Technical Memorandum
Preliminary Hydraulic Analysis and Design of STRUCTURE P-19-G_Minor REPLACEMENT
As a part of the
REGION TWO BRIDGE BUNDLE PACKAGE
Las Animas COUNTY, COLORADO

A Part of Section 6, Township 33 South, Range 63 West of the 6th P.M.,
County of Las Animas, Colorado

February 5, 2021

Prepared for:

Colorado Department of Transportation
Region 2
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Pueblo, CO 81008

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1. INTRODUCTION

1.1 Background and Purpose

The objective of Colorado Department of Transportation (CDOT) Region 2 Bridge Bundle Design Build project is to replace nineteen (19) rural structures spread across highway corridors in southern and western Colorado. The structures are located on US 350, US 24, CO 9, and CO 239. The role of Stanley Consultants is to assist CDOT in the design build procurement, geotechnical engineering, environmental clearances, survey, utility location and coordination, hydrology and hydraulics, preliminary structural design and roadway design.

This design build project is partially funded by the USDOT FHWA Competitive Highway Bridge Program grant (14 structures, project number 23558) and funds from the Colorado Bridge Enterprise (5 additional structures, project number 23559). These projects are combined to form one design-build project.

The nineteen bridges identified to be included in the 'Region 2 Bridge Bundle' were selected based on similarities in the bridge conditions, risk factors, site characteristics, and probable replacement type, with the goal of achieving economy of scale. Seventeen of the bridges being replaced are at least 80 years old. Five of the bridges are Load Restricted limiting trucking routes through major sections of the US 24 and US 350 corridors. The bundle is comprised of nine timber bridges, four concrete box culverts, one corrugated metal pipe (CMP), four concrete I-beam bridges, and one I-beam bridge with corrugated metal deck.

1.2 Site Description

The purpose of this report is to document the preliminary hydraulic analysis and design for the replacement of Structure P-19-G_Minor as a part of the CDOT Region 2 Bridge Bundle Design Build. The project is located within Las Animas County at Mile Post 1.74 along State Highway (SH) 239, north of Trinidad, Colorado. Structure P-19-G_Minor crosses over the Picketwire Ditch. Figure 1 below illustrates the project location. The project is located in Section 6, Township 33 South, Range 63 West of the 6th P.M., County of Otero, Colorado. **Figure 1** shows the project limits.

The report will document preliminary hydrology, hydraulic, and scour analysis/outlet protection to support the proposed structure replacement design.

Figure 1: Vicinity Map

2. EXISTING CONDITIONS

2.1 Existing Structure

The existing structure is a single span asphalt deck on metal decking, steel I beam girder bridge built in 1932 to span the Picketwire Canal. The bridge is on a tangent. The existing bridge has a span of 20'-0" and total bridge length of 22'-8". The width of the existing bridge is 31'-0" out to out of deck. The existing vertical clearance is approximately 5'-0".

2.2 Existing Ditch

Structure P-19-G_Minor spans over the Picketwire Ditch. This ditch carries irrigation flows to downstream farms customers, pulling water from the Purgatoire River from the south, in Trinidad. Irrigation water under the bridge goes from east to west. The existing ditch runs close to perpendicular to SH 239 as it flows under the bridge.

Initial discussions with the ditch company were performed to coordinate the design and determine decreed flows and document times of operation. Approximate capacity of the ditch as provided by the ditch company is 125 to 150 cfs. For preliminary analysis 150 cfs was used. Decreed flows will need to be documented in later phases of the design.

The Picketwire Ditch conveys irrigation water between April 1 through October 15 yearly. Stock water is also run through the ditch occasionally in the winter months. Construction schedule must be coordinated with the ditch company.

2.3 Site Investigation

A site investigation by Stanley Consultants in August 2020 was performed to gain an understanding of the key hydraulic conditions of the ditch and to investigate the condition of the existing bridge. Site photos are included in **Appendix A**.

3. HYDRAULIC ANALYSIS

A hydraulic model was developed using the Hydrologic Engineering Center River Analysis System (HEC-RAS), version 5.0.7, a software developed by the U.S. Army Corps of Engineers (USACE). The model was run as a steady state flow model with the estimated decreed flow of 150 cfs. For this analysis, three models were developed:

- Existing Conditions
- Proposed Conditions: Bridge Replacement
- Proposed Conditions: Box Culvert Replacement

3.1 Freeboard

The CDOT Drainage Design Manual (2019) specifies freeboard requirements for all bridges. Freeboard is the minimum clearance between the design approach WSE and the low chord of the bridge. It is a factor of safety that acts as a buffer to account for unknown factors that could increase the height of the calculated WSE. The elevation of the water surface 50 to 100 feet upstream of the face of the bridge shall be the elevation to which the freeboard is added to get the bottom or low-girder elevation of the bridge.

The channel was not identified as having a high potential for debris production. Therefore, if a bridge is selected for the proposed conveyance structure, 2 feet of freeboard would typically be required. However, the existing decreed flow WSE provides less than 2 feet of freeboard. Due to economic and site constraints, it is not feasible to raise the bridge to provide 2 feet of freeboard. The proposed preliminary bridge design option does not reduce the freeboard from the existing condition.

3.2 Modeling Parameters

3.2.1 Elevation Data

Existing conditions survey for the bridge and channel cross sections was performed by CDOT in June, 2020. This data source was used for the modeling elevation surface.

A local, custom projection was used for the data collection in the existing conditions survey. All elevations are referenced to NAVD 88 (feet).

3.2.2 Cross Sections

13 cross sections were added to the model spaced between 20 and 90 feet apart along the ditch channel. 6 were plotted upstream (southeast) of the bridge, and 7 were placed downstream (west).

3.2.3 Surface Roughness

A Manning's n-value was assigned to the channel, left, and right overbanks. These were defined based on aerial imagery, topography, a site visit in August, 2020, and engineering judgment. An n-value of 0.035 was used for the channel, left and right overbanks. Design flows are contained within the main channel. Photos from the site visit used to confirm the n-values selected are shown in **Appendix A**.

3.2.4 Hydraulic Structures

The modeled existing bridge geometry is based on the survey completed in August 2020 and as-built information. The bridge slopes down gradient from south to north. The high chord of the bridge is 5969.9 feet at the south abutment and 5969.6 feet at the north abutment.
With a superstructure depth of 24.5 inches, the low chord is approximately 5967.9 feet at the south abutment and approximately 5967.6 feet at the north abutment.

3.3 Model Results

3.3.1 Existing Conditions

The existing condition model shows that flows within the channel are maintained at approximately 4.2 feet of depth. The existing WSE is 5967.00 at the cross section just upstream of the bridge, which is 0.58 feet of freeboard below the low chord of the bridge. Existing conditions WSEs are shown in **Appendix B**.

3.3.2 Alternatives Analysis

An alternatives/risk analysis was completed in the preliminary design process to determine the most feasible options for the hydraulic conveyance structure. Both a bridge and reinforced concrete box culvert (RCBC) option were analyzed. Many factors were taken into consideration when determining the preferred alternative for this preliminary analysis. These factors included cost, constructability, effects on the ditch hydraulics, and environmental impacts among others.

Proposed RCBC

This option was modeled using the same HEC-RAS model as was used for the existing conditions. Modifications to the model included implementing a proposed RCBC that has a 16-foot width and a 4-foot height. This culvert was modeled with a 46-foot length. The inlet of the culvert was modeled with flared wingwalls with a 0.4 entrance loss coefficient. The inverts of the box culvert were set at the thalweg of the channel which set the longitudinal slope of the culvert at 0.03%. The preliminary model shows the roadway embankment sloping at 3:1.

The proposed RCBC model shows the depth of flow in the channel to remain the same as existing upstream and downstream of the bridge, with slight changes to the WSEs at the RCBC. The WSE at the upstream cross section is 5966.97 feet. This is 0.03 feet lower than existing. This condition provides 0.2 feet of freeboard. See **Appendix C** for WSE comparison tables and HEC-RAS cross sections for the proposed RCBC alternative.

Proposed Bridge

This option was modeled using the same HEC-RAS model as was used for the existing conditions. The proposed bridge is a single-span 25-ft long structure. Modifications to the model included changing the superstructure depth to 30 inches. The deck of the proposed

bridge is modeled at the same elevation as the existing structure. The abutment locations are also modeled the same as the existing structure.

The proposed bridge model shows the depth of flow in the channel to remain the same as existing upstream and downstream of the bridge. The WSE at the upstream cross section is 5967.00 feet. This matches existing. This condition provides 0.12 feet of freeboard. See **Appendix D** for WSE comparison tables and HEC-RAS cross sections for the proposed bridge alternative.

Preferred Alternative

Because of the decrease in freeboard the preferred alternative for the replacement of the existing bridge is the RCBC.

4. RCBC OUTLET ENERGY DISSIPATION

The design procedure recommended in section 11.4 of the DDM was followed for outlet protection and energy dissipation at the outlet of the box culvert. All hydraulic data from the proposed culvert was gathered including height, width, length, slope, etc. The culvert control was determined, and outlet depth, velocity and Froude number was determined. To determine tailwater data, the downstream channel information was gathered from the survey data and field inspection.

Allowable scour estimation was completed using HY-8. Soil parameters of the downstream channel were extracted from the geotechnical investigation. The estimated scour hole was then determined using HY-8. The estimated scour hole for this culvert was very small given the low velocity in the channel. Because of this result, no energy dissipation is required for the RCBC outlet. See **Appendix G** for geotechnical information and **Appendix F** for outlet protection analysis.

5. CONCLUSIONS

This report presents preliminary analysis and results from the hydraulic study for the Region 2 Bridge Bundle Design Build – Bridge P-19-G_Minor. This report documents preliminary analysis in determining costs for proposed structure replacement at this location.

A HEC-RAS model was developed to analyze the flows through the existing bridge and compare the WSEs and velocities to the proposed design. This model was utilized to optimize the proposed solution for the replacement of the existing bridge.

Based on the hydraulic analysis, the proposed replacement for this bridge is a 16-foot(width) by 4-foot(height) reinforced concrete box culvert (RCBC). The proposed freeboard is 0.2 feet and the proposed WSE upstream of the proposed bridge is 5966.97 feet. The proposed RCBC decreases the WSE at the entrance to the culvert.

6. REFERENCES

1. "Colorado Department of Transportation Drainage Design Manual", Colorado Department of Transportation, 2019.
2. Mile High Flood District, Urban Storm Drainage Criteria Manual (USDCM), Volumes I, II, and III, August 2018.
3. "Hydraulic Engineering Circular No. 18 – Evaluating Scour At Bridges Fifth Edition". U.S. Department of Transportation Federal Highway Administration, April 2012.
4. "Hydraulic Engineering Circular No. 20 – Stream Stability at Highway Structures". U.S. Department of Transportation Federal Highway Administration, April 2012.
5. "Hydraulic Engineering Circular No. 23 – Bridge Scour and Stream Instability Countermeasures: Experience, Selection, and Design Guidance – Third Edition," U.S. Department of Transportation, Federal Highway Administration, September 2009.
6. CDOT Region 2 2D Quick Check Hydrology Summary Report and Matrix, Colorado Department of Transportation, 2020.

APPENDIX A PHOTOS

PHOTO 1: DOWNSTREAM OF BRIDGE
STRUCTURE P-19-G_MINOR
APPENDIX A

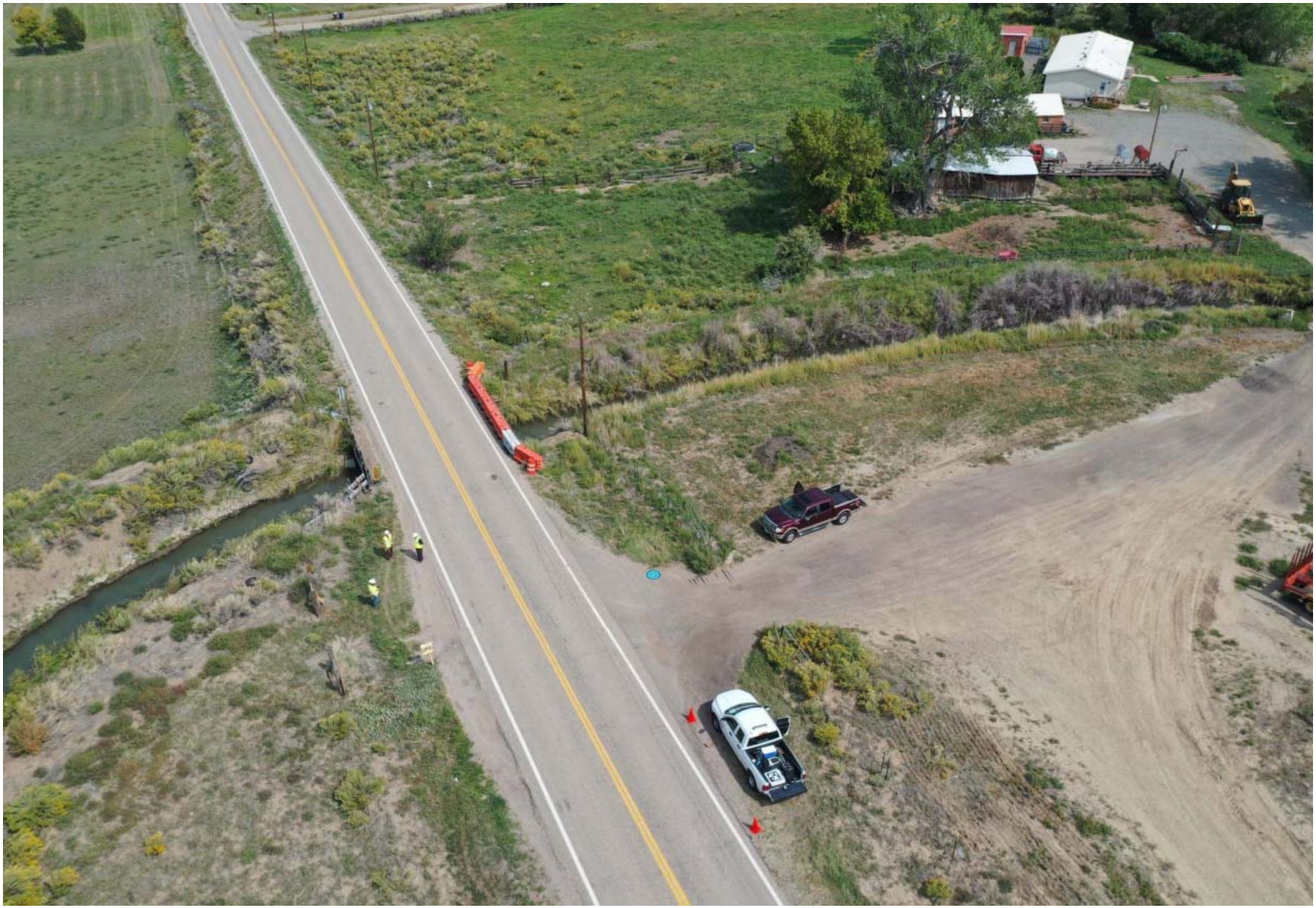


PHOTO 2: AERIAL OF BRIDGE
STRUCTURE P-19-G_MINOR
APPENDIX A

PHOTO 3: BRIDGE AND DITCH LOOKING (EAST)

STRUCTURE P-19-G_MINOR

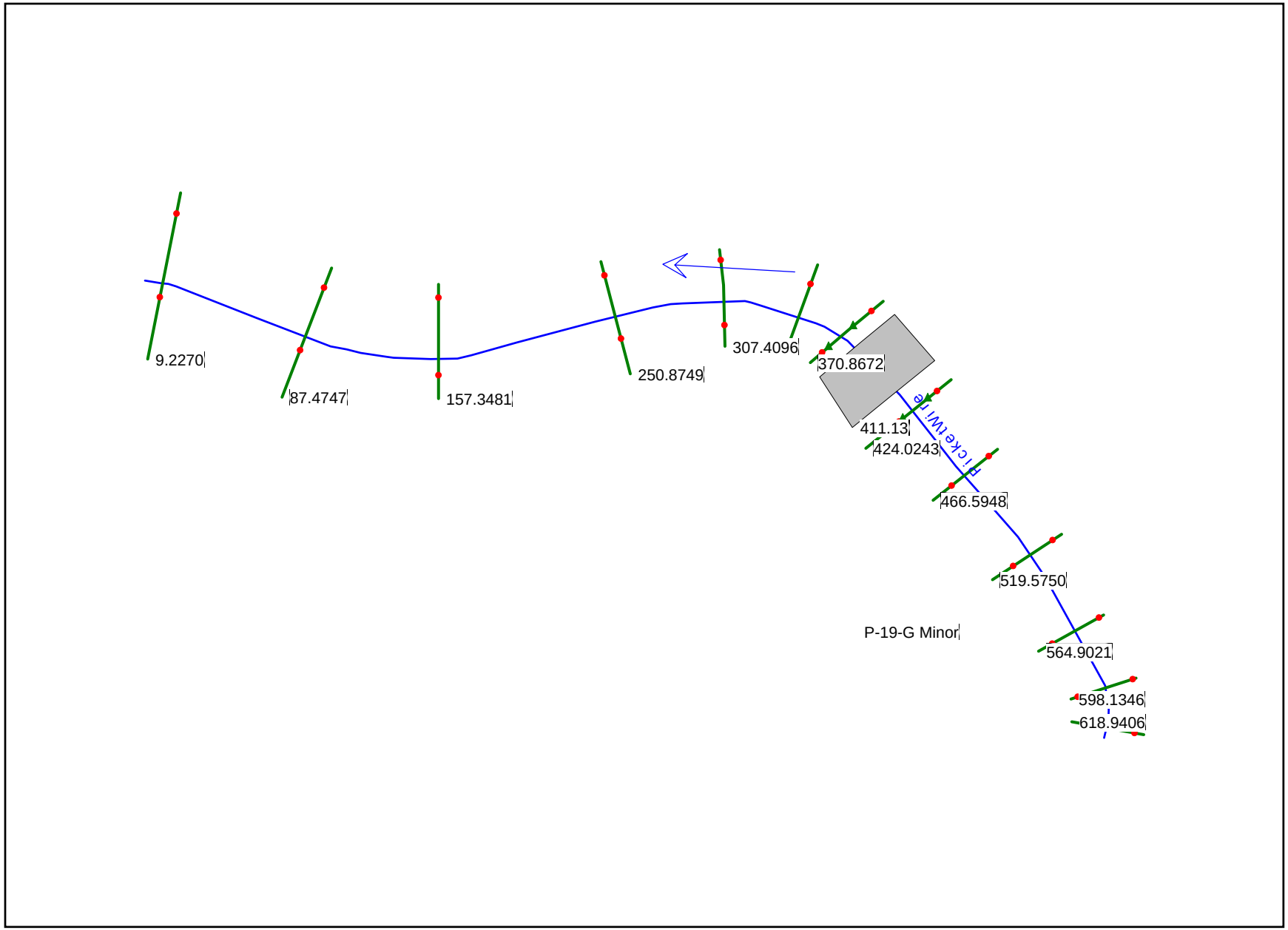
APPENDIX A

PHOTO 4: CHANNEL DOWNSTREAM (LOOKING WEST)

STRUCTURE P-19-G_MINOR

APPENDIX A

APPENDIX B EXISTING CONDITIONS ANALYSIS GRAPHICS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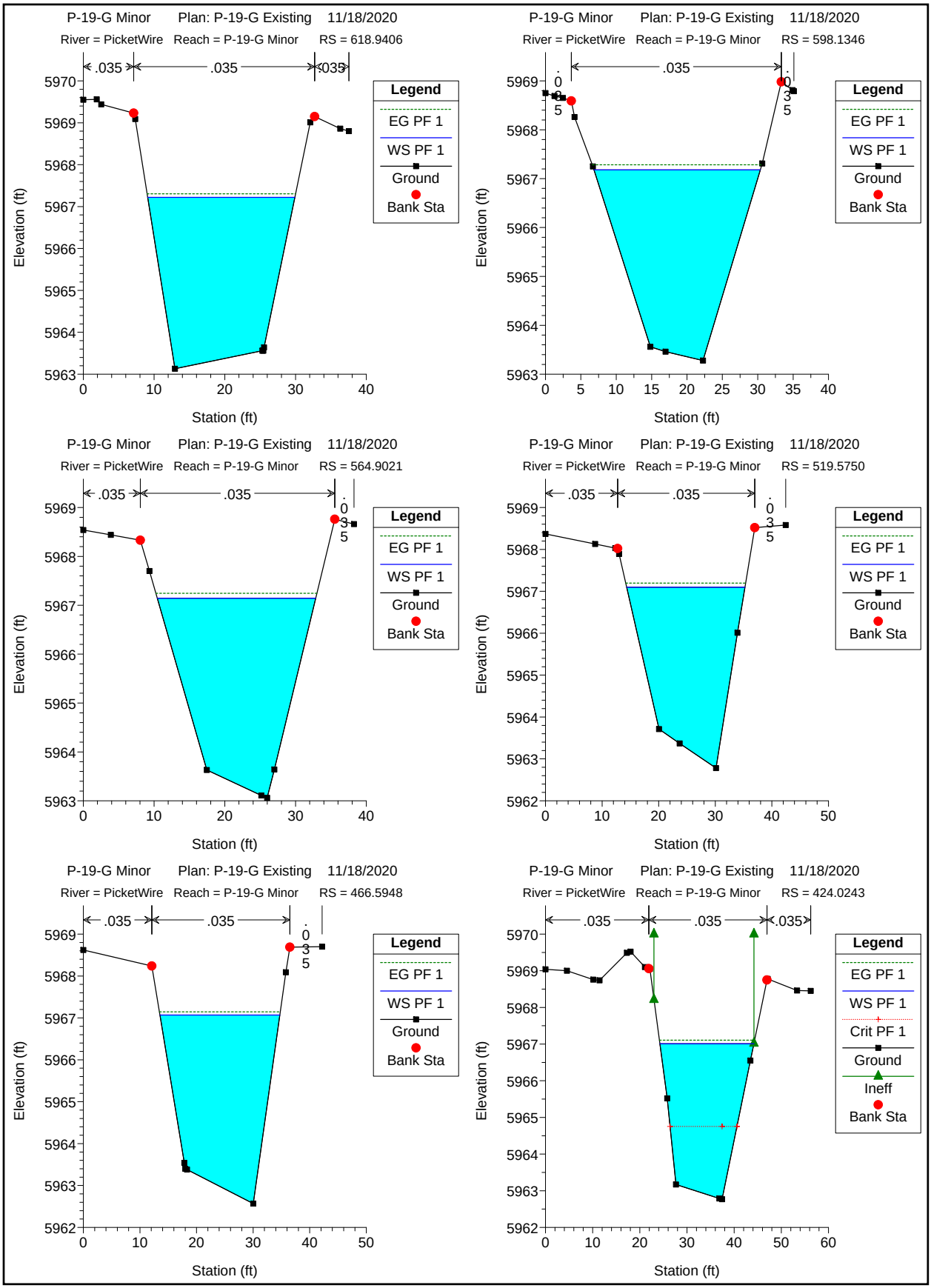
P-19-G Minor

HEC-RAS Plan: Existing River: PicketWire Reach: P-19-G Minor Profile: PF 1

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
P-19-G Minor	618.9406	PF 1	150.00	5963.13	5967.22		5967.30	0.000801	2.33	64.44	20.80	0.23
P-19-G Minor	598.1346	PF 1	150.00	5963.28	5967.18		5967.28	0.001202	2.57	58.27	23.51	0.29
P-19-G Minor	564.9021	PF 1	150.00	5963.06	5967.14		5967.24	0.001115	2.55	58.82	22.40	0.28
P-19-G Minor	519.5750	PF 1	150.00	5962.78	5967.10		5967.20	0.001023	2.52	59.42	20.90	0.26
P-19-G Minor	466.5948	PF 1	150.00	5962.57	5967.07		5967.14	0.000693	2.21	67.77	21.17	0.22
P-19-G Minor	424.0243	PF 1	150.00	5962.77	5967.01	5964.76	5967.11	0.000965	2.50	59.91	19.93	0.25
P-19-G Minor	411.13		Bridge									
P-19-G Minor	370.8672	PF 1	150.00	5963.16	5966.94	5964.96	5967.04	0.001027	2.64	56.90	23.99	0.28
P-19-G Minor	346.8917	PF 1	150.00	5962.81	5966.90		5967.01	0.001361	2.71	55.28	21.48	0.30
P-19-G Minor	307.4096	PF 1	150.00	5962.18	5966.87		5966.96	0.001084	2.46	61.05	22.95	0.27
P-19-G Minor	250.8749	PF 1	150.00	5962.45	5966.80		5966.90	0.001124	2.44	61.37	24.33	0.27
P-19-G Minor	157.3481	PF 1	150.00	5963.03	5966.65		5966.77	0.001529	2.77	54.20	22.91	0.32
P-19-G Minor	87.4747	PF 1	150.00	5963.08	5966.52		5966.66	0.001666	2.94	50.96	20.49	0.33
P-19-G Minor	9.2270	PF 1	150.00	5962.97	5966.48	5964.50	5966.55	0.000801	2.11	71.15	29.16	0.24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River = PicketWire Reach = P-19-G Minor RS = 466.5948
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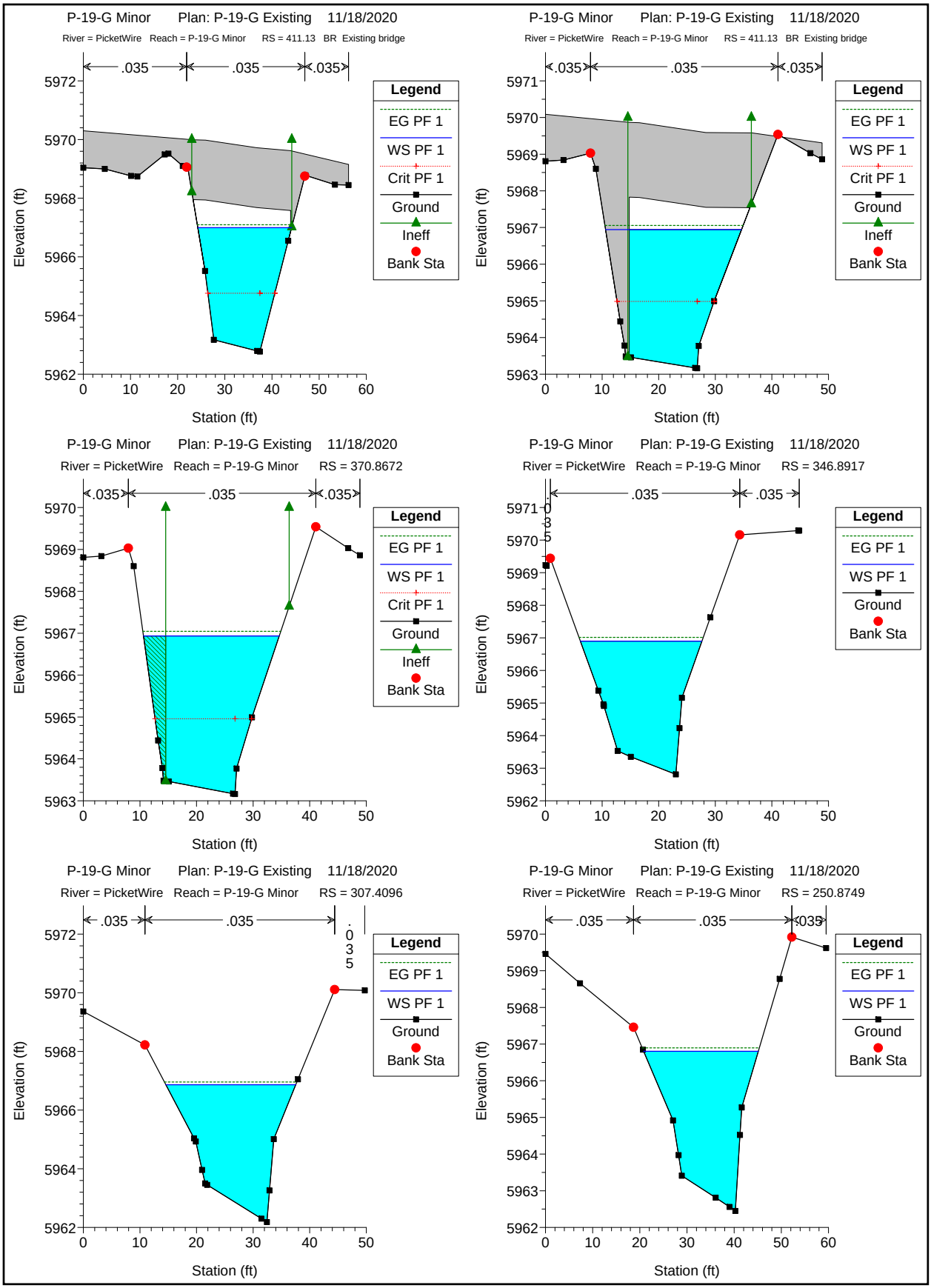
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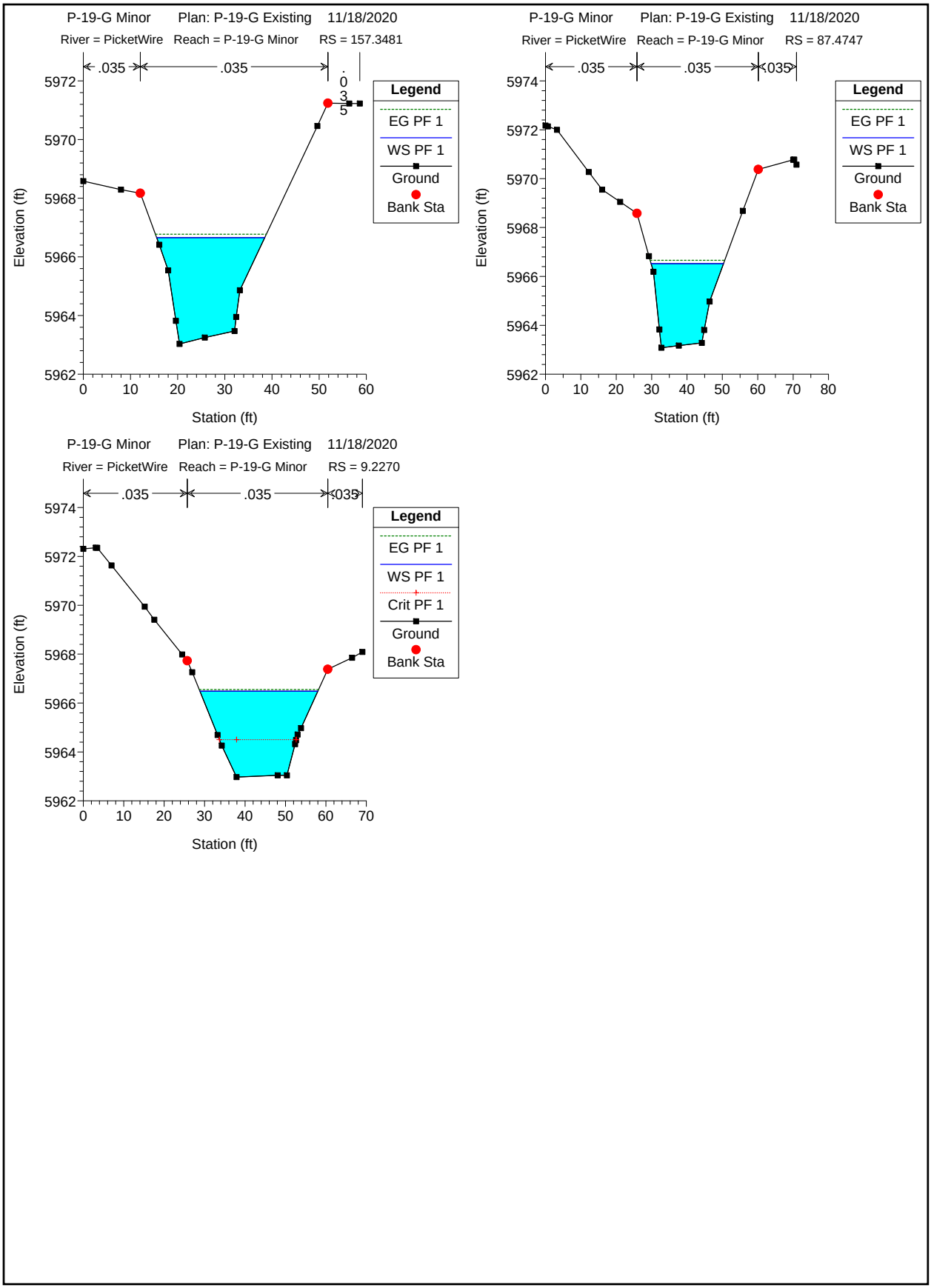
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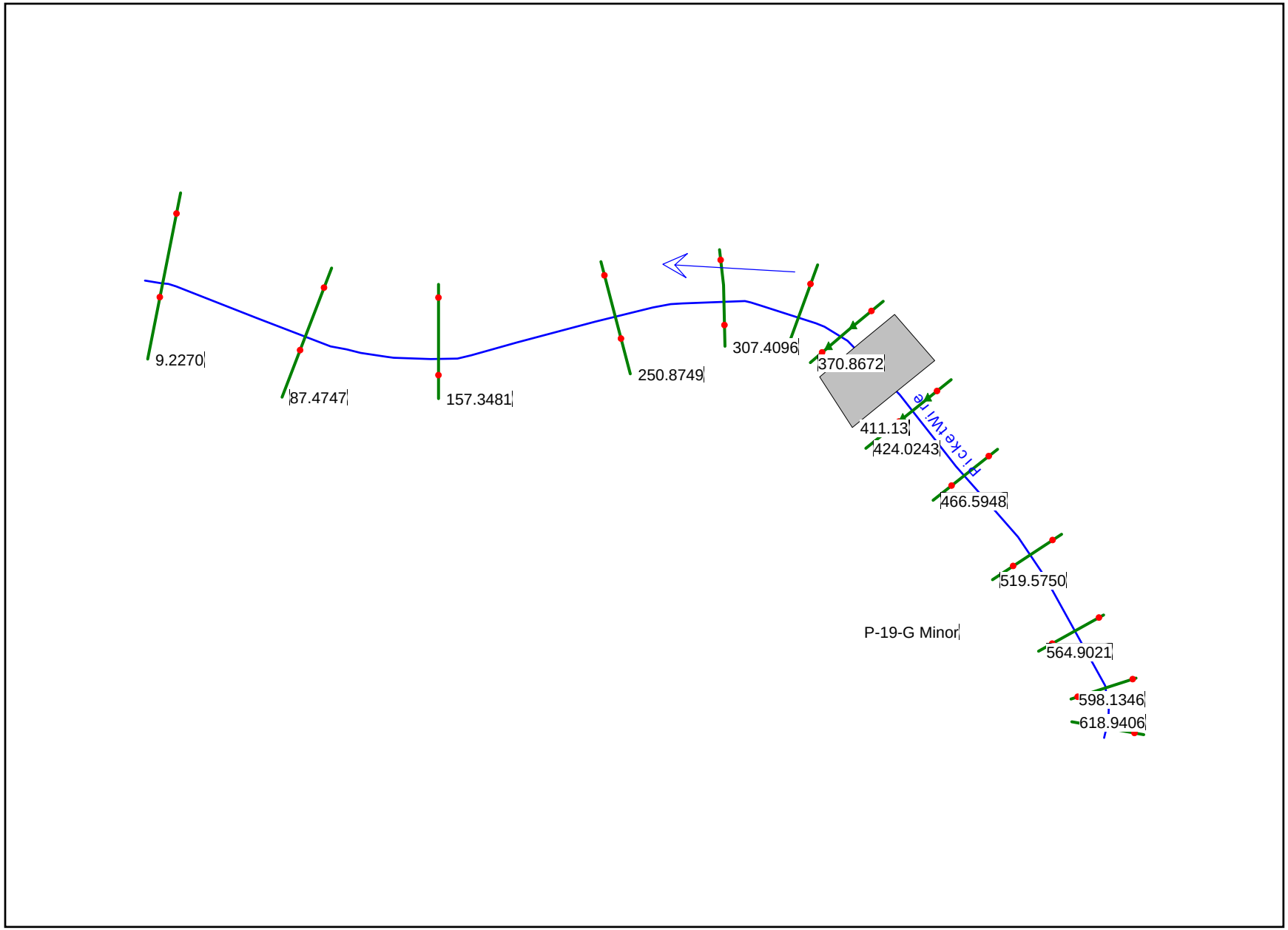
APPENDIX C PROPOSED RCBC ALTERNATIVE ANALYSIS GRAPHICS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564.9021
598.1346
618.9406
P-19-G Minor

HEC-RAS Plan: Proposed 16x4 River: PicketWire Reach: P-19-G Minor Profile: PF 1

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
P-19-G Minor	618.9406	PF 1	150.00	5963.13	5967.20		5967.28	0.000818	2.35	63.95	20.75	0.24
P-19-G Minor	598.1346	PF 1	150.00	5963.28	5967.16		5967.26	0.001234	2.60	57.70	23.41	0.29
P-19-G Minor	564.9021	PF 1	150.00	5963.06	5967.12		5967.22	0.001144	2.58	58.25	22.31	0.28
P-19-G Minor	519.5750	PF 1	150.00	5962.78	5967.07		5967.17	0.001051	2.55	58.86	20.82	0.27
P-19-G Minor	466.5948	PF 1	150.00	5962.57	5967.04		5967.12	0.000710	2.23	67.19	21.11	0.22
P-19-G Minor	424.0243	PF 1	150.00	5962.77	5966.97	5964.76	5967.08	0.000951	2.70	55.63	19.82	0.26
P-19-G Minor	411.13		Culvert									
P-19-G Minor	370.8672	PF 1	150.00	5963.16	5966.93	5964.90	5967.04	0.000872	2.68	55.88	23.96	0.26
P-19-G Minor	346.8917	PF 1	150.00	5962.81	5966.90		5967.01	0.001361	2.71	55.28	21.48	0.30
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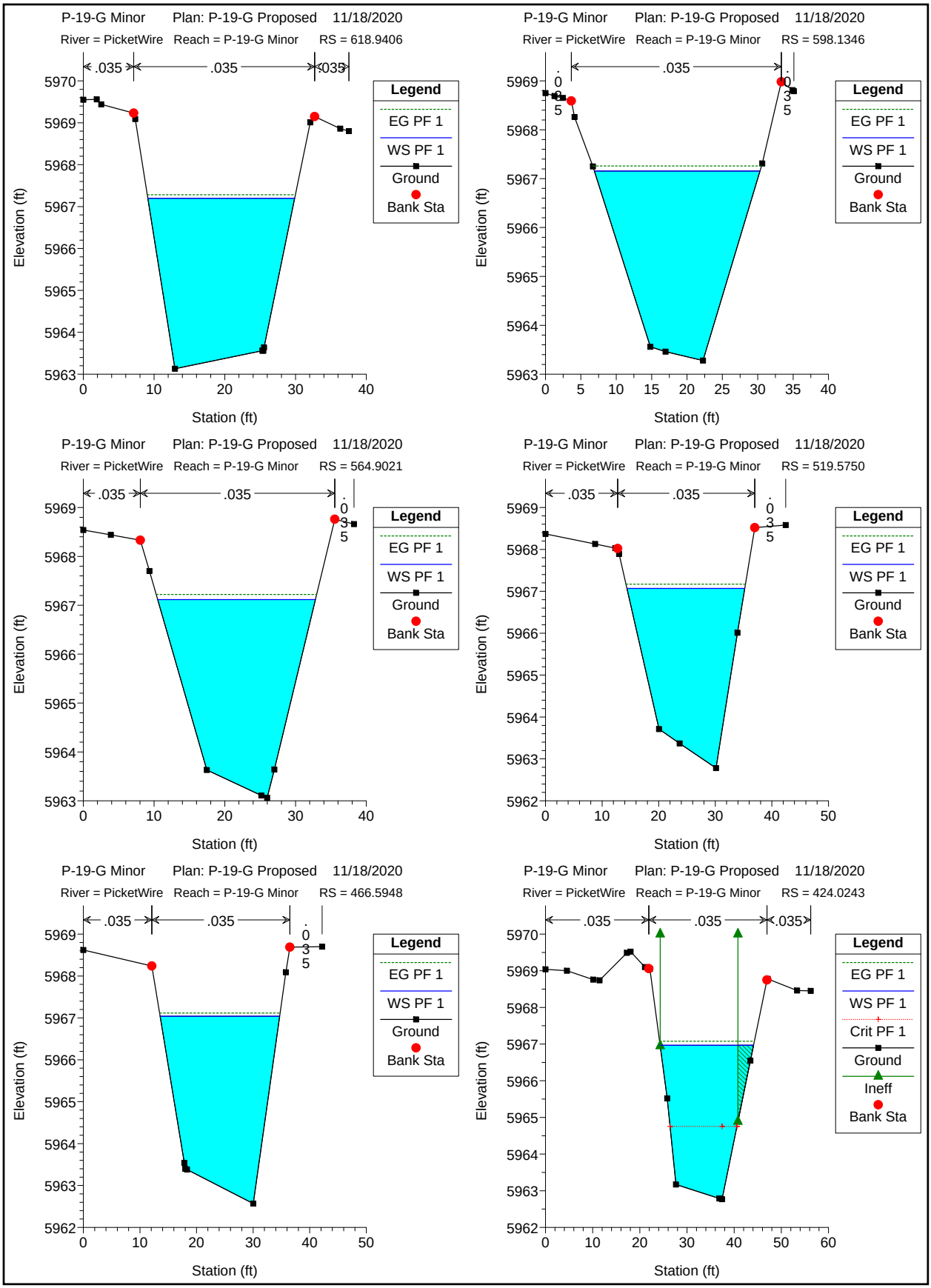
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River = PicketWire Reach = P-19-G Minor RS = 424.0243
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Legend
EG PF 1
WS PF 1
Crit PF 1
Ground
Ineff
Bank Sta
Elevation (ft)
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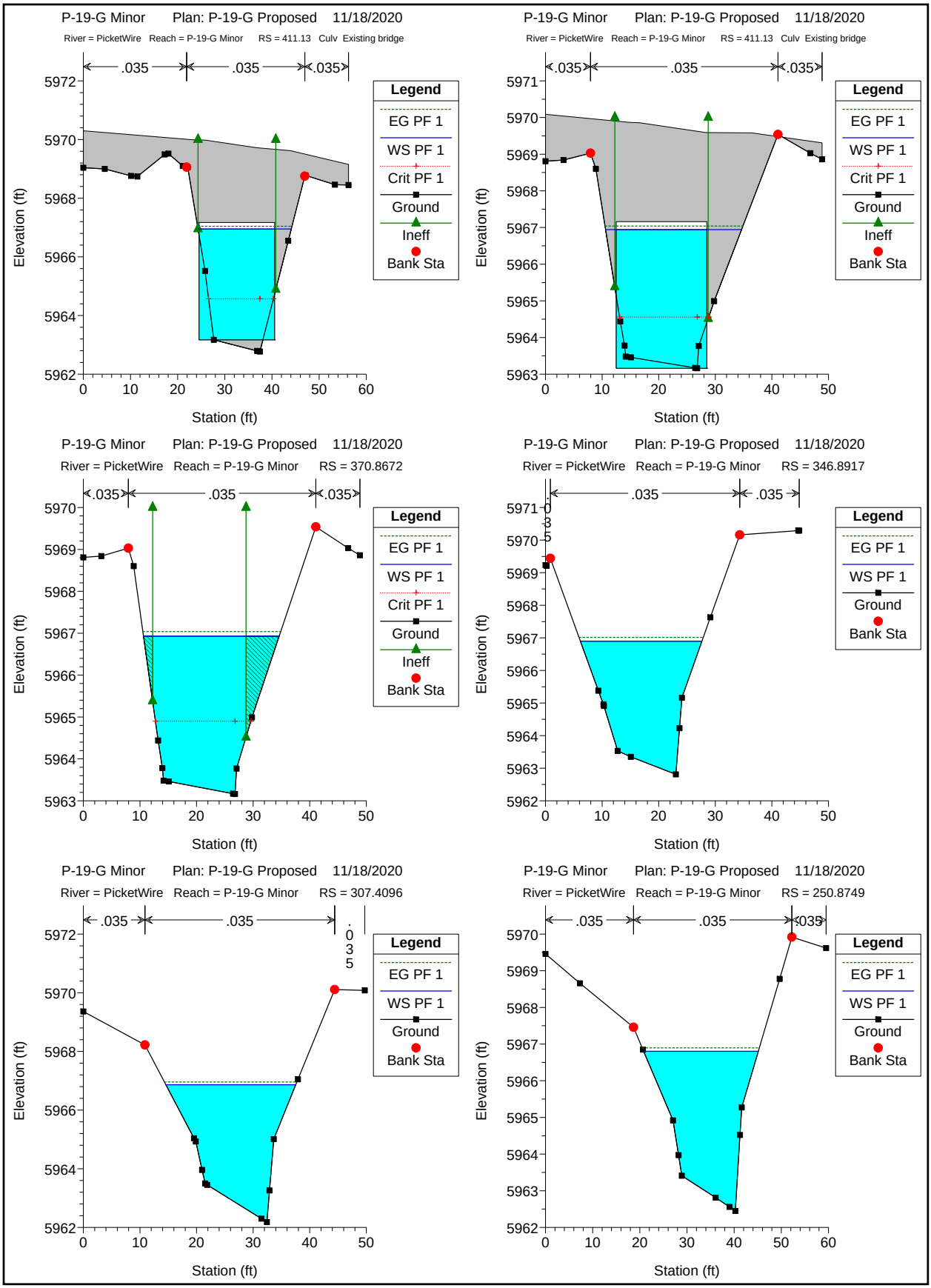
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Station (ft)
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River = PicketWire Reach = P-19-G Minor RS = 411.13 Culv Existing bridge
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Legend
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Crit PF 1
Ground
Ineff
Bank Sta
Elevation (ft)
Station (ft)
P-19-G Minor Plan: P-19-G Proposed 11/18/2020
River = PicketWire Reach = P-19-G Minor RS = 370.8672
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Legend
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WS PF 1
Crit PF 1
Ground
Ineff
Bank Sta
Elevation (ft)
Station (ft)
P-19-G Minor Plan: P-19-G Proposed 11/18/2020
River = PicketWire Reach = P-19-G Minor RS = 346.8917
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Legend
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WS PF 1
Ground
Bank Sta
Elevation (ft)
Station (ft)
P-19-G Minor Plan: P-19-G Proposed 11/18/2020
River = PicketWire Reach = P-19-G Minor RS = 307.4096
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Legend
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WS PF 1
Ground
Bank Sta
Elevation (ft)
Station (ft)
P-19-G Minor Plan: P-19-G Proposed 11/18/2020
River = PicketWire Reach = P-19-G Minor RS = 250.8749
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Legend
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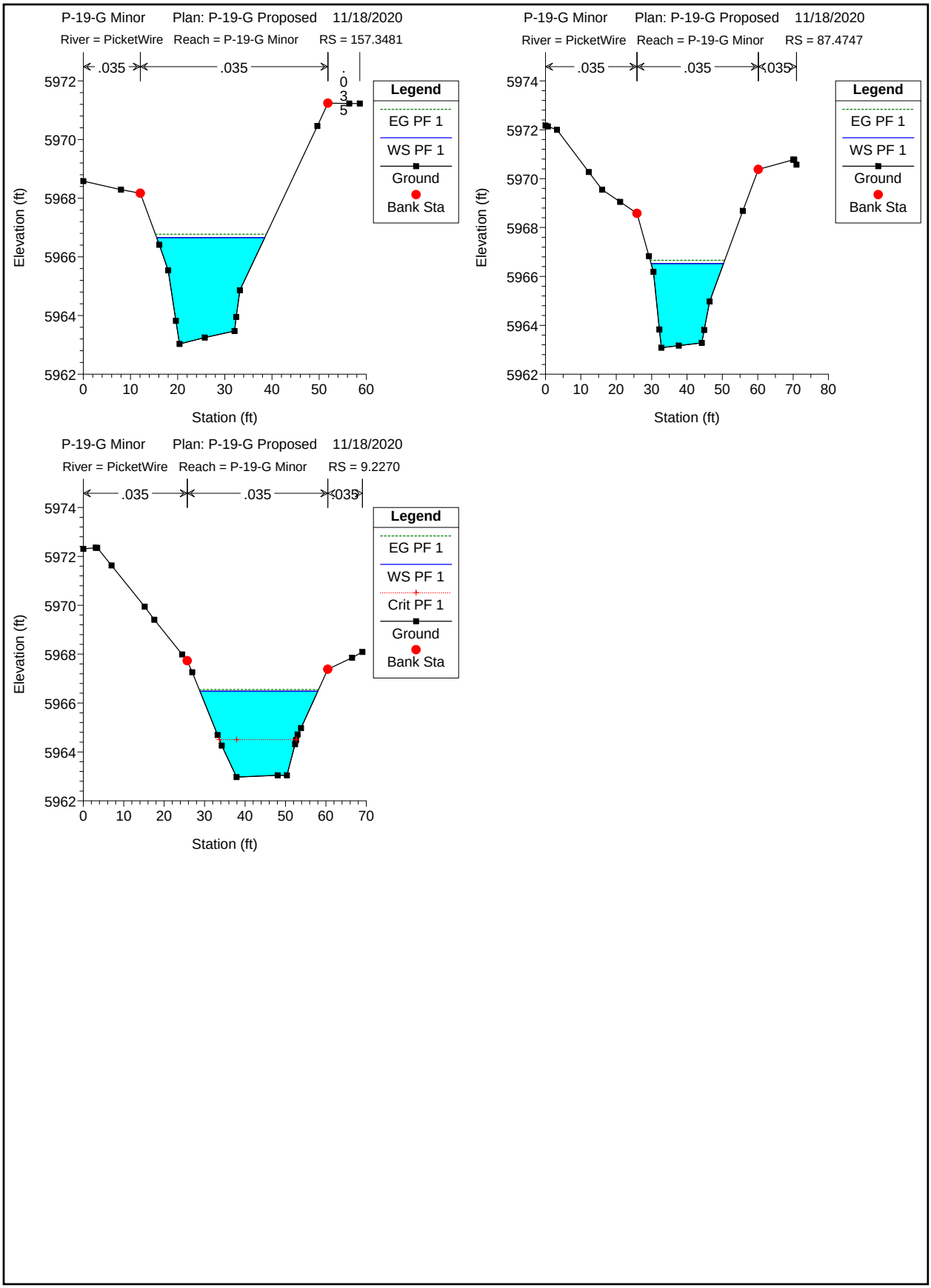
WS PF 1
Ground
Bank Sta
Elevation (ft)
Station (ft)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River = PicketWire Reach = P-19-G Minor RS = 157.3481
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EG PF 1
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Ground
Bank Sta
Elevation (ft)
Station (ft)
P-19-G Minor Plan: P-19-G Proposed 11/18/2020
River = PicketWire Reach = P-19-G Minor RS = 87.4747
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Legend
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WS PF 1
Ground
Bank Sta
Elevation (ft)
Station (ft)
P-19-G Minor Plan: P-19-G Proposed 11/18/2020
River = PicketWire Reach = P-19-G Minor RS = 9.2270
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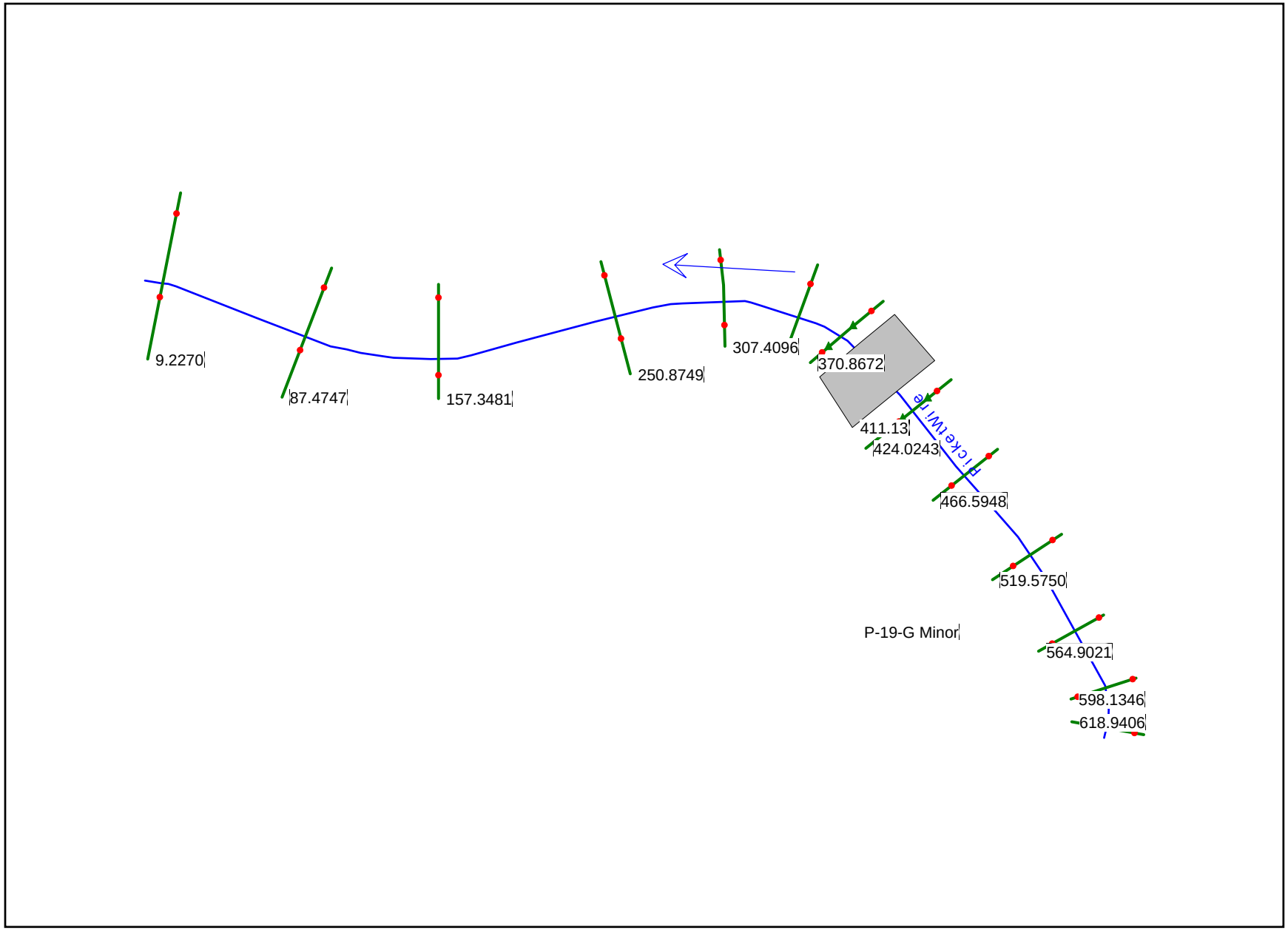
Legend
EG PF 1
WS PF 1
Crit PF 1
Ground
Bank Sta
Elevation (ft)
Station (ft)

APPENDIX D PROPOSED BRIDGE ALTERNATIVE ANALYSIS GRAPHICS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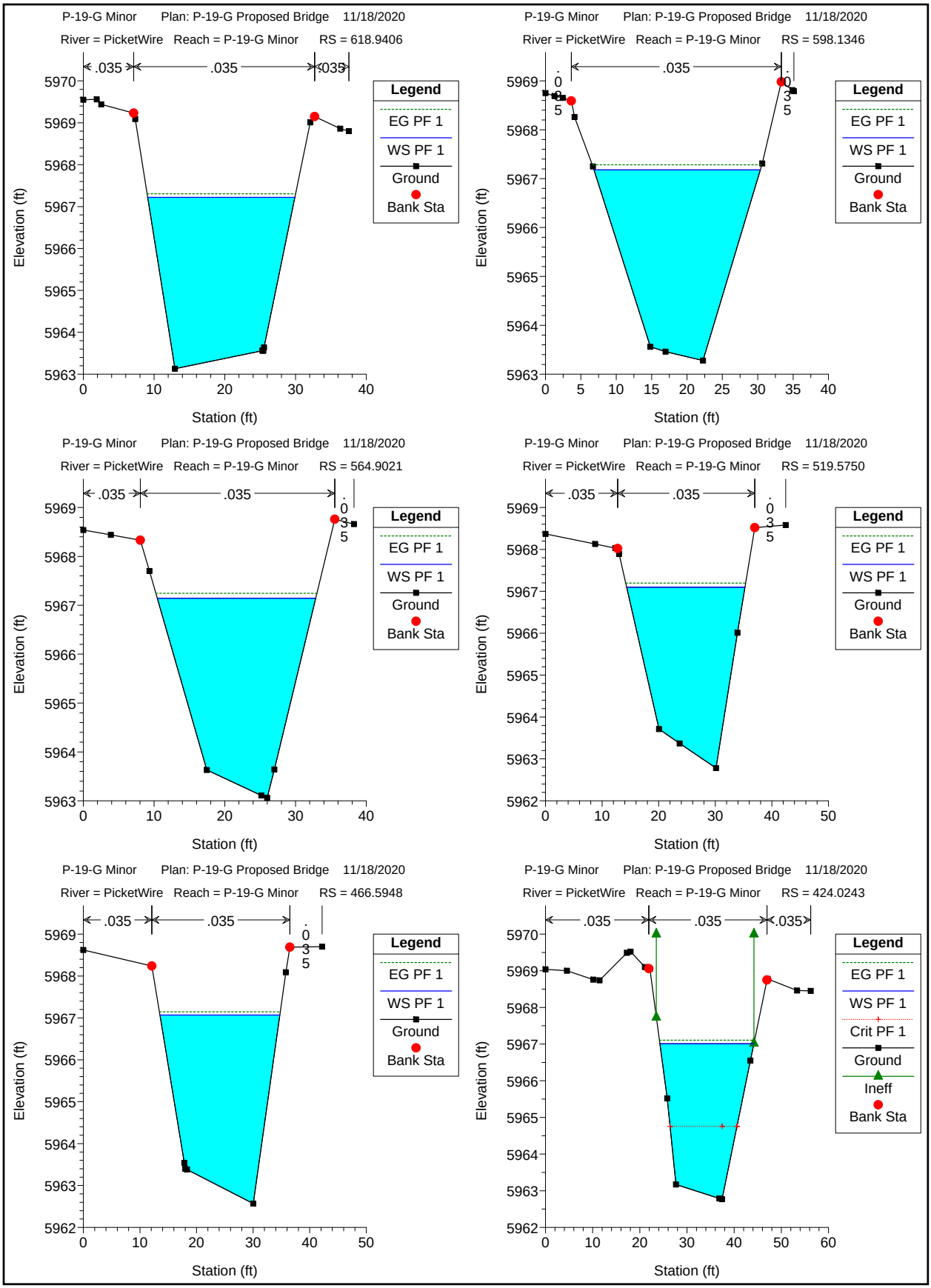
87.4747
157.3481
250.8749
307.4096
370.8672
411.13
424.0243
466.5948
519.5750
564.9021
598.1346
618.9406
P-19-G Minor

HEC-RAS Plan: Bridge River: PicketWire Reach: P-19-G Minor Profile: PF 1

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
P-19-G Minor	618.9406	PF 1	150.00	5963.13	5967.22		5967.30	0.000801	2.33	64.44	20.80	0.23
P-19-G Minor	598.1346	PF 1	150.00	5963.28	5967.18		5967.28	0.001202	2.57	58.27	23.51	0.29
P-19-G Minor	564.9021	PF 1	150.00	5963.06	5967.14		5967.24	0.001115	2.55	58.82	22.40	0.28
P-19-G Minor	519.5750	PF 1	150.00	5962.78	5967.10		5967.20	0.001023	2.52	59.42	20.90	0.26
P-19-G Minor	466.5948	PF 1	150.00	5962.57	5967.07		5967.14	0.000693	2.21	67.77	21.17	0.22
P-19-G Minor	424.0243	PF 1	150.00	5962.77	5967.01	5964.76	5967.11	0.000965	2.50	59.91	19.93	0.25
P-19-G Minor	411.13		Bridge									
P-19-G Minor	370.8672	PF 1	150.00	5963.16	5966.94	5964.96	5967.04	0.001027	2.64	56.90	23.99	0.28
P-19-G Minor	346.8917	PF 1	150.00	5962.81	5966.90		5967.01	0.001361	2.71	55.28	21.48	0.30
P-19-G Minor	307.4096	PF 1	150.00	5962.18	5966.87		5966.96	0.001084	2.46	61.05	22.95	0.27
P-19-G Minor	250.8749	PF 1	150.00	5962.45	5966.80		5966.90	0.001124	2.44	61.37	24.33	0.27
P-19-G Minor	157.3481	PF 1	150.00	5963.03	5966.65		5966.77	0.001529	2.77	54.20	22.91	0.32
P-19-G Minor	87.4747	PF 1	150.00	5963.08	5966.52		5966.66	0.001666	2.94	50.96	20.49	0.33
P-19-G Minor	9.2270	PF 1	150.00	5962.97	5966.48	5964.50	5966.55	0.000801	2.11	71.15	29.16	0.24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River = PicketWire Reach = P-19-G Minor RS = 618.9406
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EG PF 1
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Elevation (ft)
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P-19-G Minor Plan: P-19-G Proposed Bridge 11/18/2020
River = PicketWire Reach = P-19-G Minor RS = 598.1346
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Elevation (ft)
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P-19-G Minor Plan: P-19-G Proposed Bridge 11/18/2020
River = PicketWire Reach = P-19-G Minor RS = 564.9021
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Ground
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Elevation (ft)
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P-19-G Minor Plan: P-19-G Proposed Bridge 11/18/2020
River = PicketWire Reach = P-19-G Minor RS = 519.5750
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Ground
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Elevation (ft)
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River = PicketWire Reach = P-19-G Minor RS = 466.5948
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P-19-G Minor Plan: P-19-G Proposed Bridge 11/18/2020
River = PicketWire Reach = P-19-G Minor RS = 424.0243
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Crit PF 1
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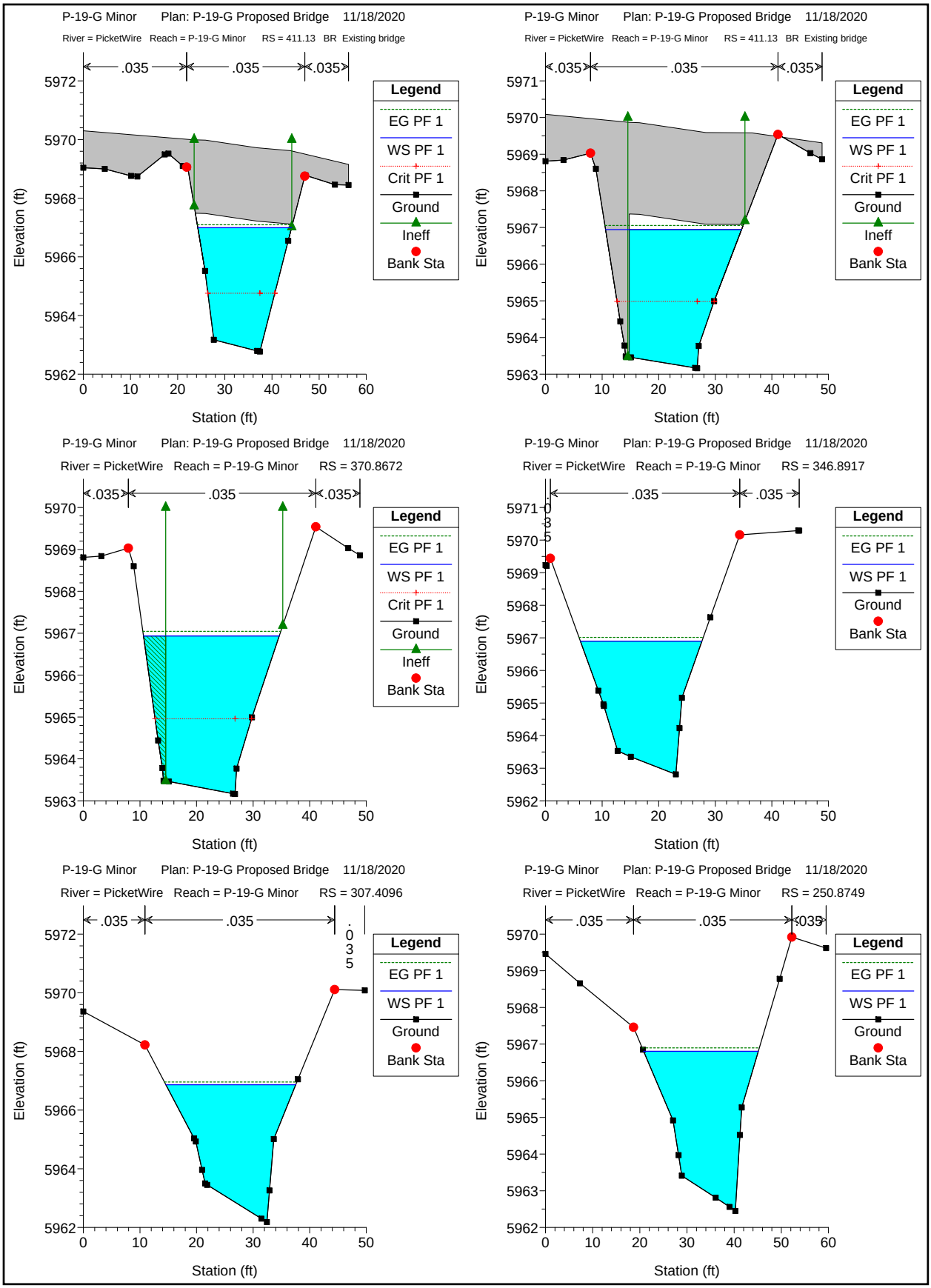
Station (ft)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Crit PF 1
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Ineff
Bank Sta
Elevation (ft)
Station (ft)
P-19-G Minor Plan: P-19-G Proposed Bridge 11/18/2020
River = PicketWire Reach = P-19-G Minor RS = 411.13 BR Existing bridge
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Ground
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Elevation (ft)
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P-19-G Minor Plan: P-19-G Proposed Bridge 11/18/2020
River = PicketWire Reach = P-19-G Minor RS = 370.8672
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Elevation (ft)
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P-19-G Minor Plan: P-19-G Proposed Bridge 11/18/2020
River = PicketWire Reach = P-19-G Minor RS = 346.8917
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Ground
Bank Sta
Elevation (ft)
Station (ft)
P-19-G Minor Plan: P-19-G Proposed Bridge 11/18/2020
River = PicketWire Reach = P-19-G Minor RS = 307.4096
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Legend
EG PF 1
WS PF 1
Ground
Bank Sta
Elevation (ft)
Station (ft)
P-19-G Minor Plan: P-19-G Proposed Bridge 11/18/2020
River = PicketWire Reach = P-19-G Minor RS = 250.8749
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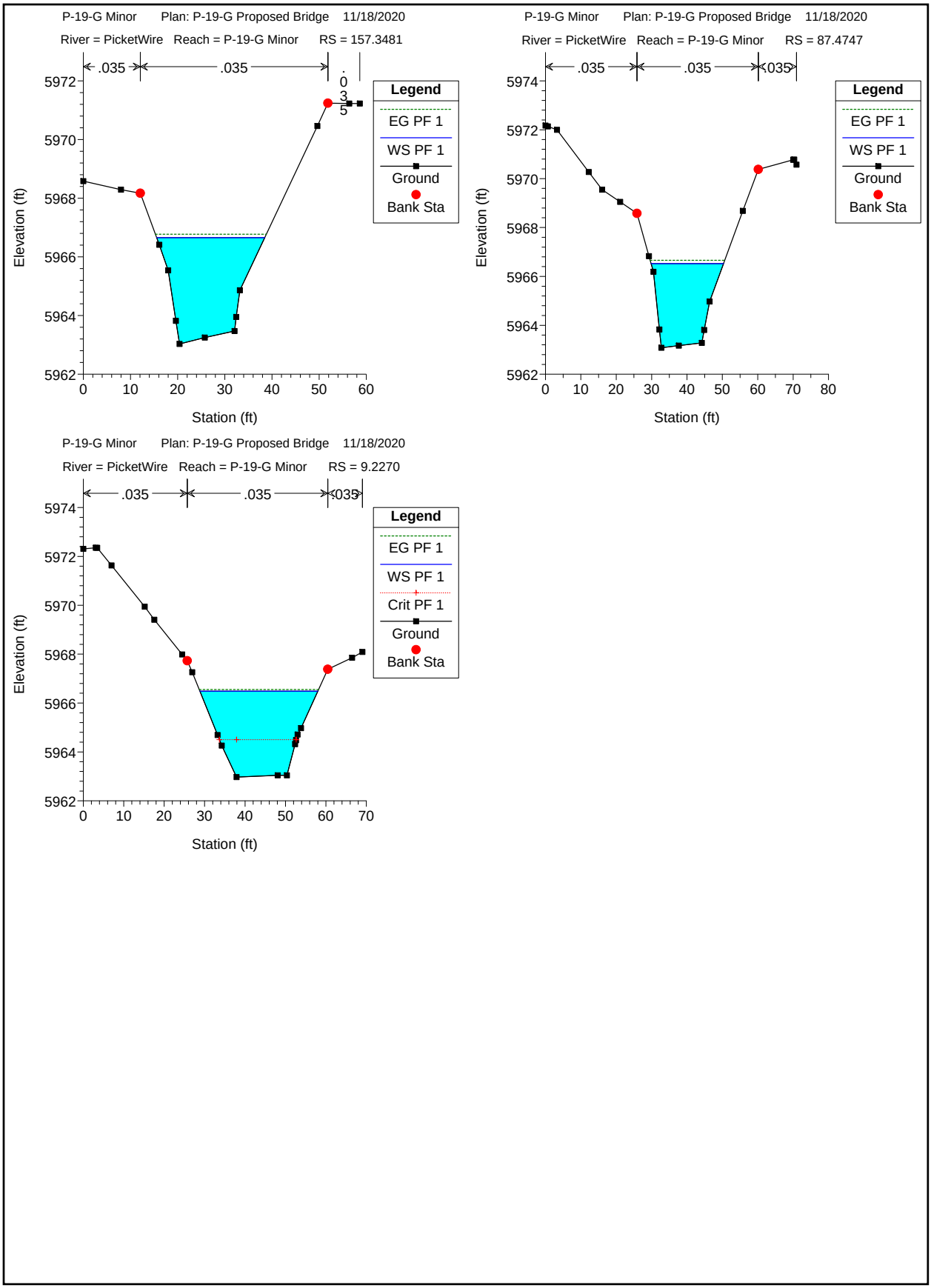
WS PF 1
Ground
Bank Sta
Elevation (ft)
Station (ft)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Bank Sta
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Station (ft)
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River = PicketWire Reach = P-19-G Minor RS = 87.4747
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WS PF 1
Ground
Bank Sta
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Station (ft)
P-19-G Minor Plan: P-19-G Proposed Bridge 11/18/2020
River = PicketWire Reach = P-19-G Minor RS = 9.2270
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Legend
EG PF 1
WS PF 1
Crit PF 1
Ground
Bank Sta
Elevation (ft)
Station (ft)

APPENDIX E WATER SURFACE ELEVATION COMPARISON

CDOT BRIDGE BUNDLE DESIGN BUILD - P-19-G_MINOR OVER PICKETWIRE DITCH

Table 1: Picketwire Ditch Water Surface Elevation Comparison

Design JRR Date 11/13/2020

Check JM Date 11/16/2020

Project Name/Identifyer:

CDOT Bridge Bundle P-19-G_Minor

Design Discharge (cfs)	HEC-RAS Section	Existing Conditions WSE (HEC-RAS) NAVD 88	Proposed RCBC WSE NAVD 88	Proposed RCBC - Existing	Proposed Bridge WSE NAVD 88	Proposed Bridge- Existing Condition
150	618.94	5967.22	5967.20	-0.02	5967.22	0.00
	598.13	5967.18	5967.16	-0.02	5967.18	0.00
	564.90	5967.14	5967.12	-0.02	5967.14	0.00
	519.58	5967.10	5967.07	-0.03	5967.10	0.00
	466.59	5967.07	5967.04	-0.03	5967.07	0.00
	424.02	5967.01	5966.97	-0.04	5967.01	0.00
	411.13			-		-
	370.87	5966.94	5966.93	-0.01	5966.94	0.00
	346.89	5966.90	5966.90	0.00	5966.90	0.00
	307.41	5966.87	5966.87	0.00	5966.87	0.00
	250.87	5966.80	5966.80	0.00	5966.80	0.00
	157.35	5966.65	5966.65	0.00	5966.65	0.00
	87.47	5966.52	5966.52	0.00	5966.52	0.00
	9.23	5966.48	5966.48	0.00	5966.48	0.00

APPENDIX F OUTLET PROTECTION ANALYSIS

HY-8 Energy Dissipation Report

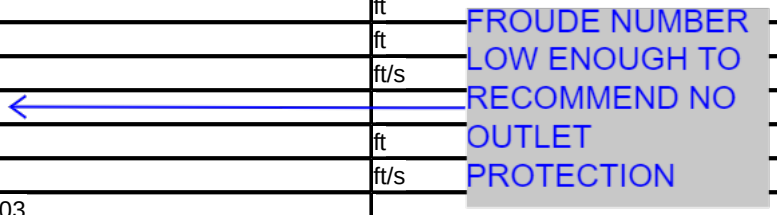
Scour Hole Geometry

Parameter	Value	Units
Select Culvert and Flow		
Crossing	P-19-G_Minor	
Culvert	Culvert 1	
Flow	150.00	cfs
Culvert Data		
Culvert Width (including multiple barrels)	16.0	ft
Culvert Height	4.0	ft
Outlet Depth	3.70	ft
Outlet Velocity	2.53	ft/s
Froude Number	0.23	
Tailwater Depth	3.70	ft
Tailwater Velocity	1.61	ft/s
Tailwater Slope (SO)	0.0003	
Scour Data		
Time to Peak		
Note:	if Time to Peak is unknown, enter 30 min	
Time to Peak	30.00	min
Cohesion	Noncohesive	
D16 Value	0.14	mm
D84 Value	8.50	mm
Tailwater Flow Depth after Culvert Outlet	Normal Depth	
Results		
Assumptions		
Soil Sigma	7.79	
Scour Hole Dimensions		
Length	32.169	ft
Width	16.838	ft
Depth	3.559	ft
Volume	2451.453	ft^3
DS at .4(LS)	12.868	ft
Tailwater Depth (TW)	3.700	ft
Velocity with TW and WS	1.554	ft/s

HY-8 Energy Dissipation Report

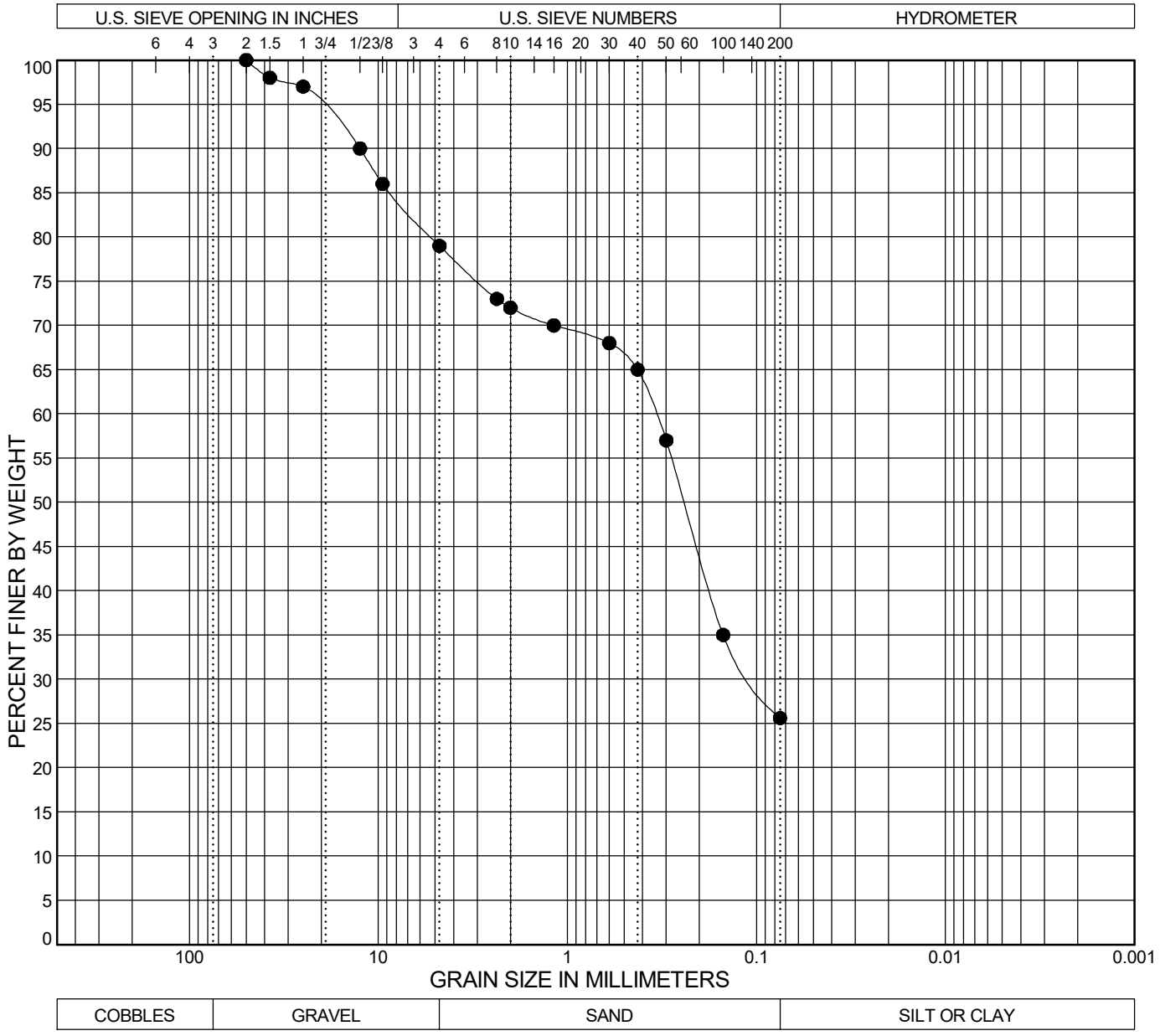
External Energy Dissipator

Parameter	Value	Units
Select Culvert and Flow		
Crossing	P-19-G_Minor	
Culvert	Culvert 1	
Flow	150.00	cfs
Culvert Data		
Culvert Width (including multiple barrels)	16.0	ft
Culvert Height	4.0	ft
Outlet Depth	3.70	ft
Outlet Velocity	2.53	ft/s
Froude Number	0.23	
Tailwater Depth	3.70	ft
Tailwater Velocity	1.61	ft/s
Tailwater Slope (SO)	0.0003	
External Dissipator Data		
External Dissipator Category	Streambed Level Structures	
External Dissipator Type	Riprap Basin	
Restrictions		
Froude Number	<3	
Input Data		
Condition to be used to Compute Basin Outlet Velocity	Envelope Curve	
D50 of the Riprap Mixture		
Note:	Minimum HS/D50 = 2 is Obtained if D50 = 0.039 ft	
D50 of the Riprap Mixture	0.039	ft
DMax of the Riprap Mixture	12.000	ft
Results		
Brink Depth	3.700	ft
Brink Velocity	2.534	ft/s
Depth (YE)	3.700	ft
Riprap Thickness	18.000	ft
Riprap Foreslope	24.0000	ft
Check HS/D50		
Note:	OK if HS/D50 > 2.0	
HS/D50	3.958	
HS/D50 Check	HS/D50 is OK	
Check D50/YE		
Note:	OK if 0.1 < D50/YE < 0.7	
Check D50/YE	0.011	
D50/YE Check	D50/YE is NOT OK	
Basin Length (LB)	64.000	ft
Basin Width	58.667	ft
Apron Length	16.000	ft
Pool Length	48.000	ft
Pool Depth (HS)	0.154	ft
TW/YE	1.000	
Tailwater Depth (TW)	3.700	ft
Average Velocity with TW	0.614	ft/s



Critical Depth (Yc)	0.584	ft
Average Velocity with Yc	4.292	ft/s
Downstream Riprap for High TW		
Distance: 1 LB		
Velocity	1.906	ft/s
Size	0.024	ft
Distance: 2 LB		
Velocity	1.042	ft/s
Size	0.007	ft
Distance: 3 LB		
Velocity	0.693	ft/s
Size	0.003	ft
Distance: 4 LB		
Velocity	0.518	ft/s
Size	0.002	ft

APPENDIX G GEOTECHNICAL INFORMATION



BOREHOLE	DEPTH (ft)	AASHTO Classification	USCS Classification	LL	PL	PI	%Gravel	%Sand	%Fines	
									%Silt	%Clay
● **P-19-G Scour**	**0.0**						**21.0**	**53.4**	**25.6**	

Yeh and Associates, Inc.
Geotechnical • Geological • Construction Services

SIEVE ANALYSIS

FIGURE

S- 10

Project No. 220-063 Date: 11-06-2020
Report By: D. Gruenwald Yeh Lab: Colorado Springs
Checked By: J. McCall

CDOT Region 2 Bridge Bundle
Scour Test Results

03 GRAIN SIZE YEH 220-063 R2 BRIDGE BUNDLE.GPJ 2019 YEH COLORADO TEMPLATE.GDT 2019 YEH COLORADO LIBRARY.GLB 11/6/20