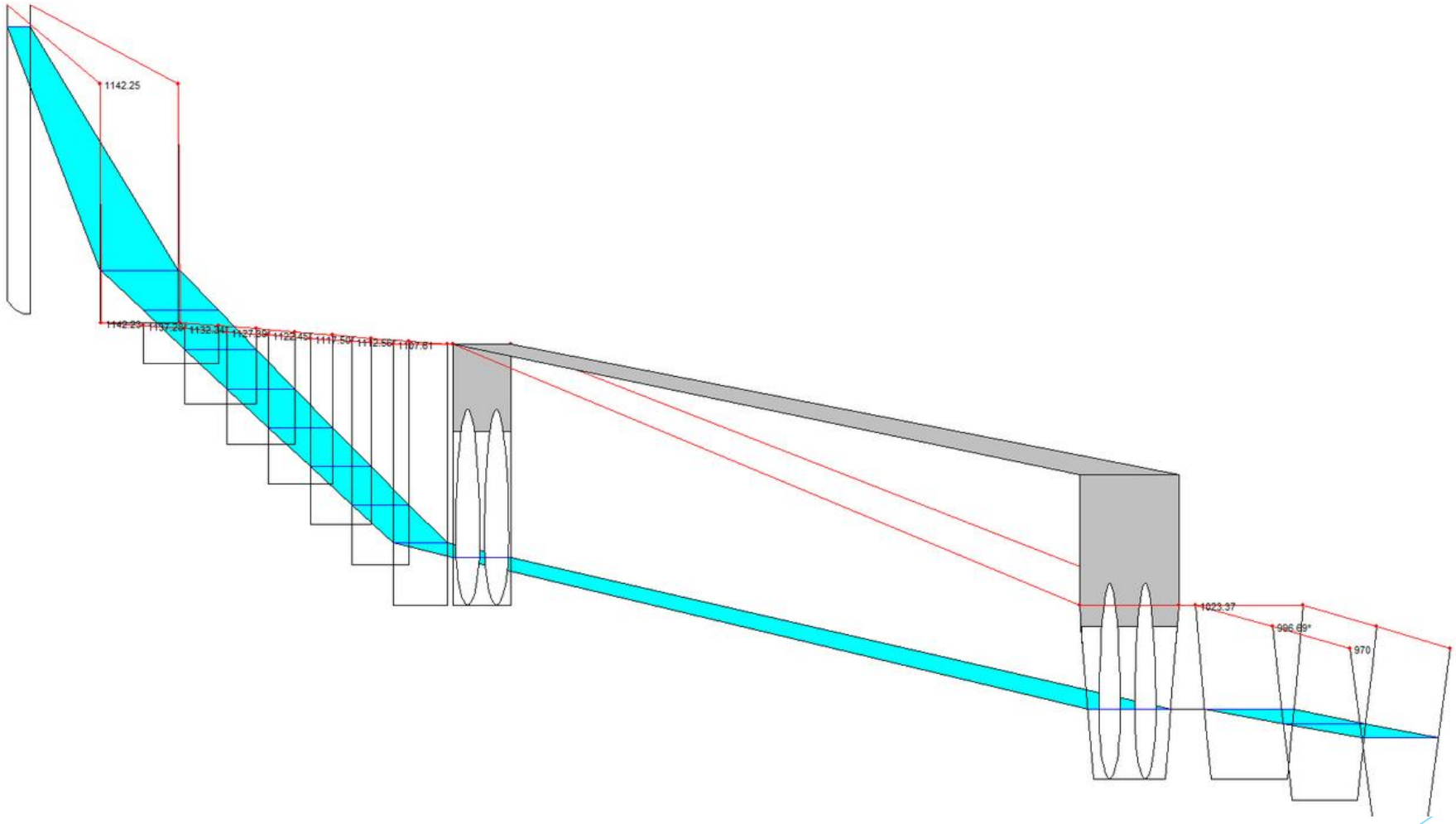

Figure 16: Alternative #4 3D Flow Model

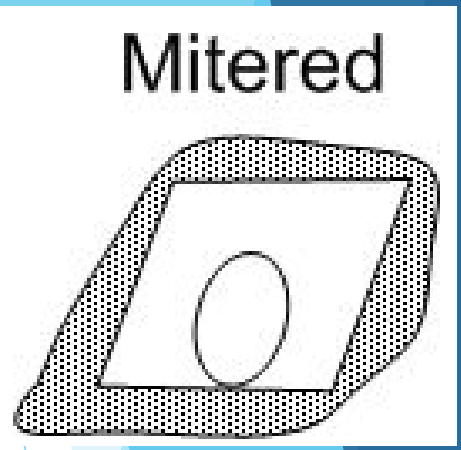

Figure 17: Inlet Type [3]

Comparison of Alternative Outputs

Criteria U= Upstream D = Downstream	Q Total (cfs)	W.S. Elev (ft)	Invert Elev (ft)	Velocity (ft/s)	Flow Regime
Triple Barrel 7' CMP (U)	570	6771.02	6770	22.40	Supercritical
Triple Barrel 7' CMP (D)	570	6770.57	6768	15.32	Supercritical
Triple Barrel 7' Conc. (U)	570	6771.02	6770	22.40	Supercritical
Triple Barrel 7' Conc. (D)	570	6770.57	6768	21.45	Supercritical
Double 12' x 7' Box Culvert (U)	570	6770.76	6770	24.44	Supercritical
Double 12' x 7' Box Culvert (D)	570	6768.46	6766	9.14	Supercritical
Two 5.9' x 4.5' Arched (U)	570	6773.43	6772	23.57	Supercritical
Two 5.9' x 4.5' Arched (D)	570	6772.01	6768	6.40	Supercritical

Table 3: Key HEC-RAS Outputs for Alternatives

HEC-RAS and Culvert master comparison

50-year flood (570 cfs)						
Analysis	Culvert	Exit Velocity (ft/s)	WSE (ft)	HW/D	Normal Depth (ft)	Flow Regime
HEC-RAS	5.9' x 4.5' Double Pipe Arch	6.40	6773.43	0.37	1.7	Subcritical
Culvert Master	5.9' x 4.5' Double Pipe Arch	8.37	6775.69	0.95	1.47	Supercritical
HEC-RAS	12' x 7' Double Box	9.14	6770.76	0.70	2.60	Supercritical
Culvert Master	12' x 7' Double Box	18.53	6773.55	0.65	1.04	Supercritical
HEC-RAS	6' Triple Barrel CMP	15.32	6772.04	0.523	3.14	Supercritical
Culvert Master	6' Triple Barrel CMP	9.49	6773.5	1.08	2.57	Supercritical
HEC-RAS	6' Triple Barrel Concrete	21.45	6772.04	0.37	2.22	Supercritical
Culvert Master	6' Triple Barrel Concrete	9.77	6702.72	0.82	1.86	Supercritical

Table 4: HEC-RAS and Culvert Master Comparison (50-year flood)

HEC-RAS and Culvert master comparison

100-year flood (730 cfs)						
Analysis	Culvert	Exit Velocity (ft/s)	WSE (ft)	HW/D	Normal Depth (ft)	Flow Regime
HEC-RAS	5.9' x 4.5' Double Pipe Arch	17.02	6773.74	0.44	2.0	Supercritical
Culvert Master	5.9' x 4.5' Double Pipe Arch	10.71	6775.75	1.13	1.68	Supercritical
HEC-RAS	12' x 7' Double Box	9.93	6770.91	0.85	5.92	Supercritical
Culvert Master	12' x 7' Double Box	19.46	6772.36	0.77	1.22	Supercritical
HEC-RAS	6' Triple Barrel CMP	16.77	6772.35	0.61	3.67	Supercritical
Culvert Master	6' Triple Barrel CMP	16.74	6775.98	0.99	2.96	Supercritical
HEC-RAS	6' Triple Barrel Concrete	22.85	6772.35	0.42	2.54	Supercritical
Culvert Master	6' Triple Barrel Concrete	20.21	6773.62	0.95	2.12	Supercritical

Table 5: HEC-RAS and Culvert Master Comparison (100-year flood)

Decision Matrix (100 year)

100 Year Flood (730 cfs) CHECK STORM					
Potential Solution	Control	Outlet Velocity (ft/s)	Overtopping	Meets COF Requirements	Material Cost Estimate ($)
Double Pipe Arch 5.9' x 4.5'	Inlet	17.02	No	Yes	25,500
12' x 7' Double Box	Outlet	9.93	No	Yes	38,000
3 – 6' CMP	Outlet	16.77	No	Yes	30,500
3 – 6' Concrete	Outlet	22.85	No	No	51,000

Table 6: Decision Matrix (100-year flood)

Decision Matrix (50 year)

50 Year Flood (570 cfs) DESIGN STORM					
Potential Solution	Control	Outlet Velocity (ft/s)	Overtopping	Meets COF Requirements	Material Cost Estimate ($)
Double Pipe Arch 5.9' x 4.5'	Inlet	6.4	No	Yes	25,500
12' x 7' Double Box	Inlet	9.14	No	Yes	38,000
3 – 6' CMP	Outlet	15.32	No	Yes	30,500
3 – 6' Concrete	Inlet	21.45	No	No	51,000

Table 7: Decision Matrix (50-year flood)

Decision Matrix (cont.)

	Outlet Velocity		Construction Duration		Cost	
Rating Description	**Rating**	Description	**Rating**	Description	**Rating**	Description
3 - Highest Rating	**3**	10 ft/s and below	**3**	Shortest Time (< 2 Months)	**3**	Least Amount (<30000$)
2 - Average Rating	**2**	10 ft/s - 20 ft/s	**2**	Average Time (2-4 Months)	**2**	Average Amount ($30000-$40000)
1 - Lowest Rating	**1**	20 ft/s and above	**1**	Longest Time (> 4 Months)	**1**	Highest Amount (>$40000)

Table 8: Decision Matrix Criteria [6] & [8]

Final Design Selection

Fanning Wash Culvert Decision Matrix									
	Weight (percent)	Double Pipe Arch 5.9' x 4.5'		12' x 7' Double Box		3 - 6' CMP		3 - 6' Concrete	
		Score	WT Score	Score	WT score	Score	WT score	Score	WT score
Outlet Velocity	50.00%	3	150	2	100	2	100	1	50
Constructability	25.00%	2	50	2	50	2	50	2	50
Cost	25.00%	3	75	2	50	2	50	1	25
Sum			275		200		200		125

Table 9: Final Design Selection [8]

Final Design Selection Model

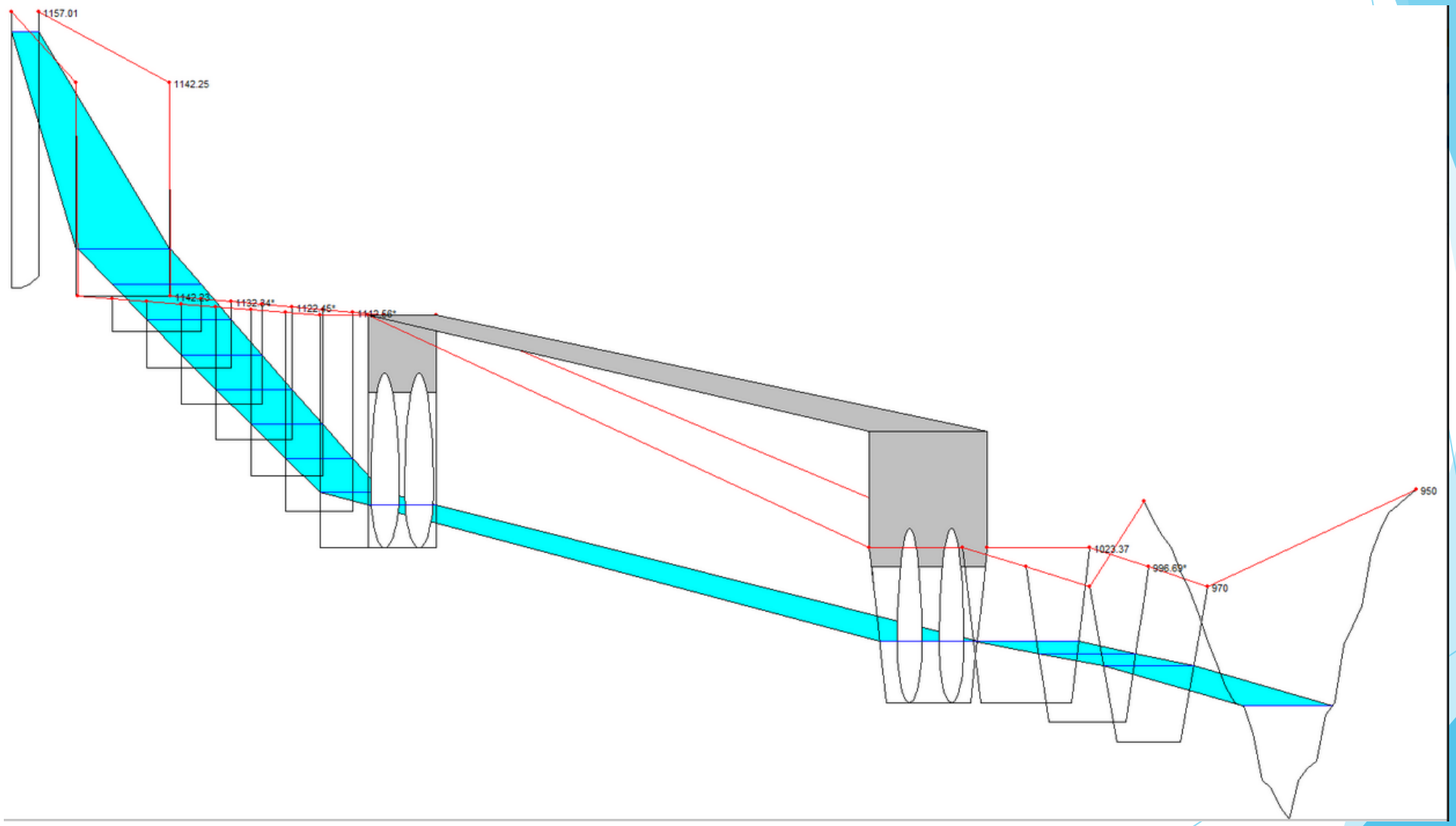

Figure 18: HEC-RAS Final Design Selection 3D Model

Cross Sections Modifications

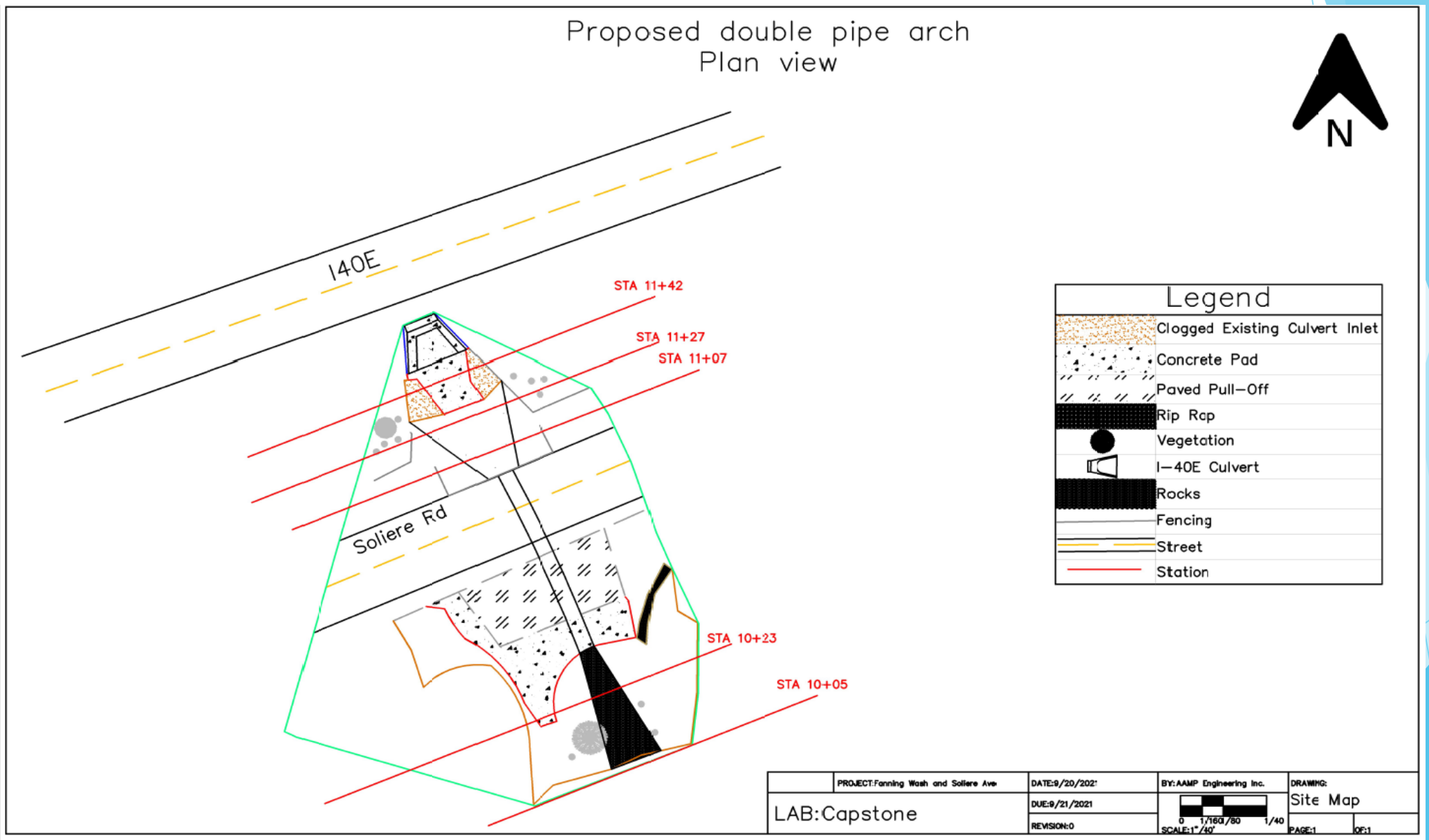

Figure 19: Modified Channel Cross Sections

Channel Cross Sections

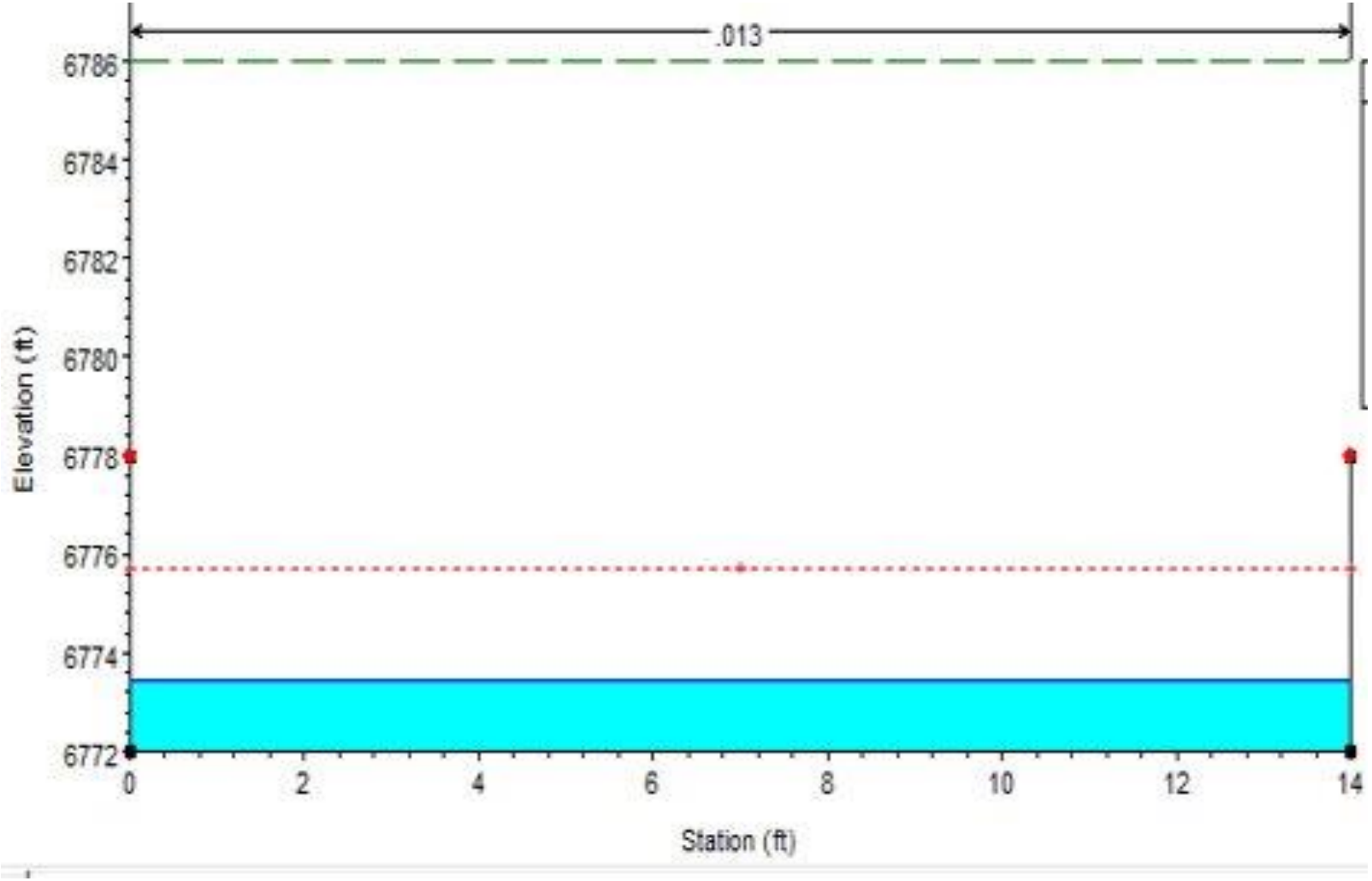

Figure 20: Cross Section 11+42

Channel Cross Sections (cont.)

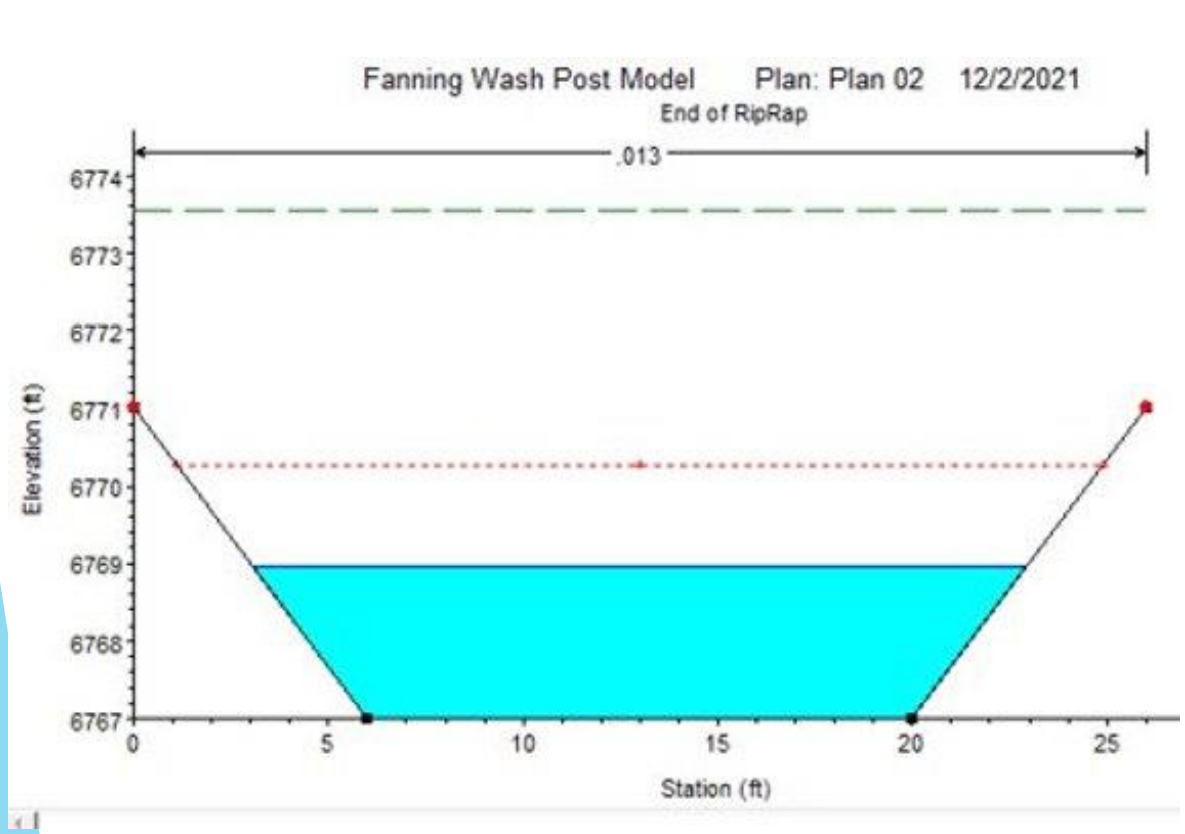

Figure 21: Cross Section 10+05

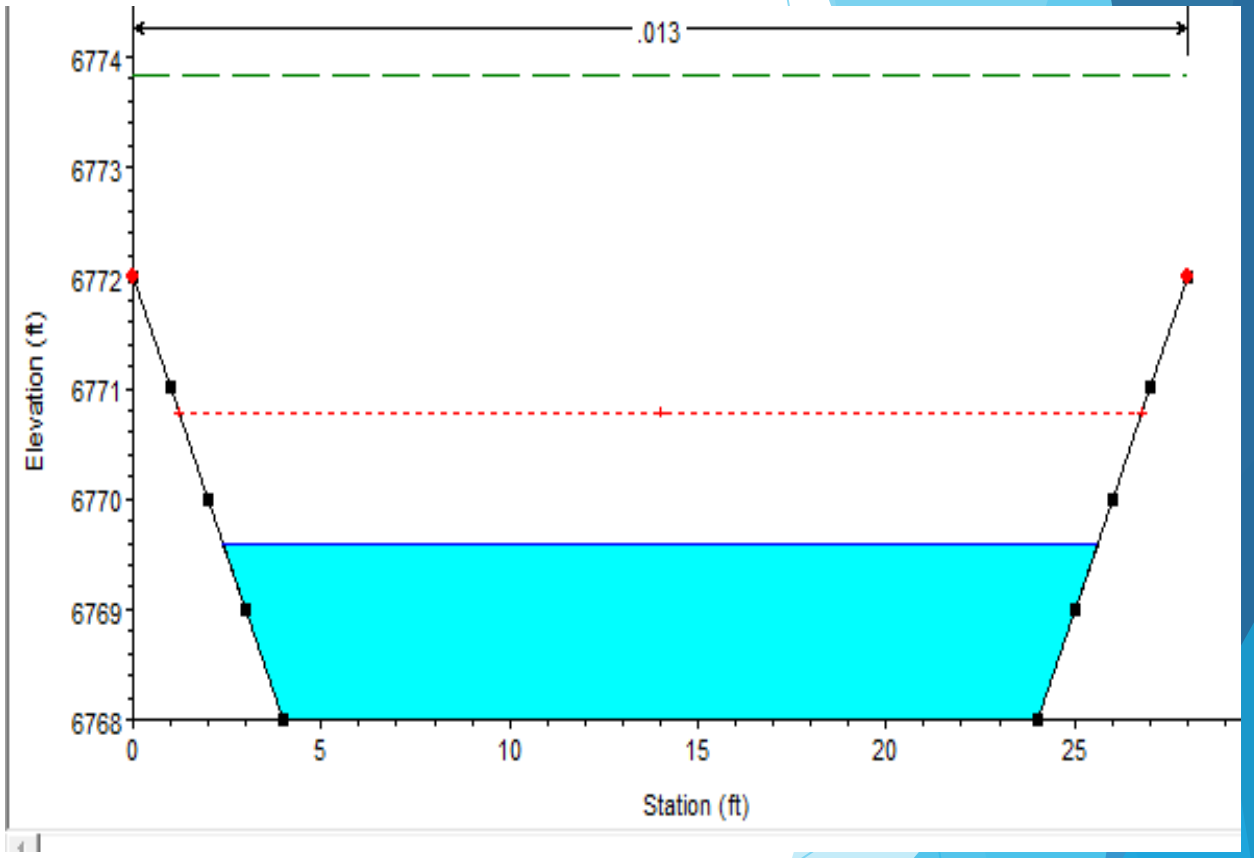

Figure 22: Cross Section 10+23

Upstream Culvert Entrance Dimensions

- Channel Height is 6 ft
- Channel Width 12 ft
- Each Culvert is 5.9 ft x 4.5 ft
- The cover is 1.5 ft
- Concrete Blocks are 3 ft x 1.5 ft x 1.5 ft
- Blocks Requested by Client (Edward Schenck)

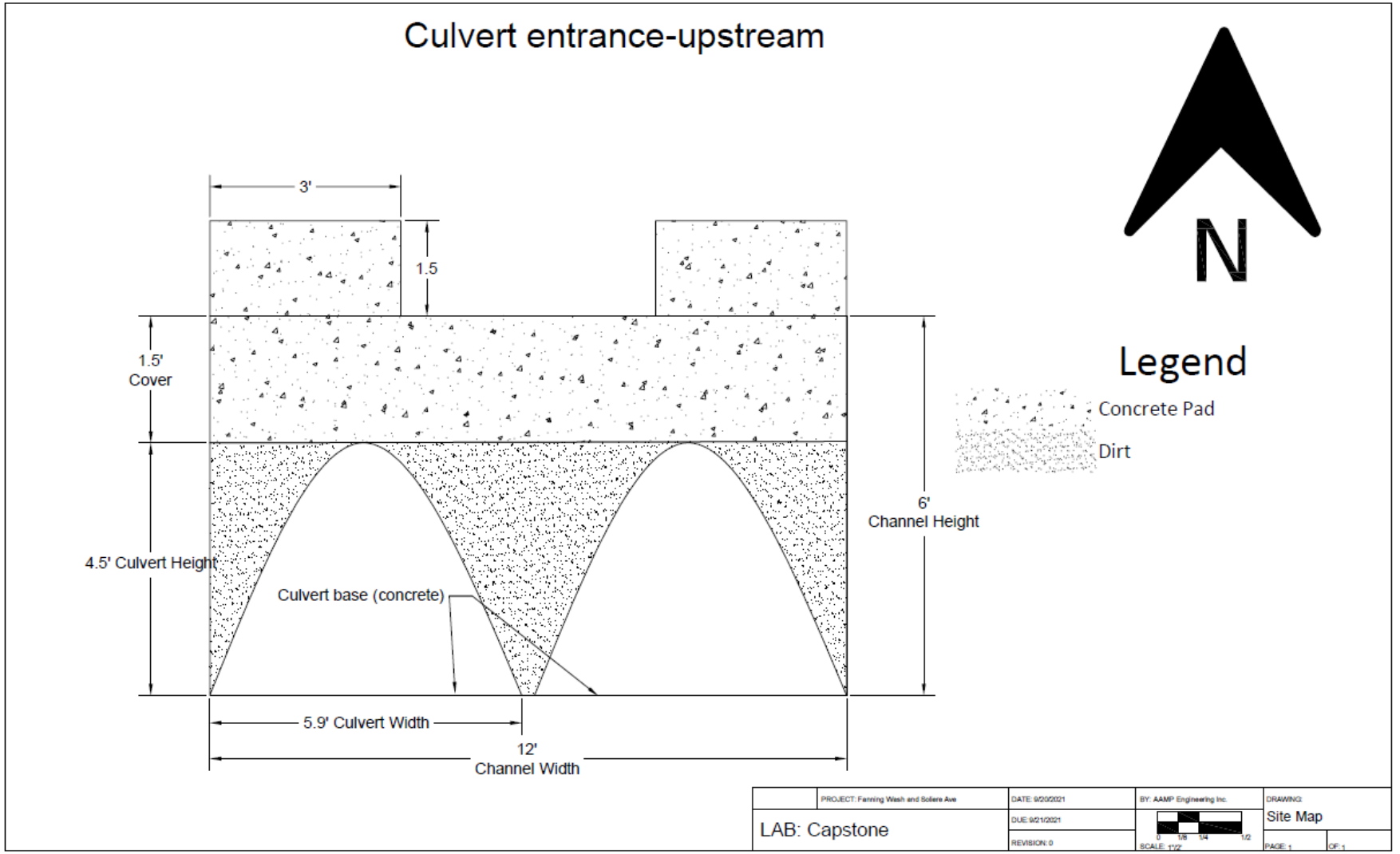

Figure 23: Culvert Entrance (Upstream)

Concrete Blocks Plan View

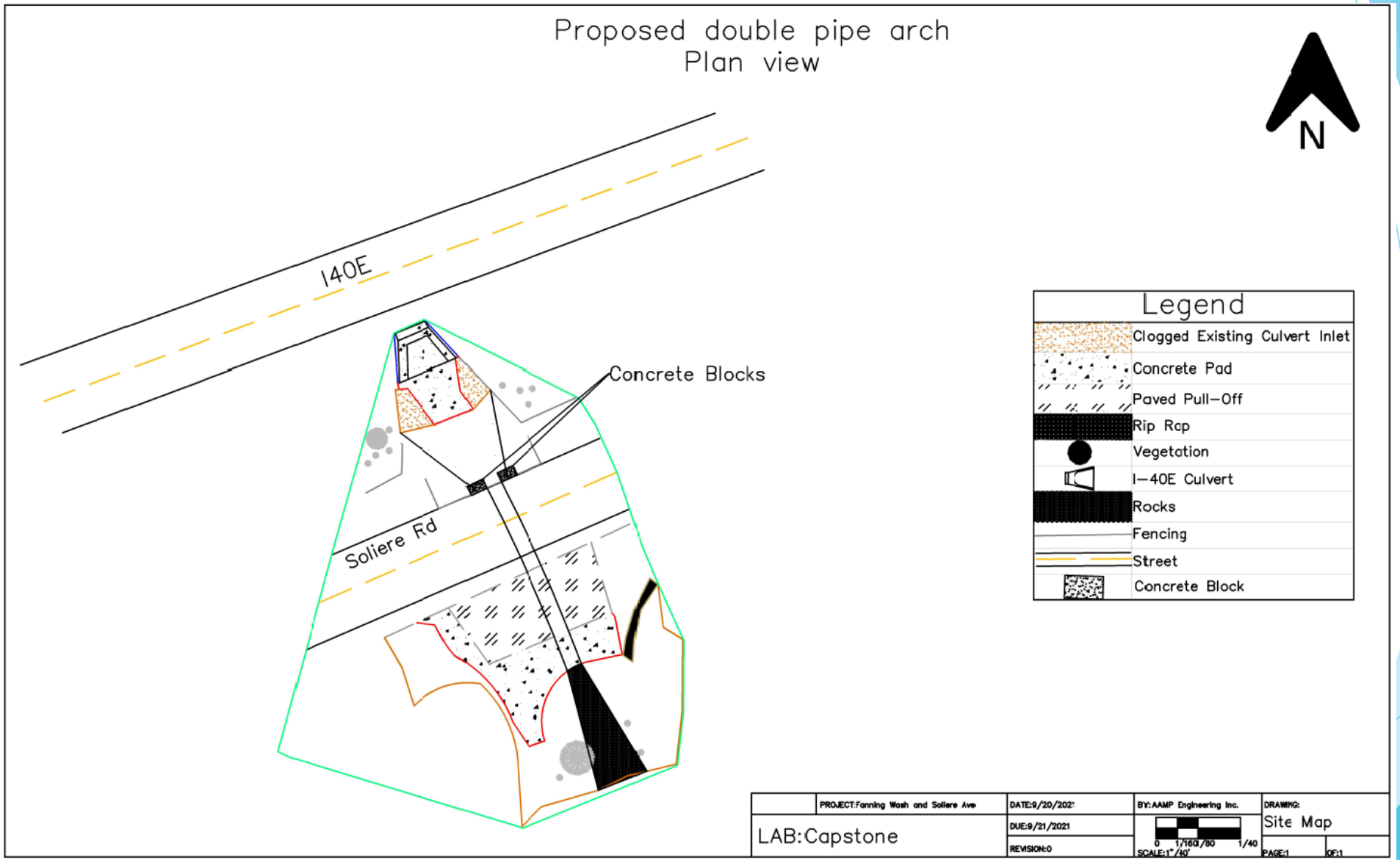

Figure 24: Plan View Concrete Blocks

Impacts (Short & Long-Term)

KEY: (P) = Positive and (N) = Negative

Type of Impact	Long-Term (N)	Long-Term (P)	Short-Term (N)	Short-Term (P)
Economic	Flagstaff Stormwater Annual Cost	Land or Property Value Increase	Construction Time and Roadway Interference	Maintenance & Implementation Costs
Environmental	Long-Term Concrete Use	Erosion Reduction	Construction and Wildlife Conflicts	Reduce loose soil & carcinogens
Social	Crowding & Congested Traffic	Public Faith in Flagstaff Companies Public Emotions for Trash Issue	Construction Noise	Commerical & Shopping Increase Road Safety

Table 10: Impacts (Short-Term & Long-Term)

Construction Cost Estimate

Construction Costs						
	Item	Description	Plan QTY	Unit	Unit Price ($)	Amount ($)
Excavation	1	Removal & Dispose of Asphalt	616	SF	15.00	9,240.00
	2	Removal of Existing Culvert	85	LF	25.00	2,125.00
	3	Remove & Disposal of Soil	490	CY	125.00	61,250.00
	4	Remove & Disposal of Concrete	154	SF	14.00	2,156.00
Installation	5	Subgrade Preparation	173.90	SF	6.00	1,043.40
	6	Concrete Channel Walls	659.82	SF	35.00	23,093.70
	7	Concrete Blocks	13.5	SF	30.00	405.00
	8	Channel Bottom Concrete	396.95	SF	7.50	2,977.13
	9 (a)	Premade Arch CMP 5.9' x 4.5'	85	LF	300.00	25,500.00
	9 (b)	Premade Arch CMP 5.9' x 4.5'	85	LF	300.00	25,500.00
	10	Culvert Concrete Pad	850	SF	8.50	7,225.00
	11	Structural Fill	88.75	CY	120.00	10,650.00
	12	Riprap (Dumped)	75	CY	200.00	15,000.00
Roadway Structures	13	Paving	350	SY	31.00	10,850.00
	14	Safety Rail (3'x6' height)	26	LF	62.00	1,612.00
					Total Cost	198,627.23

Table 11: Construction Cost Estimation [6] & [7]

References

- [1] “Title 13: Engineering Design Standards and Specifications for New Infrastructure,” *Flagstaff Municipal Code*. [Online]. Available: https://www.codepublishing.com/AZ/Flagstaff/. [Accessed: Sep-2021].
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- [6] “Construction Cost Estimation Tool,” *Gordian*. [Online]. Available: https://www.rsmeansonline.com/ManageEstimate. [Accessed: 02-Dec-2021].
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