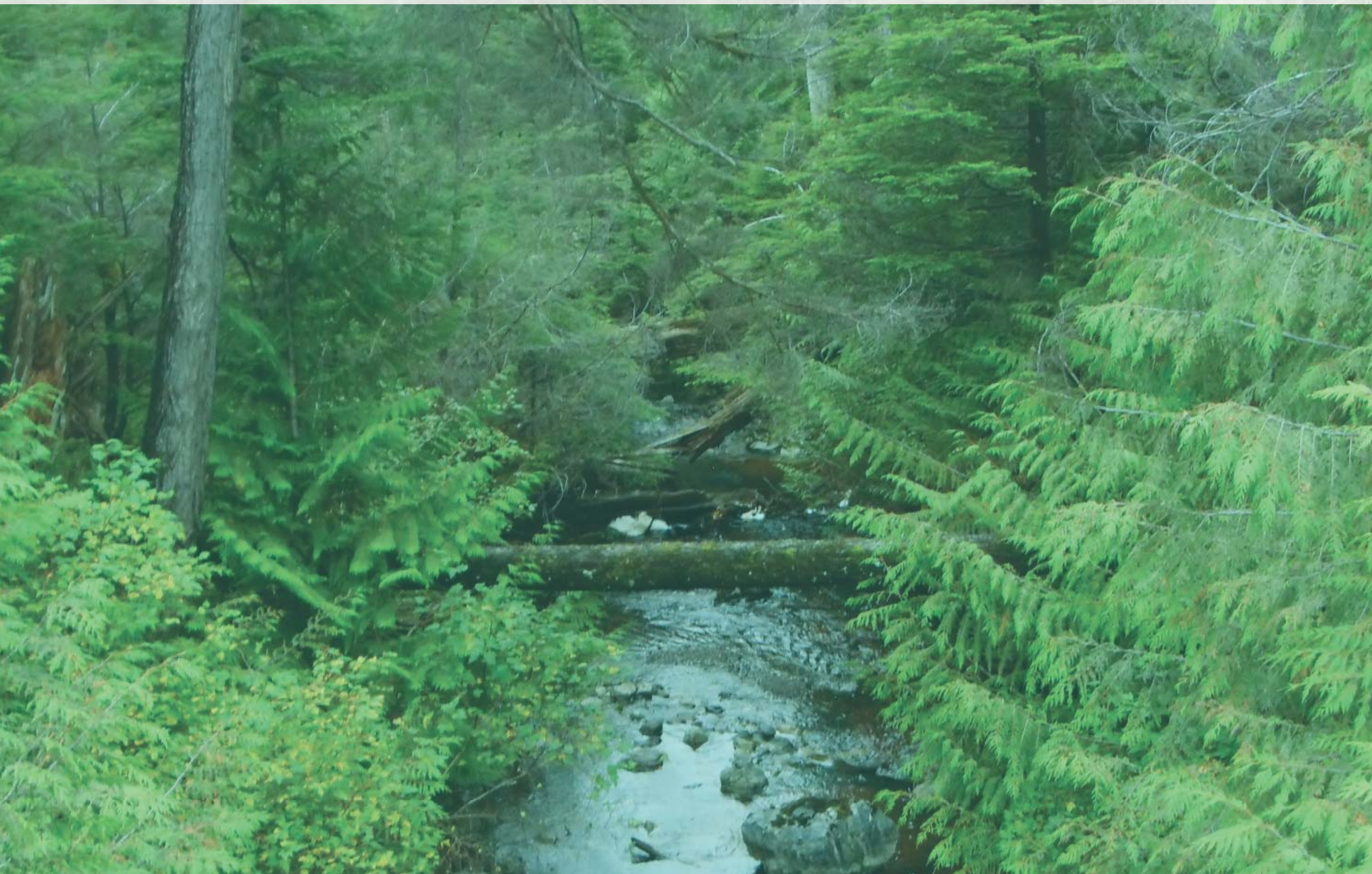
Final Hydraulics Report

AK PFH 43(10) Deweyville Trailhead To Neck Lake Road

MP 81.4 to MP 93.4



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ACRONYMS

ADF&G .... Alaska Department of Fish and Game
ADOT&PF .... Alaska Department of Transportation & Public Facilities
AOP .... Aquatic Organism Passage
BMP .... Best Management Practices
C .... Culvert
CMP .... Corrugated Metal Pipe
CSP .... Corrugated Galvanized Steel Pipe
CAP .... Corrugated Aluminized Pipe
FH .... Forest Highway
FHWA .... Federal Highway Administration
FP .... Fish Passage
MOA .... Memorandum of Agreement
MP .... Mile Post
PDDM .... Project Development and Design Manual
PND .... PND Engineers, Inc.
USFS .... United States Forest Service
USGS .... United States Geological Survey
WFLHD .... Western Federal Lands Highway Division

FISH SPECIES: cutthroat trout (CT), dolly varden (DV), silver salmon (SS), stickleback (SB), steelhead (SH), chum salmon (CS), and pink salmon (PS).

1.0 INTRODUCTION

This report presents the hydrologic and hydraulic findings and recommendations for the AK PFH 43(10) Deweyville Trailhead to Neck Lake Road project. This report has been prepared in accordance with the project scope of work, the Federal Highway Administration (FHWA) Federal Lands Highway *Project Development and Design Manual* (PDDM) and supplemental design documentation.

1.1 Project Description

The AK PFH 43(10) Deweyville Trailhead to Neck Lake Road (FH-43) project is located within the Tongass National Forest on the northern portion of Prince of Wales Island in Southeast Alaska. A project vicinity map is shown in Figure 1-1. The project consists of reconstruction of approximately 11 miles of road between Deweyville Trailhead and Neck Lake Road (MP 81.4 to 93.4).

PND Engineers, Inc. (PND), with concurrence from the Alaska Department of Fish & Game (ADF&G) and United States Forest Service (USFS), has identified a total of eighteen streams within the project limits that will be required to meet aquatic organism passage (AOP) requirements. Sixteen of the existing crossings are culverts, and one is a bridge. The proposed project will include replacing these structures with new culverts and bridges at Chum Creek and Tunga Creek. A list of the existing stream crossing locations is provided in Table 1-1. Locations of the streams are shown in the design plans which can be found in Appendix A.

Table 1-1: AOP Stream Existing Conditions

Stream Name/No.	FH43 MP	Stream Class	Species (ADF&G and USFS)	Current Structure
FP-01	82.667	2	CT, DV	60" CSP
FP-02	83.391	1	CT, DV, SS	36" CAP
FP-03	83.500	2	CT	72" CSP
FP-04	83.541	2	CT, DV	36" CSP
Tunga Creek	83.710	1	SS, CT, SB	96" CSP
FP-05	85.884	2	DV	60" CSP
FP-06	86.061	2	CT, DV	60" CAP
FP-07	86.956	2	SS, DV, CT	60" CSP w/ baffles
FP-08*	87.055	1	SS	24" CAP
FP-09	87.172	1	CT, DV, SH	60" CSP
Chum Creek	87.272	1	CT, CS, PS, SS	Bridge
FP-10	87.469	2	CT, DV, SH	48" CAP
FP-11	88.386	2	CT	48" CAP w/ baffles
FP-12	88.413	2	CT, DV	24" CAP
FP-13	89.035	2	CT, DV, SS, PS, SH	84" multi-plate
FP-14	89.894	2	CT	112" x 72" open-bottom galvanized arch
FP-15	90.201	2	CT	60" CSP
FP-16	90.696	2	CT	24" CAP
FP-17	91.120	2	CT	36" CSP

* The proposed drainage structure at FP-08 falls outside the limits of existing fish habitat and as such will not be designed as an AOP structure. Fish Species: cutthroat trout (CT), dolly varden (DV), silver salmon (SS), stickleback (SB), steelhead (SH), chum salmon (CS), and pink salmon (PS)

Thirteen additional drainages that do not require AOP structures were also investigated. A summary of the existing stream crossing at these locations is provided in Table 1-2.

Table 1-2: Non-AOP Streams Existing Conditions

Stream Name/No.	FH 43 MP	Current Structure
C-01	81.990	36" CSP
C-02	84.448	24" CAP
C-03	86.388	36" CSP
C-04	88.509	18" CAP
C-05	88.581	36" CSP
C-06	88.703	36" CSP w/ baffles
C-07	89.341	36" CSP
C-08	90.593	60" CSP
C-09	91.221	18" CSP
		18" CAP
		24" CAP
C-10	91.276	24" CAP
C-11	91.721	24" CAP
C-12	91.860	84" x 60" Galvanized Pipe Arch
C-13	91.920	48" CSP

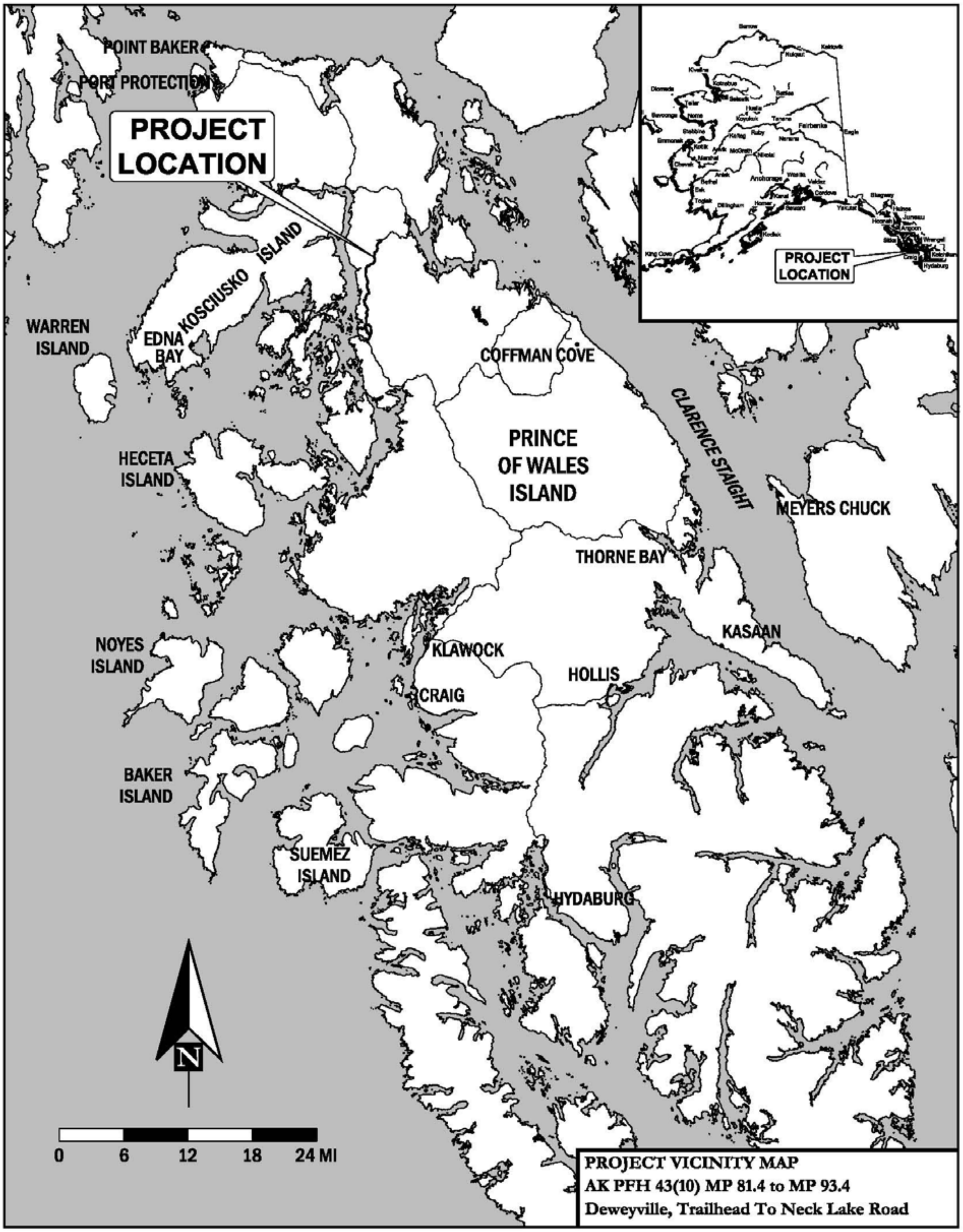

Figure 1-1: Project Vicinity Map

2.0 DATA COLLECTION AND SITE RECONNAISSANCE

2.1 Field Studies

Studies regarding fish passage within the project area have previously been completed by PND, DOWL, FHWA (WFLHD) and the USFS. Studies included information such as the location of the structure, size, gradient, fish species present and passage assessments.

PND conducted a field reconnaissance in October 2012 along Forest Highway (FH) 43 between mileposts 81.4 and 93.4 on Prince of Wales Island, Alaska. Field activities consisted of review of the project area with a representative from Alaska Department of Fish & Game, reviews of existing project survey data, field review of major existing and proposed stream crossing locations and stream pH measurements. The field data collected was utilized in conjunction with previous project studies for the design and construction of culverts and bridges within the project limits. Findings from this investigation were presented in a Hydraulics Reconnaissance Report (PND, 2012a). Additional field data was collected by Kiewit in December 2012 which has been presented in the Fish Stream Bankfull Measurements – Data Supplement (PND, 2013).

DOWL conducted a study of stream crossings along FH-43 and provided preliminary data and analyses for replacement of the existing structures (culverts and a bridge) between MP 81.4 and MP 93.4.

FHWA created a preliminary stream crossing list in May 2012 for the project that included nineteen stream crossings potentially requiring structures that allow fish passage.

USFS fisheries biologists conducted fish stream identification surveys in 2003 for the North Prince of Wales Road Upgrade Project. In those surveys, stream crossings along the road, designated by milepost, were surveyed for species of fish present and habitat stretch upstream and downstream. The seventeen AOP crossings proposed by PND for this project encompass all of the crossings that have fish presence verified upstream, according to the 2003 surveys, as well as a few additional crossings that did not have verification of fish presence upstream.

2.2 Preliminary Design Studies

PND presented preliminary hydrologic and hydraulic findings and recommendations for the AK PFH 43(10) Deweyville Trailhead to Neck Lake Road project have been presented in the Preliminary Hydraulics Report (PND 2012b).

2.3 Design Standards

- Chapter 7 of the PDDM
- HDS 1 (Hydraulics of Bridge Waterways)
- HEC 15 (Design of Roadside Channel with Flexible Linings)
- HEC 18 (Evaluating Scour at Bridges)
- HEC 20 (Stream Stability at Highway Structures)
- HEC 21 (Design of Bridge Deck Drainage)
- HEC 23 (Bridge Scour and Stream Instability Countermeasures
- HDS 5 (Hydraulic Design of Culverts)

- Memorandum of Agreement (MOA) between ADF&G and ADOT&PF for the Design, Permitting, and Construction of Culverts for Fish Passage
- Stream Simulation: An Ecological Approach to Providing Passage for Aquatic Organisms at Road-Stream Crossings, May 2008
- FHWA-HIF-07-033 Design for Fish Passage at Roadway-Stream Crossings: Synthesis Report

2.4 Field Survey Data

Project hydraulic and hydrologic analysis was developed based on a comparison of existing (baseline) field conditions to proposed design criteria alternatives. For the purpose of design analysis, baseline conditions are assumed to be existing roadway conditions along the project alignment. To accurately analyze the existing and proposed conditions, detailed project base maps were developed for each proposed drainage structure identified within this report from the following available survey data:

- Templin 2002 – Ground Field Survey
- Aero-Metrics 2012 – LiDAR Survey
- USGS SRTM (Satellite) topographic data
- PND 2012 – Ground Field Survey

2.5 Field Observations and Photographs

Detailed stream observations and reconnaissance photographs can be found in PND's Hydraulics Reconnaissance Report (PND 2012a) and the Fish Stream Bankfull Measurements – Data Supplement (PND 2013).

2.6 Flood History

No evidence of roadway flood problems was visibly evident during the 2012 field reconnaissance.

2.7 Flood Plane Mapping

There are no National Flood Insurance Program maps or information developed by the highway agency for the area.

2.8 Risk Assessment

Design for new and replacement drainage features will either maintain or upgrade the hydraulic capacity of existing drainage structures for the roadway to adequately meet current design standards. As such, it has been determined that the design criteria and standards presented in the project scope of work and in the PDDM are sufficient and appropriate for detailed design.

3.0 HYDROLOGIC ANALYSIS

Final hydrologic analysis has been performed for the seventeen identified AOP stream crossings, including fifteen proposed culverts and two bridge crossings, plus an additional four large non-AOP drainages (C-05, C-08, C-12 and C-13). Preliminary design analysis of the remaining nine non-AOP drainages determined that proposed culvert structures did not exceed the design threshold requiring detailed hydraulic analysis. Preliminary analysis for these culverts is presented in the Preliminary Hydraulics Report (PND, 2012b). Additionally, modifications of the proposed roadway alignment during preliminary design resulted in the proposed drainage structure at FP-08 falling outside the limits of existing fish habitat and as such will not be designed as an AOP structure.

All of the streams and drainages within the project limits are ungaged. Peak discharges for the drainages were calculated with weighted regression equations following the methodology presented in the United States Geological Survey (USGS) Report 03-4188 *Estimating the Magnitude and Frequency of Peak Streamflows for Ungaged Sites on Streams in Alaska and Conterminous Basins in Canada.*

The project is located in Southeast Alaska and falls within Region 1 as designated by the USGS report. Peak flow values are calculated through regression equations that take into account the drainage area, percentage of lakes and ponds (storage), mean annual precipitation and the mean minimum January temperature. Basin size and percent storage were determined based on detailed LiDAR topographic surveys along a narrow corridor following the road, available USGS topographic information of the surrounding area including the USGS Shuttle Radar Topography Mission (SRTM) data collected in 2000, and limited ground survey data. The mean annual precipitation is estimated as 100 inches and the mean minimum January temperature is 30 degrees Fahrenheit.

The USGS regression equations were adjusted based on historical data from the nearby gaged North Fork Staney Creek (Gage #15081495), located approximately 15 miles south of the project area and having a drainage basin area of 3.07 square miles. By that analysis, 14 years of peak flow data at North Fork Staney Creek were used to estimate peak flood frequencies using the USGS PeakFQ program. These peaks were combined with estimates obtained using the USGS regression equations to obtain weighted estimates. By comparing historical peak flow from the Staney Creek gage to peak flow rates generated by the USGS regression equations, individual scale factors for 2-, 5-, 10-, 25-, 50-, 100-, 200- and 500-year return intervals were generated. The resulting individual scale factors used to adjust the design peak flows are provided in Table 3-1. Using these scale factors, the flow estimates from the USGS regression equations were increased by about 10 percent for most return periods. Design peak discharges are presented in Tables 3-2 and 3-3. Detailed hydrologic analysis results are presented in Appendix B.

Table 3-1: Peak Discharge Scale Factors

Return Period	Scale Factor
Q2	1.18
Q5	1.10
Q10	1.08
Q25	1.07
Q50	1.08
Q100	1.09
Q200	1.10
Q500	1.12

Table 3-2: AOP Stream Peak Flow Summary

Stream	FH-43 MP	Basin Area (sq. mi.)	Q2 (cfs)	Q5 (cfs)	Q10 (cfs)	Q25 (cfs)	Q50 (cfs)	Q100 (cfs)	Q200 (cfs)	Q500 (cfs)	Qfish .4 Q2
FP-01	82.667	0.14	51	69	81	98	111	124	139	158	21
FP-02	83.391	0.01	5	7	9	10	12	13	15	17	2
FP-03	83.500	0.40	87	116	136	163	185	208	233	265	35
FP-04	83.541	0.01	7	10	12	14	16	18	20	23	3
Tunga	83.710	1.72	155	202	236	282	320	358	402	461	62
FP-05	85.884	0.14	51	68	80	96	109	122	137	156	20
FP-06	86.061	0.18	63	84	99	119	135	152	170	193	25
FP-07	86.956	0.04	17	23	27	32	36	41	46	52	7
FP-09	87.172	0.11	43	57	67	81	92	103	115	131	17
Chum	87.272	1.10	137	180	211	252	286	320	359	411	55
FP-10	87.469	0.13	49	65	77	93	105	118	132	150	19
FP-11	88.386	0.10	31	41	49	58	66	74	83	95	12
FP-12	88.413	0.02	10	14	16	20	22	25	28	32	4
FP-13	89.035	0.45	99	132	155	186	211	236	264	301	40
FP-14	89.894	0.08	33	44	52	62	70	79	88	101	13
FP-15	90.201	0.35	66	87	102	122	139	155	174	199	26
FP-16	90.696	0.01	5	7	8	10	11	12	14	16	2
FP-17	91.120	0.03	14	19	22	27	30	34	38	43	6

Table 3-3 Non-AOP Stream Peak Flow Summary

Stream	FH-43 MP	Basin Area (sq. mi.)	Q2 (cfs)	Q5 (cfs)	Q10 (cfs)	Q25 (cfs)	Q50 (cfs)	Q100 (cfs)	Q200 (cfs)	Q500 (cfs)
C-05	88.581	0.05	23	31	37	45	51	57	64	72
C-08	90.593	0.22	74	99	116	140	159	177	198	226
C-12	91.86	0.16	57	76	90	107	122	137	153	174
C-13	91.92	0.06	27	36	43	51	58	65	73	83

4.0 HYDRAULIC ANALYSIS

4.1 AOP Fish Passage Hydraulics

Hydraulic design of the AOP structures was based on the criteria outlined under the Memorandum of Agreement (MOA) between the ADF&G and ADOT&PF for the Design, Permitting and Construction of Culverts for Fish Passage and design standards presented in the PDDM. Typically, preliminary fish passage culvert sizing is governed by the Tier 1 stream simulation method presented in the MOA. Design requirements for the AOP culverts are summarized in the following:

- Culverts will convey runoff from the 50-year flood
- Design all culverts for a 50-year service life
- Sizing & Entrance Treatments in culverts larger than 48 inches, use mitered ends that conform to slope, or headwalls with beveled edge
- Headwater elevation will not be greater than the bottom of the aggregate base layer for the roadway pavement structure at the local roadway low point.
- Allowable HW/D Ratio
    - 48 inches or smaller = 1.5
    - Larger than 48 inches = 1.2
    - Debris or sediment: A ratio range of 0.8 to 1.0, depending on severity, is suggested where the potential for heavy debris or sediment bed loads are a concern.
- Align culvert at a maximum skew of 45 degrees from centerline of the roadway
- Pipe anchors required for exposed pipes or those on steep slopes (>25%) that can experience joint separation
- The structure slope shall be within 1% of the natural streambed grade
- The structure width shall be bankfull width plus one foot on each side.
- The pipe will be embedded either 40 percent of its diameter for circular pipe, and the greater of 20 percent of its depth or 2 feet for pipe arches.
- Material and layout within the culvert shall match natural stream conditions.
- Substrate material will be designed to be stable within the culvert up to and including the 50-year flood.

4.2 Culvert Capacity and HW/D

Final hydraulic analysis for each AOP fish passage structure was performed using the FHWA HY-8 culvert analysis program to determine the performance of each culvert. A summary of the final design recommendations for the AOP fish passage structures is presented in Table 4-1. Detailed calculations can be found in Appendix C.

Table 4-1: AOP Fish Passage Design Summary

Stream Name	MP	Design Bankfull Width (ft)	Proposed Structure	Length (ft)	Slope	Embedment Depth (ft)	Qfish Outlet Velocity (fps)	Q50 Outlet Velocity (fps)	Q50 HW/D
FP-01	82.667	4.0	84"	85.46	0.50%	2.8	3.5	5.3	1.15
FP-02	83.391	3.0	72"	78.64	2.99%	2.4	1.9	3.0	0.26
FP-03	83.5	9.8	11'-10" x 7-7"	78.39	0.00%	2.0	1.5	2.4	0.84
FP-04	83.541	3.5	66"	88.95	0.50%	2.2	0.7	1.1	0.55
FP-05	85.884	7.0	108”	70.55	2.27%	3.6	3.3	5.3	0.58
FP-06	86.061	9.0	11’-5” x 7-3”	100.25	1.73%	2.0	2.7	4.2	0.64
FP-07	86.956	3.5	66"	88.25	11.06%	2.2	4.0	6.1	0.38
FP-09	87.172	6.0	96"	96.68	13.93%	3.2	4.0	7.1	0.37
FP-10	87.469	6.0	96"	79.66	8.70%	3.2	5.2	9.1	0.44
FP-11	88.386	6.0	96"	88.33	10.00%	3.2	4.0	7.0	0.30
FP-12	88.413	2.4	60"	76.81	10.68%	2.0	2.9	5.0	0.32
FP-13	89.035	12.6	14'-3" x 9'-2"	115.24	9.13%	2.0	5.3	8.0	0.73
FP-14	89.894	5.0	96"	124.81	11.67%	3.2	3.8	6.3	0.30
FP-15	90.201	8.2	10'-8" x 6'-11"	99.64	7.93%	2.0	4.7	7.9	0.68
FP-16	90.696	2.0	60"	81.31	1.42%	2.0	0.5	1.0	0.54
FP-17	91.12	3.0	60"	89.34	8.06%	2.0	4.4	6.2	0.42

4.3 Streambed Material and Streambed Retention

The in-situ streambed material varies by stream depending on the gradient, ranging from fines in flatter, slow moving areas, to cobbles and boulders in steeper grade streams. Most streams consisted of step pools created by boulders and downed trees in steep areas, or muskeg and beaver dams in flatter areas. In addition, exposed bedrock was observed in a majority of the studied streams.

Streambed stability analysis was conducted for all AOP structures to determine the median size of a stable rock inside the embedded culverts. Calculations were done following the methods outlined in HEC 15 utilizing a 50-year design flow and culvert outlet velocity. The streambed stability analysis was completed assuming no retention structures in the pipe, and that the stream channel geometry continues throughout the pipe. The detailed analysis for all culverts with slopes exceeding 6 percent can be found in Appendix C.

These calculated values of stable rock material have been compared to the project design specification sections 647.05 Streambed Material and 703.20 Furnished Streambed Material. In a number of instances (at culverts exceeding a design slope of 6%) the largest design streambed gradation Class E does not meet the d50 requirements for stability and will require additional methods of bed retention. Per the project scope of work, streambed retention has been provided for AOP structures exceeding 3% slope to provide continuous recruitment of stream bed load and are to meet the following requirements:

- AOP structures with slopes ranging >3% will be constructed with metal retention baffles
- AOP restoration channels with slopes >3% will be constructed with constructed rock weir step pools.
- Spacing and height of the rock weirs and baffles were designed as a function of the culvert size as referenced in FHWA's Design for Fish Passage at Roadway-Stream Crossings Synthesis Report. Spacing was designed to be between 1 and 1.2x the pipe diameter to limit the steps to a 0.8-foot drop (Hotchkiss & Frei, 2011)
- Rock weirs are to consist of stable streambed boulders

Fish passage design details were developed utilizing methods outlined under USFS stream simulation guidelines in accordance with the project scope of work and design specifications and are intended to meet the Title 16 permit requirements. Table 4-2 summarizes the rock weir and retention baffle design for the proposed AOP streams and structures. Detailed analysis is presented in Appendix C.

Table 4-2: Retention Structures

Stream Name	Culvert Slope	Culvert Size	Streambed Class	Culvert Retention Type	Baffle Height (ft)	Channel Retention Type	Boulder Size (in)		Spacing (ft)
							Min	Max	
FP-01	0.50%	84"	Class E	N/A	N/A	N/A	18**	24**	N/A
FP-02	2.99%	72"	Class D	N/A	N/A	rock weir	15	24	26
FP-03	0.00%	11'-10" x 7-7"	Class A	N/A	N/A	N/A	6**	12**	N/A
FP-04	0.50%	66"	Class A	N/A	N/A	N/A	6**	12**	N/A
FP-05	2.27%	108"	Class E	N/A	N/A	N/A	18**	24**	N/A
FP-06	1.73%	11'-5" x 7-3"	Class C	N/A	N/A	N/A	12**	24**	N/A
FP-07	11.06%	66"	Class E*	baffles	2.2	rock weir	18	24	6
FP-09	13.93%	96"	Class E*	baffles	3.2	rock weir	18	36	5
FP-10	8.70%	96"	Class E*	baffles	3.2	rock weir	18	24	9
FP-11	10.00%	96"	Class E*	baffles	3.2	rock weir	18	24	8
FP-12	10.68%	60"	Class E*	baffles	2.0	rock weir	18	18	6
FP-13	9.13%	14'-3" x 9'-2"	Class E*	baffles	2.0	rock weir	18	30	8
FP-14	11.67%	96"	Class E*	baffles	3.2	rock weir	18	30	6
FP-15	7.93%	10'-8" x 6'-11"	Class E*	baffles	2.0	rock weir	18	24	8
FP-16	1.42%	60"	Class C	N/A	N/A	N/A	12**	24**	N/A
FP-17	8.06%	60"	Class E	baffles	2.0	rock weir	18	24	6

***** Class E material not stable

****** Sizing provided for rock weir to be installed at culvert outlet transition

4.4 Scour Protection

Riprap transition aprons and headwalls have been provided as inlet and outlet scour protection for AOP structures. Riprap sizing was performed in accordance with Chapter 10 of HEC 14 and Design Guideline 18 per HEC 23, detailed analysis reports can be found in Appendix C. Furthermore, proposed culvert profiles and channel restoration segments have been designed to begin and end at stable bedforms and slopes. Streambed material and retention formations are designed to transition into the natural stream channels upstream and downstream of new AOP development.

4.5 Service Life

Designed culverts on the FH 43 Deweyville Trailhead to Neck Lake Road project are projected to have a 50-year service life. The durability of corrugated metal pipes is affected by multiple environmental factors including soil resistivity, moisture content, acidity (or pH), and abrasion. Soils to be used around the culverts will be obtained from a quarry. Soil resistivity values and pH of the soil to be used was analyzed and is provided in Appendix D. The following was used for service life calculations (also available in Appendix D):

- A minimum soil resistivity of 14000 ohm-cm
- pH measurements of the water taken at each fish stream and larger drainage streams ranged from 5 to 6.5 (reference PND's 2012 Hydraulics Reconnaissance Report)
- pH of the soil was measured to be around 8
- Site conditions for project culverts have been assumed to be Level 2 (Low Abrasion) based on observations during hydraulic reconnaissance of existing structures, including the predominantly bedrock stream beds and relatively low sediment transport rates, the relative lack of mobile sand and gravel sediments in most of the drainages, and the use of baffles and streambed materials placed within fish passage culverts, which will minimize wear on these culvert inverts.

Considering the environmental factors along the project, including mildly acidic water pH values of the water and low abrasion conditions, it is recommended that all corrugated steel pipe culverts be coated with Aluminized Type 2. This coating meets the design requirements of AASHTO M 274 and performs well in a wider range of conditions (water softness, pH, and resistivity) than galvanized CSP, and achieves a minimum service life of 75-years.

4.6 Non - AOP Stream Hydraulics

Design requirements for non-AOP culverts are summarized as follows:

- Culverts will convey runoff from the 50-year flood
- Design all culverts for a 50-year service life
- Headwater elevation will not be greater than the bottom of the aggregate base layer for the roadway pavement structure at the local roadway low point.
- Align culvert at a maximum skew of 45 degrees from centerline of the roadway
- Allowable HW/D Ratio
    - 48 inches or smaller = 1.5
    - Larger than 48 inches = 1.2
    - Debris or sediment: A ratio range of 0.8 to 1.0, depending on severity, is suggested where the potential for heavy debris or sediment bed loads are a concern.
- Pipe slope will generally conform to the average streambed flow line and should match the channel elevations on both the upstream and downstream sides.

- Pipe anchors required for exposed pipes or those on steep slopes (>25%) that can experience joint separation

Final hydraulic analysis for the four non-AOP culvert structures was performed using the FHWA HY-8 culvert analysis program to determine the performance of each culvert. A summary of the final design recommendations for each culvert structure is presented in Table 4-3. Detailed calculations can be found in Appendix C.

Table 4-3: Non-AOP Streams Culvert Design Summary

Stream Name/No.	MP	Proposed Structure	Length (ft)	Slope	Q50 Outlet Velocity (fps)	Q50 HW/D
C-05	88.58	48"	65.57	4.27%	6.8	0.78
C-08	90.59	72"	77.11	9.89%	8.9	0.88
C-12	91.86	72"	71.95	6.95%	6.4	0.78
C-13	91.92	48"	95.77	4.57%	8.8	0.91

4.7 Bridge Hydraulics

Hydraulic analysis for the two bridge sites, Chum Creek and Tunga Creek, will be performed in accordance with the design standards outlined in Chapter 7 of the PDDM, HDS 1 (Hydraulic Design of Bridge Waterways), HEC 18 (Evaluating Scour at Bridges), HEC 20 (Stream Stability at Highway Structures), HEC 21 (Design of Bridge Deck Drainage) and HEC 23 (Bridge Scour and Stream Instability Countermeasures) upon completion of the bridge design. Hydraulic analysis will be completed utilizing the United States Army Corps of Engineers HEC-RAS program. Hydraulic design requirements for bridges include:

- Develop water surface profiles using peak flood estimates (2, 10, 25, 50, 100 and 500-year)
- Analyze conditions for pre, interim and post bridge construction
- Evaluate all piers in the 500-year floodplain for scour design to be stable for the predicted scour.
- Design bridges to convey the 50-year flood with a minimum of 3.5 feet of freeboard.
- Design approaches above flood elevations (do not design for overtopping).
- Design abutments to be constructed outside the active channel.

The channels of both Tunga Creek and Chum Creek primarily consist of exposed bedrock with overlying gravel and cobbles and their streambeds are assumed stable. Lateral channel movement, aggradation and degradation trends, and local scour were not evident during field visits, and are not expected to be an issue in the future. Additionally, bridge abutments are being designed to be outside of the floodplain which will lessen the unlikely impact of any scour.

Debris accumulation was observed along the lengths of both streams due to downed trees across the channel; however, the elevations of the bridges' low chords will take this into account and provide a sufficient amount of space to allow debris to pass. The amount of debris and large material does affect the roughness of the streambed. For open channel flow calculations a Manning's n value of 0.045 will be used for both Tunga and Chum Creek.

Final values for water surface elevations at peak flood, abutment riprap protection, and deck drainage will be calculated upon completion of bridge design. This analysis will be provided in an addendum to this report.

4.8 Road Side Ditches and Ditch Relief Culverts

4.8.1 Roadside Ditch Analysis

Roadway ditch design was completed in conformance with the project scope of work and design was governed by the standards outlined in Chapter 7 of the PDDM, in HEC 15 "Design of Roadside Channels with Flexible Linings" and adhered to the following design criteria:

- Roadside ditches will be designed to convey the 10-year flood
- Design roadside ditches for stability for the 10-year flood
- Minimum ditch slope is 0.5% where possible. Where practical, provide a desired 1.0% minimum ditch slope
- Ditches steeper than 3% will be designed for erosion control
- Typical roadside ditches were designed to be regular v-shaped ditches with a 2H:1V and a 1.5H:1V side slope and maximum depths of 1.25 feet
- Ditches within rock cuts were designed with a 2H:1V side slope in the embankment and a 0.25H:1V side slope in the rock cut
- Ditches prone to larger flows and shallower slopes were designed to accommodate greater depths of water.
- Ditch size was determined through analysis of representative worst case scenarios where large basins drain into long, shallow sloped ditches.

Ditch flows were calculated using weighted USGS regression analysis, and following the same methods presented for the culvert streams. Discharge values are presented in Appendix B. These flows and typical cross-sections were modeled in AutoCAD Civil 3D's Hydraflow Express program to give a flow depth and average velocity. HEC 15 procedures were utilized to determine a median grain size, d50, for the rock lining. For ditches less than 3% slope, analysis was first conducted using HEC 15 for the adequacy of vegetated lining, and if that proved insufficient a rock lining was sized. Table 4-4 displays the results of analyzed ditches with slopes less than 3% (see following page), and calculations can be found in Appendix C.

Table 4-4: Shallow Ditch Design

Ditch Designation	Ditch Slope (ft/ft)	Q10 (cfs)	Velocity (fps)	Water Depth (ft)	d50 (in)
C-104W	0.020	5.5	3.3	0.97	7
C-105	0.005	5.3	2.0	1.24	vegetated
C-106	0.008	11.0	2.8	1.49	4
C-107	0.005	6.3	2.1	1.32	vegetated
C-216E	0.005	16.0	2.6	1.88	vegetated
C-217	0.005	5.1	2.0	1.22	vegetated
C-03	0.028	6.1	3.9	0.95	5
C-315	0.022	6.0	3.5	0.99	4
C-405	0.017	8.8	3.6	1.19	4
C-409	0.010	12.1	3.2	1.48	5
C-414	0.016	5.6	3.1	1.02	6
C-418	0.008	6.4	2.5	1.22	vegetated
C-504	0.015	5.5	3.0	1.03	6
C-517	0.005	5.4	2.0	1.25	vegetated
C-524	0.008	9.4	2.7	1.41	4
C-526	0.008	7.0	2.5	1.26	vegetated
C-601	0.008	8.9	2.7	1.38	4
C-603	0.008	5.4	2.3	1.15	vegetated
C-608	0.008	5.1	2.3	1.12	vegetated
C-614	0.008	7.9	2.6	1.32	4
C-615	0.008	6.2	2.4	1.21	vegetated
C-623	0.020	7.3	3.6	1.08	1
C-1399	0.012	18.7	3.7	1.69	7

Rock lining for steep ditches, greater than 3% slope, was analyzed through determination of a worst-case scenario ditch. Surface water drainages were delineated in order to determine a representative worst-case ditch location. Ditches placed in rock cuts were also investigated as one slope of ditch will be in the embankment and will be vulnerable to erosion. These sections have a 0.25H:1V side slope in the rock cut, and a 2H:1V side slope in the embankment. The 10-year design flood event was then calculated through a weighted USGS regression analysis and channel velocities were obtained after inputting geometry and flow data into AutoCAD Civil 3D's Hydraflow Express program. HEC 15 was then utilized to obtain a stable d50 to be used in the steep ditches. Table 4-5 displays these results, and detailed analysis can be found in Appendix C.

Table 4-5: Steep Ditch Design

Ditch Designation	Ditch Slope (ft/ft)	Q10 (cfs)	Velocity (fps)	Flow Depth (ft)	d50 (in)	Ditch Type
FP-01 to C-110	0.058	4.7	4.7	0.71	9	Typical
C-118 to FP-02	0.088	6.4	6.0	0.78	11	Typical
FP-10 to C-401	0.047	10.6	5.4	1.06	9	Typical
C-212 to C-215	0.068	9.8	6.1	0.96	10	Typical
C-07 to C-501	0.081	3.0	4.7	0.75	11	In Rock Cut
C-301 to C-303	0.060	17.7	6.7	0.93	13	In Rock Cut

4.8.2 Ditch Relief Culvert Analysis

Ditch relief culverts design is in conformance with the design standards outlined in Chapter 7 of the PDDM and the requirements outlined under HDS 5.

- Design all culverts for a 50-year service life
- Design all culverts to convey the 25-year flood
- Culverts 100 feet or shorter shall be a minimum 24 inches diameter
- Culverts longer than 100 feet shall be a minimum 36 inches diameter
- Ditch relief culverts are to be installed at a minimum 3% grade

The majority of these culverts are 24 inches in diameter, and all are smaller than 48 inches in diameter. All minor culverts are corrugated HDPE pipe. Hydraulics for these culverts was performed in FHWA's HY-8 program. Multiple representative culverts with the largest flowrates and shallow slopes were analyzed for hydraulic capacity and are designed to pass the design 25-year flood event.

Rock aprons are designed for any culvert with an outlet velocity greater than 6 feet per second. A conservative design flow was used with varying culvert slopes in the HY-8 program to obtain outlet velocities. These velocities and estimated tailwater depths were used in accordance with HEC 14 to size the outlet protection. Design aprons are to be a minimum width 3.0 times the diameter of the culvert at the outlet, a length of 4.0 times the diameter, and tapering out at 3:1 along its length. The size of the rock to be used at any culvert requiring an apron is to be Class 1 riprap. Culverts which will require outlet protection are indicated on the design plans, and detailed analysis can be found in Appendix C.

5.0 CONSTRUCTION & MAINTENANCE RECOMMENDATIONS

In-stream work will correspond to periods allowable by USFS and ADF&G. All AOP culverts will be constructed inside specific construction windows during which fish will not be disturbed. Construction activities will be planned and executed so that all negative impacts on the stream and surrounding area will be minimized. Erosion and sediment control measures will be implemented.

5.1 Construction Techniques

Any given stream may be diverted during construction of the new culvert. Diversion durations will be kept to the minimum necessary to reconnect the new culvert. Unless otherwise noted in the attached site-specific descriptions, new structures will be located as close to existing culverts as possible to minimize stream relocation. Upon completion of the new culvert construction, the stream flow will be permanently redirected. Banks of the existing stream will be altered to the minimum extent required to connect the existing channel to the new culvert. This will include some excavation to ultimately breach the existing banks. During construction, reinforcement of the existing banks may be necessary to prevent premature breaching. Work will be performed mostly using an excavator. Some work will likely be done by hand. Care will be taken to ensure that construction equipment does not enter the flowing stream except for during connection to the new structure.

5.2 Temporary Stream Diversion Options

Construction of the new fish passage culverts and obliteration of the existing culverts may require a temporary diversion of the existing streams. This is most likely in locations where the new culvert will be constructed very close to the existing culvert. Three stream diversion options are presented below and included on Sheet J.27 of the attached preliminary drawing set found in Appendix A. If the contractor determines it is impractical or impossible to maintain the existing culverts during construction of the new culverts, one of these options may be chosen.

It is estimated that any particular stream may be diverted for approximately five days. Upon completion, flow would be directed to the new fish passage culvert permanently. All temporary measures would be removed and where appropriate, grades restored and seeded to stabilize the soils and encourage natural colonization of native plant life.

1. <u>Temporary Open Diversion Channel:</u> Flow would be diverted from slightly upstream of the existing culvert entry to an open channel dug parallel to the existing culvert and connected to the existing channel slightly downstream of the outlet of the existing culvert. A temporary barrier would be used to prevent flow into the culvert and direct it into the temporary channel. The channel width would match the stream mouth of the existing stream. Channel details are shown on sheet J.27 in Appendix A.
2. <u>Temporary Culvert Diversion:</u> Flow would be diverted from slightly upstream of the existing culvert entry to an open channel (using one of the options listed under item 1) and connecting to a temporary culvert. The outlet would connect to the existing stream via an open channel slightly downstream of the outlet of the existing culvert. The channel width would match the stream mouth to the existing stream.
3. <u>Temporary Pumped Diversion:</u> Flow would be diverted via pump directly from upstream of the existing culvert into a temporary force main and released below the culvert into the existing stream. A temporary riprap energy dissipater would be installed at the outlet of the pipe. A screen would be used at the intake point to prevent fish entrapment, entrainment or injury.

5.3 Streambed Material & Placement

Streambed material will be mixed and placed in accordance with Special Contract Requirements, Section 647 – Environmental Mitigation. Materials excavated at each culvert site should be reserved, and can be used within the streambed if deemed suitable and meeting the designed gradation; however, in no case should material be taken from adjacent streams (FHWA, 2010).

An important aspect of placing the streambed is ensuring that the stream flows above the bed. An adequate amount of fine sediment should be included per the streambed material specification mix design.

5.4 Work Timing and Schedule

The overall FH-43 Improvement project is a design build project scheduled for construction starting in April 2013 and concluding in December 2014. AOP structure construction will be completed during allowable work windows for each of these years.

Allowable work windows per species will be determined by ADF&G and USFS. In instances where a stream hosts multiple species, dates of overlap for all of the species defines the combined allowable work window. The following table reflects these stream-specific combined work windows as submitted to and tentatively approved by ADF&G (Minnillo, 10/17/2012 via email) and USFS (Brandy, 9/13/2012) staff. All in-water work associated with fish passage structures will adhere to these windows.

Table 5-1: In-Stream Work Windows

Stream Name	Estimated In-Water Work-Construction Window	Estimated Duration
FP-01	June 25 to September 1	69 days
FP-02	June 25 to September 1	69 days
FP-03	June 25 to September 1	69 days
FP-04	June 25 to September 1	69 days
FP-05	June 25 to September 1	69 days
FP-06	June 25 to September 1	69 days
FP-07	June 25 to September 1	69 days
FP-09	July 15 to August 15	32 days
FP-10	July 15 to August 15	32 days
FP-11	June 25 to September 1	69 days
FP-12	June 25 to September 1	69 days
FP-13	July 15 to August 15	32 days
FP-14	June 25 to September 1	69 days
FP-15	June 25 to September 1	69 days
FP-16	June 25 to September 1	69 days
FP-17	June 25 to September 1	69 days

5.5 Best Management Practices (BMP)

Construction BMPs, standard for Southeast Alaska, will be implemented during construction. In-water work windows will be strictly adhered to as well as permit conditions directed by agencies.

5.6 Bank Armoring and Revegetation

Disturbed areas will be revegetated as specified by FHWA with a mix of Red Fescue (*Festuca rubra,* Boreal variety), Annual Ryegrass (*Lolium multiflorum*), and Arctared Fescue (*Festuca rubra*, Arctared variety) (Specification section 713.04).

5.7 Restoration

Where the new road alignment does not overlap the existing, a new fish passage culvert will be located outside of the footprint of the existing culvert and the old roadway will be obliterated. Roadway areas to be obliterated will be shaped to match natural conditions. Where existing culverts are no longer needed, they will be removed. At these locations, drainages will be restored to the approximate original contours to align with upstream and downstream conditions, and streambed material will be placed in the newly restored channels to reestablish the drainage to natural conditions.

5.8 Post-Construction & Maintenance

All culverts must be inspected every two years using 23 CFR 650 Part C of the National Bridge Inspection Standards as a guide (FHWA, 2004). A monitoring program for fish passage on all AOP structures is suggested in order to determine the success of the structures. Maintenance may occur on a regularly scheduled basis or triggered by inspection results.

Culverts have been designed to allow for minimal maintenance following installation. For the duration of the entire FH-43 project, all maintenance will be performed by Kiewit. During this time, culvert performance will be periodically checked to ensure each is functioning properly. Upon project completion, Kiewit will transfer these permits to FHWA (or other entity as directed by FHWA) for long term maintenance.

6.0 CONCLUSION

Final design recommendations for culverts are presented in Tables 4-1 and 4-3 and throughout this report. These are based on the presented hydrologic and hydraulics analyses, in addition to the project criteria and design guidelines. A total of eighteen streams requiring AOP structures and four large non-fish culverts are presented in this report. All culverts larger than 48 inches in diameter will be aluminized CMP to protect from corrosion over the 50-year life of the structure. Culverts 30 to 48 inches in diameter will be smooth interior, corrugated polyethylene pipe. All 24-inch-diameter culverts will be single wall corrugated polyethylene pipe. Appendix A includes the final design plans for all aforementioned culverts.

The remainder of the analyses presented in this report verifies the hydraulic adequacy of the structures and material to be used on the AK PFH 43(10) Deweyville Trailhead to Neck Lake Road project.

7.0 REFERENCES

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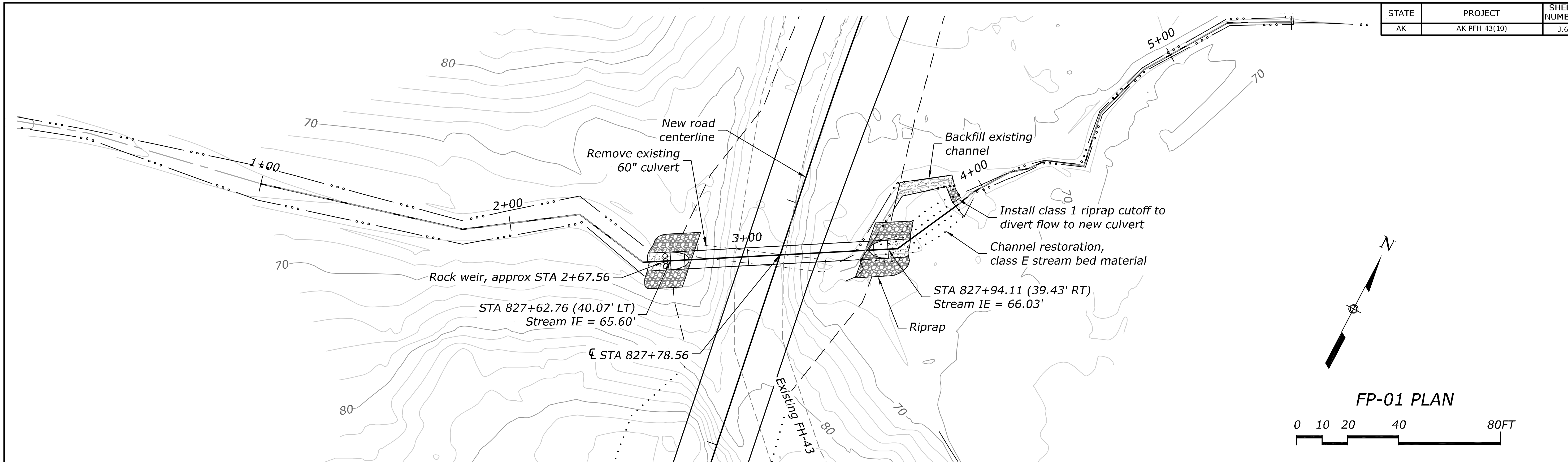
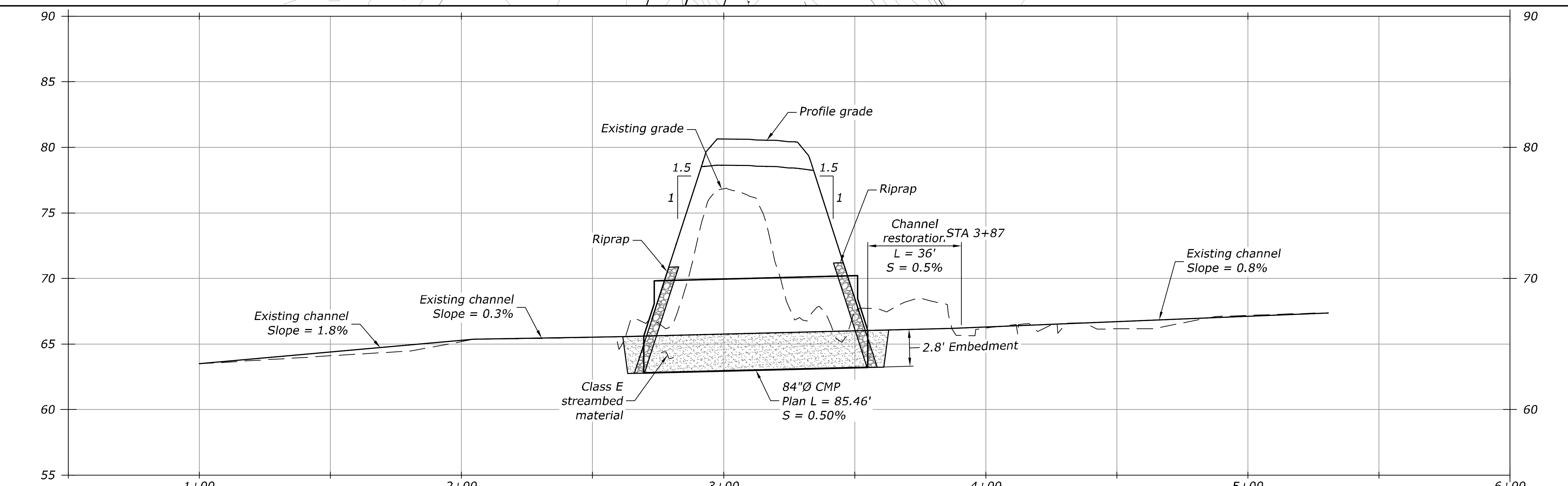
APPENDIX A

Design Plans

STATE	PROJECT	SHEET NUMBER
AK	AK PFH 43(10)	J.6



FP-01 PLAN



FP-01 PROFILE

5:1 Vertical exaggeration

Notes:

Drainage area (sq-mi)	= 0.14		Q50 Headwater elevation (ft)	=	70.85
Design exceedance	= 2%		Q50 Tailwater elevation (ft)	=	69.55
Q2 (cfs)	= 51.43		Overtopping flood (cfs)	=	258
Q50 (cfs)	= 111.04		Overtopping probability	<	0.2%
QFish (cfs)	= 20.57		Overtopping elevation (ft)	=	78.55
Fish species	= CT, DV		Hw/D ratio Q50	=	1.15
Design bankfull width (ft)	= 4				

Notes:

1. Do not begin construction until Title 16 permit is received. Any additional requirements in the Title 16 permit shall be met and documented in the project asbuilts.
2. Field verify inlet elevations, outlet elevations, and slope.
3. Overtopping elevation measured at top of subgrade.

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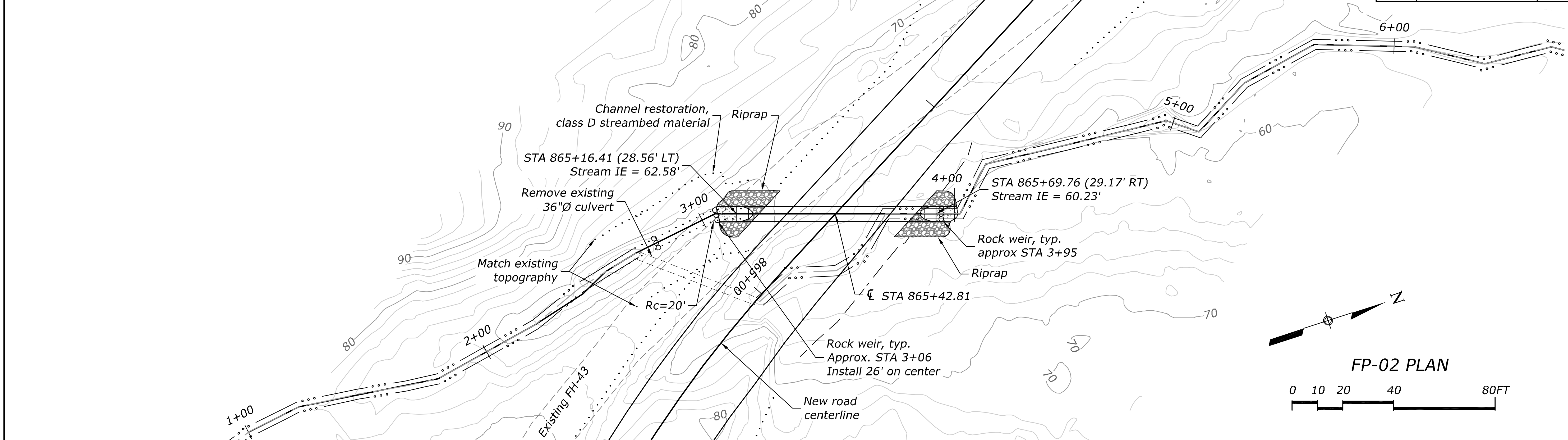
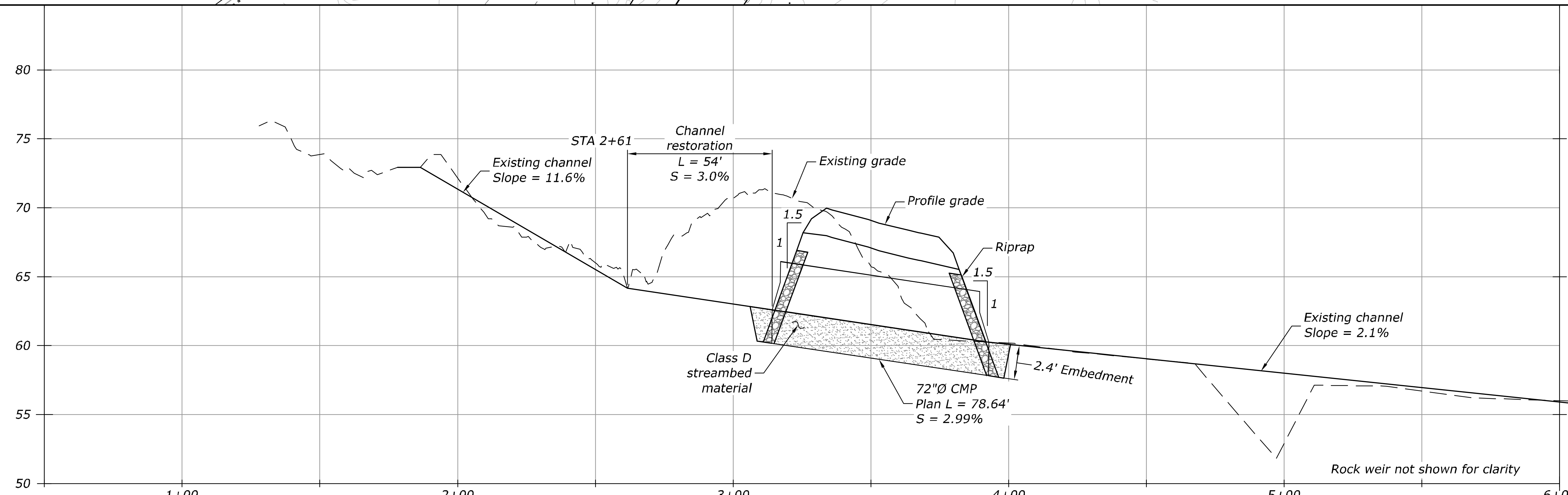
STATE	PROJECT	SHEET NUMBER
AK	AK PFH 43(10)	J.7



FP-02 PLAN



FP-02 PROFILE

5:1 Vertical exaggeration

Notes:

1. Do not begin construction until Title 16 permit is received. Any additional requirements in the Title 16 permit shall be met and documented in the project asbuilts.
2. Field verify inlet elevations, outlet elevations, and slope.
3. Overtopping elevation measured at top of subgrade.

Notes:

Drainage area (sq-mi)	=	0.01	Q50 Headwater elevation (ft)	=	63.51
Design exceedance	=	2%	Q50 Tailwater elevation (ft)	=	61.78
Q2 (cfs)	=	5.36	Overtopping flood (cfs)	=	106
Q50 (cfs)	=	11.80	Overtopping probability	<	0.2%
QFish (cfs)	=	2.14	Overtopping elevation (ft)	=	66.89
Fish species	=	SS, CT, DV	Hw/D ratio Q50	=	0.26
Design bankfull width (ft)	=	3			

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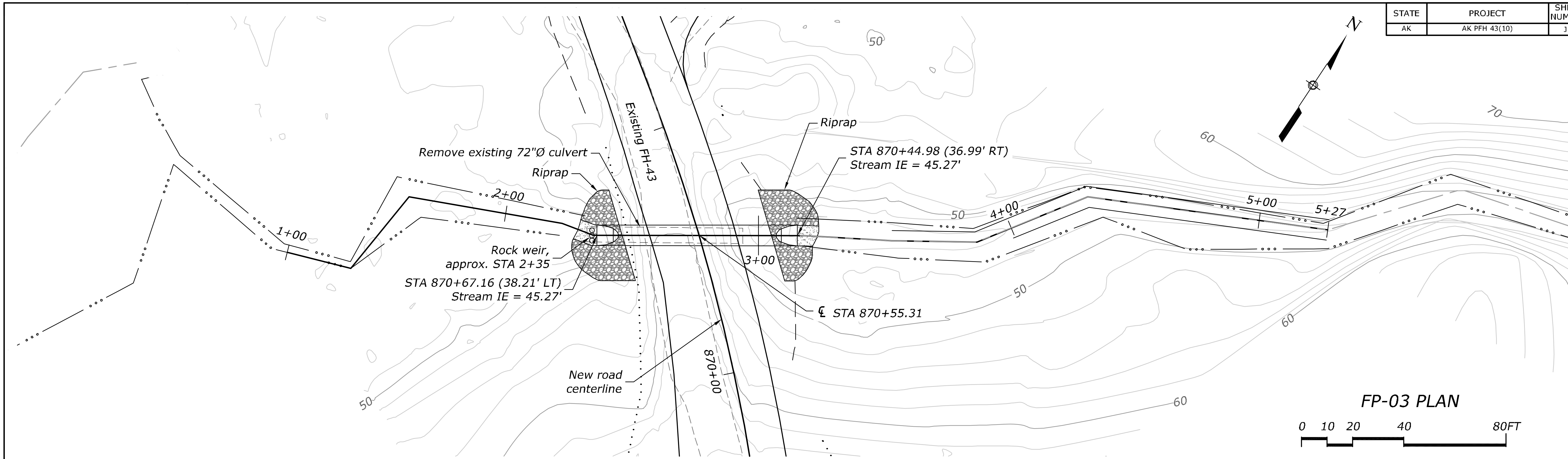
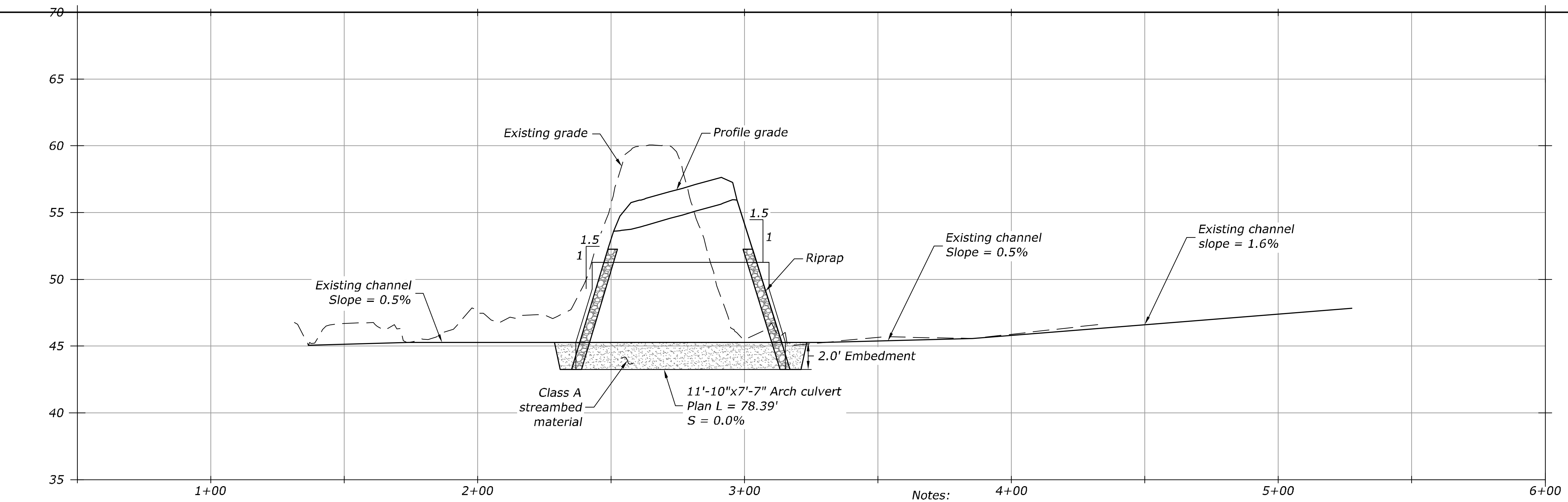
STATE	PROJECT	SHEET NUMBER
AK	AK PFH 43(10)	J.8



FP-03 PLAN



FP-03 PROFILE
5:1 Vertical exaggeration

Notes:

1. Do not begin construction until Title 16 permit is received. Any additional requirements in the Title 16 permit shall be met and documented in the project asbuilts.
2. Field verify inlet elevations, outlet elevations, and slope.
3. Overtopping elevation measured at top of subgrade.

Notes:

Drainage area (sq-mi)	=	0.40	Q50 Headwater elevation (ft)	=	49.96
Design exceedance	=	2%	Q50 Tailwater elevation (ft)	=	48.29
Q2 (cfs)	=	87.40	Overtopping flood (cfs)	=	522
Q50 (cfs)	=	185.39	Overtopping probability	<	0.2%
QFish (cfs)	=	34.96	Overtopping elevation (ft)	=	54.57
Fish species	=	CT	Hw/D ratio Q50	=	0.84
Design bankfull width (ft)	=	9.8			

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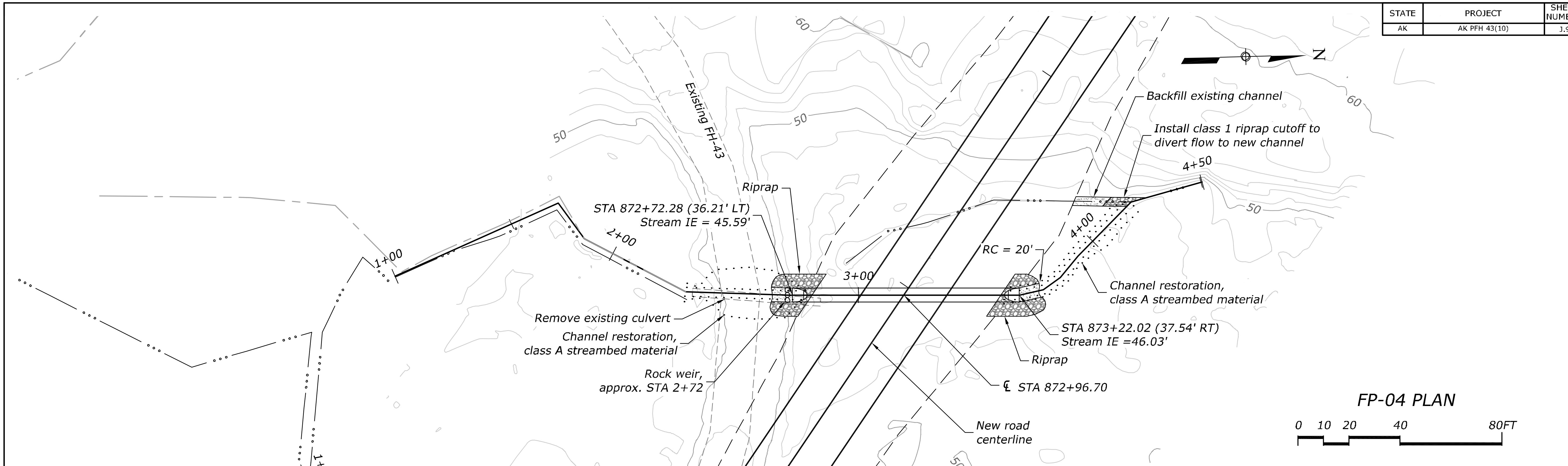
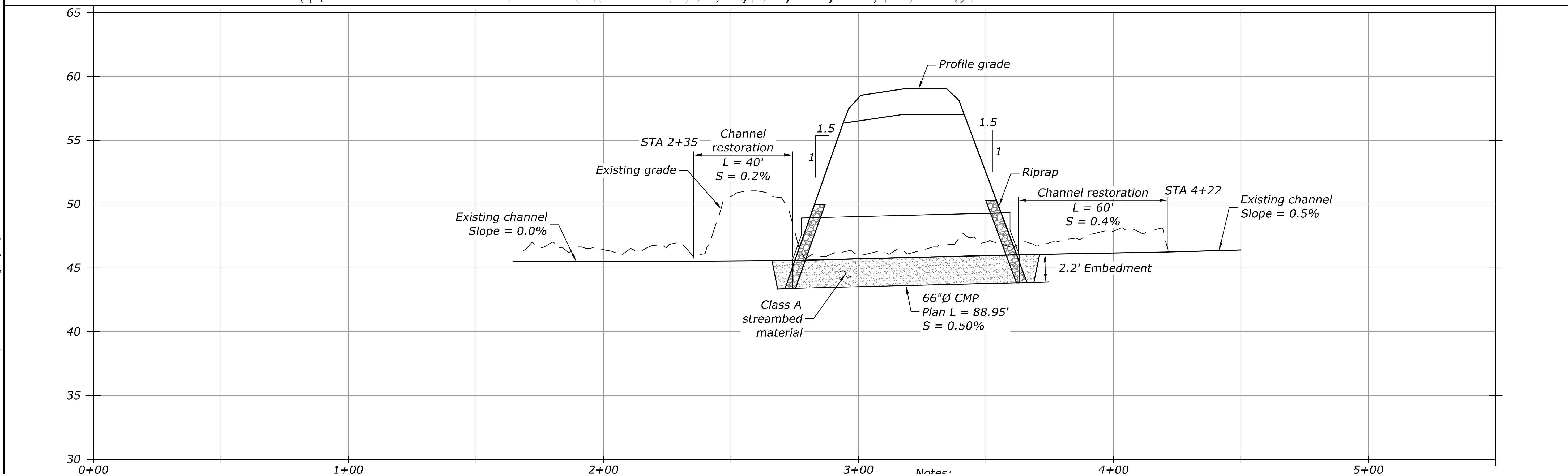
STATE	PROJECT	SHEET NUMBER
AK	AK PFH 43(10)	J.9



FP-04 PLAN



FP-04 PROFILE

5:1 Vertical exaggeration

Notes:

1. Do not begin construction until Title 16 permit is received. Any additional requirements in the Title 16 permit shall be met and documented in the project asbuilts.
2. Field verify inlet elevations, outlet elevations, and slope.
3. Overtopping elevation measured at top of subgrade.

Notes:

Drainage area (sq-mi)	= 0.01		Q50 Headwater elevation (ft)	= 47.83	
Design exceedance	= 2%		Q50 Tailwater elevation (ft)	= 47.42	
Q2 (cfs)	= 7.20		Overtopping flood (cfs)	= 116	
Q50 (cfs)	= 15.83		Overtopping probability	< 0.2%	
QFish (cfs)	= 2.88		Overtopping elevation (ft)	= 57.04	
Fish species	= CT, DV		Hw/D ratio Q50	= 0.55	
Design bankfull width (ft)	= 3.5				

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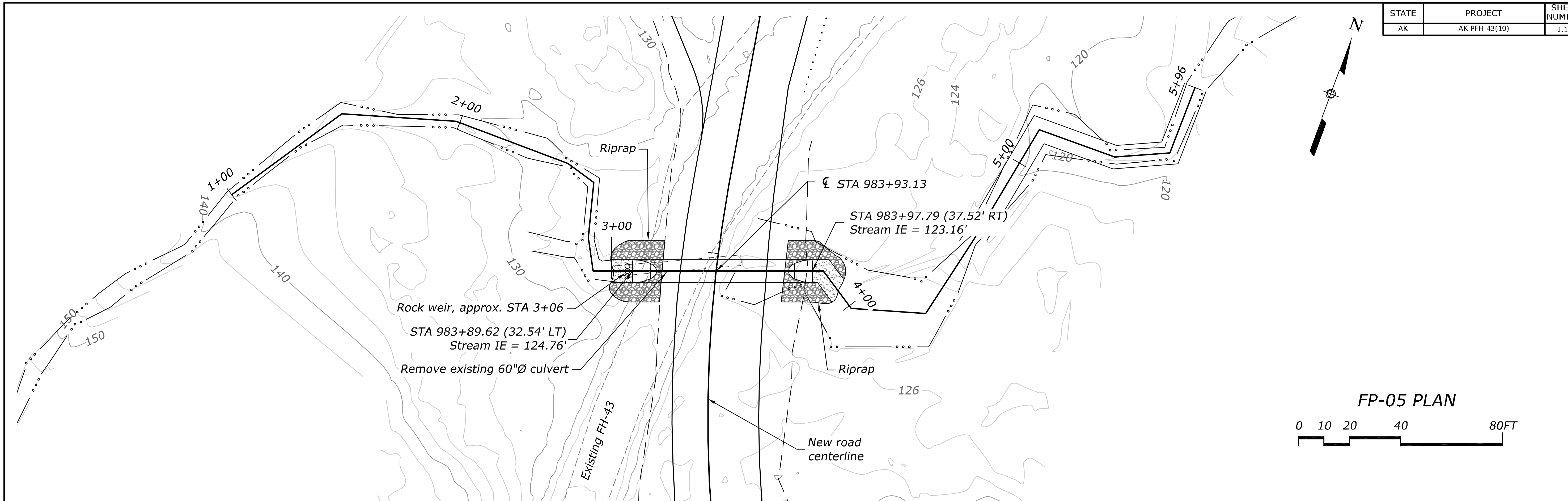
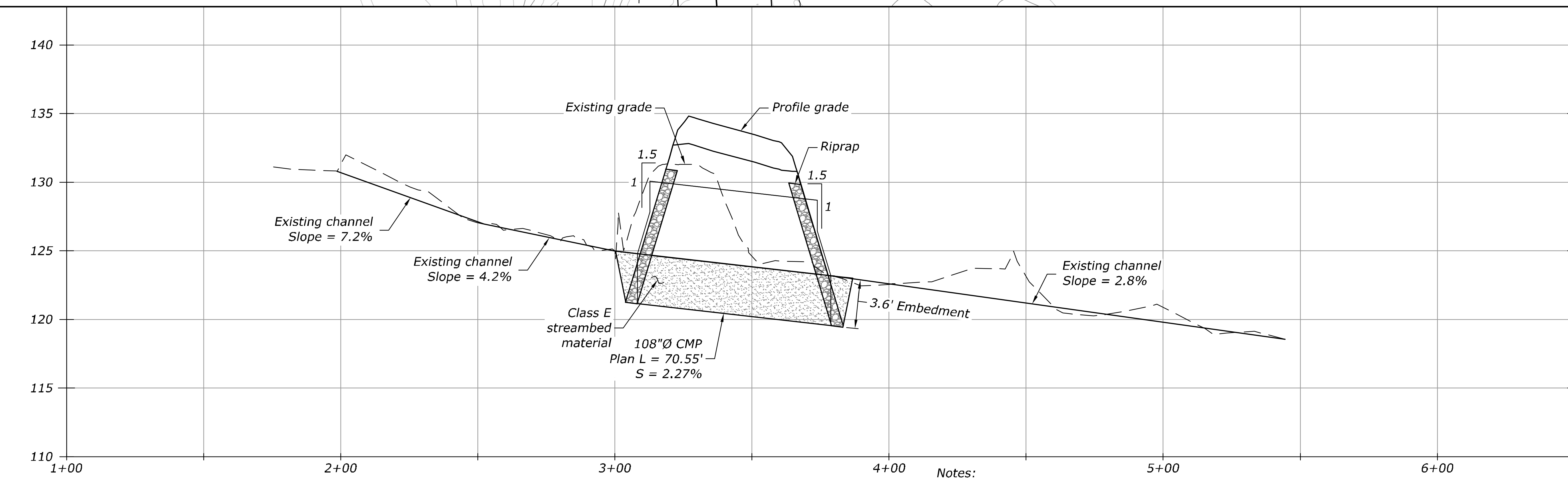
STATE	PROJECT	SHEET NUMBER
AK	AK PFH 43(10)	J.10



FP-05 PLAN



FP-05 PROFILE

5:1 Vertical exaggeration

Notes:

1. Do not begin construction until Title 16 permit is received. Any additional requirements in the Title 16 permit shall be met and documented in the project asbuilts.
2. Field verify inlet elevations, outlet elevations, and slope.
3. Overtopping elevation measured at top of subgrade.

Notes:

Drainage area (sq-mi)	=	0.14	Q50 Headwater elevation (ft)	=	127.88
Design exceedance	=	2%	Q50 Tailwater elevation (ft)	=	125.51
Q2 (cfs)	=	50.55	Overtopping flood (cfs)	=	334
Q50 (cfs)	=	109.15	Overtopping probability	<	0.2%
QFish (cfs)	=	20.22	Overtopping elevation (ft)	=	131.99
Fish species	=	DV	Hw/D ratio Q50	=	0.58
Design bankfull width (ft)	=	7			

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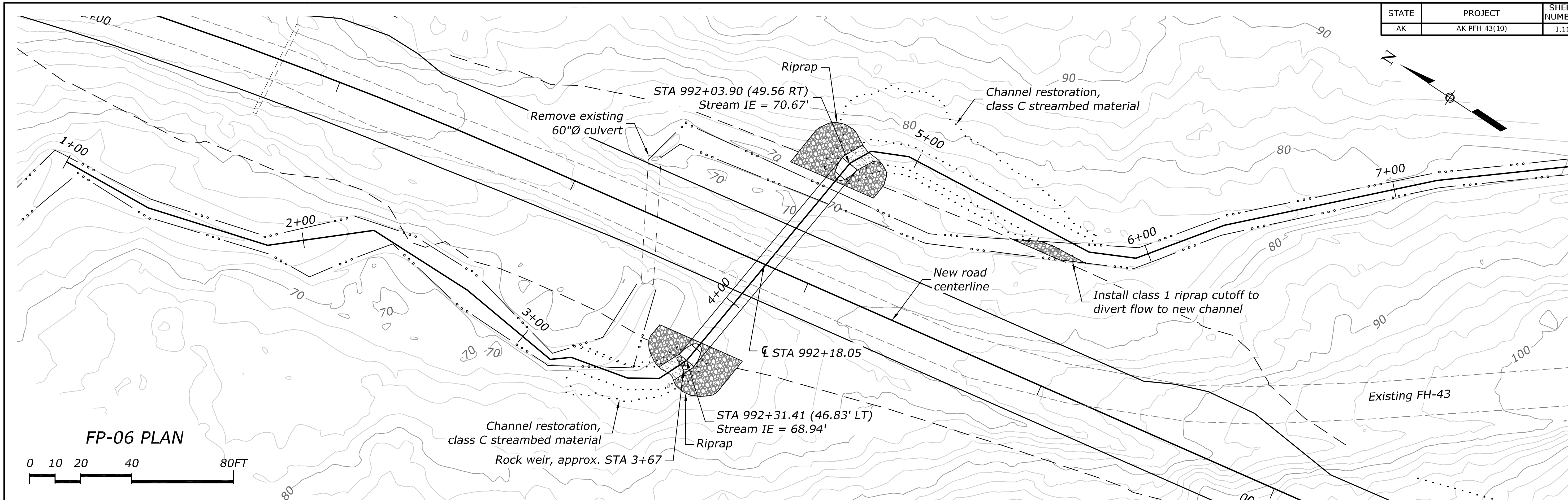
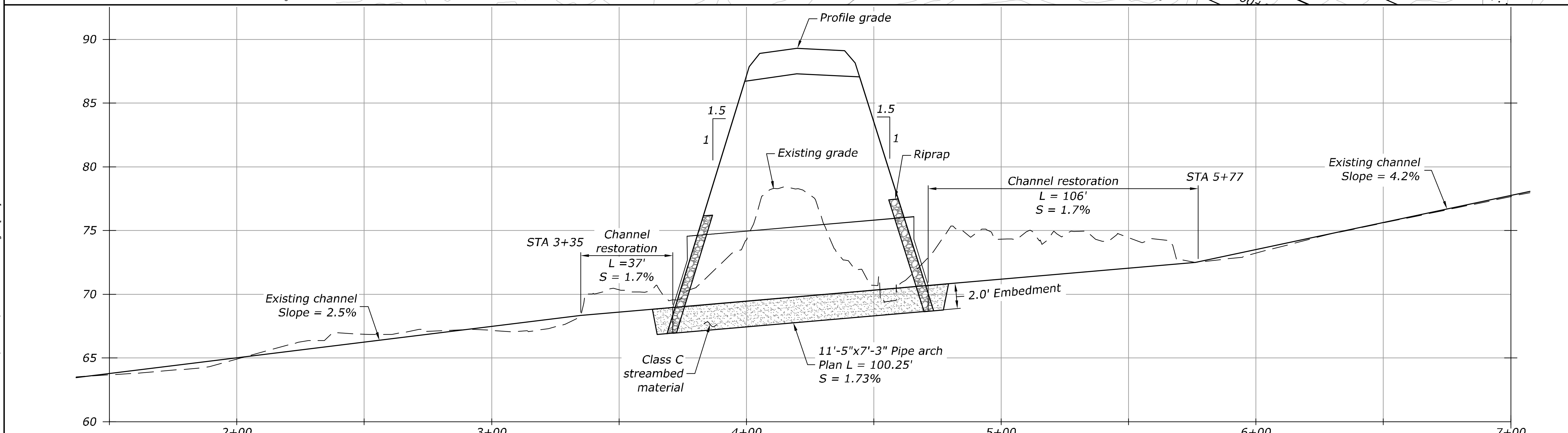
STATE	PROJECT	SHEET NUMBER
AK	AK PFH 43(10)	J.11





FP-06 PROFILE

5:1 Vertical exaggeration

Notes:

1. Do not begin construction until Title 16 permit is received. Any additional requirements in the Title 16 permit shall be met and documented in the project asbuilts.
2. Field verify inlet elevations, outlet elevations, and slope.
3. Overtopping elevation measured at top of subgrade.

Notes:

Drainage area (sq-mi)	=	0.18	Q50 Headwater elevation (ft)	=	73.90
Design exceedance	=	2%	Q50 Tailwater elevation (ft)	=	71.37
Q2 (cfs)	=	62.86	Overtopping flood (cfs)	=	601
Q50 (cfs)	=	135.47	Overtopping probability	<	0.2%
QFish (cfs)	=	25.14	Overtopping elevation (ft)	=	87.30
Fish species	=	CT, DV	Hw/D ratio Q50	=	0.64
Design bankfull width (ft)	=	9			

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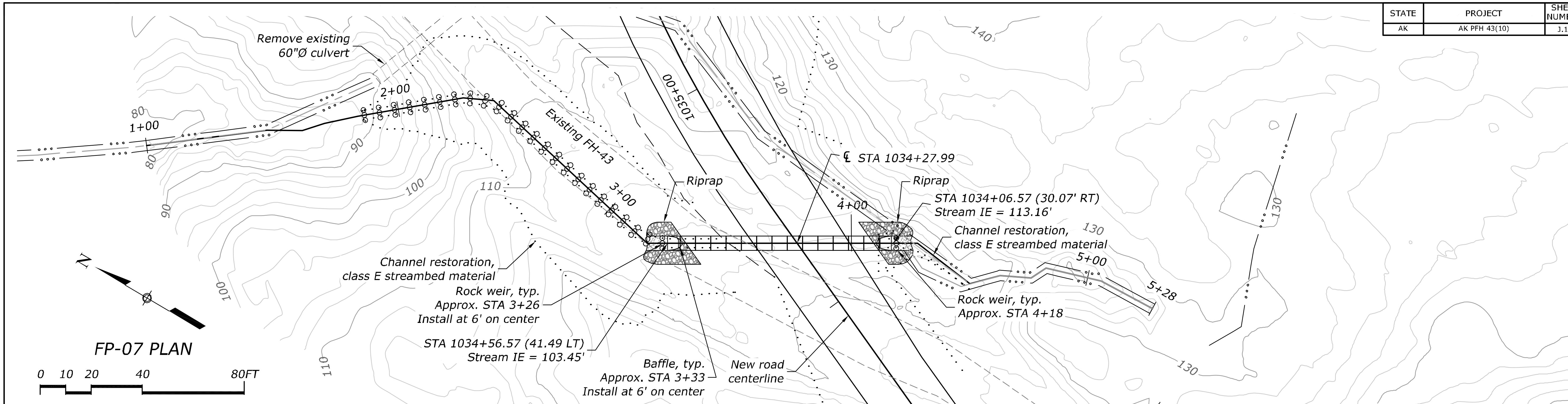
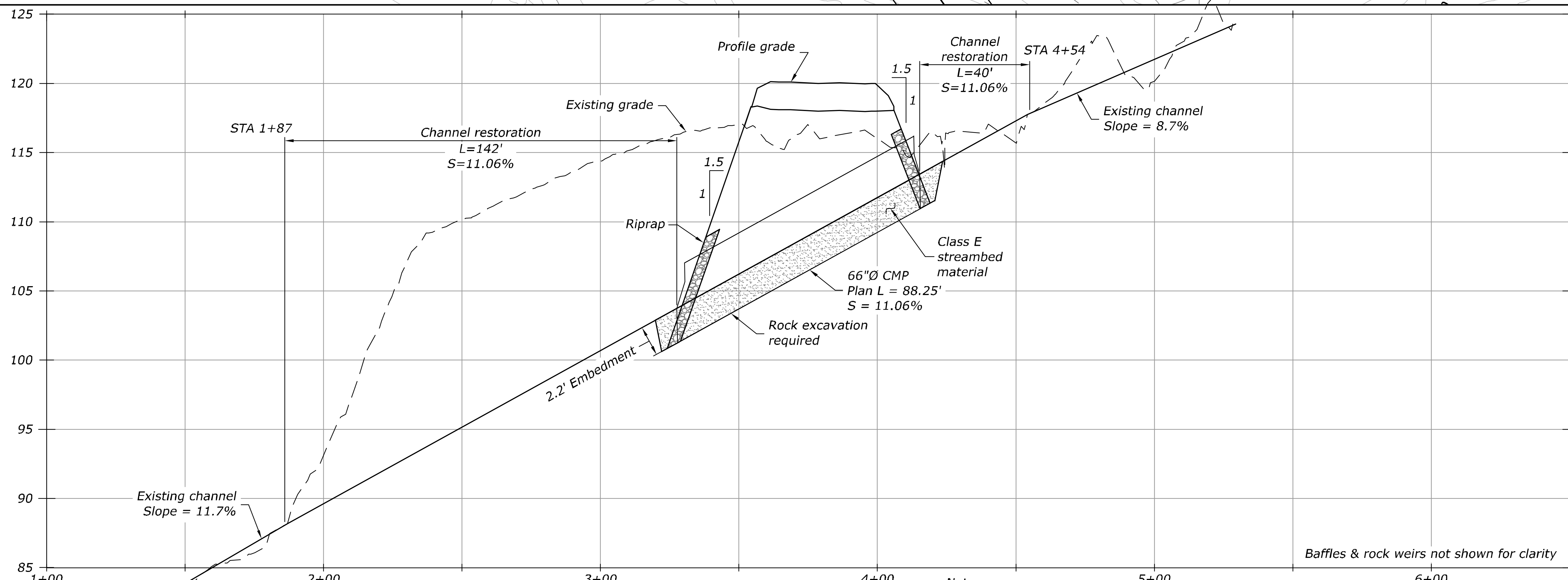
STATE	PROJECT	SHEET NUMBER
AK	AK PFH 43(10)	J.12



FP-07 PLAN



FP-07 PROFILE

5:1 Vertical exaggeration

Notes:

1. Do not begin construction until Title 16 permit is received. Any additional requirements in the Title 16 permit shall be met and documented in the project asbuilts.
2. Field verify inlet elevations, outlet elevations, and slope.
3. Overtopping elevation measured at top of subgrade.
4. For channels excavated in bedrock, construct step pools within proposed channel profile to match existing channel conditions at a spacing approximately equal to the rock weirs or baffles installed within proposed AOP structure. Install streambed within excavated channels in-between excavated pools.

Notes:

Drainage area (sq-mi)	=	0.04	Q50 Headwater elevation (ft)	=	114.43
Design exceedance	=	2%	Q50 Tailwater elevation (ft)	=	104.74
Q2 (cfs)	=	16.72	Overtopping flood (cfs)	=	160
Q50 (cfs)	=	36.45	Overtopping probability	<	0.2%
QFish (cfs)	=	6.69	Overtopping elevation (ft)	=	117.98
Fish species	=	SS, CT, DV	Hw/D ratio Q50	=	0.38
Design bankfull width (ft)	=	3.5			

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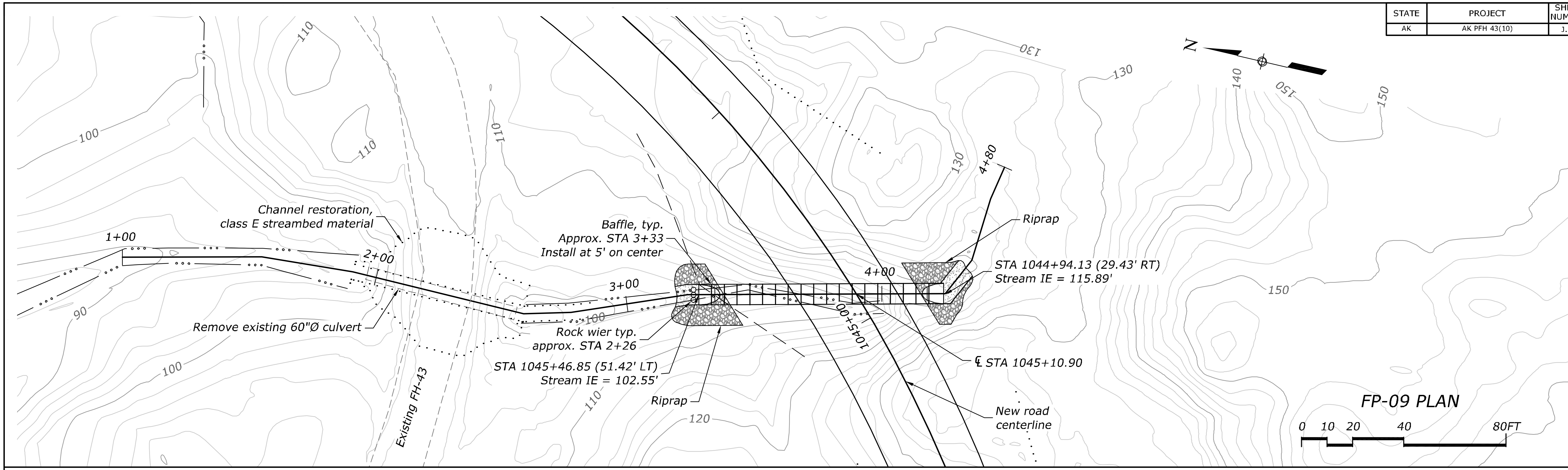
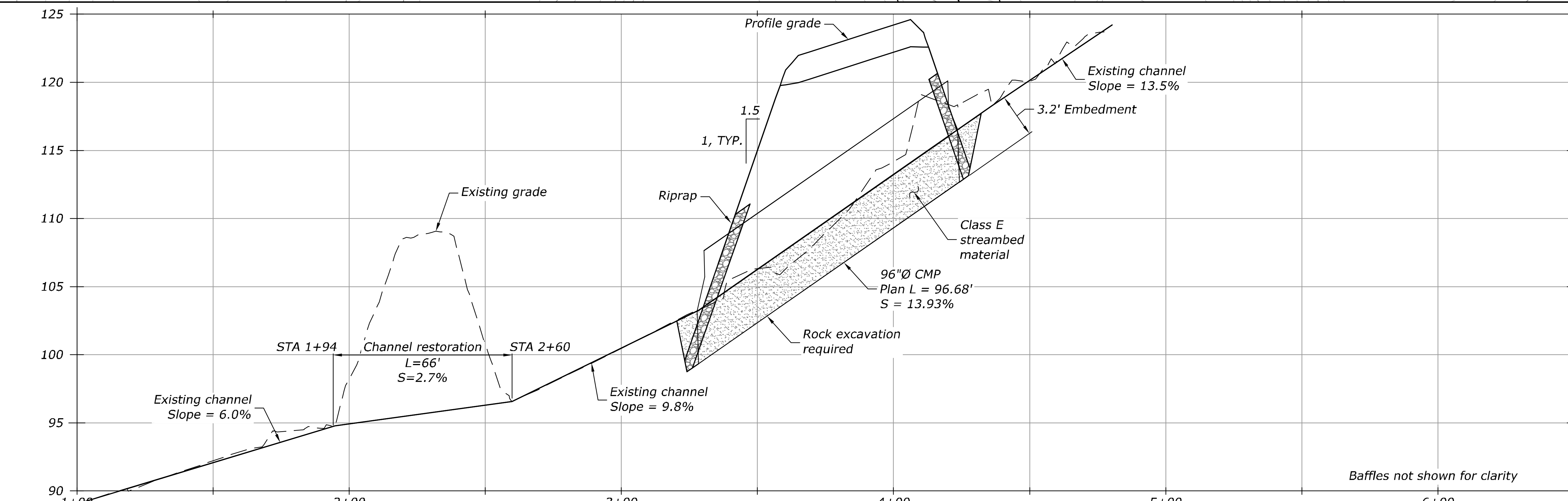
STATE	PROJECT	SHEET NUMBER
AK	AK PFH 43(10)	J.13



FP-09 PLAN



FP-09 PROFILE

5:1 Vertical exaggeration

Notes:

1. Do not begin construction until Title 16 permit is received. Any additional requirements in the Title 16 permit shall be met and documented in the project asbuilts.
2. Field verify inlet elevations, outlet elevations, and slope.
3. Overtopping elevation measured at top of subgrade.
4. For channels excavated in bedrock, construct step pools within proposed channel profile to match existing channel conditions at a spacing approximately equal to the rock weirs or baffles installed within proposed AOP structure. Install streambed within excavated channels in-between excavated pools.

Notes:

Drainage area (sq-mi)	= 0.11		Q50 Headwater elevation (ft)	=	117.65
Design exceedance	= 2%		Q50 Tailwater elevation (ft)	=	103.98
Q2 (cfs)	= 42.54		Overtopping flood (cfs)	=	318
Q50 (cfs)	= 92.01		Overtopping probability	<	0.2%
QFish (cfs)	= 17.02		Overtopping elevation (ft)	=	121.15
Fish species	= CT, DV, SH		Hw/D ratio Q50	=	0.37
Design bankfull width (ft)	= 6				

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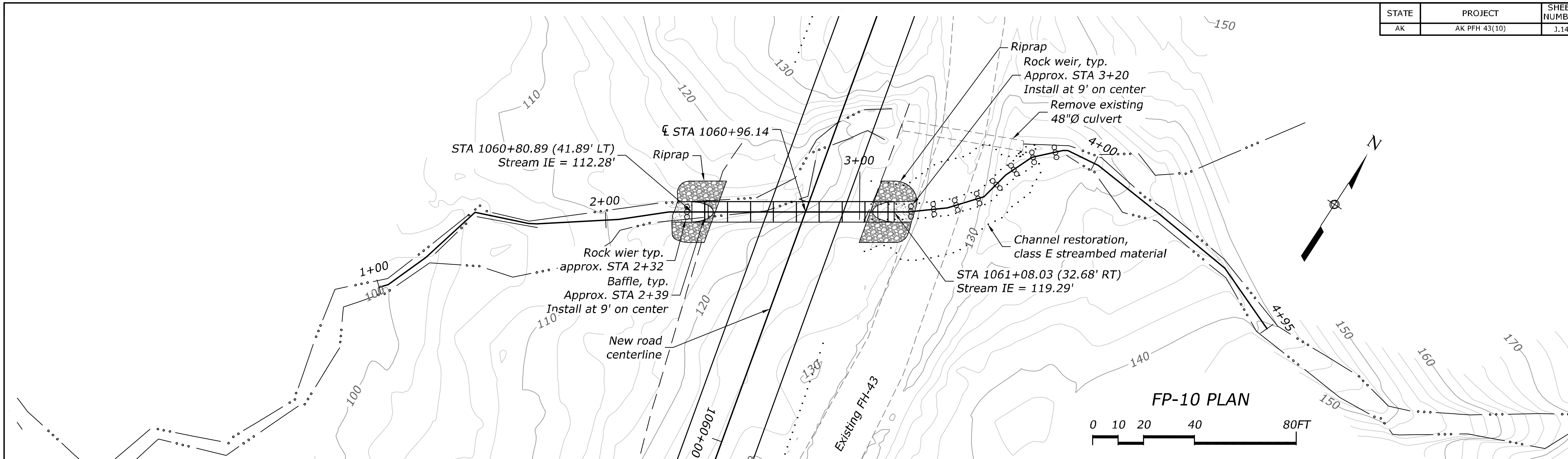
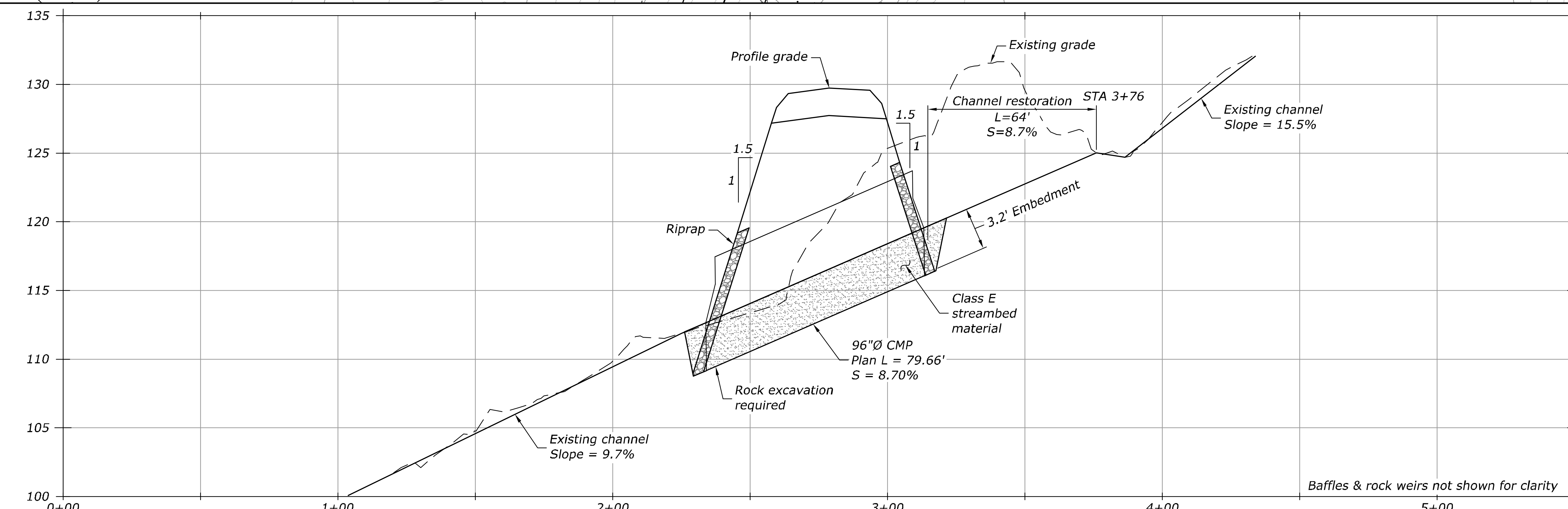
STATE	PROJECT	SHEET NUMBER
AK	AK PFH 43(10)	J.14



FP-10 PLAN



FP-10 PROFILE
5:1 Vertical exaggeration

Notes:

1. Do not begin construction until Title 16 permit is received. Any additional requirements in the Title 16 permit shall be met and documented in the project asbuilts.
2. Field verify inlet elevations, outlet elevations, and slope.
3. Overtopping elevation measured at top of subgrade.
4. For channels excavated in bedrock, construct step pools within proposed channel profile to match existing channel conditions at a spacing approximately equal to the rock weirs or baffles installed within proposed AOP structure. Install streambed within excavated channels in-between excavated pools.

Notes:

Drainage area (sq-mi)	= 0.13	Q50 Headwater elevation (ft)	=	121.39
Design exceedance	= 2%	Q50 Tailwater elevation (ft)	=	113.67
Q2 (cfs)	= 48.74	Overtopping flood (cfs)	=	469
Q50 (cfs)	= 105.28	Overtopping probability	<	0.2%
QFish (cfs)	= 19.50	Overtopping elevation (ft)	=	127.73
Fish species	= CT, DV, SH	Hw/D ratio Q50	=	0.44
Design bankfull width (ft)	= 6			

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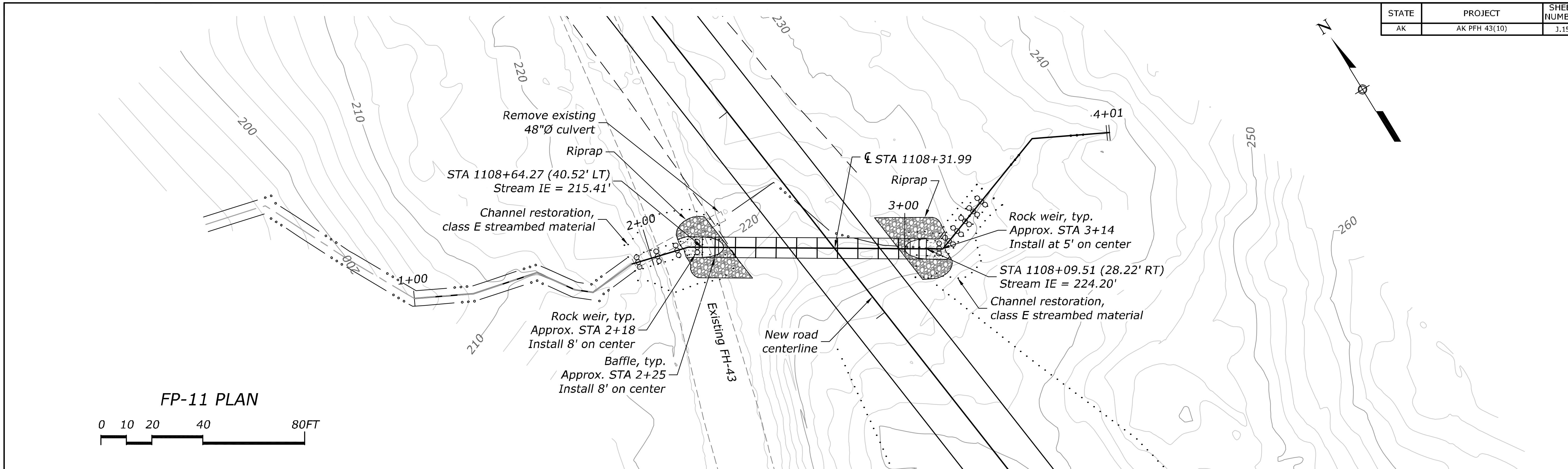
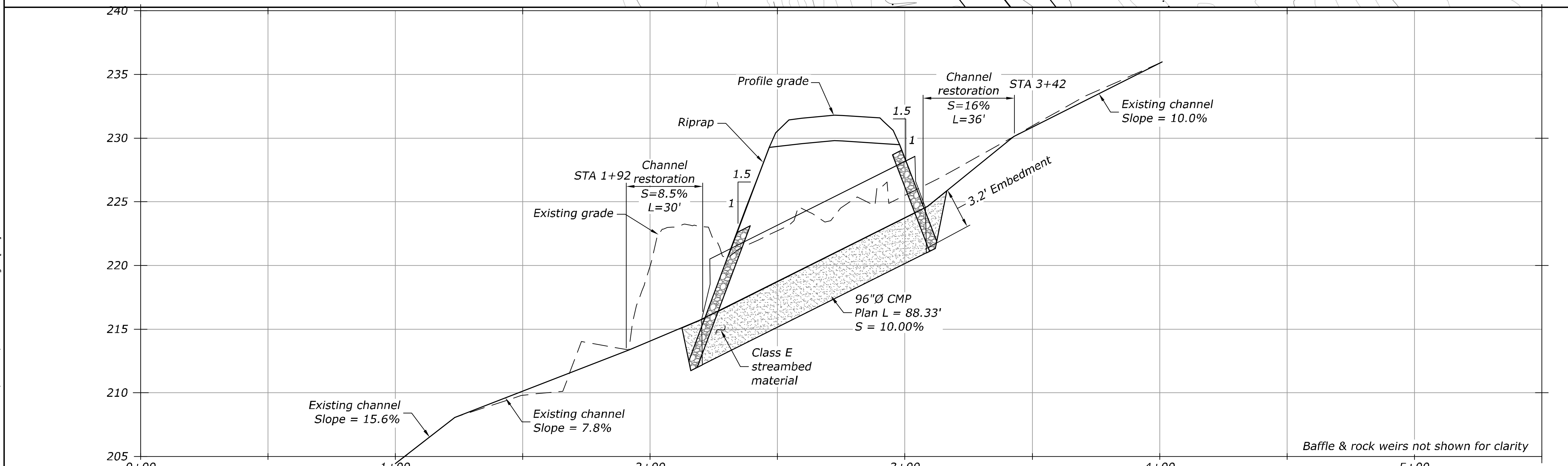
STATE	PROJECT	SHEET NUMBER
AK	AK PFH 43(10)	J.15



FP-11 PLAN



FP-11 PROFILE

5:1 Vertical exaggeration

Notes:

1. Do not begin construction until Title 16 permit is received. Any additional requirements in the Title 16 permit shall be met and documented in the project asbuilts.
2. Field verify inlet elevations, outlet elevations, and slope.
3. Overtopping elevation measured at top of subgrade.

Notes:

Drainage area (sq-mi)	= 0.10	Q50 Headwater elevation (ft)	= 225.62
Design exceedance	= 2%	Q50 Tailwater elevation (ft)	= 216.49
Q2 (cfs)	= 30.88	Overtopping flood (cfs)	= 333
Q50 (cfs)	= 66.40	Overtopping probability	< 0.2%
QFish (cfs)	= 12.35	Overtopping elevation (ft)	= 229.81
Fish species	= CT	Hw/D ratio Q50	= 0.30
Design bankfull width (ft)	= 6		

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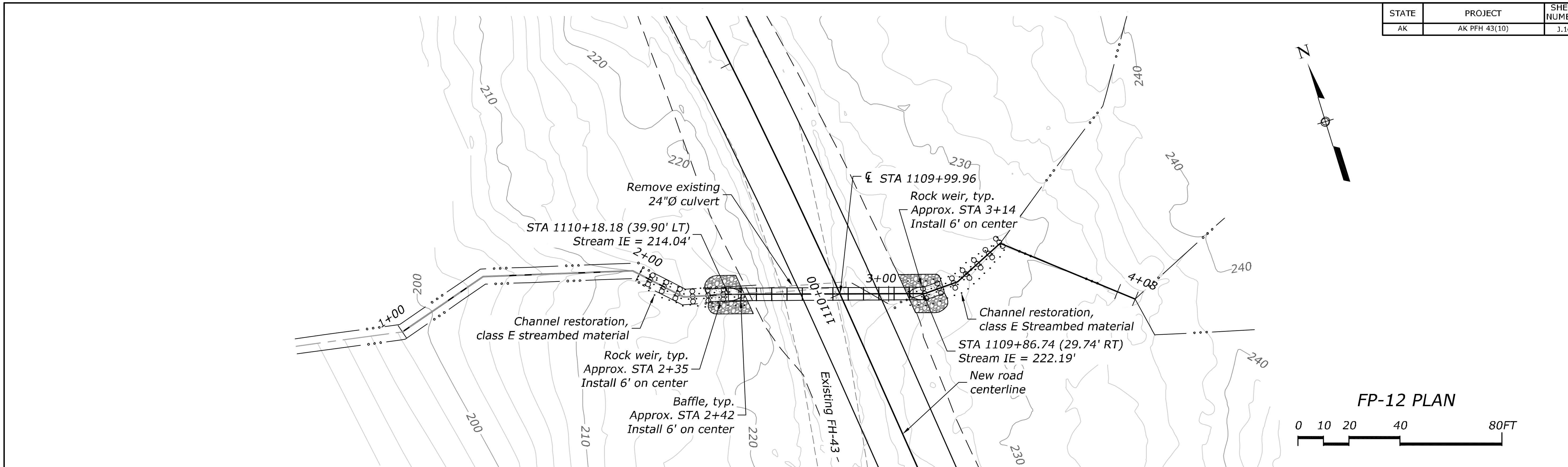
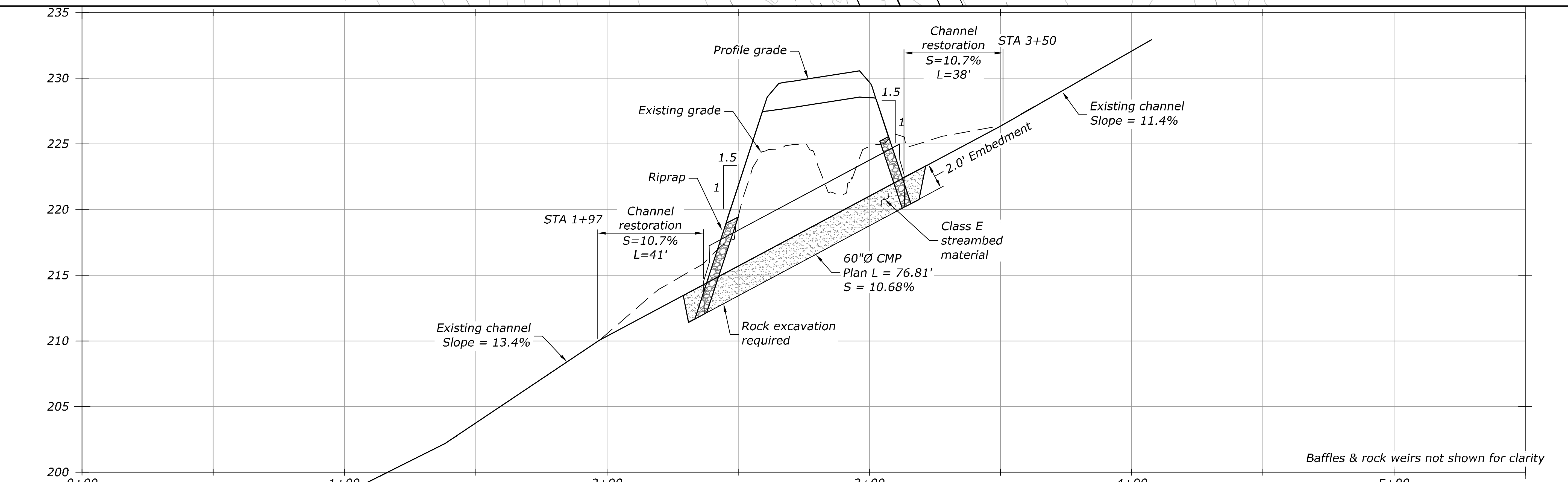
STATE	PROJECT	SHEET NUMBER
AK	AK PFH 43(10)	J.16



FP-12 PLAN



FP-12 PROFILE
5:1 Vertical exaggeration

Notes:

1. Do not begin construction until Title 16 permit is received. Any additional requirements in the Title 16 permit shall be met and documented in the project asbuilts.
2. Field verify inlet elevations, outlet elevations, and slope.
3. Overtopping elevation measured at top of subgrade.
4. For channels excavated in bedrock, construct step pools within proposed channel profile to match existing channel conditions at a spacing approximately equal to the rock weirs or baffles installed within proposed AOP structure. Install streambed within excavated channels in-between excavated pools.

Notes:

Drainage area (sq-mi)	= 0.02	Q50 Headwater elevation (ft)	= 223.14
Design exceedance	= 2%	Q50 Tailwater elevation (ft)	= 214.68
Q2 (cfs)	= 10.19	Overtopping flood (cfs)	= 127
Q50 (cfs)	= 22.32	Overtopping probability	< 0.2%
QFish (cfs)	= 4.08	Overtopping elevation (ft)	= 228.08
Fish species	= CT, DV	Hw/D ratio Q50	= 0.32
Design bankfull width (ft)	= 2.4		

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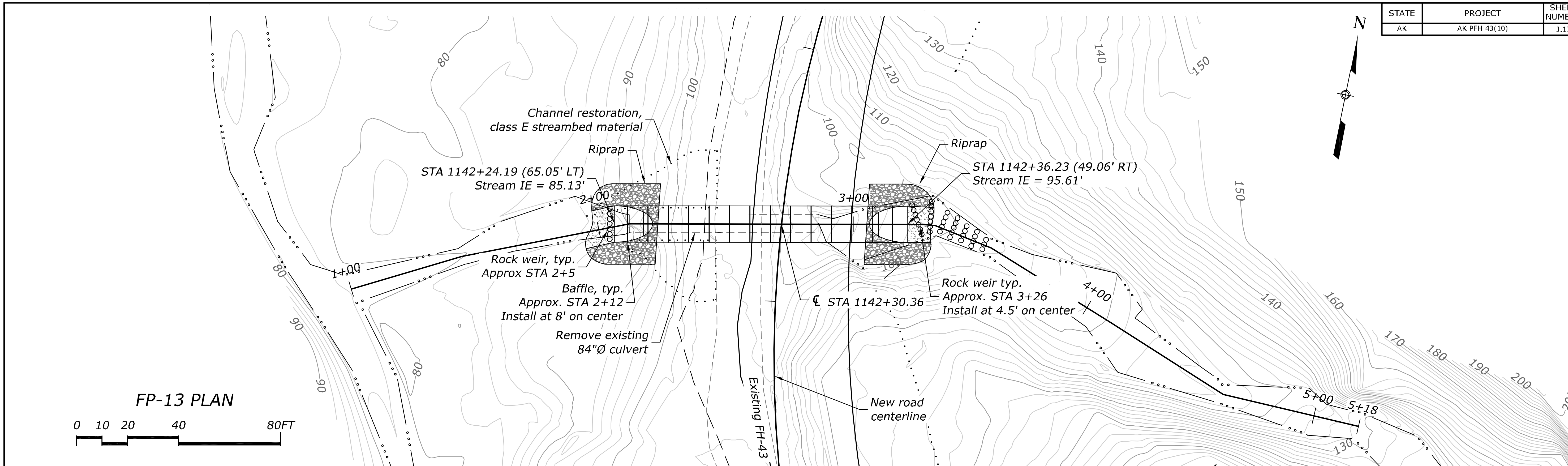
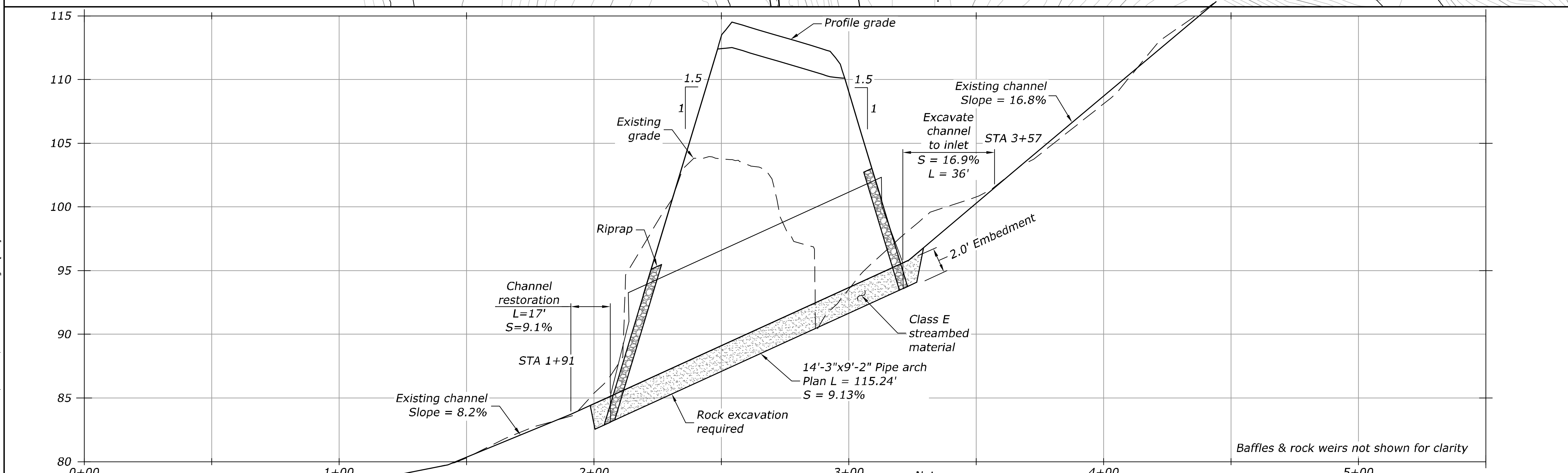
STATE	PROJECT	SHEET NUMBER
AK	AK PFH 43(10)	J.17



FP-13 PLAN

0 10 20 40 80FT



FP-13 PROFILE

5:1 Vertical exaggeration

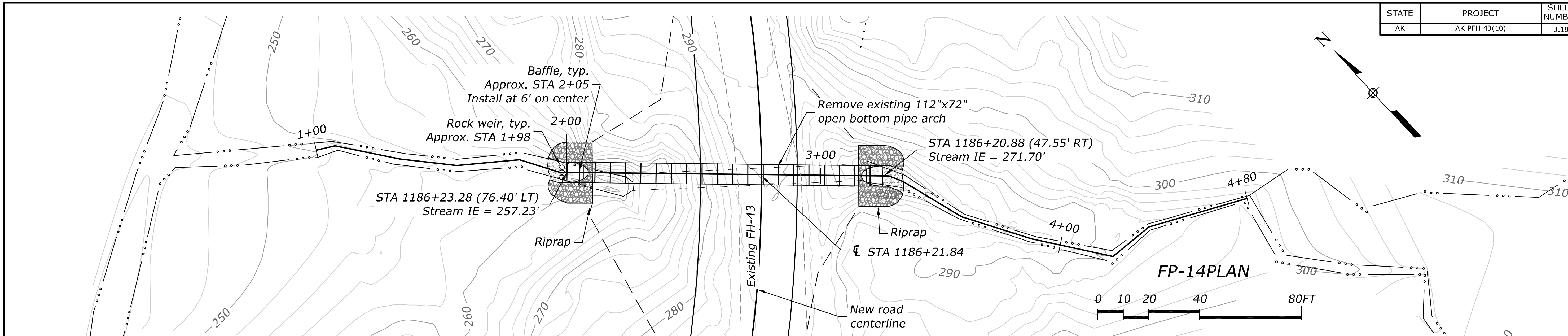
Notes:

1. Do not begin construction until Title 16 permit is received. Any additional requirements in the Title 16 permit shall be met and documented in the project asbuilts.
2. Field verify inlet elevations, outlet elevations, and slope.
3. Overtopping elevation measured at top of subgrade.
4. For channels excavated in bedrock, construct step pools within proposed channel profile to match existing channel conditions at a spacing approximately equal to the rock weirs or baffles installed within proposed AOP structure. Install streambed within excavated channels in-between excavated pools.

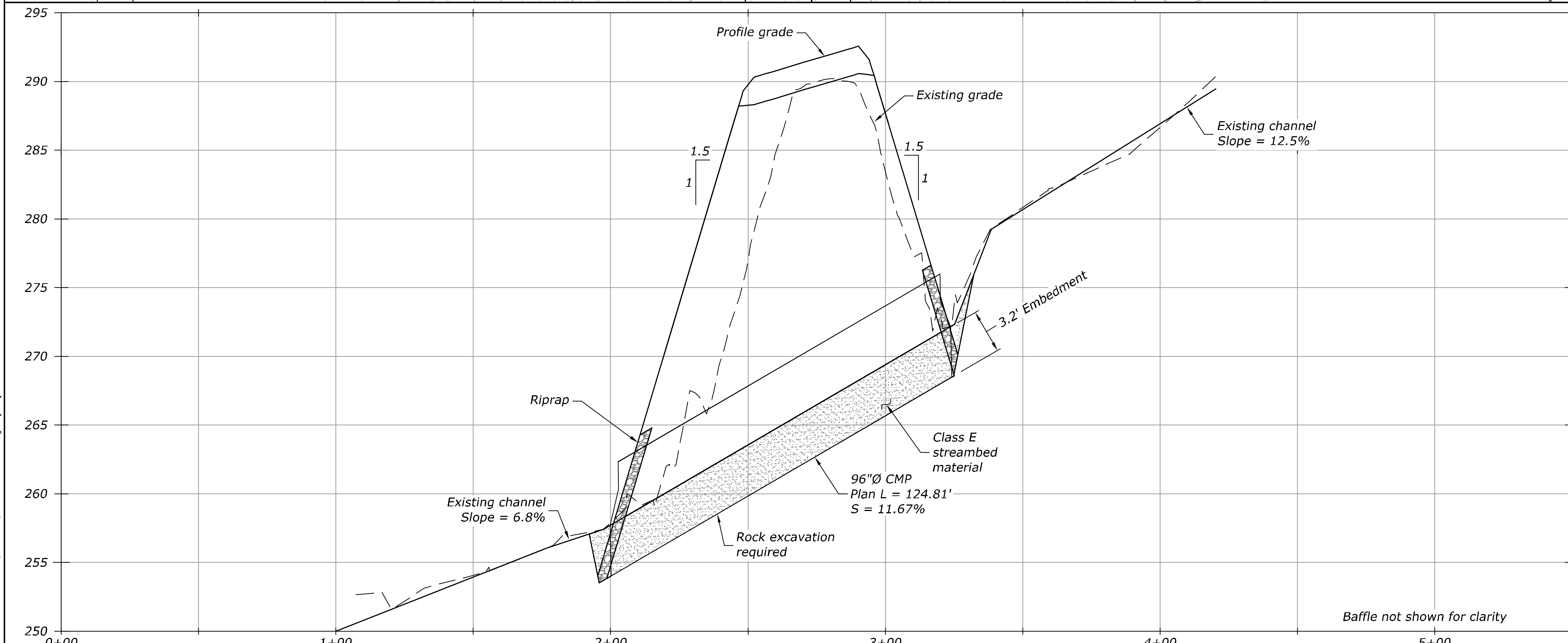
Notes:

Drainage area (sq-mi)	=	0.45	Q50 Headwater elevation (ft)	=	100.83
Design exceedance	=	2%	Q50 Tailwater elevation (ft)	=	86.41
Q2 (cfs)	=	99.43	Overtopping flood (cfs)	=	1232
Q50 (cfs)	=	210.80	Overtopping probability	<	0.2%
QFish (cfs)	=	39.77	Overtopping elevation (ft)	=	111.43
Fish species	=	SS,CT,DV,PS,SH	Hw/D ratio Q50	=	0.73
Design bankfull width (ft)	=	12.6			

STATE	PROJECT	SHEET NUMBER
AK	AK PFH 43(10)	J.18



FP-14PLAN



FP-14 PROFILE

5:1 Vertical exaggeration

Notes:

1. Do not begin construction until Title 16 permit is received. Any additional requirements in the Title 16 permit shall be met and documented in the project asbuilts.
2. Field verify inlet elevations, outlet elevations, and slope.
3. Overtopping elevation measured at top of subgrade.
4. For channels excavated in bedrock, construct step pools within proposed channel profile to match existing channel conditions at a spacing approximately equal to the rock weirs or baffles installed within proposed AOP structure. Install streambed within excavated channels in-between excavated pools.

Notes:

Drainage area (sq-mi)	=	0.08
Design exceedance	=	2%
Q2 (cfs)	=	32.52
Q50 (cfs)	=	70.49
QFish (cfs)	=	13.01
Fish species	=	CT
Design bankfull width (ft)	=	5
Q50 Headwater elevation (ft)	=	273.15
Q50 Tailwater elevation (ft)	=	258.82
Overtopping flood (cfs)	=	533
Overtopping probability	<	0.2%
Overtopping elevation (ft)	=	289.75
Hw/D ratio Q50	=	0.30

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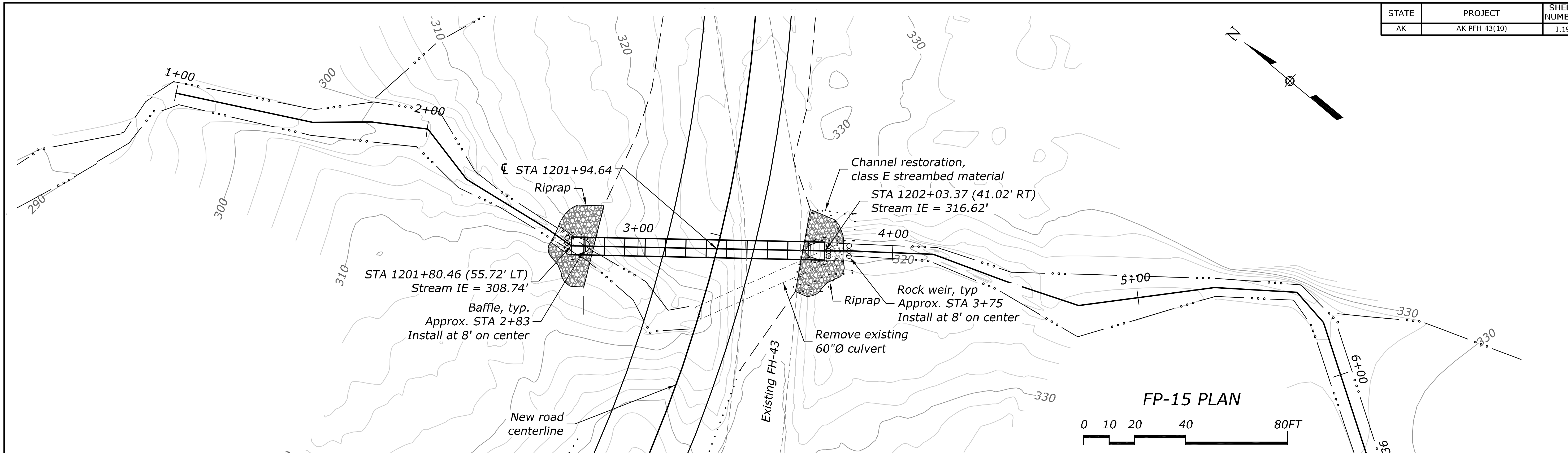
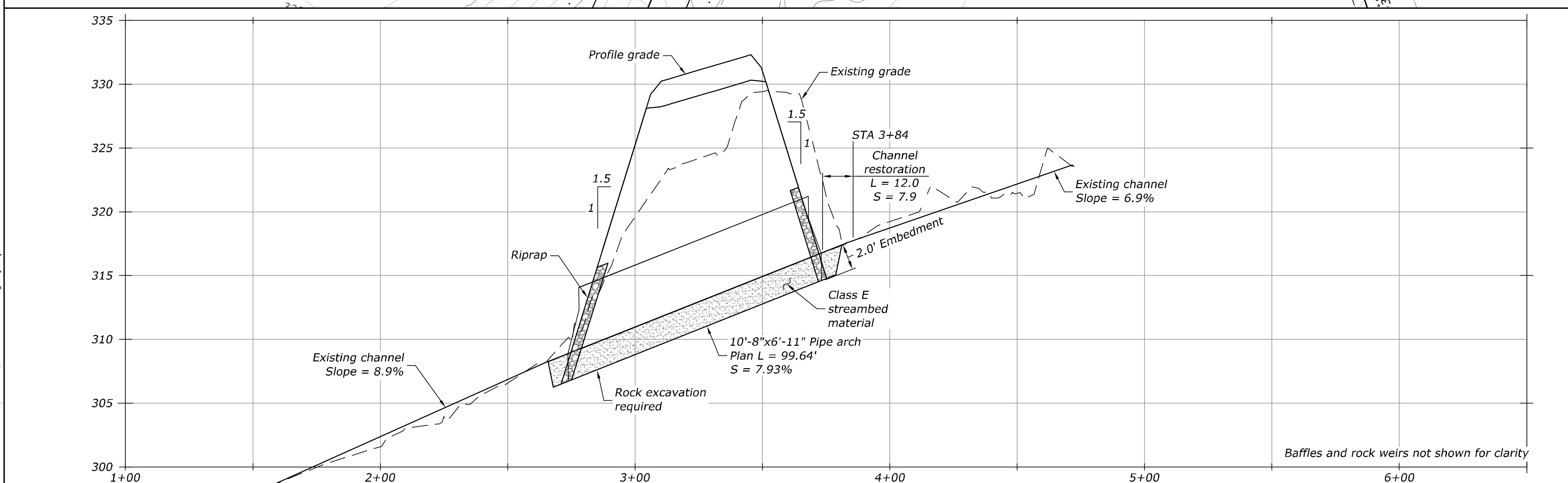
STATE	PROJECT	SHEET NUMBER
AK	AK PFH 43(10)	J.19



FP-15 PLAN



FP-15 PROFILE

5:1 Vertical exaggeration

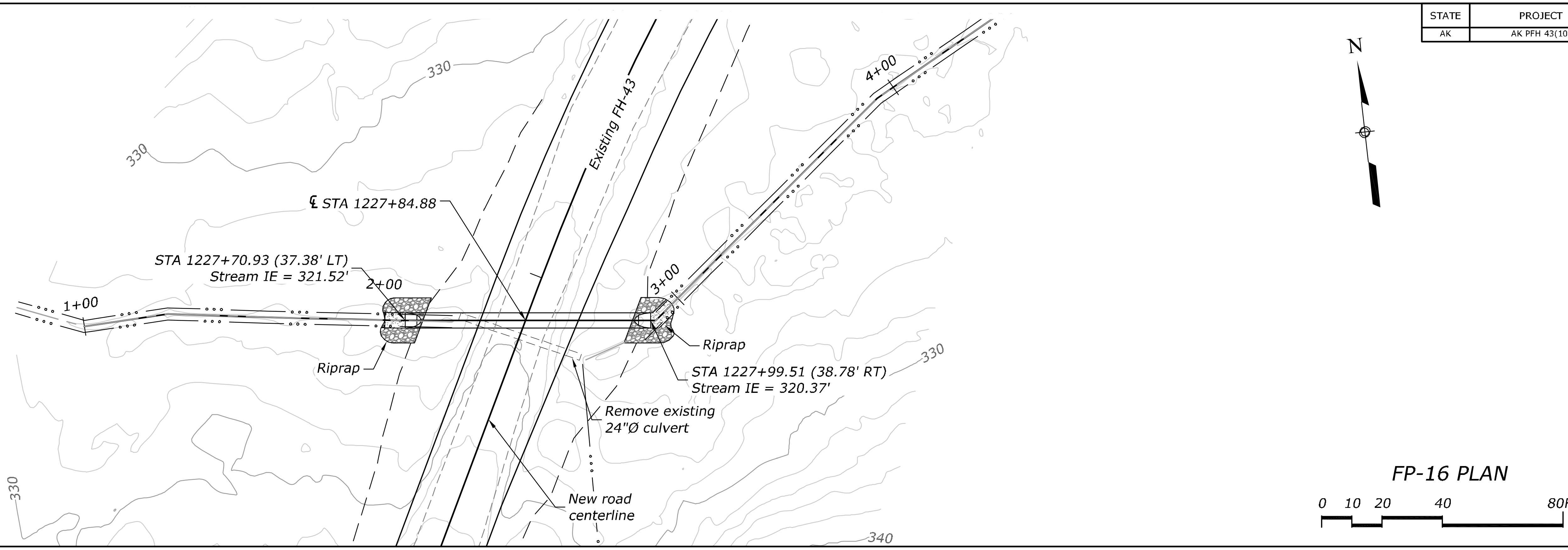
Notes:

1. Do not begin construction until Title 16 permit is received. Any additional requirements in the Title 16 permit shall be met and documented in the project asbuilts.
2. Field verify inlet elevations, outlet elevations, and slope.
3. Overtopping elevation measured at top of subgrade.
4. For channels excavated in bedrock, construct step pools within proposed channel profile to match existing channel conditions at a spacing approximately equal to the rock weirs or baffles installed within proposed AOP structure. Install streambed within excavated channels in-between excavated pools.

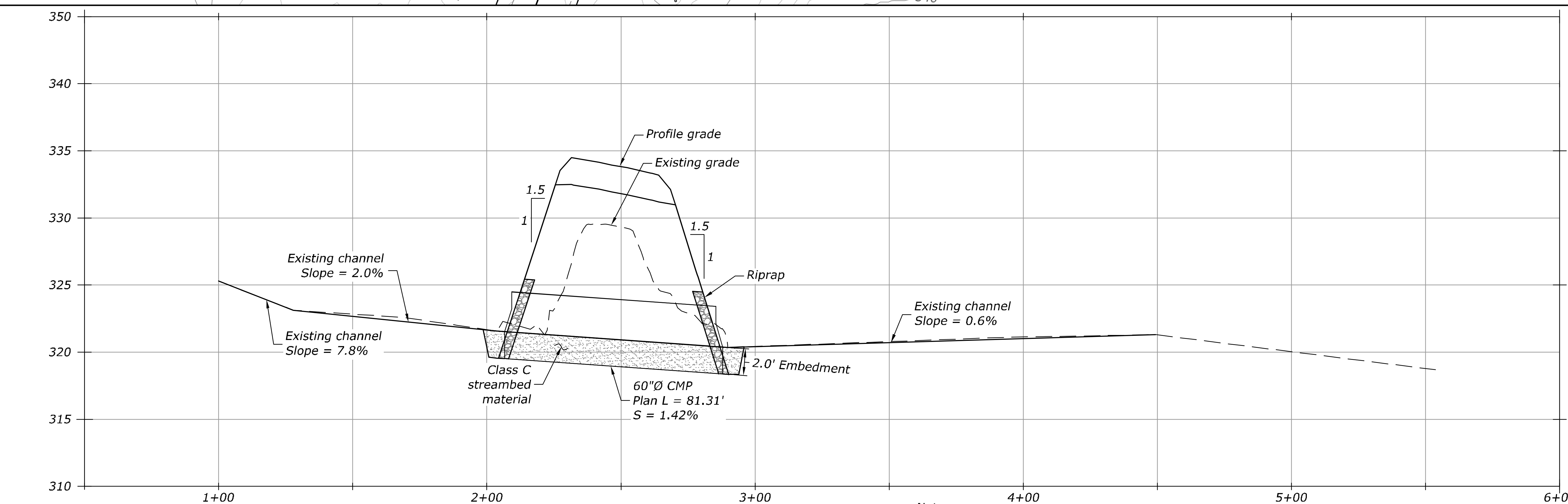
Notes:

Drainage area (sq-mi)	=	0.35	Q50 Headwater elevation (ft)	=	319.98
Design exceedance	=	2%	Q50 Tailwater elevation (ft)	=	310.35
Q2 (cfs)	=	65.63	Overtopping flood (cfs)	=	559
Q50 (cfs)	=	138.57	Overtopping probability	<	0.2%
QFish (cfs)	=	26.25	Overtopping elevation (ft)	=	329.34
Fish species	=	CT	Hw/D ratio Q50	=	0.68
Design bankfull width (ft)	=	8.2			

STATE	PROJECT	SHEET NUMBER
AK	AK PFH 43(10)	J.20



FP-16 PLAN



FP-16 PROFILE

5:1 Vertical exaggeration

Notes:

Drainage area (sq-mi)	= 0.01		Q50 Headwater elevation (ft)	=	323.14
Design exceedance	= 2%		Q50 Tailwater elevation (ft)	=	322.90
Q2 (cfs)	= 4.93		Overtopping flood (cfs)	=	86
Q50 (cfs)	= 10.87		Overtopping probability	<	0.2%
QFish (cfs)	= 1.97		Overtopping elevation (ft)	=	331.81
Fish species	= CT		Hw/D ratio Q50	=	0.54
Design bankfull width (ft)	= 2				

Notes:

1. Do not begin construction until Title 16 permit is received. Any additional requirements in the Title 16 permit shall be met and documented in the project asbuilts.
2. Field verify inlet elevations, outlet elevations, and slope.
3. Overtopping elevation measured at top of subgrade.

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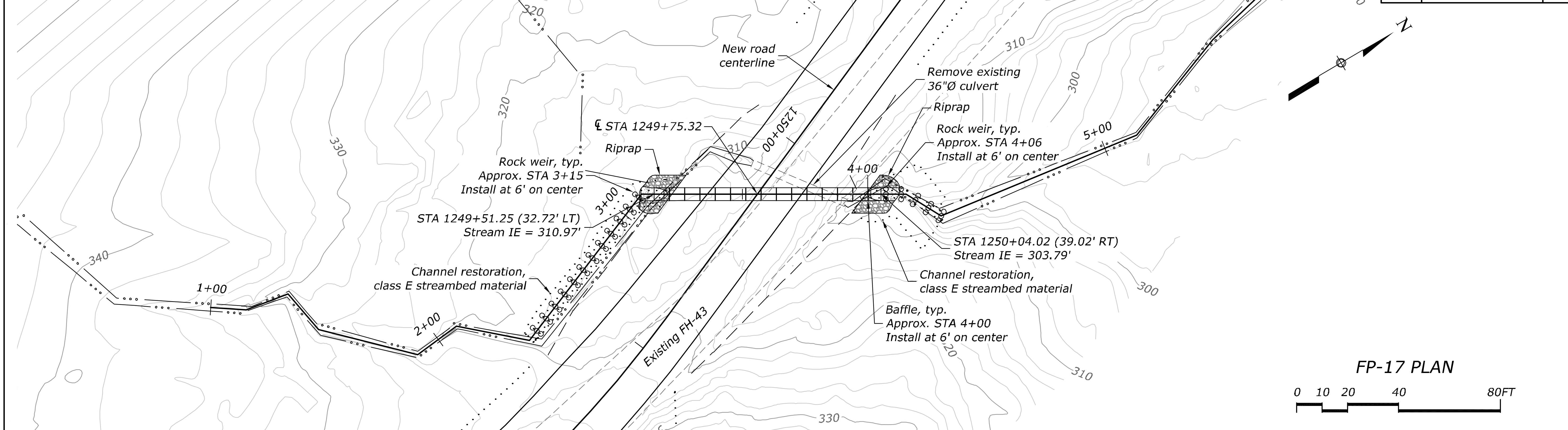
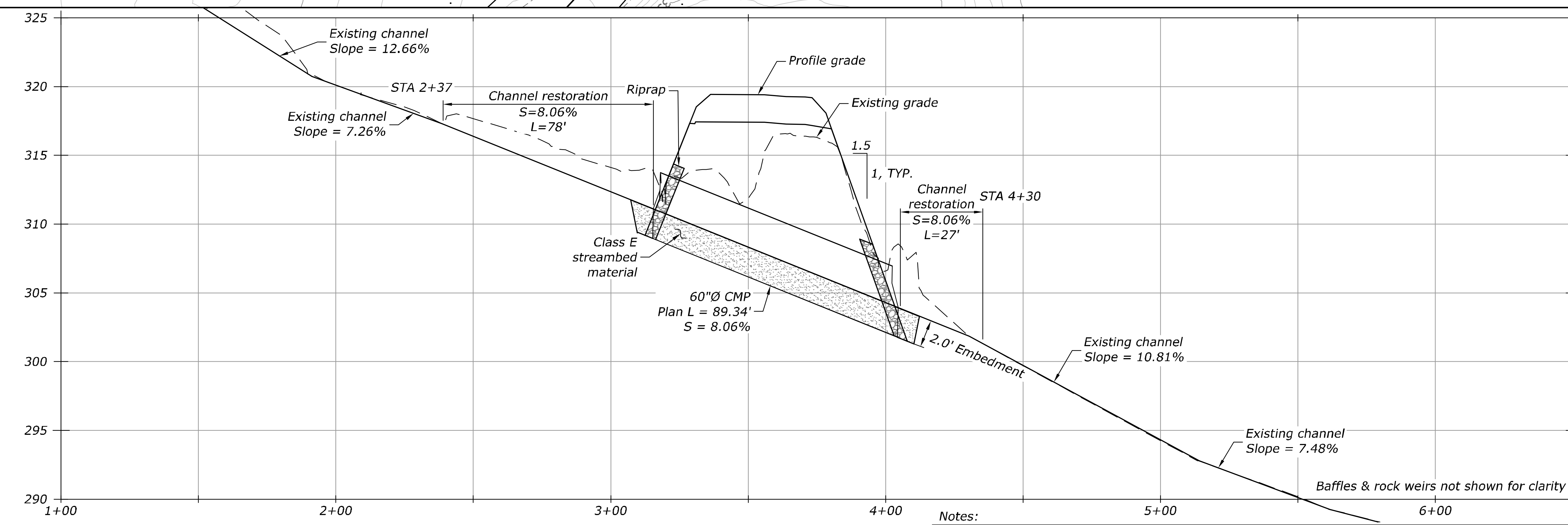
STATE	PROJECT	SHEET NUMBER
AK	AK PFH 43(10)	J.21



FP-17 PLAN



FP-17 PROFILE
5:1 Vertical exaggeration

Notes:

1. Do not begin construction until Title 16 permit is received. Any additional requirements in the Title 16 permit shall be met and documented in the project asbuilts.
2. Field verify inlet elevations, outlet elevations, and slope.
3. Overtopping elevation measured at top of subgrade.

Notes:

Drainage area (sq-mi)	= 0.03		Q50 Headwater elevation (ft)	=	312.22
Design exceedance	= 2%		Q50 Tailwater elevation (ft)	=	305.66
Q2 (cfs)	= 13.89		Overtopping flood (cfs)	=	121
Q50 (cfs)	= 30.34		Overtopping probability	<	0.2%
QFish (cfs)	= 5.56		Overtopping elevation (ft)	=	317.61
Fish species	= CT		Hw/D ratio Q50	=	0.42
Design bankfull width (ft)	= 3				

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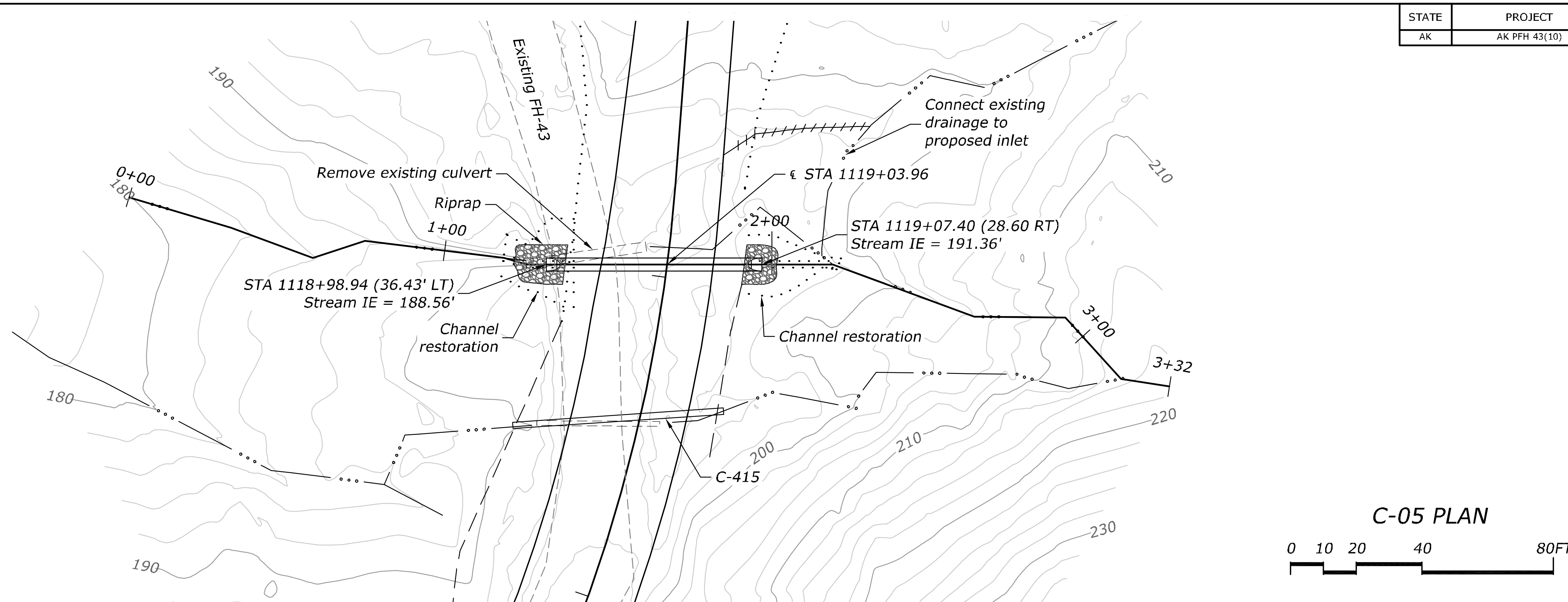
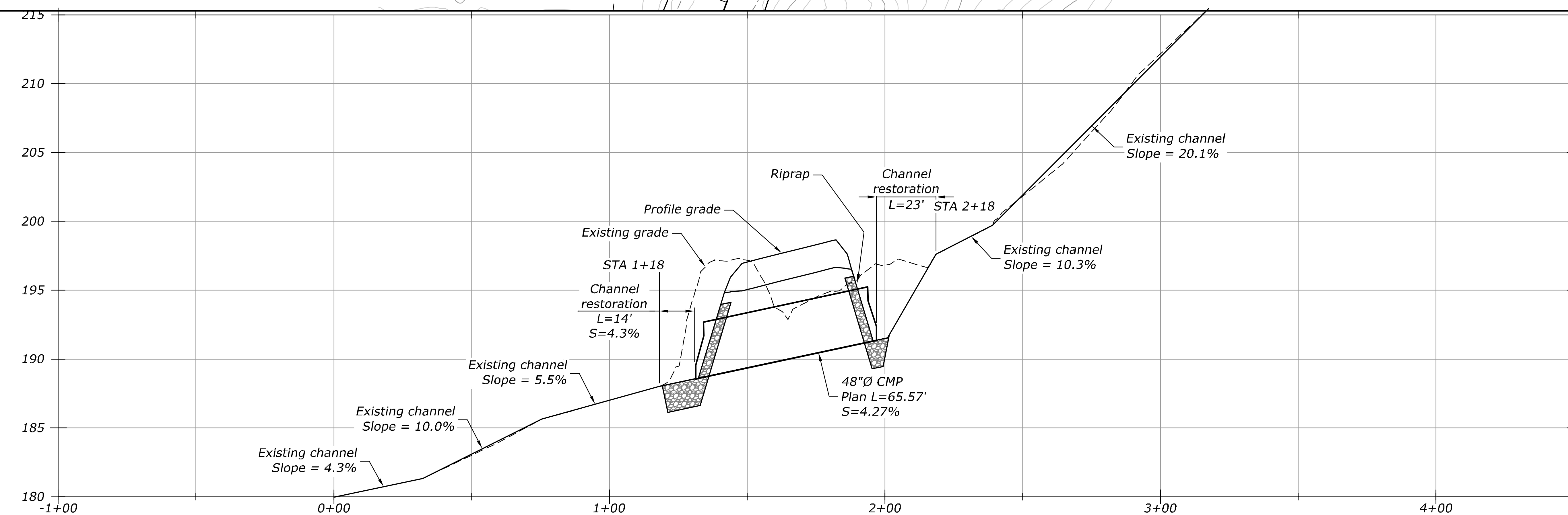
STATE	PROJECT	SHEET NUMBER
AK	AK PFH 43(10)	J.22



C-05 PLAN



C-05 PROFILE

5:1 Vertical exaggeration

Notes:

1. Field verify inlet elevations, outlet elevations, and slope.
2. Overtopping elevation measured at top of subgrade.

Notes:

Drainage area (sq-mi)	= 0.05		Q50 Headwater elevation (ft)	=	194.46
Design exceedance	= 2%		Q50 Tailwater elevation (ft)	=	191.29
Q2 (cfs)	= 23.29		Overtopping flood (cfs)	=	81
Q50 (cfs)	= 50.65		Overtopping probability	<	0.2%
Hw/D ratio Q50	= 0.78		Overtopping elevation (ft)	=	195.64

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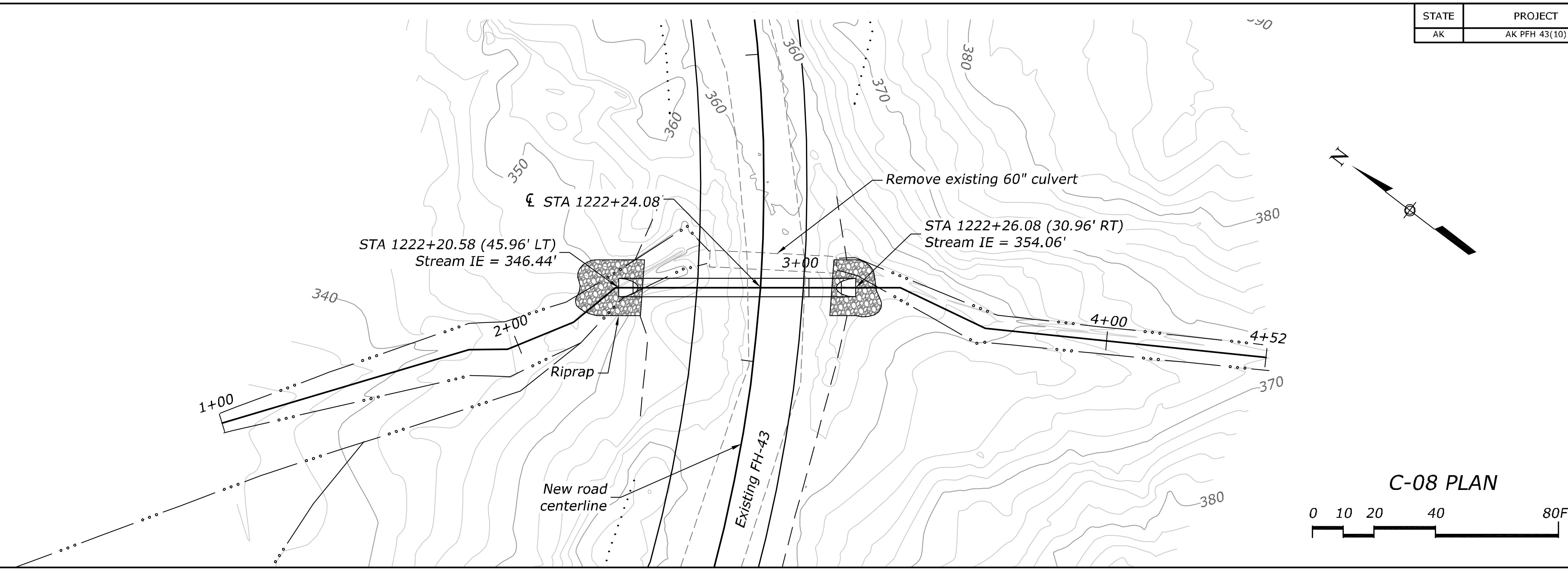
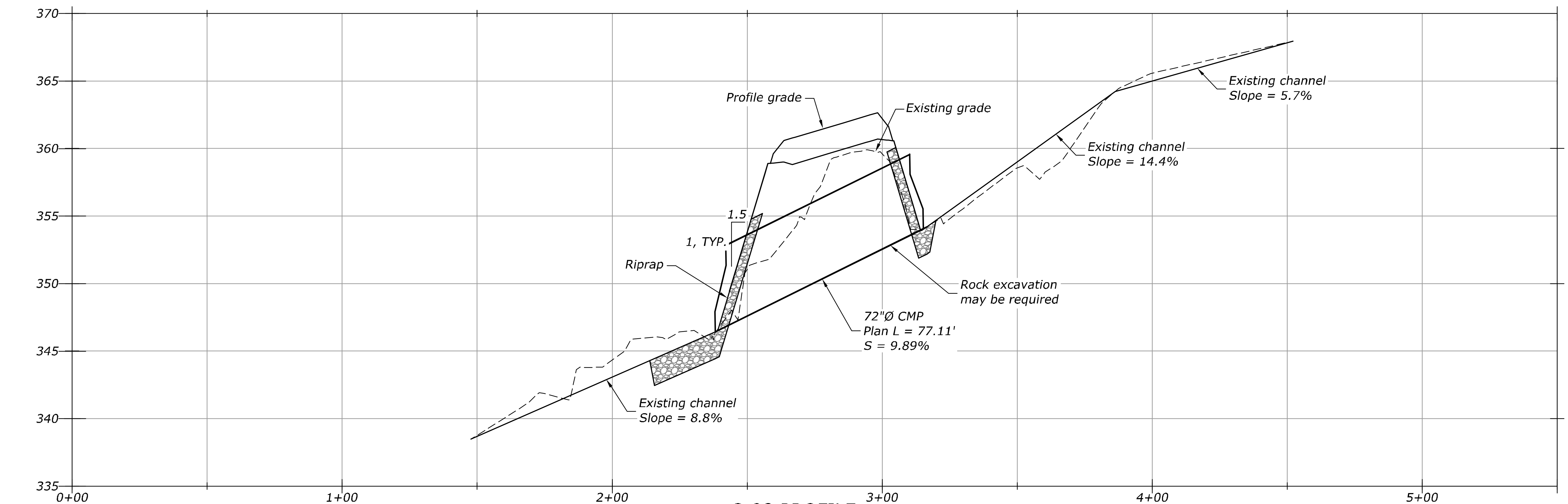
STATE	PROJECT	SHEET NUMBER
AK	AK PFH 43(10)	J.23



C-08 PLAN



C-08 PROFILE

5:1 Vertical exaggeration

Notes:

1. Field verify inlet elevations, outlet elevations, and slope.
2. Overtopping elevation measured at top of subgrade.

Notes:

Drainage area (sq-mi)	=	0.22	Q50 Headwater elevation (ft)	=	359.33
Design exceedance	=	2%	Q50 Tailwater elevation (ft)	=	348.19
Q2 (cfs)	=	73.64	Overtopping flood (cfs)	=	170
Q50 (cfs)	=	158.48	Overtopping probability	<	2%
Hw/D ratio Q50	=	0.88	Overtopping elevation (ft)	=	359.63

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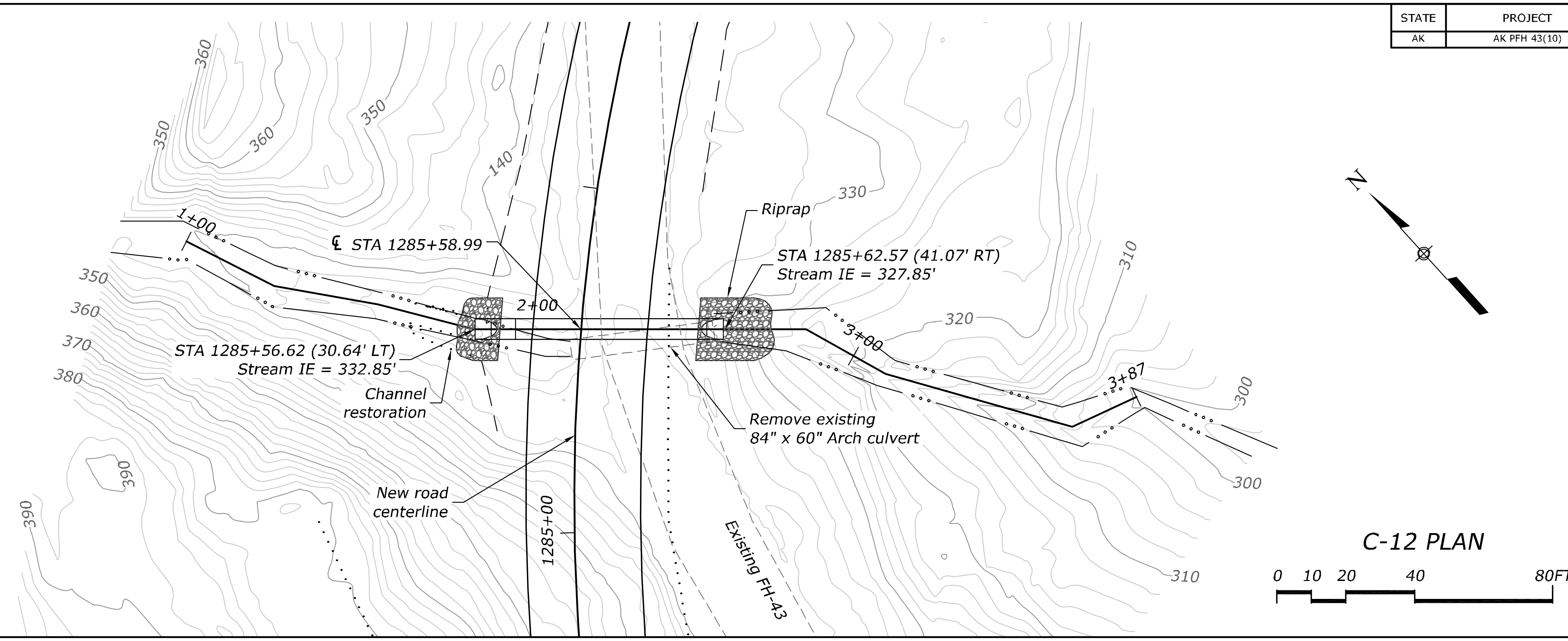
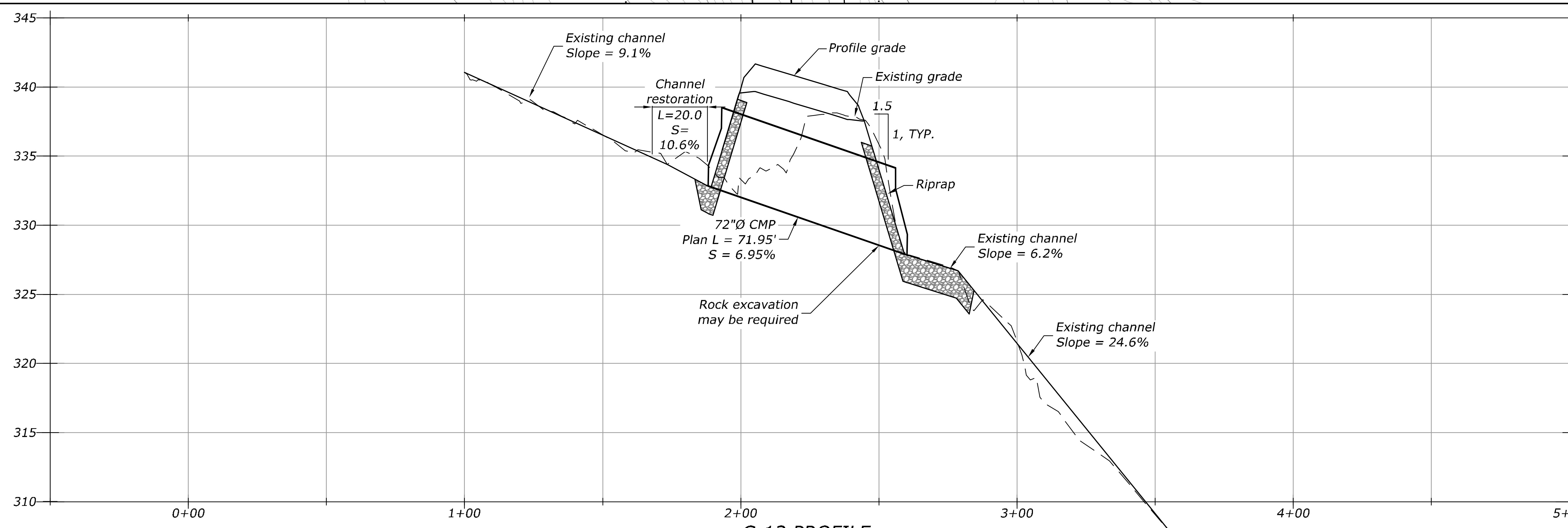
STATE	PROJECT	SHEET NUMBER
AK	AK PFH 43(10)	J.24



C-12 PLAN



C-12 PROFILE
5:1 Vertical exaggeration

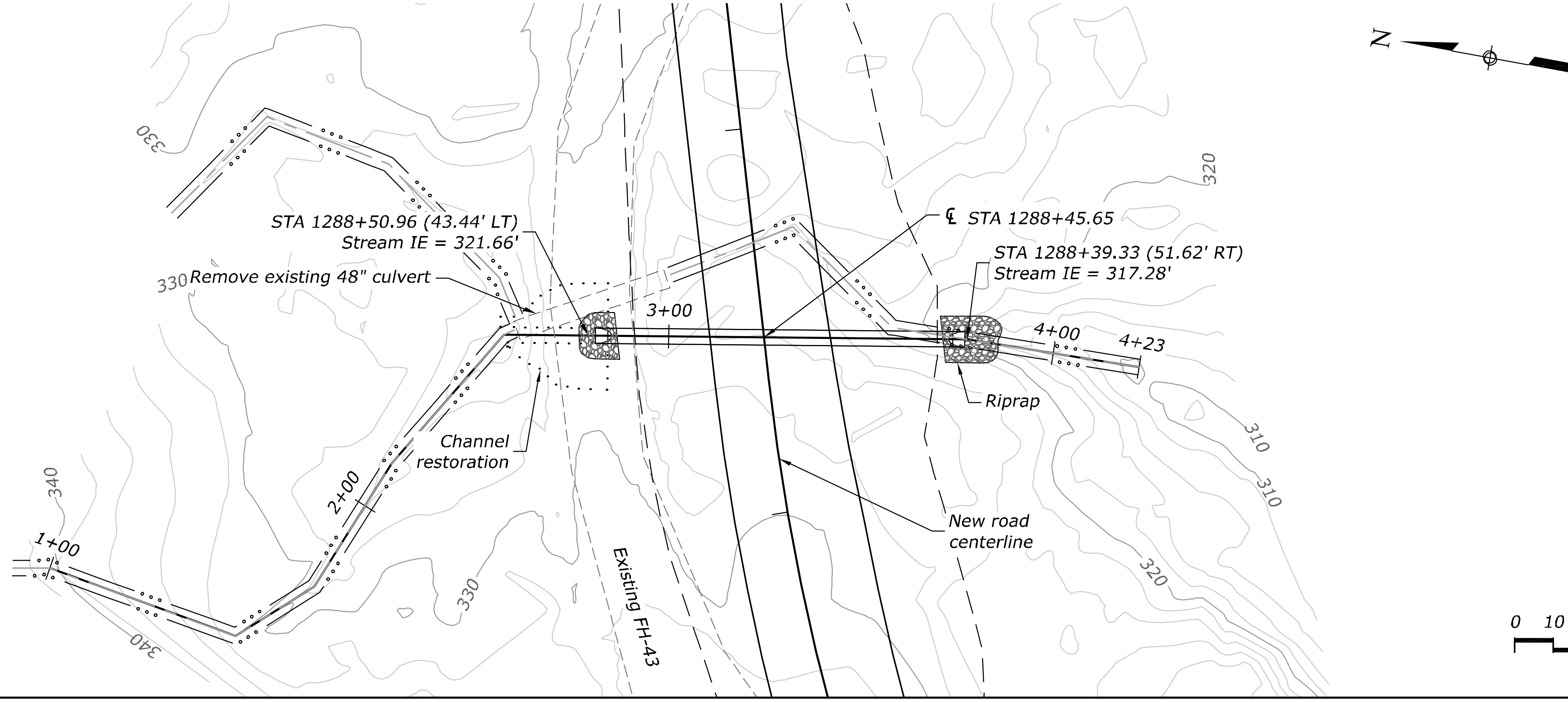
Notes:

1. Field verify inlet elevations, outlet elevations, and slope.
2. Overtopping elevation measured at top of subgrade.

Notes:

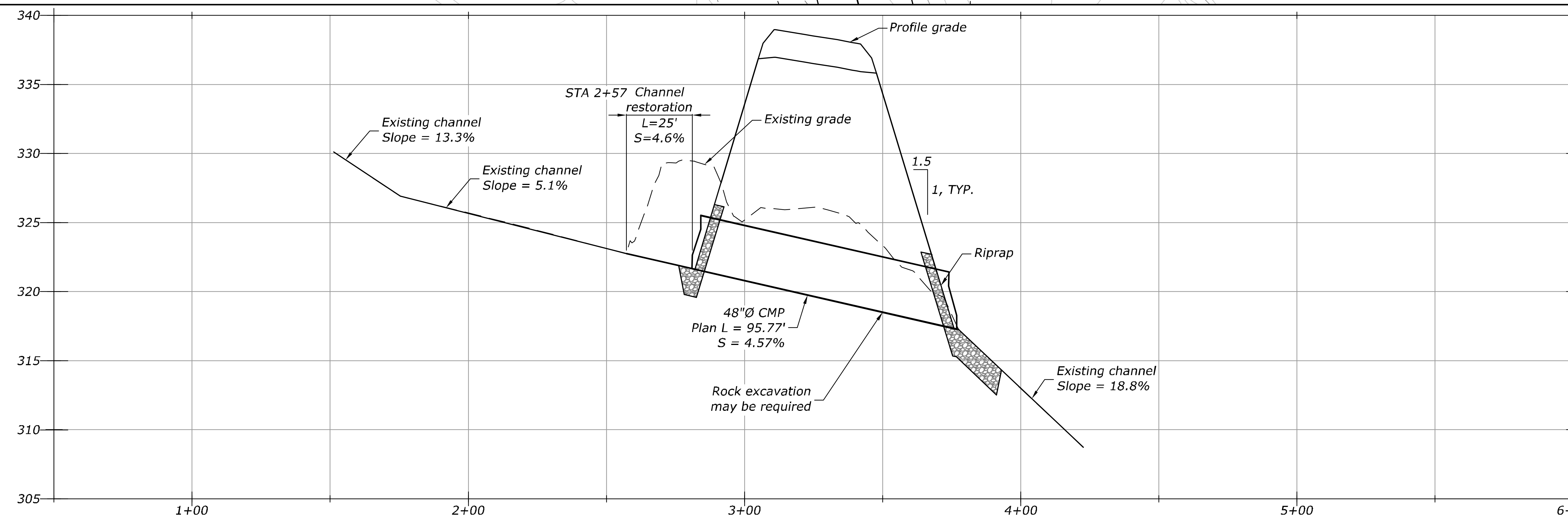
Drainage area (sq-mi)	=	0.16	Q50 Headwater elevation (ft)	=	337.56
Design exceedance	=	2%	Q50 Tailwater elevation (ft)	=	330.74
Q2 (cfs)	=	56.61	Overtopping flood (cfs)	=	180
Q50 (cfs)	=	122.11	Overtopping probability	<	0.2%
Hw/D ratio Q50	=	0.78	Overtopping elevation (ft)	=	338.83

STATE	PROJECT	SHEET NUMBER
AK	AK PFH 43(10)	J.25



C-13 PLAN

0 10 20 40 80FT



C-13 PROFILE

5:1 Vertical exaggeration

Notes:

1. Field verify inlet elevations, outlet elevations, and slope.
2. Overtopping elevation measured at top of subgrade.

Notes:

Drainage area (sq-mi)	=	0.06	Q50 Headwater elevation (ft)	=	325.31
Design exceedance	=	2%	Q50 Tailwater elevation (ft)	=	318.96
Q2 (cfs)	=	26.81	Overtopping flood (cfs)	=	188
Q50 (cfs)	=	58.23	Overtopping probability	<	0.2%
Hw/D ratio Q50	=	0.91	Overtopping elevation (ft)	=	336.52

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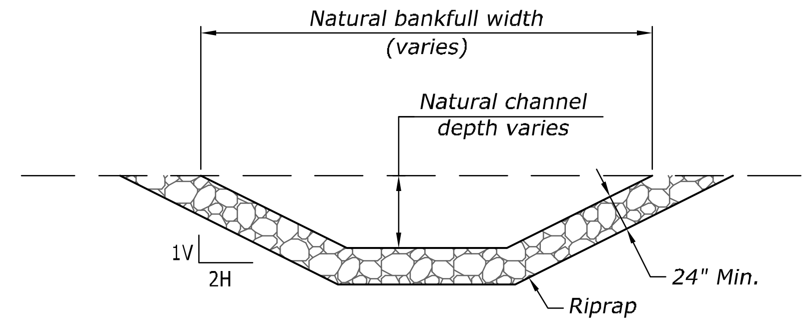
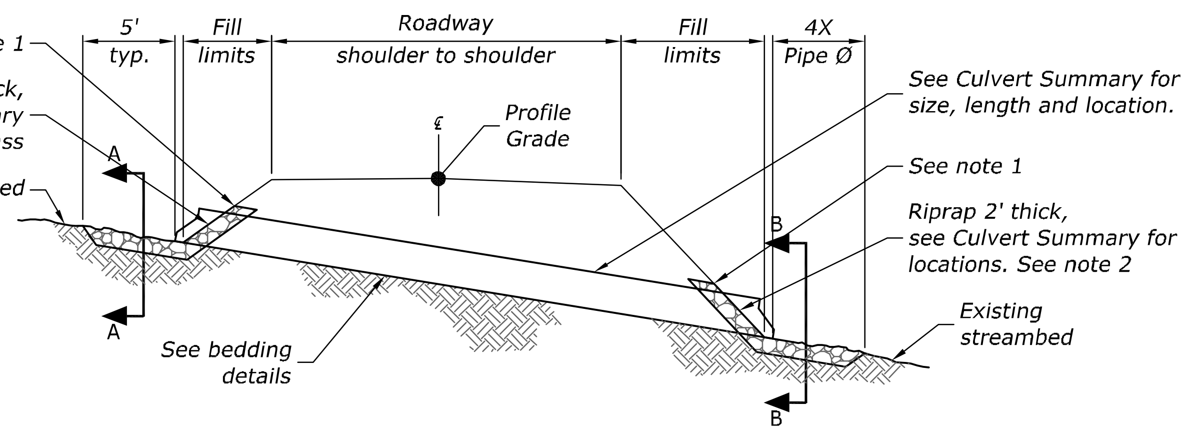
STATE	PROJECT	SHEET NUMBER
AK	AK PFH 43(10) Deweyville	J.26

Notes:

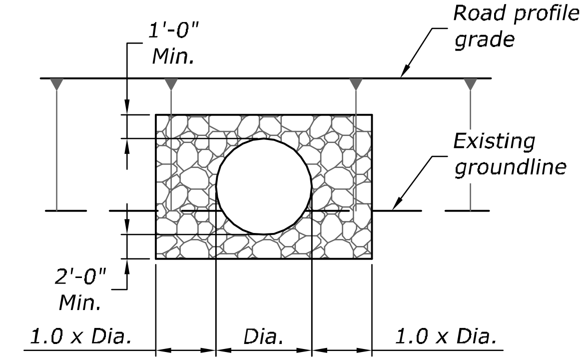
1. Extend riprap 1' above culvert or to the q50 flood elevation, whichever is greater.
2. Where culvert is seated on bedrock, riprap apron may be omitted
3. Install retention baffle per details and plan sheets
4. Culverts 48"Ø or smaller are to be installed with flared end sections per FHWA standard plans.
5. Culverts greater than 48"Ø are to be provided with mitered pipe ends that conform to fill slope or headwalls with beveled edges



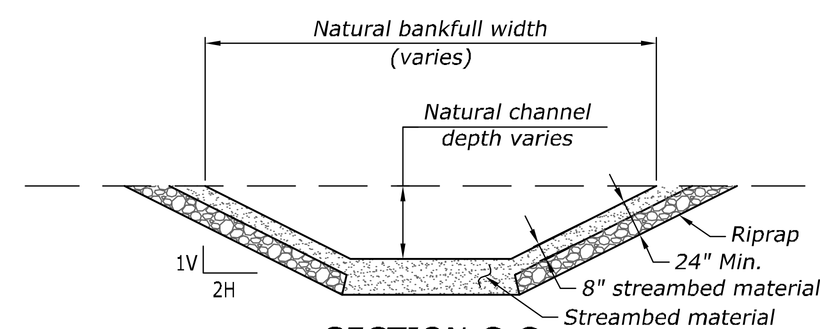
SECTION A-A
NON-FISH STREAMS



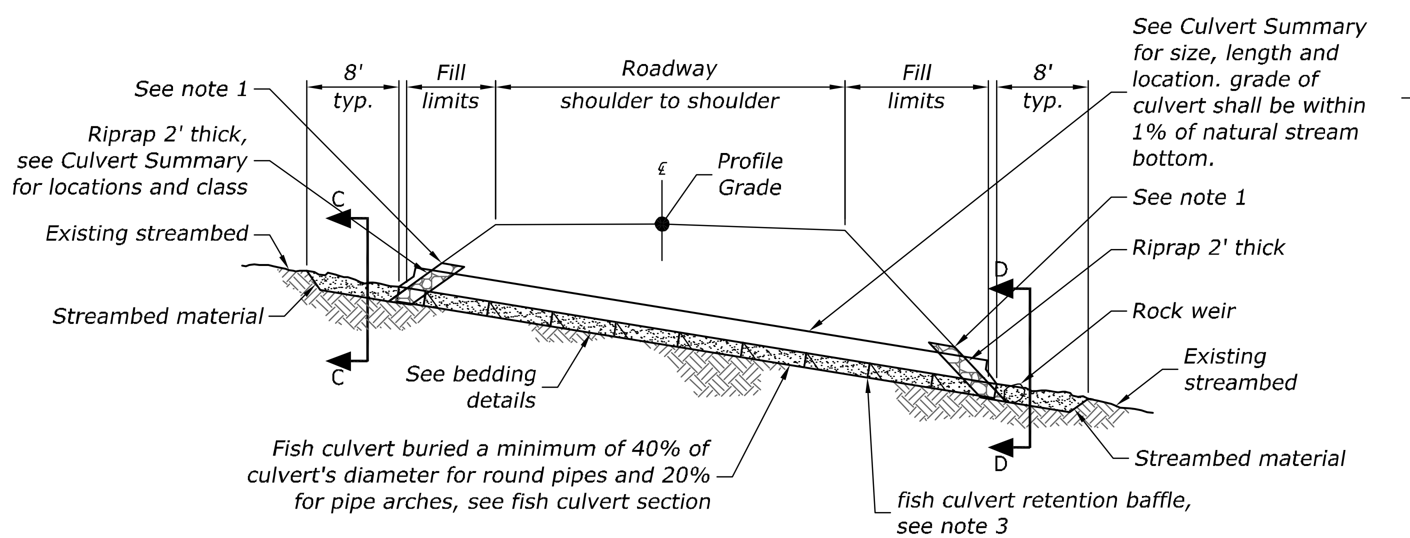
TYPICAL PIPE CULVERT INSTALLATION
NON-FISH STREAMS



SECTION B-B
NON-FISH STREAMS

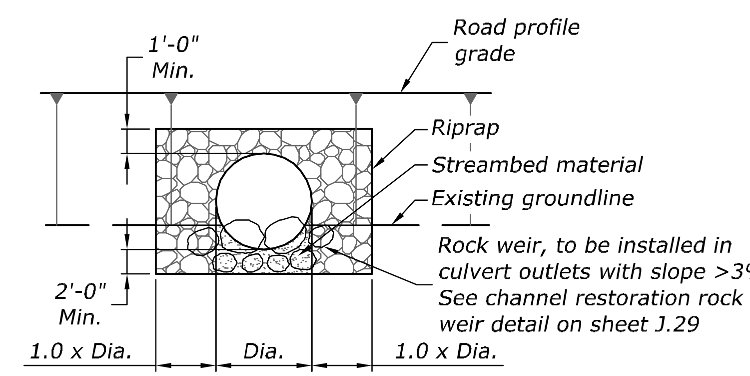


SECTION C-C
FISH STREAMS



TYPICAL PIPE CULVERT INSTALLATION
FISH STREAMS

Note: See sheets J6-J21 for individual fish streams plan and profile



SECTION D-D
FISH STREAMS

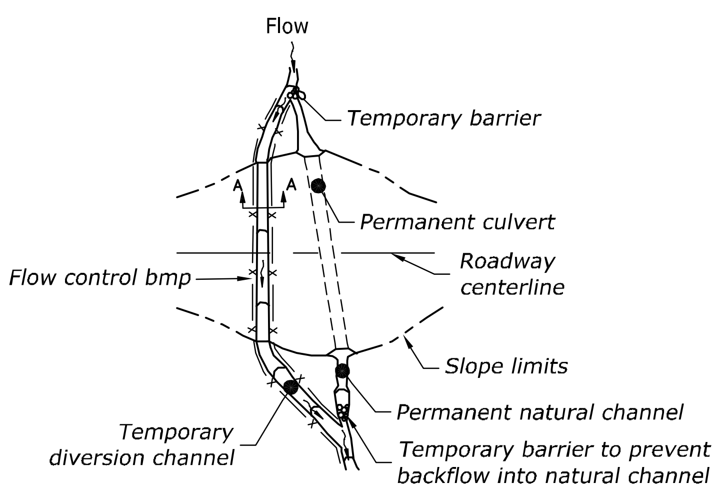
U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION
WESTERN FEDERAL LANDS HIGHWAY DIVISION

CULVERT DETAILS

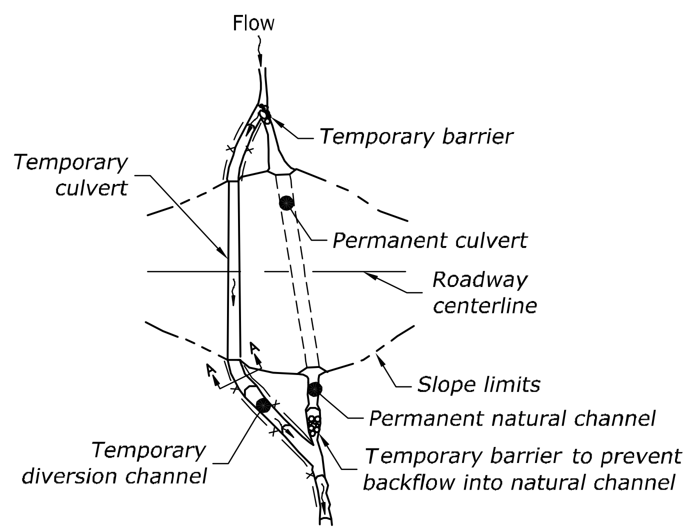
STATE	PROJECT	SHEET NUMBER
AK	AK PFH 43(10) Deweyville	J.27

Notes:

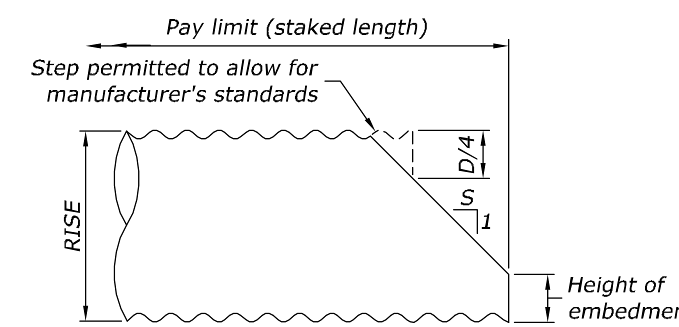
1. *"W" - Match channel width to existing stream width.*
2. *Construct channel to maintain positive drainage. provide a minimum grade of 0.5 percent where possible.*
3. *If pumping is used during construction the intake must be operated and maintained to prevent fish entrapment, entrainment, or injury with the use of perforated plate and woven wire having a mesh size not greater than 3/32 inches or profile bar and wedgewire having openings not greater than 1/16 inches. approach velocities shall not exceed a passive. velocity of 0.2 feet per second (fps) or an active velocity of 0.4 fps.*
4. *The culvert ends shall be beveled to match the embankment or ditch slope. Shape the slope in the vicinity of the culvert end to ensure no part of the culvert protrudes more than 4" above the ground line.*
5. *Field cutting of culvert ends is permitted when approved by the Engineer. All field-cut culverts edges shall be treated per manufacture's recommendations.*



DIVERSION CHANNEL

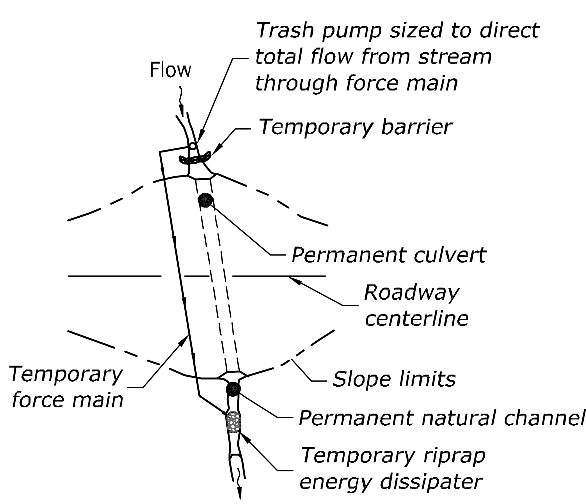


TEMPORARY
CULVERT DIVERSION

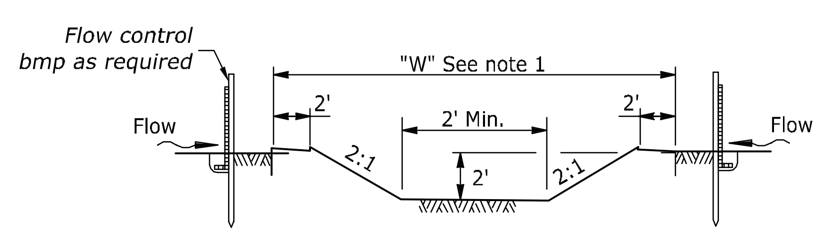


S = 1.5 for 1V:1.5H fill slopes

END TREATMENT DIAGRAM FOR
FISH PASSAGE CULVERTS



DIVERSION PUMP
(See note 3)

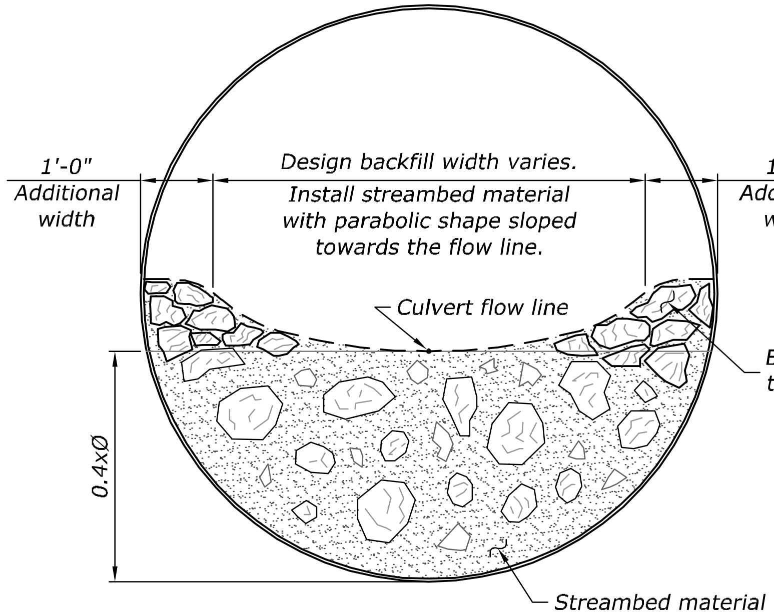


SECTION A-A
TYPICAL DIVERSION CHANNEL

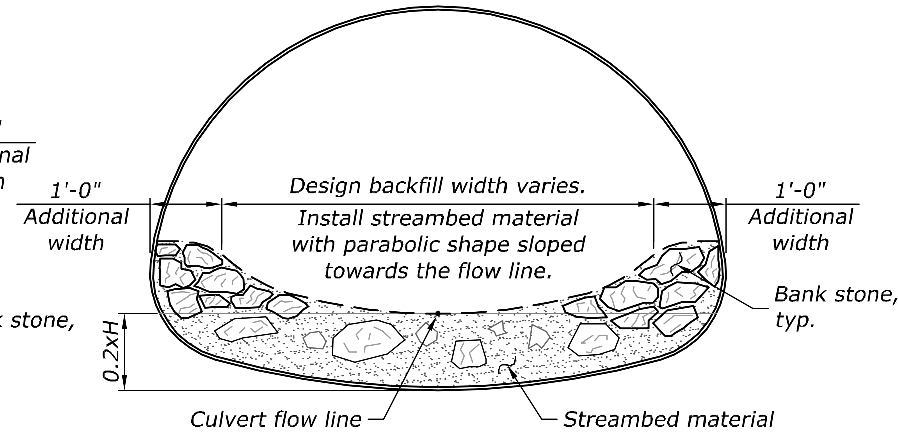
U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION
WESTERN FEDERAL LANDS HIGHWAY DIVISION

CULVERT DETAILS

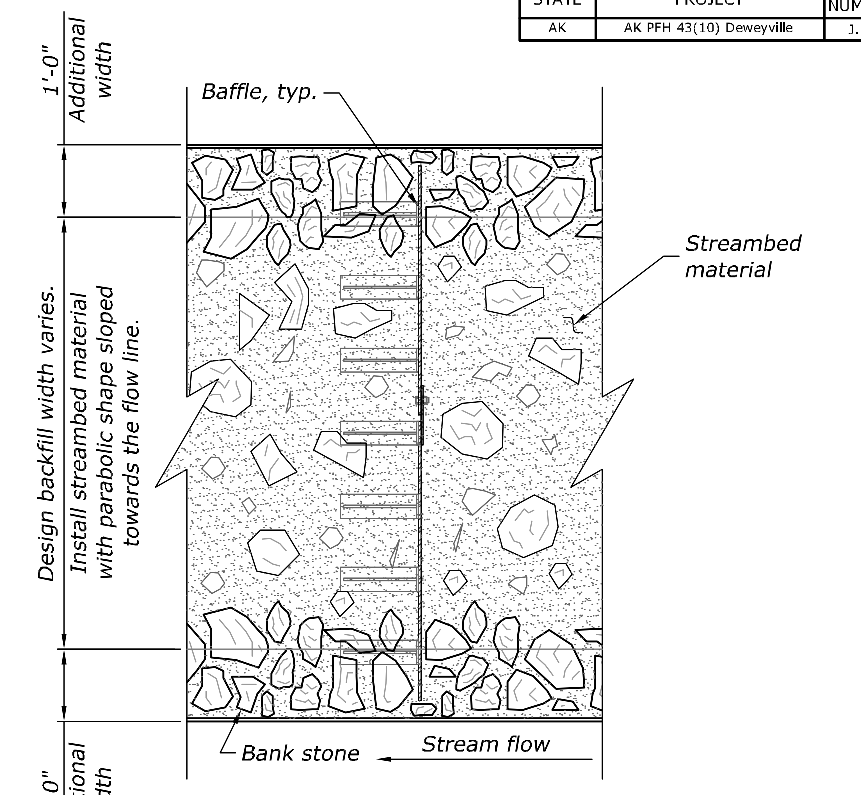
STATE	PROJECT	SHEET NUMBER
AK	AK PFH 43(10) Deweyville	J.28



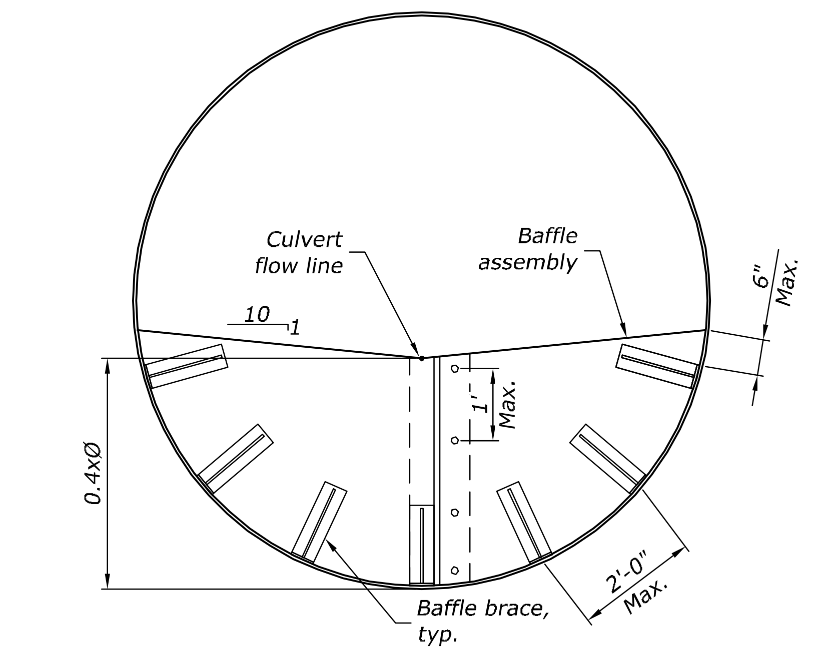
TYPICAL FISH CULVERT CROSS SECTION



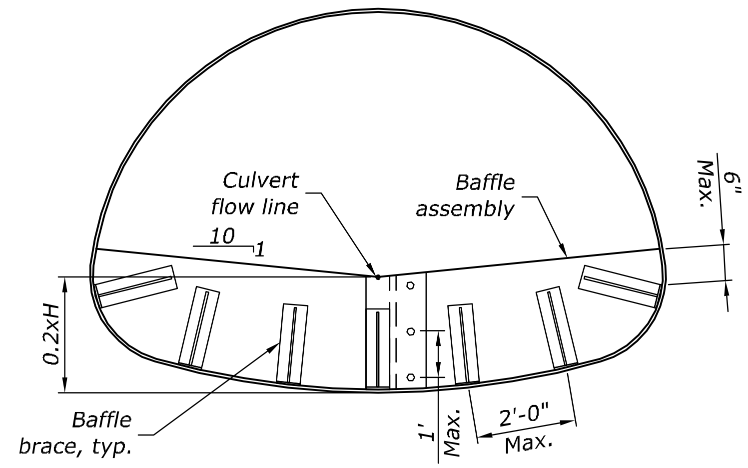
TYPICAL FISH ARCH PIPE CROSS SECTION



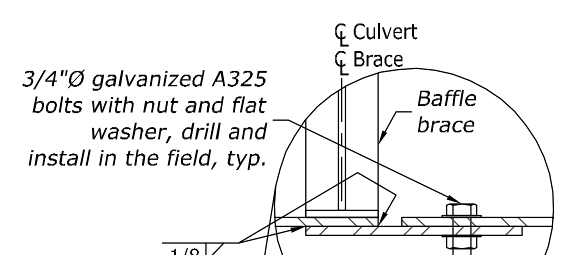
3%-15% BAFFLE PLAN



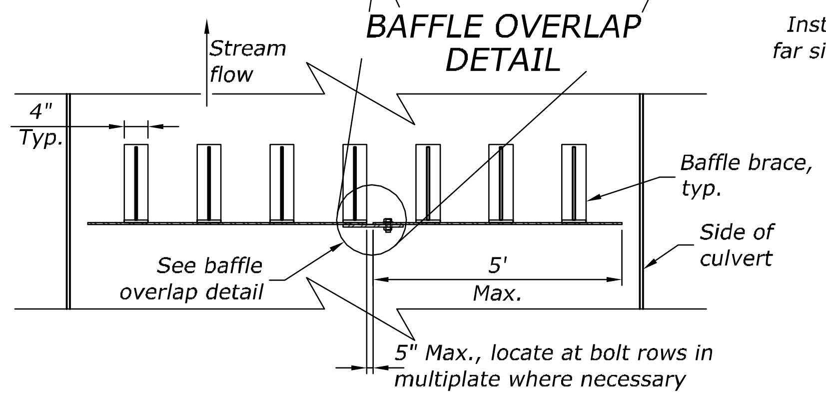
TYPICAL FISH CULVERT BAFFLE DETAIL



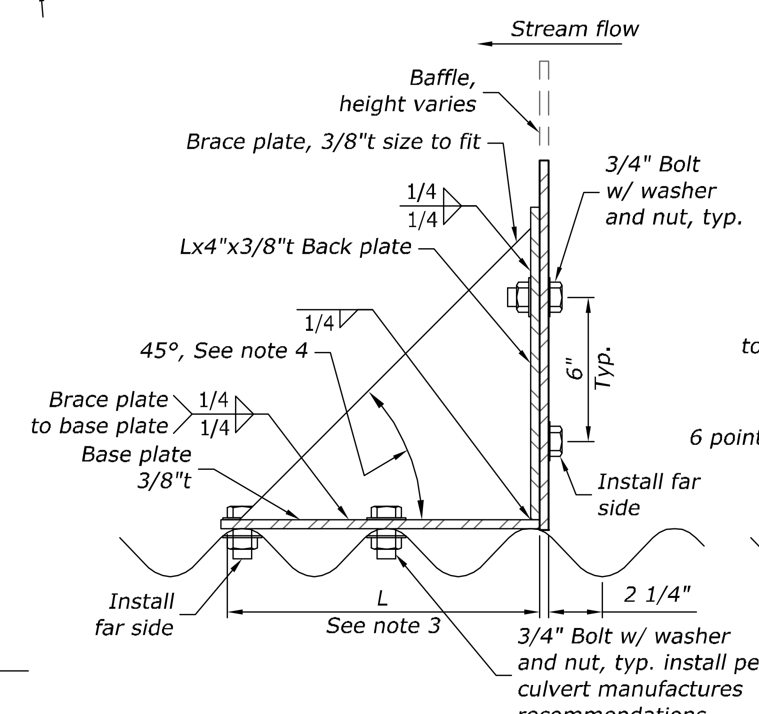
TYPICAL FISH ARCH PIPE BAFFLE DETAIL



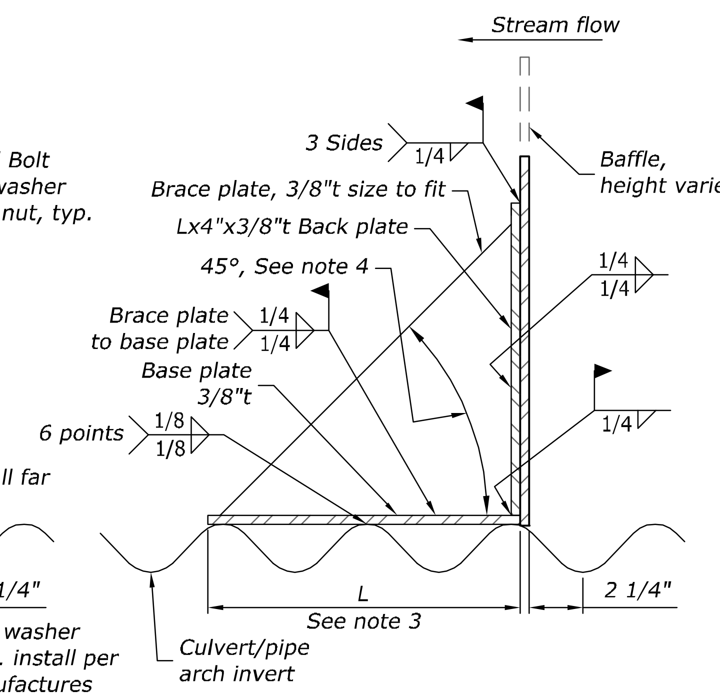
BAFFLE OVERLAP DETAIL



TYPICAL BAFFLE PLAN



TYPICAL BAFFLE BOLTED CONNECTION



TYPICAL BAFFLE WELDED CONNECTION

Baffle Notes:

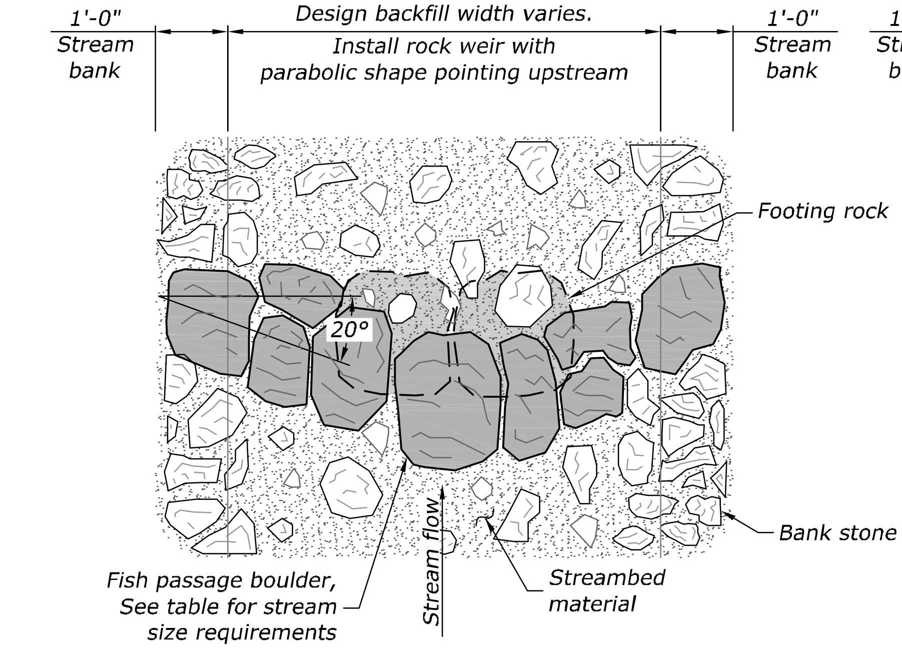
1. All baffles and braces shall be manufactured from 3/8" A572 Grade 50 steel plate and shall be installed with either a bolted or welded connection.
2. All dimensions on this sheet are nominal-baffles shall be manufactured to fit particular pipe.
3. Baffle base shall be sized to weld at 3 corrugations. L=13" minimum for FP-07, FP-12, FP-13, FP-15, and FP-19. L=19" for FP-09, FP-10, FP-11, and FP-14.
4. Baffle brace angle shall be 45° as noted, but may be decreased to ensure span of at least 2 corrugations.
5. Baffle assemblies shall be hot dip galvanized after fabrication per ASTM A123.
6. Welds between base plate and corrugated pipe shall be applied in small enough passes to ensure that corrugated pipe is not burned through.
7. All damaged galvanizing and pipe coatings, including that removed for welding, shall be repaired per ASTM A780 and modified as follows: Repair using Galv-Viz Bar zinc sticks, as manufactured by American Solder & Flux. Alternately, damage coating may be repaired by spray metalizing per AWS C2.23-2003 to a minimum thickness of 12 mils. All repairs shall have a top coat of zinc-rich paint.
8. All bolts shall be A525 galvanized.

U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION
WESTERN FEDERAL LANDS HIGHWAY DIVISION

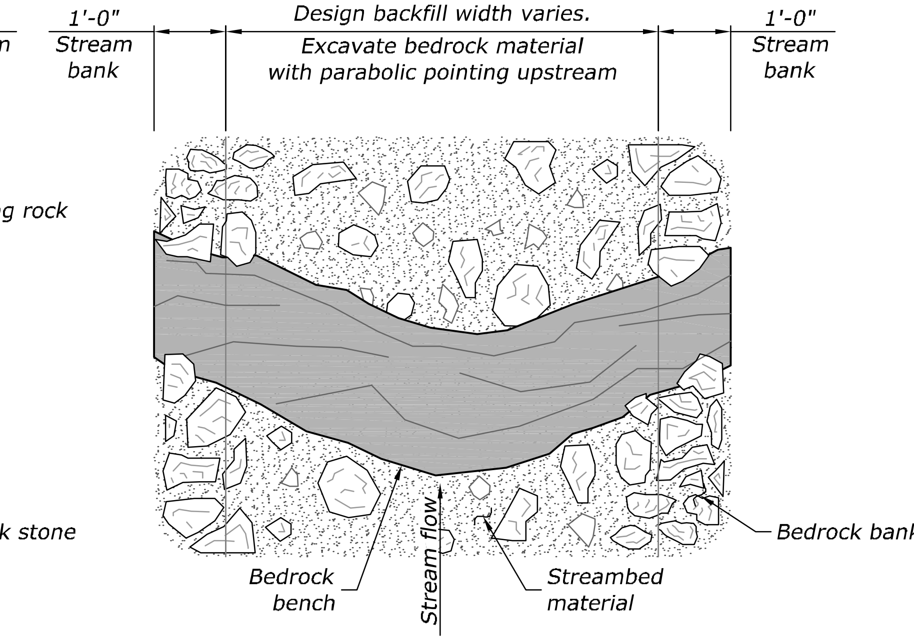
FISH PASSAGE DETAILS

K:\2012\121088 - FH43 Deweyville Trailhead to Neck Lake\100% IFC\J.28.FISH PASSAGE DETAILS.100% IFC.dwg [USC] 20 March 2013 5:04 PM

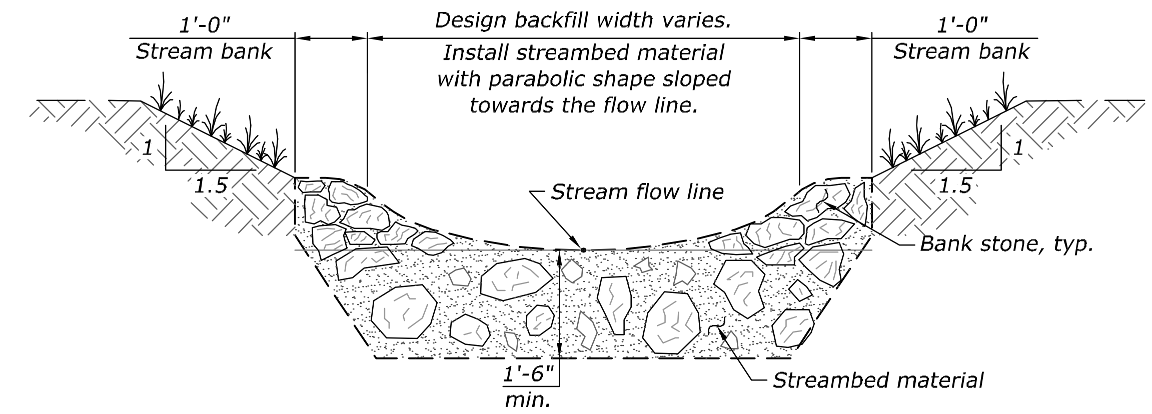
STATE	PROJECT	SHEET NUMBER
AK	AK PFH 43(10) Deweyville	J.29



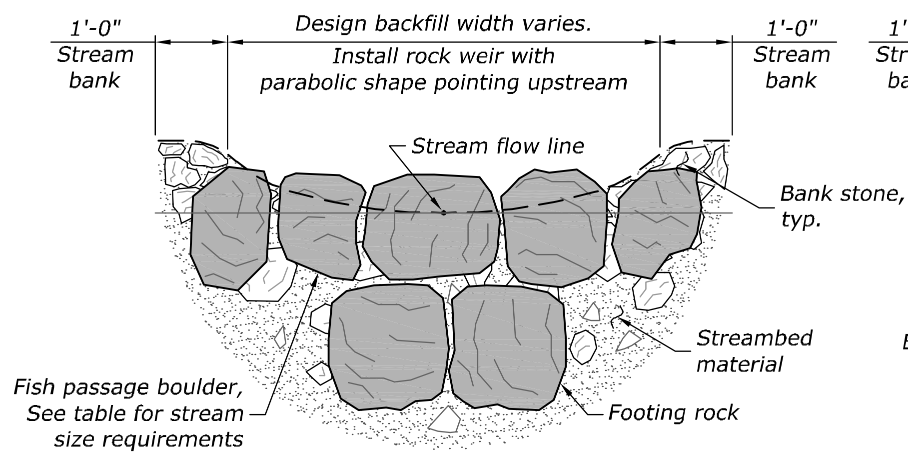
CHANNEL RESTORATION
ROCK WEIR PLAN



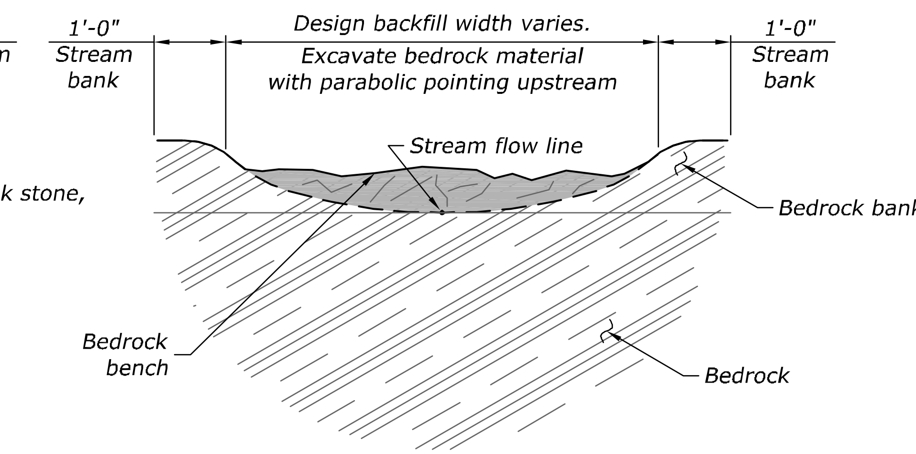
BEDROCK CHANNEL RESTORATION
ROCK WEIR PLAN



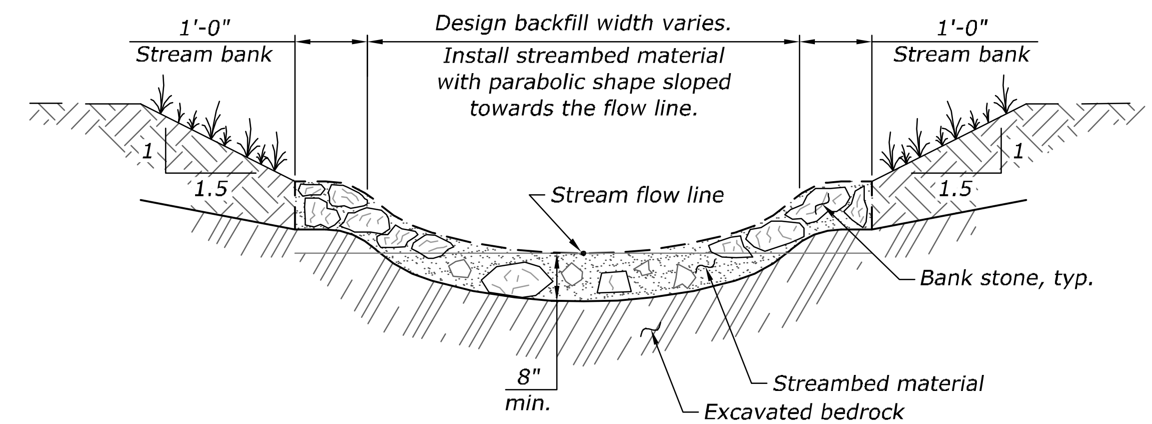
TYPICAL FISH STREAM
CHANNEL SECTION



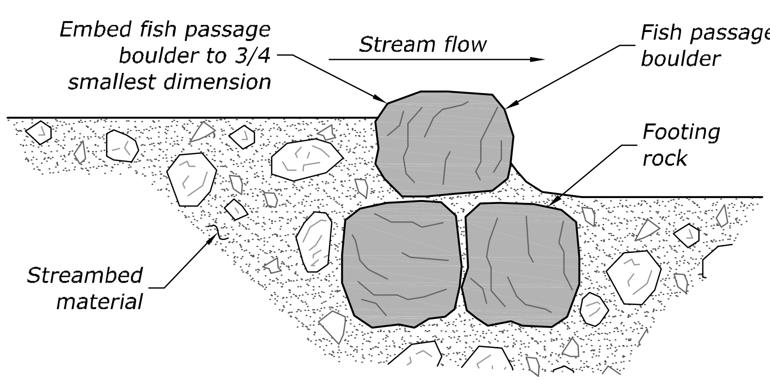
CHANNEL RESTORATION
ROCK WEIR SECTION



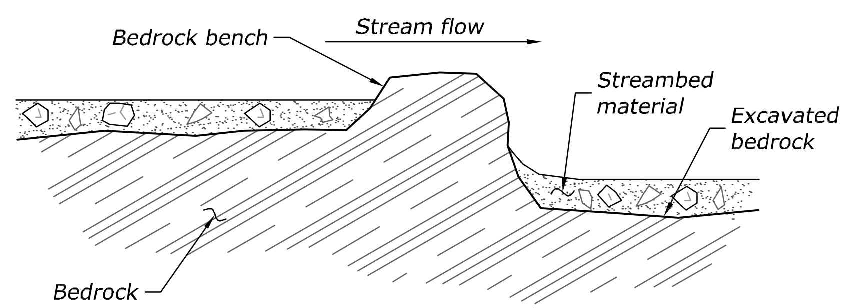
BEDROCK CHANNEL RESTORATION
ROCK WEIR SECTION



TYPICAL FISH STREAM
BEDROCK CHANNEL SECTION



CHANNEL RESTORATION
ROCK WEIR PROFILE



BEDROCK CHANNEL RESTORATION
ROCK WEIR PROFILE

FISH PASSAGE BOULDER SUMMARY

Structure	Boulder Size (in)	
	Min	MAX
FP-01	18	24
FP-02	15	24
FP-03	6	12
FP-04	6	12
FP-05	18	24
FP-06	12	24
FP-07	18	24
FP-09	18	36
FP-10	18	24
FP-11	18	24
FP-12	18	24
FP-13	18	30
FP-14	18	30
FP-15	18	24
FP-16	12	24
FP-17	18	24

U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION
WESTERN FEDERAL LANDS HIGHWAY DIVISION

FISH PASSAGE DETAILS

STATE	PROJECT	SHEET NUMBER
AK	AK PFH 43(10)	J.30

METAL ROUND PIPE CULVERT

FILL HEIGHT AND METAL THICKNESS TABLE FOR HELICAL LOCKSEAM AND WELDED SEAM PIPE CULVERT

STEEL

PIPE SIZE DIAMETER	MINIMUM COVER	2⅔" x ½" CORRUGATIONS					3" x 1" CORRUGATIONS					5" x 1" CORRUGATIONS				
		METAL THICKNESS (INCH/GAGE)														
		0.064/16	0.079/14	0.109/12	0.138/10	0.168/8	0.064/16	0.079/14	0.109/12	0.138/10	0.168/8	0.064/16	0.079/14	0.109/12	0.138/10	0.168/8
INCHES	INCHES	MAXIMUM FILL HEIGHT ABOVE TOP OF PIPE (FEET)														
12	12	100	100	100	100	100										
15	12	100	100	100	100	100										
18	12	100	100	100	100	100										
21	12	100	100	100	100	100										
24	12	100	100	100	100	100										
30	12	85	100	100	100	100										
36	12	71	89	100	100	100	81	100	100	100	100					
42	12	61	76	100	100	100	70	87	100	100	100					
48	12	53	66	93	100	100	61	76	100	100	100	54	68	95	100	100
54	12		59	83	100	100	54	68	95	100	100	48	60	85	100	100
60	12			74	97	100	49	61	86	100	100	43	54	76	98	100
66	12				87	100	44	55	78	100	100	39	49	69	89	100
72	12				80	97	40	51	71	92	100	36	45	63	82	100
78	12					87	37	47	66	85	100	33	42	58	75	92
84	12					75	35	43	61	78	96	31	39	54	70	86
90	12						32	40	57	73	90	29	36	51	65	80
96	12							38	53	69	84		34	48	61	75
102	18							36	50	65	79		32	45	57	71
108	18								47	61	75			42	54	67
114	18								45	58	71			40	52	63
120	18								43	55	67			38	49	60
126	18									52	64				47	57
132	18									50	61				44	54
138	18									48	58				42	52
144	18										56					50

ALUMINUM

PIPE SIZE DIAMETER	MINIMUM COVER	2⅔" x ½" CORRUGATIONS					3" x 1" CORRUGATIONS				
		METAL THICKNESS (INCH/GAGE)									
		0.060/16	0.075/14	0.105/12	0.135/10	0.164/8	0.060/16	0.075/14	0.105/12	0.135/10	0.164/8
INCHES	INCHES	MAXIMUM FILL HEIGHT ABOVE TOP OF PIPE (FEET)									
12	12	100	100	100	100	100					
15	12	100	100	100	100	100					
18	12	100	100	100	100	100					
21	12	88	100	100	100	100					
24	12	77	97	100	100	100					
30	12	62	77	100	100	100	71	89	100	100	100
36	12	52	64	90	100	100	59	74	100	100	100
42	12	44	55	77	99	100	51	64	89	100	100
48	12			67	87	100	44	56	78	100	100
54	18			54	71	88	39	50	69	93	100
60	18				57	72	35	45	62	83	98
66	18					58	32	40	56	76	89
72	18					45	30	37	55	70	82
78	24							34	48	64	75
84	24								44	59	70
90	24								41	62	65
96	24								38	51	61
102	24									46	55
108	24									42	50
114	24										45
120	24										40

NOTE:

1. When directed, camber pipe culverts upward from a chord through the inlet and outlet inverts an ordinate amount equal to 1% of the pipe length. Develop camber on a parabolic curve. If the midpoint elevation on the parabolic curve as designed exceeds the elevation of the inlet invert, reduce the amount of camber or increase the pipe culvert gradient.
2. Fill heights exceeding 100 feet require special analysis by the CO.
3. The fill heights in the table are for helical lockseam and welded seam pipe only. Fill heights for culvert pipe with annular corrugations are more restrictive than those of helical lockseam and welded seam pipe. Obtain approval before furnishing annular corrugation pipe.
4. Measure minimum cover from the top of the pipe culvert to the subgrade for flexible pavements, and to the top of the pavement for rigid pavements. Measure maximum fill height from the top of the pipe to the top of the pavement for both flexible and rigid pavement.

METAL PIPE ARCH CULVERT

FILL HEIGHT AND METAL THICKNESS TABLE FOR HELICAL LOCKSEAM AND WELDED SEAM PIPE CULVERT

STEEL

PIPE ARCH SIZE SPAN x RISE	EQUI-VALENT DIAMETER	MINIMUM CORNER RADIUS	MINIMUM COVER	2⅔" x ½" CORRUGATIONS					3" x 1" CORRUGATIONS				5" x 1" CORRUGATIONS			
				METAL THICKNESS (INCH/GAGE)												
				0.064/16	0.079/14	0.109/12	0.138/10	0.168/8	0.079/14	0.109/12	0.138/10	0.168/8	0.079/14	0.109/12	0.138/10	0.168/8
INCHES	INCHES	INCHES	INCHES	MAXIMUM FILL HEIGHT ABOVE TOP OF PIPE (FEET)												
17 x 13	15	3	12	13												
21 x 15	18	3	12	12												
24 x 18	21	3	12	13												
28 x 20	24	3	12	13												
35 x 24	30	3	12	12												
42 x 29	36	3.5	12	12												
49 x 33	42	4	12		12											
57 x 38	48	5	12			12										
60 x 46	54	8	15							21				21		
64 x 43	54	6	12			12										
66 x 51	60	9	15							21				21		
71 x 47	60	7	12				12									
73 x 55	66	12	18							20				20		
77 x 52	66	8	12					12								
81 x 59	72	14	18						17				17			
83 x 57	72	9	12					12								
87 x 63	78	14	18						17				17			
95 x 67	84	16	18						17				17			
103 x 71	90	16	18							17			17			
112 x 75	96	18	21							16				16		
117 x 79	102	18	21							16				16		
128 x 83	108	18	24								16				16	
137 x 87	114	18	24								16				16	
142 x 91	120	18	24									16				16

ALUMINUM

PIPE ARCH SIZE SPAN x RISE	EQUI-VALENT DIAMETER	MINIMUM CORNER RADIUS	MINIMUM COVER	2⅔" x ½" CORRUGATIONS				3" x 1" CORRUGATIONS			
				METAL THICKNESS (INCH/GAGE)							
				0.060/16	0.075/14	0.105/12	0.135/10	0.060/16	0.075/14	0.105/12	0.135/10
INCHES	INCHES	INCHES	INCHES	MAXIMUM FILL HEIGHT ABOVE TOP OF PIPE (FEET)							
17 x 13	15	3	12	13							
21 x 15	18	3	12	12							
24 x 18	21	3	12	13							
28 x 20	24	3	12		13						
35 x 24	30	3	12		12						
42 x 29	36	3.5	15			12					
49 x 33	42	4	15			12					
57 x 38	48	5	15				12				
60 x 46	54	8	15					21			
64 x 43	54	6	18				12				
66 x 51	60	9	18					21			
73 x 55	66	12	18						20		
81 x 59	72	14	21							17	
87 x 63	78	14	21							17	
95 x 67	84	16	24							17	
103 x 71	90	16	24								17

NO SCALE

U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION
FEDERAL LANDS HIGHWAY

U.S. CUSTOMARY STANDARD

METAL PIPE CULVERT

STANDARD APPROVED FOR USE 12/1993
REVISED: 4/1994 6/2005

STANDARD 602-1

COUPLING BANDS FOR METAL PIPE CULVERT [1]

CORRUGATION SIZE [2] INCHES	ROUND PIPE DIAMETER INCHES	PIPE ARCH SPAN x RISE INCHES	MINIMUM BAND WIDTH (INCHES) ANNULAR CORRUGATED BANDS [3]	HELICALLY CORRUGATED BANDS [4]	SEMI-CORRUGATED BANDS [5]
1½ x ¼	underdrain [6]	-	10.5	7	10.5
2⅔ x ½	12 to 36	17 x 13 to 42 x 29	7	12	
	42 to 72	49 x 33 to 83 x 57	10.5	12	
	78 to 84	-	10.5	12	10.5
3 x 1	36 to 72	60 x 46 to 81 x 59	12	14	10.5
	78 to 144	87 x 64 to 142 x 91	12	14	10.5
5 x 1	36 to 72	60 x 46 to 81 x 59	20	22	
	78 to 144	87 x 64 to 142 x 91	20	22	

[1] Fabricate annular, helical and semi-corrugated type coupling bands from the same metal as the connecting pipe. Provide coupling bands not more than 3 nominal sheet thicknesses thinner than the thickness of the pipe to be connected, and no thinner than 0.052 inch for steel or 0.048 inch for aluminum. Fasten coupling bands with the following diameter of bolt:
 ⅜" for 18" round culvert (21" x 15" pipe arch) or less
 ½" for 21" round culvert (24" x 18" pipe arch) or more

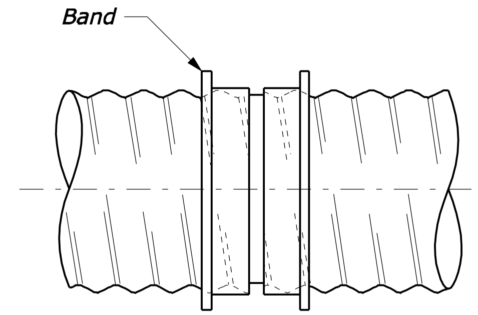
[2] For helically corrugated pipe with rerolled ends, the nominal corrugations size refers to the dimension of the end corrugation in the pipe.

[3] Use annular corrugated bands with pipes having annular corrugations or with helical pipe having rerolled end to form annular corrugations. A 10.5 inch band is acceptable on pipe ends rerolled with 2⅔" x ½" corrugations. A 12 inch band is acceptable on pipe ends rerolled with 3" x 1" pipe corrugations.

[4] Use helical corrugated bands with pipes having helically corrugated ends.

[5] The minimum band widths shown for 3" x 1" and 5" x 1" corrugated sizes apply to 2⅔" x ½" corrugations on rerolled pipe ends.

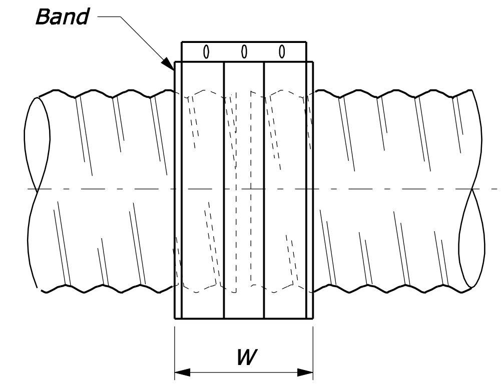
[6] Smooth sleeve-type couplers and flat bands may be used for pipe diameters of 12" or less. Use a matching metal having a nominal thickness of not less than 0.040 inch for steel, or 0.036 inch for aluminum, or a plastic with an equivalent strength to metal.



SLEEVE JOINT

Smoother sleeve with center stop.
Stab type joint

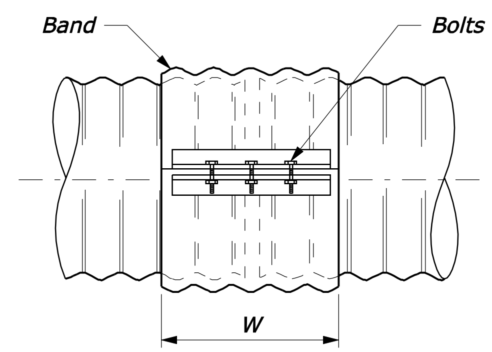
SMOOTH SLEEVE BAND



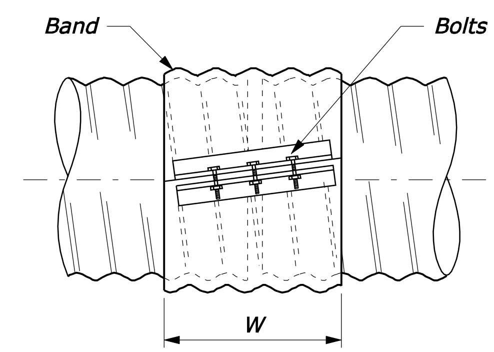
FLAT BAND

NOTE:

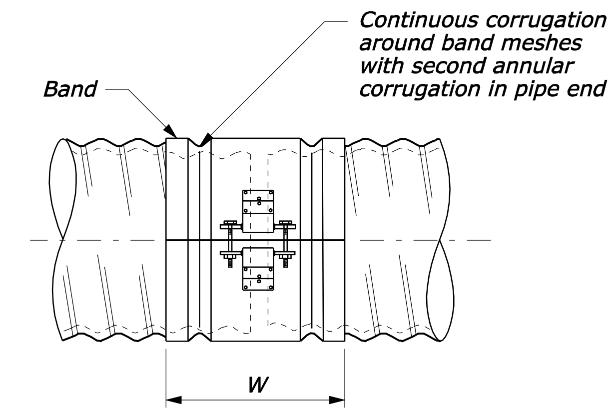
1. Watertight pipe joints are not required unless specified in the Special Contract Requirements.
2. Other types of coupling bands or fastening devices that comply with the joint performance criteria of AASHTO Standard specifications for Highway Bridges, Division II Section 26 may be used.



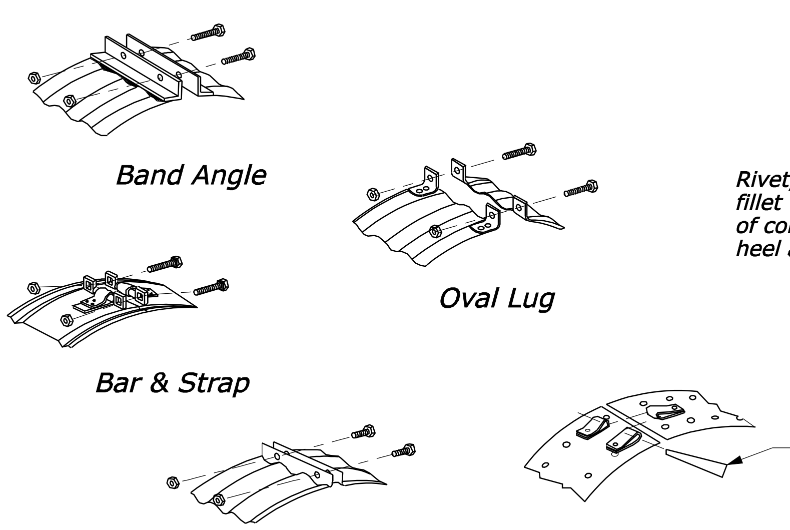
SIDE VIEW



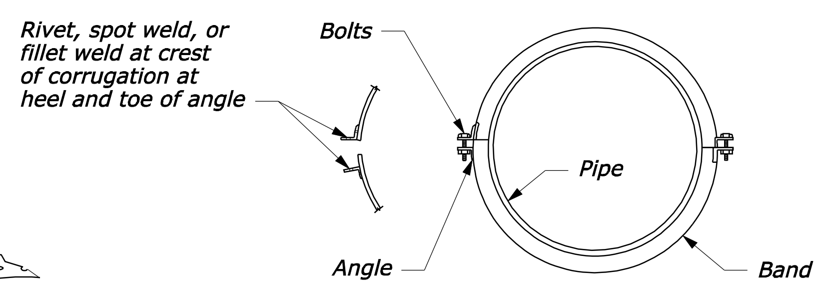
SIDE VIEW



SIDE VIEW



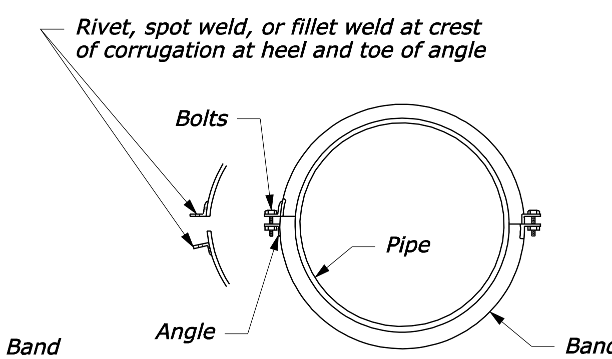
STANDARD BAND CONNECTIONS



END VIEW

Second angle connection optional to 42" diameter, required above 42" diameter

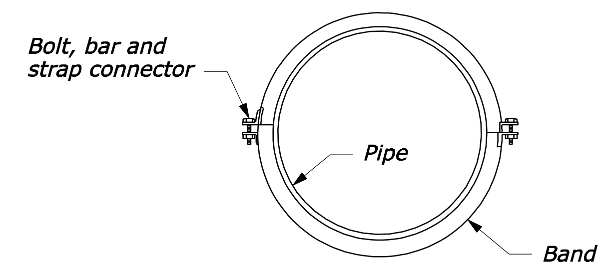
ANNULAR BAND



END VIEW

Second angle connection optional to 42" diameter, required above 42" diameter

HELICAL BAND



END VIEW

SEMI-CORRUGATED BAND

NO SCALE

U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION
FEDERAL LANDS HIGHWAY

U.S. CUSTOMARY STANDARD

METAL PIPE CULVERT COUPLING BAND

STANDARD APPROVED FOR USE 12/1993
REVISED: 4/1994 6/2005

STANDARD 602-2

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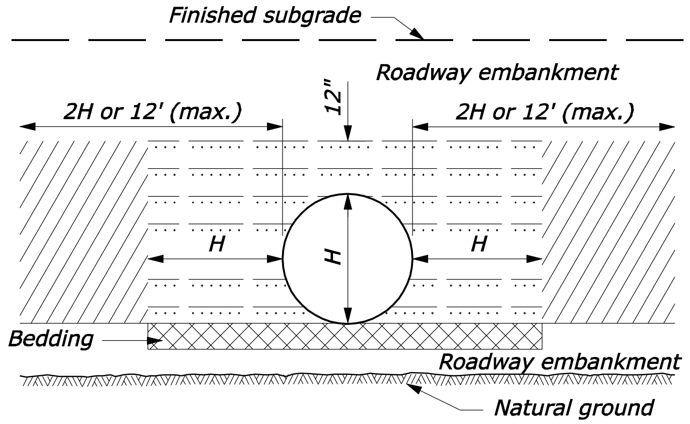
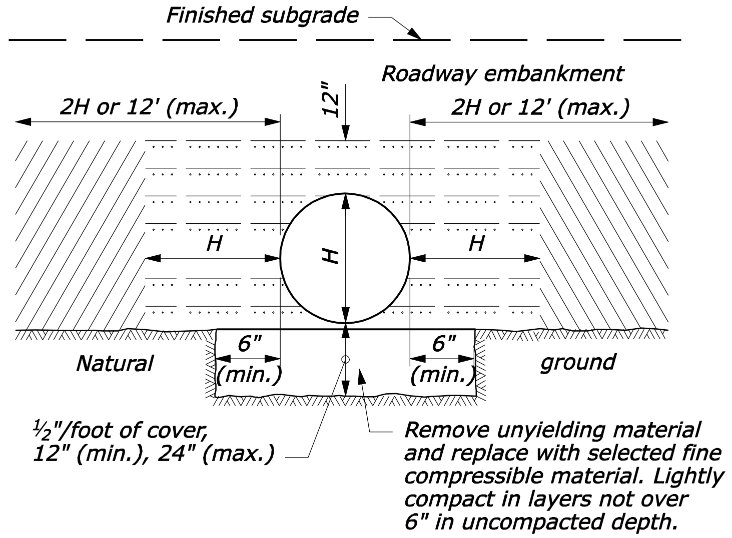
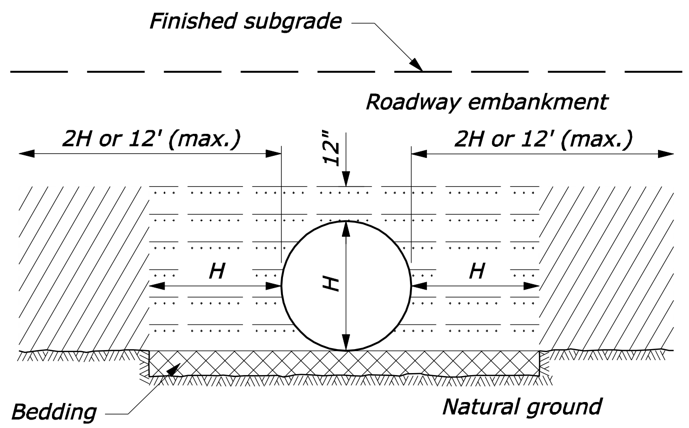
STATE	PROJECT	SHEET NUMBER
AK	AK PFH 43(10)	J.32



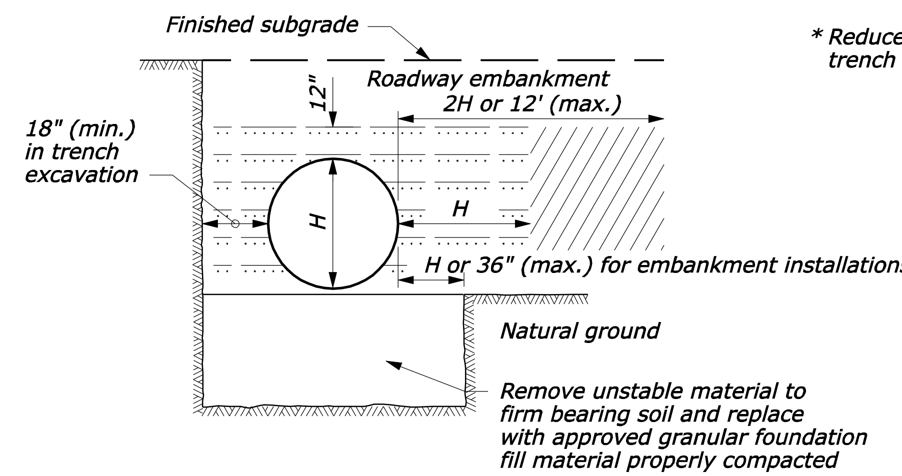
ABOVE NATURAL GROUND



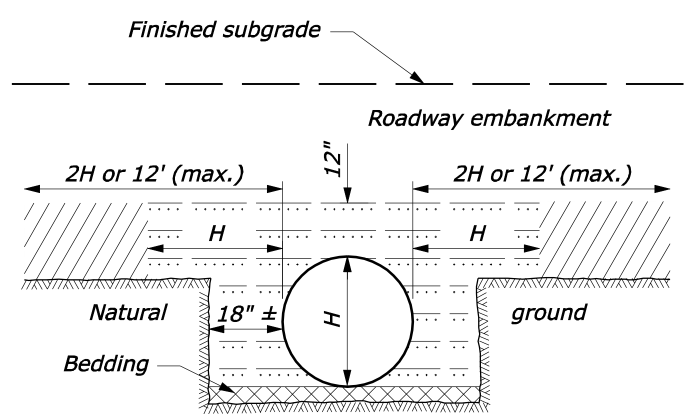
ON UNYIELDING MATERIAL



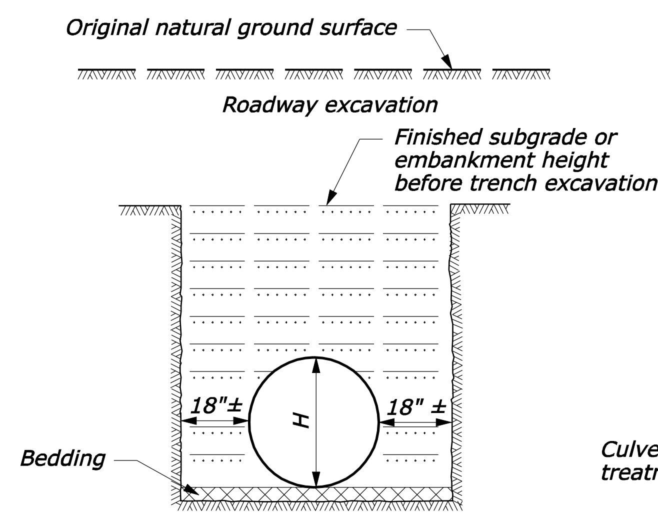
ON NATURAL GROUND



ON UNSTABLE MATERIAL



ABOVE AND BELOW NATURAL GROUND



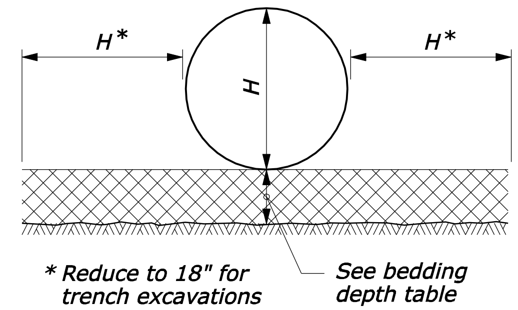
BELOW NATURAL GROUND OR TRENCH EXCAVATION IN EMBANKMENT

Bedding material (uncompacted)

Embankment material placed in layers not exceeding 6" compacted depth.

Compacted backfill material placed in layers not exceeding 6" compacted depth meeting the following:
Metal Pipe: Maximum particle size = 3"
Soil classification: A-1, A-2, or A-3
Plastic Pipe: Maximum particle size: 1½"
Soil classification: A-1, A-2-4, A-2-5, or A-3
Or lean concrete backfill in accordance with Section 614.

BEDDING DEPTH	
PIPE SIZE (H)	DEPTH
12" to 54"	4"
> 54"	6"

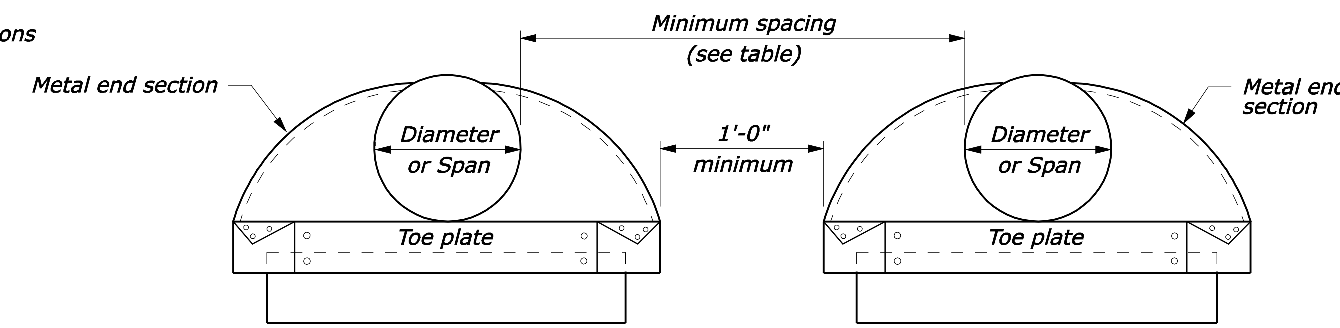


PIPE BEDDING

NOTE:

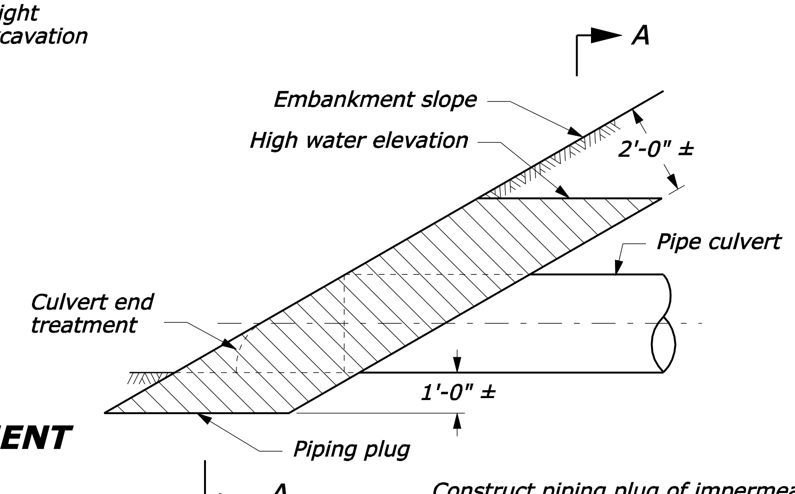
1. When directed, camber pipe culverts upward from a chord through the inlet and outlet inverts an ordinate amount equal to 1% of the pipe length. Develop camber on a parabolic curve. If the midpoint elevation on the parabolic curve as designed exceeds the elevation of the inlet invert, reduce the amount of camber or increase the pipe culvert gradient.
2. H equals the diameter of all round pipe culverts or the rise dimension of all pipe arch culverts.

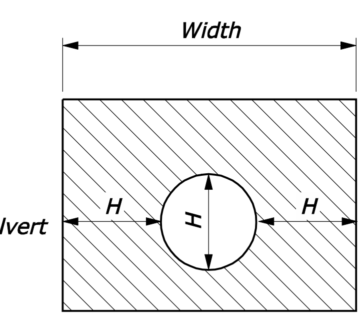
MINIMUM SPACING	
DIAMETER or SPAN	SPACING
UP to 48"	24"
48" and UP	Half diameter or span OR 36" whichever is less



ELEVATION

MULTIPLE PIPE INSTALLATION





SECTION A-A

Construct piping plug of impermeable backfill material at the pipe culvert inlet where granular material is used for backfill. Width may be adjusted to tie into impervious material.

PIPING PLUG

NO SCALE

U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION
FEDERAL LANDS HIGHWAY

U.S. CUSTOMARY STANDARD

METAL AND PLASTIC PIPE CULVERT BEDDING

STANDARD APPROVED FOR USE 12/1993
REVISED: 4/1994 6/2005

STANDARD 602-3

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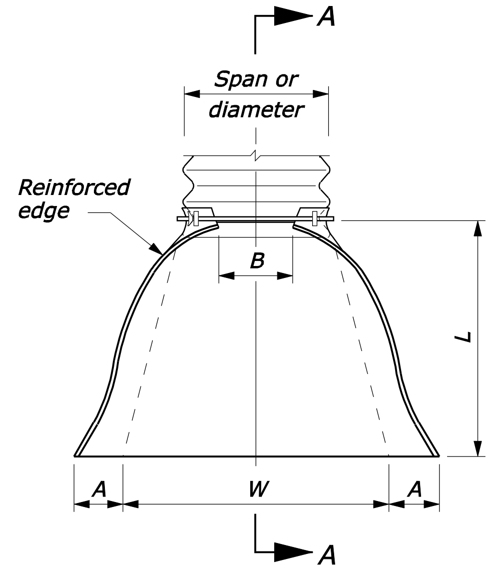
END SECTIONS FOR ROUND PIPE CULVERT

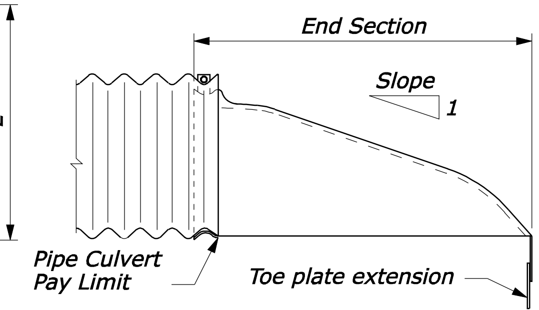
PIPE SIZE DIAMETER INCHES	METAL THICKNESS				DIMENSIONS INCHES					SLOPE
	STEEL		ALUMINUM							
	INCHES	GAGE	INCHES	GAGE	A (min)	B (max)	H (min)	L (±2")	W (max)	Approx.
12	0.064	16	0.060	16	5	7	6	21	44	2¼
15	0.064	16	0.060	16	6	8	6	26	52	2¼
18	0.064	16	0.060	16	7	10	6	31	58	2⅛
21	0.064	16	0.060	16	8	12	6	36	66	2⅛
24	0.064	16	0.060	16	9	13	6	41	72	2⅛
30	0.079	14	0.075	14	11	16	8	51	88	2⅛
36	0.079	14	0.075	14	13	19	9	60	105	2
42	0.109	12	0.105	12	15	25	10	69	122	2⅛
48	0.109	12	0.105	12	17	29	12	78	131	2
54	0.109	12	0.105	12	17	33	12	84	143	2
60	0.109	12	0.105	12	17	36	12	87	157	1⅞
66	0.109	12	0.105	12	17	39	12	87	162	1⅝
72	0.109	12	0.105	12	17	44	12	87	169	1½
78	0.109	12	0.105	12	17	48	12	87	178	1⅜
84	0.109	12	0.105	12	17	52	12	87	184	1⅓
90	0.109	12	0.105	12	17	58	12	87	188	1¼
96	0.109	12	0.105	12	17	58	12	87	197	1⅛

END SECTIONS FOR PIPE ARCH CULVERT

PIPE SIZE SPAN x RISE INCHES	METAL THICKNESS				DIMENSIONS INCHES					SLOPE
	STEEL		ALUMINUM							
	INCHES	GAGE	INCHES	GAGE	A (min)	B (max)	H (min)	L (±2")	W (max)	Approx.
17 x 13	0.064	16	0.060	16	5	9	6	20	52	2⅛
21 x 15	0.064	16	0.060	16	6	11	6	24	58	2
24 x 18	0.064	16	0.060	16	7	12	6	28	58	2⅛
28 x 20	0.064	16	0.060	16	7	16	6	32	66	2
35 x 24	0.079	14	0.075	14	9	16	6	39	72	1⅞
42 x 29	0.079	14	0.075	14	11	18	7	46	88	1⅞
49 x 33	0.109	12	0.105	12	12	21	9	53	105	1¾
57 x 38	0.109	12	0.105	12	16	26	12	62	122	1⅞
60 x 46	0.109	12	0.105	12	17	36	12	70	142	1⅞
64 x 43	0.109	12	0.105	12	17	30	12	69	131	1⅞
66 x 51	0.109	12	0.105	12	17	36	12	77	156	1¾
71 x 47	0.109	12	0.105	12	17	36	12	77	143	1⅞
73 x 55	0.109	12	0.105	12	17	36	12	77	168	1½
77 x 52	0.109	12	0.105	12	17	36	12	77	157	1⅝
81 x 59	0.109	12	0.105	12	17	44	12	77	179	1⅝
83 x 57	0.109	12	0.105	12	17	44	12	77	162	1½
87 x 63	0.109	12	0.105	12	17	44	12	77	186	1½
95 x 67	0.109	12	0.105	12	17	44	12	87	210	1½
103 x 71	0.109	12	0.105	12	17	44	12	87	222	1⅓
112 x 75	0.109	12	0.105	12	17	44	12	87	226	1¼



PLAN

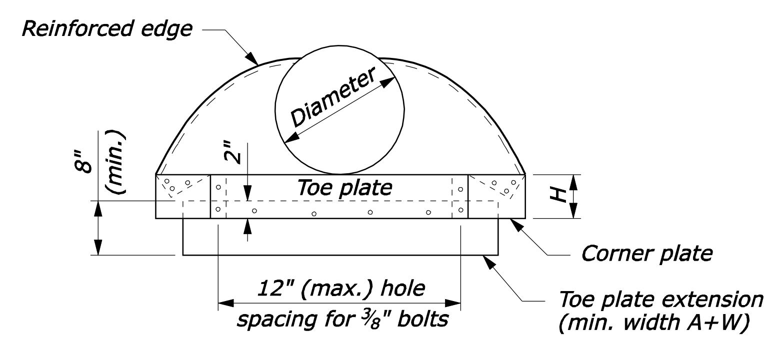


SECTION A-A

ROUND OR PIPE ARCH CULVERT

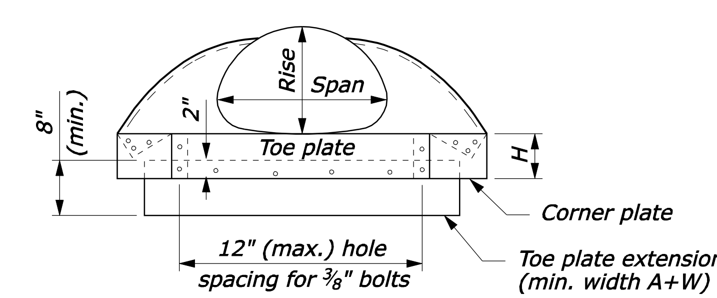
NOTE:

1. Variations in design and dimensions are permitted to allow for manufacturer's standards.
2. Fabricate the diameter of the end section of Design B to match the inside diameter of the concrete pipe culvert.
3. Design C may be used in lieu of design A for all metal pipe culvert sizes. Coupling bands may be any acceptable type for the pipe culvert specified.
4. Fabricate multiple piece bodies with lap seams tightly joined by ⅜" rivets or bolts. Fabricate end section center panels for 60" and larger diameter pipe and equivalent pipe arch from 0.138 inch steel or 0.135 inch aluminum.
5. On end section center panels for 66" and larger equivalent pipe arch provide 2½" x 2½" x ¼" angle reinforcement bolted or riveted under the center panel seam.
6. Supplement the reinforced edges of end sections for 60" and larger diameter pipe and 66" and larger equivalent pipe arch with 2½" x 2½" x ¼" stiffener angles attached with bolts or rivets.
7. Fabricate connector section, corner plate and toe plate extensions from the same metal thickness as the panel body. Use toe plate extension where shown on the plans.
8. Warp embankment slopes to match the slope of the flared end sections.



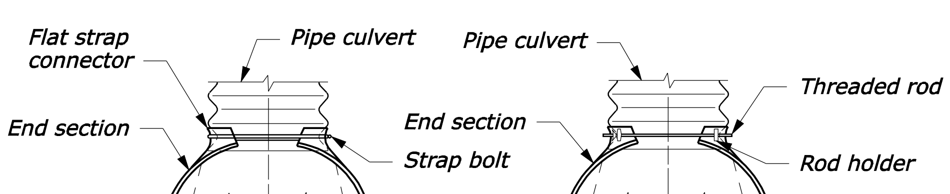
ELEVATION

ROUND PIPE CULVERT



ELEVATION

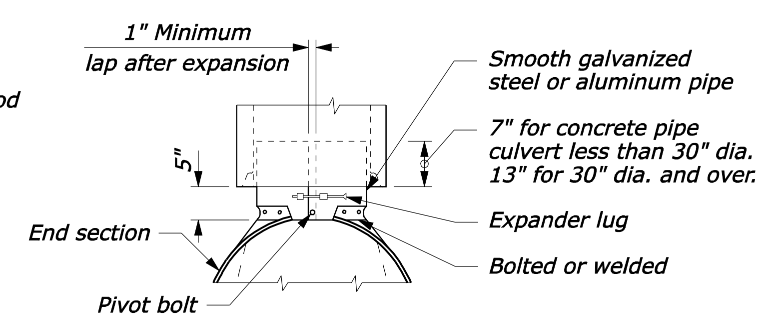
PIPE ARCH CULVERT



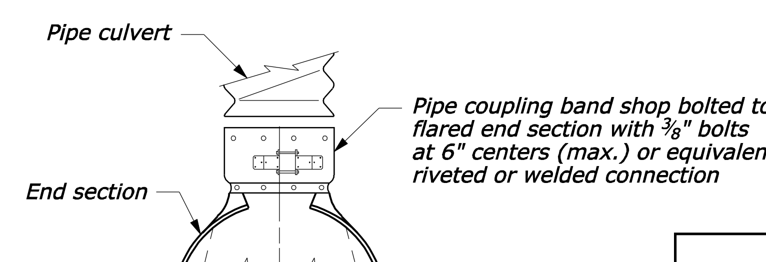
For 12" thru 24" round pipe and 17" x 13" thru 28" x 20" pipe arch

For 30" thru 60" round pipe and 35" x 24" thru 66" x 51" pipe arch

DESIGN A CONNECTION TO ANNULAR CORRUGATED METAL PIPE



DESIGN B CONNECTION TO CONCRETE PIPE INLET END



For all sizes of round pipe and pipe arch

DESIGN C CONNECTION TO METAL PIPE OR OUTLET END OF CONCRETE PIPE

NO SCALE

U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION
FEDERAL LANDS HIGHWAY

U.S. CUSTOMARY STANDARD

METAL END SECTIONS

STANDARD APPROVED FOR USE 12/1993

REVISED: 4/1994 6/2005
DRAFT: 10/2007

STANDARD 602-4

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POLYETHYLENE (PE) PLASTIC ROUND PIPE CULVERT

FILL HEIGHT TABLE AND MINIMUM CELL CLASSIFICATION NUMBER PER ASTM D 3350

SMOOTH WALL (SOLID WALL)

PIPE SIZE DIAMETER INCHES	MINIMUM COVER INCHES	CELL CLASSIFICATION NUMBER 335434C						
		MINIMUM WALL THICKNESS (INCHES)						
		0.607	0.857	0.923	1.154	1.385	1.292	1.477
		MAXIMUM FILL HEIGHT (FEET)						
12	12	57						
18	12		52					
24	12			38				
30	12				38			
36	12					38		
42	12						27	
48	12							27

CORRUGATED

PIPE SIZE DIAMETER INCHES	MINIMUM COVER INCHES	CELL CLASS. NO. 435400C MAXIMUM FILL HEIGHT (FEET)
12	12	10
15	12	10
18	12	10
24	12	10
30	12	10
36	12	10

RIBBED

PIPE SIZE DIAMETER INCHES	MINIMUM COVER INCHES	CELL CLASS. NO. 334433C	CELL CLASS. NO. 335434C
		MAXIMUM FILL HEIGHT (FEET)	
18	12	18	24
24	12	22	28
30	12	22	28
36	12	25	31
42	12	21	27
48	12	21	26

NOTE:

1. When directed, camber pipe culverts upward from a chord through the inlet and outlet inverts an ordinate amount equal to 1% of the pipe length. Develop camber on a parabolic curve. If the midpoint elevation on the parabolic curve as designed exceeds the elevation of the inlet invert, reduce the amount of camber or increase the pipe culvert gradient.
2. Measure minimum cover from the top of the pipe culvert to the subgrade for flexible pavements, and to the top of the pavement for rigid pavements. Measure maximum fill height from the top of the pipe to the top of the pavement for both flexible and rigid pavement.

POLYVINYL CHLORIDE (PVC) PLASTIC ROUND PIPE CULVERT

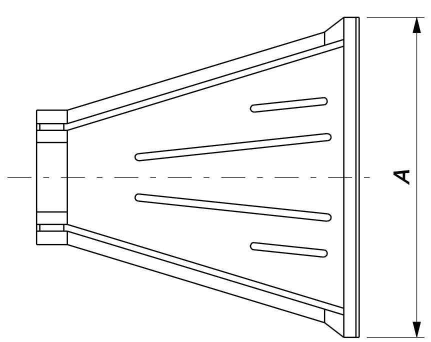
FILL HEIGHT TABLE AND MINIMUM CELL CLASSIFICATION NUMBER PER ASTM D 1784

SMOOTH WALL (SOLID WALL)

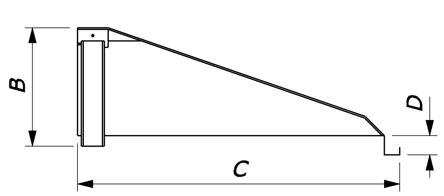
PIPE SIZE DIAMETER INCHES	MINIMUM COVER INCHES	CELL CLASS. NO. 12454		CELL CLASS. NO. 12364	
		MINIMUM WALL THICKNESS (INCHES)			
		0.358	0.438	0.358	0.438
		MAXIMUM FILL HEIGHT (FEET)			
12	12	65		69	
15	12		62		66

RIBBED

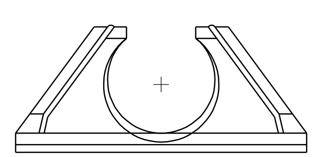
PIPE SIZE DIAMETER INCHES	MINIMUM COVER INCHES	CELL CLASS. NO. 12454C	CELL CLASS. NO. 12364C
		MAXIMUM FILL HEIGHT (FEET)	
12	12	37	26
15	12	32	22
18	12	33	23
24	12	29	21
30	12	28	20
36	12	27	19
42	12	26	18
48	12	24	17



TOP



SIDE



FRONT

PLASTIC PIPE END SECTION

END SECTION DIMENSIONS

PIPE SIZE DIAMETER INCHES	DIMENSIONS INCHES A	B	C	D
12	42	14.5	33	6
15	46	24.5	45.5	6
18	54	29	55	6
24	64	37	65	6
30	88	36	63.5	6
36	88	43	66.5	6

NO SCALE

U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION
FEDERAL LANDS HIGHWAY

U.S. CUSTOMARY STANDARD

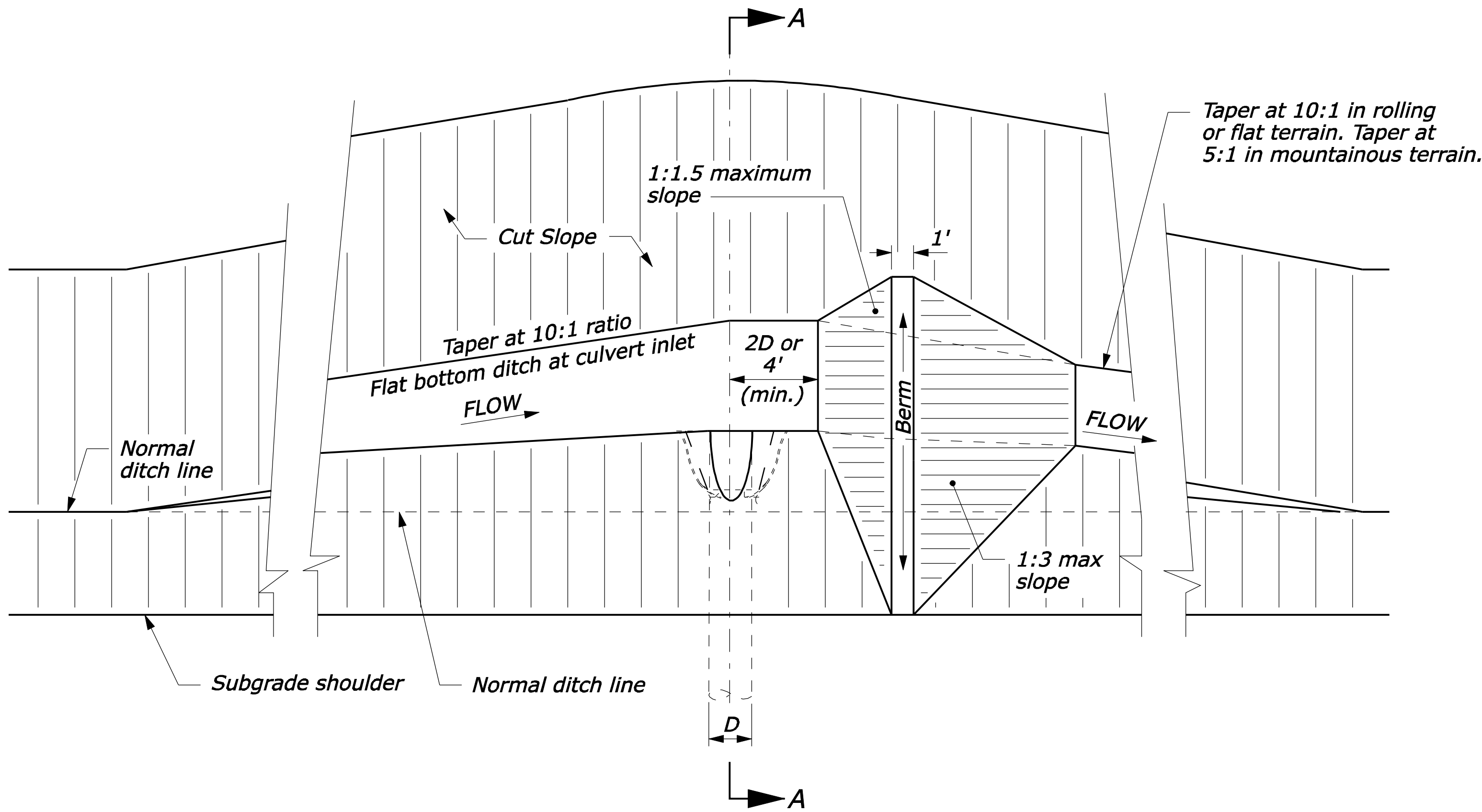
PLASTIC PIPE CULVERT

STANDARD APPROVED FOR USE 12/1993
REVISED: 4/1994 6/2005
DRAFT 12/2008
STANDARD 602-5

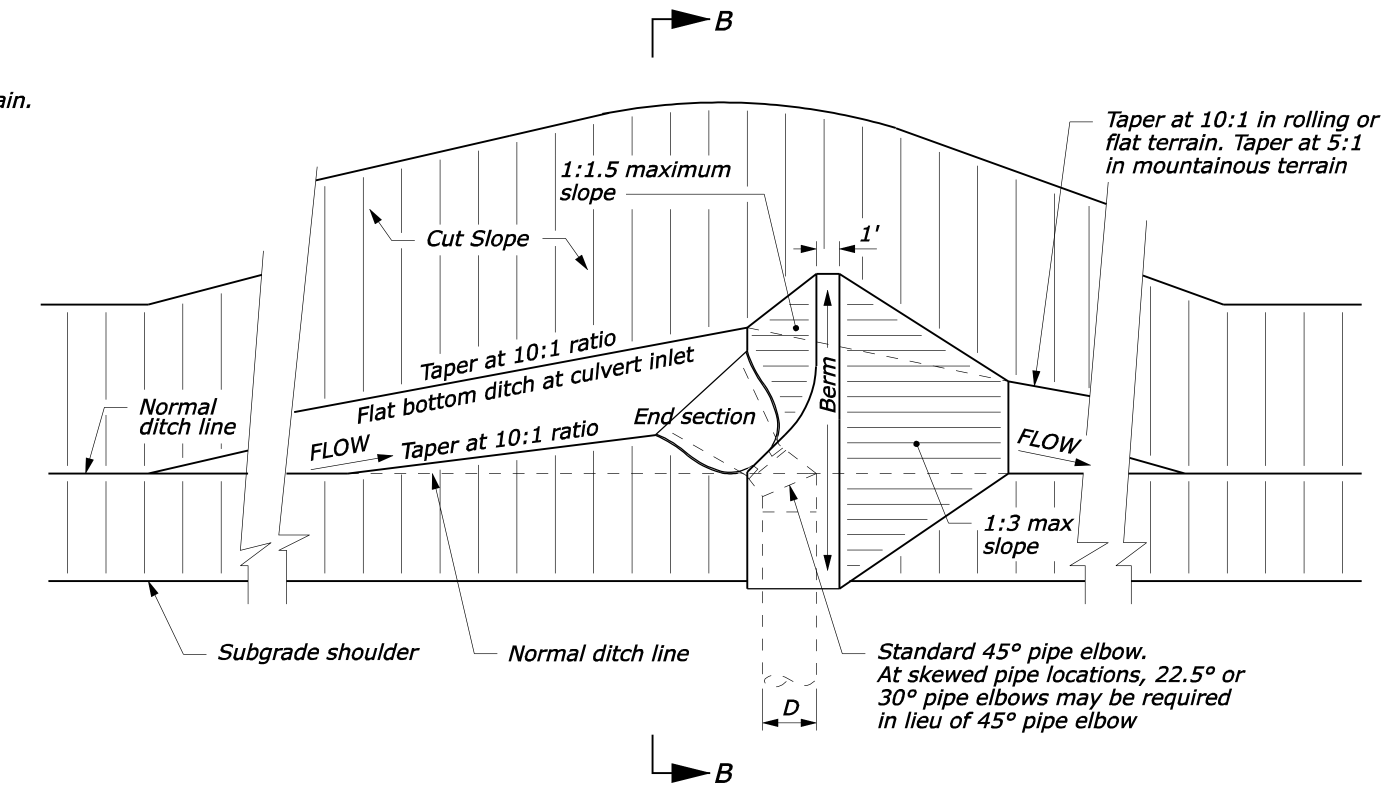
STATE	PROJECT	SHEET NUMBER
AK	AK PFH 43(10)	J.35

NOTE:

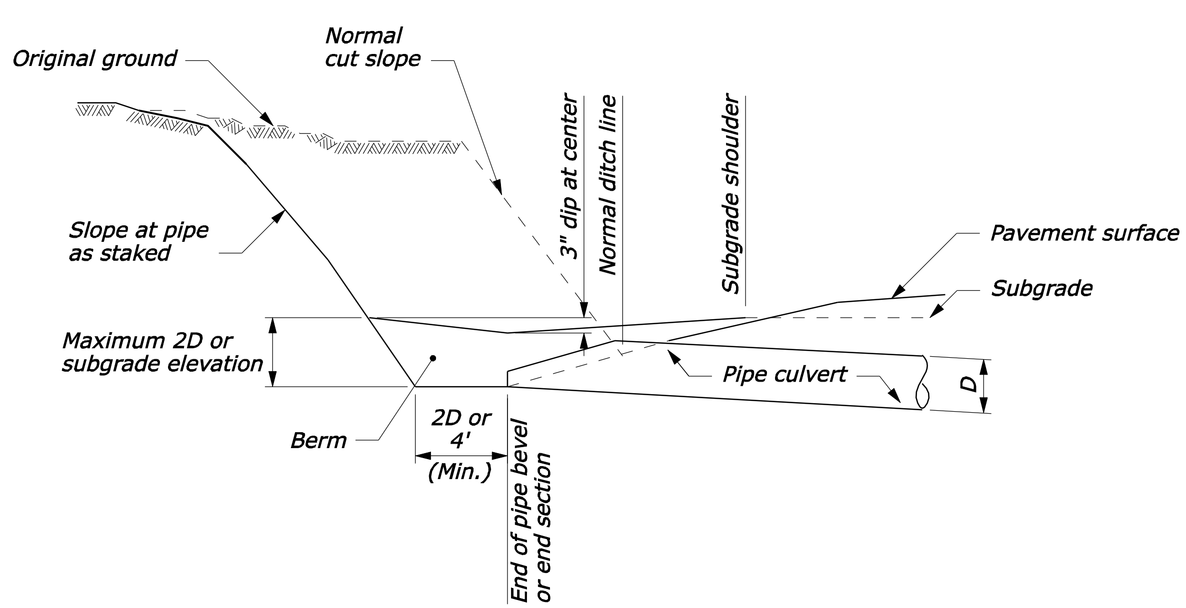
1. D equals the diameter of all round pipe or the rise dimension of all pipe arch culverts.



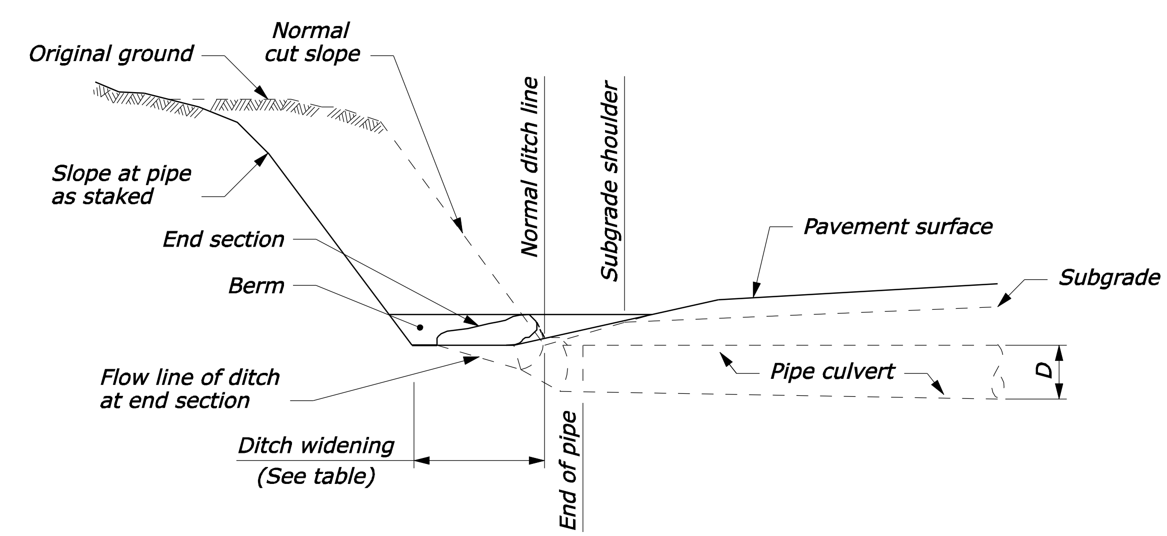
PLAN



PLAN



SECTION A-A
TYPE I



DITCH WIDENING	
PIPE SIZE (D)	WIDENING
18"	5'
24"	6'
30"	7'

SECTION B-B
TYPE II

NO SCALE

U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION
FEDERAL LANDS HIGHWAY

U.S. CUSTOMARY STANDARD

PIPE CULVERT INLET TREATMENT IN CUT SLOPES

STANDARD APPROVED FOR USE 12/1993
REVISED: 4/1994 6/2005

STANDARD 602-6

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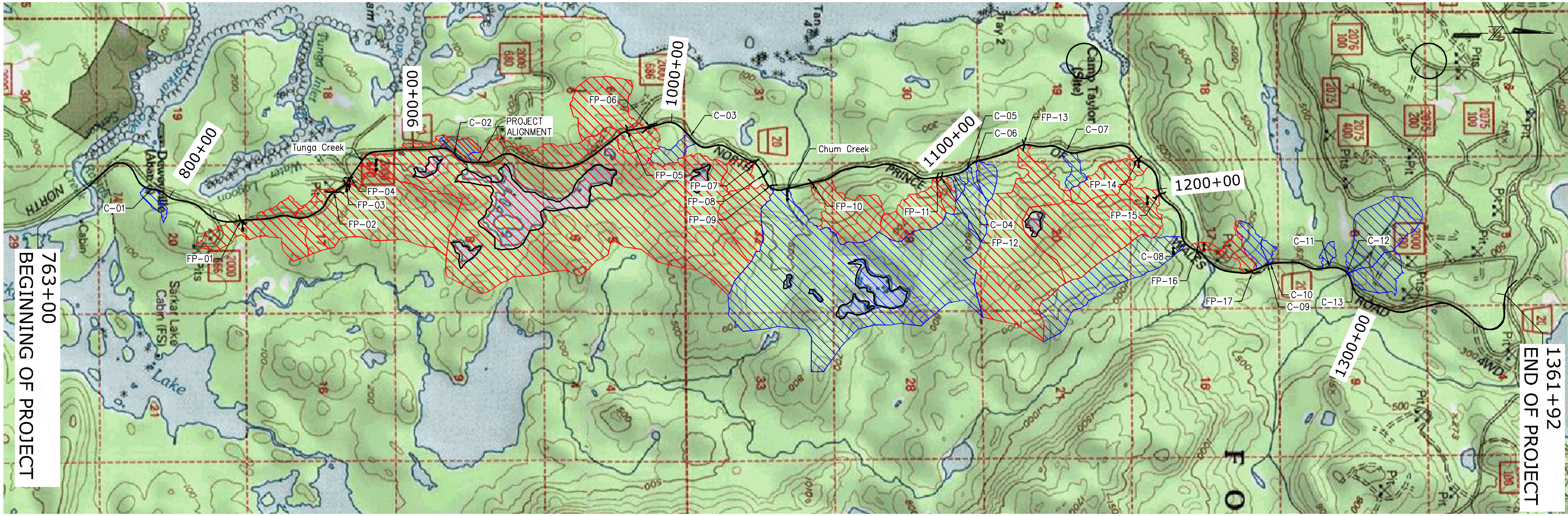
APPENDIX B

Hydrologic Analysis

Drainage Basin Delineation Maps



BASIN MAP

FISH PASSAGE STREAM		
STREAM ID	FH-43 MP	DRAINAGE BASIN (sq. mi.)
FP-01	82.6670	0.14
FP-02	83.3910	0.01
FP-03	83.5000	0.40
FP-04	83.5410	0.01
TUNGA	83.7100	1.72
FP-05	85.8840	0.14
FP-06	86.0610	0.18
FP-07	86.9560	0.04
FP-08	87.0550	0.01
FP-09	87.1720	0.11
CHUM	87.2720	1.10
FP-10	87.4690	0.13
FP-11	88.3860	0.10
FP-12	88.4130	0.02
FP-13	89.0350	0.45
FP-14	89.8940	0.08
FP-15	90.2010	0.35
FP-16	90.6960	0.01
FP-17	91.1200	0.03

NON-FISH PASSAGE		
STREAM ID	FH-43 MP	DRAINAGE BASIN (sq. mi.)
C-01	81.9900	0.02
C-02	84.4480	0.03
C-03	86.3880	0.03
C-04	88.5090	0.01
C-05	88.5810	0.05
C-06	88.7030	0.03
C-07	89.3410	0.02
C-08	90.5930	0.22
C-09	91.2210	0.03
C-10	91.2760	0.01
C-11	91.7210	0.01
C-12	91.8600	0.16
C-13	91.9200	0.06

AK PFH 43(10) DEWEYVILLE TRAILHEAD
TO NECK LAKE ROAD
PRELIMINARY HYDRAULICS REPORT
DRAINAGE BASIN MAP
DECEMBER 2012

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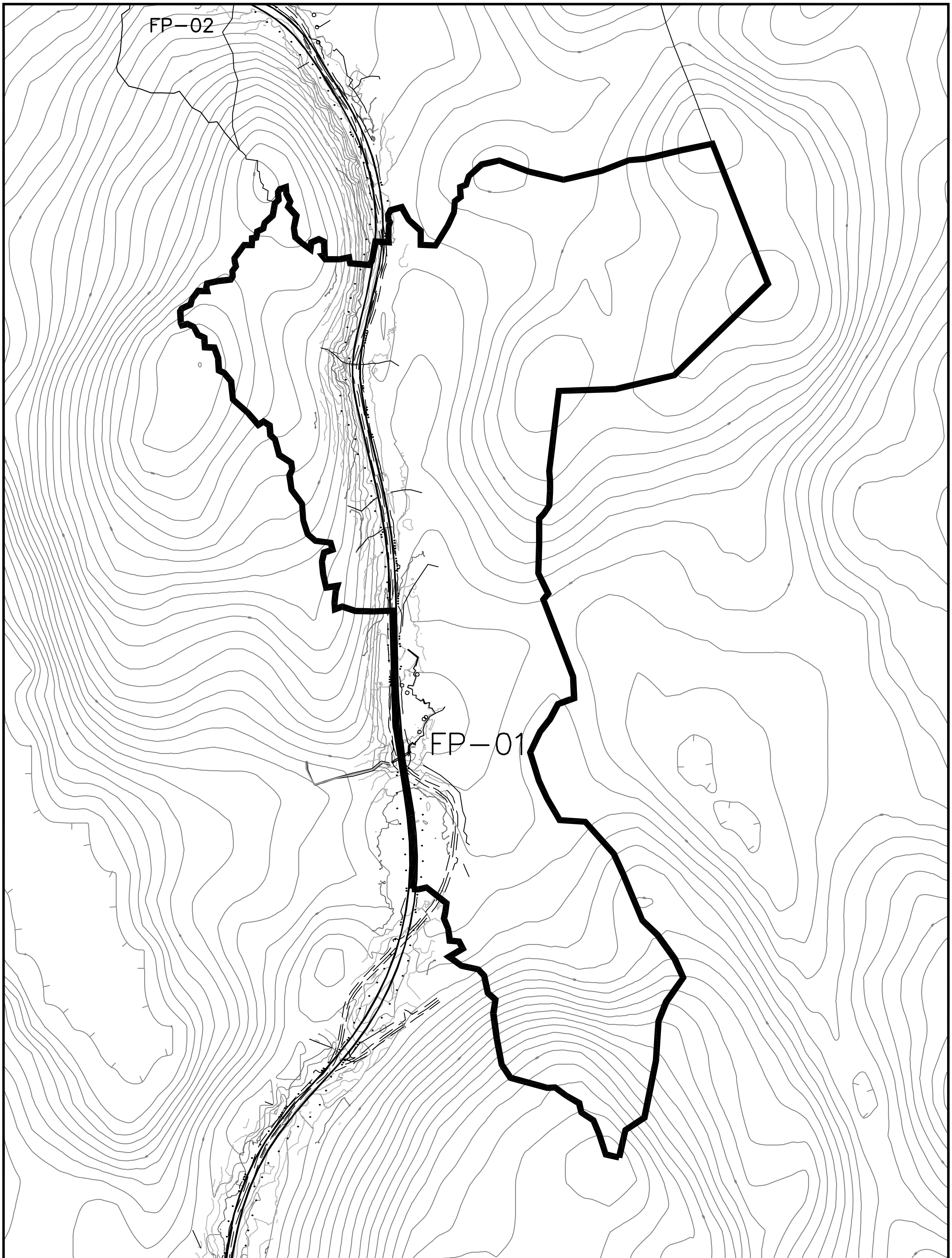
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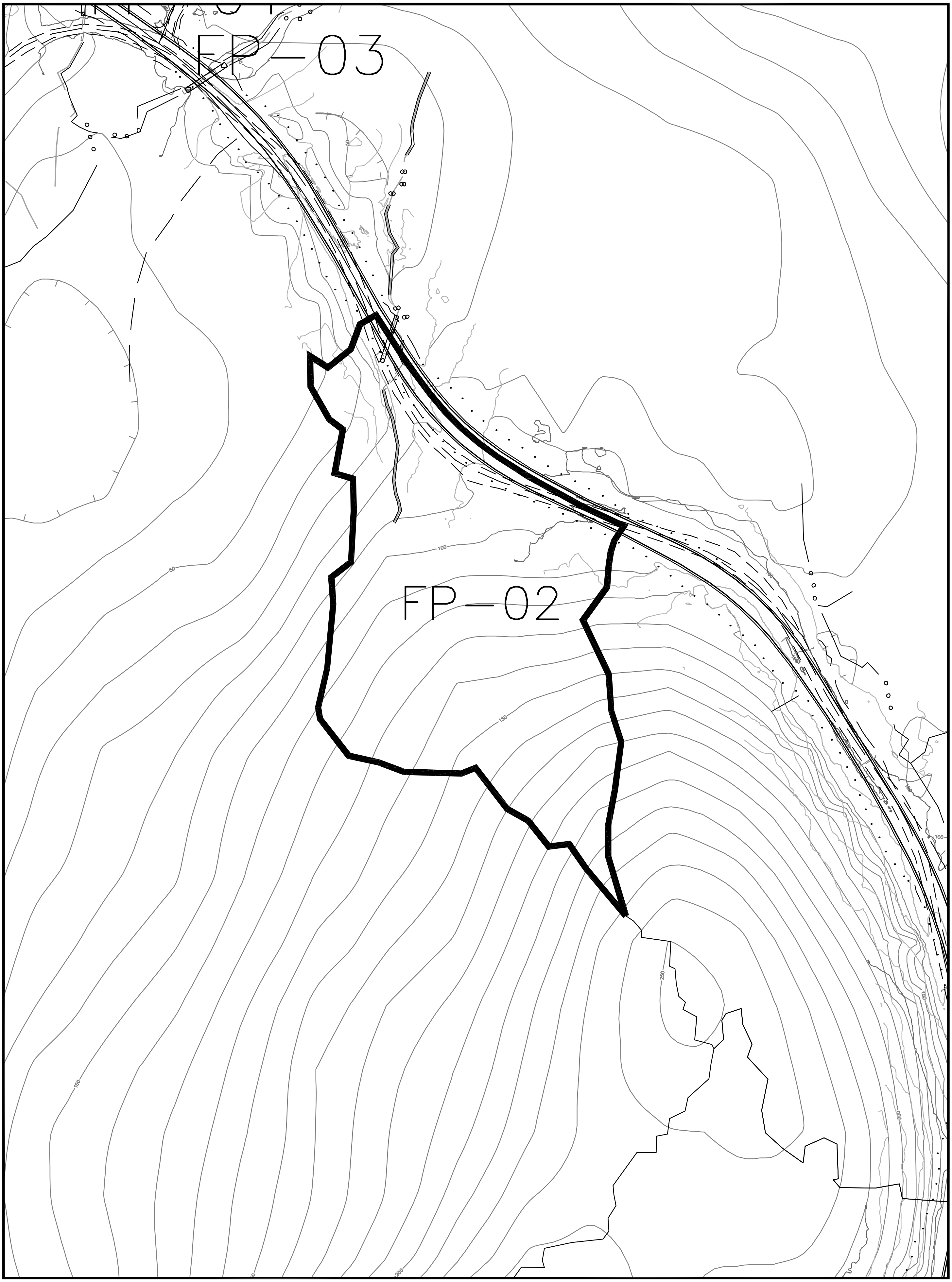
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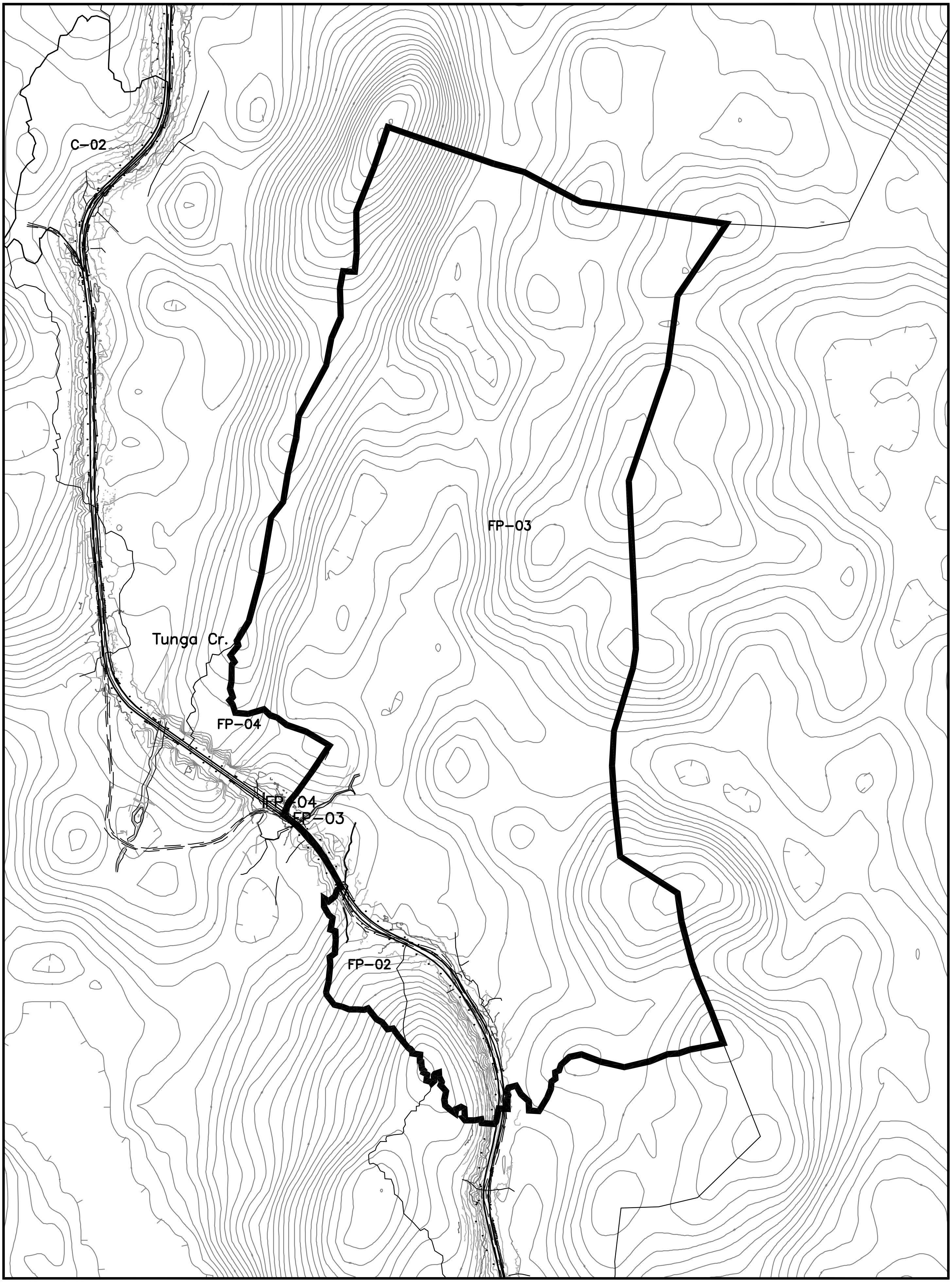
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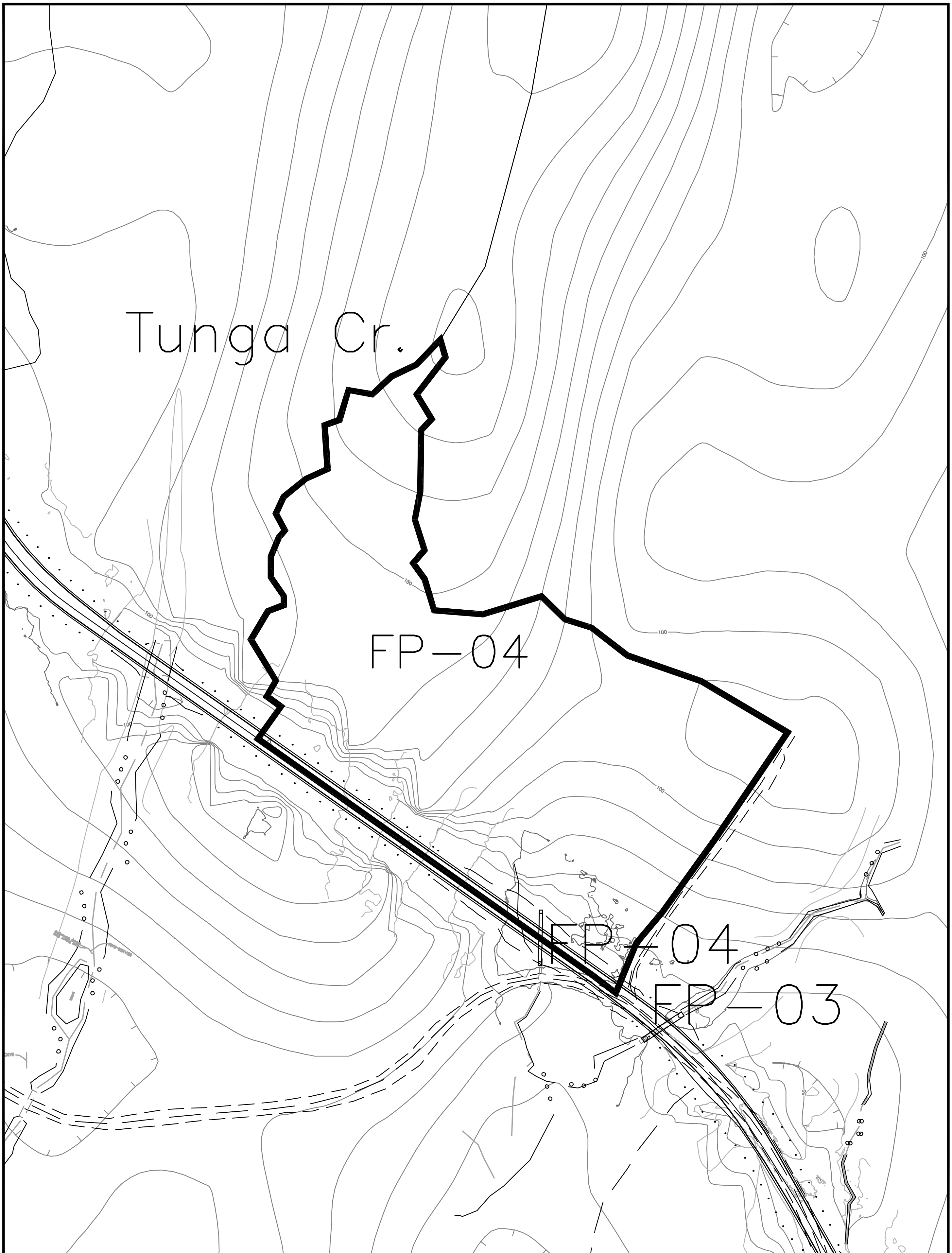
FP-03
FP-02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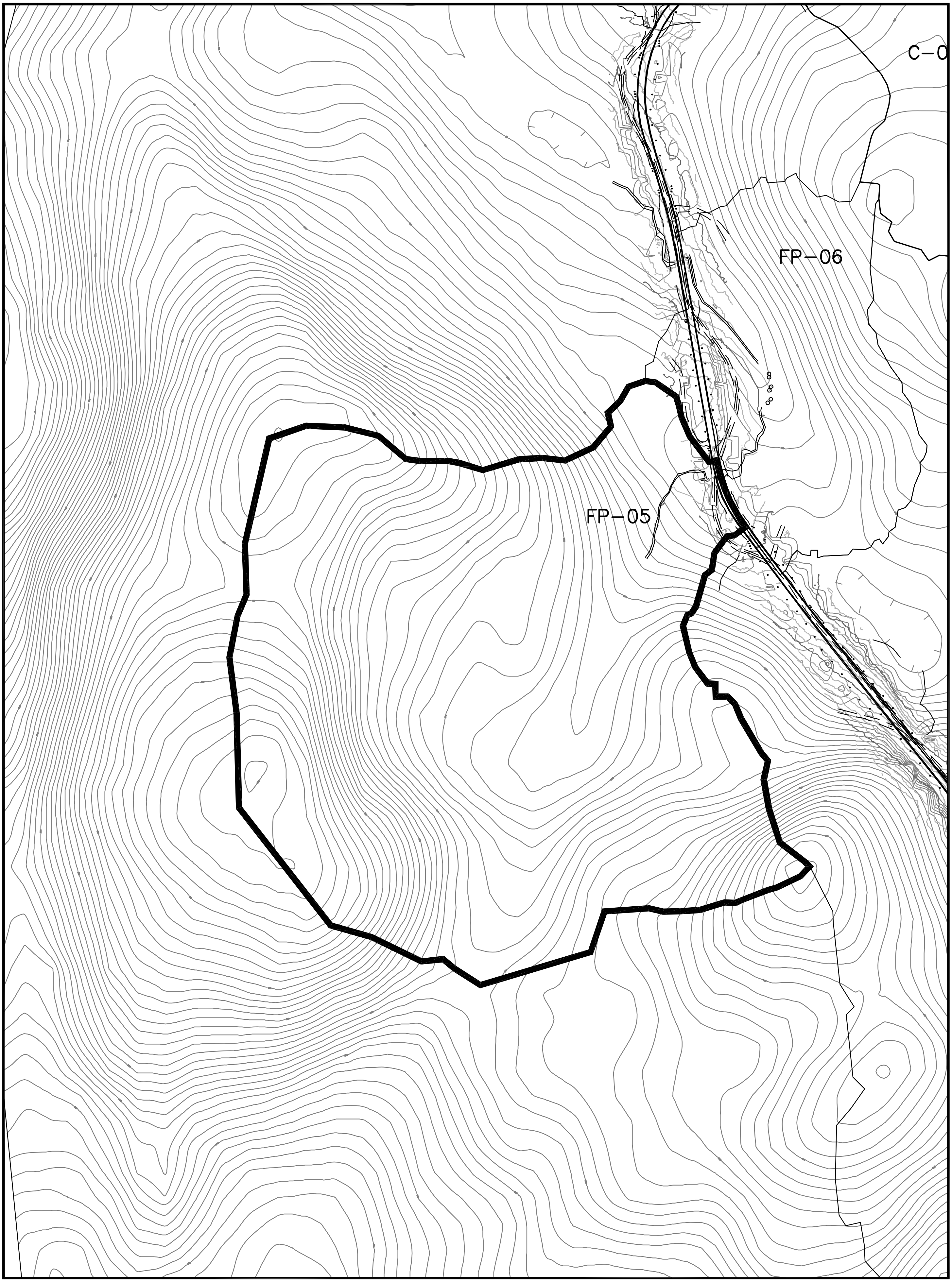

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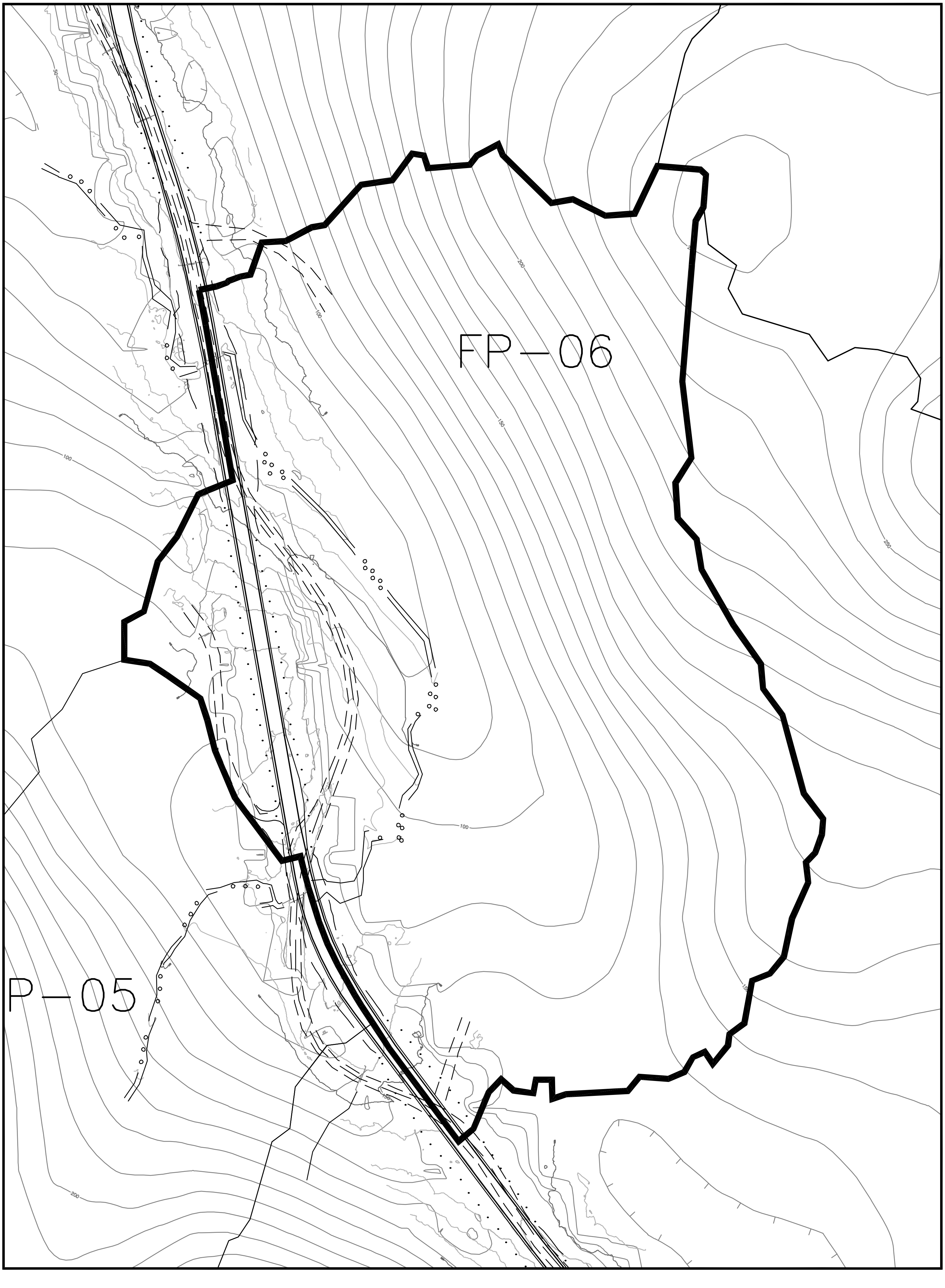
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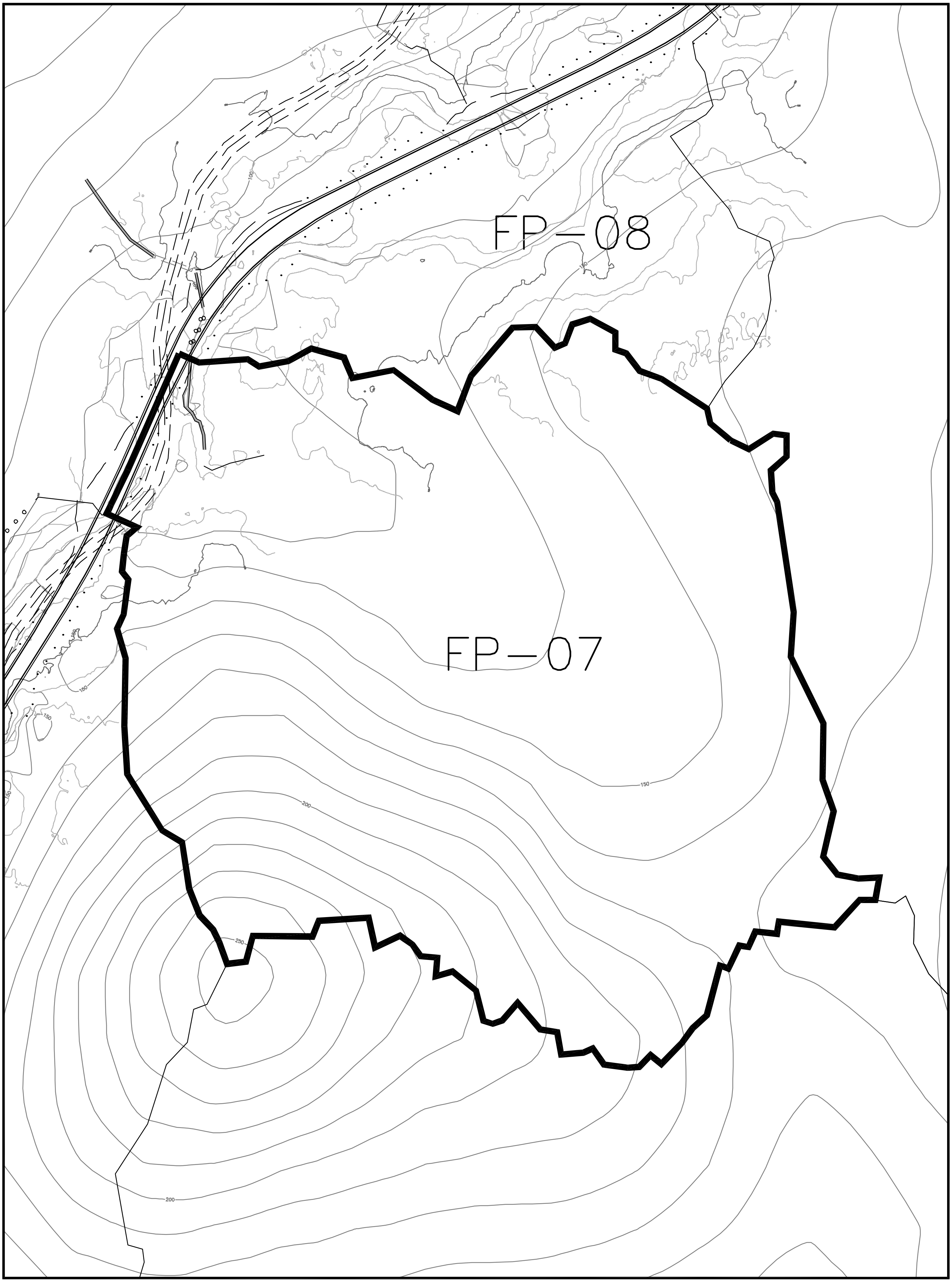
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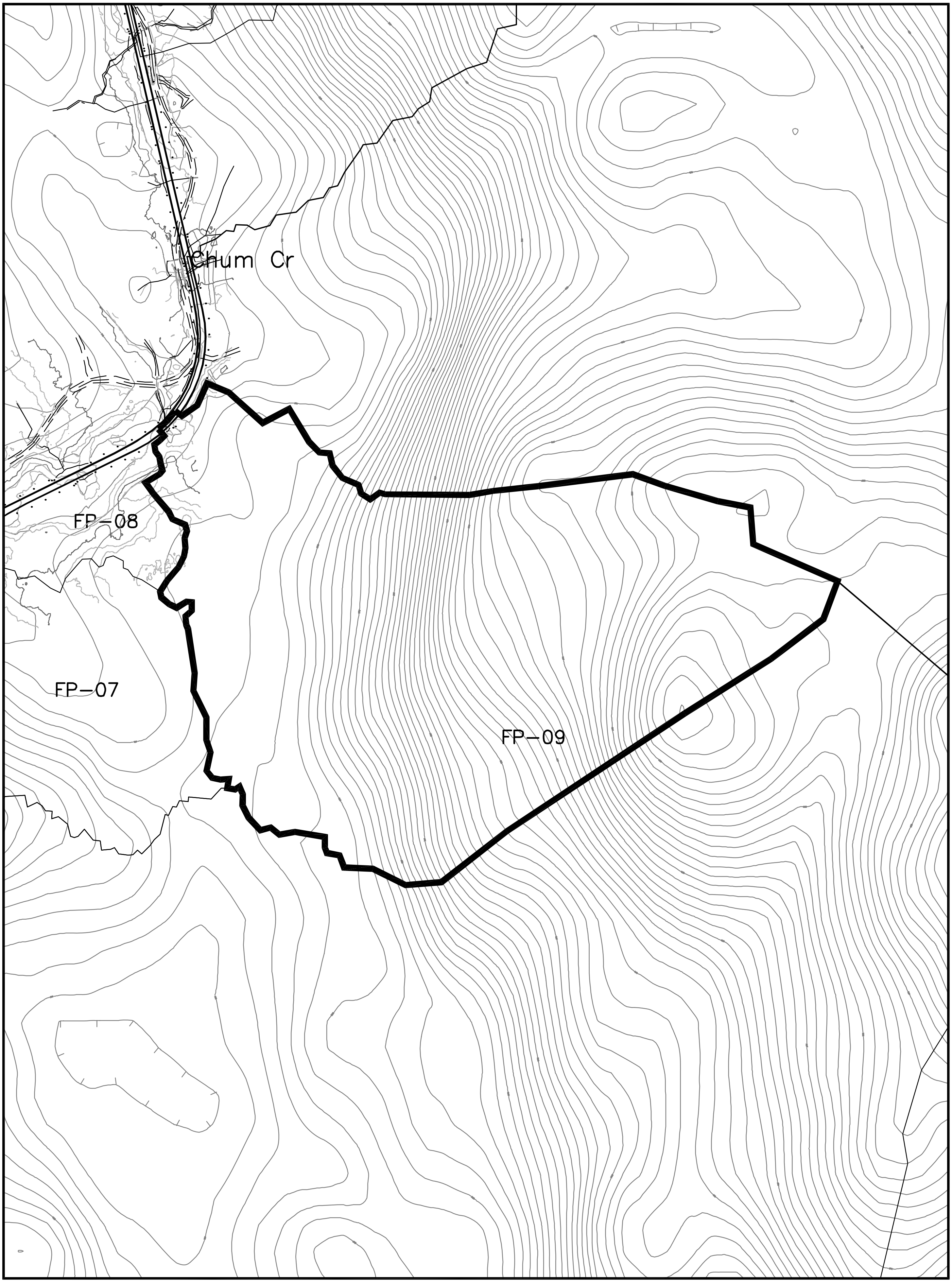
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FP-11
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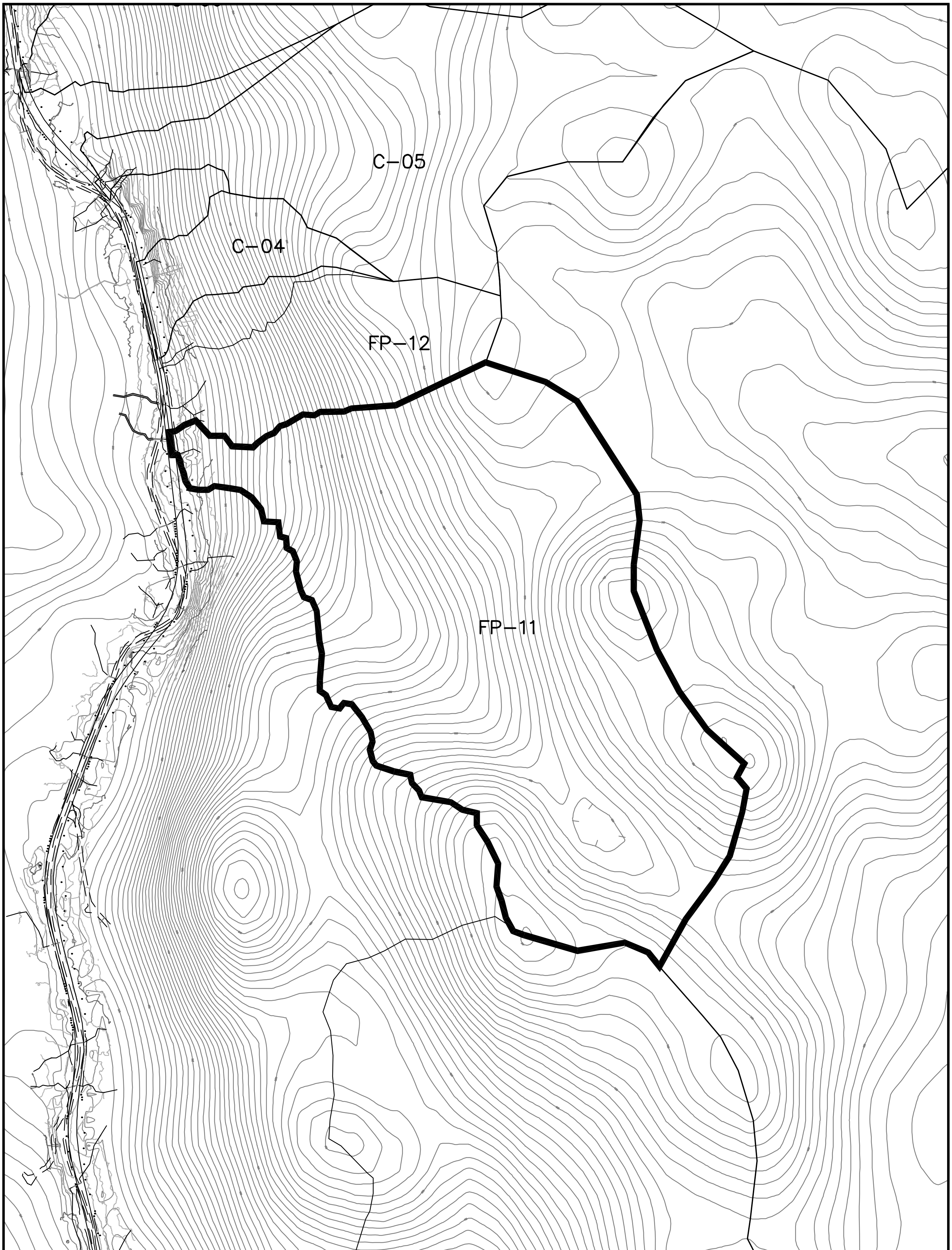
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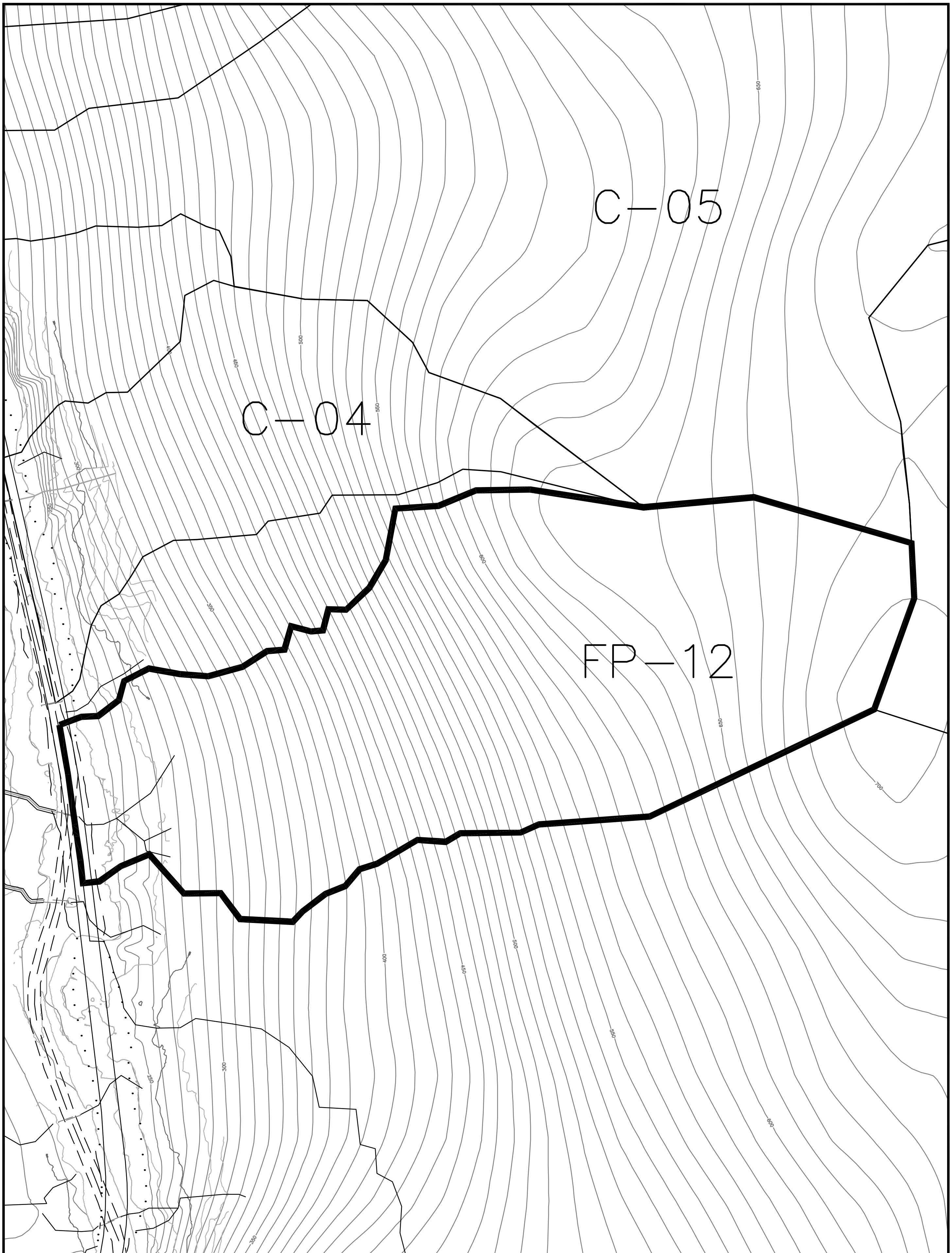
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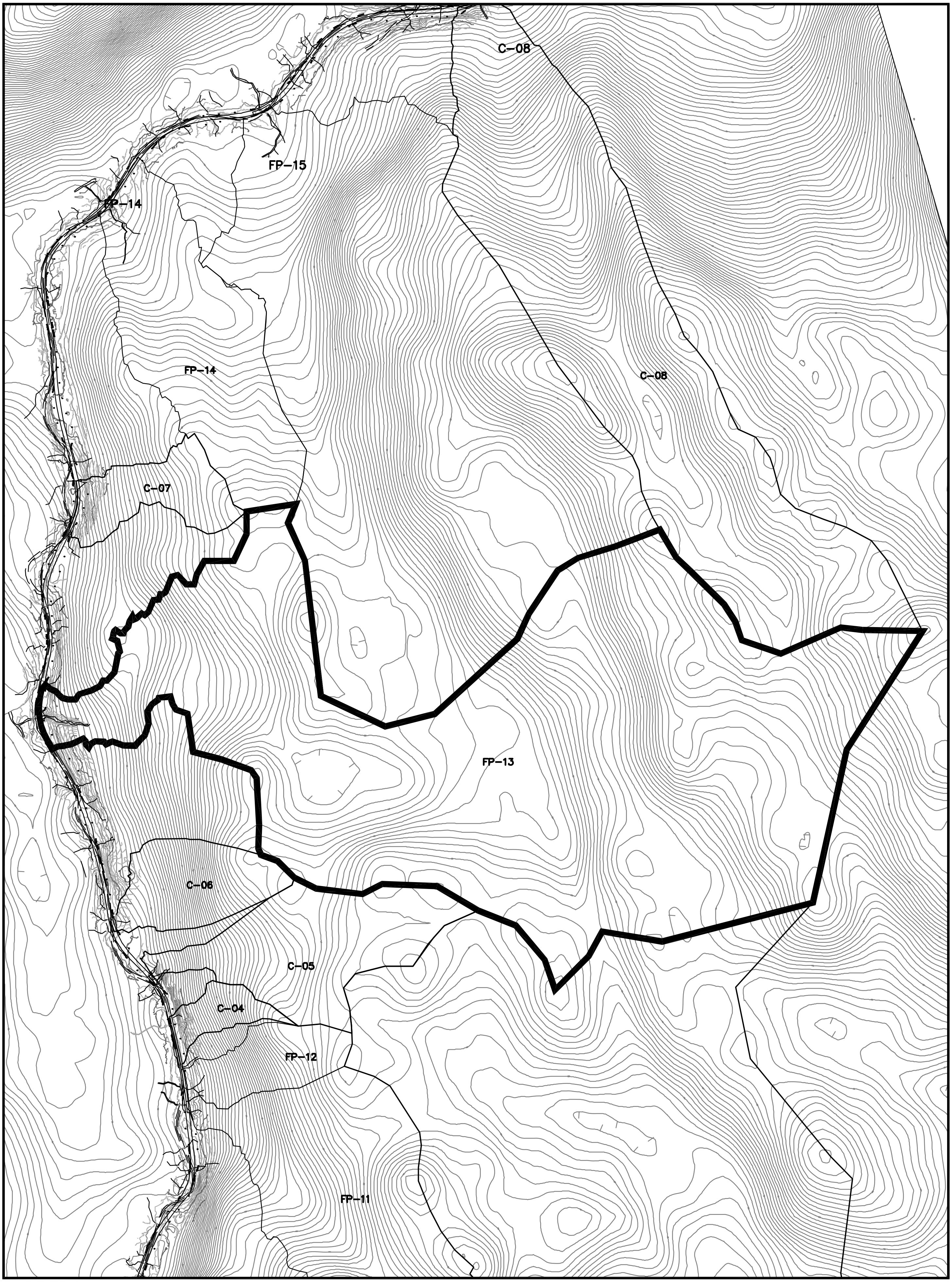

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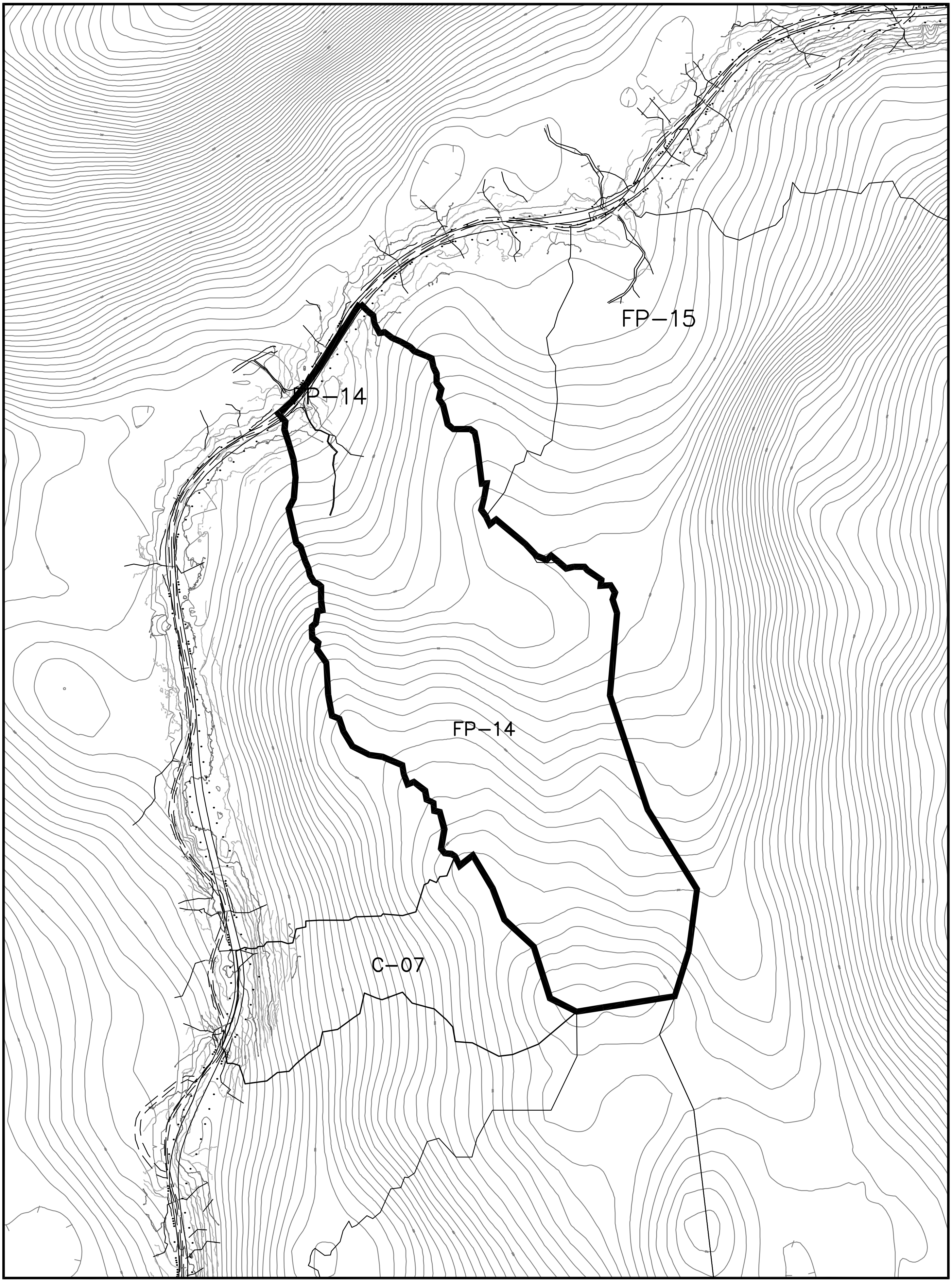
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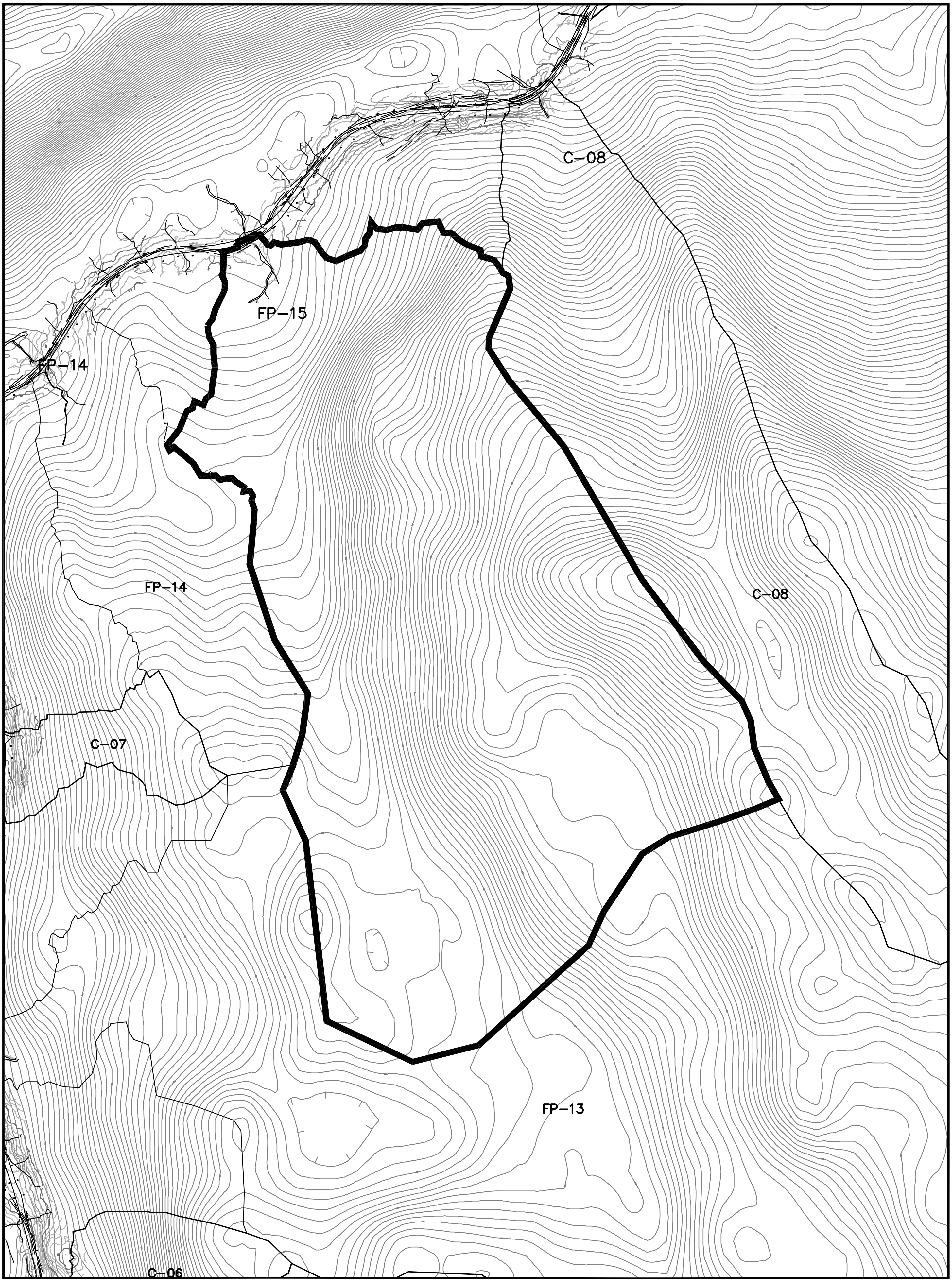
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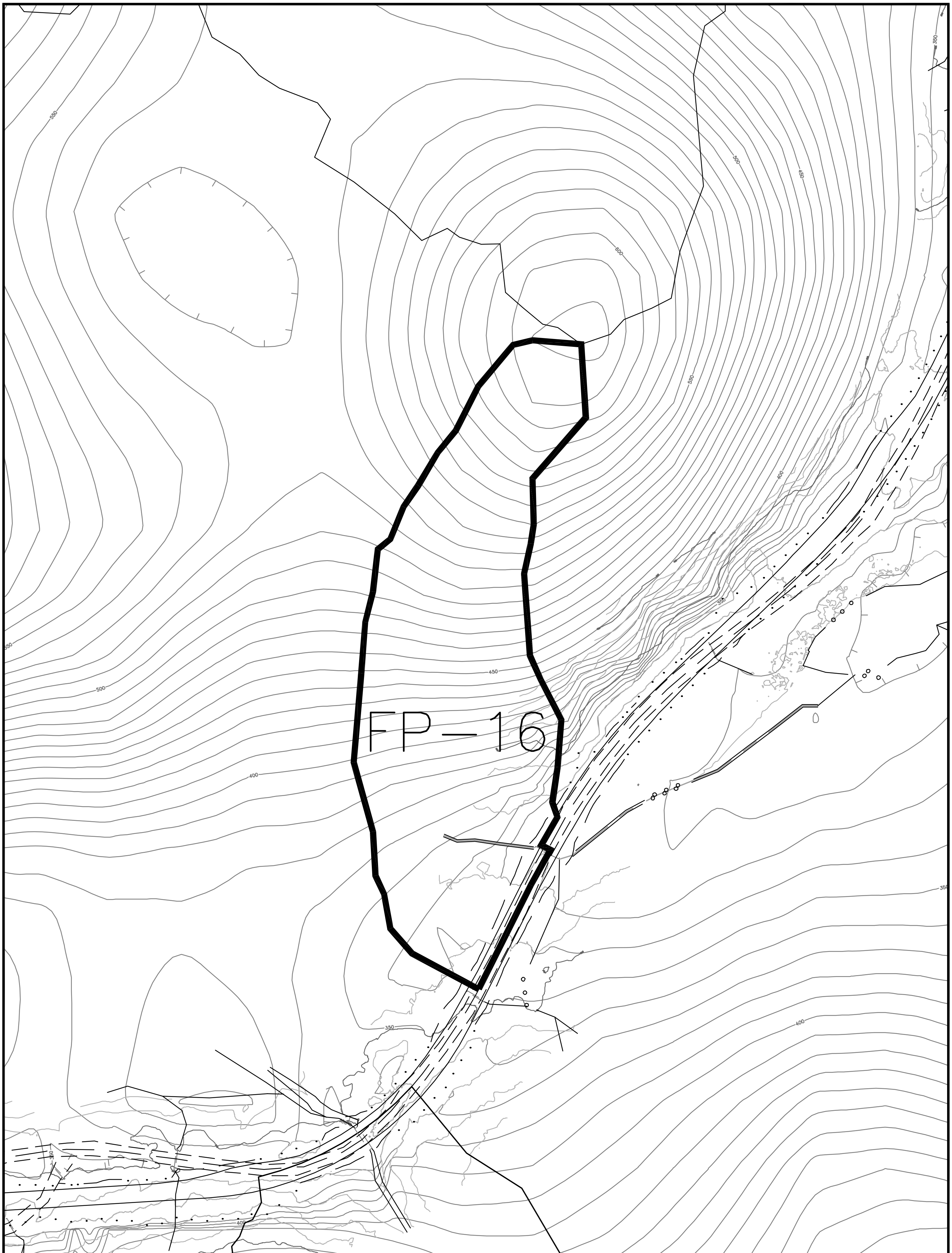
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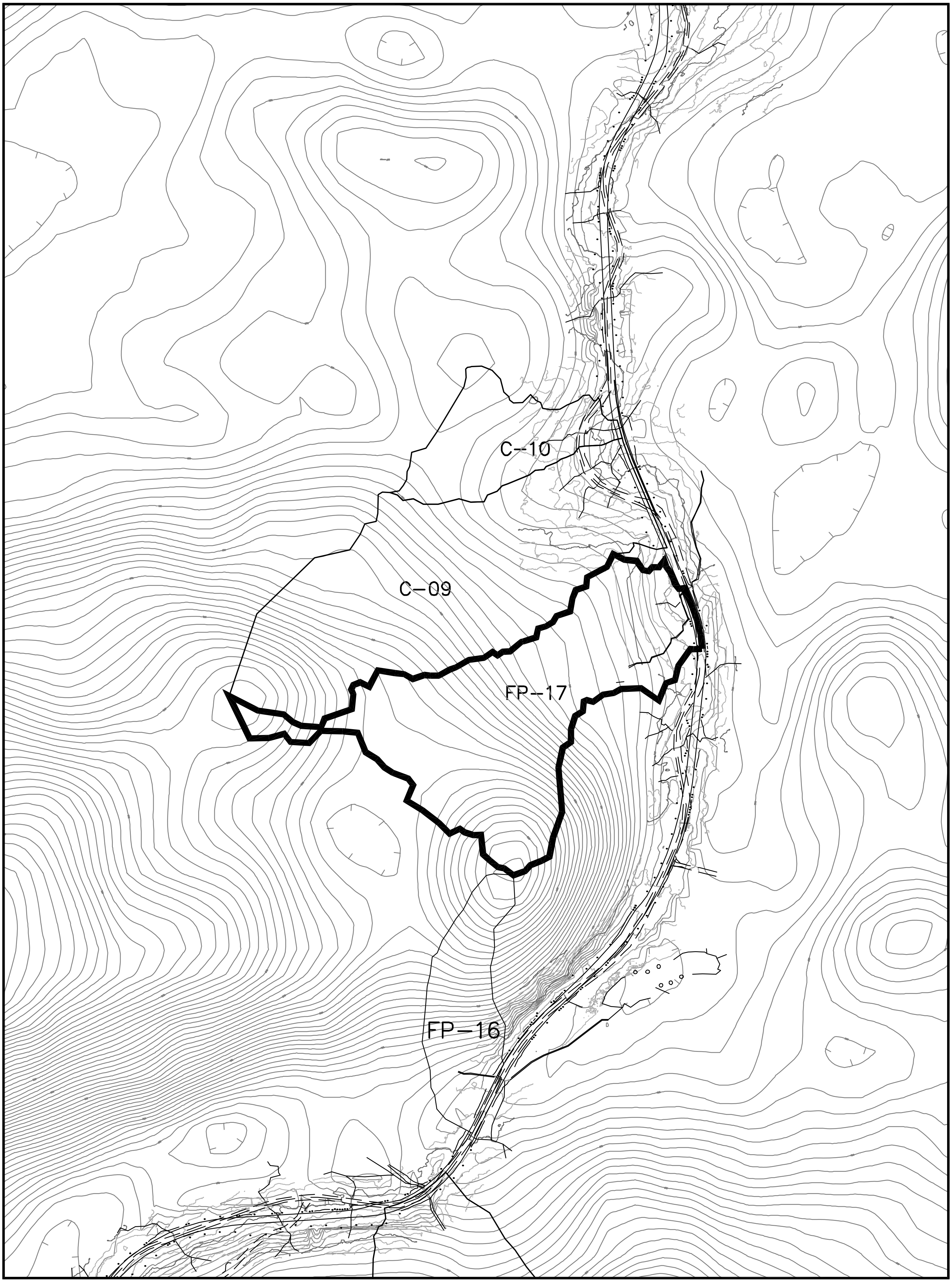
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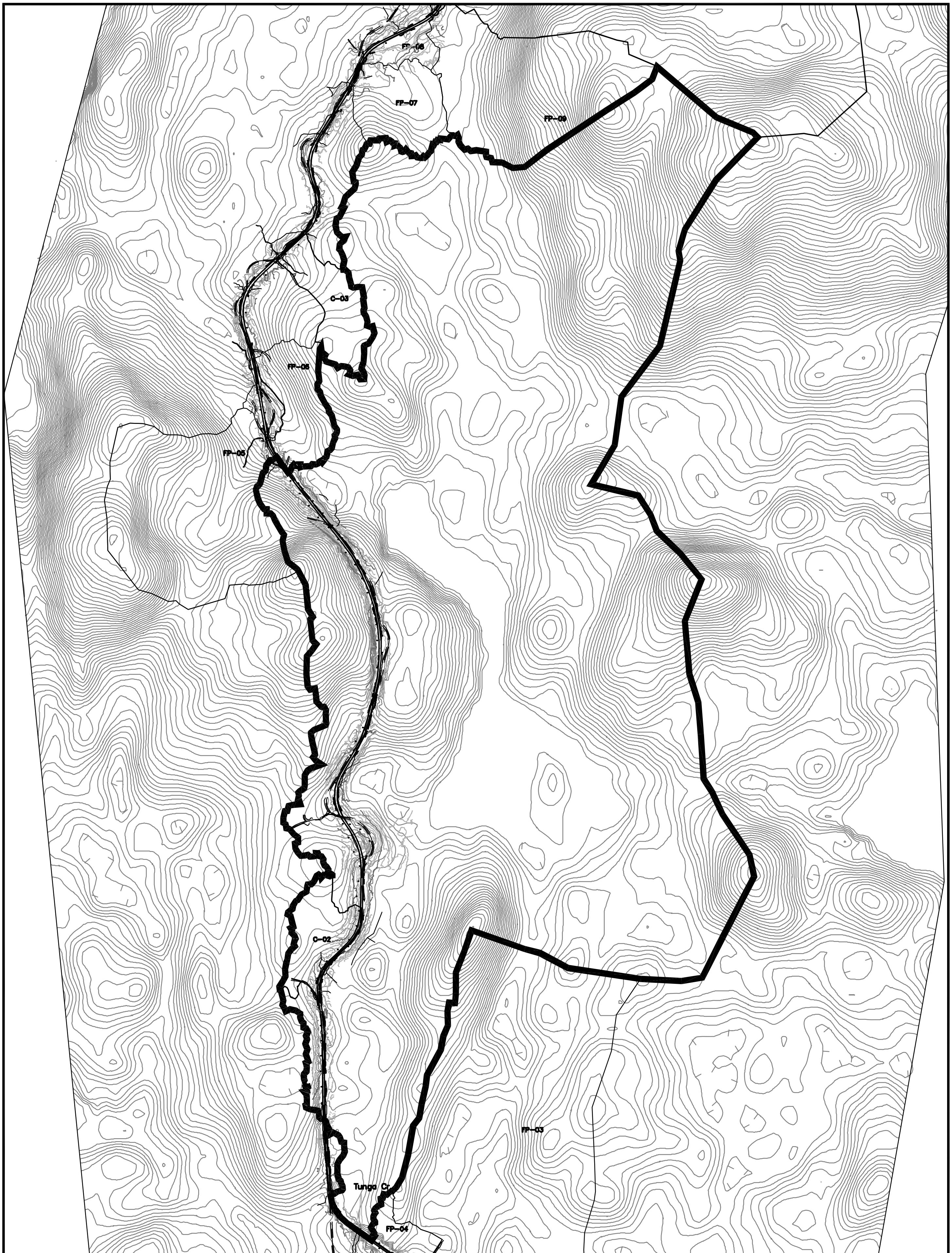

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FP-07
FP-09
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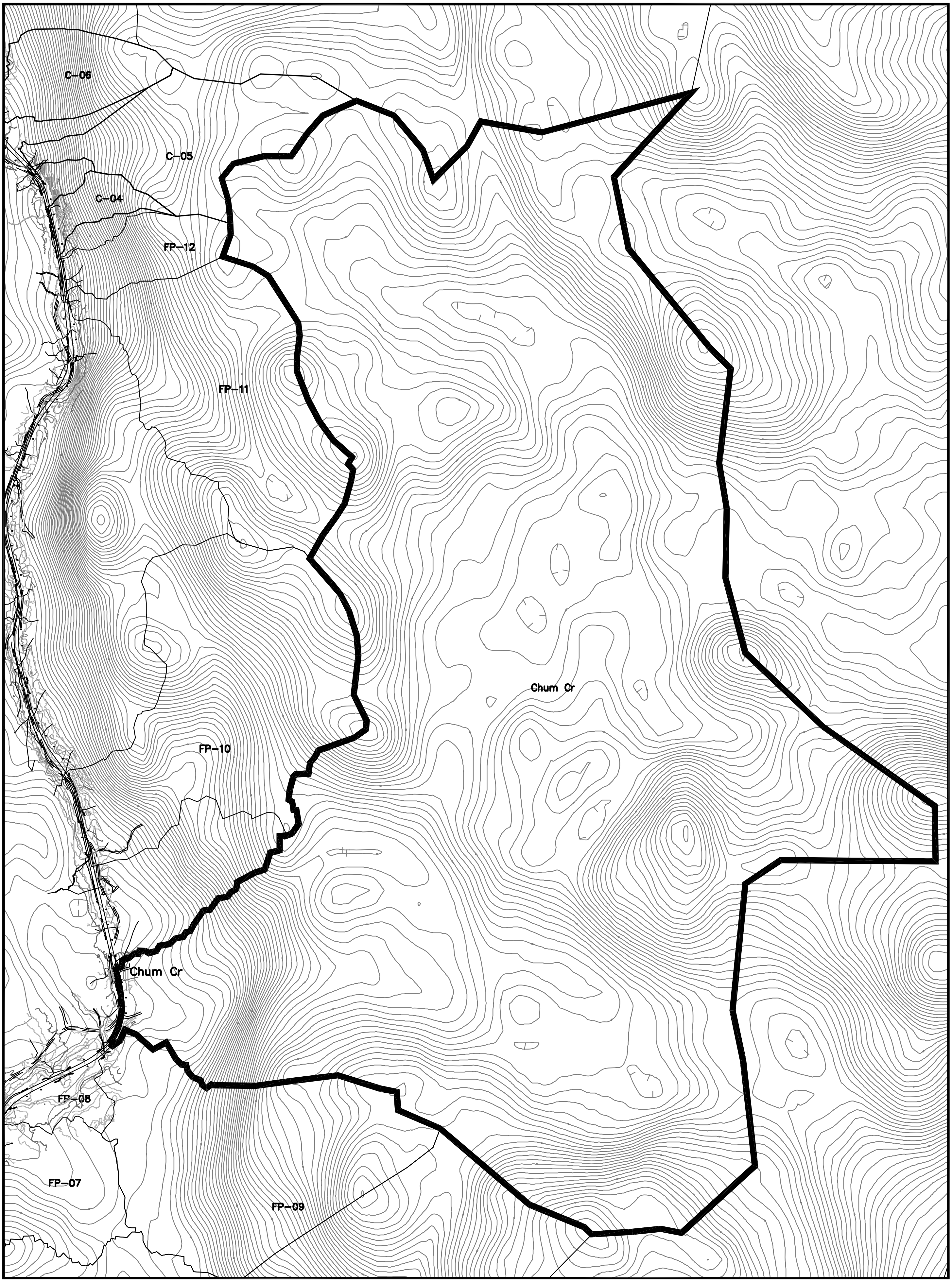
FP-06
FP-05
C-02
FP-03
Tunga Cr
FP-04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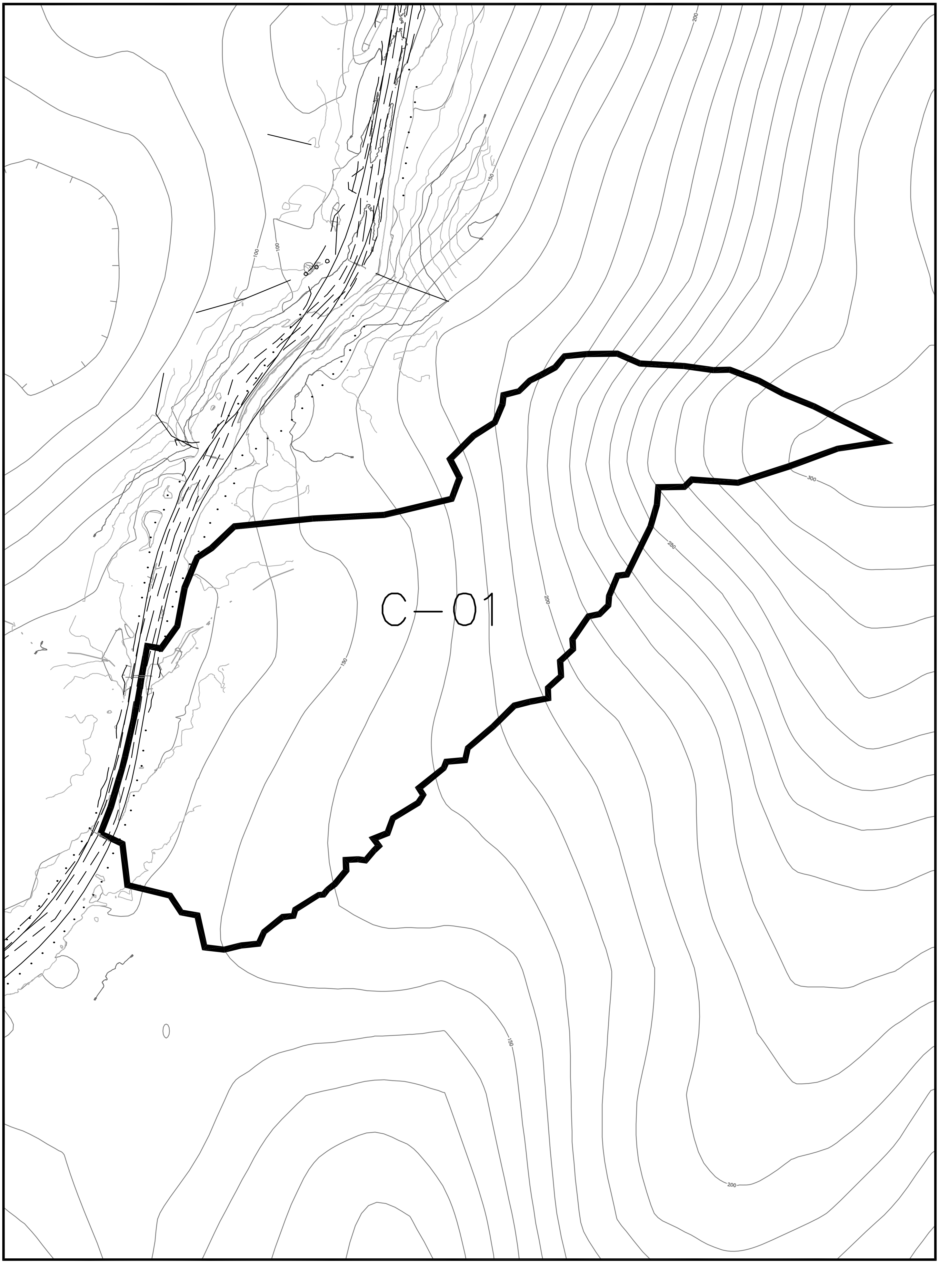
C-04
FP-12
FP-11
Chum Cr
FP-10
Chum Cr
FP-08
FP-07
FP-09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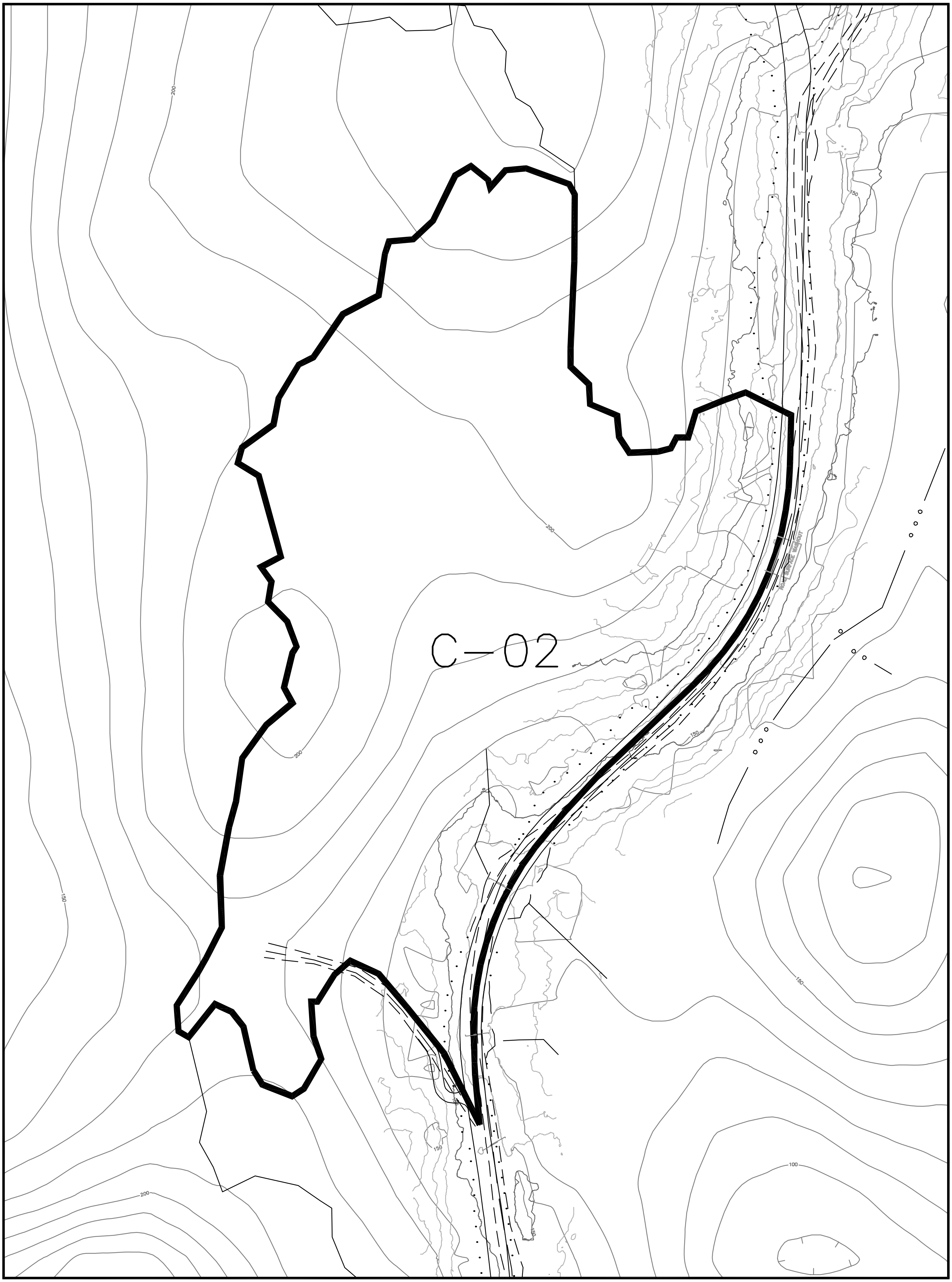
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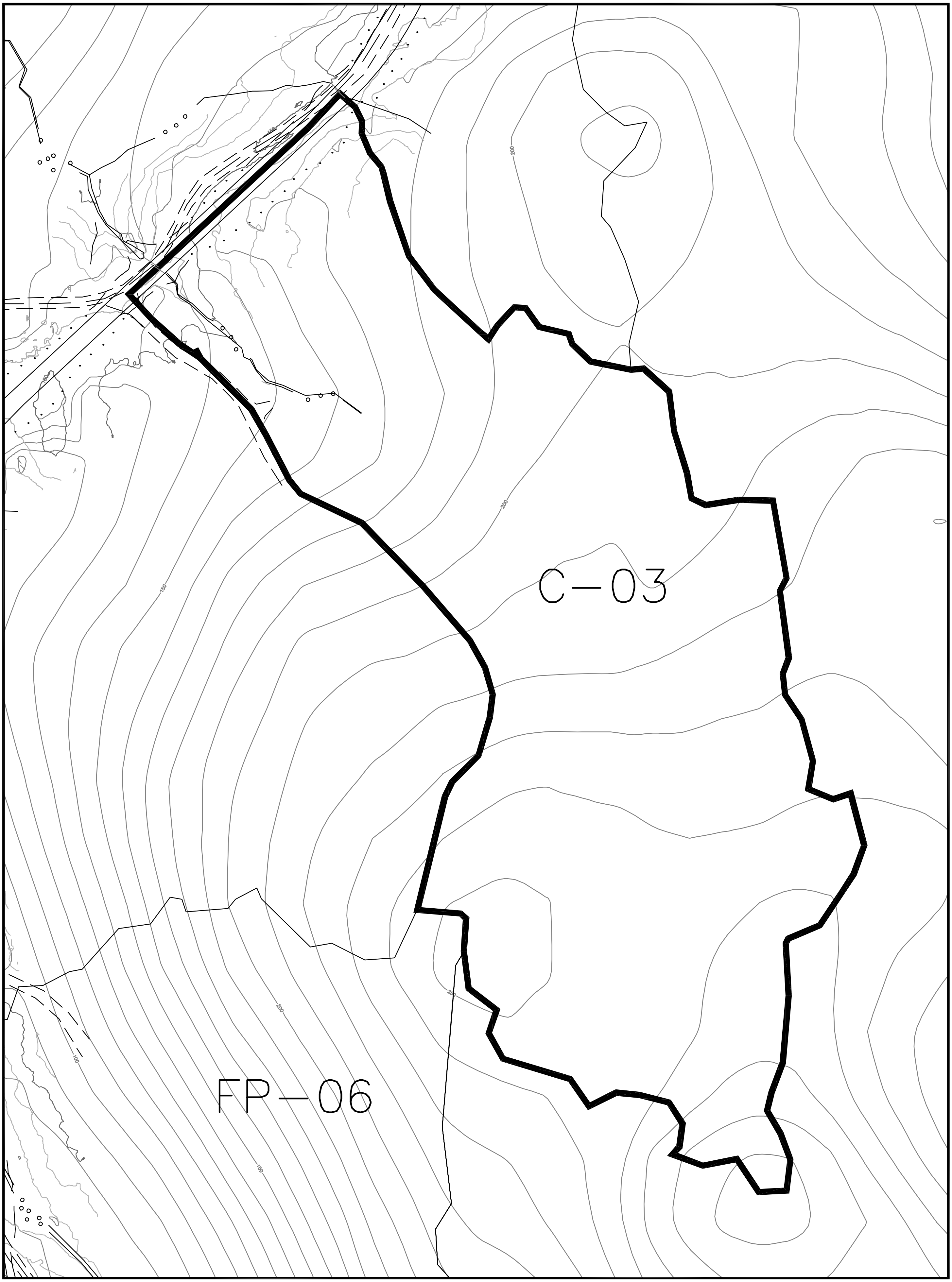
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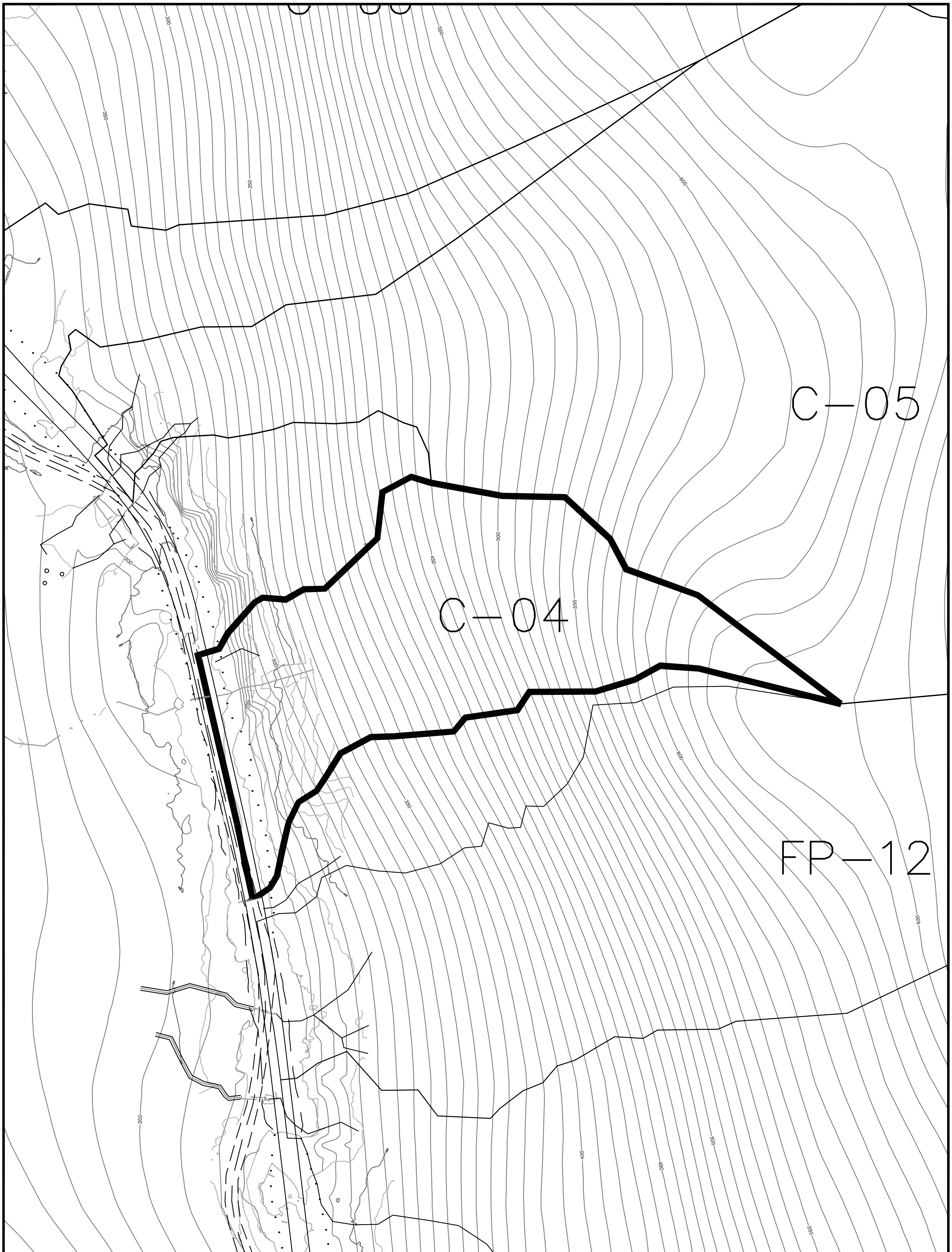
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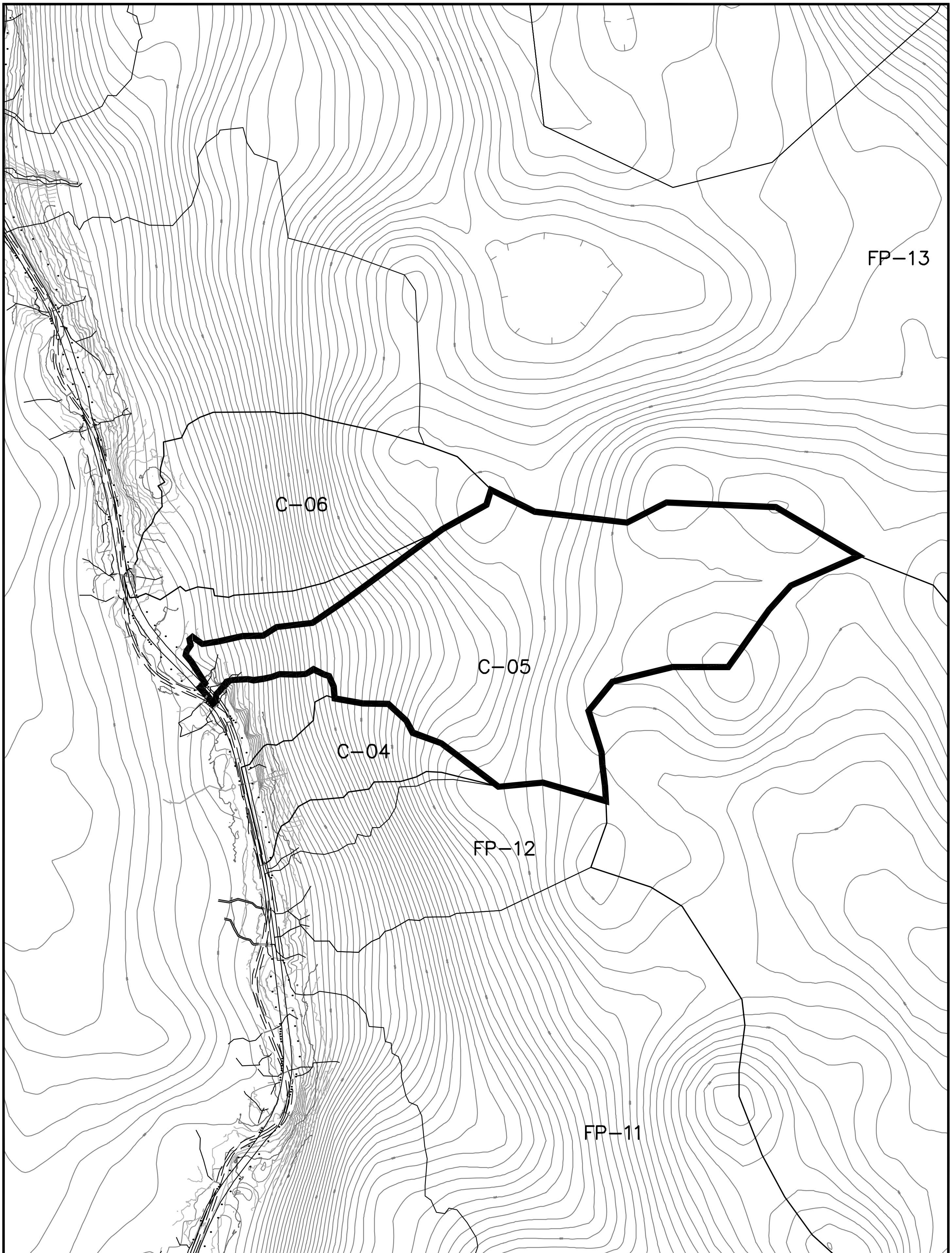
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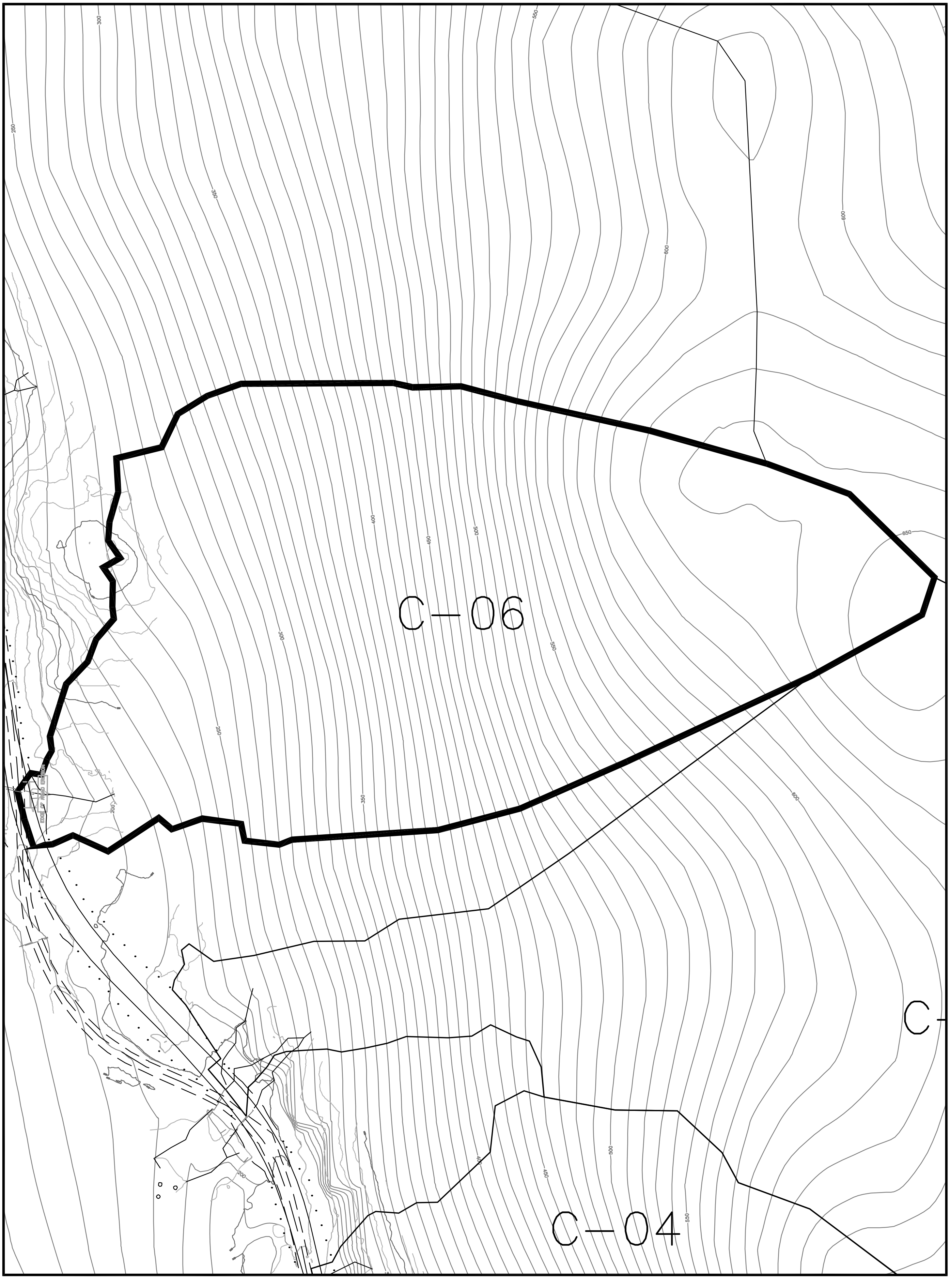
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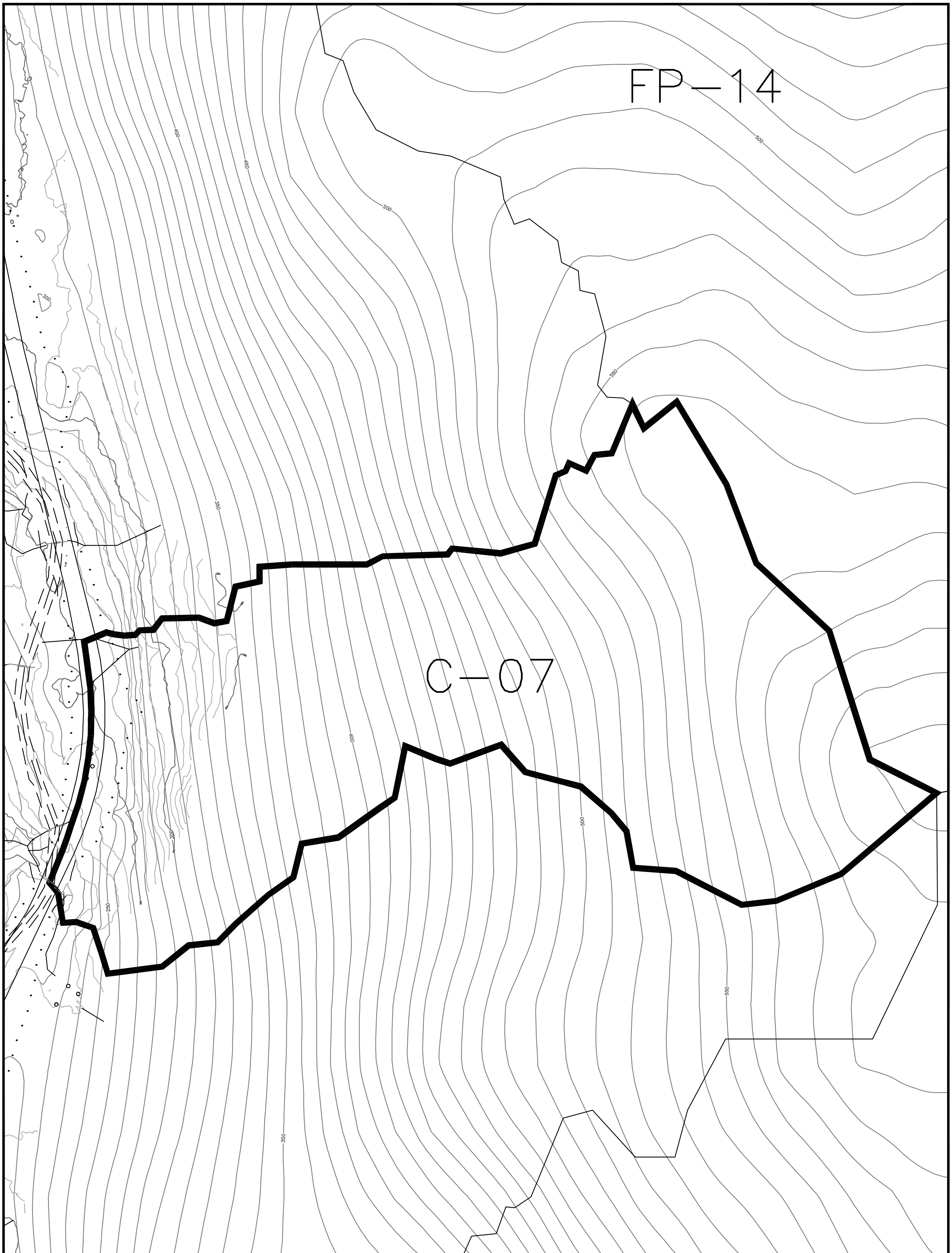
C–04
C–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C-07


FP-16
C-08
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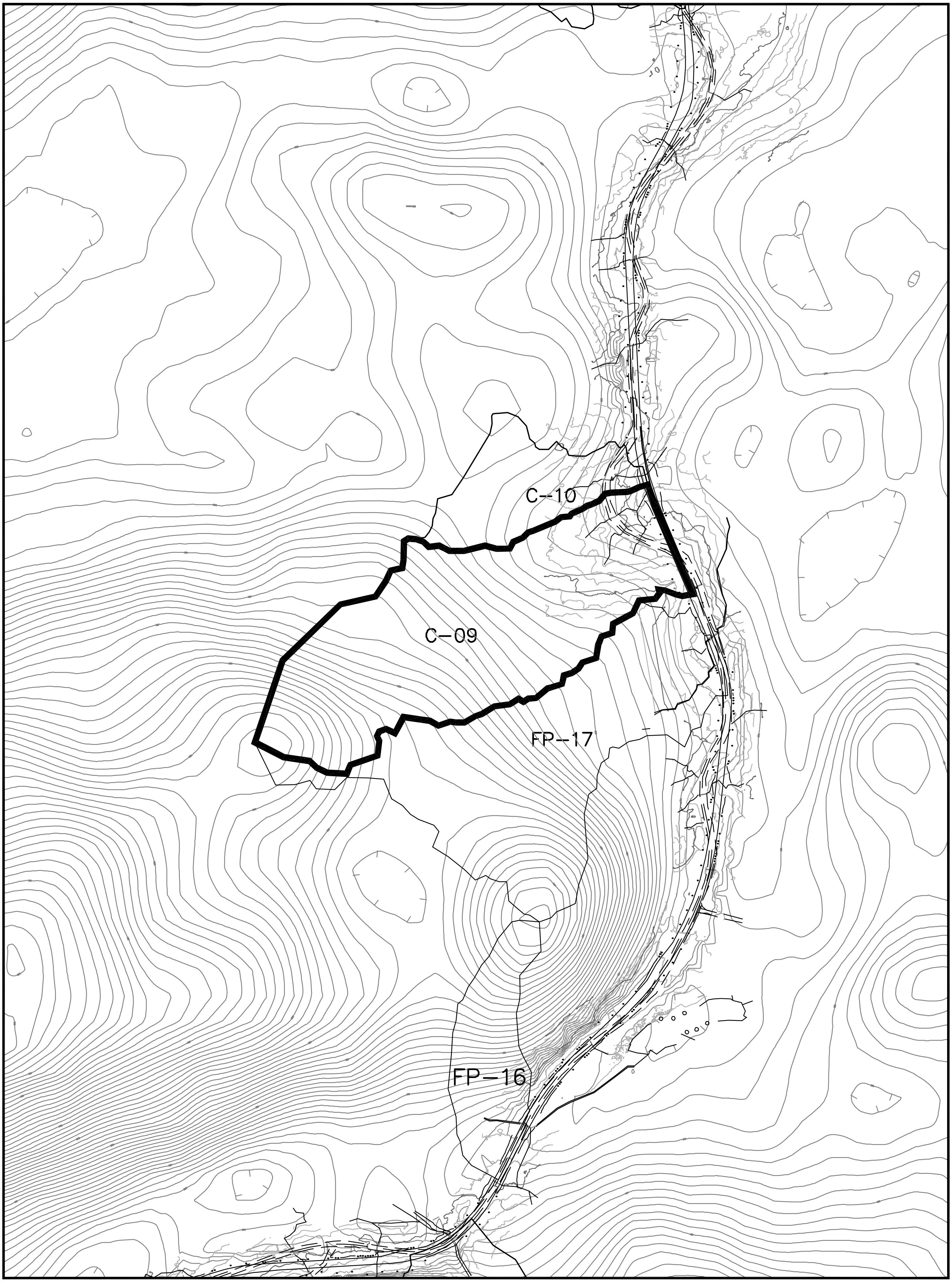
FP-13



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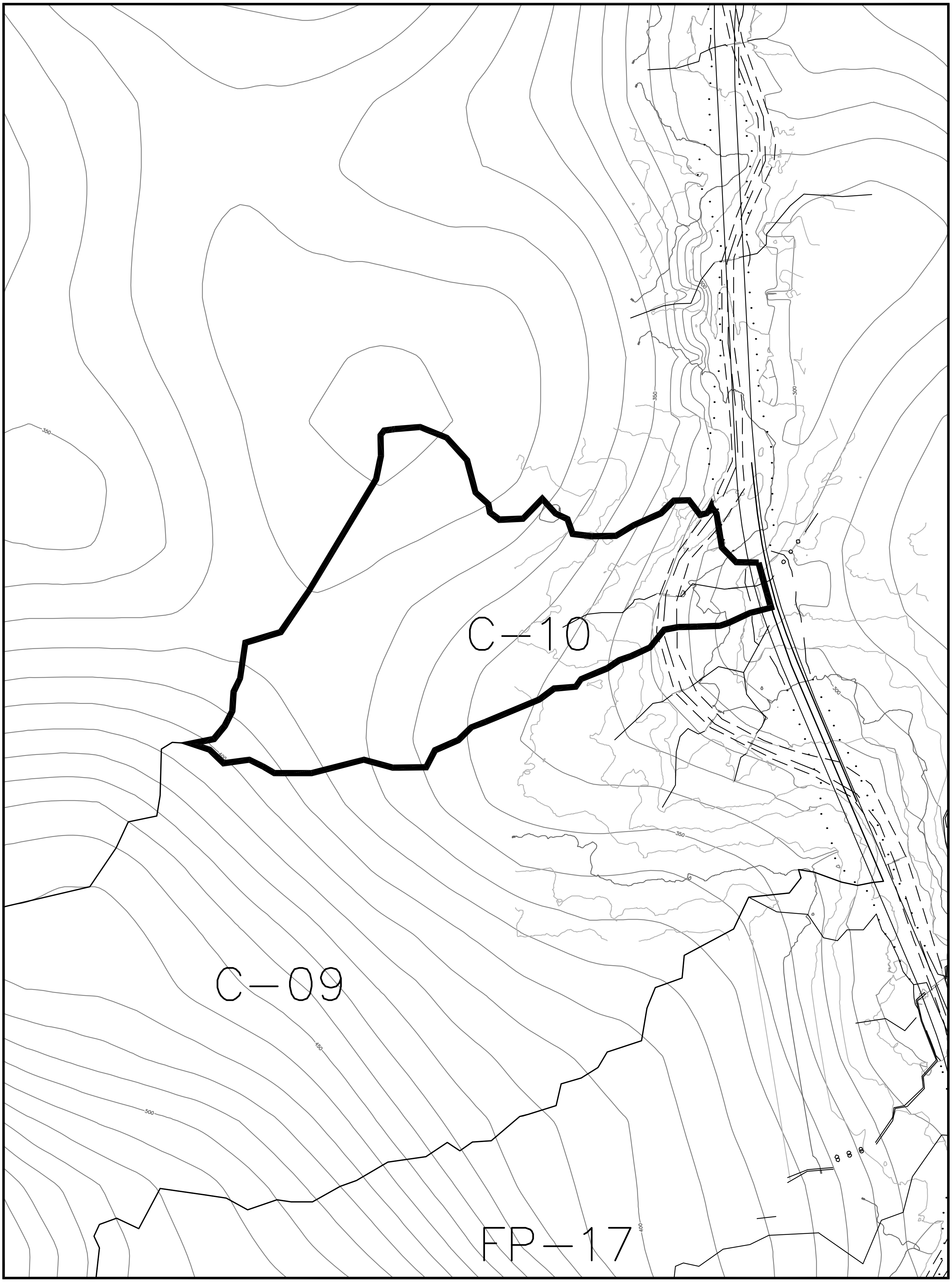

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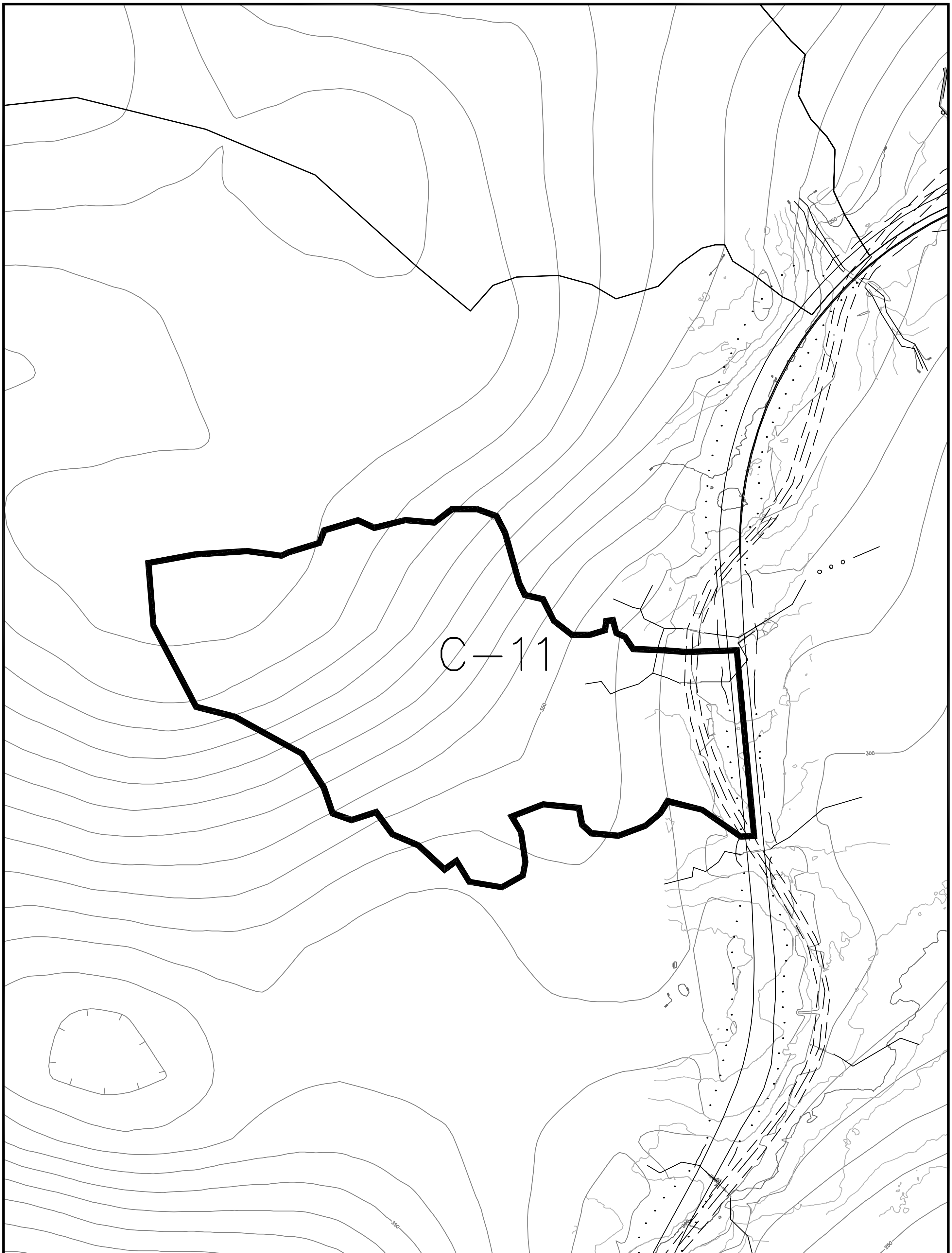
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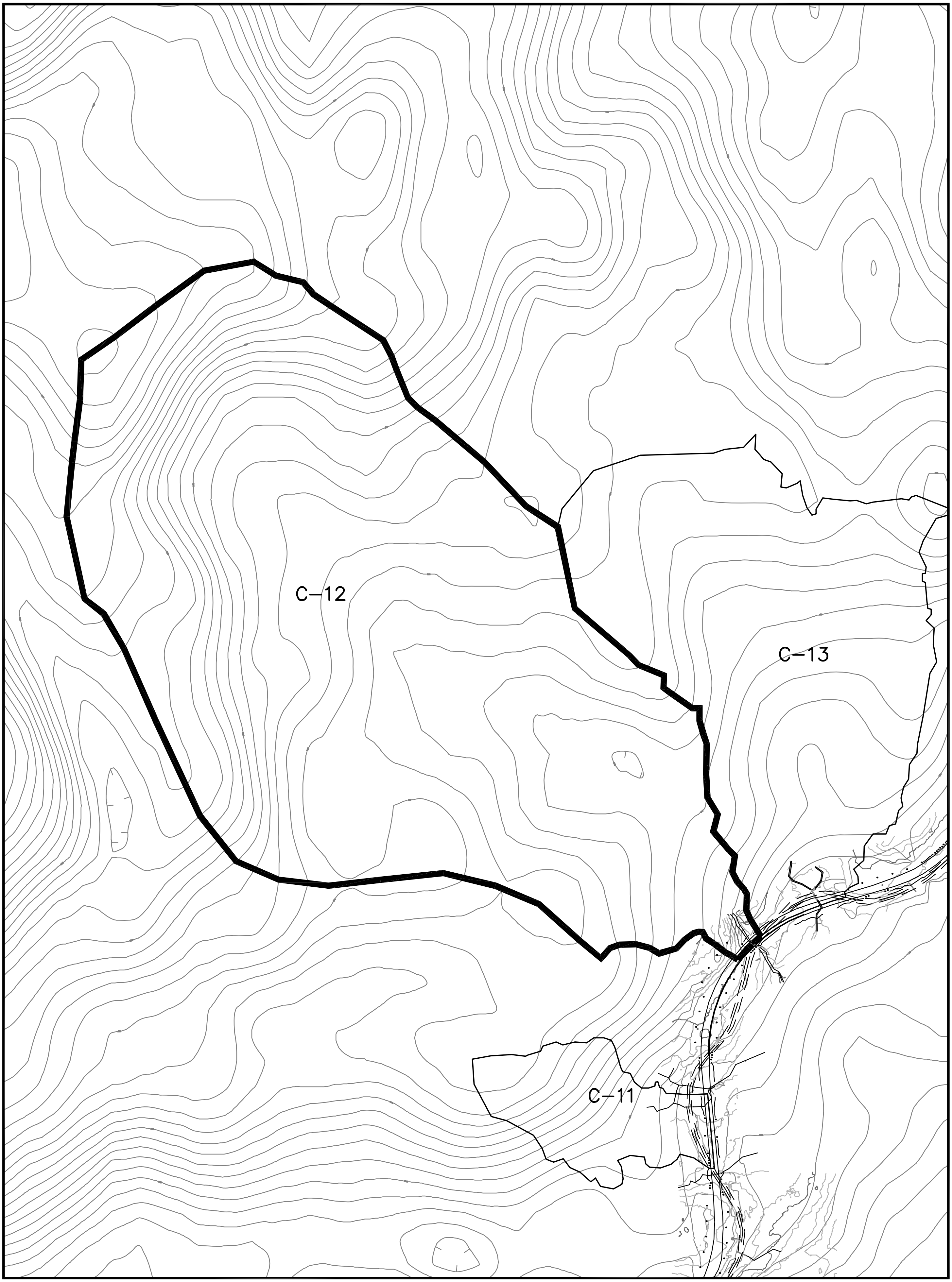
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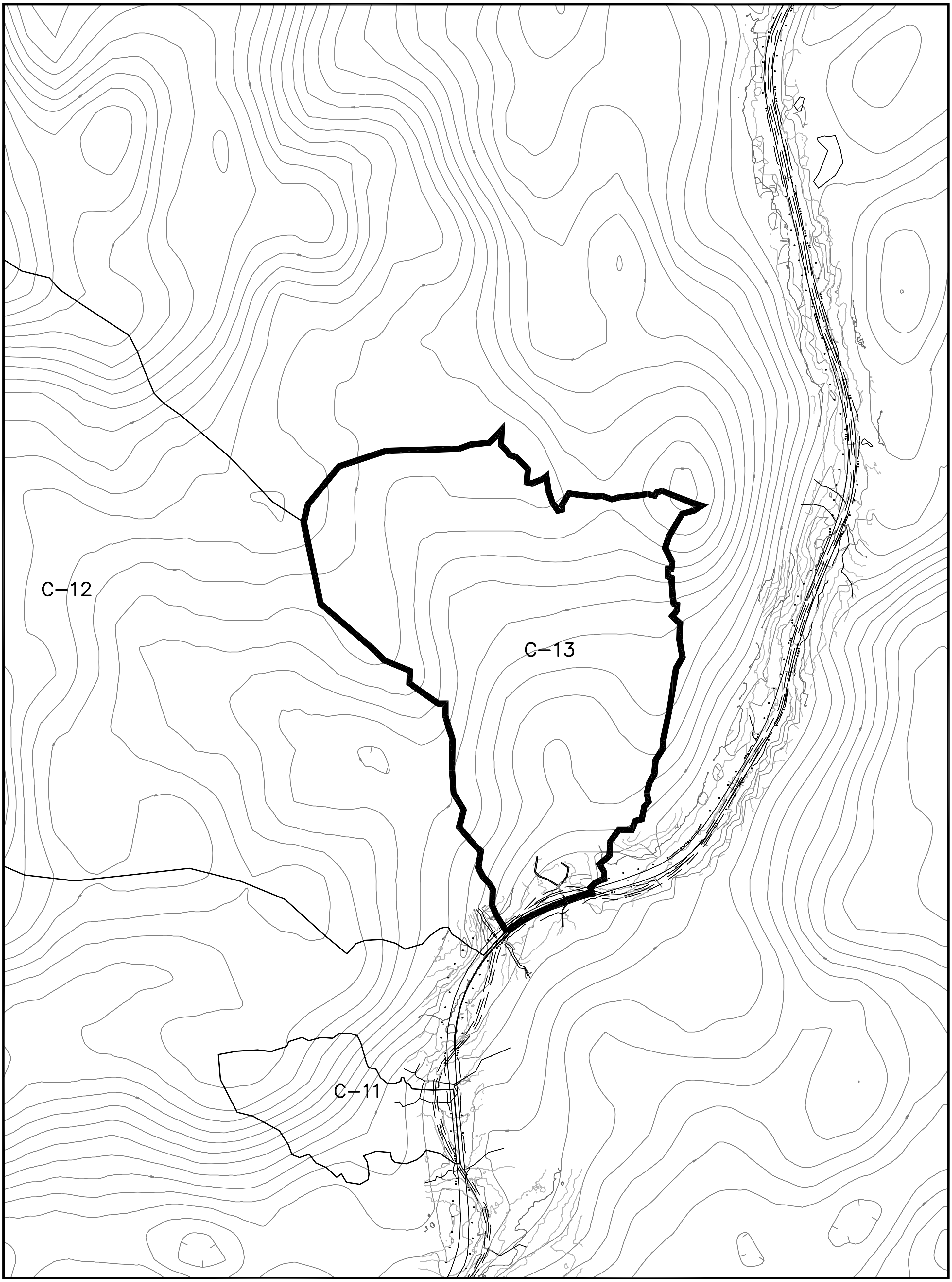

C–12
C–13
C–11

North Fork Staney Creek
(USGS Station 15081495)

PeakFQ and Regression
Analysis for Computation
of Scale Factors

```
1
  Program PeakFq           U. S. GEOLOGICAL SURVEY             Seq.000.000
  Ver. 5.2            Annual peak flow frequency analysis      Run Date / Time
  11/01/2007          following Bulletin 17-B Guidelines       12/18/2012 10:58

                         --- PROCESSING OPTIONS ---

                      Plot option         = Graphics device
                      Basin char output   = TAB-SEPARATED
                      Print option        = Yes
                      Debug print         = No
                      Input peaks listing = Long
                      Input peaks format  = WATSTORE peak file

                      Input files used:
                         peaks (ascii)  - C:\PROGRAM FILES (X86)\PKFQWIN\BIN\STANEY CREEK NORTH FORK
PEAK.TXT
                         specifications - PKFQWPSF.TMP

                      Output file(s):
                         main - C:\PROGRAM FILES (X86)\PKFQWIN\BIN\STANEY CREEK NORTH FORK PEAK.PRT

                         bcd  - STANEY CREEK NORTH FORK PEAK.BCD


1


  Program PeakFq           U. S. GEOLOGICAL SURVEY             Seq.001.001
  Ver. 5.2            Annual peak flow frequency analysis      Run Date / Time
  11/01/2007          following Bulletin 17-B Guidelines       12/18/2012 10:58

                 Station - 15081495  NF STANEY C NR KLAWOCK AK


                     I N P U T   D A T A   S U M M A R Y

                Number of peaks in record           =       14
                Peaks not used in analysis          =        0
                Systematic peaks in analysis        =       14
                Historic peaks in analysis          =        0
                Years of historic record            =        0
                Generalized skew                    =    0.330
                     Standard error                 =    0.550
                     Mean Square error              =    0.303
                Skew option                         =   WEIGHTED
                Gage base discharge                 =      0.0
                User supplied high outlier threshold =   --
                User supplied low outlier criterion  =   --
                Plotting position parameter         =     0.00


  *********  NOTICE  --  Preliminary machine computations.        *********
  *********  User responsible for assessment and interpretation.  *********

    WCF134I-NO SYSTEMATIC PEAKS WERE BELOW GAGE BASE.                   0.0
    WCF198I-LOW OUTLIERS BELOW FLOOD BASE WERE DROPPED.       1       237.6
    WCF163I-NO HIGH OUTLIERS OR HISTORIC PEAKS EXCEEDED HHBASE.      1243.8
1

  Program PeakFq           U. S. GEOLOGICAL SURVEY             Seq.001.002
  Ver. 5.2            Annual peak flow frequency analysis      Run Date / Time
  11/01/2007          following Bulletin 17-B Guidelines       12/18/2012 10:58

                 Station - 15081495  NF STANEY C NR KLAWOCK AK


           ANNUAL FREQUENCY CURVE PARAMETERS -- LOG-PEARSON TYPE III

                       FLOOD BASE                  LOGARITHMIC
                ----------------------  -------------------------------
                            EXCEEDANCE                 STANDARD
```

	DISCHARGE	PROBABILITY	MEAN	DEVIATION	SKEW
SYSTEMATIC RECORD	0.0	1.0000	2.7384	0.1638	-0.300
BULL.17B ESTIMATE	237.6	0.9286	2.7540	0.1342	0.506

ANNUAL FREQUENCY CURVE -- DISCHARGES AT SELECTED EXCEEDANCE PROBABILITIES

ANNUAL EXCEEDANCE PROBABILITY	BULL.17B ESTIMATE	SYSTEMATIC RECORD	'EXPECTED PROBABILITY' ESTIMATE	95-PCT CONFIDENCE LIMITS FOR BULL. 17B ESTIMATES LOWER	UPPER
0.9950	--	186.4	--	--	--
0.9900	--	209.7	--	--	--
0.9500	--	285.6	--	--	--
0.9000	389.9	334.1	379.2	306.4	454.6
0.8000	435.6	401.3	428.9	355.5	501.8
0.6667	487.2	472.9	483.8	410.4	558.2
0.5000	553.0	558.0	553.0	477.5	636.7
0.4292	584.5	596.3	586.2	507.8	677.3
0.2000	728.6	755.4	743.8	633.1	888.5
0.1000	854.5	875.8	892.8	729.5	1101.0
0.0400	1025.0	1018.0	1119.0	849.2	1419.0
0.0200	1161.0	1117.0	1324.0	939.0	1694.0
0.0100	1304.0	1211.0	1571.0	1030.0	2002.0
0.0050	1456.0	1301.0	1874.0	1124.0	2347.0
0.0020	1672.0	1415.0	2394.0	1252.0	2870.0

1

Station - 15081495 NF STANEY C NR KLAWOCK AK

I N P U T D A T A L I S T I N G

WATER YEAR	DISCHARGE	CODES	WATER YEAR	DISCHARGE	CODES
1990	234.0		1997	516.0	
1991	740.0		1998	486.0	
1992	419.0		1999	422.0	
1993	1110.0		2000	704.0	
1994	849.0		2001	612.0	
1995	516.0		2002	660.0	
1996	466.0		2003	440.0	

Explanation of peak discharge qualification codes

PeakFQ CODE	NWIS CODE	DEFINITION
D	3	Dam failure, non-recurrent flow anomaly
G	8	Discharge greater than stated value
X	3+8	Both of the above
L	4	Discharge less than stated value
K	6 OR C	Known effect of regulation or urbanization
H	7	Historic peak

- Minus-flagged discharge -- Not used in computation
  -8888.0 -- No discharge value given
- Minus-flagged water year -- Historic peak used in computation

1

Ver. 5.2   Annual peak flow frequency analysis   Run Date / Time
11/01/2007   following Bulletin 17-B Guidelines   12/18/2012 10:58

Station - 15081495 NF STANEY C NR KLAWOCK AK

EMPIRICAL FREQUENCY CURVES -- WEIBULL PLOTTING POSITIONS

WATER YEAR	RANKED DISCHARGE	SYSTEMATIC RECORD	BULL.17B ESTIMATE
1993	1110.0	0.0667	0.0667
1994	849.0	0.1333	0.1333
1991	740.0	0.2000	0.2000
2000	704.0	0.2667	0.2667
2002	660.0	0.3333	0.3333
2001	612.0	0.4000	0.4000
1995	516.0	0.4667	0.4667
1997	516.0	0.5333	0.5333
1998	486.0	0.6000	0.6000
1996	466.0	0.6667	0.6667
2003	440.0	0.7333	0.7333
1999	422.0	0.8000	0.8000
1992	419.0	0.8667	0.8667
1990	234.0	0.9333	0.9333

1

End PeakFQ analysis.
Stations processed :   1
Number of errors   :   0
Stations skipped   :   0
Station years   :   14

Data records may have been ignored for the stations listed below.
(Card type must be Y, Z, N, H, I, 2, 3, 4, or *.)
(2, 4, and * records are ignored.)

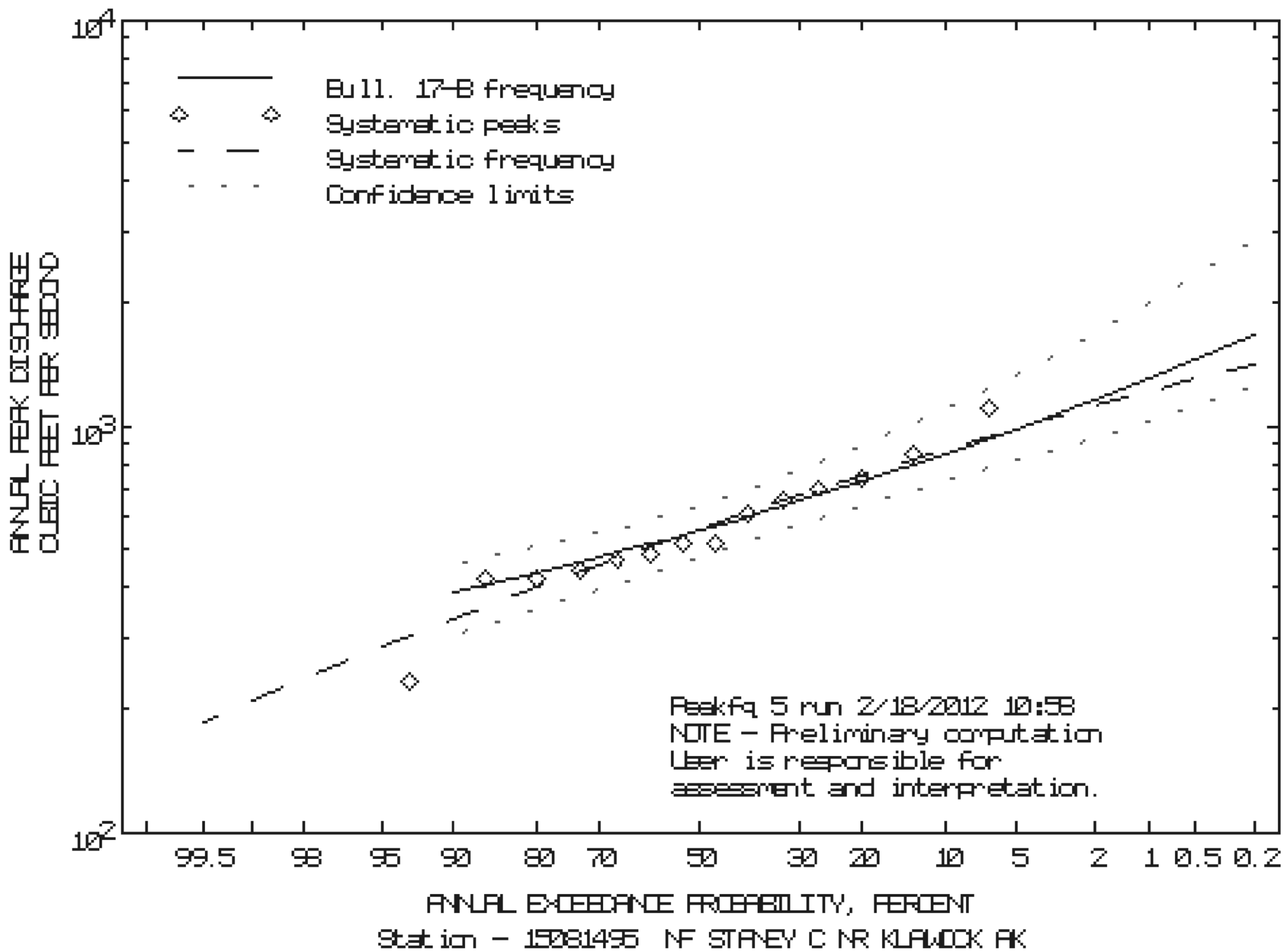
For the station below, the following records were ignored:

FINISHED PROCESSING STATION: 15081495   USGS NF STANEY C NR KLAWOCK AK

For the station below, the following records were ignored:

FINISHED PROCESSING STATION:

Z15081495	USGS		
H15081495	5543581325802000202201SW190101033.07		
N15081495	NF STANEY C NR KLAWOCK AK		
Y15081495			
315081495	19900923	234	3.93
315081495	19901205	740	5.52
315081495	19911130	419	4.62
315081495	19930129	1110	6.34
315081495	19931026	849	5.78
315081495	19941016	516	4.92
315081495	19960110	466	4.77
315081495	19970402	516	4.92
315081495	19971025	486	4.83
315081495	19981018	422	4.63
315081495	19991021	704	5.43
315081495	20010930	612	5.19
315081495	20020214	660	5.32
315081495	20030913	440	4.69



Bull. 17-B frequency
Systematic peaks
Systematic frequency
Confidence limits
Peakfq 5 run 2/18/2012 10:58
NOTE - Preliminary computation
User is responsible for
assessment and interpretation.
ANNUAL PEAK DISCHARGE
CUBIC FEET PER SECOND
10^4
10^3
10^2
99.5
98
95
90
80
70
50
30
20
10
5
2
1
0.5
0.2
ANNUAL EXCEEDANCE PROBABILITY, PERCENT
Station - 15081495 NF STANEY C NR KLAWOCK AK

Table 3. Regression equations for estimating 2-, 5-, 10-, 25-, 50-, 100-, 200-, and 500-year peak streamflows for unregulated streams in Regions 1-7, Alaska and conterminous basins in Canada

[Q_T, T-year peak streamflow, in cubic feet per second; A, drainage area, in square miles; ST, area of lakes and ponds (storage), in percent; P, mean annual precipitation, in inches; J, mean minimum January temperature, in degrees Fahrenheit; E, elevation, in feet; F, area of forest, in percent]

	Constant	Exponent for A	Exponent for ST	Exponent for P	Exponent for J	Avg std error of prediction (log units)	Avg std error of prediction (percent)	Average equivalent years of record	Estimate of recurrence interval Q_T using user-supplied		
									User: Enter values in shaded area for this region (9999 indicates a dummy value that must be replaced)		
	Region 1, Region 3 (93 gaging stations)								**A=**	3.07	
	Applicable range of variables:								**ST=**	1	
	A: 0.720-571; ST: 0-26; P: 70-300; J: 0-32								**P=**	100	
									J=	30	
											N = 14
NF STANEY CREEK (USGS STATION 15081495)									USGS Qt (cfs)	PeakFQ (cfs)	Qt wtd (cfs)
Q2	0.004119	0.8361	-0.3590	0.9110	1.635	0.158	38	0.88	464	553	547
Q5	0.009024	0.8322	-0.3670	0.8128	1.640	0.156	37	1.3	654	729	722
Q10	0.01450	0.8306	-0.3691	0.7655	1.622	0.157	37	1.8	782	854	845
Q25	0.02522	0.8292	-0.3697	0.7165	1.588	0.161	38	2.4	941	1020	1008
Q50	0.03711	0.8286	-0.3693	0.6847	1.559	0.166	40	2.8	1061	1160	1143
Q100	0.05364	0.8281	-0.3683	0.6556	1.527	0.171	41	3.1	1175	1300	1276
Q200	0.07658	0.8276	-0.3669	0.6284	1.495	0.178	43	3.4	1298	1460	1427
Q500	0.1209	0.8272	-0.3646	0.5948	1.449	0.188	45	3.6	1453	1670	1623

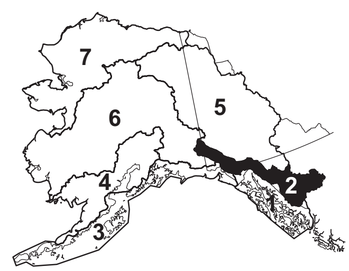
Basin Flood Frequencies
Using USGS WRIR 03-4188
Regression Equations

Table 3. Regression equations for estimating 2-, 5-, 10-, 25-, 50-, 100-, 200-, and 500-year peak streamflows for unregulated streams in Regions 1-7, Alaska and conterminous basins in Canada

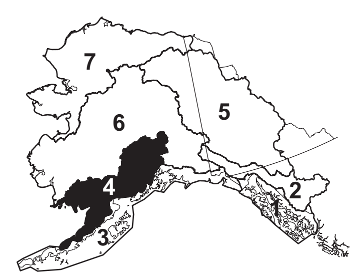
[Q_T, *T*-year peak streamflow, in cubic feet per second; *A*, drainage area, in square miles; *ST*, area of lakes and ponds (storage), in percent; *P*, mean annual precipitation, in inches; *J*, mean minimum January temperature, in degrees Fahrenheit; *E*, elevation, in feet; *F*, area of forest, in percent]

Regression equation for specified recurrence interval Q_T	Average standard error of prediction (log units)	Average standard error of prediction (percent)	Average equivalent years of record
Region 1, Region 3 (93 gaging stations)			
Applicable range of variables:			
***A*: 0.720–571; *ST*: 0–26; *P*: 70–300; *J*: 0–32**			
$Q_2 = 0.004119\,A^{0.8361}\,(ST{+}1)^{-0.3590}\,P^{0.9110}\,(J{+}32)^{1.635}$	0.158	38	0.88
$Q_5 = 0.009024\,A^{0.8322}\,(ST{+}1)^{-0.3670}\,P^{0.8128}\,(J{+}32)^{1.640}$	.156	37	1.3
$Q_{10} = 0.01450\,A^{0.8306}\,(ST{+}1)^{-0.3691}\,P^{0.7655}\,(J{+}32)^{1.622}$	.157	37	1.8
$Q_{25} = 0.02522\,A^{0.8292}\,(ST{+}1)^{-0.3697}\,P^{0.7165}\,(J{+}32)^{1.588}$	.161	38	2.4
$Q_{50} = 0.03711\,A^{0.8286}\,(ST{+}1)^{-0.3693}\,P^{0.6847}\,(J{+}32)^{1.559}$	.166	40	2.8
$Q_{100} = 0.05364\,A^{0.8281}\,(ST{+}1)^{-0.3683}\,P^{0.6556}\,(J{+}32)^{1.527}$	.171	41	3.1
$Q_{200} = 0.07658\,A^{0.8276}\,(ST{+}1)^{-0.3669}\,P^{0.6284}\,(J{+}32)^{1.495}$	.178	43	3.4
$Q_{500} = 0.1209\,A^{0.8272}\,(ST{+}1)^{-0.3646}\,P^{0.5948}\,(J{+}32)^{1.449}$	.188	45	3.6

Regression equation for specified recurrence interval Q_T	Average standard error of prediction (log units)	Average standard error of prediction (percent)	Average equivalent years of record
Region 2 (25 gaging stations)			
Applicable range of variables:			
***A*: 92.7–19,900; *ST*: 0–9; *P*: 12–100**			
$Q_2 = 0.7479\,A^{0.9580}\,(ST{+}1)^{-0.03292}\,P^{0.9284}$	.121	28	.82
$Q_5 = 1.021\,A^{0.9449}\,(ST{+}1)^{-0.03603}\,P^{0.9359}$	.116	27	1.5
$Q_{10} = 1.184\,A^{0.9368}\,(ST{+}1)^{-0.03813}\,P^{0.9500}$	.119	28	2.0
$Q_{25} = 1.374\,A^{0.9274}\,(ST{+}1)^{-0.04074}\,P^{0.9713}$	.129	30	2.5
$Q_{50} = 1.506\,A^{0.9209}\,(ST{+}1)^{-0.04263}\,P^{0.9887}$	.141	33	2.7
$Q_{100} = 1.628\,A^{0.9147}\,(ST{+}1)^{-0.04448}\,P^{1.007}$	.154	37	2.7
$Q_{200} = 1.742\,A^{0.9086}\,(ST{+}1)^{-0.04629}\,P^{1.027}$	.168	40	2.7
$Q_{500} = 1.880\,A^{0.9008}\,(ST{+}1)^{-0.04864}\,P^{1.056}$	.189	46	2.6



Regression equation for specified recurrence interval Q_T	Average standard error of prediction (log units)	Average standard error of prediction (percent)	Average equivalent years of record
Region 4 (71 gaging stations)			
Applicable range of variables:			
***A*: 1.07–19,400; *ST*: 0–28; *P*: 20–158**			
$Q_2 = 0.2535\,A^{0.9462}\,(ST{+}1)^{-0.1981}\,P^{1.201}$	.177	42	.98
$Q_5 = 0.5171\,A^{0.9084}\,(ST{+}1)^{-0.2128}\,P^{1.162}$	.162	39	2.2
$Q_{10} = 0.7445\,A^{0.8887}\,(ST{+}1)^{-0.2204}\,P^{1.147}$	.159	38	3.5
$Q_{25} = 1.091\,A^{0.8686}\,(ST{+}1)^{-0.2273}\,P^{1.131}$	.164	39	5.0
$Q_{50} = 1.395\,A^{0.8563}\,(ST{+}1)^{-0.2313}\,P^{1.120}$	.172	41	5.9
$Q_{100} = 1.738\,A^{0.8457}\,(ST{+}1)^{-0.2347}\,P^{1.109}$	.183	44	6.6
$Q_{200} = 2.124\,A^{0.8363}\,(ST{+}1)^{-0.2377}\,P^{1.099}$	.194	47	7.1
$Q_{500} = 2.704\,A^{0.8253}\,(ST{+}1)^{-0.2413}\,P^{1.088}$	.212	52	7.4



Region 1 (93 gaging stations)

A = 0.720-571	drainage area, sq mi
ST = 0-26	area of lakes and ponds (storage) %
P = 70-300	mean annual precipitation, in
J = 0-32	mean minimum January temperatures, degree F

A	3.07	mi^2	*Estimate for North Fork Staney Creek*
ST	1	%	gage 15081495
P	100	in	
J	30	F	

			Weighted USGS Staney Creek	
Q2	464.06502	cfs	549.295473	cfs
Q5	653.79261	cfs	722.2867	cfs
Q10	781.86952	cfs	845.4578	cfs
Q25	941.2553	cfs	1008.07749	cfs
Q50	1060.9675	cfs	1142.8748	cfs
Q100	1175.441	cfs	1276.4782	cfs
Q200	1297.9225	cfs	1426.8128	cfs
Q500	1453.4737	cfs	1623.23157	cfs

See next sheet (PND USGS Regression Scaled) for scaled data based on USGS and historical peak flows for Staney Creek

A >=0.72 mi^2

Stream	MP	A	ST	P	J	Q2	Q5	Q10	Q25	Q50	Q100	Q200	Q500
FP-01	82.667	0.14	0.0	97.3	29.6	43.5	62.5	75.3	91.2	103.1	114.4	126.5	141.8
FP-02	83.391	0.01	0.0	97.3	29.6	4.5	6.6	8.0	9.7	11.0	12.2	13.5	15.1
FP-03	83.5	0.40	1.6	97.3	29.6	73.8	104.9	126.0	152.3	172.1	191.1	211.5	237.5
FP-04	83.541	0.01	0.0	97.3	29.6	6.1	8.8	10.7	13.0	14.7	16.3	18.1	20.3
Tunga	83.71	1.72	14.9	97.3	29.6	131.2	182.8	218.1	262.9	297.0	330.1	366.0	412.5
FP-05	85.884	0.14	0.0	97.3	29.6	42.7	61.4	74.0	89.7	101.3	112.5	124.4	139.4
FP-06	86.061	0.18	0.0	97.3	29.6	53.1	76.3	91.9	111.3	125.8	139.6	154.3	173.0
FP-07	86.956	0.04	0.0	97.3	29.6	14.1	20.4	24.7	29.9	33.8	37.6	41.6	46.6
FP-08	87.055	0.01	0.0	97.3	29.6	4.5	6.6	8.0	9.7	11.0	12.2	13.6	15.2
FP-09	87.172	0.11	0.0	97.3	29.6	35.9	51.7	62.4	75.6	85.4	94.8	104.9	117.5
Chum	87.272	1.10	6.9	97.3	29.6	116.1	162.8	194.7	235.0	265.4	294.9	326.8	367.7
FP-10	87.469	0.13	0.0	97.3	29.6	41.2	59.2	71.4	86.5	97.7	108.5	120.0	134.5
FP-11	88.386	0.10	0.9	97.3	29.6	26.1	37.4	45.0	54.5	61.6	68.5	75.8	85.1
FP-12	88.413	0.02	0.0	97.3	29.6	8.6	12.5	15.1	18.3	20.7	23.0	25.5	28.6
FP-13	89.035	0.45	1.5	97.3	29.6	84.0	119.3	143.3	173.2	195.7	217.3	240.4	269.9
FP-14	89.894	0.08	0.0	97.3	29.6	27.5	39.6	47.7	57.9	65.4	72.7	80.4	90.1
FP-15	90.201	0.35	3.4	97.3	29.6	55.4	78.5	94.2	113.8	128.6	142.9	158.3	178.0
FP-16	90.696	0.01	0.0	97.3	29.6	4.2	6.1	7.3	8.9	10.1	11.2	12.4	13.9
FP-17	91.12	0.03	0.0	97.3	29.6	11.7	17.0	20.5	24.9	28.2	31.3	34.6	38.8
C-01	81.99	0.02	0.0	97.3	29.6	7.5	10.9	13.2	16.0	18.1	20.1	22.3	25.0
C-02	84.448	0.03	0.0	97.3	29.6	10.9	15.8	19.0	23.1	26.2	29.1	32.2	36.1
C-03	86.388	0.03	0.0	97.3	29.6	11.9	17.1	20.7	25.2	28.5	31.6	35.0	39.2
C-04	88.509	0.01	0.0	97.3	29.6	4.4	6.4	7.7	9.4	10.6	11.8	13.1	14.6
C-05	88.581	0.05	0.0	97.3	29.6	19.7	28.4	34.3	41.6	47.0	52.2	57.8	64.8
C-06	88.703	0.03	0.0	97.3	29.6	10.9	15.8	19.0	23.1	26.2	29.1	32.2	36.1
C-07	89.341	0.02	0.0	97.3	29.6	9.3	13.5	16.3	19.8	22.4	24.9	27.5	30.9
C-08	90.593	0.22	0.0	97.3	29.6	62.2	89.3	107.5	130.2	147.1	163.3	180.5	202.3
C-09	91.221	0.03	0.0	97.3	29.6	13.4	19.3	23.4	28.3	32.1	35.6	39.4	44.2
C-10	91.276	0.01	0.0	97.3	29.6	4.3	6.3	7.6	9.3	10.5	11.7	13.0	14.5
C-11	91.721	0.01	0.0	97.3	29.6	5.6	8.1	9.9	12.0	13.6	15.1	16.7	18.7
C-12	91.86	0.16	0.0	97.3	29.6	47.8	68.7	82.8	100.3	113.4	125.8	139.1	155.9
C-13	91.92	0.06	0.0	97.3	29.6	22.7	32.7	39.4	47.8	54.1	60.0	66.4	74.5

USGS Regression Analysis
Weighted Values

Region 1 (93 gaging stations)

A = 0.720-571	drainage area, sq mi
ST = 0-26	area of lakes and ponds (storage) %
P = 70-300	mean annual precipitation, in
J = 0-32	mean minimum January temperatures, degree F

A	3.07	mi^2	*Estimate for North Fork Staney Creek*
ST	1	%	gage 15081495
P	100	in	
J	30	F	

	USGS REG	USGS wtd	
Q2	464	549	cfs
Q5	654	722	cfs
Q10	782	845	cfs
Q25	941	1008	cfs
Q50	1061	1143	cfs
Q100	1175	1276	cfs
Q200	1298	1427	cfs
Q500	1453	1623	cfs

Flood	Scale Factor
Q2	1.1837
Q5	1.1048
Q10	1.0813
Q25	1.0710
Q50	1.0772
Q100	1.0860
Q200	1.0993
Q500	1.1168

developed based on USGS North Fork Staney Creek gage data

Stream	MP	A	Q2	Q5	Q10	Q25	Q50	Q100	Q200	Q500	Qfish .4 Q2
FP-01	82.667	0.14	51.4	69.0	81.4	97.7	111.0	124.3	139.1	158.4	20.57
FP-02	83.391	0.01	5.4	7.3	8.6	10.4	11.8	13.2	14.8	16.9	2.14
FP-03	83.5	0.40	87.4	115.9	136.2	163.1	185.4	207.5	232.5	265.2	34.96
FP-04	83.541	0.01	7.2	9.8	11.5	13.9	15.8	17.7	19.9	22.6	2.88
Tunga	83.71	1.72	155.3	201.9	235.9	281.5	319.9	358.5	402.4	460.6	62.14
FP-05	85.884	0.14	50.5	67.8	80.0	96.0	109.2	122.1	136.7	155.7	20.22
FP-06	86.061	0.18	62.9	84.3	99.4	119.2	135.5	151.6	169.7	193.2	25.14
FP-07	86.956	0.04	16.7	22.5	26.7	32.0	36.5	40.8	45.7	52.1	6.69
FP-08	87.055	0.01	5.4	7.3	8.7	10.4	11.9	13.3	14.9	17.0	2.15
FP-09	87.172	0.11	42.5	57.1	67.4	80.9	92.0	103.0	115.3	131.3	17.02
Chum	87.272	1.10	137.4	179.9	210.6	251.6	285.9	320.3	359.2	410.6	54.96
FP-10	87.469	0.13	48.7	65.4	77.2	92.6	105.3	117.8	131.9	150.2	19.50
FP-11	88.386	0.10	30.9	41.3	48.7	58.4	66.4	74.4	83.3	95.0	12.35
FP-12	88.413	0.02	10.2	13.8	16.3	19.6	22.3	25.0	28.0	31.9	4.08
FP-13	89.035	0.45	99.4	131.8	154.9	185.5	210.8	236.0	264.3	301.5	39.77
FP-14	89.894	0.08	32.5	43.7	51.6	62.0	70.5	78.9	88.4	100.6	13.01
FP-15	90.201	0.35	65.6	86.7	101.8	121.9	138.6	155.2	174.0	198.8	26.25
FP-16	90.696	0.01	4.9	6.7	7.9	9.5	10.9	12.2	13.7	15.6	1.97
FP-17	91.12	0.03	13.9	18.7	22.2	26.7	30.3	34.0	38.1	43.4	5.56
C-01	81.99	0.02	8.9	12.0	14.2	17.1	19.5	21.8	24.5	27.9	
C-02	84.448	0.03	12.9	17.4	20.6	24.8	28.2	31.6	35.4	40.3	
C-03	86.388	0.03	14.0	18.9	22.4	26.9	30.6	34.3	38.5	43.8	
C-04	88.509	0.01	5.2	7.0	8.3	10.0	11.4	12.8	14.4	16.4	
C-05	88.581	0.05	23.3	31.4	37.1	44.5	50.7	56.7	63.5	72.3	
C-06	88.703	0.03	12.9	17.4	20.6	24.8	28.2	31.6	35.4	40.3	
C-07	89.341	0.02	11.0	14.9	17.6	21.2	24.1	27.0	30.2	34.5	
C-08	90.593	0.22	73.6	98.6	116.3	139.5	158.5	177.3	198.4	225.9	
C-09	91.221	0.03	15.8	21.4	25.2	30.4	34.5	38.7	43.3	49.4	
C-10	91.276	0.01	5.1	7.0	8.3	10.0	11.3	12.7	14.2	16.2	
C-11	91.721	0.01	6.6	9.0	10.7	12.8	14.6	16.4	18.3	20.9	
C-12	91.86	0.16	56.6	75.9	89.5	107.4	122.1	136.6	152.9	174.1	
C-13	91.92	0.06	26.8	36.1	42.6	51.2	58.2	65.2	73.0	83.1	

Region 1 (93 gaging stations)

A = 0.720-571	drainage area, sq mi
ST = 0-26	area of lakes and ponds (storage) %
P = 70-300	mean annual precipitation, in
J = 0-32	mean minimum January temperatures, degree F

A	3.07	mi^2	*Estimate for North Fork Staney Creek*
ST	1	%	gage 15081495
P	100	in	
J	30	F	

			Weighted USGS Staney Creek	
Q2	464.065018	cfs	549.29547	cfs
Q5	653.792607	cfs	722.2867	cfs
Q10	781.869525	cfs	845.4578	cfs
Q25	941.255305	cfs	1008.0775	cfs
Q50	1060.9675	cfs	1142.8748	cfs
Q100	1175.44096	cfs	1276.4782	cfs
Q200	1297.92247	cfs	1426.8128	cfs
Q500	1453.47373	cfs	1623.2316	cfs

See next sheet (PND USGS Regression Scaled) for scaled data based on USGS and historical peak flows for Staney Creek

A >=0.72 mi^2

Stream	ft^2	mi^2	ST	P	J	Q2	Q5	Q10	Q25	Q50	Q100	Q200	Q500
C-101E	18127	6.5E-04	0.0	97.3	29.6	0.5	0.7	0.9	1.1	1.2	1.3	1.5	1.7
C-101W	55987	2.0E-03	0.0	97.3	29.6	1.2	1.8	2.2	2.7	3.1	3.4	3.8	4.2
C-102	87493	3.1E-03	0.0	97.3	29.6	1.8	2.6	3.2	3.9	4.4	4.9	5.5	6.1
C-103	29209	1.0E-03	0.0	97.3	29.6	0.7	1.1	1.3	1.6	1.8	2.0	2.2	2.5
C-104E	24074	8.6E-04	0.0	97.3	29.6	0.6	0.9	1.1	1.3	1.5	1.7	1.9	2.1
C-104W	152680	5.5E-03	0.0	97.3	29.6	2.9	4.2	5.1	6.2	7.0	7.8	8.7	9.7
C-105	144165	5.2E-03	0.0	97.3	29.6	2.8	4.0	4.9	5.9	6.7	7.5	8.3	9.3
C-106	349599	1.3E-02	0.0	97.3	29.6	5.8	8.4	10.1	12.3	14.0	15.5	17.2	19.3
C-107	177598	6.4E-03	0.0	97.3	29.6	3.3	4.8	5.8	7.0	8.0	8.9	9.8	11.0
C-112	99031	3.6E-03	0.0	97.3	29.6	2.0	2.9	3.6	4.3	4.9	5.5	6.0	6.8
C-113	81985	2.9E-03	0.0	97.3	29.6	1.7	2.5	3.0	3.7	4.2	4.7	5.2	5.8
C-114	67648	2.4E-03	0.0	97.3	29.6	1.5	2.1	2.6	3.2	3.6	4.0	4.4	5.0
C-115	22056	7.9E-04	0.0	97.3	29.6	0.6	0.8	1.0	1.2	1.4	1.6	1.7	2.0
C-117	104273	3.7E-03	0.0	97.3	29.6	2.1	3.1	3.7	4.5	5.1	5.7	6.3	7.1
C-118	107765	3.9E-03	0.0	97.3	29.6	2.2	3.2	3.8	4.6	5.3	5.9	6.5	7.3
C-201	41018	1.5E-03	0.0	97.3	29.6	1.0	1.4	1.7	2.1	2.4	2.6	2.9	3.3
C-203E	52659	1.9E-03	0.0	97.3	29.6	1.2	1.7	2.1	2.6	2.9	3.2	3.6	4.0
C-203W	14840	5.3E-04	0.0	97.3	29.6	0.4	0.6	0.7	0.9	1.0	1.1	1.3	1.4
C-204E	2446	8.8E-05	0.0	97.3	29.6	0.1	0.1	0.2	0.2	0.2	0.3	0.3	0.3
C-204W	18959	6.8E-04	0.0	97.3	29.6	0.5	0.7	0.9	1.1	1.2	1.4	1.5	1.7
C-205	97837	3.5E-03	0.0	97.3	29.6	2.0	2.9	3.5	4.3	4.9	5.4	6.0	6.7
C-206	40322	1.4E-03	0.0	97.3	29.6	0.9	1.4	1.7	2.1	2.3	2.6	2.9	3.2
C-209	74874	2.7E-03	0.0	97.3	29.6	1.6	2.3	2.8	3.4	3.9	4.3	4.8	5.4
C-210	70112	2.5E-03	0.0	97.3	29.6	1.5	2.2	2.7	3.3	3.7	4.1	4.5	5.1
C-216E	549812	2.0E-02	0.0	97.3	29.6	8.4	12.2	14.8	18.0	20.3	22.6	25.0	28.0
C-216W	98531	3.5E-03	0.0	97.3	29.6	2.0	2.9	3.5	4.3	4.9	5.4	6.0	6.8
C-217	138356	5.0E-03	0.0	97.3	29.6	2.7	3.9	4.7	5.7	6.5	7.2	8.0	9.0
C-03	173246	6.2E-03	0.0	97.3	29.6	3.2	4.7	5.7	6.9	7.8	8.7	9.6	10.8
C-314	36311	1.3E-03	0.0	97.3	29.6	0.9	1.3	1.5	1.9	2.1	2.4	2.6	3.0
C-315	170635	6.1E-03	0.0	97.3	29.6	3.2	4.6	5.6	6.8	7.7	8.6	9.5	10.6
C-316	25991	9.3E-04	0.0	97.3	29.6	0.7	1.0	1.2	1.4	1.6	1.8	2.0	2.2
C-317	56372	2.0E-03	0.0	97.3	29.6	1.3	1.8	2.2	2.7	3.1	3.4	3.8	4.3
C-318	38312	1.4E-03	0.0	97.3	29.6	0.9	1.3	1.6	2.0	2.2	2.5	2.8	3.1
C-319	19285	6.9E-04	0.0	97.3	29.6	0.5	0.8	0.9	1.1	1.3	1.4	1.6	1.8
C-320	20564	7.4E-04	0.0	97.3	29.6	0.5	0.8	1.0	1.2	1.3	1.5	1.6	1.8
C-403	17067	6.1E-04	0.0	97.3	29.6	0.5	0.7	0.8	1.0	1.1	1.3	1.4	1.6
C-404	80024	2.9E-03	0.0	97.3	29.6	1.7	2.5	3.0	3.6	4.1	4.6	5.1	5.7
C-405	269433	9.7E-03	0.0	97.3	29.6	4.6	6.8	8.2	9.9	11.3	12.5	13.8	15.5
C-406	104249	3.7E-03	0.0	97.3	29.6	2.1	3.1	3.7	4.5	5.1	5.7	6.3	7.1
C-407	72996	2.6E-03	0.0	97.3	29.6	1.6	2.3	2.8	3.4	3.8	4.2	4.7	5.3
C-408	4150	1.5E-04	0.0	97.3	29.6	0.1	0.2	0.3	0.3	0.4	0.4	0.4	0.5
C-409	393480	1.4E-02	0.0	97.3	29.6	6.4	9.3	11.2	13.6	15.4	17.1	18.9	21.3
C-414	156392	5.6E-03	0.0	97.3	29.6	2.9	4.3	5.2	6.3	7.2	8.0	8.8	9.9
C-05	30941	1.1E-03	0.0	97.3	29.6	0.8	1.1	1.4	1.7	1.9	2.1	2.3	2.6
C-417	64558	2.3E-03	0.0	97.3	29.6	1.4	2.1	2.5	3.0	3.4	3.8	4.2	4.8
C-418	183982	6.6E-03	0.0	97.3	29.6	3.4	4.9	6.0	7.2	8.2	9.1	10.1	11.3
C-503	99567	3.6E-03	0.0	97.3	29.6	2.0	2.9	3.6	4.4	4.9	5.5	6.1	6.8
C-504	152662	5.5E-03	0.0	97.3	29.6	2.9	4.2	5.1	6.2	7.0	7.8	8.7	9.7
C-505	24958	9.0E-04	0.0	97.3	29.6	0.6	0.9	1.1	1.4	1.6	1.7	1.9	2.2
C-506	26496	9.5E-04	0.0	97.3	29.6	0.7	1.0	1.2	1.5	1.6	1.8	2.0	2.3
C-507	23094	8.3E-04	0.0	97.3	29.6	0.6	0.9	1.1	1.3	1.5	1.6	1.8	2.0
C-508	93437	3.4E-03	0.0	97.3	29.6	1.9	2.8	3.4	4.1	4.7	5.2	5.8	6.5
C-509	28299	1.0E-03	0.0	97.3	29.6	0.7	1.0	1.3	1.5	1.7	1.9	2.1	2.4

Region 1 (93 gaging stations)
A = 0.720-571 drainage area, sq mi
ST = 0-26 area of lakes and ponds (storage) %
P = 70-300 mean annual precipitation, in
J = 0-32 mean minimum January temperatures, degree F

A	3.07	mi^2	*Estimate for North Fork Staney Creek*
ST	1	%	gage 15081495
P	100	in	
J	30	F	

			Weighted USGS Staney Creek	
Q2	464.065018	cfs	549.29547	cfs
Q5	653.792607	cfs	722.2867	cfs
Q10	781.869525	cfs	845.4578	cfs
Q25	941.255305	cfs	1008.0775	cfs
Q50	1060.9675	cfs	1142.8748	cfs
Q100	1175.44096	cfs	1276.4782	cfs
Q200	1297.92247	cfs	1426.8128	cfs
Q500	1453.47373	cfs	1623.2316	cfs

See next sheet (PND USGS Regression Scaled) for scaled data based on USGS and historical peak flows for Staney Creek

A >=0.72 mi^2

Stream	ft^2	mi^2	ST	P	J	Q2	Q5	Q10	Q25	Q50	Q100	Q200	Q500
C-510	32556	1.2E-03	0.0	97.3	29.6	0.8	1.2	1.4	1.7	2.0	2.2	2.4	2.7
C-511	6120	2.2E-04	0.0	97.3	29.6	0.2	0.3	0.4	0.4	0.5	0.5	0.6	0.7
C-512	67013	2.4E-03	0.0	97.3	29.6	1.5	2.1	2.6	3.1	3.6	4.0	4.4	4.9
C-513	20031	7.2E-04	0.0	97.3	29.6	0.5	0.8	0.9	1.2	1.3	1.5	1.6	1.8
C-514	25024	9.0E-04	0.0	97.3	29.6	0.6	0.9	1.1	1.4	1.6	1.7	1.9	2.2
C-515	3401	1.2E-04	0.0	97.3	29.6	0.1	0.2	0.2	0.3	0.3	0.3	0.4	0.4
C-516	12384	4.4E-04	0.0	97.3	29.6	0.4	0.5	0.6	0.8	0.9	1.0	1.1	1.2
C-517	147388	5.3E-03	0.0	97.3	29.6	2.8	4.1	5.0	6.0	6.8	7.6	8.4	9.4
C-518	129010	4.6E-03	0.0	97.3	29.6	2.5	3.7	4.4	5.4	6.1	6.8	7.5	8.4
C-519	42687	1.5E-03	0.0	97.3	29.6	1.0	1.5	1.8	2.2	2.4	2.7	3.0	3.4
C-08	100871	3.6E-03	0.0	97.3	29.6	2.0	3.0	3.6	4.4	5.0	5.5	6.1	6.9
C-520	34079	1.2E-03	0.0	97.3	29.6	0.8	1.2	1.5	1.8	2.0	2.3	2.5	2.8
C-521	40979	1.5E-03	0.0	97.3	29.6	1.0	1.4	1.7	2.1	2.4	2.6	2.9	3.3
C-523	65182	2.3E-03	0.0	97.3	29.6	1.4	2.1	2.5	3.1	3.5	3.9	4.3	4.8
C-524	291569	1.0E-02	0.0	97.3	29.6	5.0	7.2	8.7	10.6	12.0	13.4	14.8	16.6
C-525	33133	1.2E-03	0.0	97.3	29.6	0.8	1.2	1.4	1.7	2.0	2.2	2.4	2.7
C-526	204689	7.3E-03	0.0	97.3	29.6	3.7	5.4	6.5	7.9	9.0	10.0	11.0	12.4
C-09	16680	6.0E-04	0.0	97.3	29.6	0.5	0.7	0.8	1.0	1.1	1.2	1.4	1.6
C-10	3325	1.2E-04	0.0	97.3	29.6	0.1	0.2	0.2	0.3	0.3	0.3	0.4	0.4
C-601	271405	9.7E-03	0.0	97.3	29.6	4.7	6.8	8.2	10.0	11.3	12.6	13.9	15.6
C-602	33151	1.2E-03	0.0	97.3	29.6	0.8	1.2	1.4	1.7	2.0	2.2	2.4	2.7
C-603	149682	5.4E-03	0.0	97.3	29.6	2.8	4.1	5.0	6.1	6.9	7.7	8.5	9.6
C-604	1128	4.0E-05	0.0	97.3	29.6	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.2
C-11	5060	1.8E-04	0.0	97.3	29.6	0.2	0.2	0.3	0.4	0.4	0.5	0.5	0.6
C-12	23665	8.5E-04	0.0	97.3	29.6	0.6	0.9	1.1	1.3	1.5	1.7	1.9	2.1
C-13	31805	1.1E-03	0.0	97.3	29.6	0.8	1.1	1.4	1.7	1.9	2.1	2.4	2.7
C-607	75244	2.7E-03	0.0	97.3	29.6	1.6	2.3	2.8	3.5	3.9	4.3	4.8	5.4
C-608	139480	5.0E-03	0.0	97.3	29.6	2.7	3.9	4.7	5.8	6.5	7.2	8.0	9.0
C-612	47707	1.7E-03	0.0	97.3	29.6	1.1	1.6	1.9	2.4	2.7	3.0	3.3	3.7
C-613	27529	9.9E-04	0.0	97.3	29.6	0.7	1.0	1.2	1.5	1.7	1.9	2.1	2.4
C-614	235251	8.4E-03	0.0	97.3	29.6	4.2	6.0	7.3	8.9	10.1	11.2	12.4	13.9
C-615	176706	6.3E-03	0.0	97.3	29.6	3.3	4.8	5.8	7.0	7.9	8.8	9.8	11.0
C-616	36955	1.3E-03	0.0	97.3	29.6	0.9	1.3	1.6	1.9	2.2	2.4	2.7	3.0
C-618	419581	1.5E-02	0.0	97.3	29.6	6.7	9.8	11.8	14.4	16.2	18.0	20.0	22.4
C-619	119780	4.3E-03	0.0	97.3	29.6	2.4	3.4	4.2	5.1	5.7	6.4	7.1	7.9
C-620	47602	1.7E-03	0.0	97.3	29.6	1.1	1.6	1.9	2.4	2.7	3.0	3.3	3.7
C-621	0	0.0E+00	0.0	97.3	29.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
C-623	213628	7.7E-03	0.0	97.3	29.6	3.8	5.6	6.7	8.2	9.3	10.3	11.4	12.8
C-624	113687	4.1E-03	0.0	97.3	29.6	2.3	3.3	4.0	4.9	5.5	6.1	6.8	7.6
C-1399	665469	2.4E-02	0.0	97.3	29.6	9.9	14.3	17.3	21.0	23.8	26.4	29.3	32.8
C-110	125041	4.5E-03	0.0	97.3	29.6	2.4	3.6	4.3	5.3	6.0	6.6	7.3	8.2
C-118	182175	6.5E-03	0.0	97.3	29.6	3.4	4.9	5.9	7.2	8.1	9.0	10.0	11.2
C-401	335594	1.2E-02	0.0	97.3	29.6	5.6	8.1	9.8	11.9	13.5	15.0	16.6	18.6
C-212	304773	1.1E-02	0.0	97.3	29.6	5.2	7.5	9.1	11.0	12.5	13.8	15.3	17.2
C-301	623707	2.2E-02	0.0	97.3	29.6	9.4	13.6	16.4	19.9	22.6	25.1	27.7	31.1

Region 1 (93 gaging stations)

A = 0.720-571	drainage area, sq mi
ST = 0-26	area of lakes and ponds (storage) %
P = 70-300	mean annual precipitation, in
J = 0-32	mean minimum January temperatures, degree F

A	3.07	mi^2	*Estimate for North Fork Staney Creek*
ST	1	%	gage 15081495
P	100	in	
J	30	F	

	USGS REG	USGS wtd	
Q2	464	549	cfs
Q5	654	722	cfs
Q10	782	845	cfs
Q25	941	1008	cfs
Q50	1061	1143	cfs
Q100	1175	1276	cfs
Q200	1298	1427	cfs
Q500	1453	1623	cfs

Flood	Scale Factor
Q2	1.1837
Q5	1.1048
Q10	1.0813
Q25	1.0710
Q50	1.0772
Q100	1.0860
Q200	1.0993
Q500	1.1168

developed based on USGS North Fork Staney Creek gage data

Stream	ft^2	mi^2	Q2	Q5	Q10	Q25	Q50	Q100	Q200	Q500
C-101E	18127	0.00	0.6	0.8	0.9	1.1	1.3	1.5	1.6	1.9
C-101W	55987	0.00	1.5	2.0	2.4	2.9	3.3	3.7	4.1	4.7
C-102	87493	0.00	2.1	2.9	3.5	4.2	4.8	5.4	6.0	6.8
C-103	29209	0.00	0.9	1.2	1.4	1.7	1.9	2.2	2.4	2.8
C-104E	24074	0.00	0.7	1.0	1.2	1.4	1.6	1.8	2.1	2.4
C-104W	152680	0.01	3.4	4.7	5.5	6.6	7.6	8.5	9.5	10.8
C-105	144165	0.01	3.3	4.4	5.3	6.3	7.2	8.1	9.1	10.3
C-106	349599	0.01	6.8	9.3	11.0	13.2	15.0	16.9	18.9	21.5
C-107	177598	0.01	3.9	5.3	6.3	7.5	8.6	9.6	10.8	12.3
C-112	99031	0.00	2.4	3.2	3.8	4.6	5.3	5.9	6.6	7.6
C-113	81985	0.00	2.0	2.8	3.3	4.0	4.5	5.1	5.7	6.5
C-114	67648	0.00	1.7	2.4	2.8	3.4	3.9	4.3	4.9	5.5
C-115	22056	0.00	0.7	0.9	1.1	1.3	1.5	1.7	1.9	2.2
C-117	104273	0.00	2.5	3.4	4.0	4.8	5.5	6.2	6.9	7.9
C-118	107765	0.00	2.6	3.5	4.1	5.0	5.7	6.4	7.1	8.1
C-201	41018	0.00	1.1	1.6	1.9	2.2	2.5	2.9	3.2	3.7
C-203E	52659	0.00	1.4	1.9	2.3	2.7	3.1	3.5	3.9	4.5
C-203W	14840	0.00	0.5	0.7	0.8	1.0	1.1	1.2	1.4	1.6
C-204E	2446	0.00	0.1	0.1	0.2	0.2	0.2	0.3	0.3	0.4
C-204W	18959	0.00	0.6	0.8	1.0	1.2	1.3	1.5	1.7	1.9
C-205	97837	0.00	2.4	3.2	3.8	4.6	5.2	5.9	6.6	7.5
C-206	40322	0.00	1.1	1.5	1.8	2.2	2.5	2.8	3.2	3.6
C-209	74874	0.00	1.9	2.6	3.1	3.7	4.2	4.7	5.3	6.0
C-210	70112	0.00	1.8	2.4	2.9	3.5	4.0	4.5	5.0	5.7
C-216E	549812	0.02	10.0	13.5	16.0	19.2	21.9	24.5	27.5	31.3
C-216W	98531	0.00	2.4	3.2	3.8	4.6	5.3	5.9	6.6	7.6
C-217	138356	0.00	3.2	4.3	5.1	6.1	7.0	7.8	8.8	10.0
C-03	173246	0.01	3.8	5.2	6.1	7.4	8.4	9.4	10.6	12.0
C-314	36311	0.00	1.0	1.4	1.7	2.0	2.3	2.6	2.9	3.3
C-315	170635	0.01	3.8	5.1	6.0	7.3	8.3	9.3	10.4	11.9
C-316	25991	0.00	0.8	1.1	1.3	1.5	1.7	2.0	2.2	2.5
C-317	56372	0.00	1.5	2.0	2.4	2.9	3.3	3.7	4.2	4.8
C-318	38312	0.00	1.1	1.5	1.7	2.1	2.4	2.7	3.0	3.5
C-319	19285	0.00	0.6	0.8	1.0	1.2	1.4	1.5	1.7	2.0
C-320	20564	0.00	0.6	0.9	1.0	1.3	1.4	1.6	1.8	2.1
C-403	17067	0.00	0.5	0.8	0.9	1.1	1.2	1.4	1.6	1.8
C-404	80024	0.00	2.0	2.7	3.2	3.9	4.4	5.0	5.6	6.4
C-405	269433	0.01	5.5	7.5	8.8	10.6	12.1	13.6	15.2	17.4
C-406	104249	0.00	2.5	3.4	4.0	4.8	5.5	6.2	6.9	7.9
C-407	72996	0.00	1.8	2.5	3.0	3.6	4.1	4.6	5.2	5.9

USGS Regression Analysis
Weighted Values

Region 1 (93 gaging stations)

A = 0.720-571	drainage area, sq mi
ST = 0-26	area of lakes and ponds (storage) %
P = 70-300	mean annual precipitation, in
J = 0-32	mean minimum January temperatures, degree F

A	3.07	mi^2	*Estimate for North Fork Staney Creek*
ST	1	%	gage 15081495
P	100	in	
J	30	F	

	USGS REG	USGS wtd	
Q2	464	549	cfs
Q5	654	722	cfs
Q10	782	845	cfs
Q25	941	1008	cfs
Q50	1061	1143	cfs
Q100	1175	1276	cfs
Q200	1298	1427	cfs
Q500	1453	1623	cfs

Flood	Scale Factor
Q2	1.1837
Q5	1.1048
Q10	1.0813
Q25	1.0710
Q50	1.0772
Q100	1.0860
Q200	1.0993
Q500	1.1168

developed based on USGS North Fork Staney Creek gage data

Stream	ft^2	mi^2	Q2	Q5	Q10	Q25	Q50	Q100	Q200	Q500
C-408	4150	0.00	0.2	0.2	0.3	0.3	0.4	0.4	0.5	0.5
C-409	393480	0.01	7.6	10.2	12.1	14.6	16.6	18.6	20.8	23.7
C-414	156392	0.01	3.5	4.7	5.6	6.8	7.7	8.7	9.7	11.1
C-05	30941	0.00	0.9	1.2	1.5	1.8	2.0	2.3	2.5	2.9
C-417	64558	0.00	1.7	2.3	2.7	3.3	3.7	4.2	4.7	5.3
C-418	183982	0.01	4.0	5.4	6.4	7.8	8.8	9.9	11.1	12.7
C-503	99567	0.00	2.4	3.3	3.9	4.7	5.3	6.0	6.7	7.6
C-504	152662	0.01	3.4	4.7	5.5	6.6	7.6	8.5	9.5	10.8
C-505	24958	0.00	0.8	1.0	1.2	1.5	1.7	1.9	2.1	2.4
C-506	26496	0.00	0.8	1.1	1.3	1.6	1.8	2.0	2.2	2.5
C-507	23094	0.00	0.7	1.0	1.1	1.4	1.6	1.8	2.0	2.3
C-508	93437	0.00	2.3	3.1	3.7	4.4	5.0	5.7	6.3	7.2
C-509	28299	0.00	0.8	1.1	1.4	1.6	1.9	2.1	2.4	2.7
C-510	32556	0.00	0.9	1.3	1.5	1.8	2.1	2.4	2.6	3.0
C-511	6120	0.00	0.2	0.3	0.4	0.5	0.5	0.6	0.7	0.8
C-512	67013	0.00	1.7	2.3	2.8	3.4	3.8	4.3	4.8	5.5
C-513	20031	0.00	0.6	0.9	1.0	1.2	1.4	1.6	1.8	2.0
C-514	25024	0.00	0.8	1.0	1.2	1.5	1.7	1.9	2.1	2.4
C-515	3401	0.00	0.1	0.2	0.2	0.3	0.3	0.4	0.4	0.5
C-516	12384	0.00	0.4	0.6	0.7	0.8	0.9	1.1	1.2	1.4
C-517	147388	0.01	3.3	4.5	5.4	6.5	7.4	8.2	9.2	10.5
C-518	129010	0.00	3.0	4.0	4.8	5.8	6.6	7.4	8.3	9.4
C-519	42687	0.00	1.2	1.6	1.9	2.3	2.6	3.0	3.3	3.8
C-08	100871	0.00	2.4	3.3	3.9	4.7	5.4	6.0	6.8	7.7
C-520	34079	0.00	1.0	1.3	1.6	1.9	2.2	2.5	2.8	3.1
C-521	40979	0.00	1.1	1.6	1.8	2.2	2.5	2.9	3.2	3.7
C-523	65182	0.00	1.7	2.3	2.7	3.3	3.7	4.2	4.7	5.4
C-524	291569	0.01	5.9	8.0	9.4	11.4	12.9	14.5	16.3	18.5
C-525	33133	0.00	1.0	1.3	1.6	1.9	2.1	2.4	2.7	3.1
C-526	204689	0.01	4.4	5.9	7.0	8.5	9.7	10.8	12.1	13.8
C-09	16680	0.00	0.5	0.7	0.9	1.1	1.2	1.4	1.5	1.7
C-10	3325	0.00	0.1	0.2	0.2	0.3	0.3	0.4	0.4	0.5
C-601	271405	0.01	5.5	7.5	8.9	10.7	12.2	13.7	15.3	17.5
C-602	33151	0.00	1.0	1.3	1.6	1.9	2.1	2.4	2.7	3.1
C-603	149682	0.01	3.4	4.6	5.4	6.5	7.4	8.3	9.4	10.7
C-604	1128	0.00	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.2
C-11	5060	0.00	0.2	0.3	0.3	0.4	0.4	0.5	0.6	0.6
C-12	23665	0.00	0.7	1.0	1.2	1.4	1.6	1.8	2.0	2.3
C-13	31805	0.00	0.9	1.3	1.5	1.8	2.1	2.3	2.6	3.0
C-607	75244	0.00	1.9	2.6	3.1	3.7	4.2	4.7	5.3	6.0

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Q25	941	1008	cfs
Q50	1061	1143	cfs
Q100	1175	1276	cfs
Q200	1298	1427	cfs
Q500	1453	1623	cfs

Flood	Scale Factor
Q2	1.1837
Q5	1.1048
Q10	1.0813
Q25	1.0710
Q50	1.0772
Q100	1.0860
Q200	1.0993
Q500	1.1168

developed based on USGS North Fork Staney Creek gage data

Stream	ft^2	mi^2	Q2	Q5	Q10	Q25	Q50	Q100	Q200	Q500
C-608	139480	0.01	3.2	4.3	5.1	6.2	7.0	7.9	8.8	10.1
C-612	47707	0.00	1.3	1.8	2.1	2.5	2.9	3.2	3.6	4.1
C-613	27529	0.00	0.8	1.1	1.3	1.6	1.8	2.1	2.3	2.6
C-614	235251	0.01	4.9	6.7	7.9	9.5	10.8	12.1	13.6	15.5
C-615	176706	0.01	3.9	5.3	6.2	7.5	8.5	9.6	10.7	12.2
C-616	36955	0.00	1.0	1.4	1.7	2.1	2.3	2.6	2.9	3.4
C-618	419581	0.02	8.0	10.8	12.8	15.4	17.5	19.6	22.0	25.0
C-619	119780	0.00	2.8	3.8	4.5	5.4	6.2	6.9	7.8	8.9
C-620	47602	0.00	1.3	1.8	2.1	2.5	2.9	3.2	3.6	4.1
C-621	0	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
C-623	213628	0.01	4.5	6.2	7.3	8.8	10.0	11.2	12.6	14.3
C-624	113687	0.00	2.7	3.6	4.3	5.2	5.9	6.6	7.5	8.5
C-1399	665469	0.02	11.7	15.8	18.7	22.5	25.6	28.7	32.2	36.7
C-110	125041	0.00	2.9	3.9	4.7	5.6	6.4	7.2	8.1	9.2
C-118	182175	0.01	4.0	5.4	6.4	7.7	8.8	9.8	11.0	12.6
C-401	335594	0.01	6.6	9.0	10.6	12.8	14.5	16.3	18.3	20.8
C-212	304773	0.01	6.1	8.3	9.8	11.8	13.4	15.0	16.9	19.2
C-301	623707	0.02	11.1	15.0	17.7	21.4	24.3	27.2	30.5	34.7

Rational Method
Hydrology Check

NOAA Atlas 14, Volume 7, Version 2
Location name: Craig, Alaska, US*
Coordinates: 55.4833, -133.1500
Elevation: 0ft*
* source: Google Maps

POINT PRECIPITATION FREQUENCY ESTIMATES

Sanja Perica, Douglas Kane, Sarah Dietz, Kazungu Maitaria, Deborah Martin, Sandra Pavlovic, Ishani Roy, Svetlana Stuefer, Amy Tidwell, Carl Trypaluk, Dale Unruh, Michael Yekta, Erica Betts, Geoffrey Bonnin, Sarah Heim, Lillian Hiner, Elizabeth Lilly, Jayashree Narayanan, Fenglin Yan, Tan Zhao

NOAA, National Weather Service, Silver Spring, Maryland
and
University of Alaska Fairbanks, Water and Environmental Research Center

PF_tabular | PF_graphical | Maps_&_aerials

PF tabular

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

Duration	Average recurrence interval (years)									
	1	2	5	10	25	50	100	200	500	1000
5-min	**1.80** (1.31-2.52)	**2.12** (1.54-3.00)	**2.51** (1.78-3.61)	**2.84** (1.99-4.15)	**3.29** (2.26-4.88)	**3.64** (2.46-5.48)	**3.98** (2.66-6.08)	**4.34** (2.86-6.73)	**4.81** (3.11-7.60)	**5.17** (3.30-8.27)
10-min	**1.21** (0.882-1.70)	**1.42** (1.03-2.01)	**1.69** (1.19-2.42)	**1.91** (1.33-2.78)	**2.21** (1.52-3.28)	**2.44** (1.66-3.68)	**2.68** (1.79-4.09)	**2.92** (1.92-4.52)	**3.23** (2.09-5.09)	**3.47** (2.21-5.54)
15-min	**0.944** (0.688-1.32)	**1.11** (0.804-1.57)	**1.32** (0.932-1.89)	**1.49** (1.04-2.17)	**1.72** (1.18-2.56)	**1.90** (1.29-2.87)	**2.08** (1.39-3.18)	**2.27** (1.50-3.52)	**2.52** (1.63-3.98)	**2.71** (1.73-4.33)
30-min	**0.626** (0.456-0.876)	**0.738** (0.532-1.04)	**0.874** (0.620-1.26)	**0.986** (0.690-1.44)	**1.14** (0.786-1.70)	**1.26** (0.856-1.90)	**1.38** (0.924-2.11)	**1.51** (0.992-2.34)	**1.67** (1.08-2.64)	**1.80** (1.15-2.87)
60-min	**0.429** (0.313-0.600)	**0.505** (0.364-0.714)	**0.598** (0.424-0.860)	**0.676** (0.473-0.986)	**0.783** (0.538-1.16)	**0.866** (0.586-1.31)	**0.948** (0.633-1.45)	**1.03** (0.680-1.60)	**1.15** (0.740-1.81)	**1.23** (0.785-1.97)
2-hr	**0.330** (0.240-0.462)	**0.388** (0.280-0.550)	**0.460** (0.326-0.662)	**0.520** (0.364-0.758)	**0.602** (0.414-0.895)	**0.666** (0.451-1.00)	**0.730** (0.488-1.12)	**0.796** (0.524-1.23)	**0.882** (0.570-1.39)	**0.948** (0.604-1.52)
3-hr	**0.296** (0.216-0.414)	**0.348** (0.251-0.493)	**0.413** (0.293-0.593)	**0.466** (0.326-0.680)	**0.540** (0.371-0.802)	**0.597** (0.405-0.900)	**0.654** (0.437-1.00)	**0.713** (0.470-1.11)	**0.791** (0.511-1.25)	**0.850** (0.542-1.36)
6-hr	**0.244** (0.178-0.341)	**0.287** (0.207-0.406)	**0.341** (0.241-0.490)	**0.385** (0.269-0.561)	**0.446** (0.306-0.662)	**0.492** (0.333-0.742)	**0.539** (0.360-0.824)	**0.588** (0.387-0.911)	**0.652** (0.421-1.03)	**0.700** (0.447-1.12)
12-hr	**0.185** (0.135-0.259)	**0.218** (0.157-0.308)	**0.260** (0.185-0.374)	**0.294** (0.206-0.429)	**0.340** (0.233-0.504)	**0.375** (0.254-0.564)	**0.410** (0.274-0.626)	**0.446** (0.294-0.691)	**0.494** (0.319-0.779)	**0.530** (0.338-0.848)
24-hr	**0.135** (0.122-0.151)	**0.159** (0.142-0.180)	**0.191** (0.166-0.221)	**0.215** (0.185-0.253)	**0.248** (0.208-0.298)	**0.273** (0.225-0.334)	**0.298** (0.242-0.372)	**0.324** (0.258-0.411)	**0.359** (0.279-0.465)	**0.385** (0.295-0.507)
2-day	**0.090** (0.081-0.100)	**0.105** (0.093-0.119)	**0.125** (0.109-0.145)	**0.141** (0.121-0.166)	**0.162** (0.136-0.195)	**0.178** (0.147-0.218)	**0.195** (0.158-0.243)	**0.212** (0.169-0.269)	**0.235** (0.183-0.304)	**0.252** (0.193-0.332)
3-day	**0.070** (0.063-0.078)	**0.081** (0.072-0.092)	**0.096** (0.084-0.112)	**0.108** (0.093-0.127)	**0.124** (0.104-0.150)	**0.137** (0.113-0.168)	**0.150** (0.121-0.186)	**0.163** (0.130-0.207)	**0.181** (0.141-0.234)	**0.194** (0.149-0.256)
4-day	**0.059** (0.053-0.066)	**0.068** (0.061-0.077)	**0.081** (0.071-0.094)	**0.091** (0.078-0.107)	**0.104** (0.087-0.125)	**0.115** (0.094-0.140)	**0.125** (0.101-0.156)	**0.136** (0.109-0.173)	**0.151** (0.118-0.196)	**0.162** (0.124-0.214)
7-day	**0.045** (0.041-0.050)	**0.052** (0.046-0.059)	**0.061** (0.053-0.071)	**0.068** (0.059-0.080)	**0.078** (0.066-0.094)	**0.086** (0.071-0.105)	**0.093** (0.076-0.116)	**0.102** (0.081-0.129)	**0.112** (0.087-0.145)	**0.120** (0.092-0.159)
10-day	**0.038** (0.034-0.043)	**0.044** (0.039-0.050)	**0.052** (0.045-0.060)	**0.058** (0.049-0.068)	**0.066** (0.055-0.079)	**0.072** (0.059-0.088)	**0.078** (0.063-0.097)	**0.084** (0.067-0.107)	**0.093** (0.072-0.120)	**0.099** (0.076-0.131)
20-day	**0.030** (0.027-0.033)	**0.034** (0.030-0.038)	**0.039** (0.034-0.046)	**0.044** (0.037-0.051)	**0.049** (0.041-0.059)	**0.053** (0.044-0.065)	**0.057** (0.046-0.071)	**0.061** (0.049-0.077)	**0.066** (0.052-0.086)	**0.070** (0.054-0.093)
30-day	**0.026** (0.024-0.029)	**0.030** (0.027-0.034)	**0.035** (0.030-0.040)	**0.038** (0.033-0.045)	**0.043** (0.036-0.051)	**0.046** (0.038-0.056)	**0.049** (0.040-0.061)	**0.052** (0.042-0.066)	**0.057** (0.044-0.073)	**0.060** (0.046-0.079)
45-day	**0.023** (0.021-0.026)	**0.027** (0.024-0.030)	**0.031** (0.027-0.035)	**0.034** (0.029-0.039)	**0.037** (0.031-0.045)	**0.040** (0.033-0.049)	**0.042** (0.034-0.053)	**0.044** (0.035-0.056)	**0.048** (0.037-0.062)	**0.050** (0.038-0.066)
60-day	**0.021** (0.019-0.023)	**0.024** (0.021-0.027)	**0.027** (0.024-0.032)	**0.030** (0.025-0.035)	**0.032** (0.027-0.039)	**0.034** (0.028-0.042)	**0.036** (0.029-0.045)	**0.037** (0.030-0.048)	**0.039** (0.031-0.051)	**0.041** (0.031-0.054)

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

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

Please refer to NOAA Atlas 14 document for more information.

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PF graphical

Rational Method

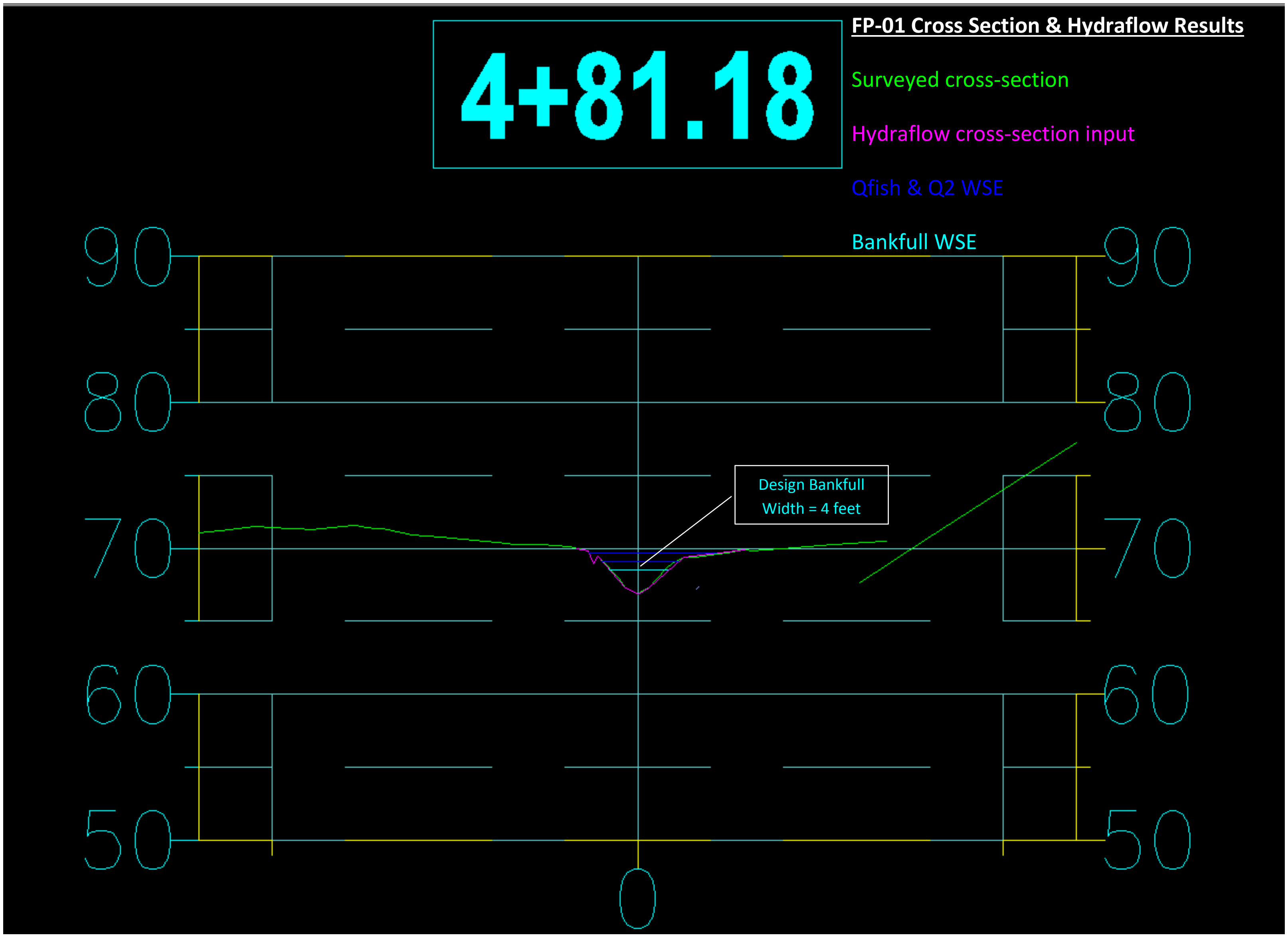
Q = nCiA

n	runnoff coefficient adjustment factor	1.2	*for 50-year recurrence interval*
C	runoff coefficient	0.3	*(0.15-0.35 for flat to steep heavy forested woodland)*
i	intensity (in/hr)	3.64	*data from Craig weather station assuming time of concentration = 5 min and looking at 50-year recurrence interval*

Stream	MP	A (sq mi)	A (sq ft)	Q50 (cfs)	% difference from USGS Regression
FP-01	82.667	0.14	3902976	118	7%
FP-02	83.391	0.01	260896	8	-33%
FP-03	83.5	0.40	11104203	337	82%
FP-04	83.541	0.01	371750	11	-29%
Tunga	83.71	1.72	47987536	1456	355%
FP-05	85.884	0.14	3823058	116	6%
FP-06	86.061	0.18	4961730	151	11%
FP-07	86.956	0.04	1017616	31	-15%
FP-08	87.055	0.01	262513	8	-33%
FP-09	87.172	0.11	3110511	94	3%
Chum	87.272	1.10	30773682	933	226%
FP-10	87.469	0.13	3660007	111	5%
FP-11	88.386	0.10	2792402	85	28%
FP-12	88.413	0.02	562929	17	-23%
FP-13	89.035	0.45	12668613	384	82%
FP-14	89.894	0.08	2255454	68	-3%
FP-15	90.201	0.35	9880340	300	116%
FP-16	90.696	0.01	236156	7	-34%
FP-17	91.12	0.03	815339	25	-18%
C-01	81.99	0.02	477975	14	-26%
C-02	84.448	0.03	745921	23	-20%
C-03	86.388	0.03	825390	25	-18%
C-04	88.509	0.01	250926	8	-33%
C-05	88.581	0.05	1513534	46	-9%
C-06	88.703	0.03	745662	23	-20%
C-07	89.341	0.02	617587	19	-22%
C-08	90.593	0.22	5995585	182	15%
C-09	91.221	0.03	953344	29	-16%
C-10	91.276	0.01	248454	8	-34%
C-11	91.721	0.01	337548	10	-30%
C-12	91.86	0.16	4377146	133	9%
C-13	91.92	0.06	1790899	54	-7%

Note: The Rational Method used here does not take into account storage. The drainages for FP-03, Tunga, Chum, and FP-15 all contained storage areas, which could explain the discrepancy in the results. It also is primarily for use on drainages that have areas smaller than 200 acres. This also leads to some error.

AOP Structure Bankfull Width & Hydrology Check


FP-01 Cross Section & Hydraflow Results
4+81.18
Surveyed cross-section
Hydraflow cross-section input
Qfish & Q2 WSE
Bankfull WSE
Design Bankfull Width = 4 feet
90
80
70
60
50
0

Channel Report

Hydraflow Express Extension for AutoCAD® Civil 3D® 2013 by Autodesk, Inc. Wednesday, Feb 6 2013

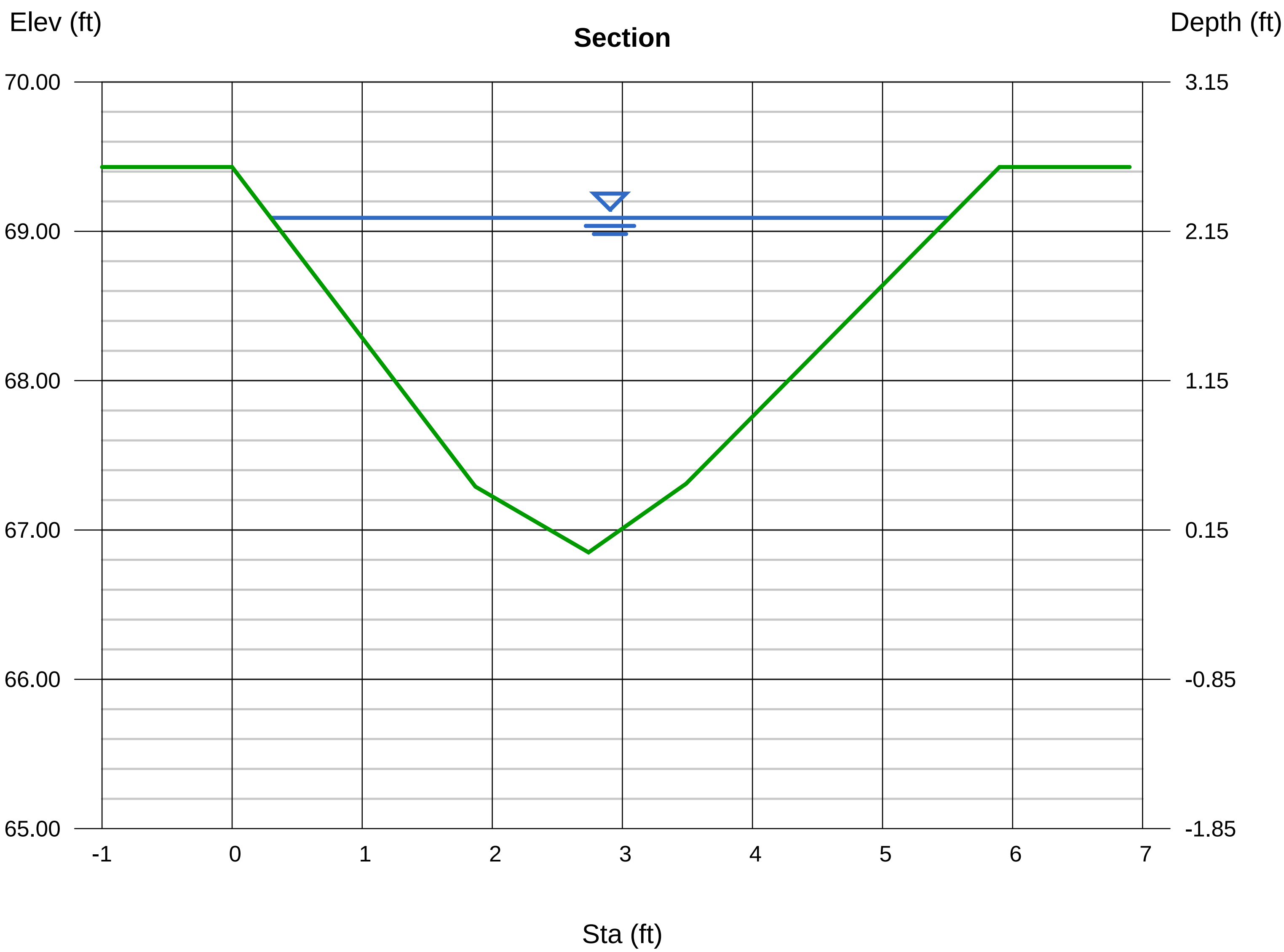
FP-01 Qfish

User-defined
Invert Elev (ft) = 66.85
Slope (%) = 0.80
N-Value = 0.040

Calculations
Compute by: Known Q
Known Q (cfs) = 20.60

Highlighted
Depth (ft) = 2.24
Q (cfs) = 20.60
Area (sqft) = 6.48
Velocity (ft/s) = 3.18
Wetted Perim (ft) = 6.94
Crit Depth, Yc (ft) = 1.66
Top Width (ft) = 5.22
EGL (ft) = 2.40

(Sta, El, n)-(Sta, El, n)...
(0.00, 69.43)-(1.87, 67.29, 0.040)-(2.74, 66.85, 0.040)-(3.49, 67.31, 0.040)-(5.90, 69.43, 0.040)



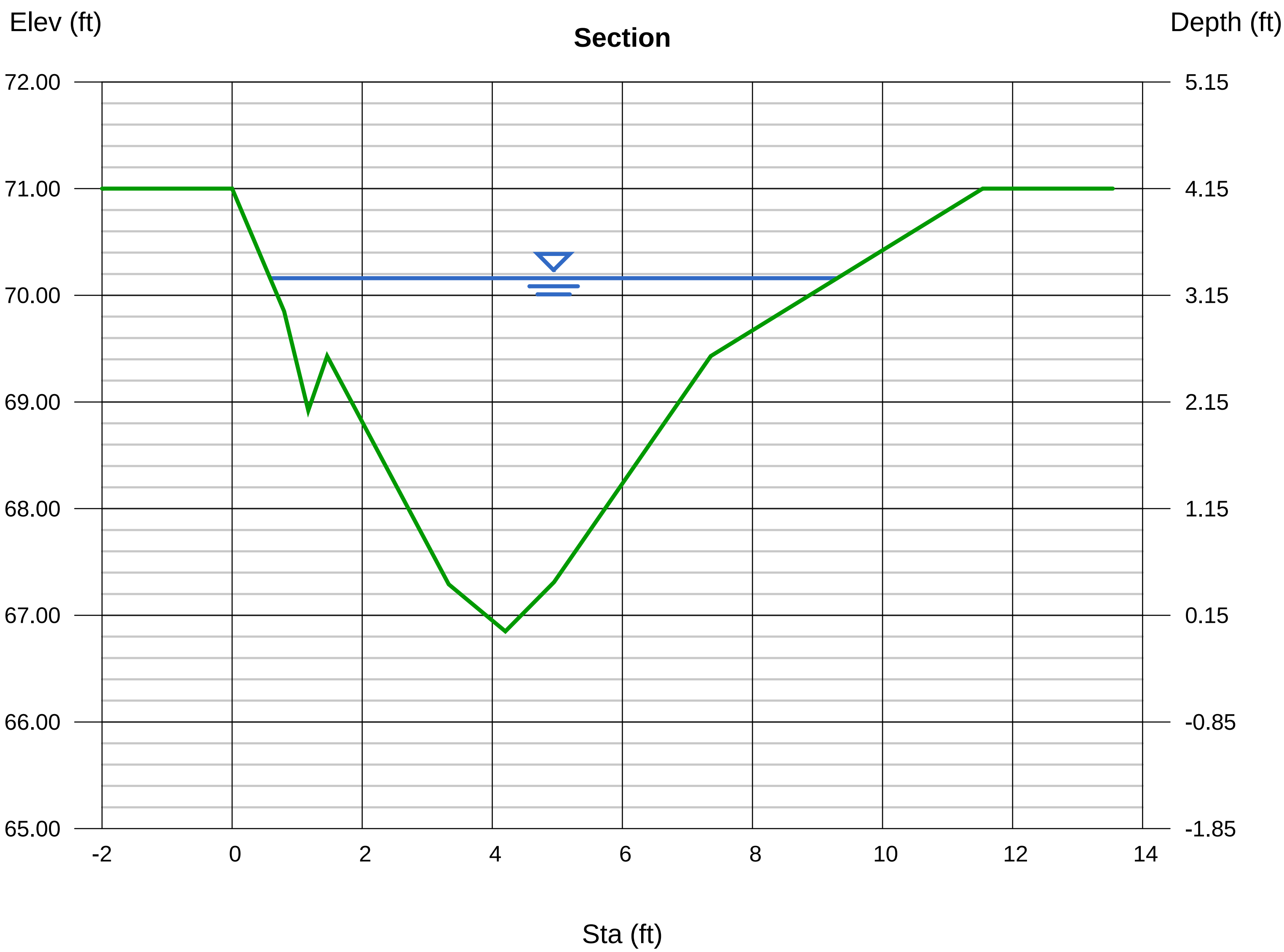
Channel Report

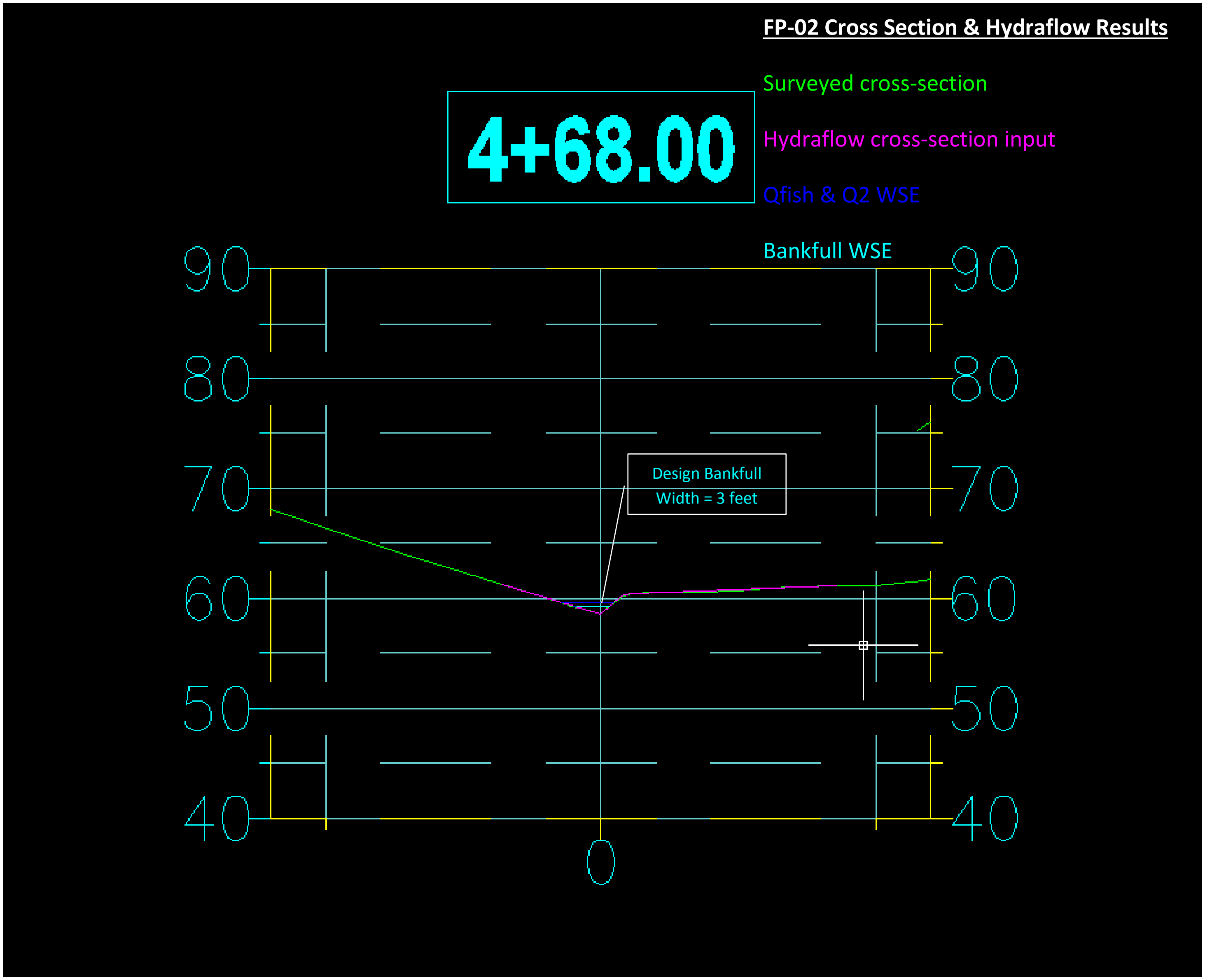
FP-01 Q2

User-defined		**Highlighted**	
Invert Elev (ft)	= 66.85	Depth (ft)	= 3.31
Slope (%)	= 0.80	Q (cfs)	= 51.40
N-Value	= 0.040	Area (sqft)	= 13.99
		Velocity (ft/s)	= 3.67
Calculations		Wetted Perim (ft)	= 11.95
Compute by:	Known Q	Crit Depth, Yc (ft)	= 2.50
Known Q (cfs)	= 51.40	Top Width (ft)	= 8.72
		EGL (ft)	= 3.52

(Sta, El, n)-(Sta, El, n)...

(0.00, 71.00)-(0.80, 69.85, 0.040)-(1.17, 68.92, 0.040)-(1.46, 69.43, 0.040)-(3.33, 67.29, 0.040)-(4.20, 66.85, 0.040)-(4.95, 67.31, 0.040)
-(7.36, 69.43, 0.040)-(11.54, 71.00, 0.040)




FP-02 Cross Section & Hydraflow Results
Surveyed cross-section
Hydraflow cross-section input
Qfish & Q2 WSE
Bankfull WSE
4+68.00
Design Bankfull Width = 3 feet
90
80
70
60
50
40
0

Channel Report

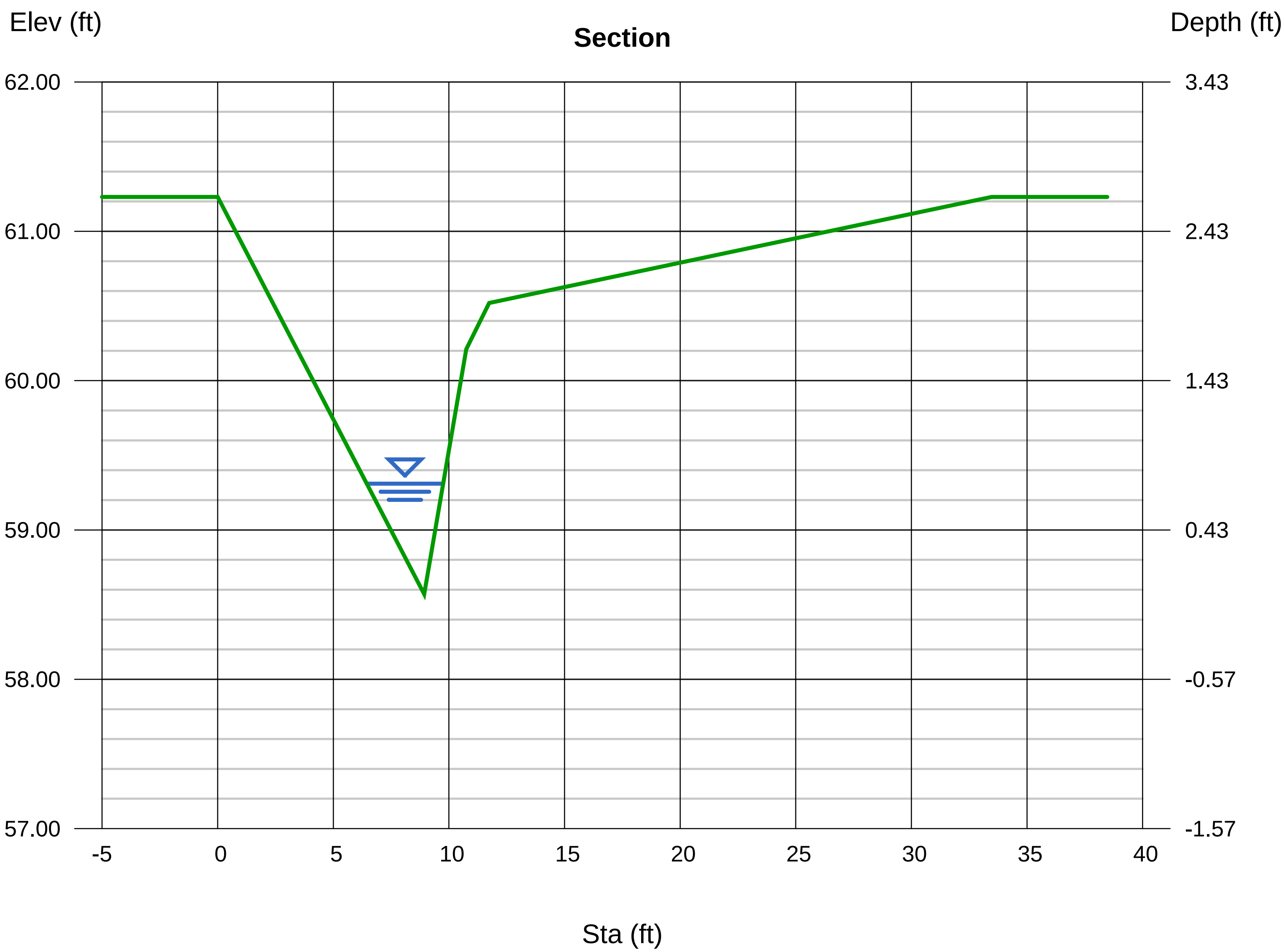
FP-02 Qfish

User-defined
Invert Elev (ft) = 58.57
Slope (%) = 2.10
N-Value = 0.060

Calculations
Compute by: Known Q
Known Q (cfs) = 2.10

(Sta, El, n)-(Sta, El, n)...
(0.00, 61.23)-(8.93, 58.57, 0.060)-(10.75, 60.21, 0.060)-(11.74, 60.52, 0.060)-(33.47, 61.23, 0.060)

Highlighted
Depth (ft) = 0.74
Q (cfs) = 2.100
Area (sqft) = 1.22
Velocity (ft/s) = 1.72
Wetted Perim (ft) = 3.70
Crit Depth, Yc (ft) = 0.56
Top Width (ft) = 3.31
EGL (ft) = 0.79



Channel Report

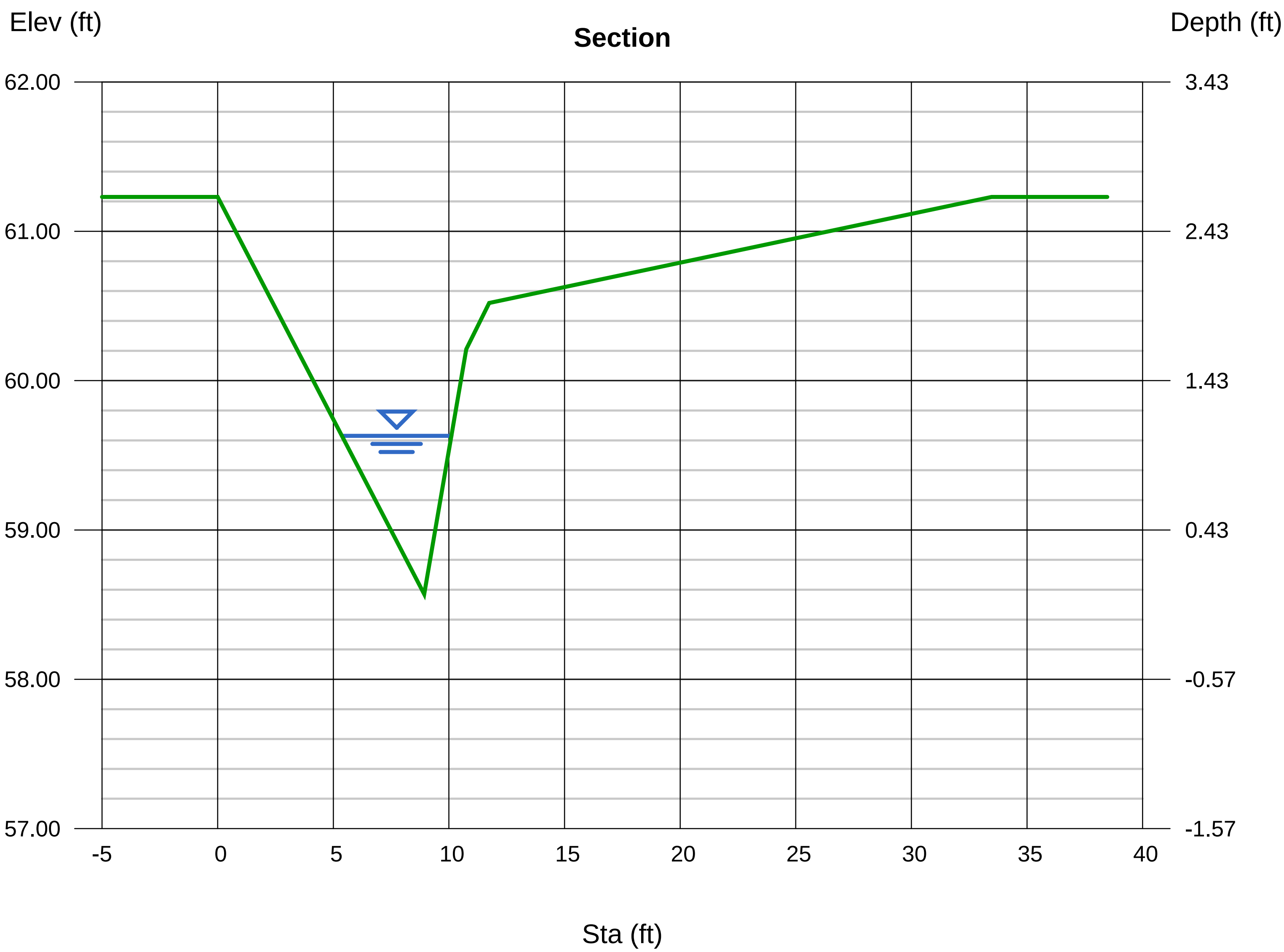
FP-02 Q2

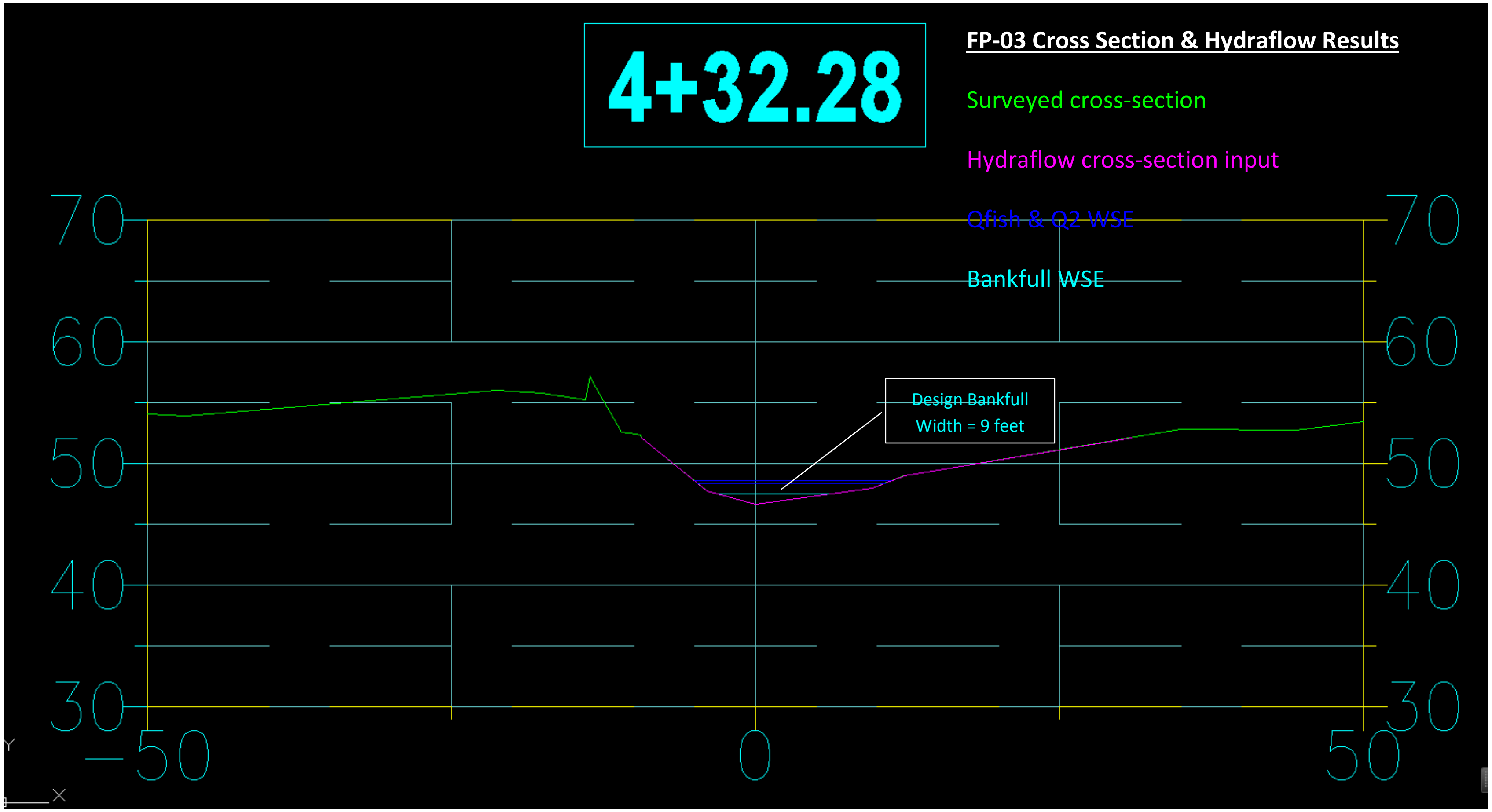
User-defined
Invert Elev (ft) = 58.57
Slope (%) = 2.10
N-Value = 0.060

Calculations
Compute by: Known Q
Known Q (cfs) = 5.40

Highlighted
Depth (ft) = 1.06
Q (cfs) = 5.400
Area (sqft) = 2.51
Velocity (ft/s) = 2.15
Wetted Perim (ft) = 5.30
Crit Depth, Yc (ft) = 0.82
Top Width (ft) = 4.73
EGL (ft) = 1.13

(Sta, El, n)-(Sta, El, n)...
(0.00, 61.23)-(8.93, 58.57, 0.060)-(10.75, 60.21, 0.060)-(11.74, 60.52, 0.060)-(33.47, 61.23, 0.060)




4+32.28
FP-03 Cross Section & Hydraflow Results
Surveyed cross-section
Hydraflow cross-section input
Qfish & Q2 WSE
Bankfull WSE
Design Bankfull
Width = 9 feet
70
60
50
40
30
-50
0
50

Channel Report

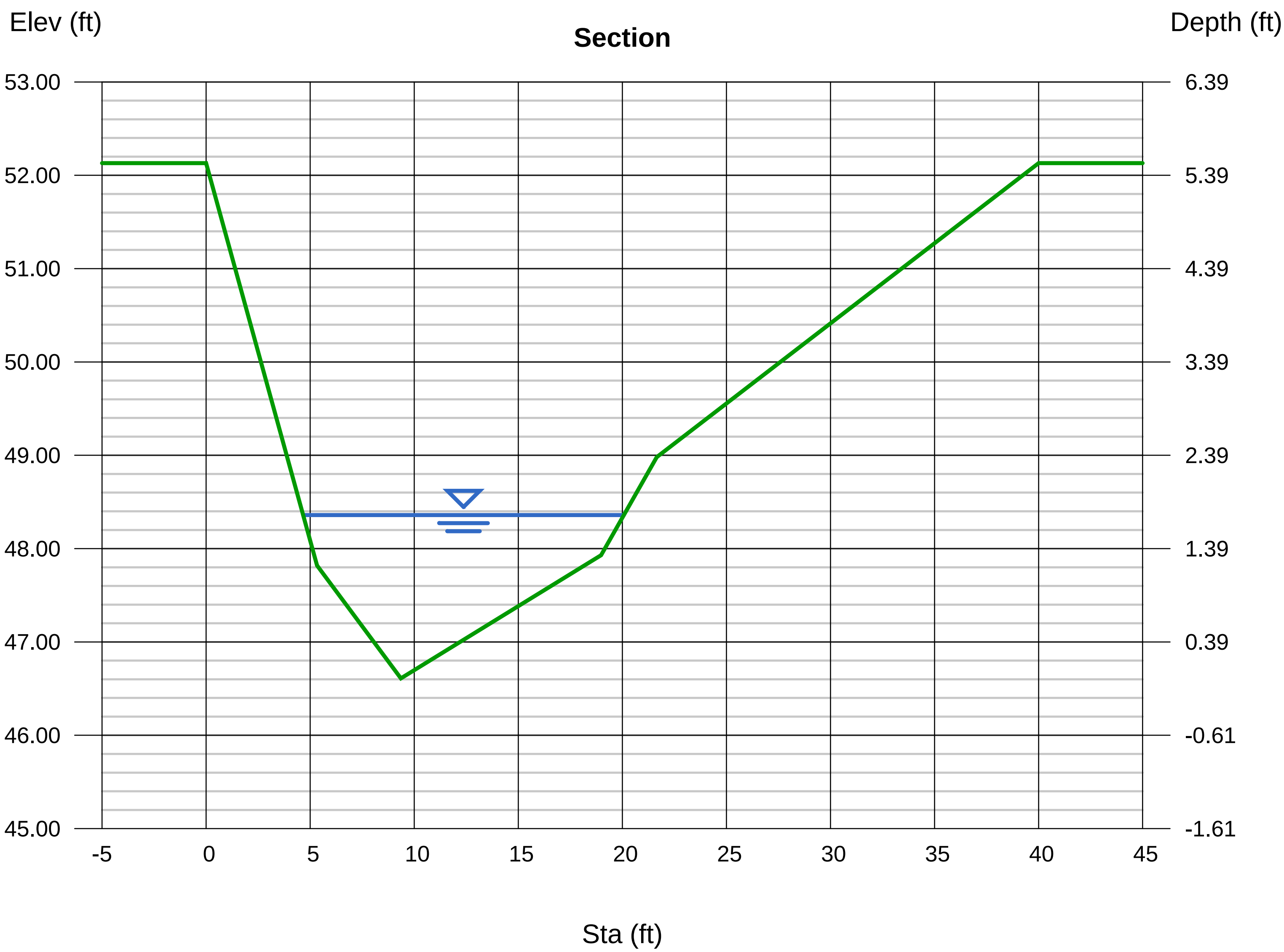
Hydraflow Express Extension for AutoCAD® Civil 3D® 2013 by Autodesk, Inc. Tuesday, Feb 5 2013

FP-03 Qfish

User-defined		**Highlighted**	
Invert Elev (ft)	= 46.61	Depth (ft)	= 1.75
Slope (%)	= 1.20	Q (cfs)	= 35.00
N-Value	= 0.070	Area (sqft)	= 15.52
		Velocity (ft/s)	= 2.26
Calculations		Wetted Perim (ft)	= 15.95
Compute by:	Known Q	Crit Depth, Yc (ft)	= 1.22
Known Q (cfs)	= 35.00	Top Width (ft)	= 15.41
		EGL (ft)	= 1.83

(Sta, El, n)-(Sta, El, n)...

(0.00, 52.13)-(5.33, 47.82, 0.070)-(9.36, 46.61, 0.070)-(18.98, 47.93, 0.070)-(21.65, 48.98, 0.070)-(40.00, 52.13, 0.070)



Channel Report

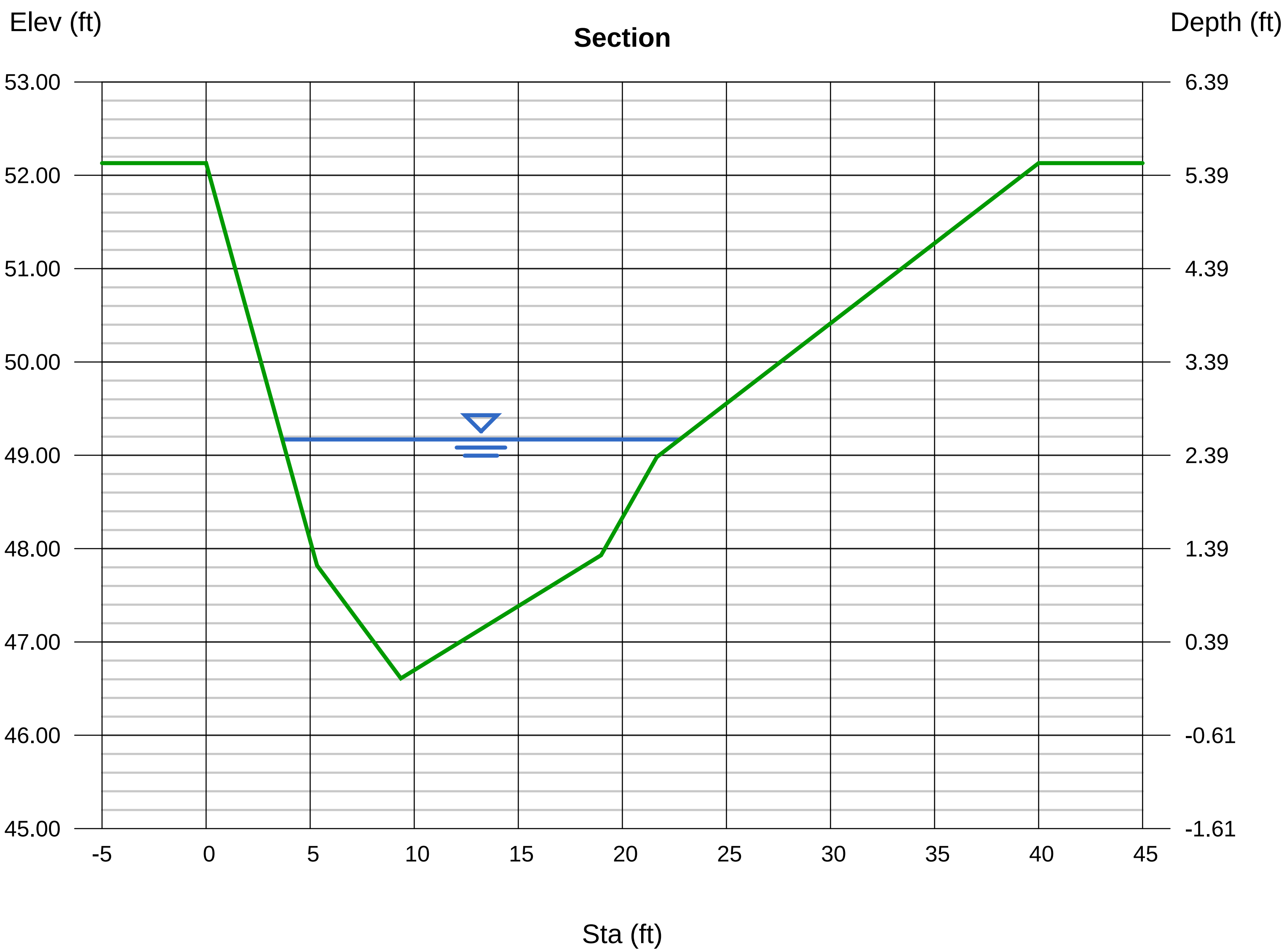
Hydraflow Express Extension for AutoCAD® Civil 3D® 2013 by Autodesk, Inc. Tuesday, Feb 12 2013

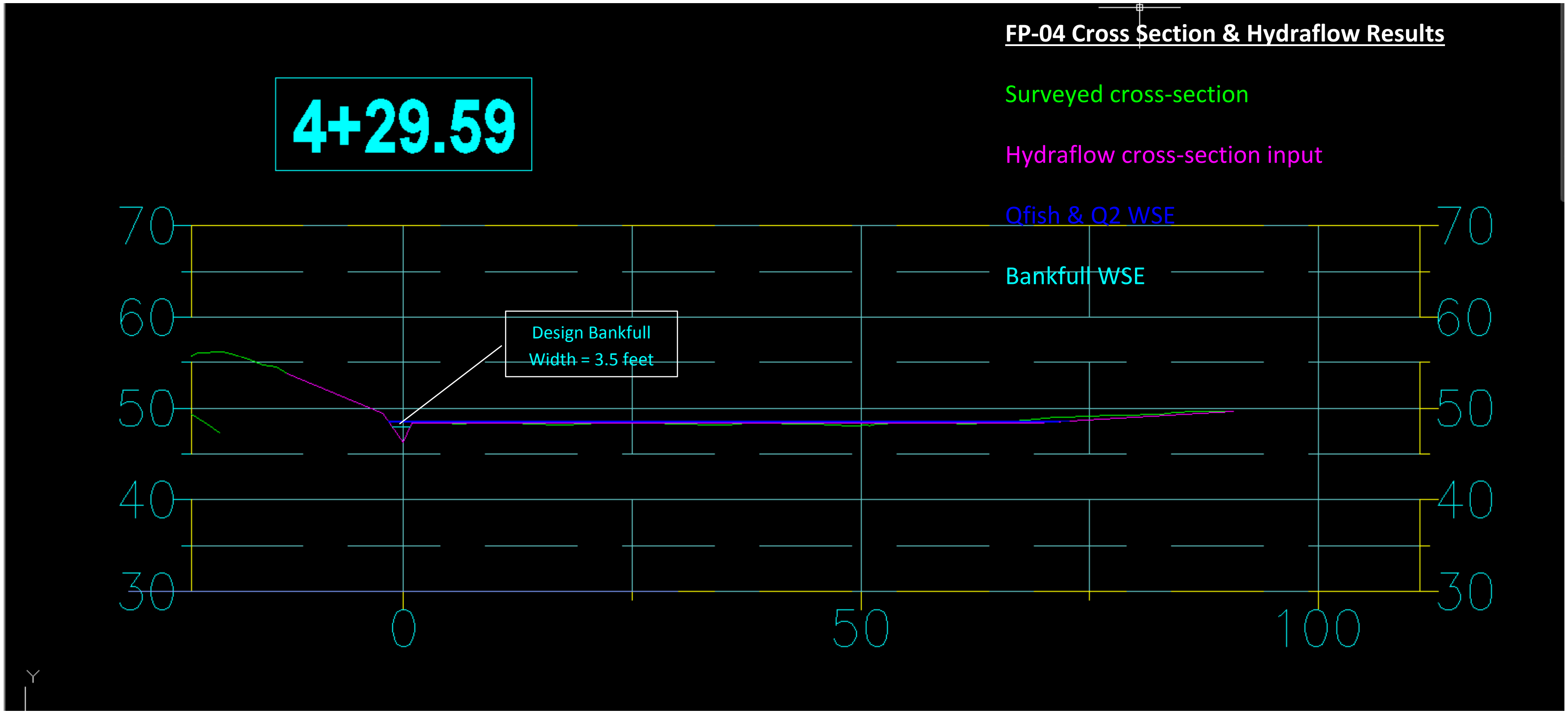
FP-03 Q2

User-defined		**Highlighted**	
Invert Elev (ft)	= 46.61	Depth (ft)	= 2.56
Slope (%)	= 1.20	Q (cfs)	= 87.40
N-Value	= 0.070	Area (sqft)	= 29.30
		Velocity (ft/s)	= 2.98
Calculations		Wetted Perim (ft)	= 20.06
Compute by:	Known Q	Crit Depth, Yc (ft)	= 1.75
Known Q (cfs)	= 87.40	Top Width (ft)	= 19.10
		EGL (ft)	= 2.70

(Sta, El, n)-(Sta, El, n)...

(0.00, 52.13)-(5.33, 47.82, 0.070)-(9.36, 46.61, 0.070)-(18.98, 47.93, 0.070)-(21.65, 48.98, 0.070)-(40.00, 52.13, 0.070)




FP-04 Cross Section & Hydraflow Results
Surveyed cross-section
Hydraflow cross-section input
Qfish & Q2 WSE
Bankfull WSE
4+29.59
Design Bankfull
Width = 3.5 feet
70
60
50
40
30
0
50
100

Channel Report

Hydraflow Express Extension for AutoCAD® Civil 3D® 2013 by Autodesk, Inc. | Wednesday, Jan 23 2013

FP-04 Qfish

User-defined

Invert Elev (ft)	= 46.29
Slope (%)	= 0.50
N-Value	= 0.070

Calculations

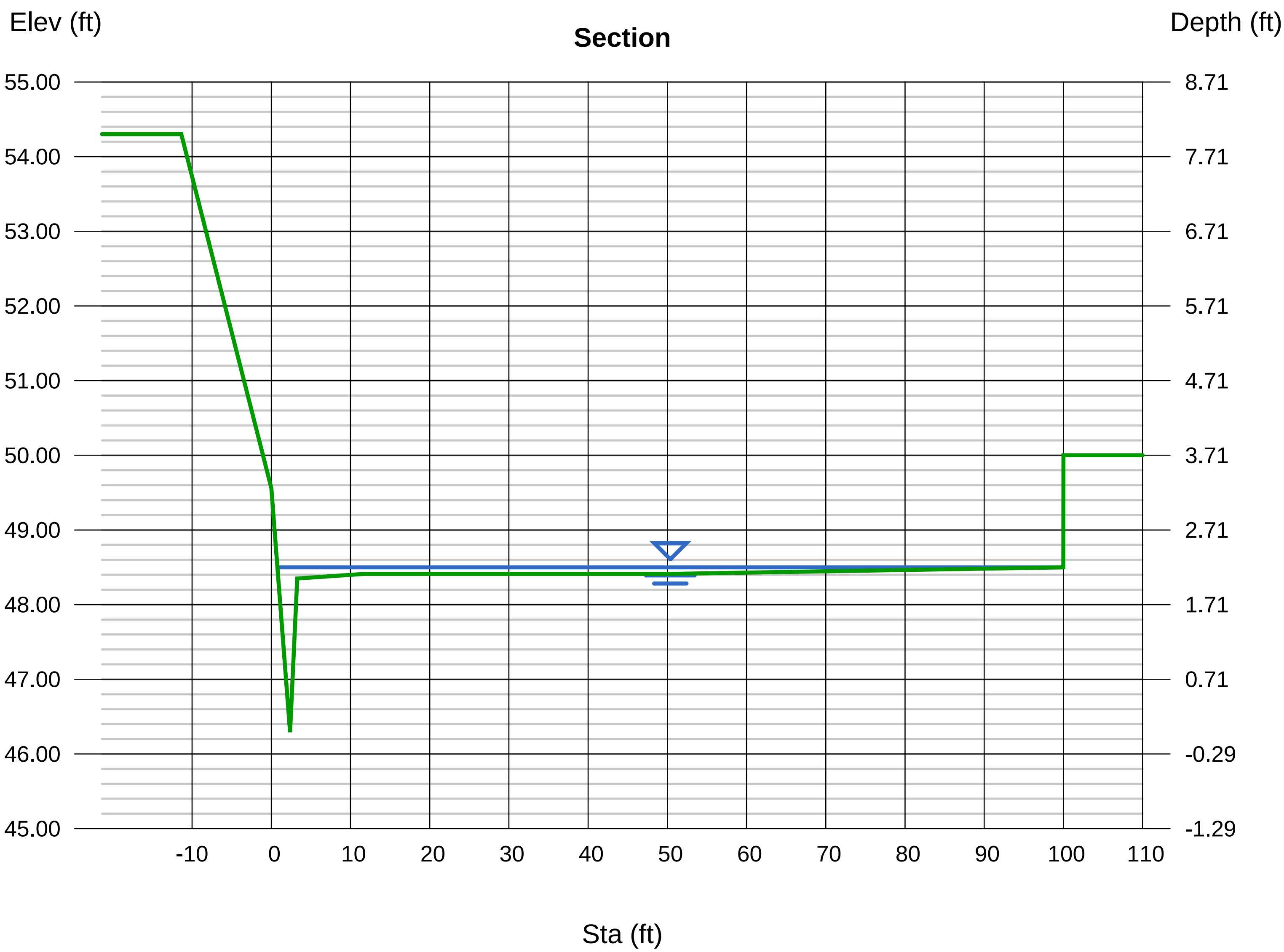
Compute by:	Known Q
Known Q (cfs)	= 2.90

Highlighted

Depth (ft)	= 2.21
Q (cfs)	= 2.900
Area (sqft)	= 9.54
Velocity (ft/s)	= 0.30
Wetted Perim (ft)	= 101.70
Crit Depth, Yc (ft)	= 1.10
Top Width (ft)	= 99.22
EGL (ft)	= 2.21

(Sta, El, n)-(Sta, El, n)...

(-11.36, 54.30)-(2.37, 46.29, 0.070)-(3.27, 48.35, 0.070)-(11.66, 48.41, 0.070)-(35.00, 48.41, 0.070)-(49.90, 48.41, 0.070)-(50.00, 48.41, 0.070)
-(99.99, 48.50, 0.070)-(100.00, 50.00, 0.070)



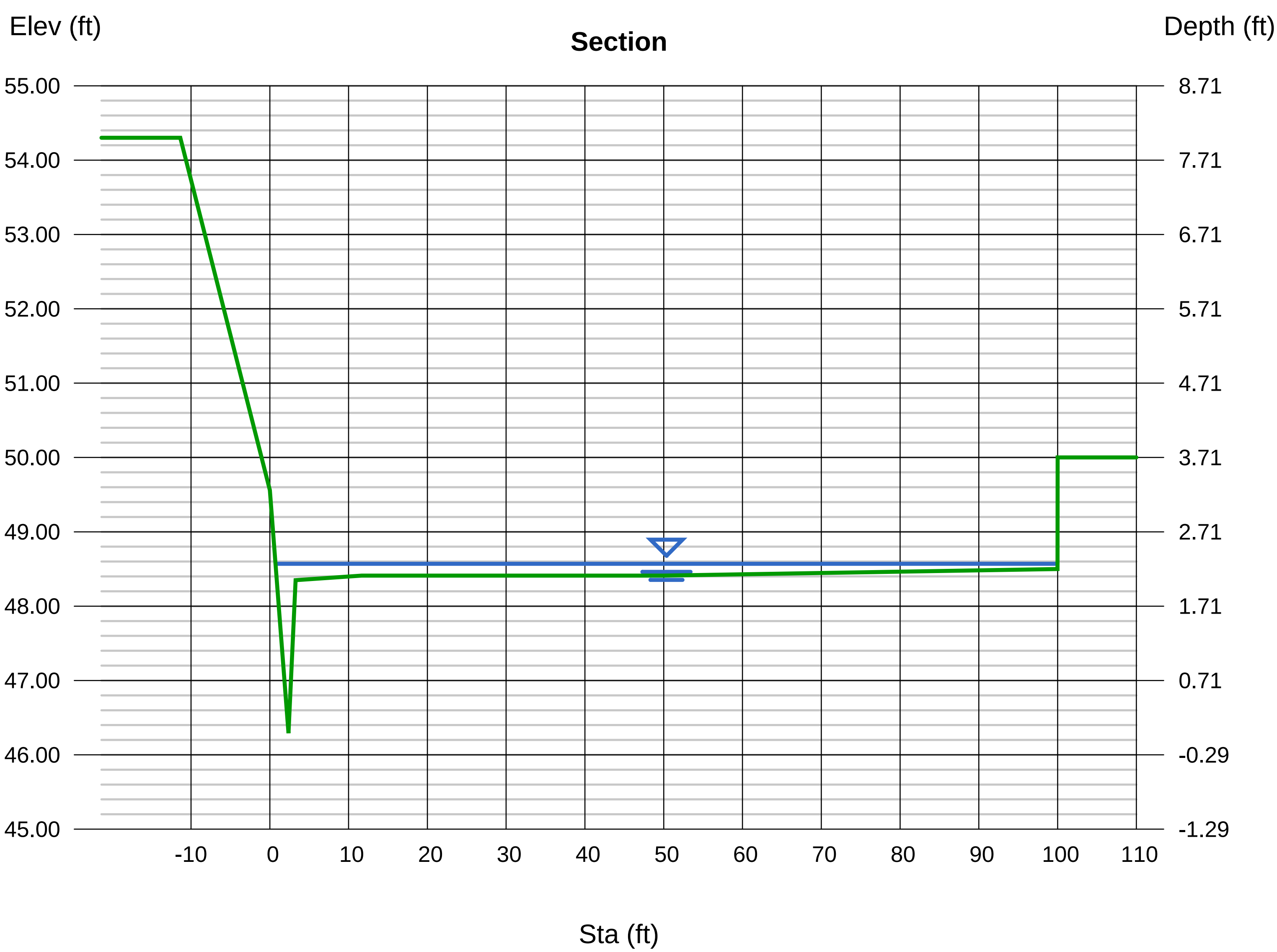
Channel Report

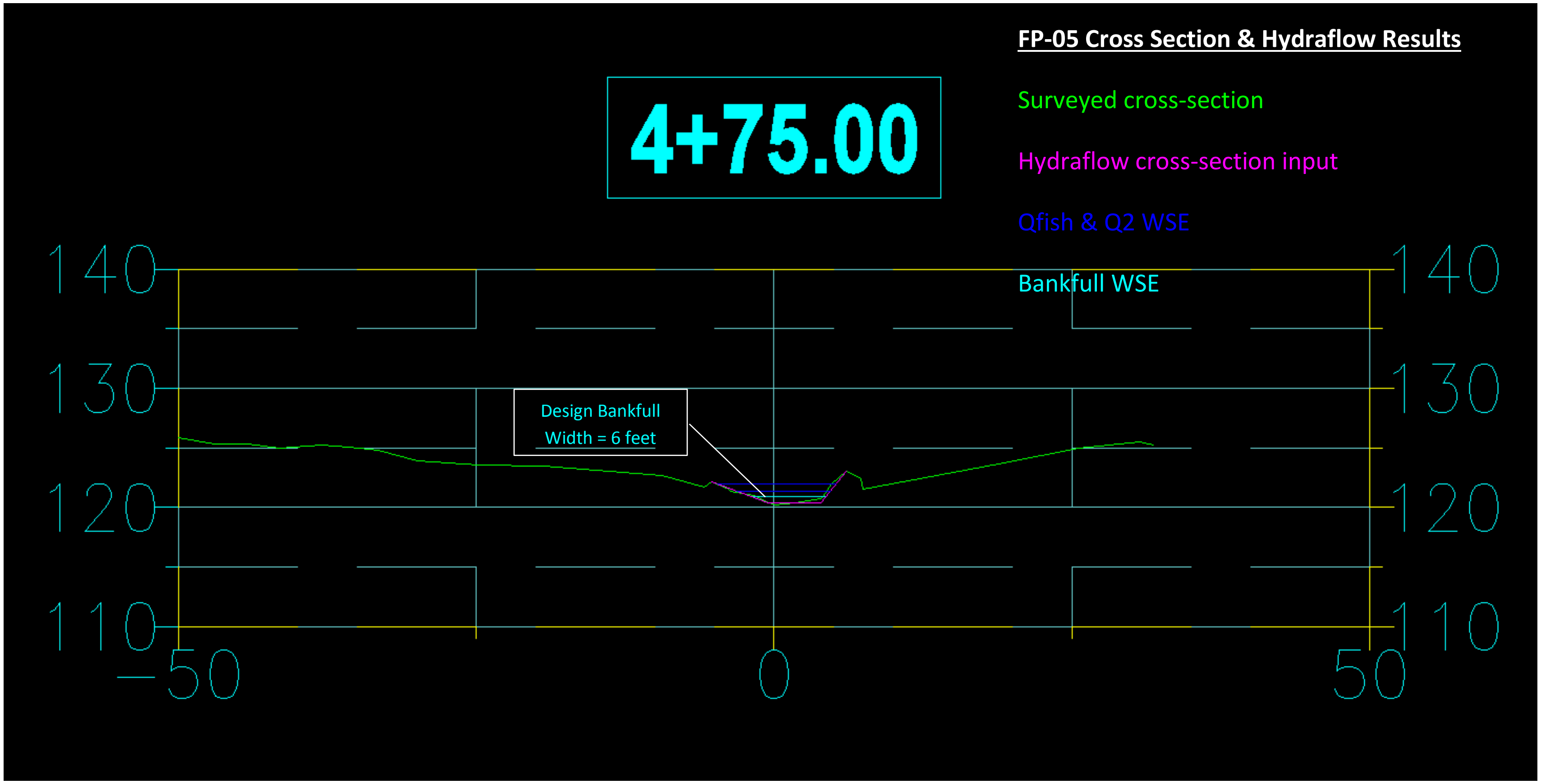
Hydraflow Express Extension for AutoCAD® Civil 3D® 2013 by Autodesk, Inc. Wednesday, Jan 23 2013

FP-04 Q2

User-defined		**Highlighted**	
Invert Elev (ft)	= 46.29	Depth (ft)	= 2.28
Slope (%)	= 0.50	Q (cfs)	= 7.200
N-Value	= 0.070	Area (sqft)	= 16.49
		Velocity (ft/s)	= 0.44
Calculations		Wetted Perim (ft)	= 101.85
Compute by:	Known Q	Crit Depth, Yc (ft)	= 1.58
Known Q (cfs)	= 7.20	Top Width (ft)	= 99.27
		EGL (ft)	= 2.28

(Sta, El, n)-(Sta, El, n)...
(-11.36, 54.30)-(2.37, 46.29, 0.070)-(3.27, 48.35, 0.070)-(11.66, 48.41, 0.070)-(35.00, 48.41, 0.070)-(49.90, 48.41, 0.070)-(50.00, 48.41, 0.070)
-(99.99, 48.50, 0.070)-(100.00, 50.00, 0.070)




FP-05 Cross Section & Hydraflow Results
4+75.00
Surveyed cross-section
Hydraflow cross-section input
Qfish & Q2 WSE
Bankfull WSE
Design Bankfull Width = 6 feet
140
130
120
110
-50
0
50

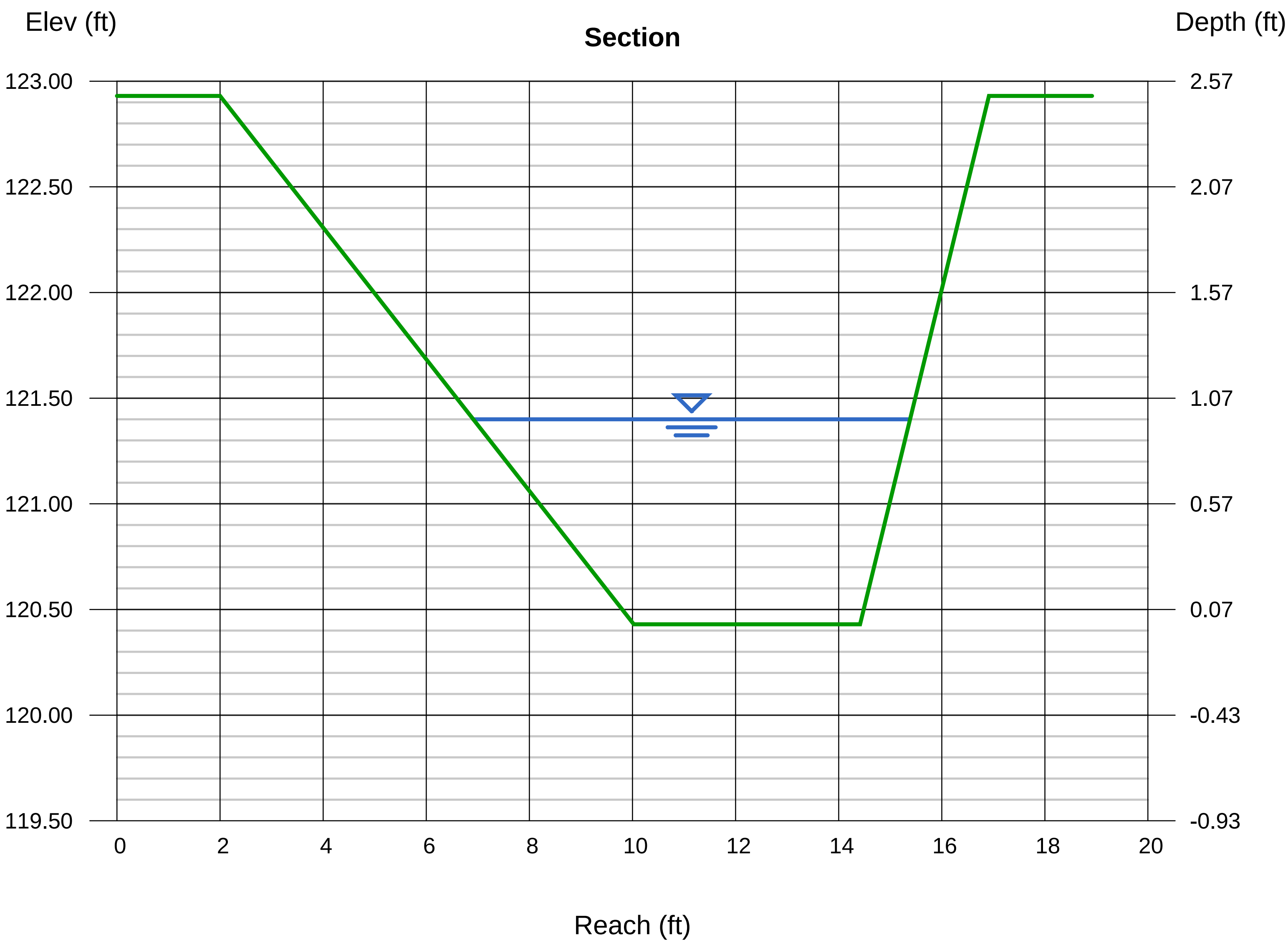
Channel Report

FP-05 Qfish

Trapezoidal
Bottom Width (ft) = 4.39
Side Slopes (z:1) = 3.21, 1.00
Total Depth (ft) = 2.50
Invert Elev (ft) = 120.43
Slope (%) = 2.80
N-Value = 0.060

Calculations
Compute by: Known Q
Known Q (cfs) = 20.20

Highlighted
Depth (ft) = 0.97
Q (cfs) = 20.20
Area (sqft) = 6.24
Velocity (ft/s) = 3.24
Wetted Perim (ft) = 9.02
Crit Depth, Yc (ft) = 0.77
Top Width (ft) = 8.47
EGL (ft) = 1.13

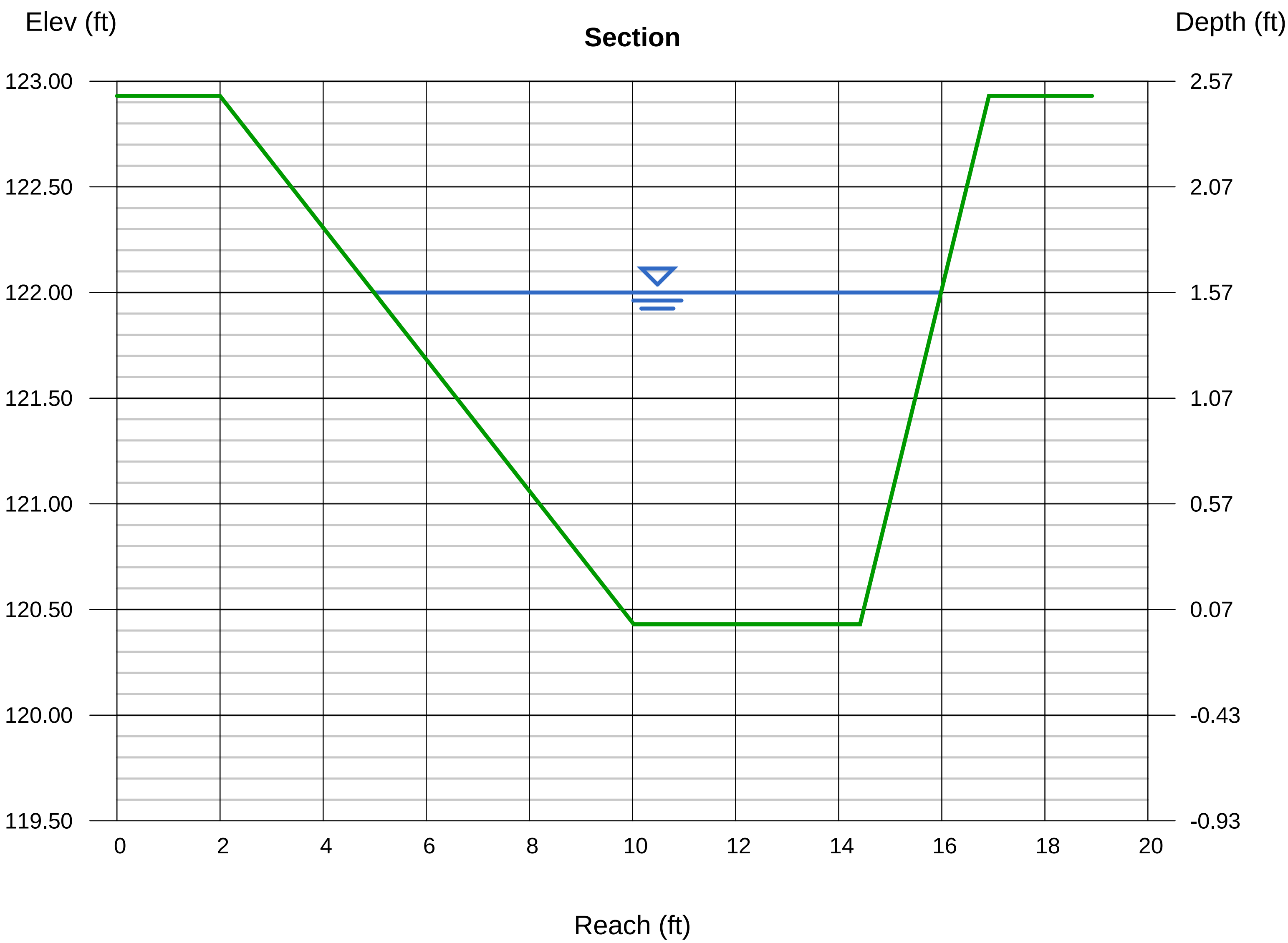


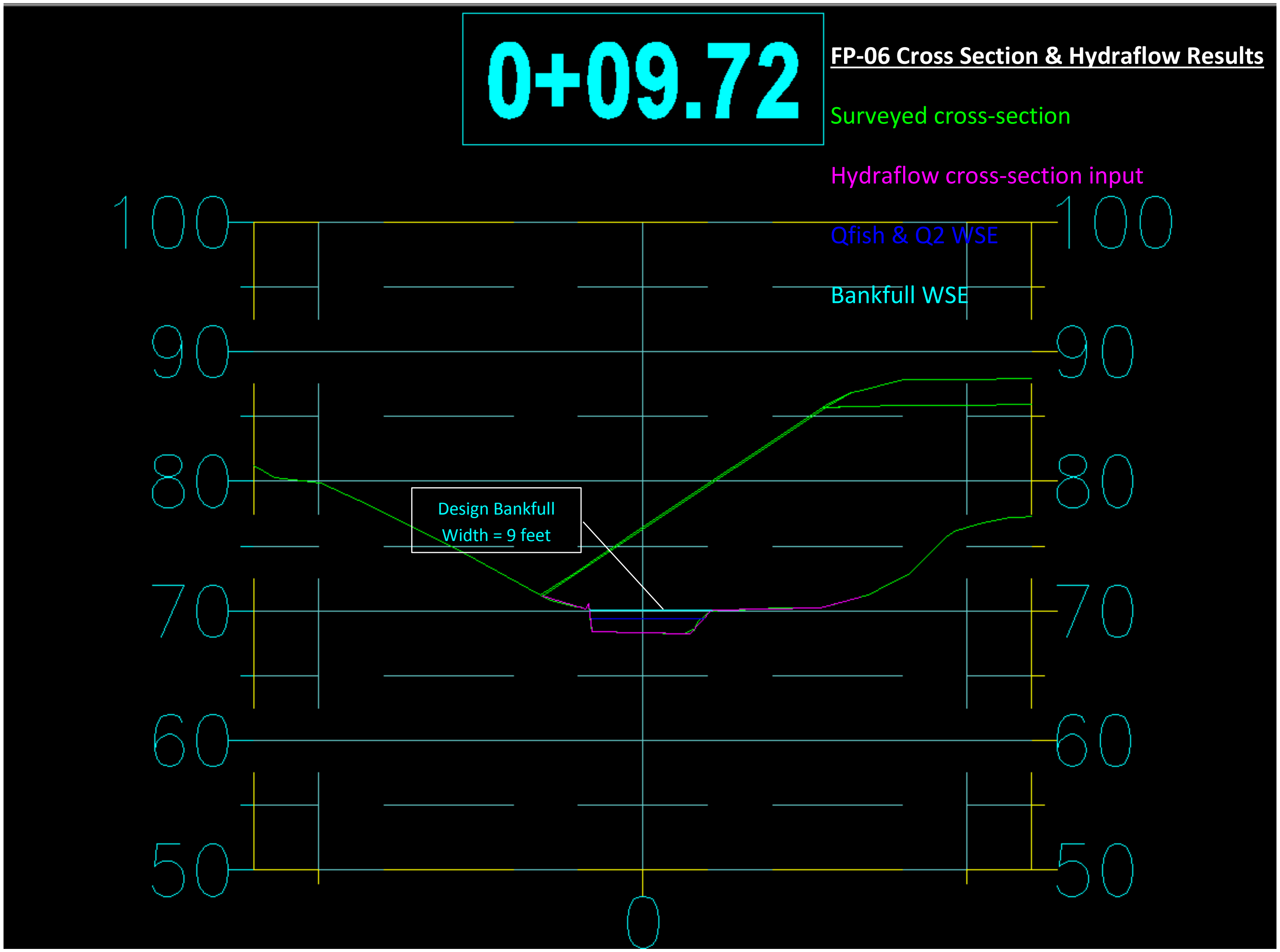
Channel Report

Hydraflow Express Extension for AutoCAD® Civil 3D® 2013 by Autodesk, Inc. — Tuesday, Feb 5 2013

FP-05 Q2

Trapezoidal		**Highlighted**	
Bottom Width (ft)	= 4.39	Depth (ft)	= 1.57
Side Slopes (z:1)	= 3.21, 1.00	Q (cfs)	= 50.50
Total Depth (ft)	= 2.50	Area (sqft)	= 12.08
Invert Elev (ft)	= 120.43	Velocity (ft/s)	= 4.18
Slope (%)	= 2.80	Wetted Perim (ft)	= 11.89
N-Value	= 0.060	Crit Depth, Yc (ft)	= 1.30
		Top Width (ft)	= 11.00
Calculations		EGL (ft)	= 1.84
Compute by:	Known Q		
Known Q (cfs)	= 50.50		



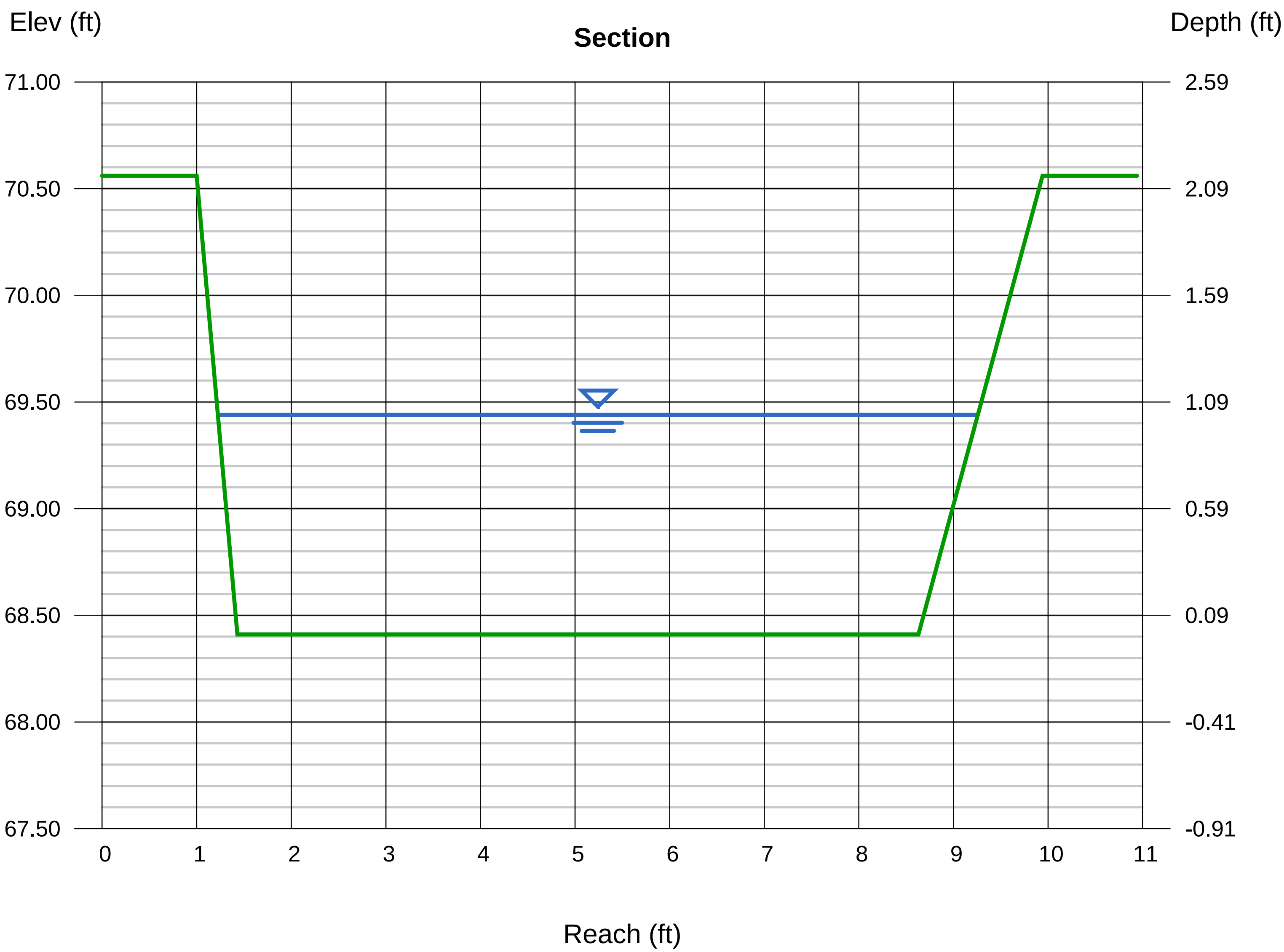


0+09.72
FP-06 Cross Section & Hydraflow Results
Surveyed cross-section
Hydraflow cross-section input
Qfish & Q2 WSE
Bankfull WSE
Design Bankfull Width = 9 feet
100
90
80
70
60
50
100
90
80
70
60
50
0

Channel Report

FP-06 Qfish

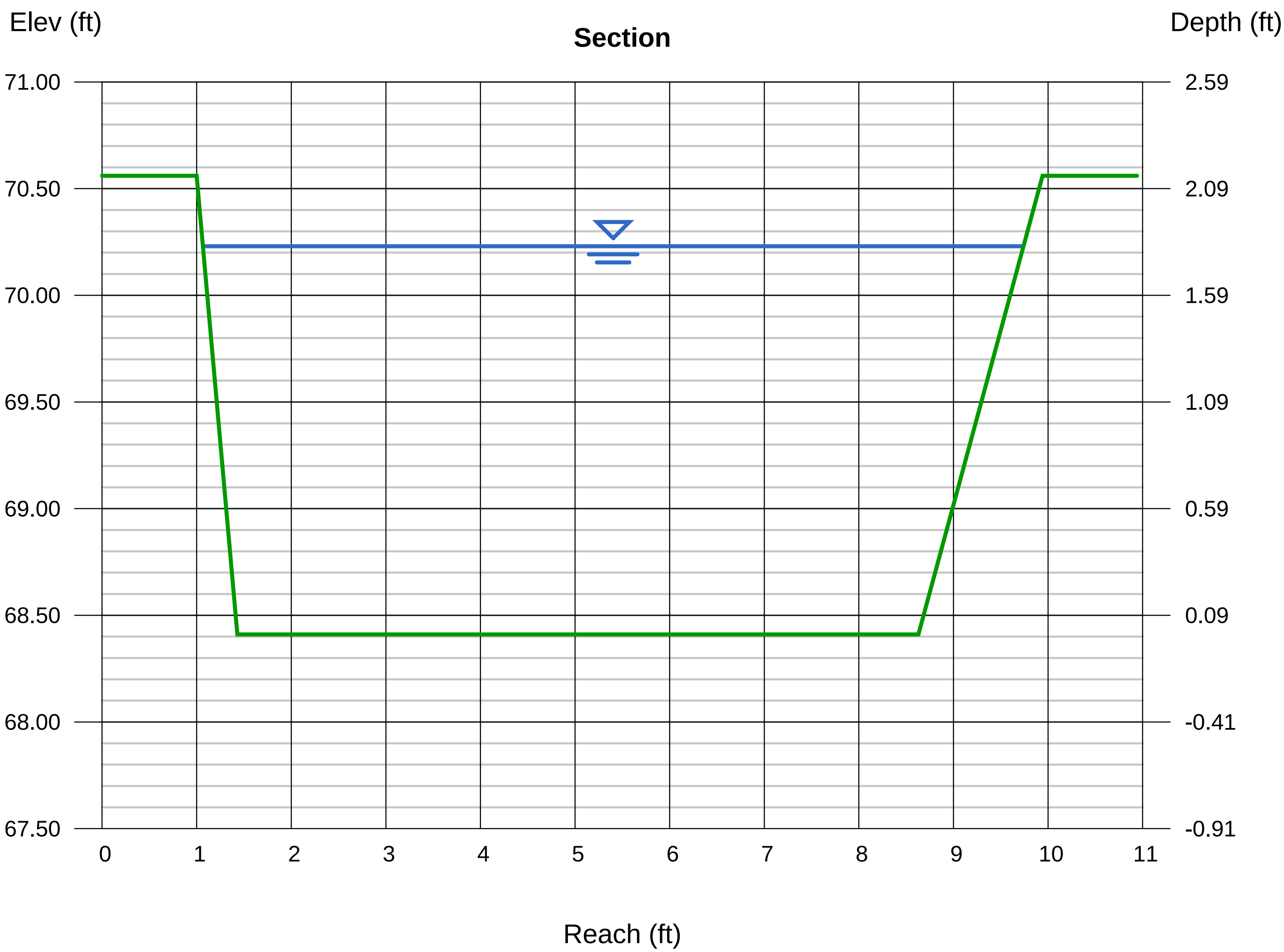
Trapezoidal		**Highlighted**	
Bottom Width (ft)	= 7.20	Depth (ft)	= 1.03
Side Slopes (z:1)	= 0.20, 0.61	Q (cfs)	= 25.10
Total Depth (ft)	= 2.15	Area (sqft)	= 7.85
Invert Elev (ft)	= 68.41	Velocity (ft/s)	= 3.20
Slope (%)	= 3.00	Wetted Perim (ft)	= 9.46
N-Value	= 0.070	Crit Depth, Yc (ft)	= 0.72
		Top Width (ft)	= 8.03
Calculations		EGL (ft)	= 1.19
Compute by:	Known Q		
Known Q (cfs)	= 25.10		

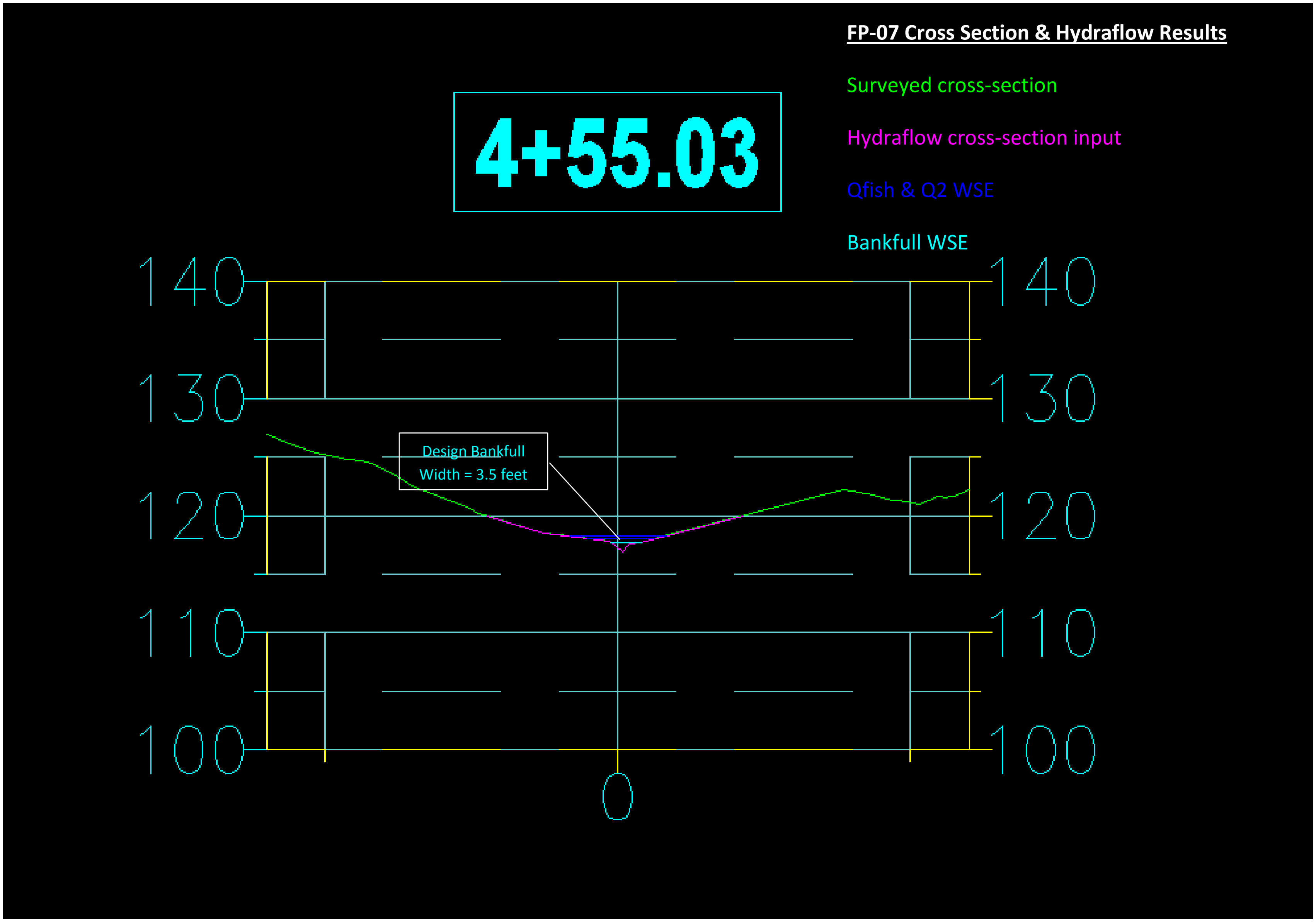


Channel Report

FP-06 Q2

Trapezoidal		**Highlighted**	
Bottom Width (ft)	= 7.20	Depth (ft)	= 1.82
Side Slopes (z:1)	= 0.20, 0.61	Q (cfs)	= 62.90
Total Depth (ft)	= 2.15	Area (sqft)	= 14.45
Invert Elev (ft)	= 68.41	Velocity (ft/s)	= 4.35
Slope (%)	= 3.00	Wetted Perim (ft)	= 11.19
N-Value	= 0.070	Crit Depth, Yc (ft)	= 1.31
		Top Width (ft)	= 8.67
Calculations		EGL (ft)	= 2.11
Compute by:	Known Q		
Known Q (cfs)	= 62.90		




FP-07 Cross Section & Hydraflow Results
Surveyed cross-section
Hydraflow cross-section input
Qfish & Q2 WSE
Bankfull WSE
4+55.03
Design Bankfull
Width = 3.5 feet
140
130
120
110
100
0

Channel Report

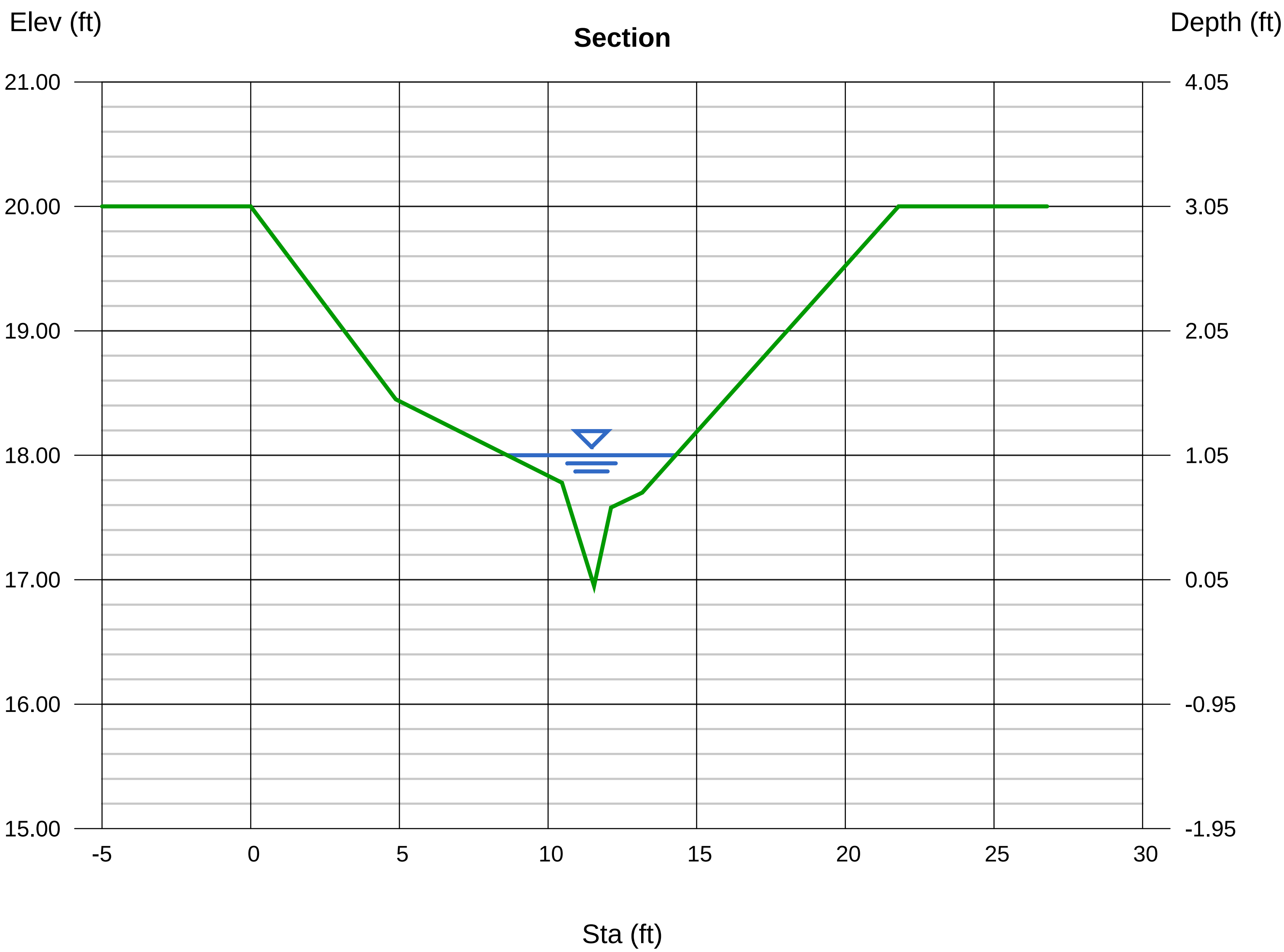
Hydraflow Express Extension for AutoCAD® Civil 3D® 2013 by Autodesk, Inc. Thursday, Jan 24 2013

FP-07 Qfish

User-defined		**Highlighted**	
Invert Elev (ft)	= 16.95	Depth (ft)	= 1.05
Slope (%)	= 11.40	Q (cfs)	= 6.700
N-Value	= 0.060	Area (sqft)	= 1.85
		Velocity (ft/s)	= 3.62
Calculations		Wetted Perim (ft)	= 6.28
Compute by:	Known Q	Crit Depth, Yc (ft)	= 1.09
Known Q (cfs)	= 6.70	Top Width (ft)	= 5.66
		EGL (ft)	= 1.25

(Sta, El, n)-(Sta, El, n)...

(0.00, 20.00)-(4.88, 18.45, 0.060)-(10.47, 17.78, 0.060)-(11.55, 16.95, 0.060)-(12.12, 17.58, 0.060)-(13.17, 17.70, 0.060)-(21.79, 20.00, 0.060)



Channel Report

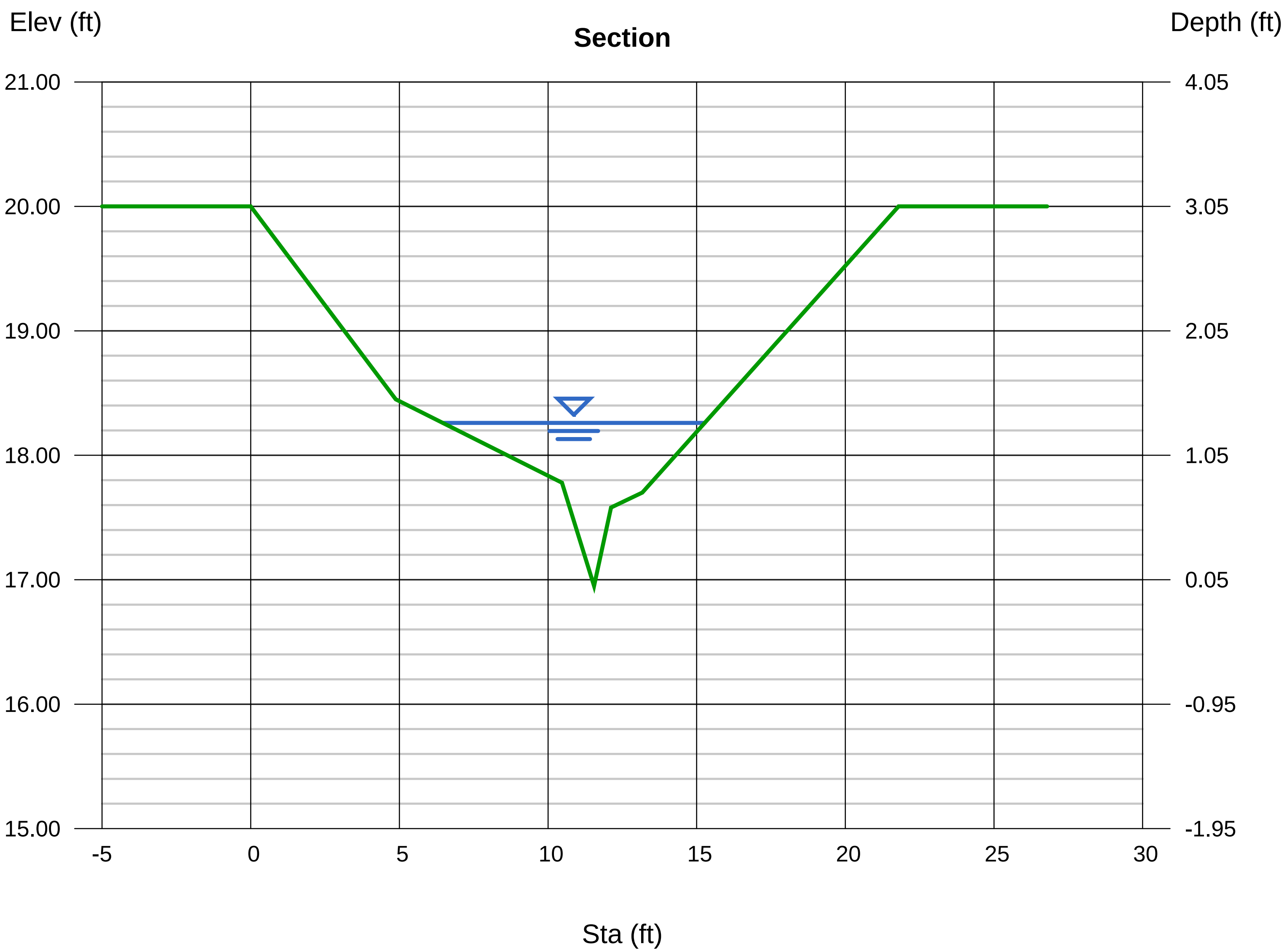
FP-07 Q2

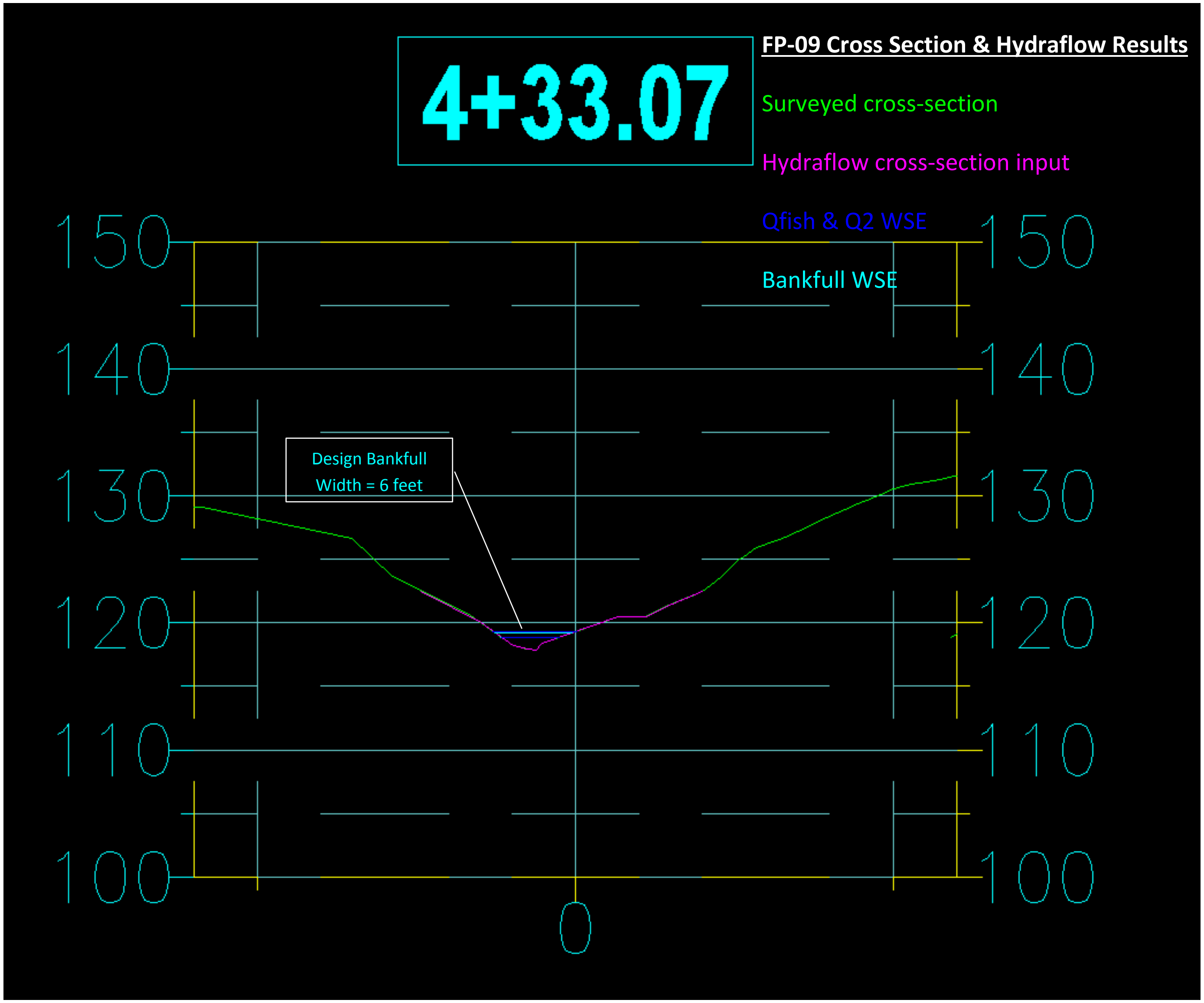
User-defined
Invert Elev (ft) = 16.95
Slope (%) = 11.40
N-Value = 0.060

Calculations
Compute by: Known Q
Known Q (cfs) = 16.70

Highlighted
Depth (ft) = 1.31
Q (cfs) = 16.70
Area (sqft) = 3.73
Velocity (ft/s) = 4.47
Wetted Perim (ft) = 9.47
Crit Depth, Yc (ft) = 1.38
Top Width (ft) = 8.80
EGL (ft) = 1.62

(Sta, El, n)-(Sta, El, n)...
(0.00, 20.00)-(4.88, 18.45, 0.060)-(10.47, 17.78, 0.060)-(11.55, 16.95, 0.060)-(12.12, 17.58, 0.060)-(13.17, 17.70, 0.060)-(21.79, 20.00, 0.060)




4+33.07
FP-09 Cross Section & Hydraflow Results
Surveyed cross-section
Hydraflow cross-section input
Qfish & Q2 WSE
Bankfull WSE
Design Bankfull Width = 6 feet
150
140
130
120
110
100
0

Channel Report

Hydraflow Express Extension for AutoCAD® Civil 3D® 2013 by Autodesk, Inc. Tuesday, Feb 5 2013

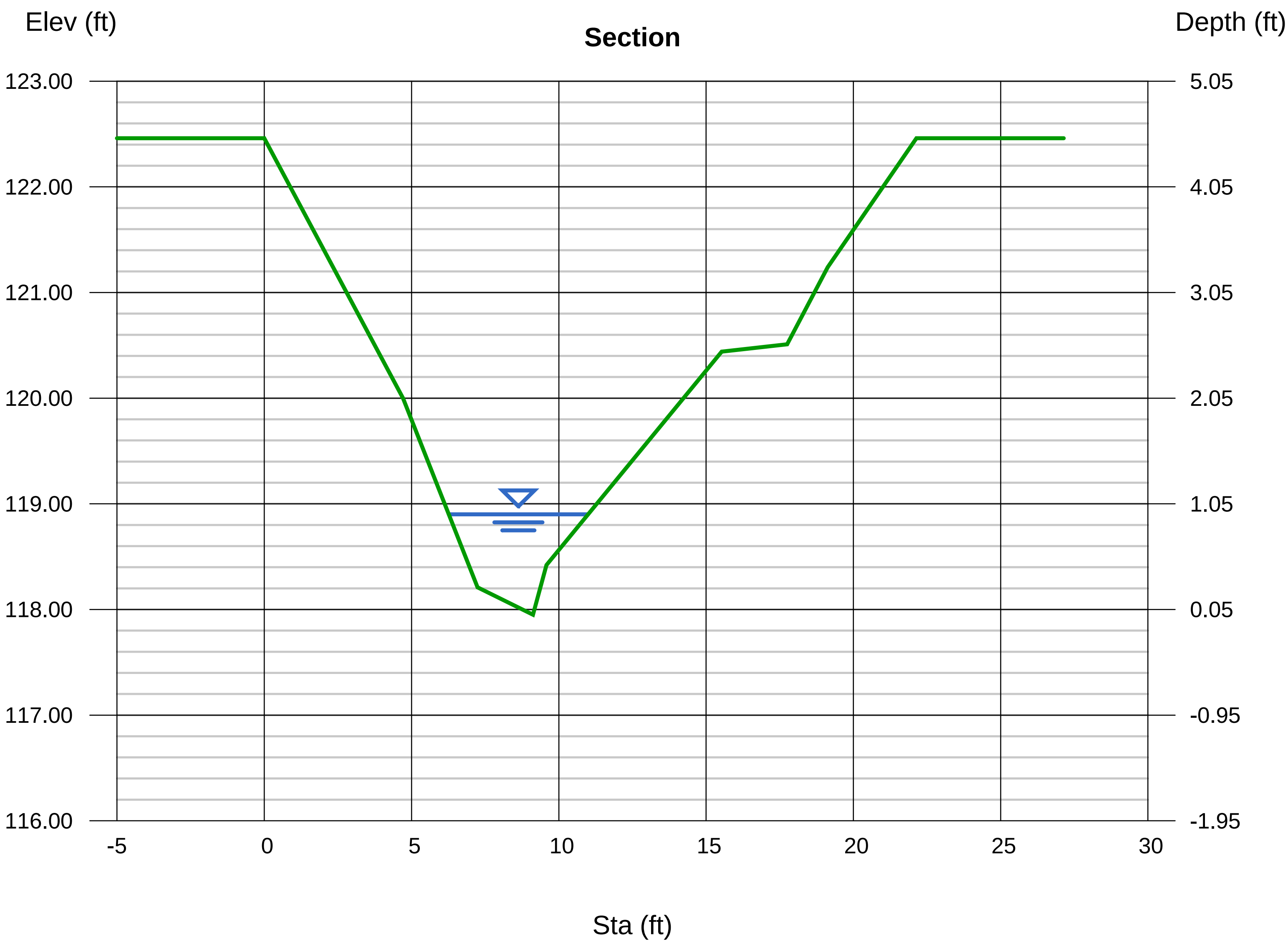
FP-09 Qfish

User-defined
Invert Elev (ft) = 117.95
Slope (%) = 13.60
N-Value = 0.050

Calculations
Compute by: Known Q
Known Q (cfs) = 17.00

Highlighted
Depth (ft) = 0.95
Q (cfs) = 17.00
Area (sqft) = 2.55
Velocity (ft/s) = 6.68
Wetted Perim (ft) = 5.24
Crit Depth, Yc (ft) = 1.18
Top Width (ft) = 4.73
EGL (ft) = 1.64

(Sta, El, n)-(Sta, El, n)...
(0.00, 122.46)-(4.71, 120.00, 0.050)-(7.24, 118.21, 0.050)-(9.12, 117.95, 0.050)-(9.58, 118.42, 0.050)-(15.53, 120.44, 0.050)-(17.75, 120.51, 0.050)-(19.13, 121.24, 0.050)-(22.14, 122.46, 0.050)



Channel Report

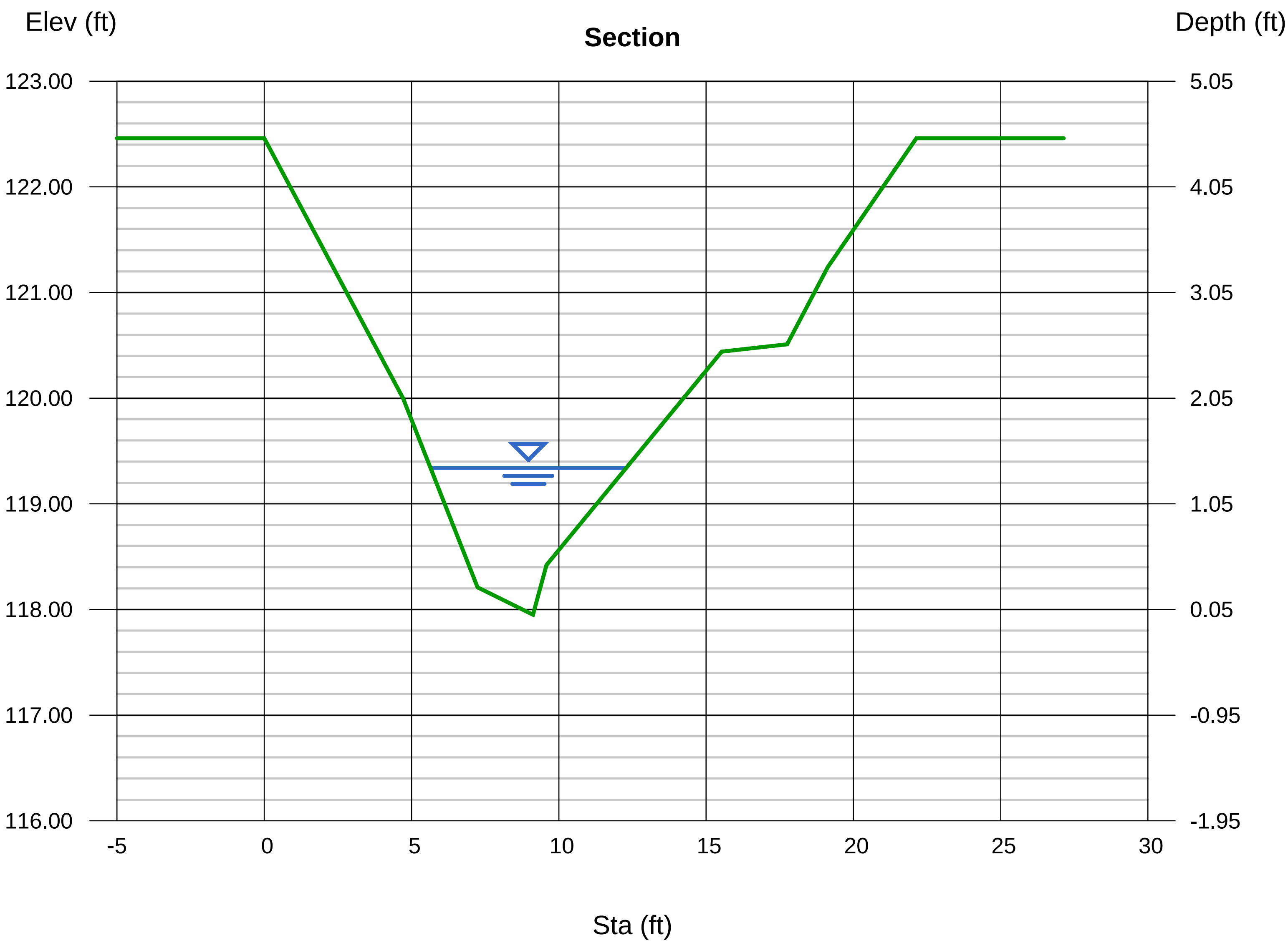
FP-09 Q2

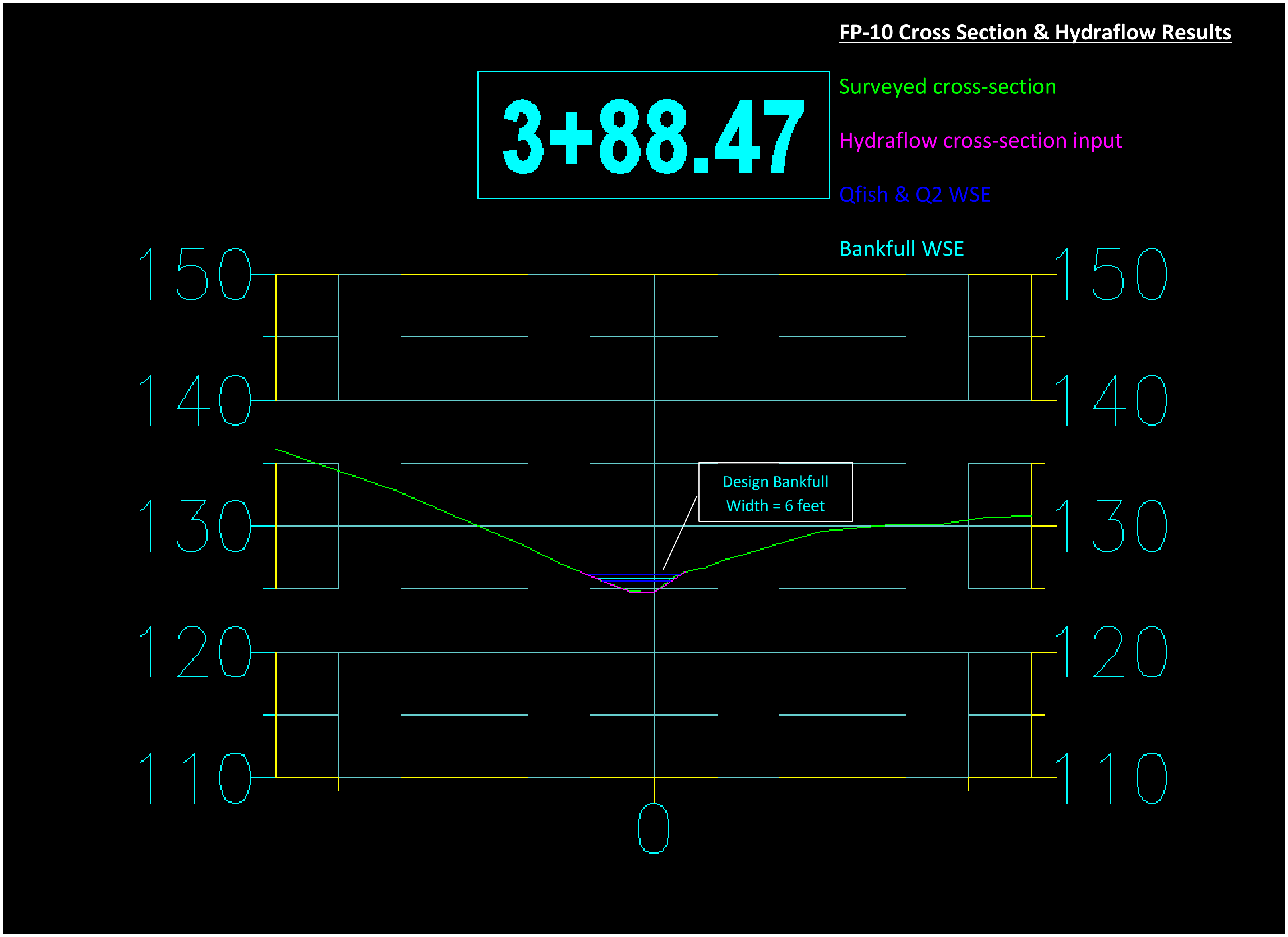
User-defined
Invert Elev (ft) = 117.95
Slope (%) = 13.60
N-Value = 0.050

Calculations
Compute by: Known Q
Known Q (cfs) = 42.50

Highlighted
Depth (ft) = 1.39
Q (cfs) = 42.50
Area (sqft) = 5.05
Velocity (ft/s) = 8.42
Wetted Perim (ft) = 7.37
Crit Depth, Yc (ft) = 1.76
Top Width (ft) = 6.65
EGL (ft) = 2.49

(Sta, El, n)-(Sta, El, n)...
(0.00, 122.46)-(4.71, 120.00, 0.050)-(7.24, 118.21, 0.050)-(9.12, 117.95, 0.050)-(9.58, 118.42, 0.050)-(15.53, 120.44, 0.050)-(17.75, 120.51, 0.050)-(19.13, 121.24, 0.050)-(22.14, 122.46, 0.050)

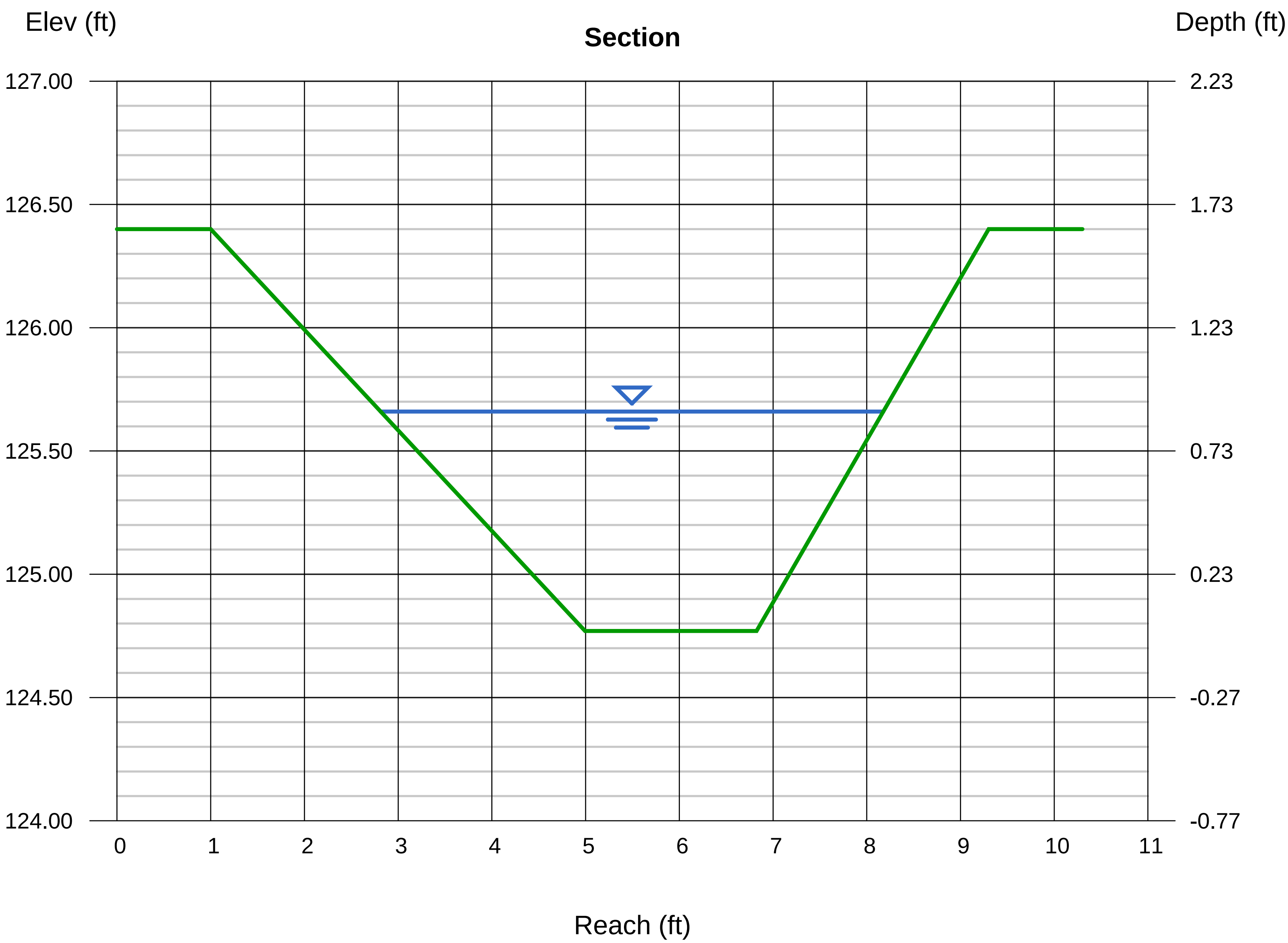



FP-10 Cross Section & Hydraflow Results
3+88.47
Surveyed cross-section
Hydraflow cross-section input
Qfish & Q2 WSE
Bankfull WSE
Design Bankfull Width = 6 feet
150
140
130
120
110
0

Channel Report

FP-10 Qfish

Trapezoidal		**Highlighted**	
Bottom Width (ft)	= 1.83	Depth (ft)	= 0.89
Side Slopes (z:1)	= 2.45, 1.52	Q (cfs)	= 19.50
Total Depth (ft)	= 1.63	Area (sqft)	= 3.20
Invert Elev (ft)	= 124.77	Velocity (ft/s)	= 6.09
Slope (%)	= 9.70	Wetted Perim (ft)	= 5.80
N-Value	= 0.050	Crit Depth, Yc (ft)	= 1.06
		Top Width (ft)	= 5.36
Calculations		EGL (ft)	= 1.47
Compute by:	Known Q		
Known Q (cfs)	= 19.50		

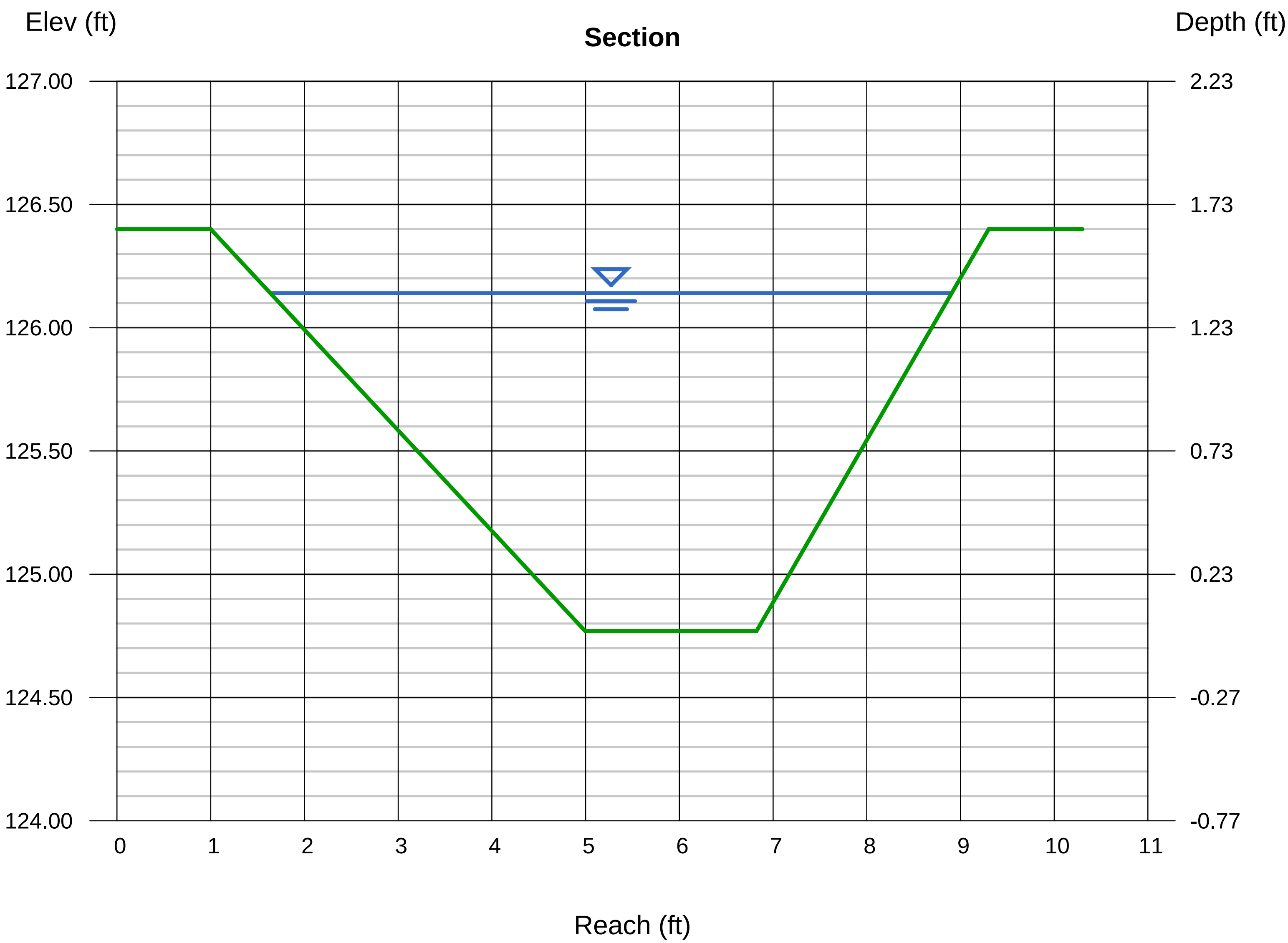


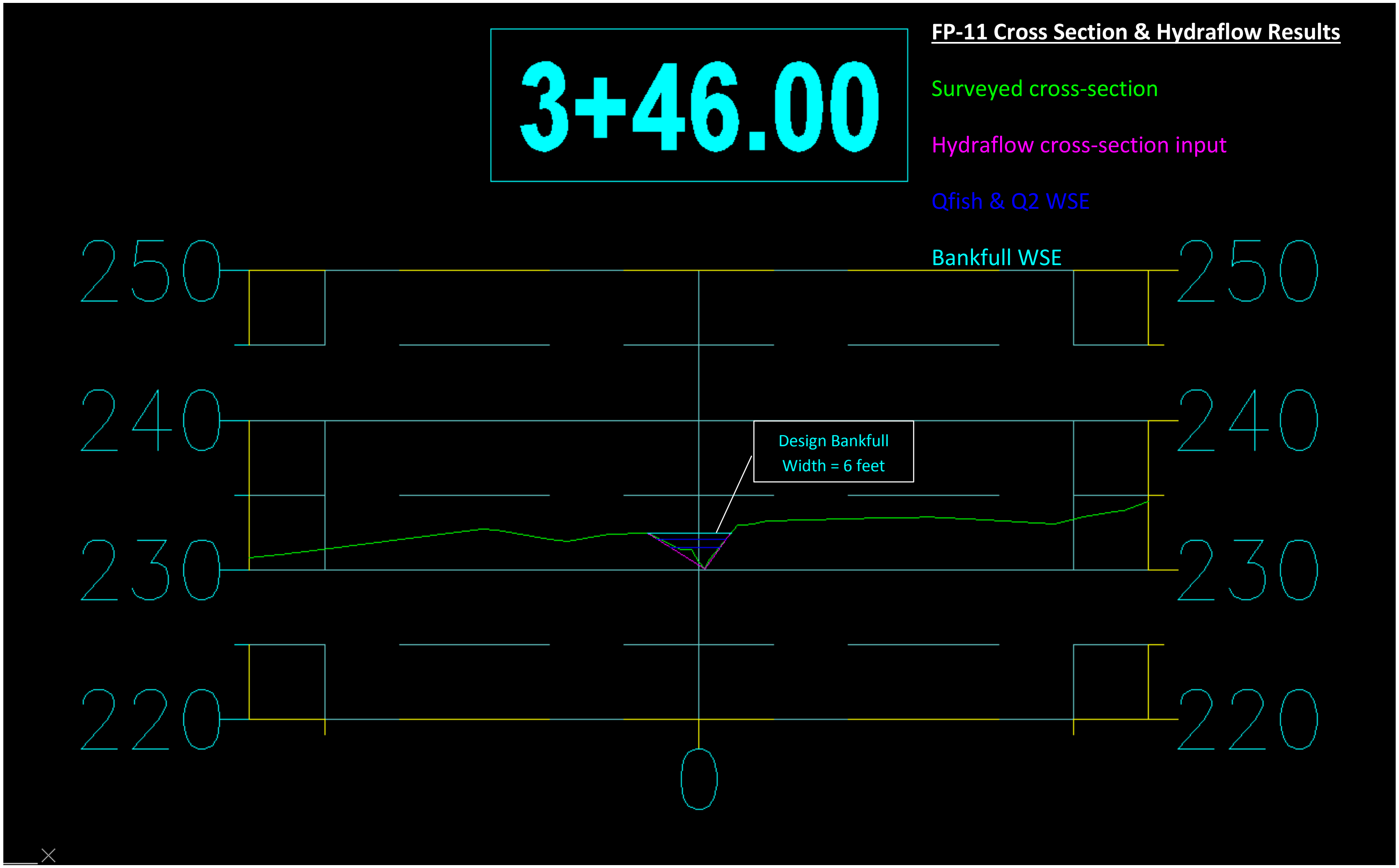
Channel Report

Hydraflow Express Extension for AutoCAD® Civil 3D® 2013 by Autodesk, Inc. Tuesday, Feb 5 2013

FP-10 Q2

Trapezoidal		**Highlighted**	
Bottom Width (ft)	= 1.83	Depth (ft)	= 1.37
Side Slopes (z:1)	= 2.45, 1.52	Q (cfs)	= 48.70
Total Depth (ft)	= 1.63	Area (sqft)	= 6.23
Invert Elev (ft)	= 124.77	Velocity (ft/s)	= 7.81
Slope (%)	= 9.70	Wetted Perim (ft)	= 7.95
N-Value	= 0.050	Crit Depth, Yc (ft)	= 1.63
		Top Width (ft)	= 7.27
Calculations		EGL (ft)	= 2.32
Compute by:	Known Q		
Known Q (cfs)	= 48.70		




3+46.00
FP-11 Cross Section & Hydraflow Results
Surveyed cross-section
Hydraflow cross-section input
Qfish & Q2 WSE
Bankfull WSE
Design Bankfull
Width = 6 feet
250
240
230
220
0

Channel Report

Hydraflow Express Extension for AutoCAD® Civil 3D® 2013 by Autodesk, Inc. — Tuesday, Feb 5 2013

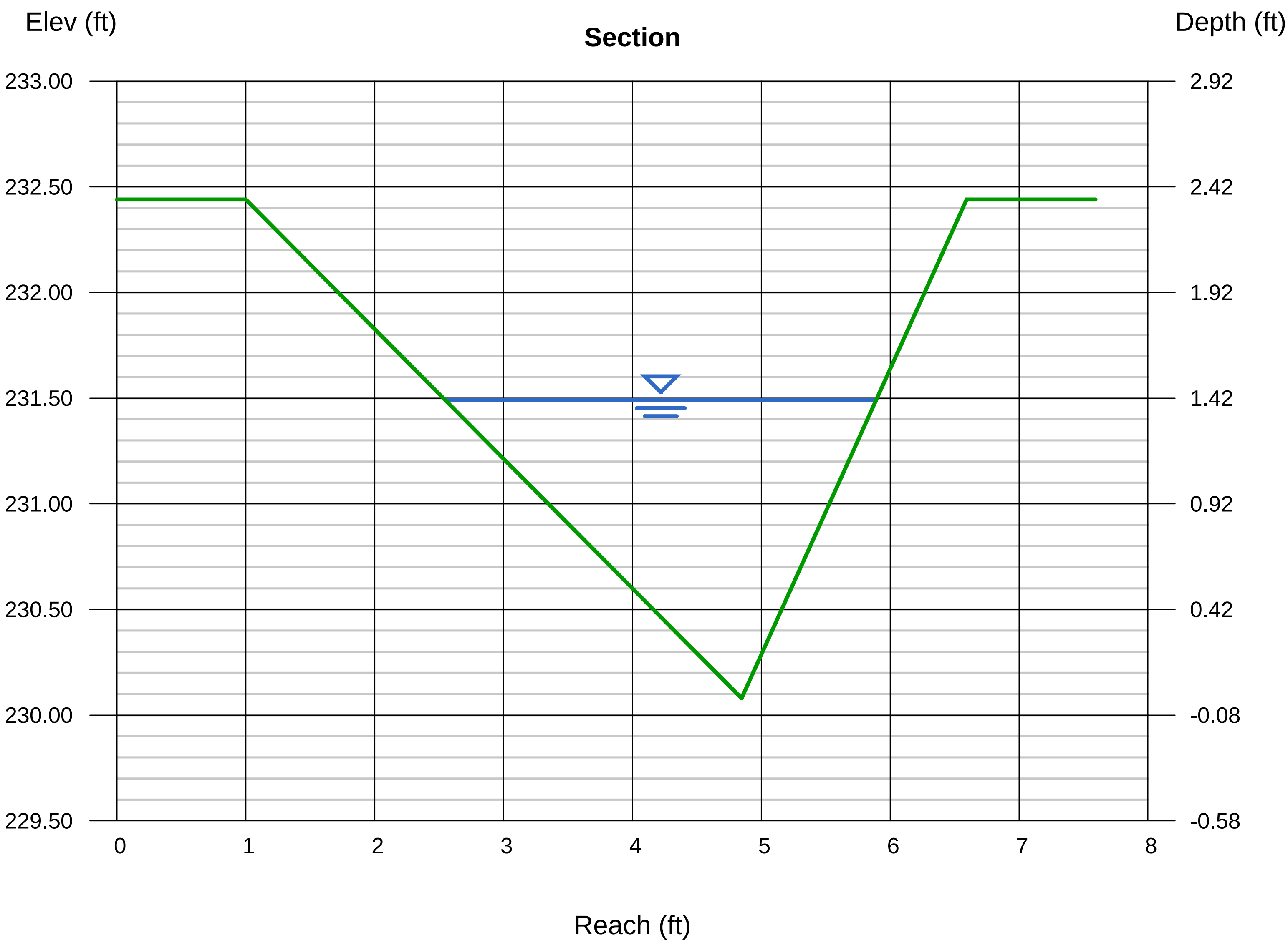
FP-11 Qfish

Triangular
Side Slopes (z:1) = 1.63, 0.74
Total Depth (ft) = 2.36

Invert Elev (ft) = 230.08
Slope (%) = 10.90
N-Value = 0.060

Calculations
Compute by: Known Q
Known Q (cfs) = 12.40

Highlighted
Depth (ft) = 1.41
Q (cfs) = 12.40
Area (sqft) = 2.36
Velocity (ft/s) = 5.26
Wetted Perim (ft) = 4.45
Crit Depth, Yc (ft) = 1.47
Top Width (ft) = 3.34
EGL (ft) = 1.84



Channel Report

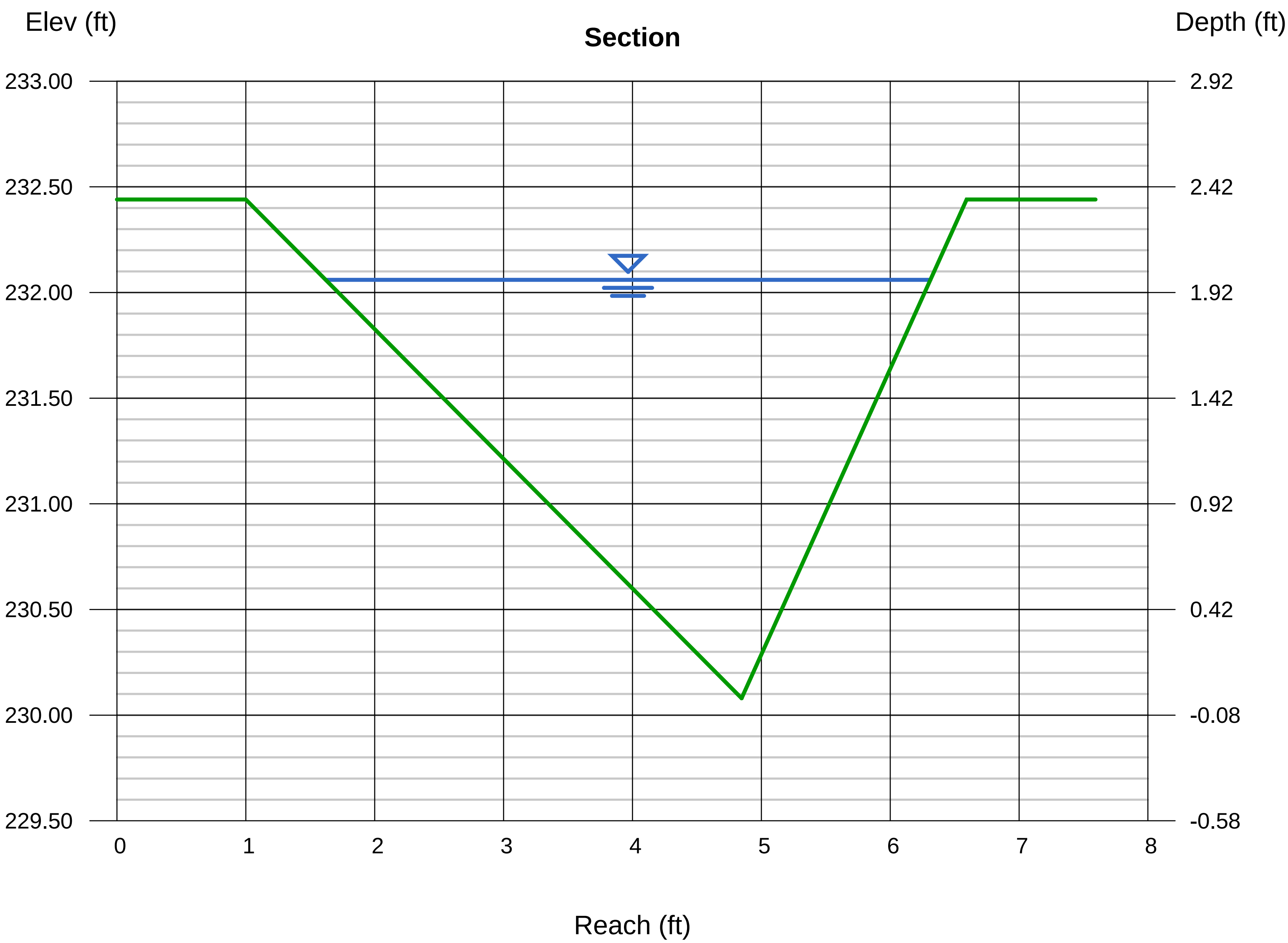
FP-11 Q2

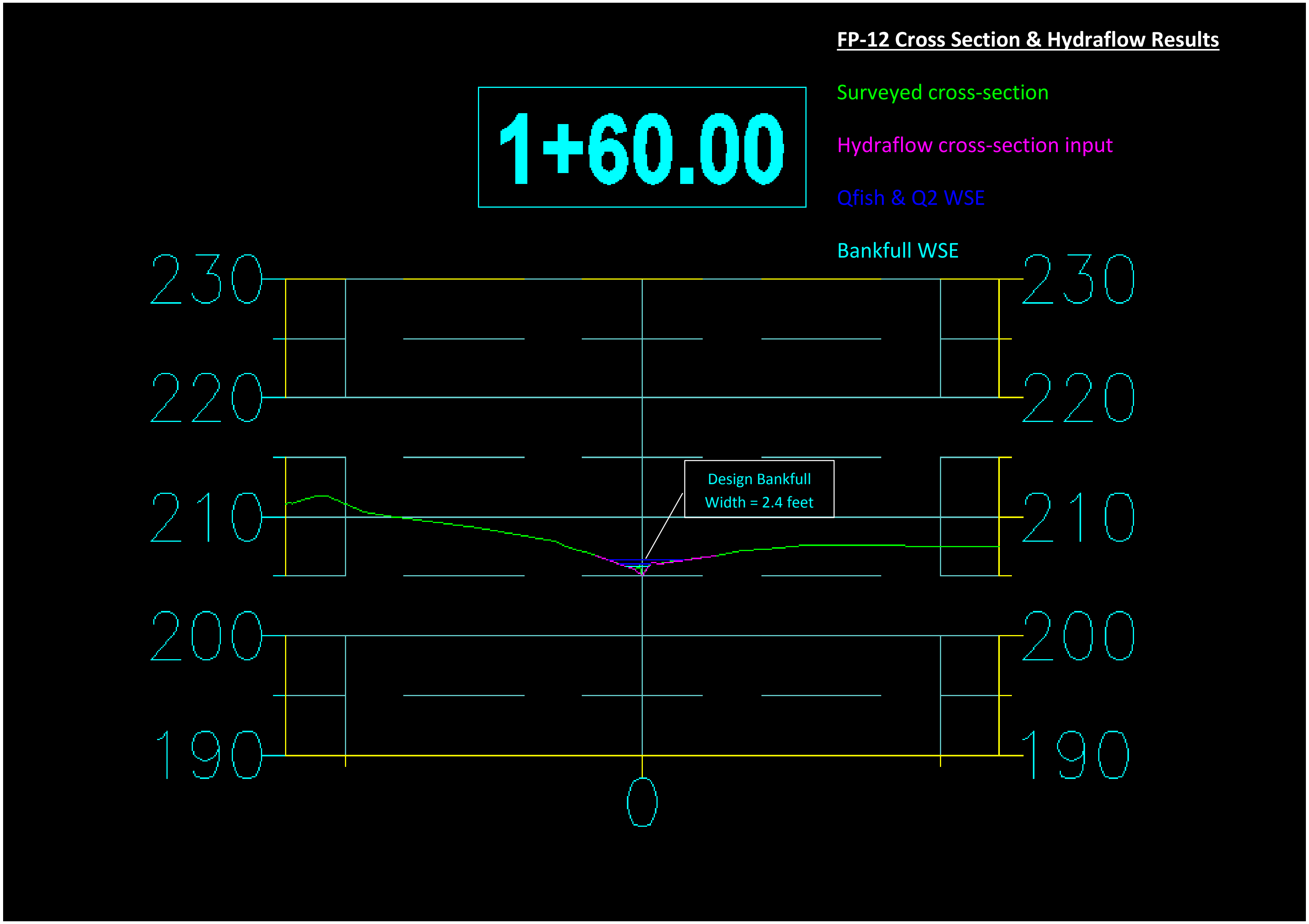
Triangular
Side Slopes (z:1) = 1.63, 0.74
Total Depth (ft) = 2.36

Invert Elev (ft) = 230.08
Slope (%) = 10.90
N-Value = 0.060

Calculations
Compute by: Known Q
Known Q (cfs) = 30.90

Highlighted
Depth (ft) = 1.98
Q (cfs) = 30.90
Area (sqft) = 4.65
Velocity (ft/s) = 6.65
Wetted Perim (ft) = 6.25
Crit Depth, Yc (ft) = 2.12
Top Width (ft) = 4.69
EGL (ft) = 2.67




FP-12 Cross Section & Hydraflow Results
Surveyed cross-section
Hydraflow cross-section input
Qfish & Q2 WSE
Bankfull WSE
1+60.00
Design Bankfull Width = 2.4 feet
230
220
210
200
190
230
220
210
200
190
0

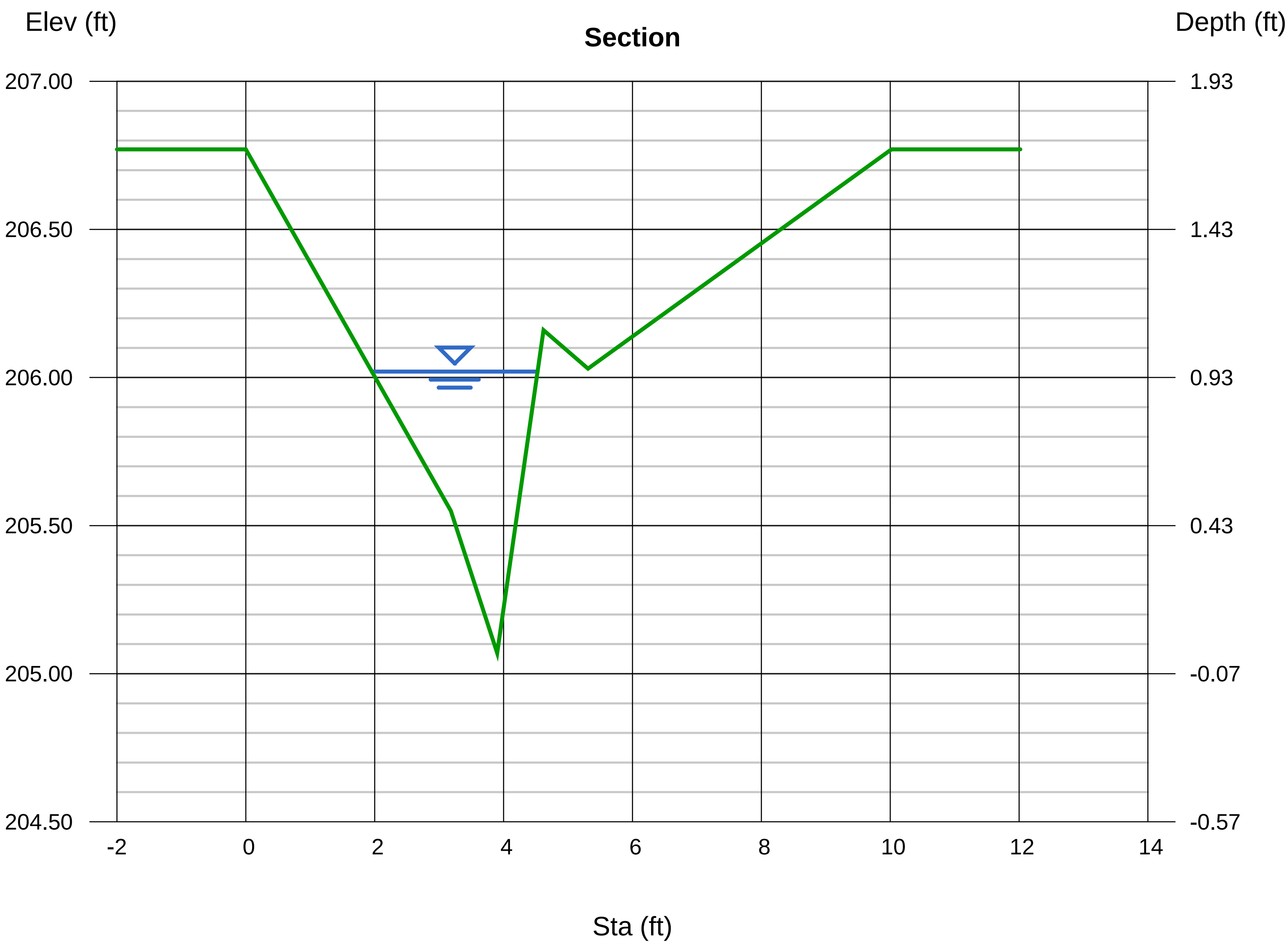
Channel Report

Hydraflow Express Extension for AutoCAD® Civil 3D® 2013 by Autodesk, Inc. Thursday, Jan 24 2013

FP-12 Qfish

User-defined		**Highlighted**	
Invert Elev (ft)	= 205.07	Depth (ft)	= 0.95
Slope (%)	= 10.10	Q (cfs)	= 4.100
N-Value	= 0.060	Area (sqft)	= 1.10
		Velocity (ft/s)	= 3.74
Calculations		Wetted Perim (ft)	= 3.32
Compute by:	Known Q	Crit Depth, Yc (ft)	= 0.96
Known Q (cfs)	= 4.10	Top Width (ft)	= 2.57
		EGL (ft)	= 1.17

(Sta, El, n)-(Sta, El, n)...
(0.00, 206.77)-(3.18, 205.55, 0.060)-(3.90, 205.07, 0.060)-(4.62, 206.16, 0.060)-(5.31, 206.03, 0.060)-(10.02, 206.77, 0.060)



Channel Report

Hydraflow Express Extension for AutoCAD® Civil 3D® 2013 by Autodesk, Inc. Thursday, Jan 24 2013

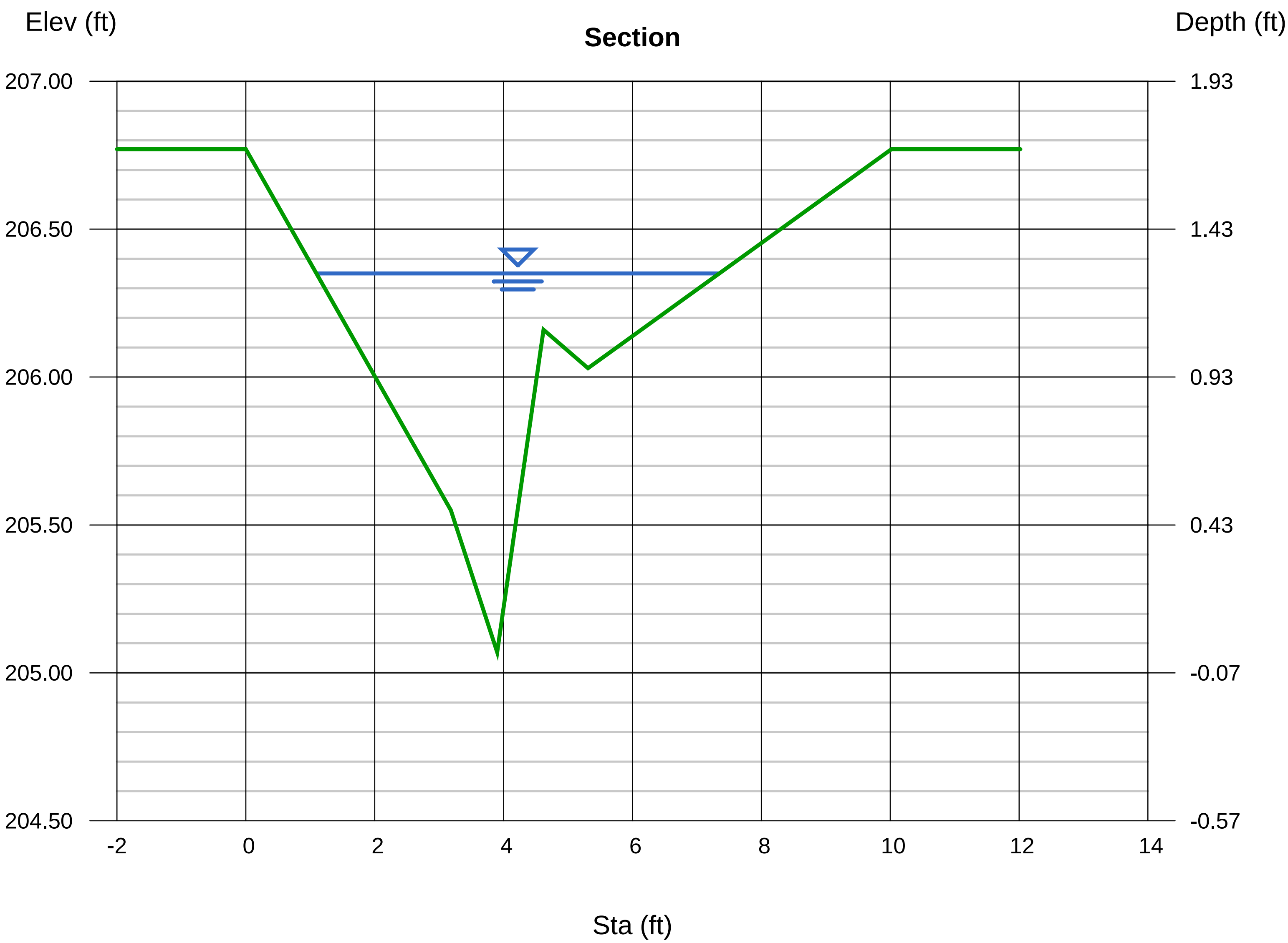
FP-12 Q2

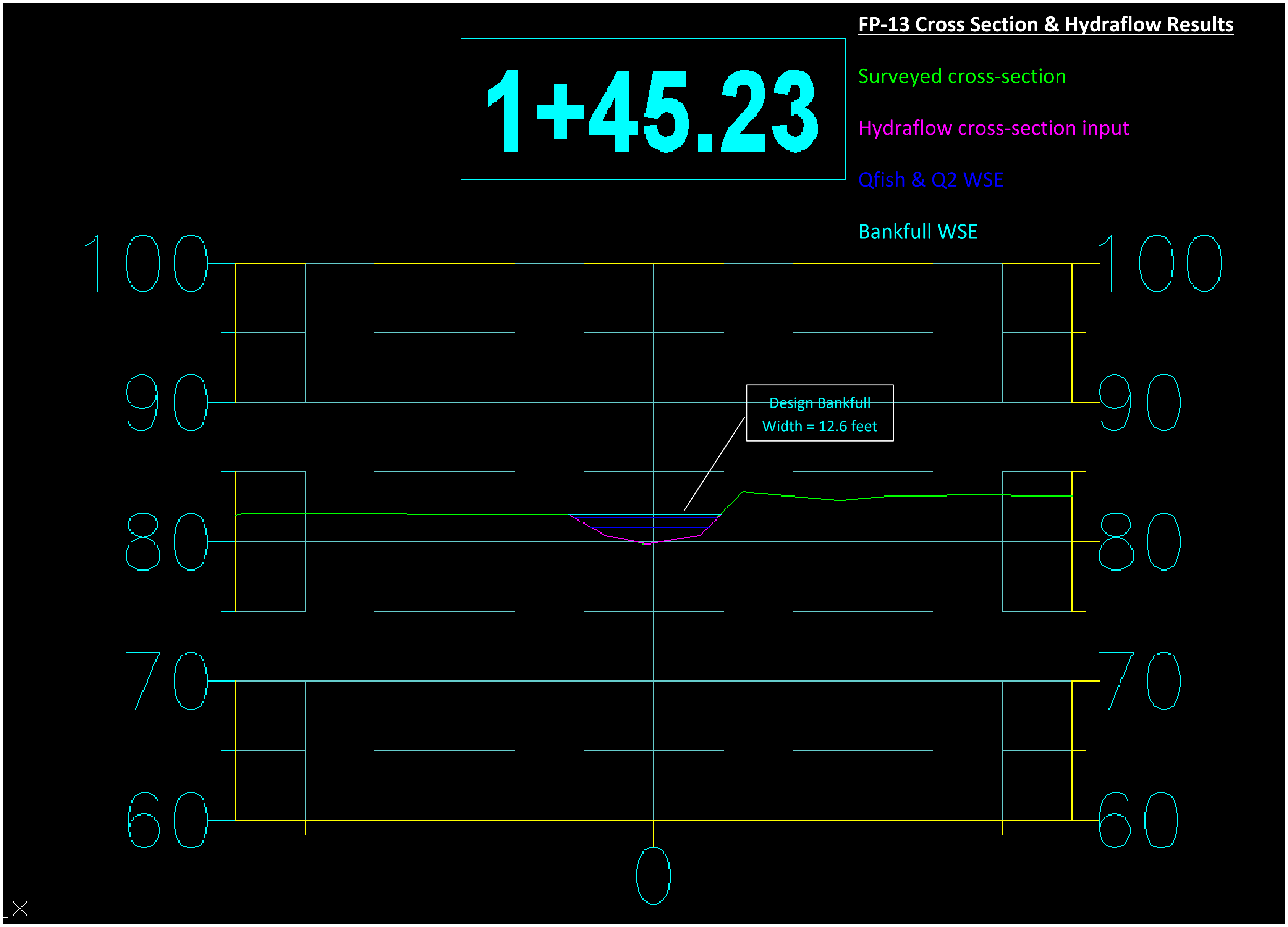
User-defined
Invert Elev (ft) = 205.07
Slope (%) = 10.10
N-Value = 0.060

Calculations
Compute by: Known Q
Known Q (cfs) = 10.20

Highlighted
Depth (ft) = 1.28
Q (cfs) = 10.20
Area (sqft) = 2.61
Velocity (ft/s) = 3.90
Wetted Perim (ft) = 7.17
Crit Depth, Yc (ft) = 1.31
Top Width (ft) = 6.25
EGL (ft) = 1.52

(Sta, El, n)-(Sta, El, n)...
(0.00, 206.77)-(3.18, 205.55, 0.060)-(3.90, 205.07, 0.060)-(4.62, 206.16, 0.060)-(5.31, 206.03, 0.060)-(10.02, 206.77, 0.060)




FP-13 Cross Section & Hydraflow Results
1+45.23
Surveyed cross-section
Hydraflow cross-section input
Qfish & Q2 WSE
Bankfull WSE
Design Bankfull
Width = 12.6 feet
100
90
80
70
60
0

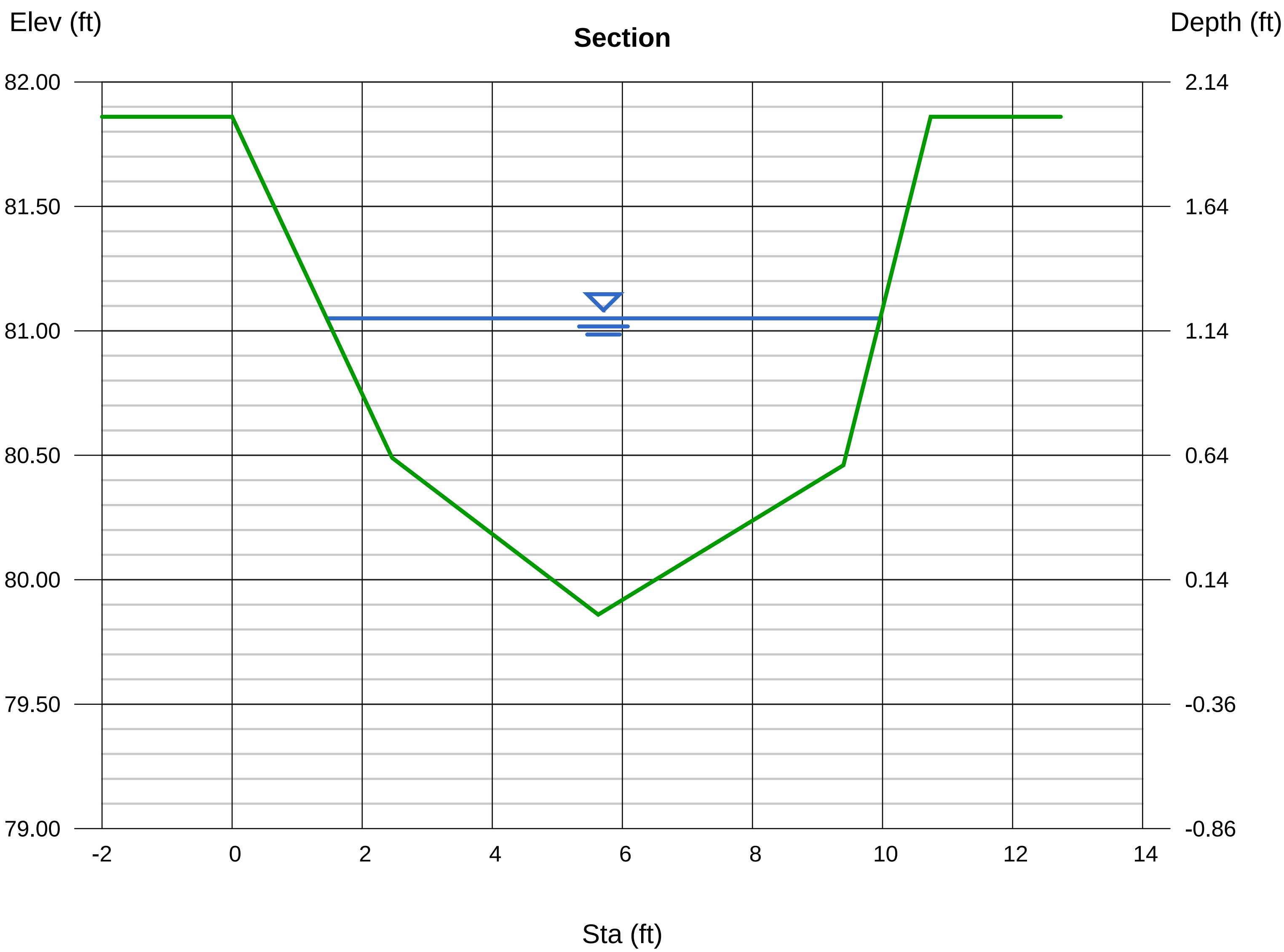
Channel Report

Hydraflow Express Extension for AutoCAD® Civil 3D® 2013 by Autodesk, Inc. Tuesday, Feb 5 2013

FP-13 Qfish

User-defined		Highlighted	
Invert Elev (ft)	= 79.86	Depth (ft)	= 1.19
Slope (%)	= 9.10	Q (cfs)	= 39.80
N-Value	= 0.060	Area (sqft)	= 6.58
		Velocity (ft/s)	= 6.05
Calculations		Wetted Perim (ft)	= 9.02
Compute by:	Known Q	Crit Depth, Yc (ft)	= 1.31
Known Q (cfs)	= 39.80	Top Width (ft)	= 8.51
		EGL (ft)	= 1.76

(Sta, El, n)-(Sta, El, n)...
(0.00, 81.86)-(2.46, 80.49, 0.060)-(5.63, 79.86, 0.060)-(9.40, 80.46, 0.060)-(10.74, 81.86, 0.060)

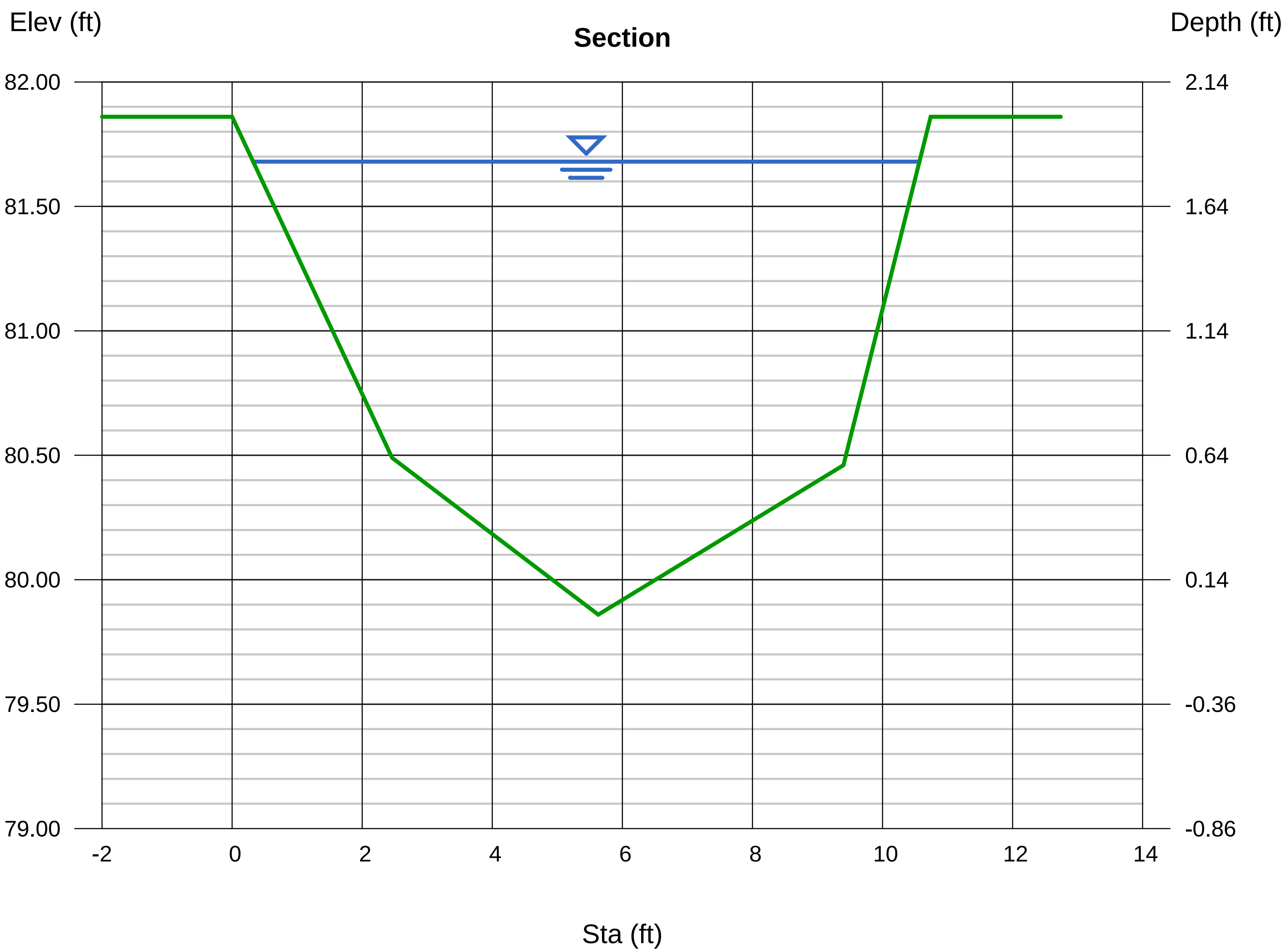


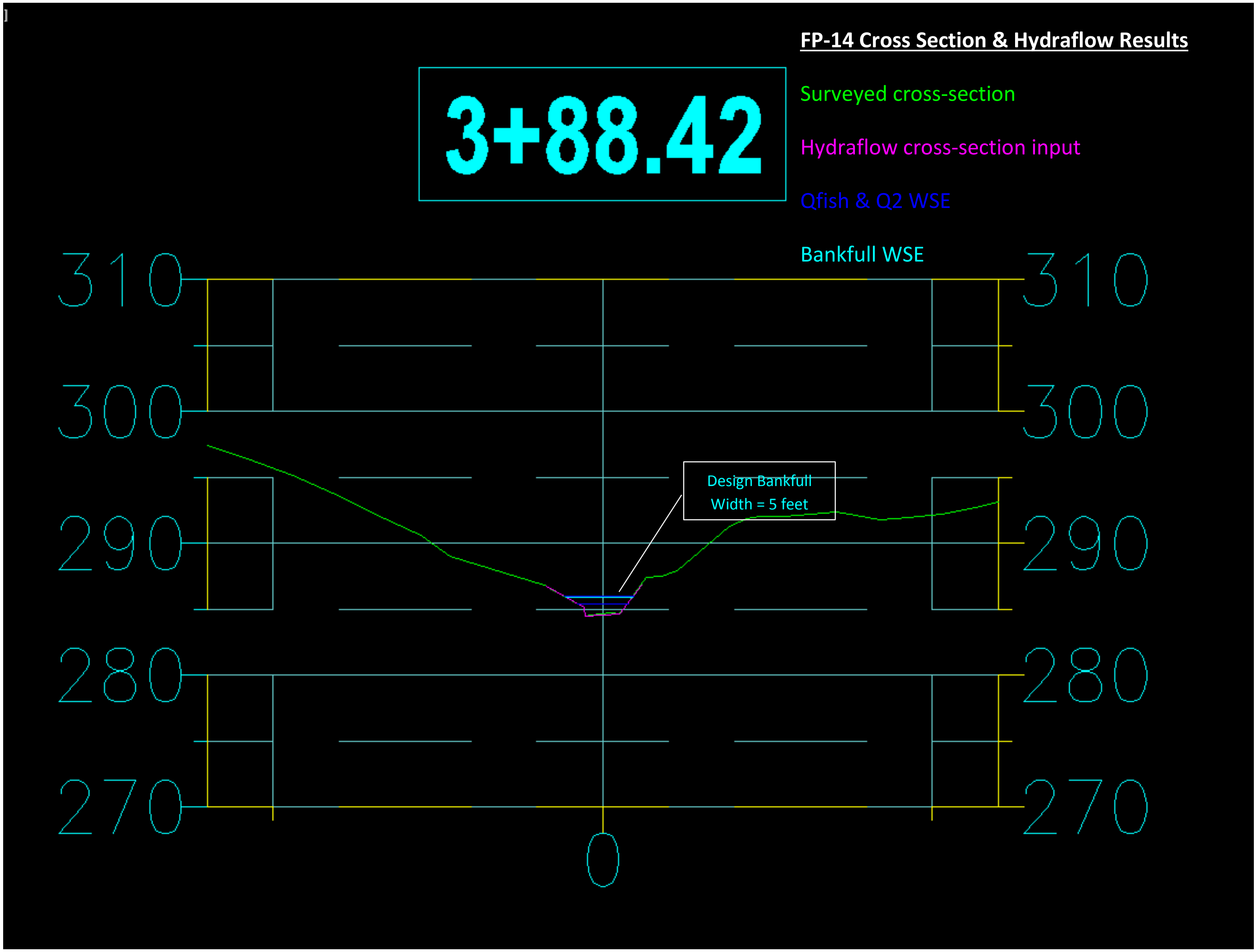
Channel Report

FP-13 Q2

User-defined		**Highlighted**	
Invert Elev (ft)	= 79.86	Depth (ft)	= 1.82
Slope (%)	= 9.10	Q (cfs)	= 99.40
N-Value	= 0.060	Area (sqft)	= 12.48
		Velocity (ft/s)	= 7.96
Calculations		Wetted Perim (ft)	= 11.18
Compute by:	Known Q	Crit Depth, Yc (ft)	= 2.00
Known Q (cfs)	= 99.40	Top Width (ft)	= 10.24
		EGL (ft)	= 2.81

(Sta, El, n)-(Sta, El, n)...
(0.00, 81.86)-(2.46, 80.49, 0.060)-(5.63, 79.86, 0.060)-(9.40, 80.46, 0.060)-(10.74, 81.86, 0.060)




FP-14 Cross Section & Hydraflow Results
3+88.42
Surveyed cross-section
Hydraflow cross-section input
Qfish & Q2 WSE
Bankfull WSE
310
300
290
280
270
310
300
290
280
270
Design Bankfull
Width = 5 feet
0

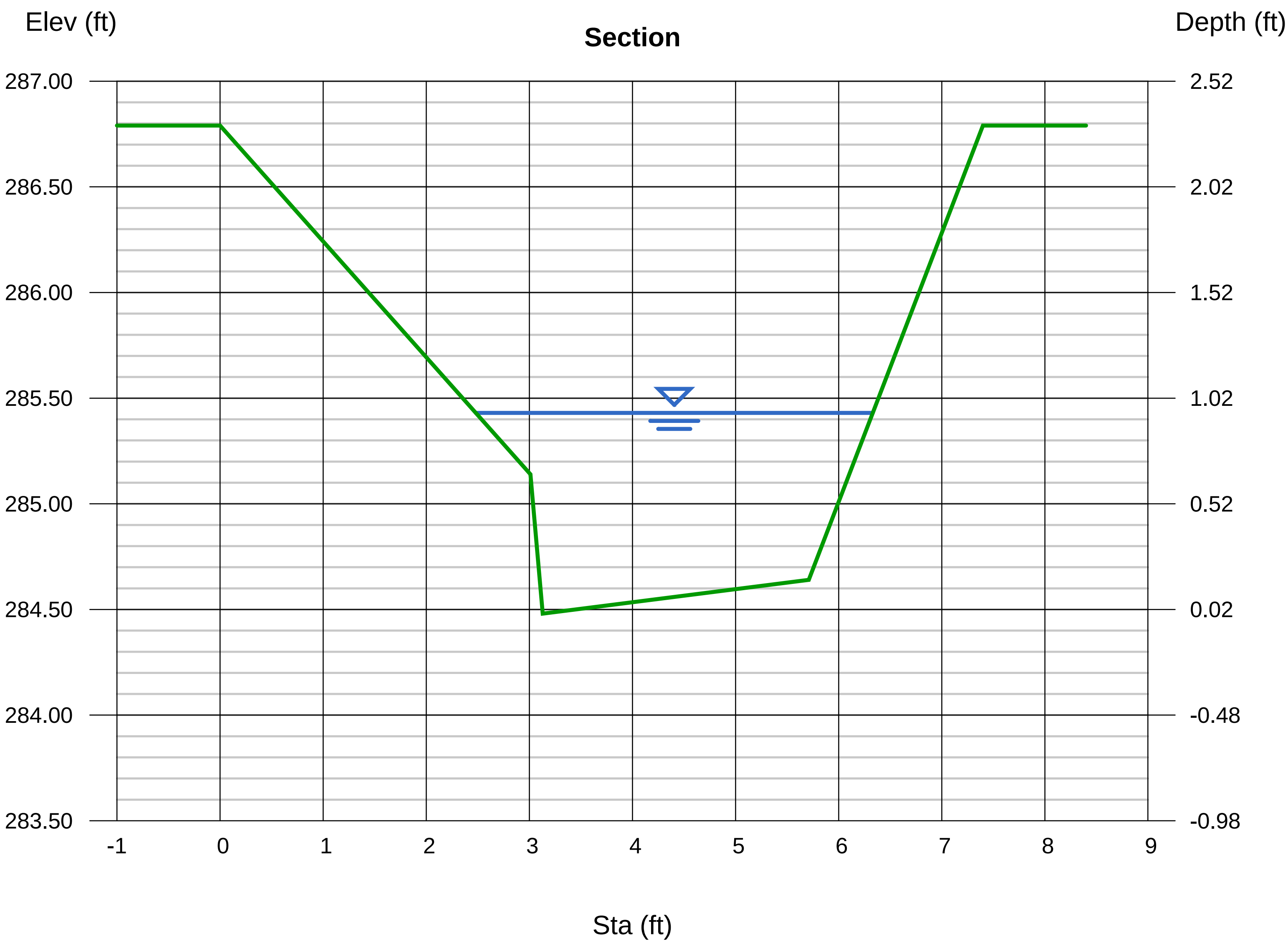
Channel Report

Hydraflow Express Extension for AutoCAD® Civil 3D® 2013 by Autodesk, Inc. — Wednesday, Feb 6 2013

FP-14 Qfish

User-defined		**Highlighted**	
Invert Elev (ft)	= 284.48	Depth (ft)	= 0.95
Slope (%)	= 12.50	Q (cfs)	= 13.00
N-Value	= 0.070	Area (sqft)	= 2.64
		Velocity (ft/s)	= 4.92
Calculations		Wetted Perim (ft)	= 4.86
Compute by:	Known Q	Crit Depth, Yc (ft)	= 0.98
Known Q (cfs)	= 13.00	Top Width (ft)	= 3.85
		EGL (ft)	= 1.33

(Sta, El, n)-(Sta, El, n)...
(0.00, 286.79)-(3.01, 285.14, 0.070)-(3.13, 284.48, 0.070)-(5.71, 284.64, 0.070)-(7.40, 286.79, 0.070)



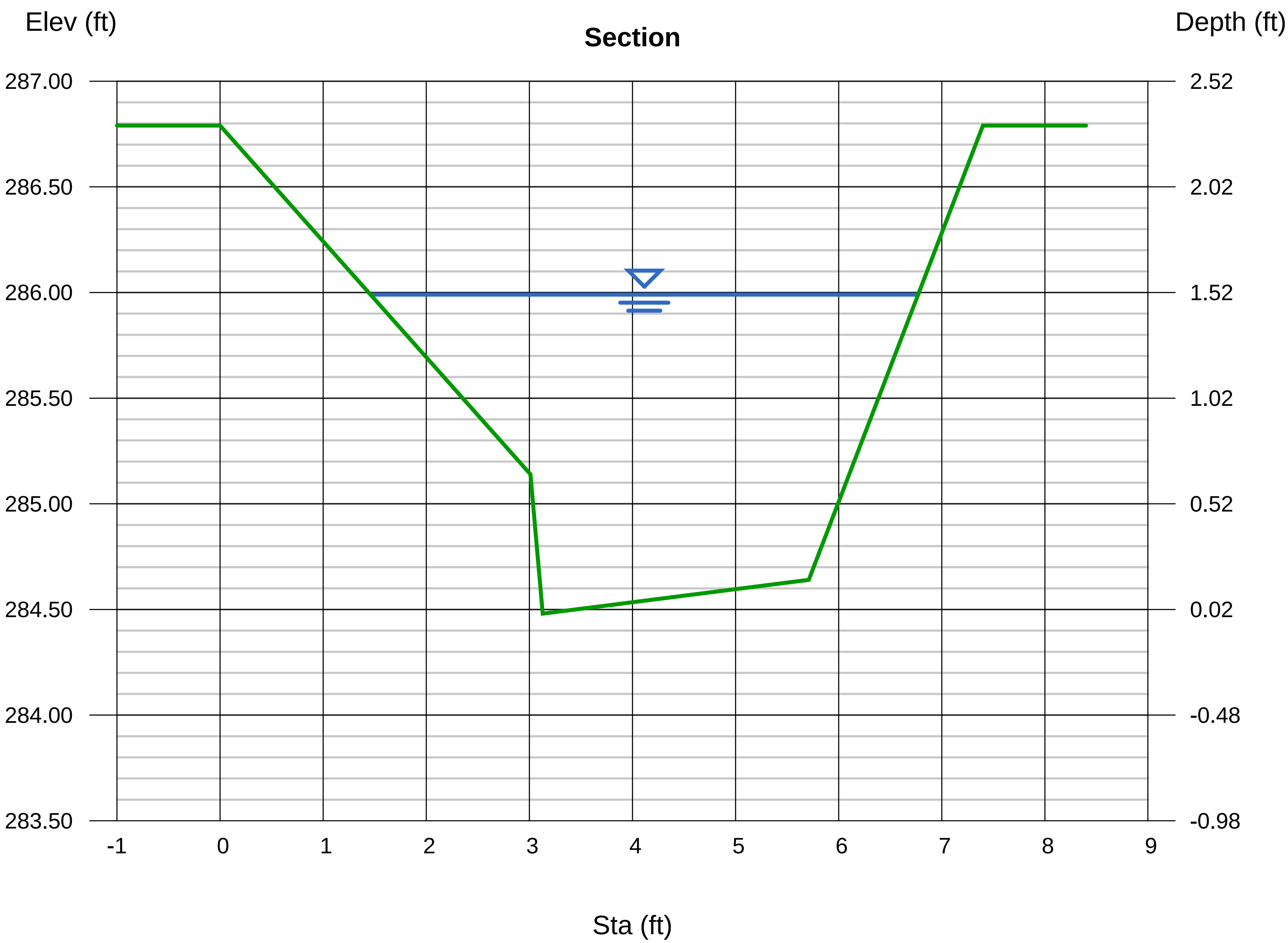
Channel Report

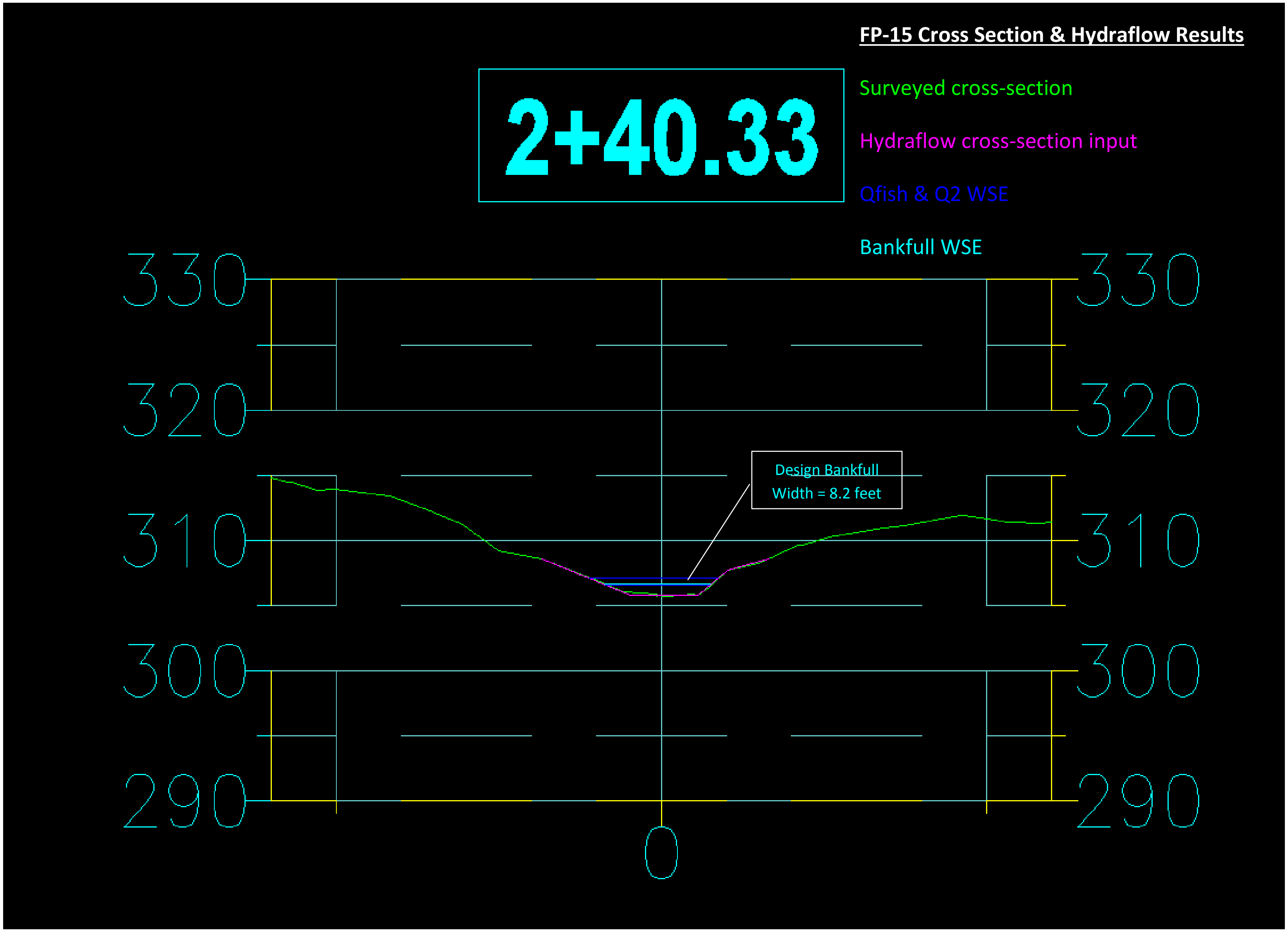
Hydraflow Express Extension for AutoCAD® Civil 3D® 2013 by Autodesk, Inc. Wednesday, Feb 6 2013

FP-14 Q2

User-defined		**Highlighted**	
Invert Elev (ft)	= 284.48	Depth (ft)	= 1.51
Slope (%)	= 12.50	Q (cfs)	= 32.50
N-Value	= 0.070	Area (sqft)	= 5.21
		Velocity (ft/s)	= 6.24
Calculations		Wetted Perim (ft)	= 6.74
Compute by:	Known Q	Crit Depth, Yc (ft)	= 1.60
Known Q (cfs)	= 32.50	Top Width (ft)	= 5.31
		EGL (ft)	= 2.12

(Sta, El, n)-(Sta, El, n)...
(0.00, 286.79)-(3.01, 285.14, 0.070)-(3.13, 284.48, 0.070)-(5.71, 284.64, 0.070)-(7.40, 286.79, 0.070)




FP-15 Cross Section & Hydraflow Results
Surveyed cross-section
Hydraflow cross-section input
Qfish & Q2 WSE
Bankfull WSE
2+40.33
330
320
310
300
290
Design Bankfull
Width = 8.2 feet
0

Channel Report

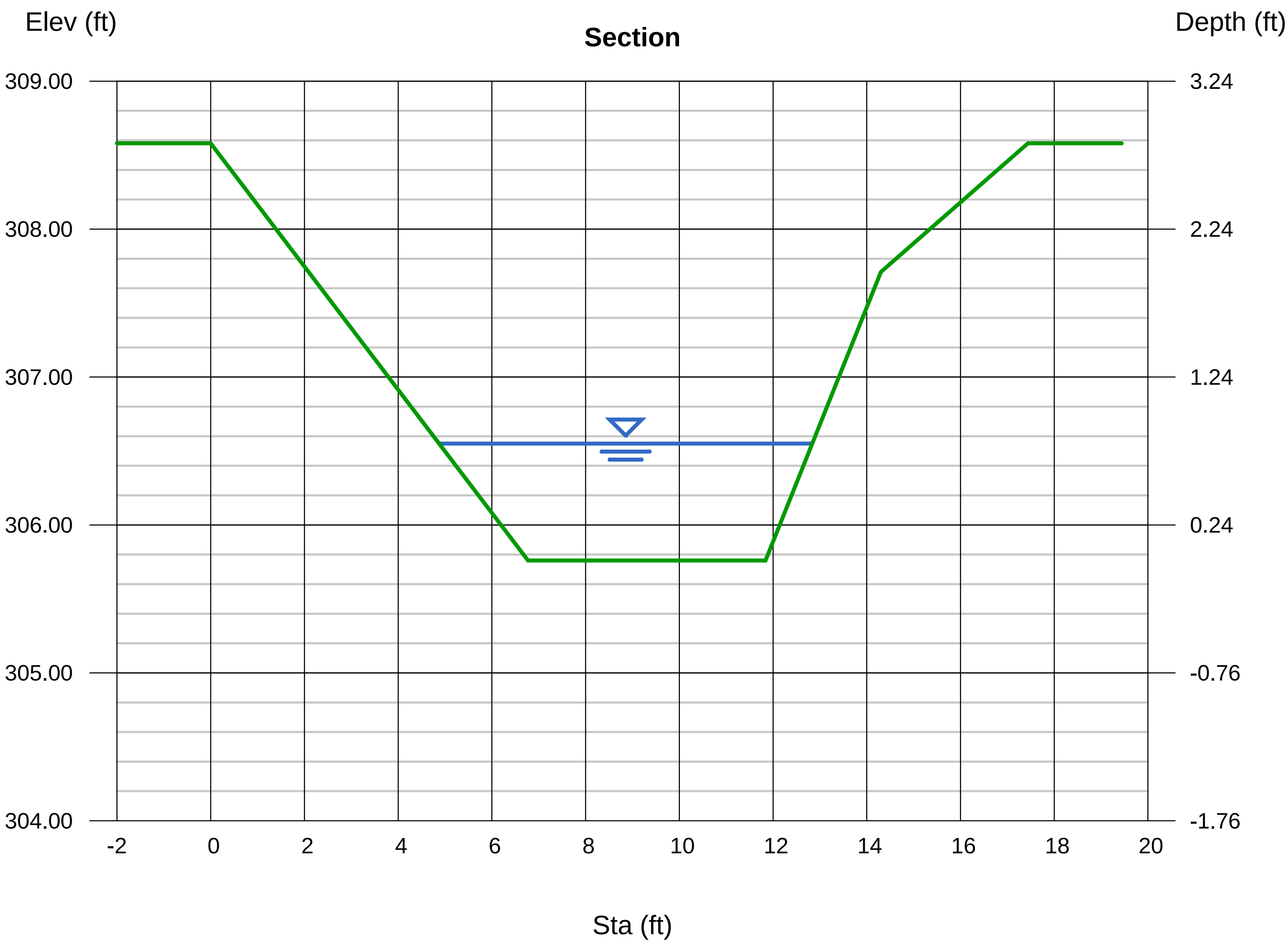
Hydraflow Express Extension for AutoCAD® Civil 3D® 2013 by Autodesk, Inc. Tuesday, Feb 5 2013

FP-15 Qfish

User-defined		**Highlighted**	
Invert Elev (ft)	= 305.76	Depth (ft)	= 0.79
Slope (%)	= 8.90	Q (cfs)	= 26.30
N-Value	= 0.062	Area (sqft)	= 5.15
		Velocity (ft/s)	= 5.11
Calculations		Wetted Perim (ft)	= 8.40
Compute by:	Known Q	Crit Depth, Yc (ft)	= 0.85
Known Q (cfs)	= 26.30	Top Width (ft)	= 7.96
		EGL (ft)	= 1.20

(Sta, El, n)-(Sta, El, n)...

(0.00, 308.58)-(6.77, 305.76, 0.062)-(11.84, 305.76, 0.062)-(14.30, 307.71, 0.062)-(17.44, 308.58, 0.062)



Channel Report

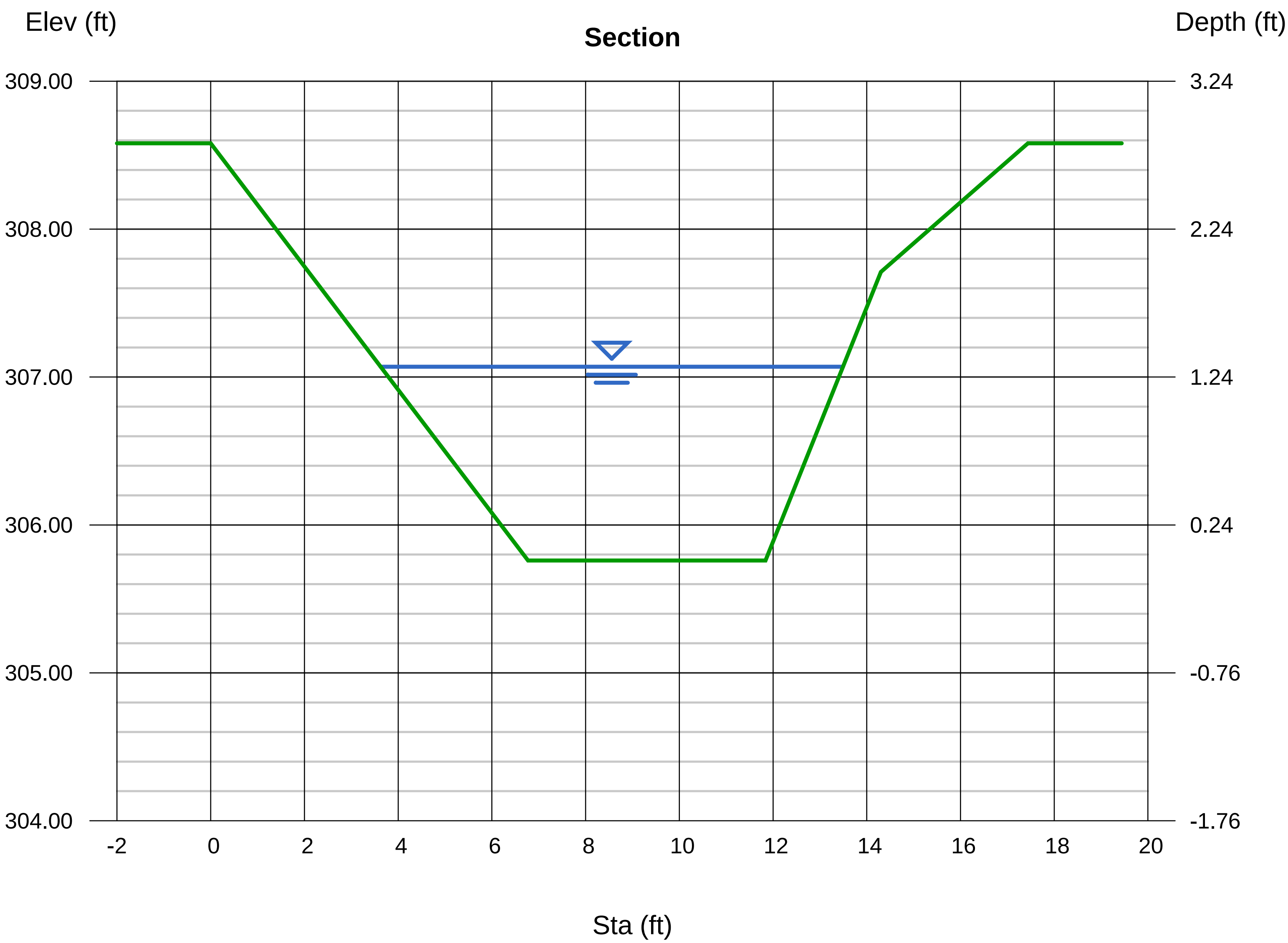
Hydraflow Express Extension for AutoCAD® Civil 3D® 2013 by Autodesk, Inc. — Tuesday, Feb 5 2013

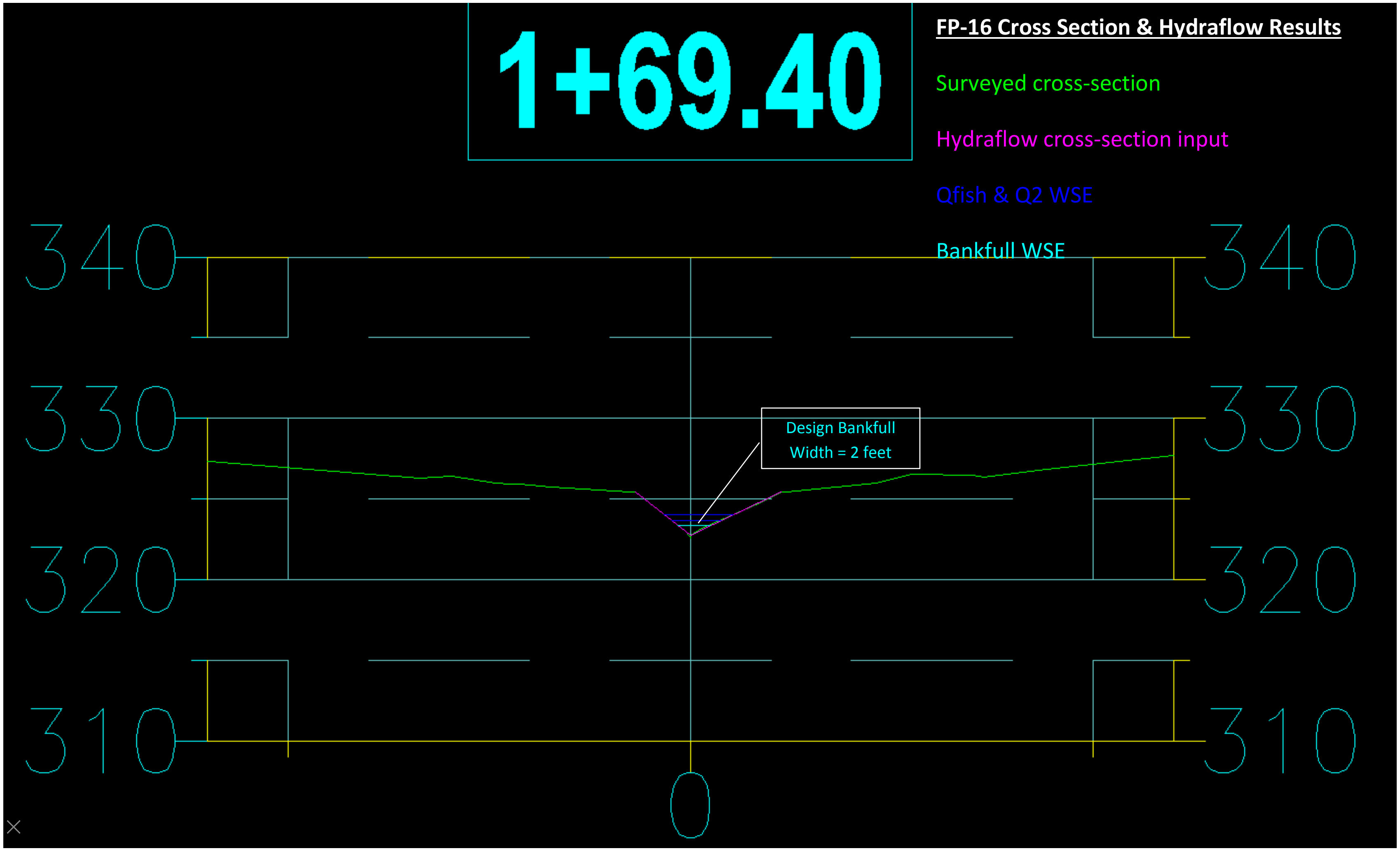
FP-15 Q2

User-defined		**Highlighted**	
Invert Elev (ft)	= 305.76	Depth (ft)	= 1.31
Slope (%)	= 8.90	Q (cfs)	= 65.60
N-Value	= 0.062	Area (sqft)	= 9.78
		Velocity (ft/s)	= 6.70
Calculations		Wetted Perim (ft)	= 10.59
Compute by:	Known Q	Crit Depth, Yc (ft)	= 1.45
Known Q (cfs)	= 65.60	Top Width (ft)	= 9.87
		EGL (ft)	= 2.01

(Sta, El, n)-(Sta, El, n)...

(0.00, 308.58)-(6.77, 305.76, 0.062)-(11.84, 305.76, 0.062)-(14.30, 307.71, 0.062)-(17.44, 308.58, 0.062)

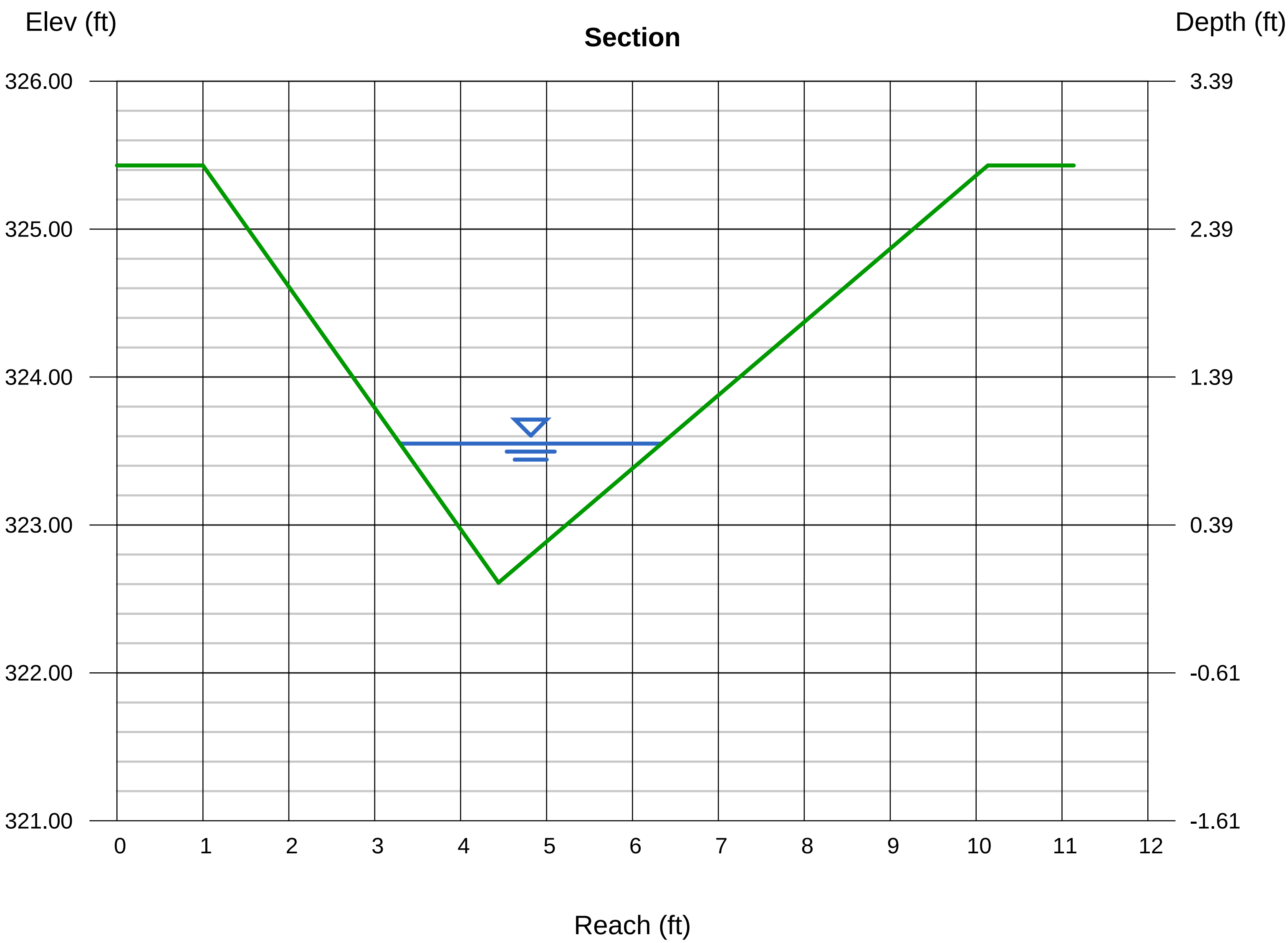



1+69.40
FP-16 Cross Section & Hydraflow Results
Surveyed cross-section
Hydraflow cross-section input
Qfish & Q2 WSE
Bankfull WSE
340
330
320
310
Design Bankfull
Width = 2 feet
0

Channel Report

FP-16 Qfish

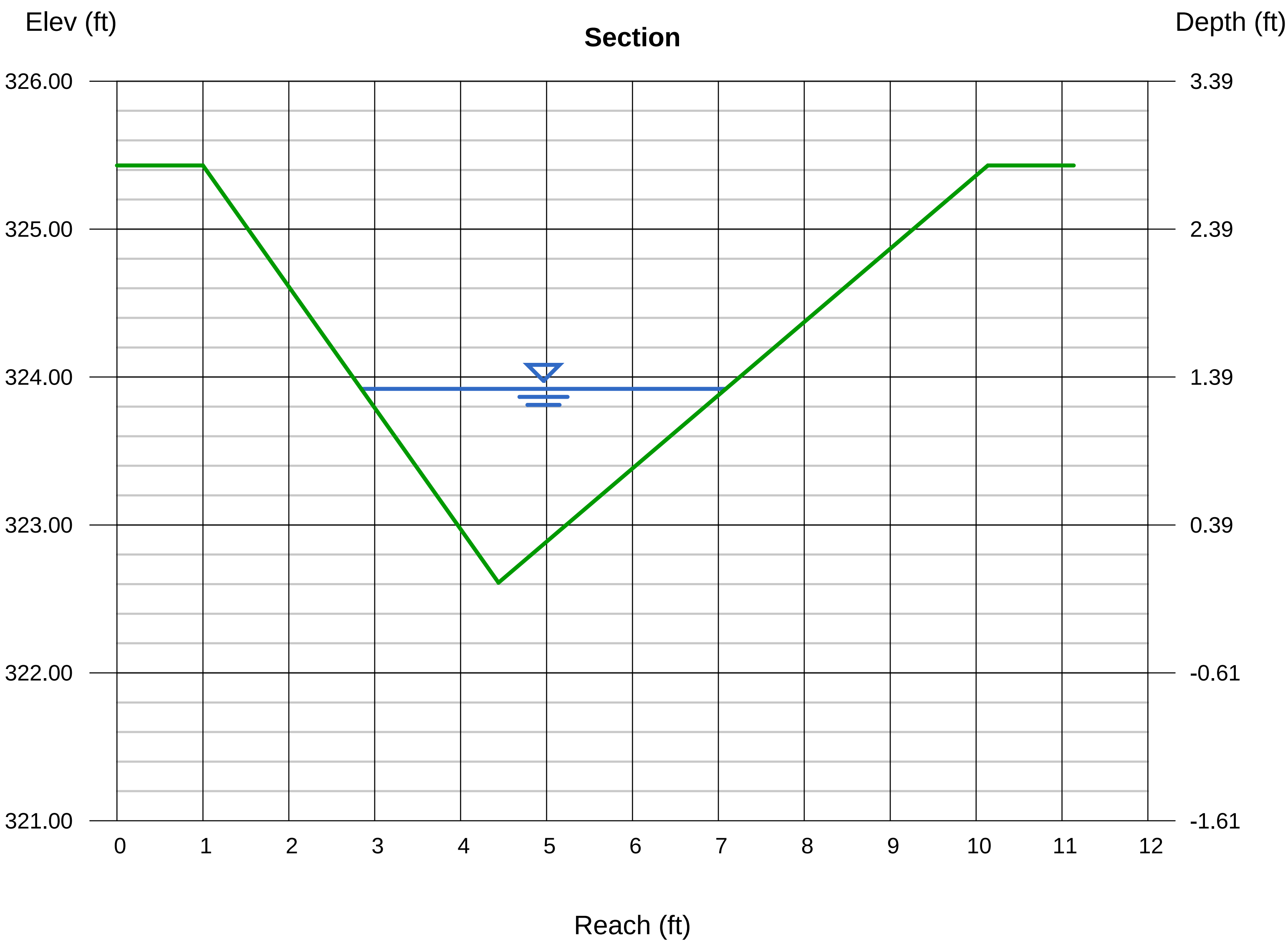
Triangular		**Highlighted**	
Side Slopes (z:1)	= 1.22, 2.02	Depth (ft)	= 0.94
Total Depth (ft)	= 2.82	Q (cfs)	= 2.000
		Area (sqft)	= 1.43
Invert Elev (ft)	= 322.61	Velocity (ft/s)	= 1.40
Slope (%)	= 2.00	Wetted Perim (ft)	= 3.60
N-Value	= 0.080	Crit Depth, Yc (ft)	= 0.63
		Top Width (ft)	= 3.05
Calculations		EGL (ft)	= 0.97
Compute by:	Known Q		
Known Q (cfs)	= 2.00		

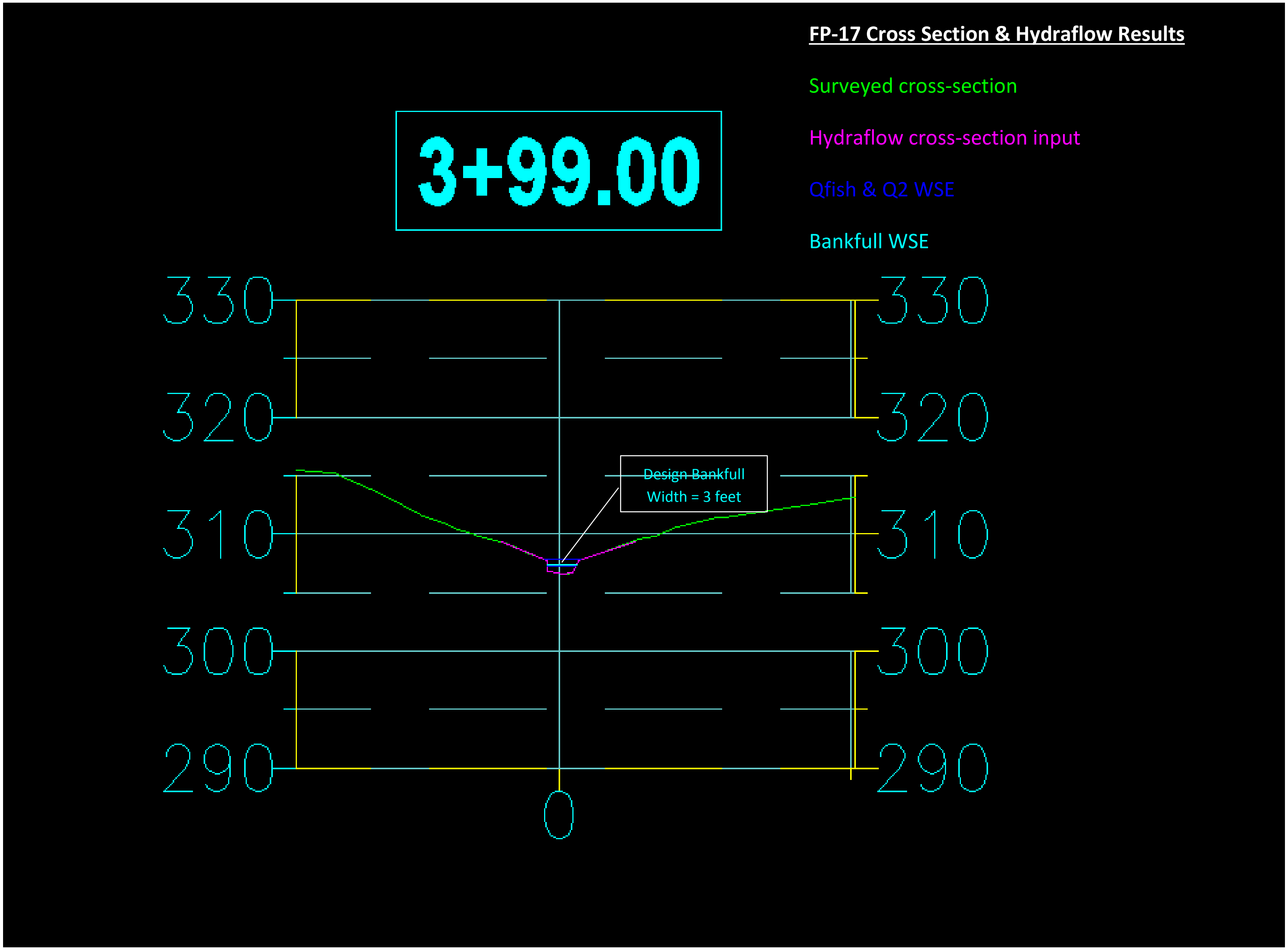


Channel Report

FP-16 Q2

Triangular		**Highlighted**	
Side Slopes (z:1)	= 1.22, 2.02	Depth (ft)	= 1.31
Total Depth (ft)	= 2.82	Q (cfs)	= 4.900
		Area (sqft)	= 2.78
Invert Elev (ft)	= 322.61	Velocity (ft/s)	= 1.76
Slope (%)	= 2.00	Wetted Perim (ft)	= 5.02
N-Value	= 0.080	Crit Depth, Yc (ft)	= 0.90
		Top Width (ft)	= 4.24
Calculations		EGL (ft)	= 1.36
Compute by:	Known Q		
Known Q (cfs)	= 4.90		




FP-17 Cross Section & Hydraflow Results
Surveyed cross-section
Hydraflow cross-section input
Qfish & Q2 WSE
Bankfull WSE
3+99.00
Design Bankfull Width = 3 feet
330
320
310
300
290
330
320
310
300
290
0

Channel Report

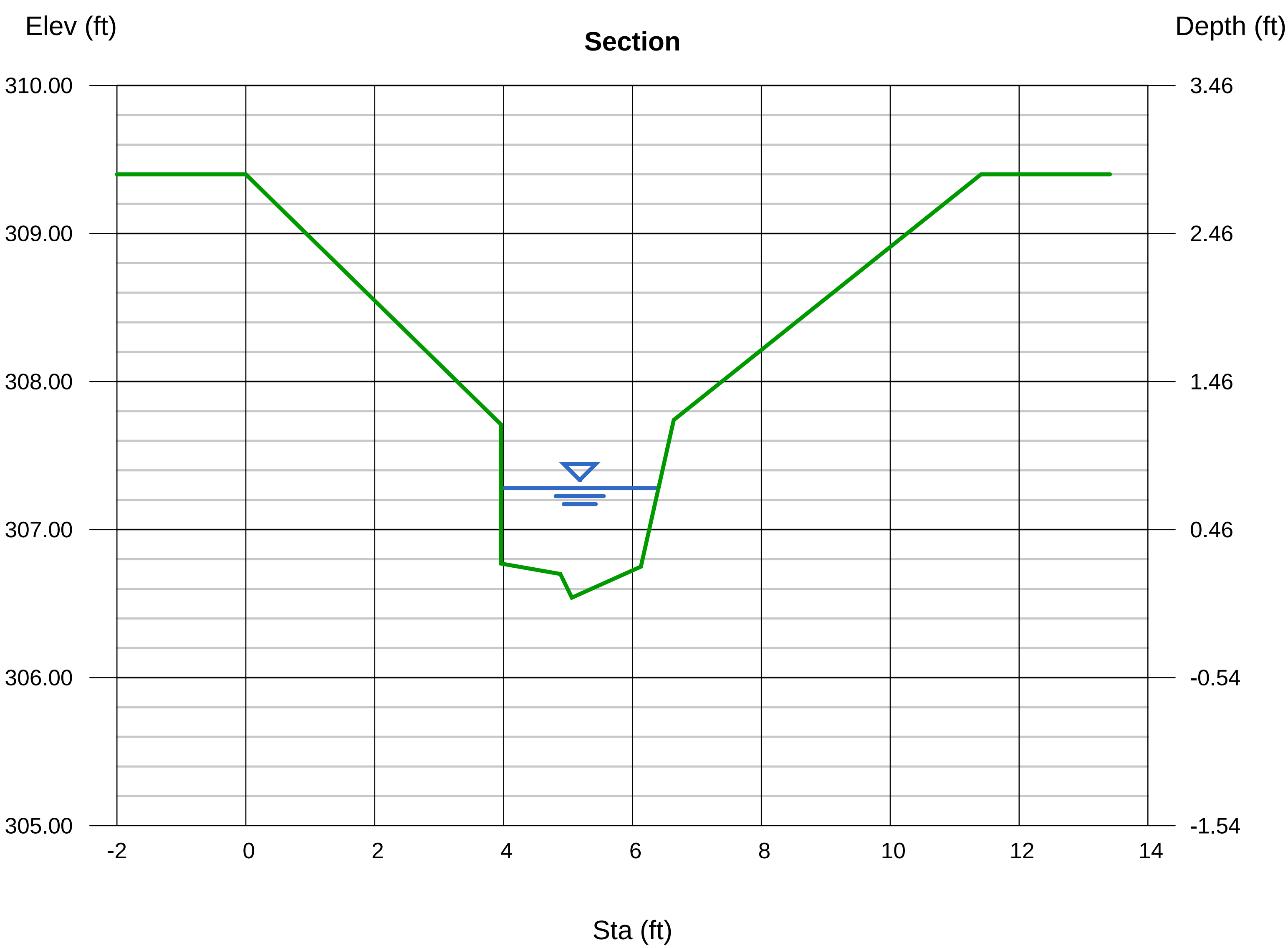
Hydraflow Express Extension for AutoCAD® Civil 3D® 2013 by Autodesk, Inc. — Thursday, Jan 24 2013

FP-17 @ Qfish

User-defined		**Highlighted**	
Invert Elev (ft)	= 306.54	Depth (ft)	= 0.74
Slope (%)	= 9.00	Q (cfs)	= 5.600
N-Value	= 0.060	Area (sqft)	= 1.37
		Velocity (ft/s)	= 4.08
Calculations		Wetted Perim (ft)	= 3.36
Compute by:	Known Q	Crit Depth, Yc (ft)	= 0.73
Known Q (cfs)	= 5.60	Top Width (ft)	= 2.44
		EGL (ft)	= 1.00

(Sta, El, n)-(Sta, El, n)...

(0.00, 309.40)-(3.96, 307.71, 0.060)-(3.96, 306.77, 0.060)-(4.88, 306.70, 0.060)-(5.06, 306.54, 0.060)-(6.13, 306.75, 0.060)-(6.64, 307.74, 0.060)
-(11.41, 309.40, 0.060)



Channel Report

Hydraflow Express Extension for AutoCAD® Civil 3D® 2013 by Autodesk, Inc. Thursday, Jan 24 2013

FP-17 @ Qfish

User-defined

Invert Elev (ft)	=	306.54
Slope (%)	=	9.00
N-Value	=	0.060

Calculations

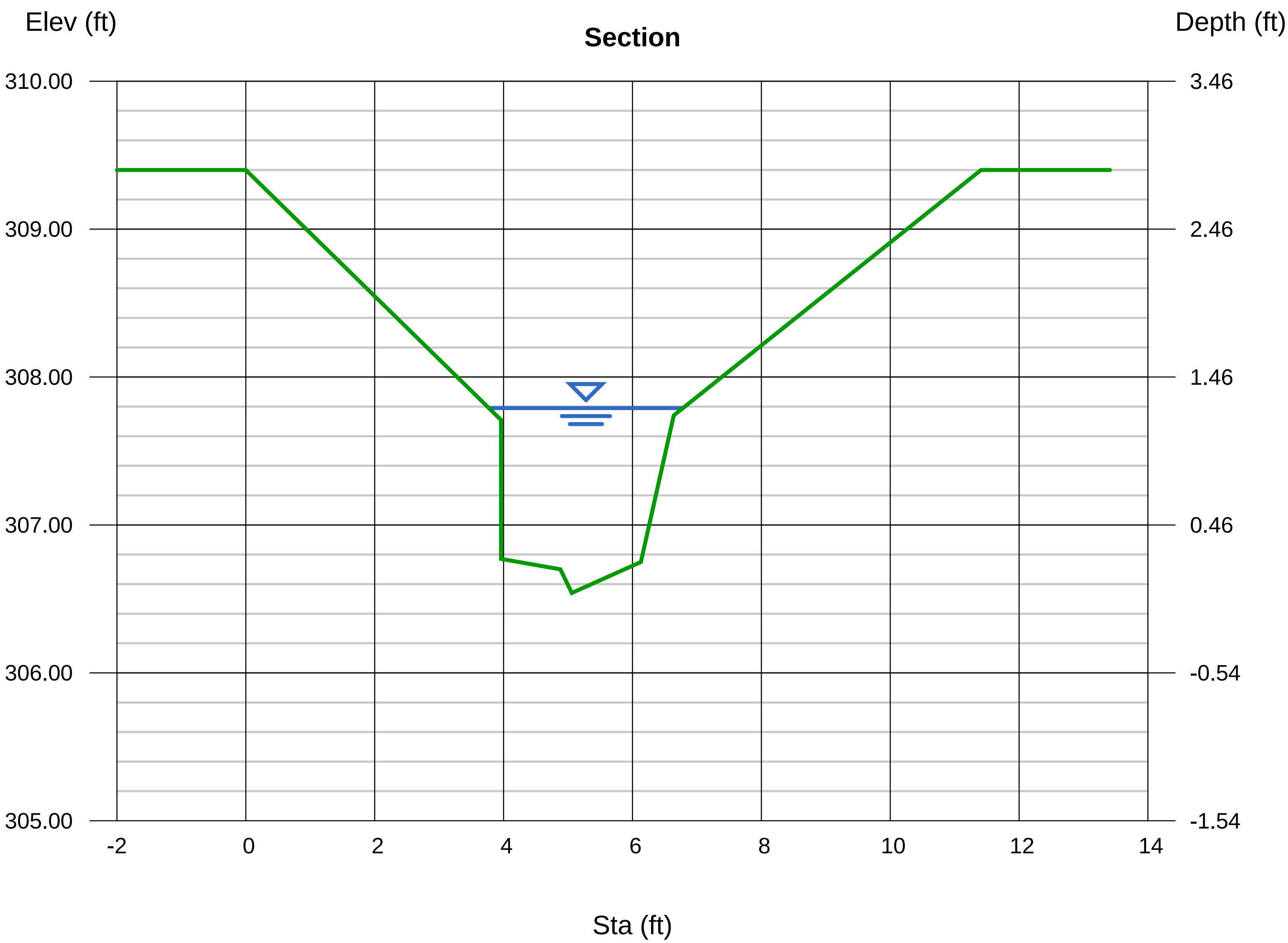
Compute by:	Known Q
Known Q (cfs)	= 13.90

Highlighted

Depth (ft)	=	1.25
Q (cfs)	=	13.90
Area (sqft)	=	2.70
Velocity (ft/s)	=	5.16
Wetted Perim (ft)	=	4.66
Crit Depth, Yc (ft)	=	1.20
Top Width (ft)	=	3.01
EGL (ft)	=	1.66

(Sta, El, n)-(Sta, El, n)...

(0.00, 309.40)-(3.96, 307.71, 0.060)-(3.96, 306.77, 0.060)-(4.88, 306.70, 0.060)-(5.06, 306.54, 0.060)-(6.13, 306.75, 0.060)-(6.64, 307.74, 0.060)
-(11.41, 309.40, 0.060)



APPENDIX C

Hydraulic Analysis

Hydraulic Analysis Summary

Stream Name/No.	MP	Proposed Structure	Length (ft)	n	Stream Slope (ft/ft)	Culvert Slope (%)	Embedment Depth	Agg. Base Layer El.	Qfish (cfs)	Q2 (cfs)	Q50 (cfs)	Q500 (cfs)	Tailwater Velocity @ Qfish (fps)	Tailwater Velocity @ Q50 (fps)	Q50 Tailwater Depth (ft)	Q50 Headwater Elevation	HW/D
FP-01	82.667	84"	86	0.04	8.60%	0.50%	2.8	78.55	20.6	51.4	111.0	158.4	3.49	5.32	3.95	70.85	1.15
FP-02	83.391	72"	79	0.06	2.10%	2.99%	2.4	66.89	2.1	5.4	11.8	16.9	1.93	2.98	1.55	63.51	0.26
FP-03	83.5	11'-10" x 7'-7"	79	0.07	1.20%	0.00%	2.0	54.57	35.0	87.4	185.4	265.2	1.49	2.42	3.02	49.96	0.84
FP-04	83.541	66"	89	0.07	0.20%	0.50%	2.2	57.04	2.9	7.2	15.8	22.6	0.65	1.06	1.83	47.83	0.55
FP-05	85.884	108"	71	0.06	2.80%	2.27%	3.6	131.99	20.2	50.5	109.2	155.7	3.32	5.31	2.35	127.88	0.58
FP-06	86.061	11'-5" x 7'-3"	101	0.07	3.00%	1.73%	2.0	87.30	25.1	62.9	135.5	193.2	2.68	4.20	2.42	73.90	0.64
FP-07	86.956	66"	89	0.06	11.40%	11.06%	2.2	117.98	6.7	16.7	36.5	52.1	3.99	6.10	1.29	114.43	0.38
FP-09	87.172	96"	97	0.07	13.60%	13.93%	3.2	121.15	17.0	42.5	92.0	131.3	4.02	7.06	1.43	117.65	0.37
FP-10	87.469	96"	80	0.05	9.70%	8.70%	3.2	127.73	19.5	48.7	105.3	150.2	5.24	9.10	1.29	121.39	0.44
FP-11	88.386	96"	89	0.06	10.90%	10.00%	3.2	229.81	12.4	30.9	66.4	95.0	3.99	7.03	1.08	225.62	0.30
FP-12	88.413	60"	77	0.06	11.40%	10.68%	2.0	228.08	4.1	10.2	22.3	31.9	2.89	4.99	0.64	223.14	0.32
FP-13	89.035	14'-3" x 9'-2"	115	0.06	6.20%	9.13%	2.0	111.43	39.8	99.4	210.8	301.5	5.25	7.96	2.79	100.83	0.73
FP-14	89.894	96"	125	0.07	12.50%	11.67%	3.2	289.75	13.0	32.5	70.5	100.6	3.76	6.31	1.59	273.15	0.30
FP-15	90.201	10'-8" x 6'-11"	100	0.062	8.90%	7.93%	2.0	329.34	26.3	65.6	138.6	198.8	4.71	7.87	1.61	319.98	0.68
FP-16	90.696	60"	82	0.08	2.00%	1.42%	2.0	331.81	2.0	4.9	10.9	15.6	0.53	0.98	2.53	323.14	0.54
FP-17	91.12	60"	90	0.06	8.80%	8.06%	2.0	317.41	5.6	13.9	30.3	43.4	4.37	6.16	1.76	312.22	0.42
C-05	88.581	48"	66	0.05	12.66%	4.27%	0	195.64	N/A	23.3	50.7	72.3	N/A	6.81	2.73	194.46	0.78
C-08	90.593	72"	77	0.06	8.52%	9.89%	0	359.63	N/A	73.6	158.5	225.9	N/A	8.87	1.75	359.33	0.88
C-12	91.860	72"	72	0.07	7.97%	6.95%	0	338.83	N/A	56.6	122.1	174.1	N/A	6.38	2.89	337.56	0.78
C-13	91.920	48"	96	0.05	2.84%	4.57%	0	336.52	N/A	26.8	58.2	83.1	N/A	8.84	1.68	325.31	0.91

AOP Structures
HY-8 Culvert Hydraulics

FP-01

HY-8 Culvert Analysis Report

Crossing Discharge Data

Discharge Selection Method: Specify Minimum, Design, and Maximum Flow

Minimum Flow: 20.6 cfs Qfish

Design Flow: 111 cfs Q50

Maximum Flow: 158.4 cfs Q500

Table 1 - Summary of Culvert Flows at Crossing: FP-01

	Headwater Elevation (ft)	Total Discharge (cfs)	FP-01 Discharge (cfs)	Roadway Discharge (cfs)	Iterations
Q_{fish}	67.53	20.60	20.60	0.00	1
	68.15	34.38	34.38	0.00	1
	68.68	48.16	48.16	0.00	1
	69.16	61.94	61.94	0.00	1
	69.62	75.72	75.72	0.00	1
	70.07	89.50	89.50	0.00	1
	70.54	103.28	103.28	0.00	1
Q_{50}	70.85	111.00	111.00	0.00	1
	71.68	130.84	130.84	0.00	1
	72.30	144.62	144.62	0.00	1
	72.94	158.40	158.40	0.00	1
Q_{500}	78.54	258.18	258.18	0.00	Overtopping

$HW = 70.85' - 66.02' = 4.83'$

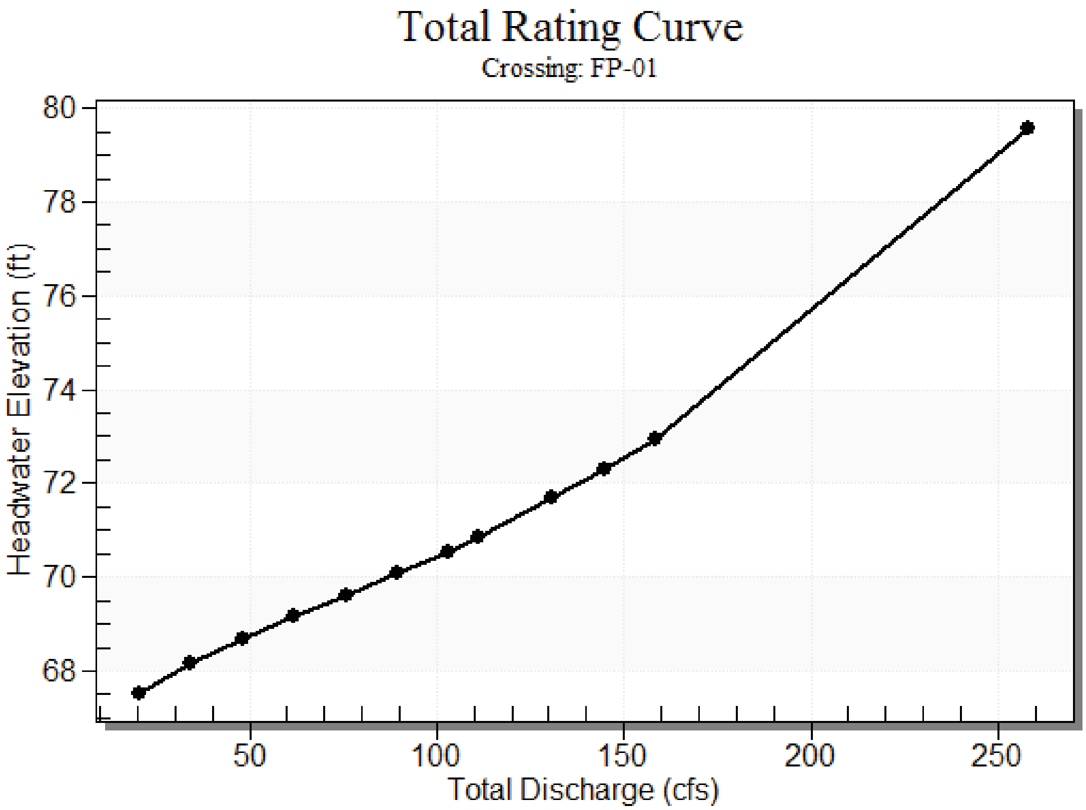
70.85': HW @ Q_{50}; 66.02': INLET ELEVATION

$D = 7' - 2.8' = 4.2'$

7': CULVERT DIAMETER; 2.8': EMBEDMENT DEPTH

$HW/D = 1.15 < 1.2$ ✓

Rating Curve Plot for Crossing: FP-01



HY-8 Analysis Results

Culvert Summary Table - FP-01

Culvert Crossing: FP-01

Total Discharge (cfs)	Culvert Discharge (cfs)	Headwater Elevation (ft)	Inlet Control Depth(ft)	Outlet Control Depth(ft)	Flow Type	Normal Depth (ft)	Critical Depth (ft)	Outlet Depth (ft)	Tailwater Depth (ft)	Outlet Velocity (ft/s)	Tailwater Velocity (ft/s)
20.60	20.60	67.53	0.85	1.51	3-M1t	1.16	0.65	1.61	1.61	1.85	3.49
34.38	34.38	68.15	1.16	2.13	3-M1t	1.63	0.92	2.14	2.14	2.35	3.99
48.16	48.16	68.68	1.46	2.66	3-M1t	2.07	1.15	2.57	2.57	2.79	4.34
61.94	61.94	69.16	1.74	3.14	3-M1t	2.52	1.36	2.93	2.93	3.21	4.62
75.72	75.72	69.62	2.01	3.60	3-M1t	3.02	1.55	3.25	3.25	3.62	4.85
89.50	89.50	70.07	2.28	4.05	3-M2t	3.81	1.72	3.54	3.54	4.03	5.05
103.28	103.28	70.54	2.54	4.52	3-M2t	4.20	1.90	3.81	3.81	4.46	5.23
111.00	111.00	70.85	2.68	4.83	3-M2t	4.20	1.98	3.95	3.95	4.71	5.32
130.84	130.84	71.68	3.04	5.66	4-FFf	4.20	2.19	4.20	4.28	5.64	5.54
144.62	144.62	72.30	3.29	6.28	4-FFf	4.20	2.34	4.20	4.50	6.23	5.67
158.40	158.40	72.94	3.54	6.92	4-FFf	4.20	2.48	4.20	4.70	6.83	5.80

****

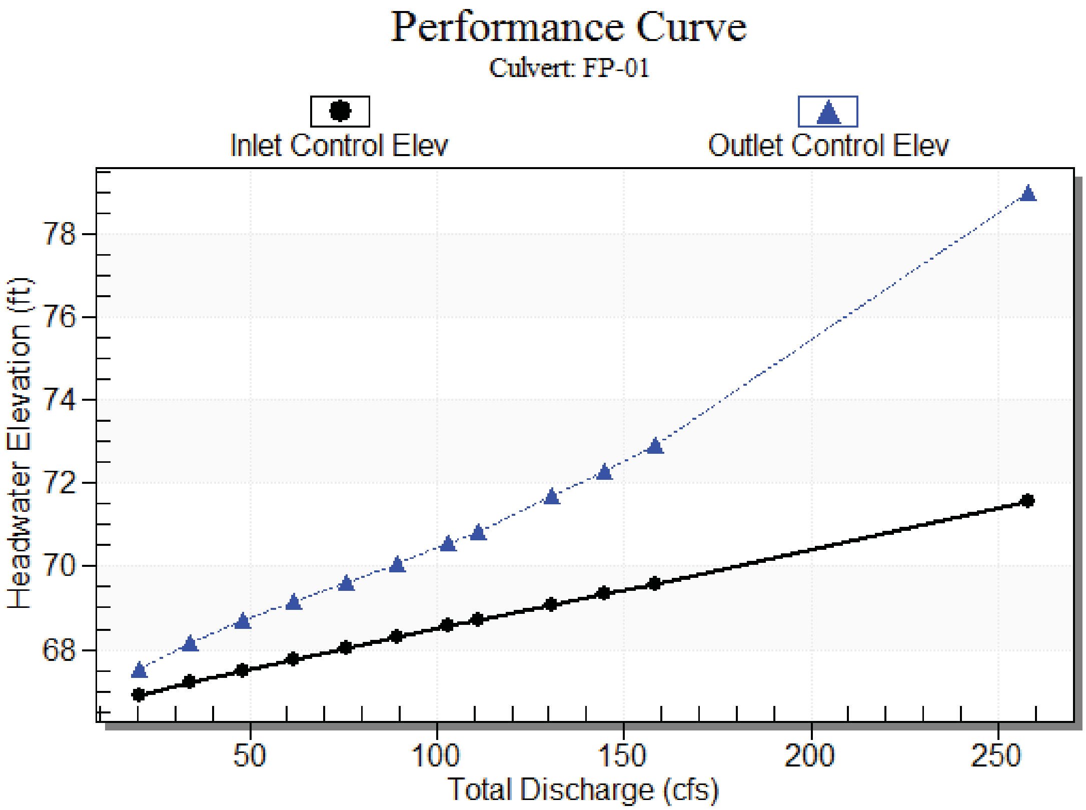
Straight Culvert

Inlet Elevation (invert): 66.03 ft,   Outlet Elevation (invert): 65.60 ft

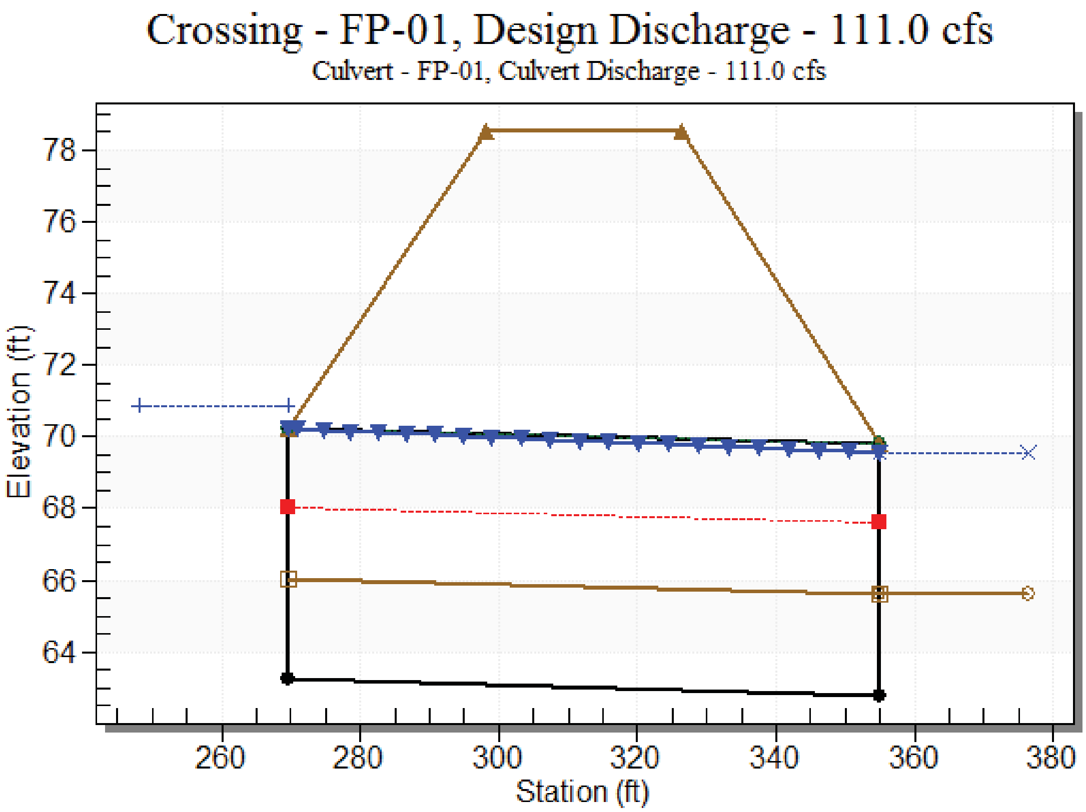
Culvert Length: 85.46 ft,   Culvert Slope: 0.0050

****

Culvert Performance Curve Plot: FP-01



Water Surface Profile Plot for Culvert: FP-01



Site Data - FP-01

Site Data Option: Culvert Invert Data

Inlet Station: 269.56 ft

Inlet Elevation: 63.23 ft

Outlet Station: 355.02 ft

Outlet Elevation: 62.80 ft

Number of Barrels: 1

Culvert Data Summary - FP-01

Barrel Shape: Circular

Barrel Diameter: 7.00 ft

Barrel Material: Corrugated Aluminum

Embedment: 33.60 in

Barrel Manning's n: 0.0310 (top and sides)

Manning's n: 0.0400 (bottom)

Culvert Type: Straight

Inlet Configuration: Mitered to Conform to Slope

Inlet Depression: NONE

Table 3 - Downstream Channel Rating Curve (Crossing: FP-01)

Flow (cfs)	Water Surface Elev (ft)	Depth (ft)	Velocity (ft/s)	Shear (psf)	Froude Number
20.60	67.21	1.61	3.49	1.01	0.55
34.38	67.74	2.14	3.99	1.34	0.56
48.16	68.17	2.57	4.34	1.60	0.57
61.94	68.53	2.93	4.62	1.83	0.57
75.72	68.85	3.25	4.85	2.03	0.58
89.50	69.14	3.54	5.05	2.21	0.58
103.28	69.41	3.81	5.23	2.38	0.58
111.00	69.55	3.95	5.32	2.46	0.58
130.84	69.88	4.28	5.54	2.67	0.59
144.62	70.10	4.50	5.67	2.81	0.59
158.40	70.30	4.70	5.80	2.93	0.59

Tailwater Channel Data - FP-01

Tailwater Channel Option: Trapezoidal Channel

Bottom Width: 2.52 ft

Side Slope (H:V): 0.70 (_:1)

Channel Slope: 0.0100

Channel Manning's n: 0.0400

Channel Invert Elevation: 65.60 ft

Roadway Data for Crossing: FP-01

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 100.00 ft

Crest Elevation: 78.55 ft

Roadway Surface: Paved

Roadway Top Width: 28.00 ft

FP-02

Crossing Discharge Data

Discharge Selection Method: Specify Minimum, Design, and Maximum Flow

Minimum Flow: 2.1 cfs — Q_{fish}

Design Flow: 11.8 cfs — Q_{50}

Maximum Flow: 16.9 cfs - Q_{500}

Table 4 - Summary of Culvert Flows at Crossing: FP-02

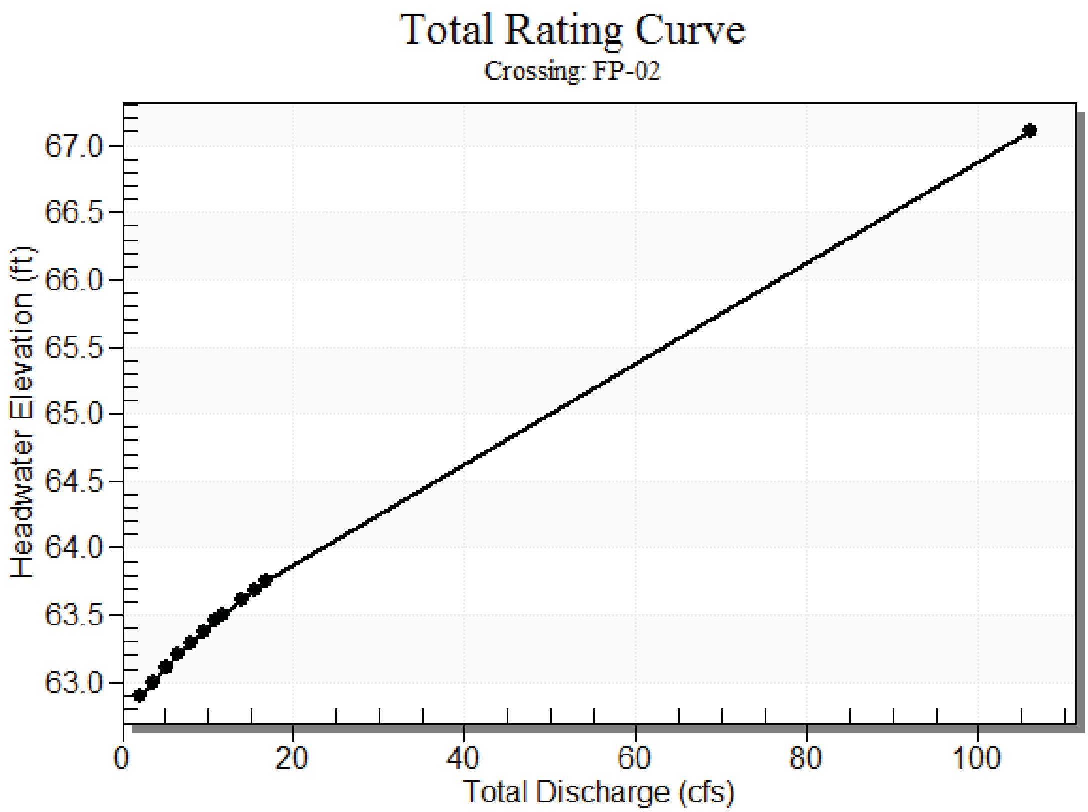
	Headwater Elevation (ft)	Total Discharge (cfs)	FP-02 Discharge (cfs)	Roadway Discharge (cfs)	Iterations
Q_2	62.91	2.10	2.10	0.00	1
	63.00	3.58	3.58	0.00	1
	63.11	5.06	5.06	0.00	1
	63.21	6.54	6.54	0.00	1
	63.30	8.02	8.02	0.00	1
	63.38	9.50	9.50	0.00	1
	63.46	10.98	10.98	0.00	1
Q_{50}	63.51	11.80	11.80	0.00	1
	63.61	13.94	13.94	0.00	1
	63.69	15.42	15.42	0.00	1
	63.75	16.90	16.90	0.00	1
Q_{500}	66.89	106.05	106.05	0.00	Overtopping

$$HW = \underbrace{63.51'}_{@\ Q_{50}} - \underbrace{62.58'}_{\text{INLET}} = 0.93'$$

$$D = \underbrace{6'}_{\varnothing} - \underbrace{2.4'}_{\text{EMBED}} = 3.6'$$

$$HW/D = 0.26 < 1.5 \ \checkmark$$

Rating Curve Plot for Crossing: FP-02



HY-8 Analysis Results

Culvert Summary Table - FP-02

Culvert Crossing: FP-02

Total Discharge (cfs)	Culvert Discharge (cfs)	Headwater Elevation (ft)	Inlet Control Depth(ft)	Outlet Control Depth(ft)	Flow Type	Normal Depth (ft)	Critical Depth (ft)	Outlet Depth (ft)	Tailwater Depth (ft)	Outlet Velocity (ft/s)	Tailwater Velocity (ft/s)
2.10	2.10	62.89	0.33~	0.30	3-M1t	0.18	0.15	0.78	0.81	0.45	1.93
3.58	3.58	62.98	0.37	0.42	3-M1t	0.30	0.22	0.96	0.99	0.63	2.21
5.06	5.06	63.09	0.42	0.53	3-M1t	0.37	0.28	1.10	1.13	0.78	2.41
6.54	6.54	63.19	0.46	0.63	3-M1t	0.43	0.33	1.21	1.24	0.91	2.57
8.02	8.02	63.28	0.51	0.72	3-M1t	0.49	0.38	1.31	1.34	1.03	2.70
9.50	9.50	63.36	0.55	0.80	3-M1t	0.55	0.42	1.40	1.43	1.15	2.82
10.98	10.98	63.44	0.60	0.88	3-M1t	0.61	0.47	1.48	1.51	1.26	2.92
11.80	11.80	63.49	0.62	0.93	3-M1t	0.64	0.49	1.52	1.55	1.31	2.98
13.94	13.94	63.59	0.68	1.03	3-M1t	0.70	0.55	1.62	1.65	1.46	3.10
15.42	15.42	63.67	0.73	1.11	3-M1t	0.75	0.59	1.68	1.71	1.56	3.18
16.90	16.90	63.73	0.77	1.17	3-M1t	0.79	0.63	1.74	1.77	1.65	3.26

****

Straight Culvert

Inlet Elevation (invert): 62.58 ft,   Outlet Elevation (invert): 60.23 ft

Culvert Length: 78.64 ft,   Culvert Slope: 0.0299

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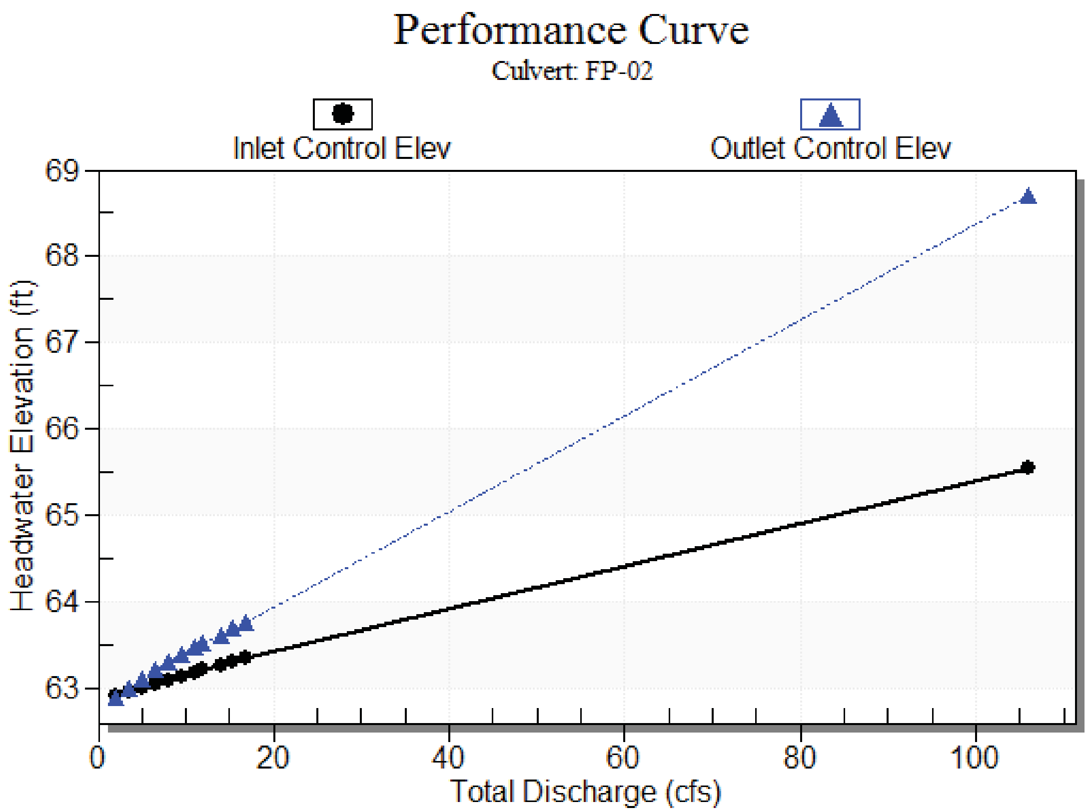
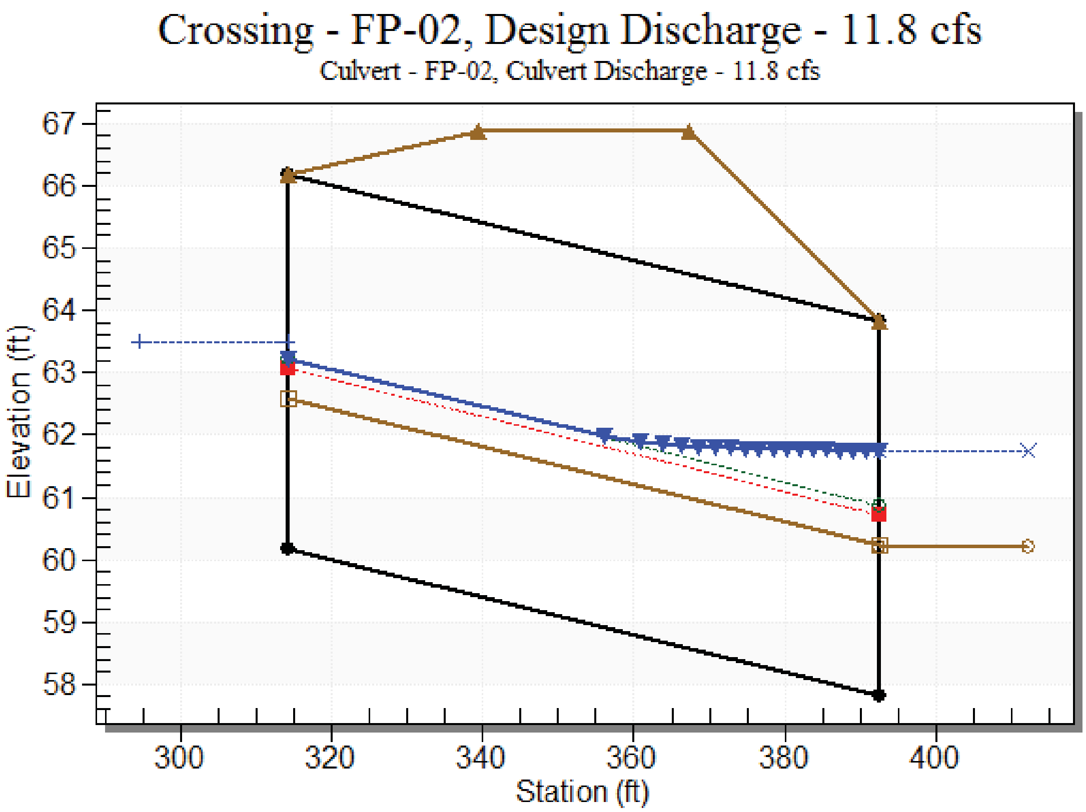
Culvert Performance Curve Plot: FP-02



Water Surface Profile Plot for Culvert: FP-02



Site Data - FP-02

Site Data Option: Culvert Invert Data

Inlet Station: 314.08 ft

Inlet Elevation: 60.18 ft

Outlet Station: 392.68 ft

Outlet Elevation: 57.83 ft

Number of Barrels: 1

Culvert Data Summary - FP-02

Barrel Shape: Circular

Barrel Diameter: 6.00 ft

Barrel Material: Corrugated Aluminum

Embedment: 28.80 in

Barrel Manning's n: 0.0310 (top and sides)

Manning's n: 0.0600 (bottom)

Culvert Type: Straight

Inlet Configuration: Mitered to Conform to Slope

Inlet Depression: NONE

Table 6 - Downstream Channel Rating Curve (Crossing: FP-02)

Flow (cfs)	Water Surface Elev (ft)	Depth (ft)	Velocity (ft/s)	Shear (psf)	Froude Number
2.10	61.01	0.81	1.93	1.27	0.53
3.58	61.19	0.99	2.21	1.55	0.55
5.06	61.33	1.13	2.41	1.76	0.57
6.54	61.44	1.24	2.57	1.94	0.57
8.02	61.54	1.34	2.70	2.09	0.58
9.50	61.63	1.43	2.82	2.23	0.59
10.98	61.71	1.51	2.92	2.35	0.59
11.80	61.75	1.55	2.98	2.42	0.60
13.94	61.85	1.65	3.10	2.57	0.60
15.42	61.91	1.71	3.18	2.67	0.61
16.90	61.97	1.77	3.26	2.77	0.61

Tailwater Channel Data - FP-02

Tailwater Channel Option: Triangular Channel

Side Slope (H:V): 1.65 (_:1)

Channel Slope: 0.0250

Channel Manning's n: 0.0600

Channel Invert Elevation: 60.20 ft

Roadway Data for Crossing: FP-02

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 100.00 ft

Crest Elevation: 66.89 ft

Roadway Surface: Paved

Roadway Top Width: 28.00 ft

FP-03

Crossing Discharge Data

Discharge Selection Method: Specify Minimum, Design, and Maximum Flow

Minimum Flow: 35 cfs – Q_{fish}

Design Flow: 185.4 cfs – Q_{50}

Maximum Flow: 265.2 cfs – Q_{500}

Table 7 - Summary of Culvert Flows at Crossing: FP-03

	Headwater Elevation (ft)	Total Discharge (cfs)	FP-03 Discharge (cfs)	Roadway Discharge (cfs)	Iterations
Q_2	47.09	35.00	35.00	0.00	1
	47.66	58.02	58.02	0.00	1
	48.15	81.04	81.04	0.00	1
	48.59	104.06	104.06	0.00	1
	49.00	127.08	127.08	0.00	1
	49.39	150.10	150.10	0.00	1
	49.76	173.12	173.12	0.00	1
Q_{50} —	49.96	185.40	185.40	0.00	1
	50.50	219.16	219.16	0.00	1
	50.87	242.18	242.18	0.00	1
	51.25	265.20	265.20	0.00	1
Q_{500}	54.57	522.51	522.51	0.00	Overtopping

$HW = 49.96' - 45.27' = 4.69'$

(49.96' @ Q_{50}; 45.27' INLET)

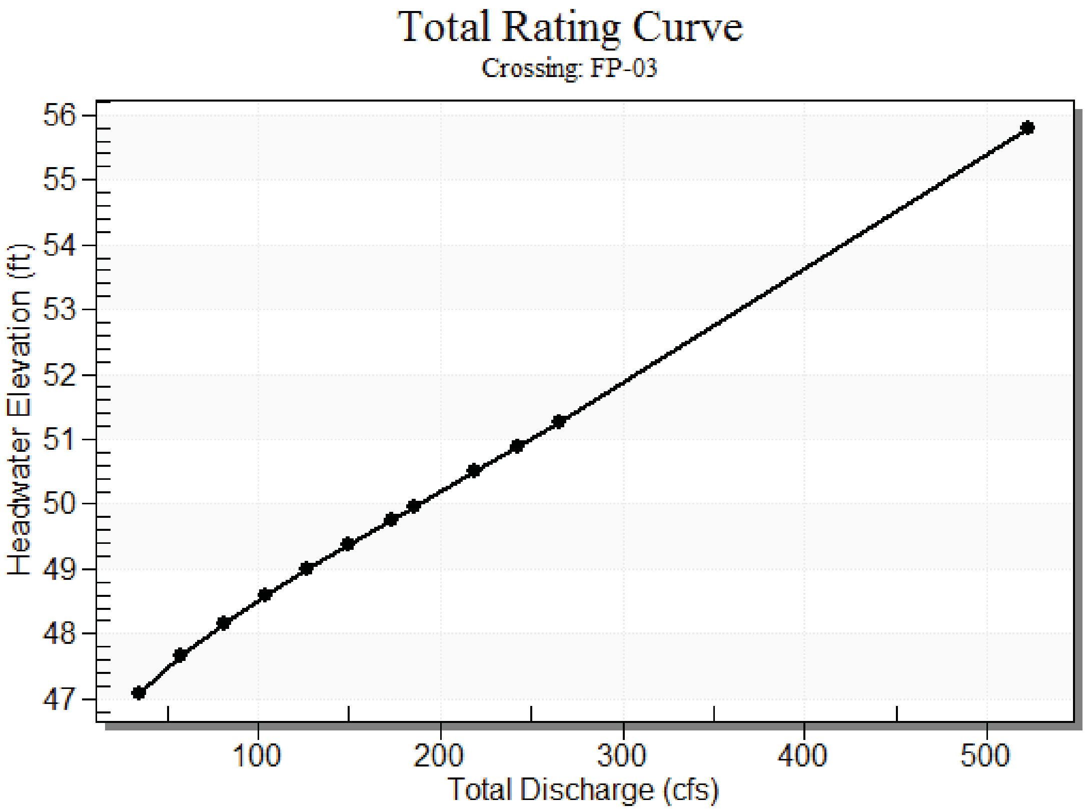
$D = 7.7' - 2' = 5.7'$

(7.7' CULVERT RISE; 2' EMBED)

$HW/D = 0.82 < 1.2$ ✓

NOTE THAT SUMMARY DISPLAYS HW/D = 0.84. THIS IS A RESULT OF ROUNDING IN THE SPREADSHEET.

Rating Curve Plot for Crossing: FP-03



HY-8 Analysis Results

Culvert Summary Table - FP-03

Culvert Crossing: FP-03

Total Discharge (cfs)	Culvert Discharge (cfs)	Headwater Elevation (ft)	Inlet Control Depth(ft)	Outlet Control Depth(ft)	Flow Type	Normal Depth (ft)	Critical Depth (ft)	Outlet Depth (ft)	Tailwater Depth (ft)	Outlet Velocity (ft/s)	Tailwater Velocity (ft/s)
35.00	35.00	47.09	1.22	1.82	8-H2t	NA	0.64	1.26	1.26	2.39	1.49
58.02	58.02	47.65	1.71	2.38	8-H2t	NA	0.90	1.65	1.65	3.04	1.74
81.04	81.04	48.14	2.13	2.87	8-H2t	NA	1.14	1.98	1.98	3.58	1.92
104.06	104.06	48.58	2.53	3.31	8-H2t	NA	1.35	2.25	2.25	4.06	2.06
127.08	127.08	48.98	2.88	3.71	8-H2t	NA	1.54	2.50	2.50	4.50	2.18
150.10	150.10	49.37	3.19	4.10	8-H2t	NA	1.72	2.72	2.72	4.92	2.28
173.12	173.12	49.74	3.49	4.47	8-H2t	NA	1.89	2.92	2.92	5.32	2.37
185.40	185.40	49.94	3.66	4.67	8-H2t	NA	1.98	3.02	3.02	5.53	2.42
219.16	219.16	50.48	4.11	5.21	8-H2t	NA	2.21	3.29	3.29	6.08	2.53
242.18	242.18	50.84	4.42	5.57	8-H2t	NA	2.37	3.45	3.45	6.44	2.60
265.20	265.20	51.22	4.71	5.95	8-H2t	NA	2.51	3.61	3.61	6.80	2.67

****

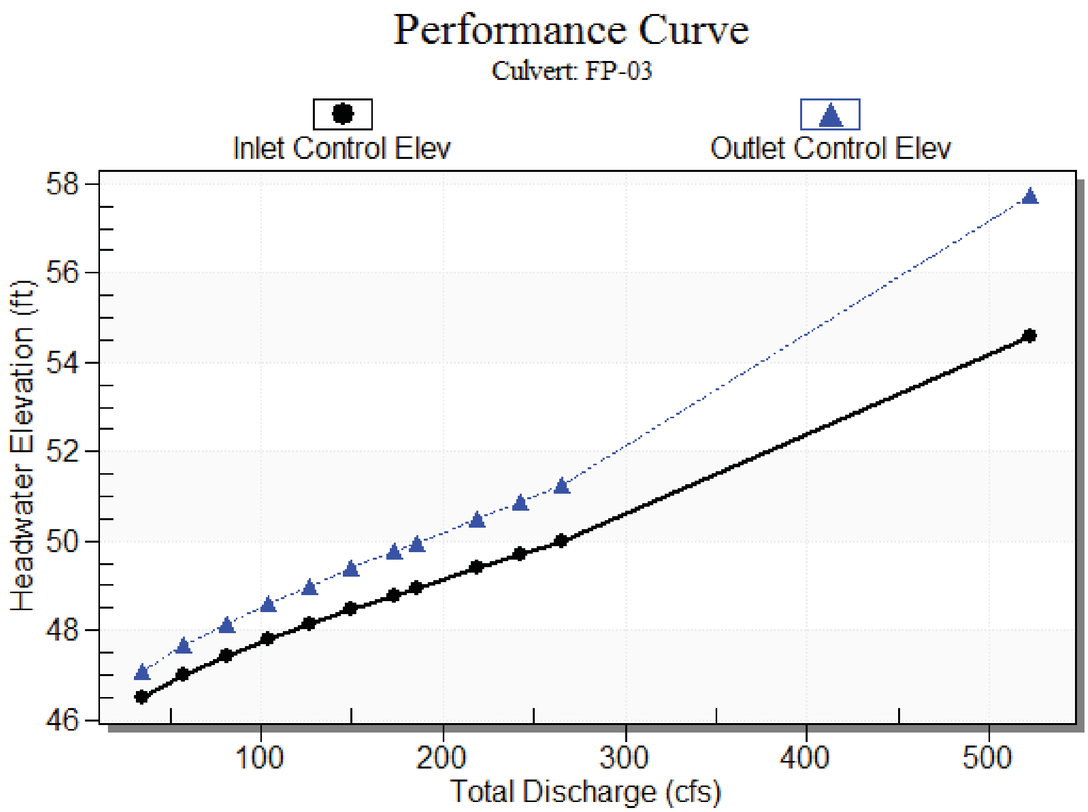
Straight Culvert

Inlet Elevation (invert): 45.27 ft,   Outlet Elevation (invert): 45.27 ft

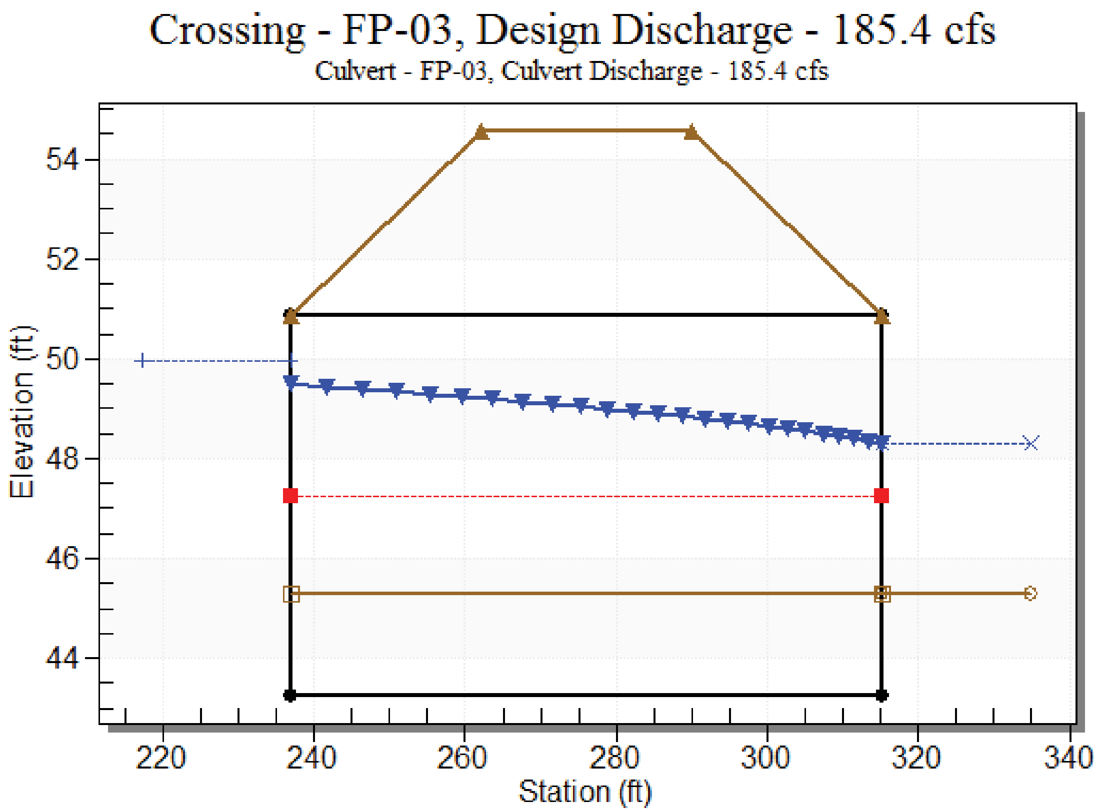
Culvert Length: 78.39 ft,   Culvert Slope: 0.0000

****

Culvert Performance Curve Plot: FP-03



Water Surface Profile Plot for Culvert: FP-03



Site Data - FP-03

Site Data Option: Culvert Invert Data

Inlet Station: 236.88 ft

Inlet Elevation: 43.27 ft

Outlet Station: 315.27 ft

Outlet Elevation: 43.27 ft

Number of Barrels: 1

Culvert Data Summary - FP-03

Barrel Shape: Pipe Arch

Barrel Span: 141.80 in

Barrel Rise: 91.30 in

Barrel Material: Steel Structural Plate

Embedment: 24.00 in

Barrel Manning's n: 0.0330 (top and sides)

Manning's n: 0.0700 (bottom)

Culvert Type: Straight

Inlet Configuration: Mitered

Inlet Depression: NONE

Table 9 - Downstream Channel Rating Curve (Crossing: FP-03)

Flow (cfs)	Water Surface Elev (ft)	Depth (ft)	Velocity (ft/s)	Shear (psf)	Froude Number
35.00	46.53	1.26	1.49	0.39	0.26
58.02	46.92	1.65	1.74	0.52	0.27
81.04	47.25	1.98	1.92	0.62	0.28
104.06	47.52	2.25	2.06	0.70	0.28
127.08	47.77	2.50	2.18	0.78	0.29
150.10	47.99	2.72	2.28	0.85	0.29
173.12	48.19	2.92	2.37	0.91	0.29
185.40	48.29	3.02	2.42	0.94	0.29
219.16	48.56	3.29	2.53	1.03	0.30
242.18	48.72	3.45	2.60	1.08	0.30
265.20	48.88	3.61	2.67	1.13	0.30

Tailwater Channel Data - FP-03

Tailwater Channel Option: Trapezoidal Channel

Bottom Width: 14.00 ft

Side Slope (H:V): 3.75 (_:1)

Channel Slope: 0.0050

Channel Manning's n: 0.0700

Channel Invert Elevation: 45.27 ft

Roadway Data for Crossing: FP-03

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 100.00 ft

Crest Elevation: 54.57 ft

Roadway Surface: Paved

Roadway Top Width: 28.00 ft

FP-04

Crossing Discharge Data

Discharge Selection Method: Specify Minimum, Design, and Maximum Flow

Minimum Flow: 2.9 cfs — Q_{fish}

Design Flow: 15.8 cfs — Q_{50}

Maximum Flow: 22.6 cfs — Q_{500}

Table 10 - Summary of Culvert Flows at Crossing: FP-04

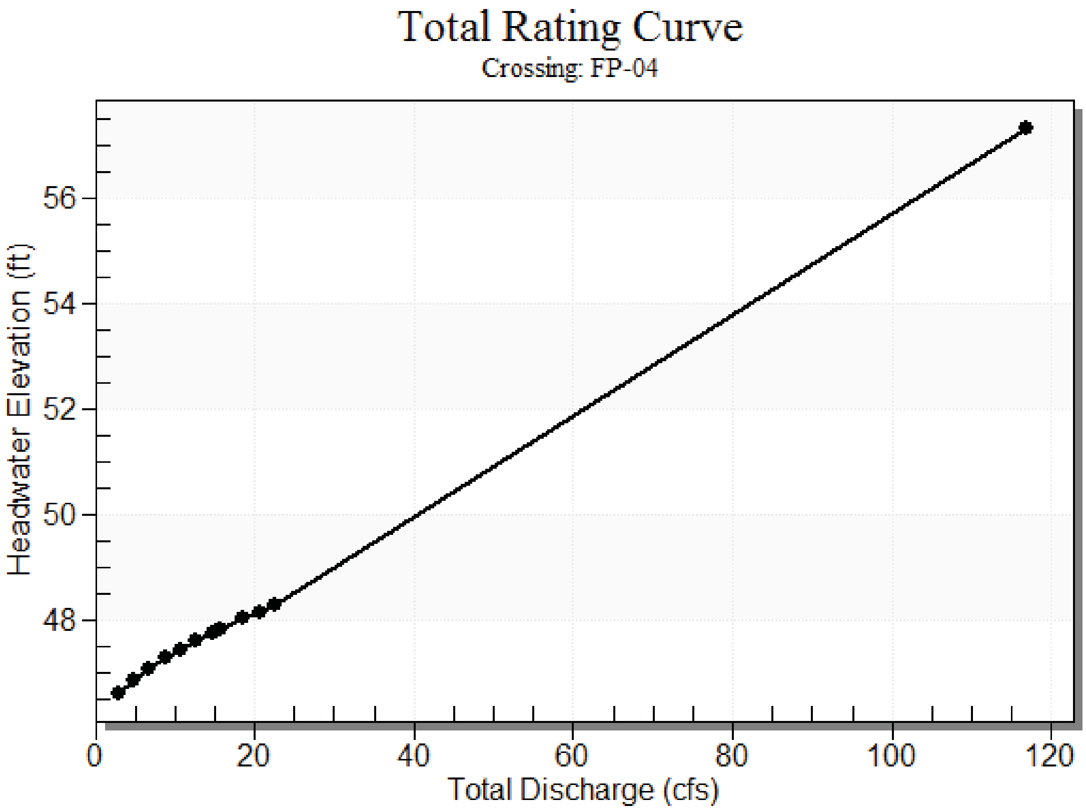
	Headwater Elevation (ft)	Total Discharge (cfs)	FP-04 Discharge (cfs)	Roadway Discharge (cfs)	Iterations
Q_{fish}	46.63	2.90	2.90	0.00	1
	46.87	4.87	4.87	0.00	1
	47.08	6.84	6.84	0.00	1
	47.27	8.81	8.81	0.00	1
	47.44	10.78	10.78	0.00	1
	47.60	12.75	12.75	0.00	1
	47.75	14.72	14.72	0.00	1
Q_{50}	47.83	15.80	15.80	0.00	1
	48.03	18.66	18.66	0.00	1
	48.16	20.63	20.63	0.00	1
	48.28	22.60	22.60	0.00	1
Q_{500}	57.03	117.23	117.23	0.00	Overtopping

HW = 47.83' (@ Q_{50}) − 46.03' (INLET) = 1.8'

D = 5.5' (Ø) − 2.2' (EMBED) = 3.3'

HW/D = 0.55 < 1.5 ✓

Rating Curve Plot for Crossing: FP-04



HY-8 Analysis Results

Culvert Summary Table - FP-04

Culvert Crossing: FP-04

Total Discharge (cfs)	Culvert Discharge (cfs)	Headwater Elevation (ft)	Inlet Control Depth(ft)	Outlet Control Depth(ft)	Flow Type	Normal Depth (ft)	Critical Depth (ft)	Outlet Depth (ft)	Tailwater Depth (ft)	Outlet Velocity (ft/s)	Tailwater Velocity (ft/s)
2.90	2.90	46.63	0.38	0.60	3-M1t	0.53	0.20	0.75	0.74	0.71	0.65
4.87	4.87	46.87	0.45	0.84	3-M1t	0.73	0.29	1.00	0.99	0.90	0.76
6.84	6.84	47.08	0.52	1.05	3-M1t	0.92	0.36	1.20	1.19	1.05	0.84
8.81	8.81	47.27	0.59	1.24	3-M1t	1.07	0.43	1.37	1.36	1.19	0.90
10.78	10.78	47.44	0.65	1.41	3-M1t	1.22	0.49	1.52	1.51	1.32	0.95
12.75	12.75	47.60	0.72	1.57	3-M1t	1.36	0.55	1.65	1.64	1.44	1.00
14.72	14.72	47.75	0.78	1.72	3-M1t	1.50	0.60	1.78	1.77	1.55	1.04
15.80	15.80	47.83	0.82	1.80	3-M1t	1.57	0.64	1.84	1.83	1.61	1.06
18.66	18.66	48.03	0.91	2.00	3-M1t	1.77	0.72	2.00	1.99	1.77	1.11
20.63	20.63	48.16	0.97	2.13	3-M1t	1.90	0.77	2.10	2.09	1.87	1.14
22.60	22.60	48.28	1.03	2.25	3-M1t	2.04	0.82	2.20	2.19	1.97	1.16

****

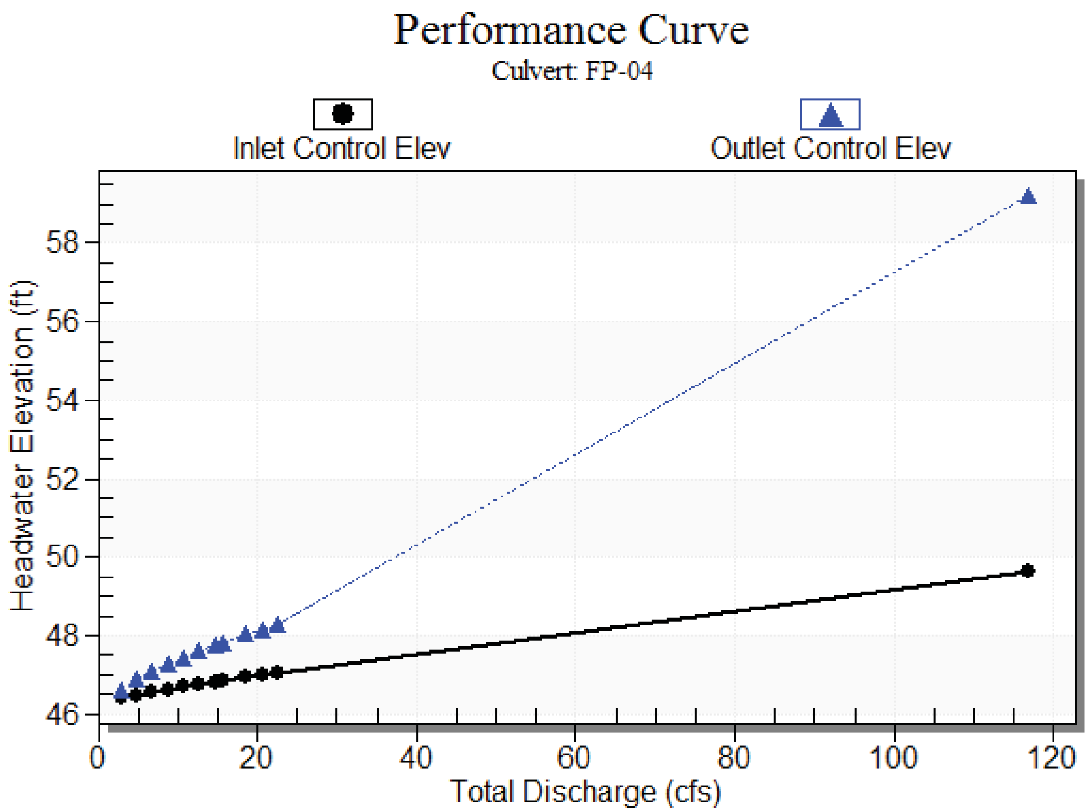
Straight Culvert

Inlet Elevation (invert): 46.03 ft,   Outlet Elevation (invert): 45.59 ft

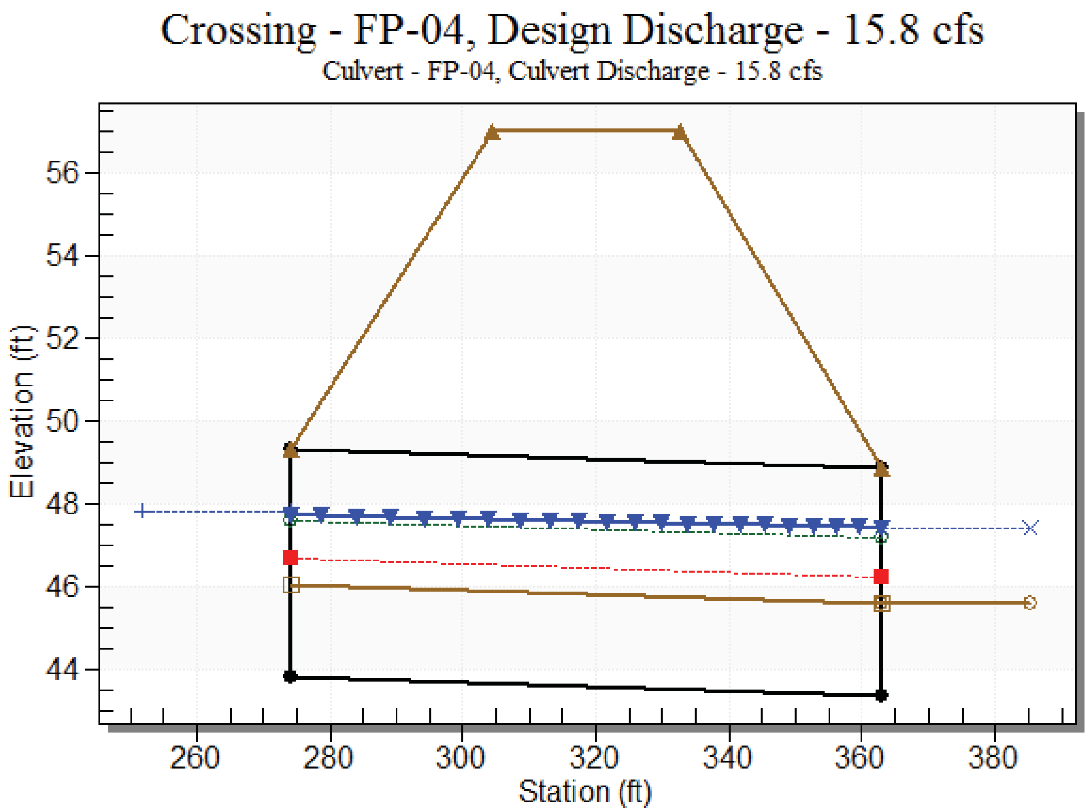
Culvert Length: 88.95 ft,   Culvert Slope: 0.0049

****

Culvert Performance Curve Plot: FP-04



Water Surface Profile Plot for Culvert: FP-04



Site Data - FP-04

Site Data Option: Culvert Invert Data

Inlet Station: 274.10 ft

Inlet Elevation: 43.83 ft

Outlet Station: 363.05 ft

Outlet Elevation: 43.39 ft

Number of Barrels: 1

Culvert Data Summary - FP-04

Barrel Shape: Circular

Barrel Diameter: 5.50 ft

Barrel Material: Corrugated Aluminum

Embedment: 26.40 in

Barrel Manning's n: 0.0310 (top and sides)

Manning's n: 0.0700 (bottom)

Culvert Type: Straight

Inlet Configuration: Mitered to Conform to Slope

Inlet Depression: NONE

Table 12 - Downstream Channel Rating Curve (Crossing: FP-04)

Flow (cfs)	Water Surface Elev (ft)	Depth (ft)	Velocity (ft/s)	Shear (psf)	Froude Number
2.90	46.34	0.74	0.65	0.09	0.15
4.87	46.59	0.99	0.76	0.12	0.15
6.84	46.79	1.19	0.84	0.15	0.16
8.81	46.96	1.36	0.90	0.17	0.16
10.78	47.11	1.51	0.95	0.19	0.16
12.75	47.24	1.64	1.00	0.20	0.16
14.72	47.37	1.77	1.04	0.22	0.17
15.80	47.43	1.83	1.06	0.23	0.17
18.66	47.59	1.99	1.11	0.25	0.17
20.63	47.69	2.09	1.14	0.26	0.17
22.60	47.79	2.19	1.16	0.27	0.17

Tailwater Channel Data - FP-04

Tailwater Channel Option: Trapezoidal Channel

Bottom Width: 4.50 ft

Side Slope (H:V): 2.00 (_:1)

Channel Slope: 0.0020

Channel Manning's n: 0.0700

Channel Invert Elevation: 45.60 ft

Roadway Data for Crossing: FP-04

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 100.00 ft

Crest Elevation: 57.04 ft

Roadway Surface: Paved

Roadway Top Width: 28.00 ft

FP-05

Crossing Discharge Data

Discharge Selection Method: Specify Minimum, Design, and Maximum Flow

Minimum Flow: 20.2 cfs — Q_{fish}

Design Flow: 109.2 cfs — Q_{50}

Maximum Flow: 155.7 cfs — Q_{500}

Table 13 - Summary of Culvert Flows at Crossing: FP-05

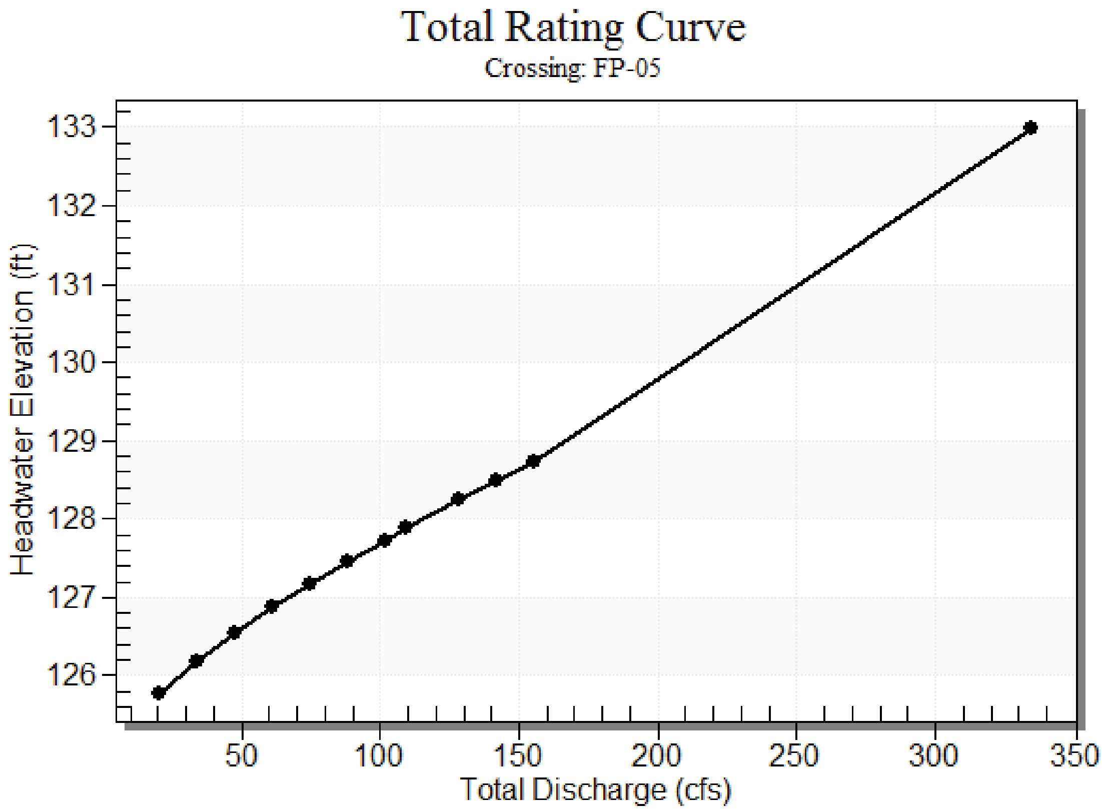
	Headwater Elevation (ft)	Total Discharge (cfs)	FP-05 Discharge (cfs)	Roadway Discharge (cfs)	Iterations
Q_2	125.78	20.20	20.20	0.00	1
	126.19	33.75	33.75	0.00	1
	126.55	47.30	47.30	0.00	1
	126.87	60.85	60.85	0.00	1
	127.17	74.40	74.40	0.00	1
	127.45	87.95	87.95	0.00	1
	127.73	101.50	101.50	0.00	1
Q_{50} —	127.88	109.20	109.20	0.00	1
	128.25	128.60	128.60	0.00	1
	128.50	142.15	142.15	0.00	1
	128.74	155.70	155.70	0.00	1
Q_{500}	131.99	334.75	334.75	0.00	Overtopping

$HW = \underbrace{127.88'}_{@\ Q_{50}} - \underbrace{124.76'}_{\text{INLET}} = 3.12'$

$D = \underbrace{9'}_{\phi} - \underbrace{3.6'}_{\text{EMBED}} = 5.4'$

$HW/D = 0.58 < 1.2$ ✓

Rating Curve Plot for Crossing: FP-05



HY-8 Analysis Results

Culvert Summary Table - FP-05

Culvert Crossing: FP-05

Total Discharge (cfs)	Culvert Discharge (cfs)	Headwater Elevation (ft)	Inlet Control Depth(ft)	Outlet Control Depth(ft)	Flow Type	Normal Depth (ft)	Critical Depth (ft)	Outlet Depth (ft)	Tailwater Depth (ft)	Outlet Velocity (ft/s)	Tailwater Velocity (ft/s)
20.20	20.20	125.83	0.77	1.10	3-M1t	0.80	0.58	0.98	0.97	2.59	3.32
33.75	33.75	126.27	1.03	1.54	3-M1t	1.10	0.82	1.30	1.29	3.28	3.85
47.30	47.30	126.66	1.27	1.93	3-M1t	1.37	1.04	1.55	1.54	3.86	4.23
60.85	60.85	127.01	1.51	2.28	3-M1t	1.60	1.23	1.76	1.75	4.37	4.54
74.40	74.40	127.34	1.75	2.61	3-M1t	1.83	1.40	1.95	1.94	4.83	4.79
87.95	87.95	127.66	1.97	2.93	3-M1t	2.05	1.57	2.12	2.11	5.27	5.01
101.50	101.50	127.96	2.19	3.23	3-M1t	2.26	1.72	2.28	2.27	5.68	5.21
109.20	109.20	128.13	2.31	3.40	3-M2t	2.38	1.80	2.36	2.35	5.91	5.31
128.60	128.60	128.54	2.62	3.81	3-M2t	2.67	2.01	2.56	2.55	6.46	5.54
142.15	142.15	128.82	2.83	4.09	3-M2t	2.88	2.14	2.69	2.68	6.83	5.69
155.70	155.70	129.11	3.03	4.38	3-M2t	3.10	2.27	2.81	2.80	7.19	5.83

****

Straight Culvert

Inlet Elevation (invert): 124.76 ft,   Outlet Elevation (invert): 123.16 ft

Culvert Length: 70.55 ft,   Culvert Slope: 0.0227

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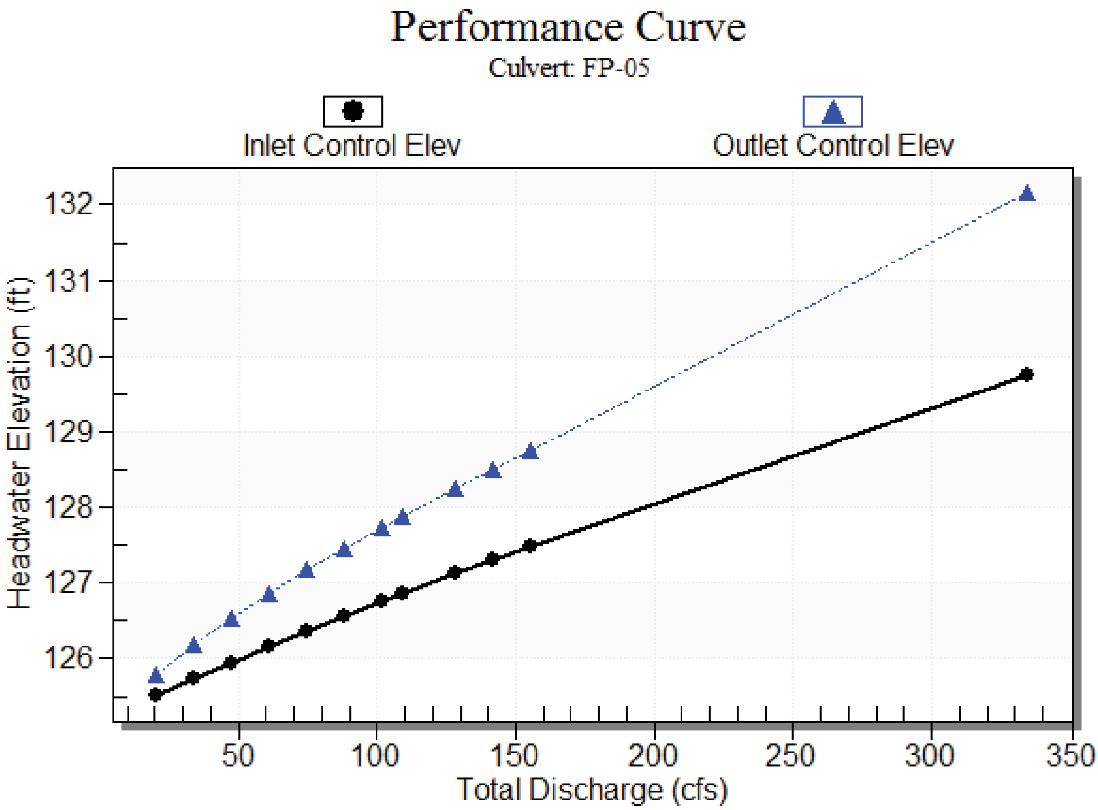
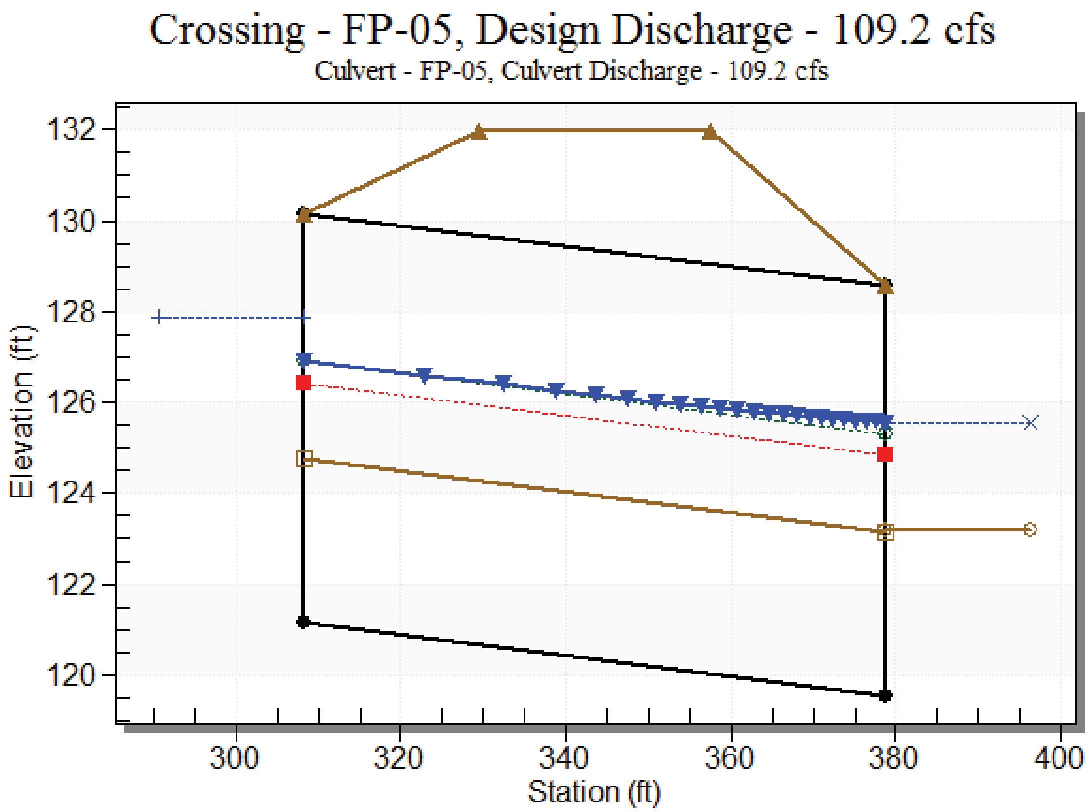
Culvert Performance Curve Plot: FP-05



Water Surface Profile Plot for Culvert: FP-05



Site Data - FP-05

Site Data Option: Culvert Invert Data

Inlet Station: 308.24 ft

Inlet Elevation: 121.16 ft

Outlet Station: 378.77 ft

Outlet Elevation: 119.56 ft

Number of Barrels: 1

Culvert Data Summary - FP-05

Barrel Shape: Circular

Barrel Diameter: 9.00 ft

Barrel Material: Corrugated Aluminum

Embedment: 43.20 in

Barrel Manning's n: 0.0310 (top and sides)

Manning's n: 0.0600 (bottom)

Culvert Type: Straight

Inlet Configuration: Mitered to Conform to Slope

Inlet Depression: NONE

Table 15 - Downstream Channel Rating Curve (Crossing: FP-05)

Flow (cfs)	Water Surface Elev (ft)	Depth (ft)	Velocity (ft/s)	Shear (psf)	Froude Number
20.20	124.17	0.97	3.32	1.70	0.67
33.75	124.49	1.29	3.85	2.25	0.69
47.30	124.74	1.54	4.23	2.69	0.71
60.85	124.95	1.75	4.54	3.06	0.72
74.40	125.14	1.94	4.79	3.39	0.73
87.95	125.31	2.11	5.01	3.69	0.73
101.50	125.47	2.27	5.21	3.97	0.74
109.20	125.55	2.35	5.31	4.11	0.74
128.60	125.75	2.55	5.54	4.46	0.75
142.15	125.88	2.68	5.69	4.68	0.75
155.70	126.00	2.80	5.83	4.89	0.76

Tailwater Channel Data - FP-05

Tailwater Channel Option: Trapezoidal Channel

Bottom Width: 4.50 ft

Side Slope (H:V): 1.80 (_:1)

Channel Slope: 0.0280

Channel Manning's n: 0.0600

Channel Invert Elevation: 123.20 ft

Roadway Data for Crossing: FP-05

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 100.00 ft

Crest Elevation: 131.99 ft

Roadway Surface: Paved

Roadway Top Width: 28.00 ft

FP-06

HY-8 Culvert Analysis Report

Crossing Discharge Data

Discharge Selection Method: Specify Minimum, Design, and Maximum Flow

Minimum Flow: 25.1 cfs ← Qfish

Design Flow: 135.5 cfs — Q_{50}

Maximum Flow: 193.2 cfs — Q_{500}

Table 16 - Summary of Culvert Flows at Crossing: FP-06

	Headwater Elevation (ft)	Total Discharge (cfs)	FP-06 Discharge (cfs)	Roadway Discharge (cfs)	Iterations
Q_2	72.58	25.10	25.10	0.00	1
	72.98	41.91	41.91	0.00	1
	73.42	58.72	58.72	0.00	1
	73.68	75.53	75.53	0.00	1
	73.94	92.34	92.34	0.00	1
	73.45	109.15	109.15	0.00	1
	73.74	125.96	125.96	0.00	1
Q_{50}	73.90	135.50	135.50	0.00	1
	74.31	159.58	159.58	0.00	1
	74.58	176.39	176.39	0.00	1
	74.86	193.20	193.20	0.00	1
Q_{500}	87.30	601.81	601.81	0.00	Overtopping

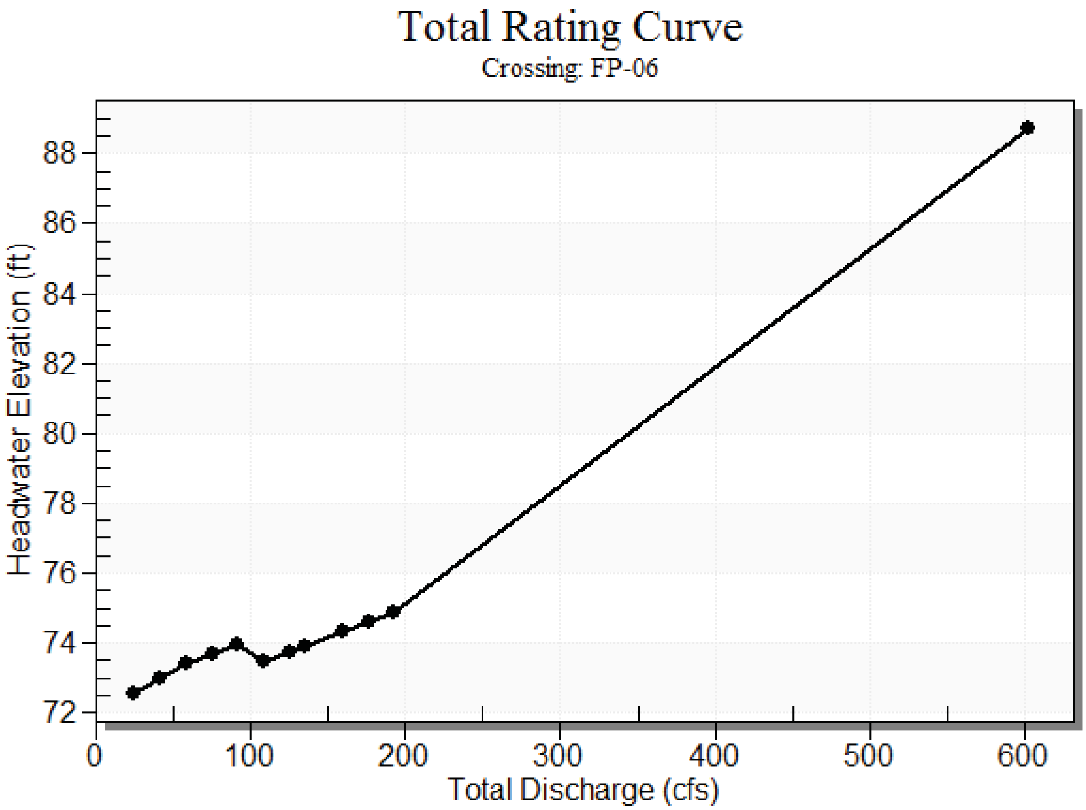
HW = 73.90' (@ Q_{50}) − 70.67' (INLET) = 3.23'

D = 7'-3" (RISE) − 2' (EMBED) = 5.25'

HW/D = 0.62 < 1.2

NOTE THAT SUMMARY DISPLAYS HW/D = 0.64. THIS IS A RESULT OF ROUNDING IN THE SPREADSHEET.

Rating Curve Plot for Crossing: FP-06



HY-8 Analysis Results

Culvert Summary Table - FP-06

Culvert Crossing: FP-06

Total Discharge (cfs)	Culvert Discharge (cfs)	Headwater Elevation (ft)	Inlet Control Depth(ft)	Outlet Control Depth(ft)	Flow Type	Normal Depth (ft)	Critical Depth (ft)	Outlet Depth (ft)	Tailwater Depth (ft)	Outlet Velocity (ft/s)	Tailwater Velocity (ft/s)
25.10	25.10	72.30	1.69~	1.09	3-M1t	0.92	0.54	1.03	1.08	2.27	2.68
41.91	41.91	72.99	2.38~	1.52	3-M1t	1.26	0.77	1.34	1.39	2.92	3.08
58.72	58.72	73.36	2.75~	1.89	3-M1t	1.57	0.96	1.59	1.64	3.48	3.37
75.53	75.53	73.64	3.03~	2.25	3-M2t	1.86	1.15	1.79	1.84	3.98	3.61
92.34	92.34	73.91	3.30~	2.58	3-M2t	2.13	1.32	1.98	2.03	4.44	3.80
109.15	109.15	73.50	2.79	2.89	3-M2t	2.39	1.47	2.14	2.19	4.87	3.97
125.96	125.96	73.81	3.05	3.20	3-M2t	2.65	1.61	2.29	2.34	5.28	4.12
135.50	135.50	73.98	3.20	3.37	3-M2t	2.80	1.69	2.37	2.42	5.51	4.20
159.58	159.58	74.41	3.56	3.80	3-M2t	3.18	1.89	2.56	2.61	6.06	4.38
176.39	176.39	74.70	3.82	4.09	3-M2t	3.46	2.02	2.68	2.73	6.43	4.49
193.20	193.20	75.00	4.07	4.39	3-M2t	3.76	2.15	2.79	2.84	6.79	4.60

****

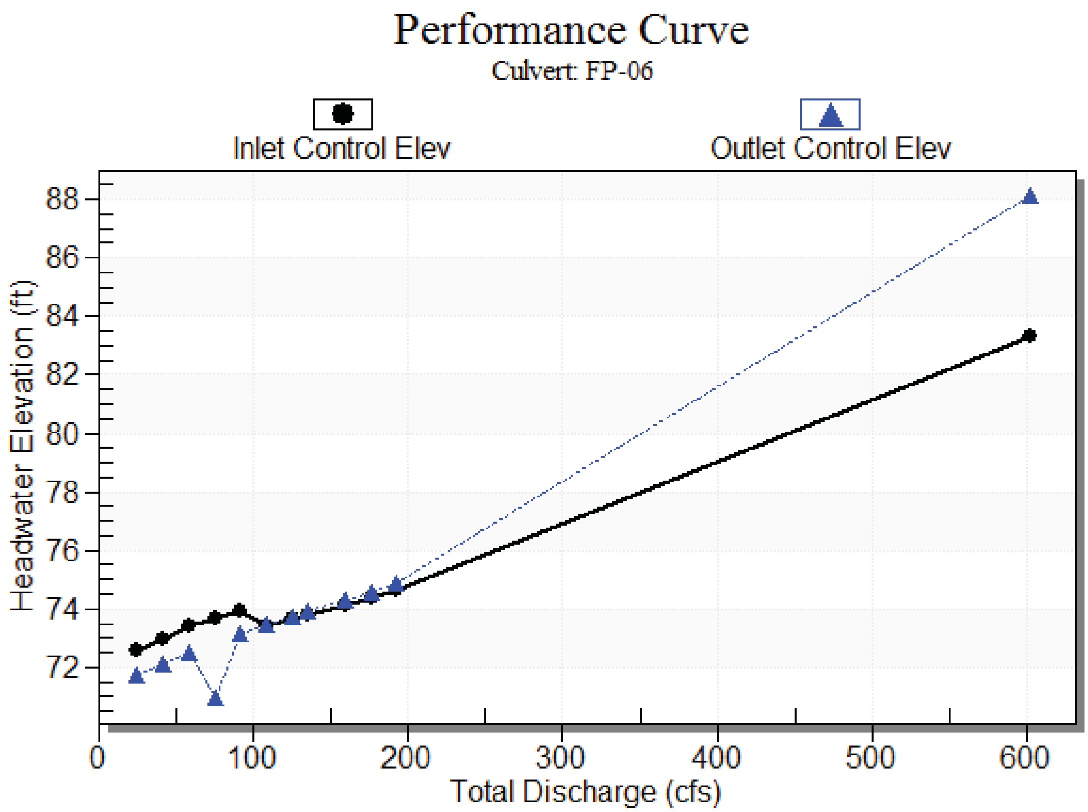
Straight Culvert

Inlet Elevation (invert): 70.67 ft,   Outlet Elevation (invert): 68.94 ft

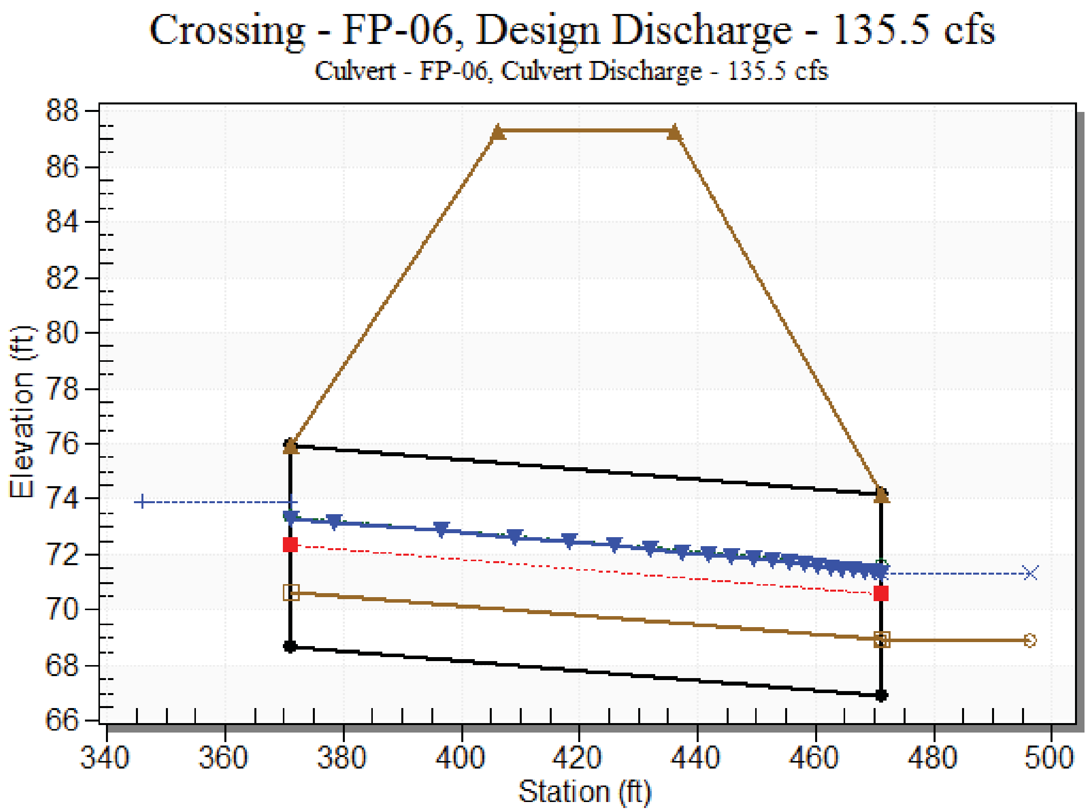
Culvert Length: 100.25 ft,   Culvert Slope: 0.0173

****

Culvert Performance Curve Plot: FP-06



Water Surface Profile Plot for Culvert: FP-06



Site Data - FP-06

Site Data Option: Culvert Invert Data

Inlet Station: 371.07 ft

Inlet Elevation: 68.67 ft

Outlet Station: 471.31 ft

Outlet Elevation: 66.94 ft

Number of Barrels: 1

Culvert Data Summary - FP-06

Barrel Shape: Pipe Arch

Barrel Span: 136.80 in

Barrel Rise: 86.90 in

Barrel Material: Steel Structural Plate

Embedment: 24.00 in

Barrel Manning's n: 0.0340 (top and sides)

Manning's n: 0.0700 (bottom)

Culvert Type: Straight

Inlet Configuration: Mitered

Inlet Depression: NONE

Table 18 - Downstream Channel Rating Curve (Crossing: FP-06)

Flow (cfs)	Water Surface Elev (ft)	Depth (ft)	Velocity (ft/s)	Shear (psf)	Froude Number
25.10	69.98	1.08	2.68	1.61	0.54
41.91	70.29	1.39	3.08	2.08	0.56
58.72	70.54	1.64	3.37	2.45	0.58
75.53	70.74	1.84	3.61	2.76	0.58
92.34	70.93	2.03	3.80	3.03	0.59
109.15	71.09	2.19	3.97	3.28	0.60
125.96	71.24	2.34	4.12	3.50	0.60
135.50	71.32	2.42	4.20	3.62	0.61
159.58	71.51	2.61	4.38	3.90	0.61
176.39	71.63	2.73	4.49	4.08	0.62
193.20	71.74	2.84	4.60	4.25	0.62

Tailwater Channel Data - FP-06

Tailwater Channel Option: Trapezoidal Channel

Bottom Width: 5.00 ft

Side Slope (H:V): 3.45 (_:1)

Channel Slope: 0.0240

Channel Manning's n: 0.0700

Channel Invert Elevation: 68.90 ft

Roadway Data for Crossing: FP-06

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 100.00 ft

Crest Elevation: 87.30 ft

Roadway Surface: Paved

Roadway Top Width: 30.00 ft

FP-07

Crossing Discharge Data

Discharge Selection Method: Specify Minimum, Design, and Maximum Flow

Minimum Flow: 6.7 cfs – Q_{fish}

Design Flow: 36.5 cfs – Q_{50}

Maximum Flow: 52.1 cfs – Q_{500}

Table 19 - Summary of Culvert Flows at Crossing: FP-07

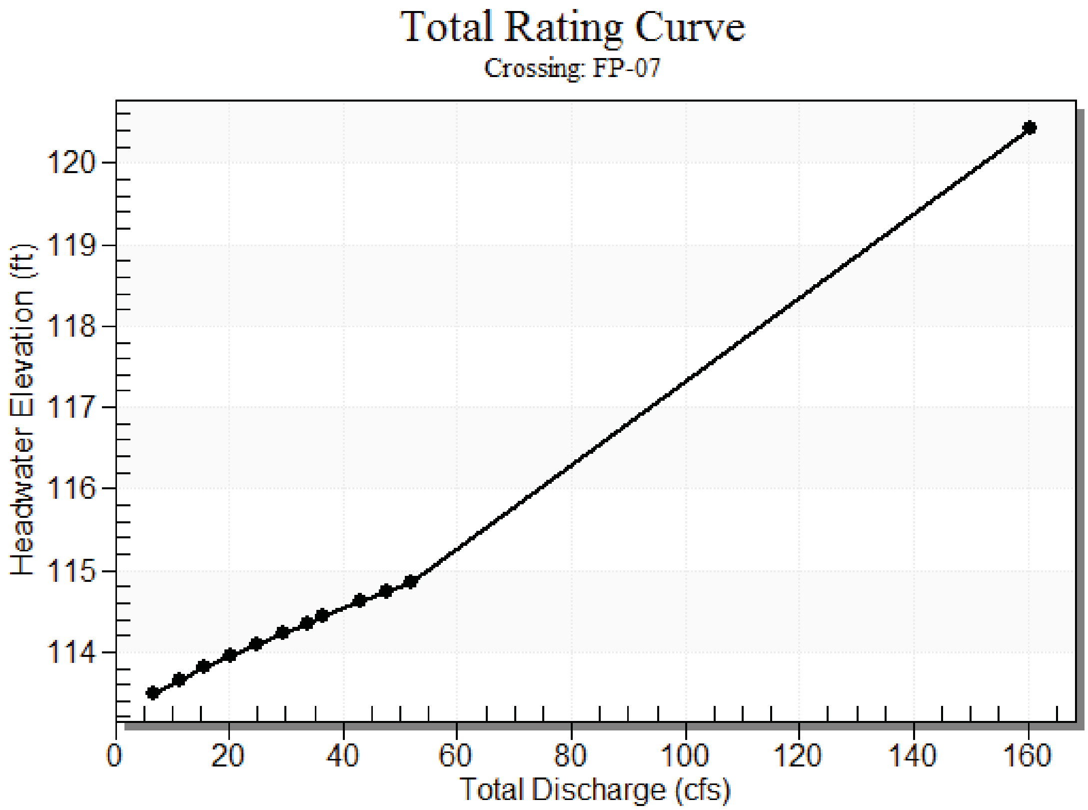
	Headwater Elevation (ft)	Total Discharge (cfs)	FP-07 Discharge (cfs)	Roadway Discharge (cfs)	Iterations
Q_2	113.50	6.70	6.70	0.00	1
	113.65	11.24	11.24	0.00	1
	113.80	15.78	15.78	0.00	1
	113.95	20.32	20.32	0.00	1
	114.09	24.86	24.86	0.00	1
	114.22	29.40	29.40	0.00	1
	114.36	33.94	33.94	0.00	1
Q_{50}	114.43	36.50	36.50	0.00	1
	114.61	43.02	43.02	0.00	1
	114.74	47.56	47.56	0.00	1
	114.86	52.10	52.10	0.00	1
Q_{500}	117.98	160.53	160.53	0.00	Overtopping

HW = 114.43' (@ Q_{50}) − 113.16' (INLET) = 1.27'

D = 5.5' (Ø) − 2.2' (EMBED) = 3.3'

HW/D = 0.38 < 1.5 ✓

Rating Curve Plot for Crossing: FP-07



HY-8 Analysis Results

Culvert Summary Table - FP-07

Culvert Crossing: FP-07

Total Discharge (cfs)	Culvert Discharge (cfs)	Headwater Elevation (ft)	Inlet Control Depth(ft)	Outlet Control Depth(ft)	Flow Type	Normal Depth (ft)	Critical Depth (ft)	Outlet Depth (ft)	Tailwater Depth (ft)	Outlet Velocity (ft/s)	Tailwater Velocity (ft/s)
6.70	6.70	113.46	0.34	0.0*	1-S2n	0.32	0.35	0.32	0.69	4.15	3.99
11.24	11.24	113.61	0.49	0.0*	1-S2n	0.42	0.50	0.42	0.83	4.88	4.55
15.78	15.78	113.76	0.64	0.0*	1-S2n	0.53	0.64	0.53	0.95	5.46	4.95
20.32	20.32	113.91	0.79	0.0*	1-S2n	0.63	0.76	0.63	1.04	5.93	5.27
24.86	24.86	114.05	0.93	0.0*	1-S2n	0.71	0.87	0.71	1.12	6.45	5.54
29.40	29.40	114.18	1.06	0.0*	1-S2n	0.79	0.97	0.79	1.19	6.85	5.78
33.94	33.94	114.32	1.20	0.0*	1-S2n	0.87	1.07	0.87	1.26	7.18	5.99
36.50	36.50	114.39	1.27	0.0*	1-S2n	0.91	1.12	0.91	1.29	7.36	6.10
43.02	43.02	114.57	1.45	0.0*	1-S2n	1.01	1.25	1.01	1.38	7.86	6.36
47.56	47.56	114.70	1.58	0.0*	1-S2n	1.07	1.33	1.07	1.43	8.15	6.52
52.10	52.10	114.82	1.70	0.0*	1-S2n	1.14	1.41	1.14	1.48	8.41	6.67

* Full Flow Headwater elevation is below inlet invert.

****

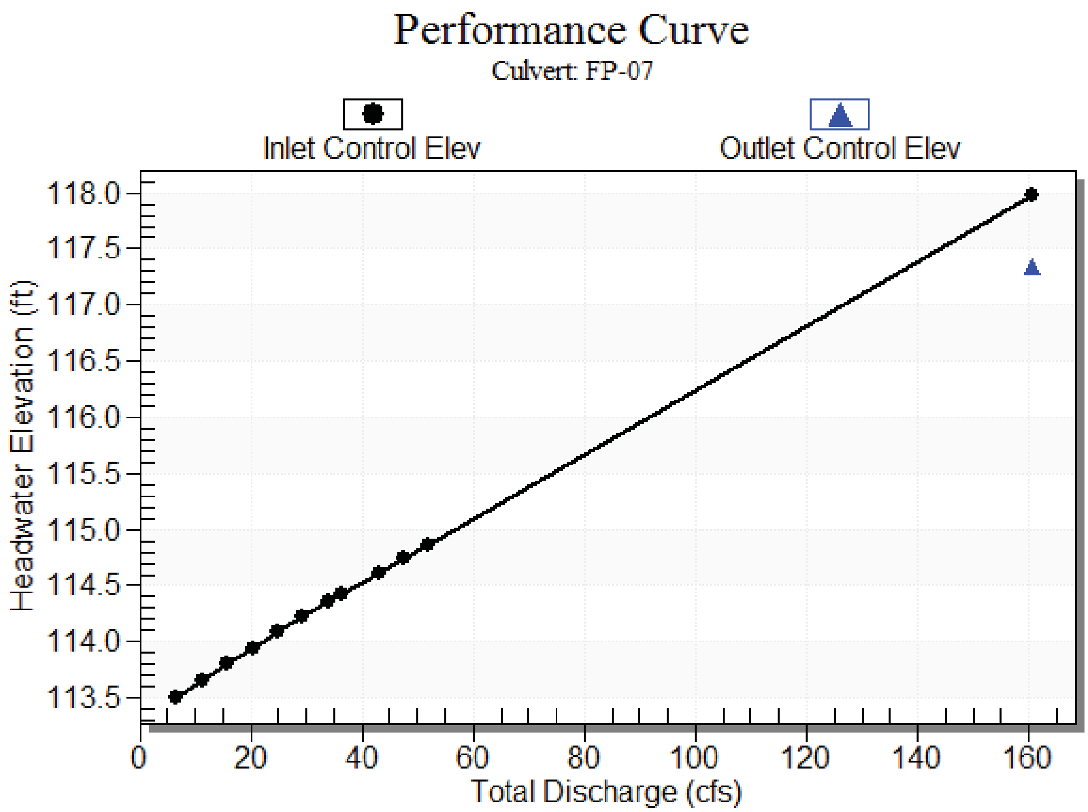
Straight Culvert

Inlet Elevation (invert): 113.16 ft,   Outlet Elevation (invert): 103.45 ft

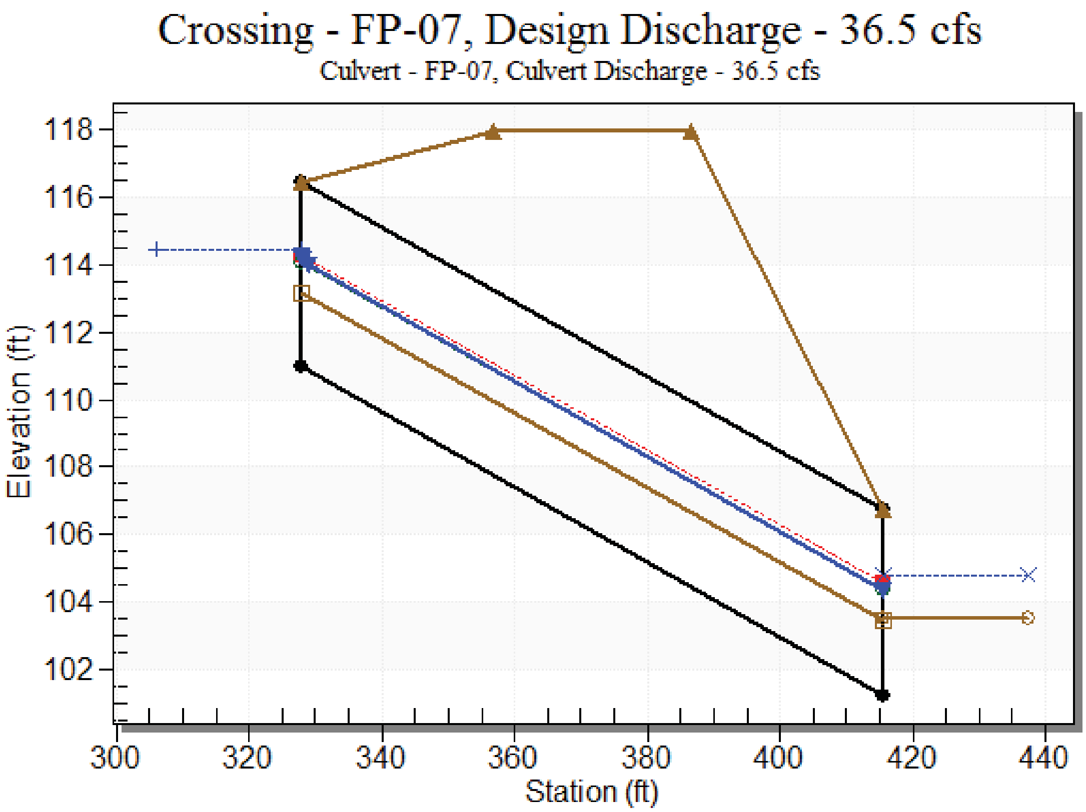
Culvert Length: 88.25 ft,   Culvert Slope: 0.1107

****

Culvert Performance Curve Plot: FP-07



Water Surface Profile Plot for Culvert: FP-07



Site Data - FP-07

Site Data Option: Culvert Invert Data

Inlet Station: 327.87 ft

Inlet Elevation: 110.96 ft

Outlet Station: 415.58 ft

Outlet Elevation: 101.25 ft

Number of Barrels: 1

Culvert Data Summary - FP-07

Barrel Shape: Circular

Barrel Diameter: 5.50 ft

Barrel Material: Corrugated Aluminum

Embedment: 26.40 in

Barrel Manning's n: 0.0310 (top and sides)

Manning's n: 0.0600 (bottom)

Culvert Type: Straight

Inlet Configuration: Mitered to Conform to Slope

Inlet Depression: NONE

Table 21 - Downstream Channel Rating Curve (Crossing: FP-07)

Flow (cfs)	Water Surface Elev (ft)	Depth (ft)	Velocity (ft/s)	Shear (psf)	Froude Number
6.70	104.19	0.69	3.99	4.88	1.20
11.24	104.33	0.83	4.55	5.92	1.24
15.78	104.45	0.95	4.95	6.72	1.27
20.32	104.54	1.04	5.27	7.39	1.29
24.86	104.62	1.12	5.54	7.97	1.30
29.40	104.69	1.19	5.78	8.49	1.32
33.94	104.76	1.26	5.99	8.96	1.33
36.50	104.79	1.29	6.10	9.21	1.34
43.02	104.88	1.38	6.36	9.79	1.35
47.56	104.93	1.43	6.52	10.17	1.36
52.10	104.98	1.48	6.67	10.52	1.37

Tailwater Channel Data - FP-07

Tailwater Channel Option: Triangular Channel

Side Slope (H:V): 3.57 (_:1)

Channel Slope: 0.1140

Channel Manning's n: 0.0600

Channel Invert Elevation: 103.50 ft

Roadway Data for Crossing: FP-07

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 100.00 ft

Crest Elevation: 117.98 ft

Roadway Surface: Paved

Roadway Top Width: 30.00 ft

FP-09

Crossing Discharge Data

Discharge Selection Method: Specify Minimum, Design, and Maximum Flow

Minimum Flow: 17 cfs — Q_{fish}

Design Flow: 92 cfs — Q_{50}

Maximum Flow: 131.3 cfs — Q_{500}

Table 28 - Summary of Culvert Flows at Crossing: FP-09

	Headwater Elevation (ft)	Total Discharge (cfs)	FP-09 Discharge (cfs)	Roadway Discharge (cfs)	Iterations
Q_{fish}	116.33	17.00	17.00	0.00	1
	116.55	28.43	28.43	0.00	1
	116.76	39.86	39.86	0.00	1
	116.97	51.29	51.29	0.00	1
	117.17	62.72	62.72	0.00	1
	117.36	74.15	74.15	0.00	1
	117.55	85.58	85.58	0.00	1
Q_{50}	117.66	92.00	92.00	0.00	1
	117.92	108.44	108.44	0.00	1
	118.10	119.87	119.87	0.00	1
	118.28	131.30	131.30	0.00	1
Q_{500}	121.53	339.73	339.73	0.00	Overtopping

$HW = 117.66' - 115.9' = 1.76'$

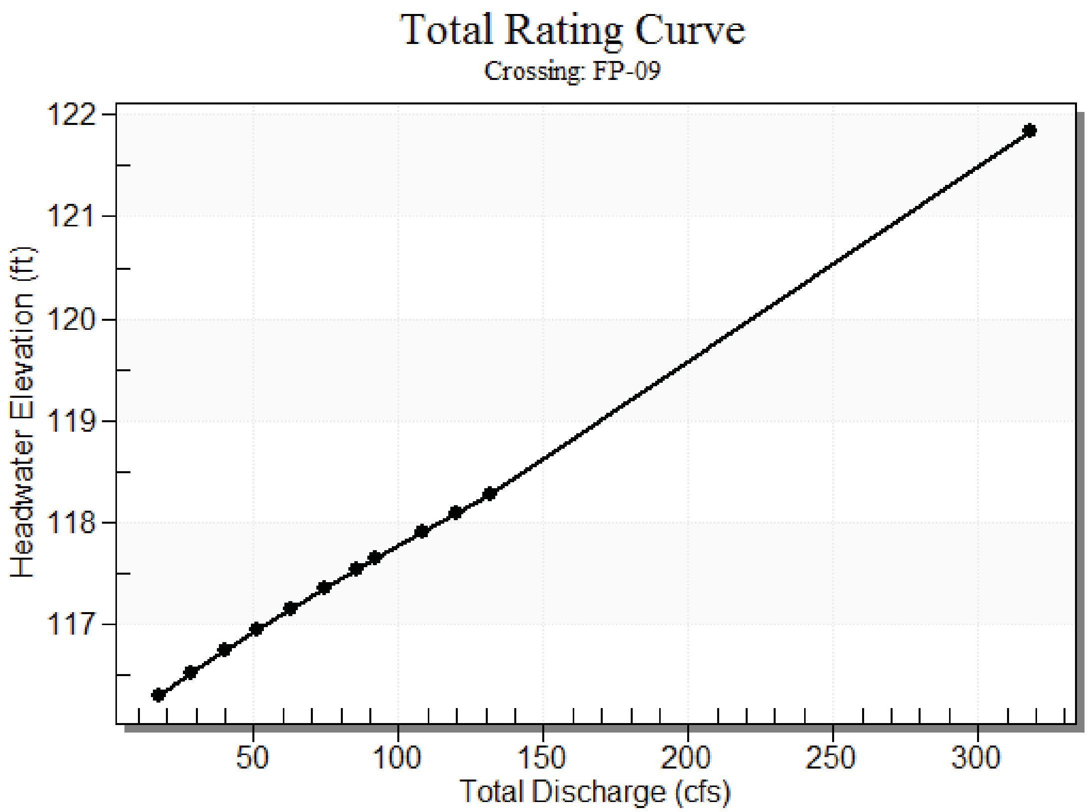
@ Q_{50} — INLET

$D = 8' - 3.2' = 4.8'$

Ø — EMBED

$HW/D = 0.37 < 1.2$ ✓

Rating Curve Plot for Crossing: FP-09



HY-8 Analysis Results

Culvert Summary Table - FP-09

Culvert Crossing: FP-09

Total Discharge (cfs)	Culvert Discharge (cfs)	Headwater Elevation (ft)	Inlet Control Depth(ft)	Outlet Control Depth(ft)	Flow Type	Normal Depth (ft)	Critical Depth (ft)	Outlet Depth (ft)	Tailwater Depth (ft)	Outlet Velocity (ft/s)	Tailwater Velocity (ft/s)
17.00	17.00	116.33	0.43	0.0*	1-S2n	0.45	0.52	0.45	0.53	4.97	4.02
28.43	28.43	116.55	0.65	0.0*	1-S2n	0.60	0.73	0.60	0.72	5.99	4.81
39.86	39.86	116.76	0.86	0.0*	1-S2n	0.75	0.92	0.75	0.88	6.72	5.39
51.29	51.29	116.97	1.07	0.0*	1-S2n	0.89	1.10	0.89	1.02	7.27	5.86
62.72	62.72	117.17	1.27	0.0*	1-S2n	1.00	1.25	1.01	1.15	7.81	6.26
74.15	74.15	117.36	1.46	0.0*	1-S2n	1.11	1.40	1.11	1.27	8.44	6.60
85.58	85.58	117.55	1.65	0.0*	1-S2n	1.22	1.54	1.22	1.38	8.86	6.91
92.00	92.00	117.66	1.76	0.0*	1-S2n	1.28	1.61	1.28	1.43	9.07	7.06
108.44	108.44	117.92	2.02	0.0*	1-S2n	1.42	1.80	1.42	1.58	9.67	7.43
119.87	119.87	118.10	2.20	0.0*	1-S2n	1.51	1.92	1.51	1.67	10.05	7.66
131.30	131.30	118.28	2.38	0.0*	1-S2n	1.60	2.03	1.60	1.76	10.39	7.88

* Full Flow Headwater elevation is below inlet invert.

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Straight Culvert

Inlet Elevation (invert): 115.89 ft,   Outlet Elevation (invert): 102.55 ft

Culvert Length: 96.68 ft,   Culvert Slope: 0.1393

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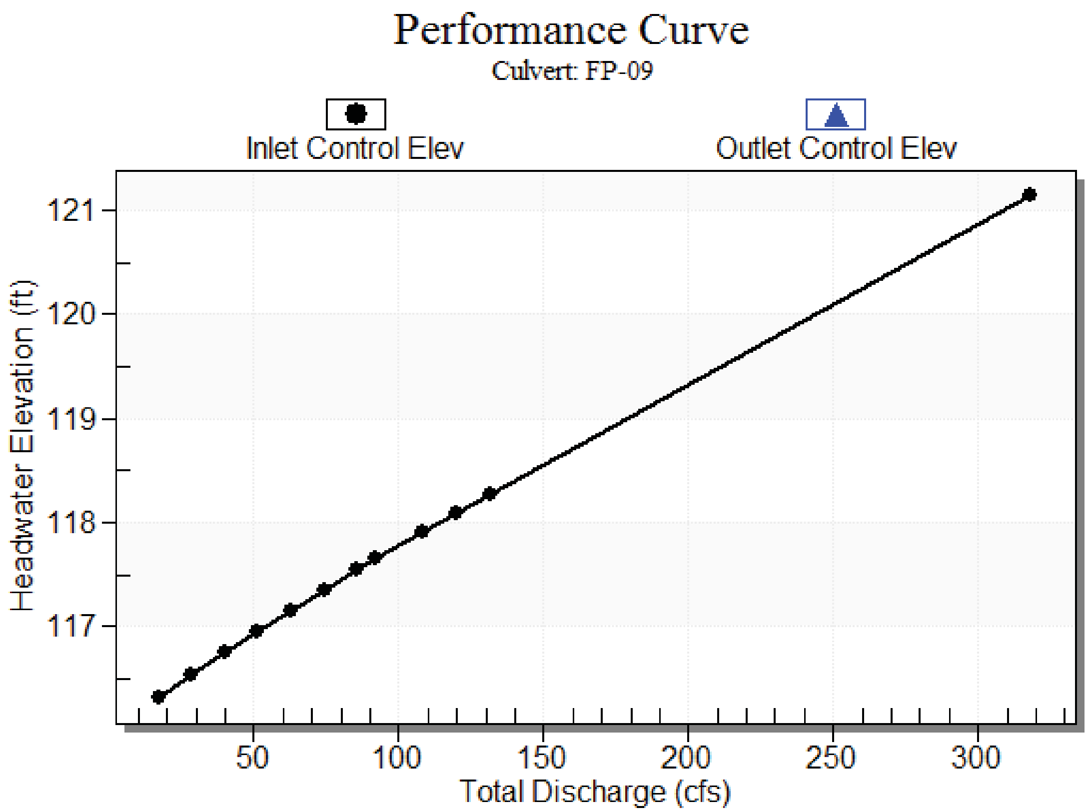
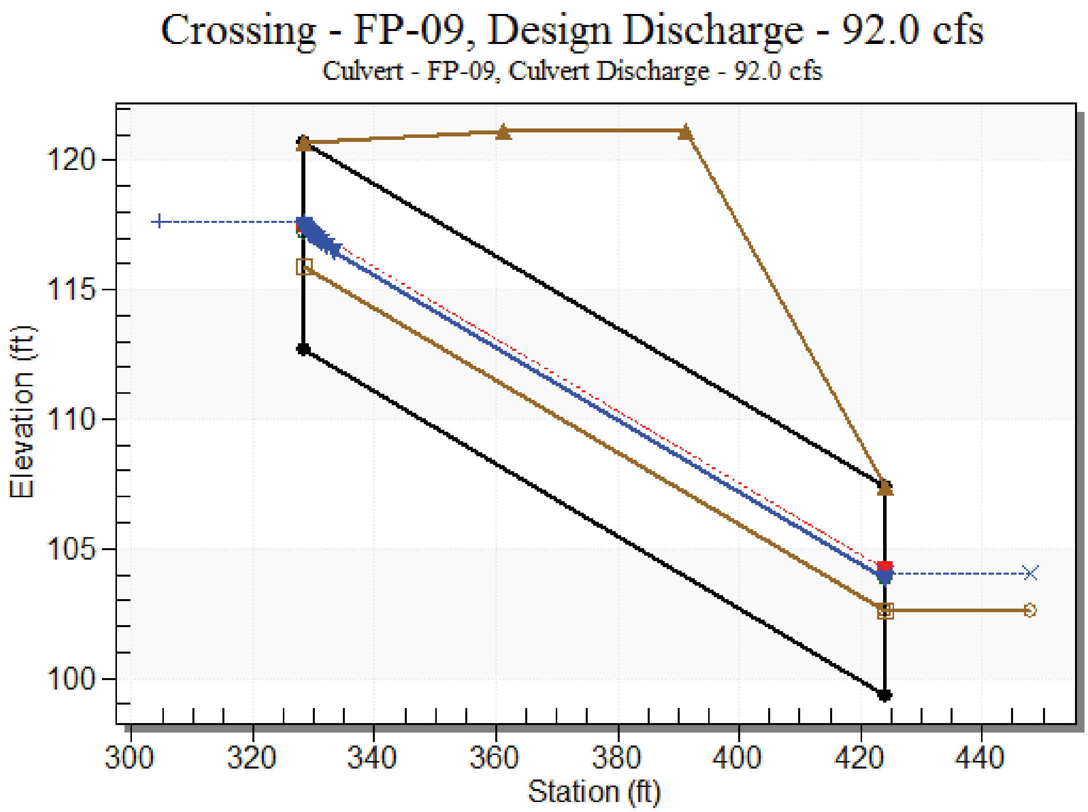
Culvert Performance Curve Plot: FP-09



Water Surface Profile Plot for Culvert: FP-09



Site Data - FP-09

Site Data Option: Culvert Invert Data

Inlet Station: 328.37 ft

Inlet Elevation: 112.69 ft

Outlet Station: 424.13 ft

Outlet Elevation: 99.35 ft

Number of Barrels: 1

Culvert Data Summary - FP-09

Barrel Shape: Circular

Barrel Diameter: 8.00 ft

Barrel Material: Corrugated Aluminum

Embedment: 38.40 in

Barrel Manning's n: 0.0310 (top and sides)

Manning's n: 0.0700 (bottom)

Culvert Type: Straight

Inlet Configuration: Mitered to Conform to Slope

Inlet Depression: NONE

Table 30 - Downstream Channel Rating Curve (Crossing: FP-09)

Flow (cfs)	Water Surface Elev (ft)	Depth (ft)	Velocity (ft/s)	Shear (psf)	Froude Number
17.00	103.13	0.53	4.02	3.25	1.01
28.43	103.32	0.72	4.81	4.41	1.05
39.86	103.48	0.88	5.39	5.39	1.08
51.29	103.62	1.02	5.86	6.25	1.10
62.72	103.75	1.15	6.26	7.02	1.11
74.15	103.87	1.27	6.60	7.74	1.12
85.58	103.98	1.38	6.91	8.41	1.13
92.00	104.03	1.43	7.06	8.77	1.14
108.44	104.18	1.58	7.43	9.64	1.15
119.87	104.27	1.67	7.66	10.20	1.16
131.30	104.36	1.76	7.88	10.74	1.16

Tailwater Channel Data - FP-09

Tailwater Channel Option: Trapezoidal Channel

Bottom Width: 7.29 ft

Side Slope (H:V): 1.25 (_:1)

Channel Slope: 0.0980

Channel Manning's n: 0.0700

Channel Invert Elevation: 102.60 ft

Roadway Data for Crossing: FP-09

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 100.00 ft

Crest Elevation: 121.15 ft

Roadway Surface: Paved

Roadway Top Width: 30.00 ft

FP-10

Crossing Discharge Data

Discharge Selection Method: Specify Minimum, Design, and Maximum Flow

Minimum Flow: 19.5 cfs — Q_{fish}

Design Flow: 105.3 cfs — Q_{50}

Maximum Flow: 150.2 cfs — Q_{500}

Table 25 - Summary of Culvert Flows at Crossing: FP-10

	Headwater Elevation (ft)	Total Discharge (cfs)	FP-10 Discharge (cfs)	Roadway Discharge (cfs)	Iterations
Q_2	119.89	19.50	19.50	0.00	1
	120.14	32.57	32.57	0.00	1
	120.38	45.64	45.64	0.00	1
	120.61	58.71	58.71	0.00	1
	120.84	71.78	71.78	0.00	1
	121.06	84.85	84.85	0.00	1
	121.27	97.92	97.92	0.00	1
Q_{50}	121.39	105.30	105.30	0.00	1
	121.68	124.06	124.06	0.00	1
	121.88	137.13	137.13	0.00	1
	122.08	150.20	150.20	0.00	1
Q_{500}	127.73	469.28	469.28	0.00	Overtopping

$HW = 121.39' - 119.29' = 2.10$

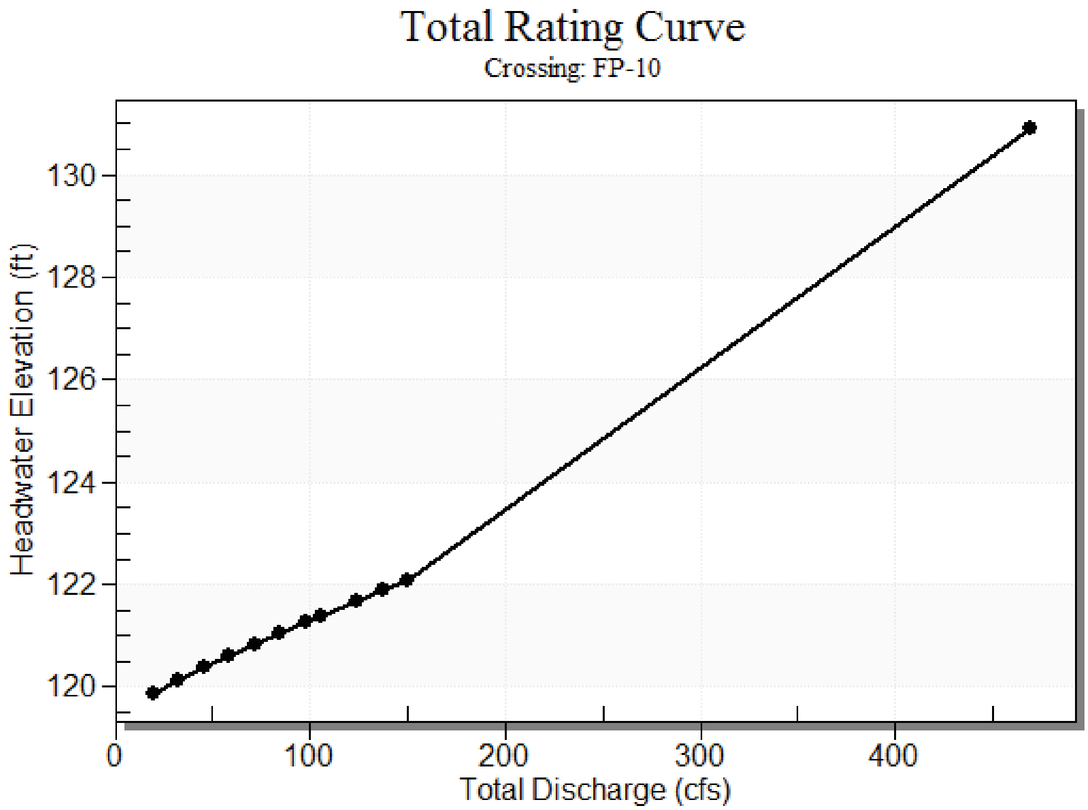
(121.39' @ Q_{50}; 119.29' INLET)

$D = 8' - 3.2' = 4.8'$

(8' Ø; 3.2' EMBED)

$HW/D = 0.44 < 1.2$ ✓

Rating Curve Plot for Crossing: FP-10



HY-8 Analysis Results

Culvert Summary Table - FP-10

Culvert Crossing: FP-10

Total Discharge (cfs)	Culvert Discharge (cfs)	Headwater Elevation (ft)	Inlet Control Depth(ft)	Outlet Control Depth(ft)	Flow Type	Normal Depth (ft)	Critical Depth (ft)	Outlet Depth (ft)	Tailwater Depth (ft)	Outlet Velocity (ft/s)	Tailwater Velocity (ft/s)
19.50	19.50	119.99	0.60	0.0*	1-S2n	0.47	0.57	0.47	0.49	5.71	5.24
32.57	32.57	120.24	0.85	0.0*	1-S2n	0.62	0.81	0.62	0.66	6.60	6.25
45.64	45.64	120.48	1.09	0.0*	1-S2n	0.78	1.01	0.78	0.80	7.36	6.99
58.71	58.71	120.71	1.32	0.0*	1-S2n	0.92	1.20	0.92	0.92	8.02	7.58
71.78	71.78	120.94	1.55	0.0*	1-S2n	1.04	1.37	1.04	1.04	8.68	8.08
84.85	84.85	121.16	1.77	0.0*	1-S2n	1.16	1.53	1.16	1.14	9.21	8.51
97.92	97.92	121.37	1.98	0.0*	1-S2n	1.28	1.68	1.28	1.24	9.64	8.90
105.30	105.30	121.49	2.10	0.0*	1-S2n	1.34	1.76	1.34	1.29	9.90	9.10
124.06	124.06	121.78	2.39	0.0*	1-S2n	1.49	1.96	1.49	1.41	10.53	9.56
137.13	137.13	121.98	2.59	0.0*	1-S2n	1.59	2.09	1.59	1.49	10.91	9.85
150.20	150.20	122.18	2.79	0.0*	1-S2n	1.69	2.22	1.71	1.57	11.08	10.12

* Full Flow Headwater elevation is below inlet invert.

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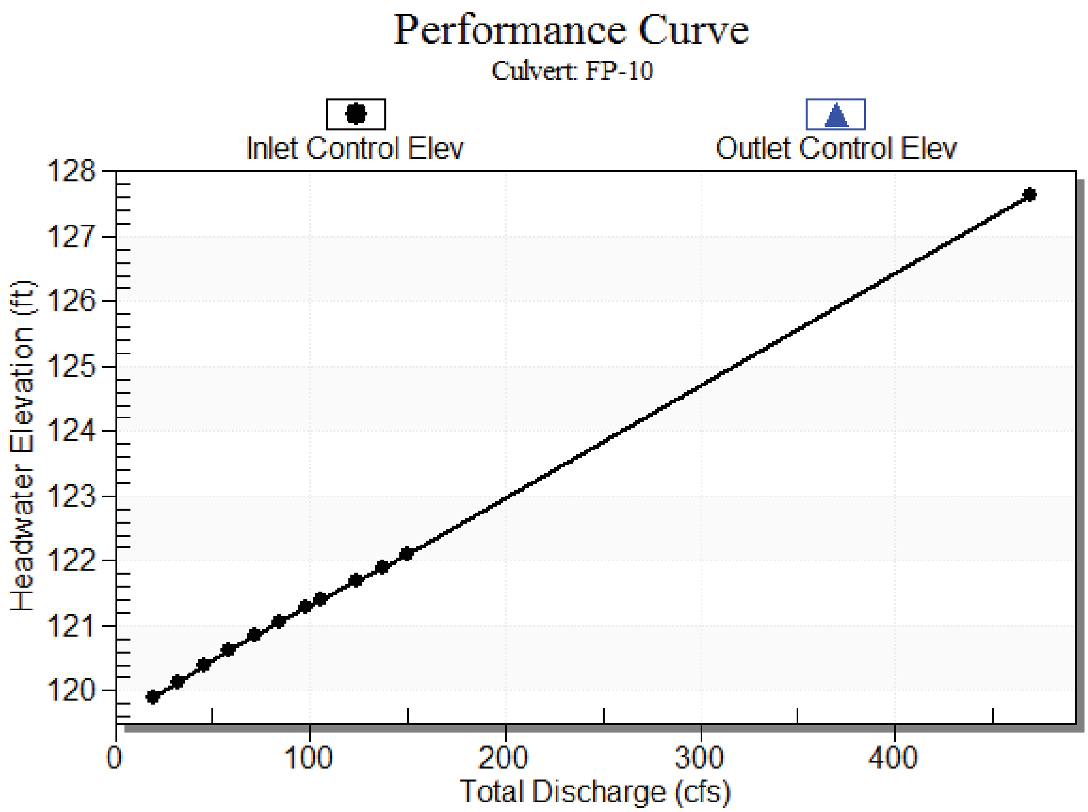
Straight Culvert

Inlet Elevation (invert): 119.29 ft,   Outlet Elevation (invert): 112.38 ft

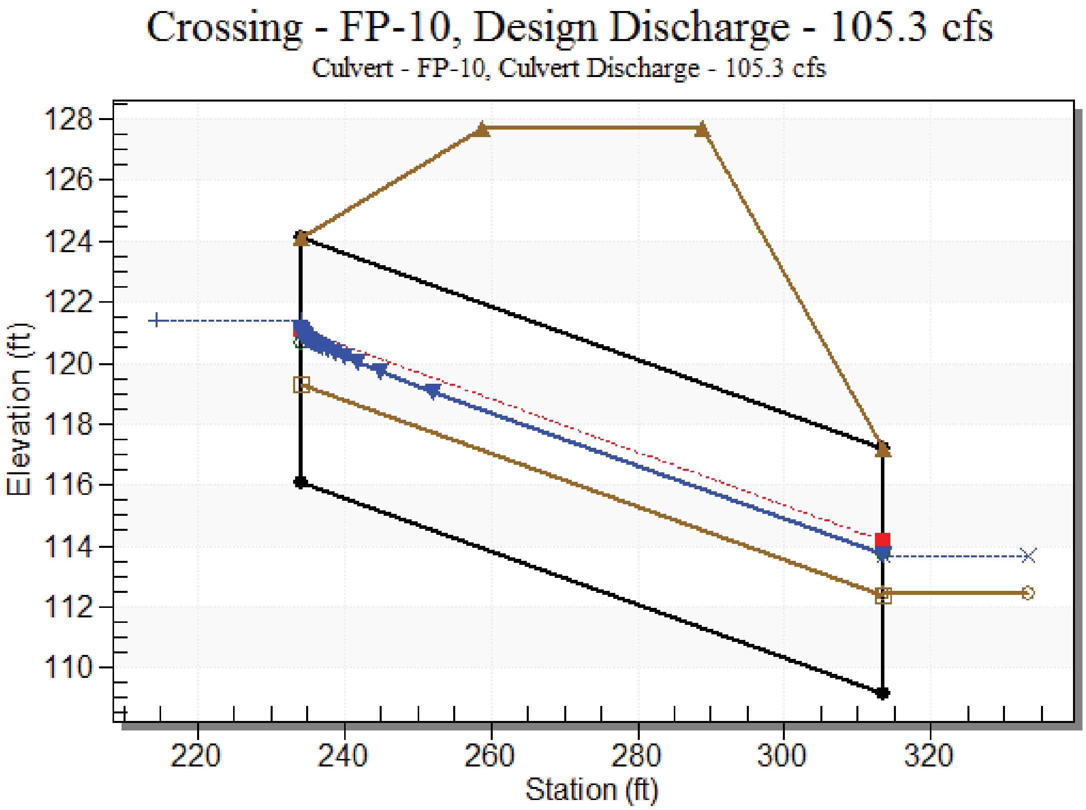
Culvert Length: 79.66 ft,   Culvert Slope: 0.0871

****

Culvert Performance Curve Plot: FP-10



Water Surface Profile Plot for Culvert: FP-10



Site Data - FP-10

Site Data Option: Culvert Invert Data

Inlet Station: 234.15 ft

Inlet Elevation: 116.09 ft

Outlet Station: 313.51 ft

Outlet Elevation: 109.18 ft

Number of Barrels: 1

Culvert Data Summary - FP-10

Barrel Shape: Circular

Barrel Diameter: 8.00 ft

Barrel Material: Corrugated Aluminum

Embedment: 38.40 in

Barrel Manning's n: 0.0310 (top and sides)

Manning's n: 0.0500 (bottom)

Culvert Type: Straight

Inlet Configuration: Mitered to Conform to Slope

Inlet Depression: NONE

Table 27 - Downstream Channel Rating Curve (Crossing: FP-10)

Flow (cfs)	Water Surface Elev (ft)	Depth (ft)	Velocity (ft/s)	Shear (psf)	Froude Number
19.50	112.89	0.49	5.24	2.95	1.39
32.57	113.06	0.66	6.25	3.98	1.45
45.64	113.20	0.80	6.99	4.84	1.49
58.71	113.32	0.92	7.58	5.60	1.51
71.78	113.44	1.04	8.08	6.28	1.54
84.85	113.54	1.14	8.51	6.90	1.55
97.92	113.64	1.24	8.90	7.48	1.57
105.30	113.69	1.29	9.10	7.79	1.58
124.06	113.81	1.41	9.56	8.54	1.59
137.13	113.89	1.49	9.85	9.03	1.60
150.20	113.97	1.57	10.12	9.49	1.61

Tailwater Channel Data - FP-10

Tailwater Channel Option: Trapezoidal Channel

Bottom Width: 6.80 ft

Side Slope (H:V): 1.70 (_:1)

Channel Slope: 0.0970

Channel Manning's n: 0.0500

Channel Invert Elevation: 112.40 ft

Roadway Data for Crossing: FP-10

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 100.00 ft

Crest Elevation: 127.73 ft

Roadway Surface: Paved

Roadway Top Width: 30.00 ft

FP-11

Crossing Discharge Data

Discharge Selection Method: Specify Minimum, Design, and Maximum Flow

Minimum Flow: 12.4 cfs — Q_{fish}

Design Flow: 66.4 cfs — Q_{50}

Maximum Flow: 95 cfs — Q_{500}

Table 31 - Summary of Culvert Flows at Crossing: FP-11

	Headwater Elevation (ft)	Total Discharge (cfs)	FP-11 Discharge (cfs)	Roadway Discharge (cfs)	Iterations
Q_2	224.63	12.40	12.40	0.00	1
	224.79	20.66	20.66	0.00	1
	224.95	28.92	28.92	0.00	1
	225.10	37.18	37.18	0.00	1
	225.25	45.44	45.44	0.00	1
	225.40	53.70	53.70	0.00	1
	225.55	61.96	61.96	0.00	1
Q_{50} →	225.62	66.40	66.40	0.00	1
	225.83	78.48	78.48	0.00	1
	225.97	86.74	86.74	0.00	1
	226.10	95.00	95.00	0.00	1
Q_{500}	229.81	333.22	333.22	0.00	Overtopping

$HW = 225.62' - 224.20' = 1.42'$

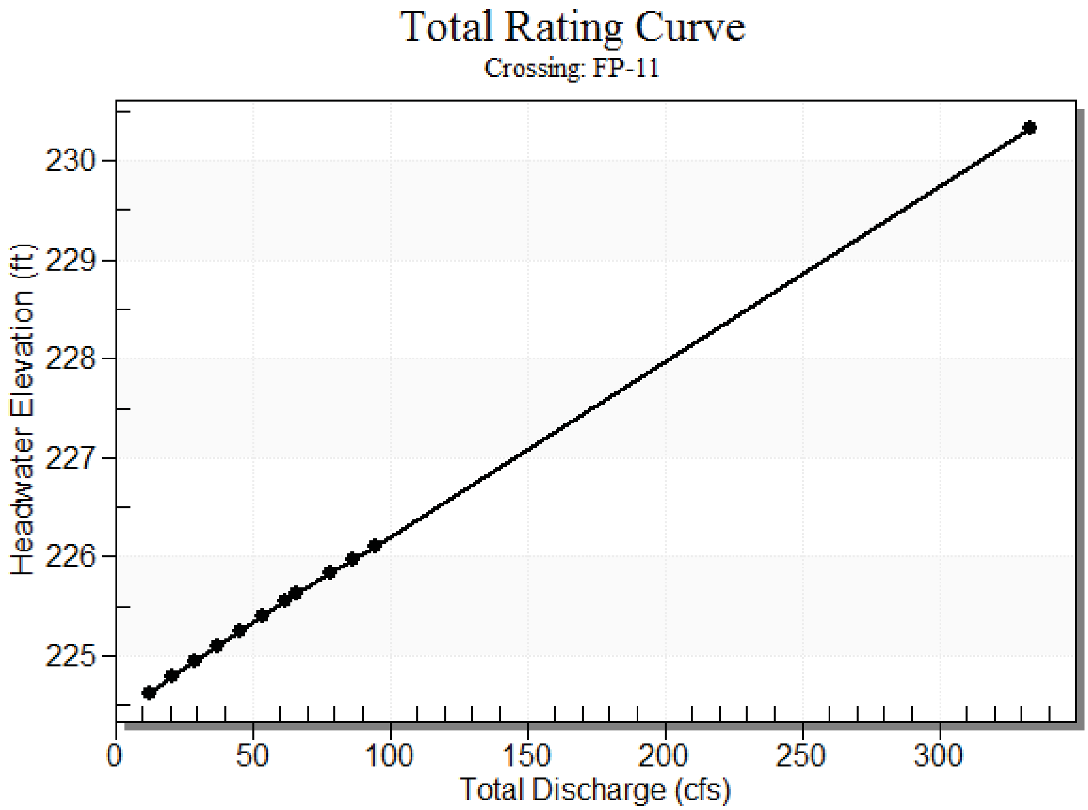
(225.62' @ Q_{50}; 224.20' INLET)

$D = 8' - 3.2' = 4.8'$

(8' Ø; 3.2' EMBED)

$HW/D = 0.30 < 1.2$ ✓

Rating Curve Plot for Crossing: FP-11



HY-8 Analysis Results

Culvert Summary Table - FP-11

Culvert Crossing: FP-11

Total Discharge (cfs)	Culvert Discharge (cfs)	Headwater Elevation (ft)	Inlet Control Depth(ft)	Outlet Control Depth(ft)	Flow Type	Normal Depth (ft)	Critical Depth (ft)	Outlet Depth (ft)	Tailwater Depth (ft)	Outlet Velocity (ft/s)	Tailwater Velocity (ft/s)
12.40	12.40	225.88	0.41	0.0*	1-S2n	0.34	0.42	0.34	0.41	3.80	3.99
20.66	20.66	226.04	0.57	0.0*	1-S2n	0.50	0.59	0.50	0.55	5.28	4.77
28.92	28.92	226.20	0.73	0.0*	1-S2n	0.60	0.74	0.60	0.67	6.07	5.36
37.18	37.18	226.36	0.89	0.0*	1-S2n	0.71	0.88	0.71	0.77	6.63	5.82
45.44	45.44	226.51	1.04	0.0*	1-S2n	0.82	1.01	0.82	0.87	7.04	6.22
53.70	53.70	226.66	1.19	0.0*	1-S2n	0.91	1.13	0.91	0.96	7.46	6.57
61.96	61.96	226.80	1.33	0.0*	1-S2n	0.99	1.24	0.99	1.04	7.92	6.87
66.40	66.40	226.88	1.41	0.0*	1-S2n	1.03	1.30	1.04	1.08	8.08	7.03
78.48	78.48	227.08	1.61	0.0*	1-S2n	1.15	1.46	1.15	1.19	8.65	7.41
86.74	86.74	227.22	1.75	0.0*	1-S2n	1.22	1.55	1.22	1.26	8.94	7.64
95.00	95.00	227.35	1.88	0.0*	1-S2n	1.30	1.65	1.30	1.33	9.20	7.86

* Full Flow Headwater elevation is below inlet invert.

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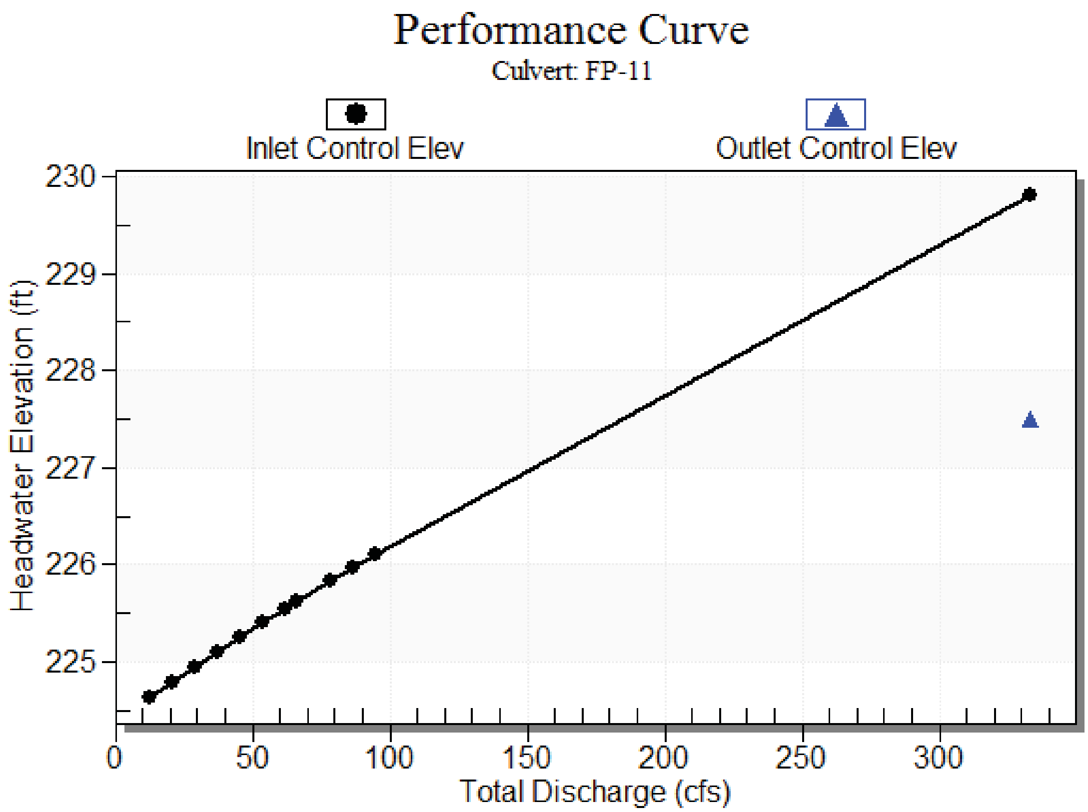
Straight Culvert

Inlet Elevation (invert): 224.20 ft,   Outlet Elevation (invert): 215.41 ft

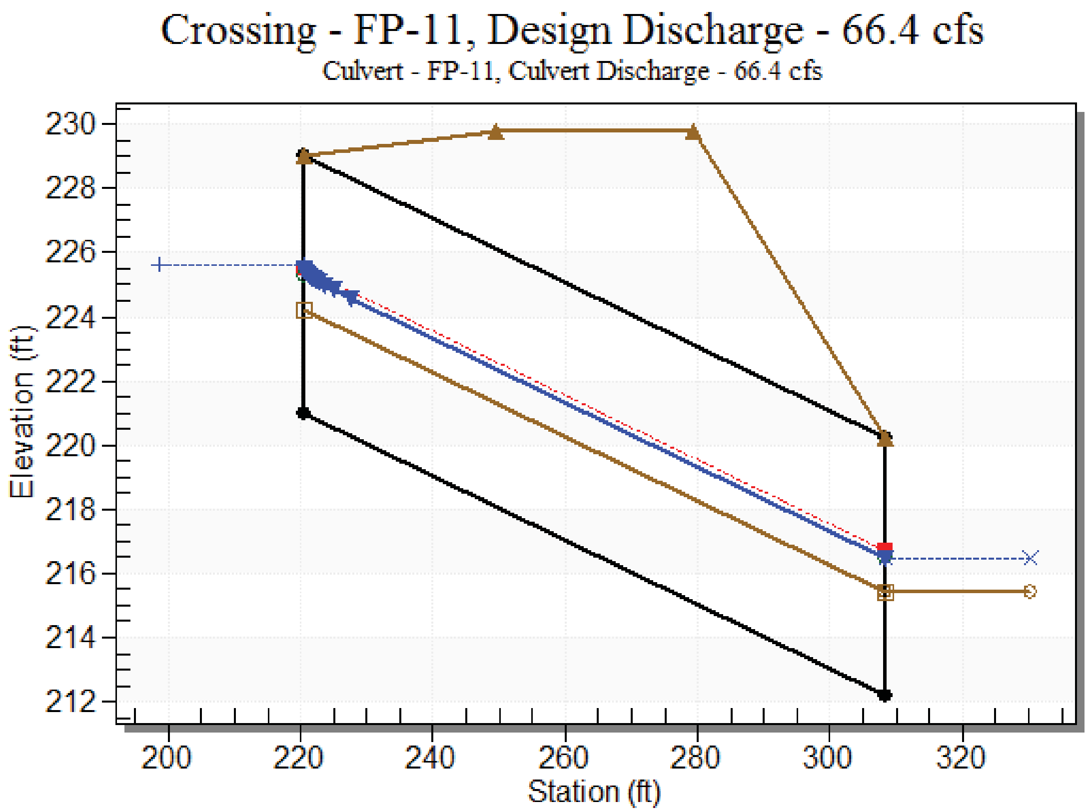
Culvert Length: 88.33 ft,   Culvert Slope: 0.1000

****

Culvert Performance Curve Plot: FP-11



Water Surface Profile Plot for Culvert: FP-11



Site Data - FP-11

Site Data Option: Culvert Invert Data

Inlet Station: 220.53 ft

Inlet Elevation: 221.00 ft

Outlet Station: 308.42 ft

Outlet Elevation: 212.21 ft

Number of Barrels: 1

Culvert Data Summary - FP-11

Barrel Shape: Circular

Barrel Diameter: 8.00 ft

Barrel Material: Corrugated Aluminum

Embedment: 38.40 in

Barrel Manning's n: 0.0310 (top and sides)

Manning's n: 0.0600 (bottom)

Culvert Type: Straight

Inlet Configuration: Mitered to Conform to Slope

Inlet Depression: NONE

Table 33 - Downstream Channel Rating Curve (Crossing: FP-11)

Flow (cfs)	Water Surface Elev (ft)	Depth (ft)	Velocity (ft/s)	Shear (psf)	Froude Number
12.40	215.81	0.41	3.99	2.53	1.15
20.66	215.95	0.55	4.77	3.41	1.20
28.92	216.07	0.67	5.36	4.16	1.23
37.18	216.17	0.77	5.82	4.82	1.25
45.44	216.27	0.87	6.22	5.41	1.27
53.70	216.36	0.96	6.57	5.96	1.28
61.96	216.44	1.04	6.87	6.46	1.30
66.40	216.48	1.08	7.03	6.73	1.30
78.48	216.59	1.19	7.41	7.40	1.32
86.74	216.66	1.26	7.64	7.83	1.33
95.00	216.73	1.33	7.86	8.24	1.33

Tailwater Channel Data - FP-11

Tailwater Channel Option: Trapezoidal Channel

Bottom Width: 7.00 ft

Side Slope (H:V): 1.60 (_:1)

Channel Slope: 0.0996

Channel Manning's n: 0.0600

Channel Invert Elevation: 215.40 ft

Roadway Data for Crossing: FP-11

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 100.00 ft

Crest Elevation: 229.81 ft

Roadway Surface: Paved

Roadway Top Width: 30.00 ft

FP-12

Crossing Discharge Data

Discharge Selection Method: Specify Minimum, Design, and Maximum Flow

Minimum Flow: 4.1 cfs — Q_{fish}

Design Flow: 22.3 cfs — Q_{50}

Maximum Flow: 31.9 cfs — Q_{500}

Table 34 - Summary of Culvert Flows at Crossing: FP-12

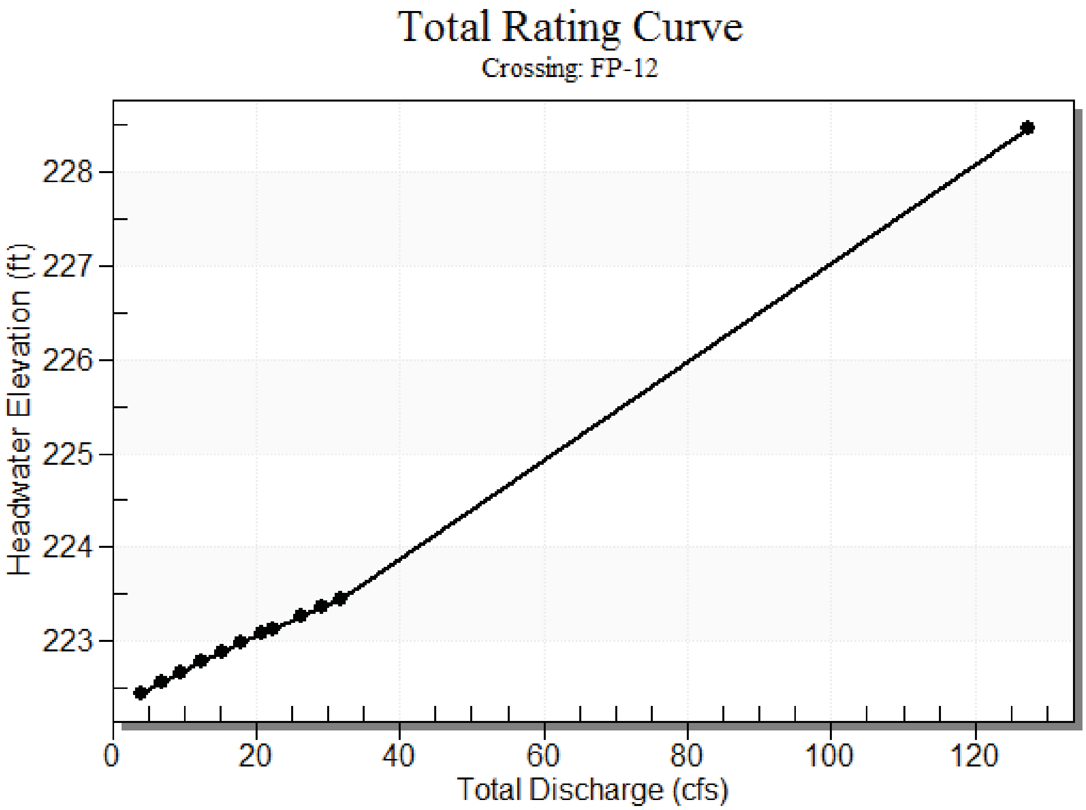
	Headwater Elevation (ft)	Total Discharge (cfs)	FP-12 Discharge (cfs)	Roadway Discharge (cfs)	Iterations
Q fish	222.47	4.10	4.10	0.00	1
	222.58	6.88	6.88	0.00	1
	222.69	9.66	9.66	0.00	1
	222.79	12.44	12.44	0.00	1
	222.89	15.22	15.22	0.00	1
	222.99	18.00	18.00	0.00	1
	223.09	20.78	20.78	0.00	1
Q_{50}	223.14	22.30	22.30	0.00	1
	223.28	26.34	26.34	0.00	1
	223.37	29.12	29.12	0.00	1
	223.46	31.90	31.90	0.00	1
Q_{500}	228.08	127.49	127.49	0.00	Overtopping

HW = 223.14' (@ Q_{50}) − 222.20' (INLET) = 0.94'

D = 5' (Ø) − 2' (EMBED) = 3'

HW/D = 0.31 < 1.5 ✓

Rating Curve Plot for Crossing: FP-12



HY-8 Analysis Results

Culvert Summary Table - FP-12

Culvert Crossing: FP-12

Total Discharge (cfs)	Culvert Discharge (cfs)	Headwater Elevation (ft)	Inlet Control Depth(ft)	Outlet Control Depth(ft)	Flow Type	Normal Depth (ft)	Critical Depth (ft)	Outlet Depth (ft)	Tailwater Depth (ft)	Outlet Velocity (ft/s)	Tailwater Velocity (ft/s)
4.10	4.10	222.47	0.27	0.0*	1-S2n	0.25	0.27	0.25	0.25	3.09	2.89
6.88	6.88	222.58	0.38	0.0*	1-S2n	0.34	0.39	0.34	0.33	4.13	3.44
9.66	9.66	222.69	0.49	0.0*	1-S2n	0.42	0.49	0.42	0.40	4.69	3.84
12.44	12.44	222.79	0.59	0.0*	1-S2n	0.50	0.58	0.50	0.46	5.08	4.17
15.22	15.22	222.89	0.69	0.0*	1-S2n	0.57	0.67	0.57	0.52	5.43	4.44
18.00	18.00	222.99	0.79	0.0*	1-S2n	0.62	0.75	0.62	0.57	5.83	4.67
20.78	20.78	223.09	0.89	0.0*	1-S2n	0.68	0.82	0.68	0.61	6.15	4.88
22.30	22.30	223.14	0.94	0.0*	1-S2n	0.71	0.86	0.71	0.64	6.31	4.99
26.34	26.34	223.28	1.08	0.0*	1-S2n	0.80	0.96	0.80	0.70	6.66	5.24
29.12	29.12	223.37	1.17	0.0*	1-S2n	0.85	1.03	0.85	0.73	6.91	5.40
31.90	31.90	223.46	1.26	0.0*	1-S2n	0.90	1.09	0.90	0.77	7.17	5.54

* Full Flow Headwater elevation is below inlet invert.

****

Straight Culvert

Inlet Elevation (invert): 222.19 ft,   Outlet Elevation (invert): 214.04 ft

Culvert Length: 76.81 ft,   Culvert Slope: 0.1067

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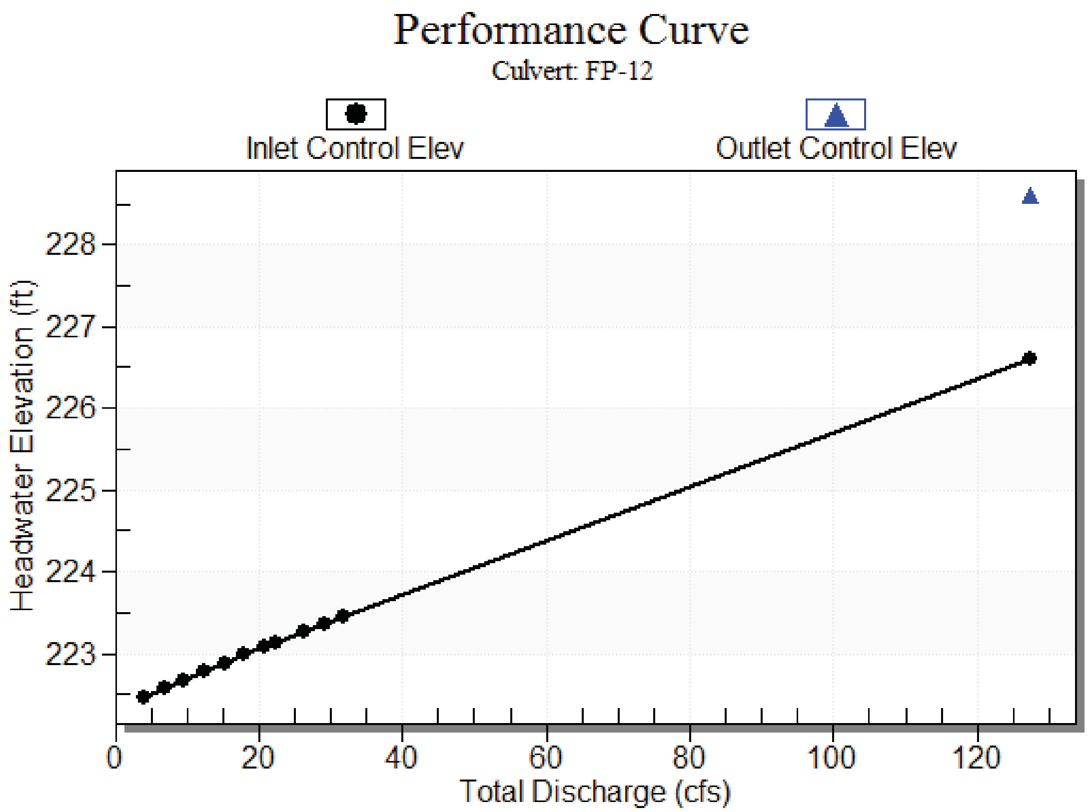
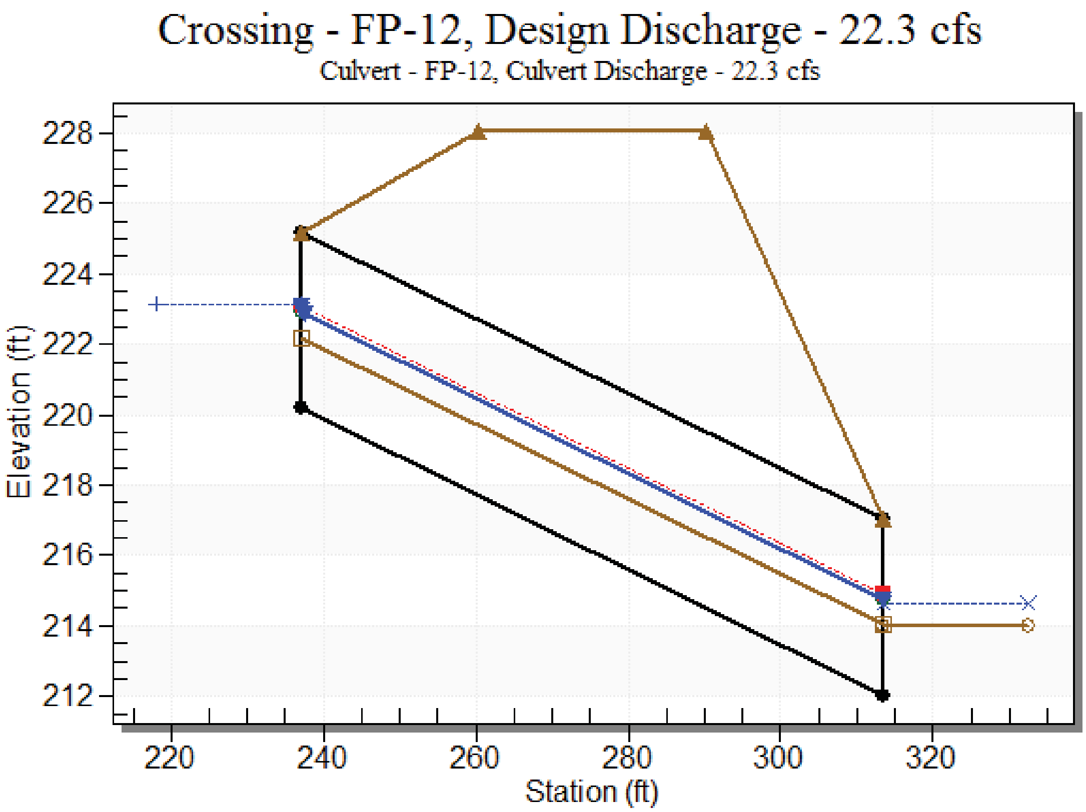
Culvert Performance Curve Plot: FP-12



Water Surface Profile Plot for Culvert: FP-12



Site Data - FP-12

Site Data Option: Culvert Invert Data

Inlet Station: 237.10 ft

Inlet Elevation: 220.19 ft

Outlet Station: 313.48 ft

Outlet Elevation: 212.04 ft

Number of Barrels: 1

Culvert Data Summary - FP-12

Barrel Shape: Circular

Barrel Diameter: 5.00 ft

Barrel Material: Corrugated Aluminum

Embedment: 24.00 in

Barrel Manning's n: 0.0310 (top and sides)

Manning's n: 0.0600 (bottom)

Culvert Type: Straight

Inlet Configuration: Mitered to Conform to Slope

Inlet Depression: NONE

Table 36 - Downstream Channel Rating Curve (Crossing: FP-12)

Flow (cfs)	Water Surface Elev (ft)	Depth (ft)	Velocity (ft/s)	Shear (psf)	Froude Number
4.10	214.25	0.25	2.89	1.64	1.10
6.88	214.33	0.33	3.44	2.20	1.14
9.66	214.40	0.40	3.84	2.67	1.18
12.44	214.46	0.46	4.17	3.08	1.20
15.22	214.52	0.52	4.44	3.44	1.22
18.00	214.57	0.57	4.67	3.78	1.23
20.78	214.61	0.61	4.88	4.09	1.24
22.30	214.64	0.64	4.99	4.24	1.25
26.34	214.70	0.70	5.24	4.64	1.27
29.12	214.73	0.73	5.40	4.90	1.27
31.90	214.77	0.77	5.54	5.15	1.28

Tailwater Channel Data - FP-12

Tailwater Channel Option: Trapezoidal Channel

Bottom Width: 5.00 ft

Side Slope (H:V): 3.20 (_:1)

Channel Slope: 0.1070

Channel Manning's n: 0.0600

Channel Invert Elevation: 214.00 ft

Roadway Data for Crossing: FP-12

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 100.00 ft

Crest Elevation: 228.08 ft

Roadway Surface: Paved

Roadway Top Width: 30.00 ft

FP-13

Crossing Discharge Data

Discharge Selection Method: Specify Minimum, Design, and Maximum Flow

Minimum Flow: 39.8 cfs – Q_{fish}

Design Flow: 210.8 cfs – Q_{50}

Maximum Flow: 301.5 cfs – Q_{500}

Table 1 - Summary of Culvert Flows at Crossing: FP-13

	Headwater Elevation (ft)	Total Discharge (cfs)	FP-13 Discharge (cfs)	Roadway Discharge (cfs)	Iterations
Q_2	97.25	39.80	39.80	0.00	1
	98.22	65.97	65.97	0.00	1
	98.86	92.14	92.14	0.00	1
	99.45	118.31	118.31	0.00	1
	100.19	144.48	144.48	0.00	1
	100.44	170.65	170.65	0.00	1
	100.70	196.82	196.82	0.00	1
Q_{50}	100.83	210.80	210.80	0.00	1
	100.02	249.16	249.16	0.00	1
	100.26	275.33	275.33	0.00	1
	100.49	301.50	301.50	0.00	1
Q_{500}	111.43	1232.77	1232.77	0.00	Overtopping

HW = 100.83' − 95.61' = 5.22'

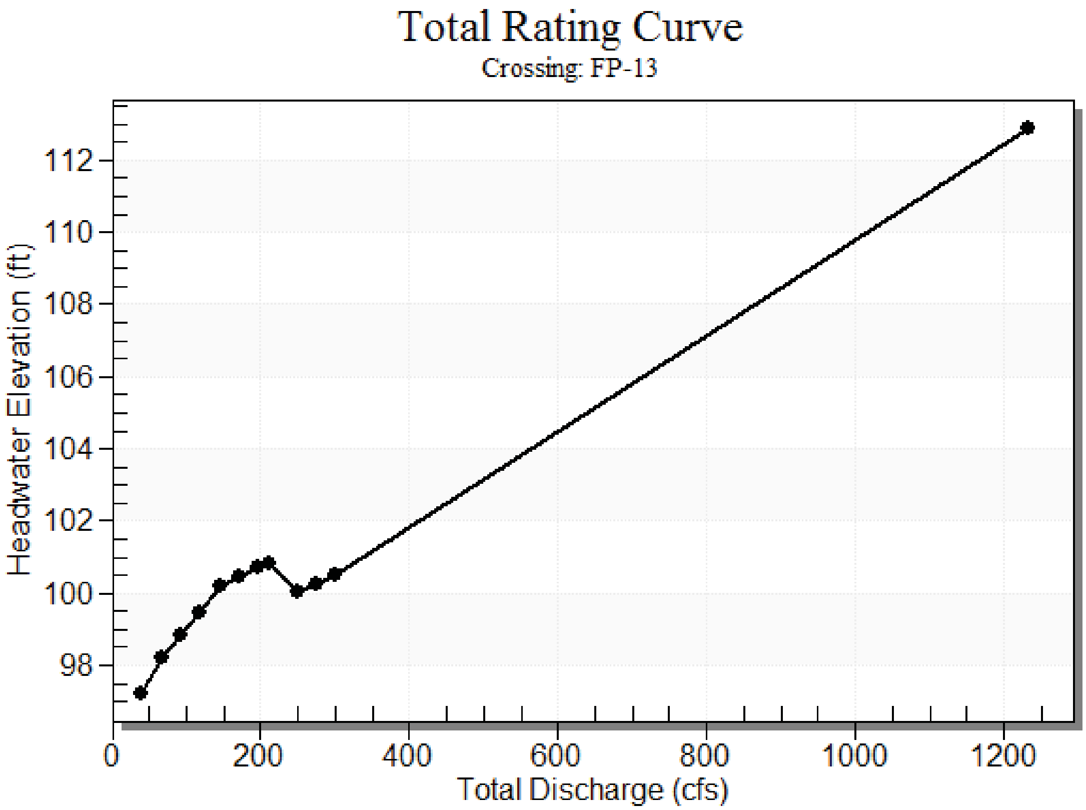
(100.83' @ Q_{50}; 95.61' INLET)

D = 9'-2" − 2' = 7.17'

(9'-2" RISE; 2' EMBED)

HW/D = 0.73 < 1.2 ✓

Rating Curve Plot for Crossing: FP-13



HY-8 Analysis Results

Culvert Summary Table - FP-13

Culvert Crossing: FP-13

Total Discharge (cfs)	Culvert Discharge (cfs)	Headwater Elevation (ft)	Inlet Control Depth(ft)	Outlet Control Depth(ft)	Flow Type	Normal Depth (ft)	Critical Depth (ft)	Outlet Depth (ft)	Tailwater Depth (ft)	Outlet Velocity (ft/s)	Tailwater Velocity (ft/s)
39.80	39.80	97.25	1.64	0.0*	1-S2n	0.57	0.63	0.62	1.49	4.11	5.25
65.97	65.97	98.22	2.61	0.0*	1-S2n	0.82	0.89	0.82	1.81	5.83	5.95
92.14	92.14	98.86	3.25	0.0*	1-S2n	0.99	1.11	0.99	2.05	6.71	6.47
118.31	118.31	99.45	3.84	0.0*	1-S2n	1.16	1.31	1.16	2.25	7.32	6.89
144.48	144.48	100.19	4.58	0.0*	1-S2n	1.33	1.49	1.33	2.42	7.77	7.24
170.65	170.65	100.44	4.83	0.0*	1-S2n	1.48	1.67	1.48	2.58	8.23	7.55
196.82	196.82	100.70	5.09	0.0*	1-S2n	1.61	1.84	1.61	2.72	8.74	7.82
210.80	210.80	100.83	5.22	0.0*	1-S2n	1.68	1.92	1.68	2.79	8.99	7.96
249.16	249.16	100.02	4.41	0.0*	1-S2n	1.86	2.15	1.86	2.97	9.56	8.30
275.33	275.33	100.26	4.65	0.0*	1-S2n	1.99	2.29	1.99	3.08	9.89	8.51
301.50	301.50	100.49	4.88	0.0*	1-S2n	2.11	2.43	2.11	3.19	10.18	8.70

* Full Flow Headwater elevation is below inlet invert.

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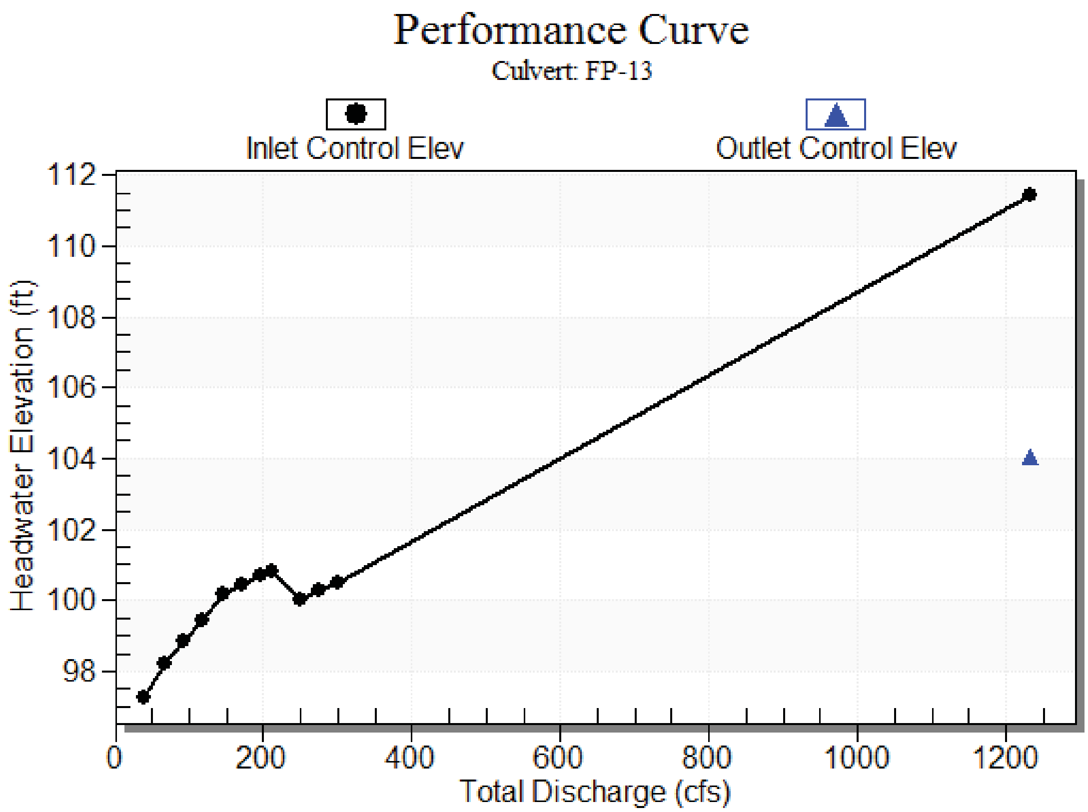
Straight Culvert

Inlet Elevation (invert): 95.61 ft, Outlet Elevation (invert): 85.13 ft

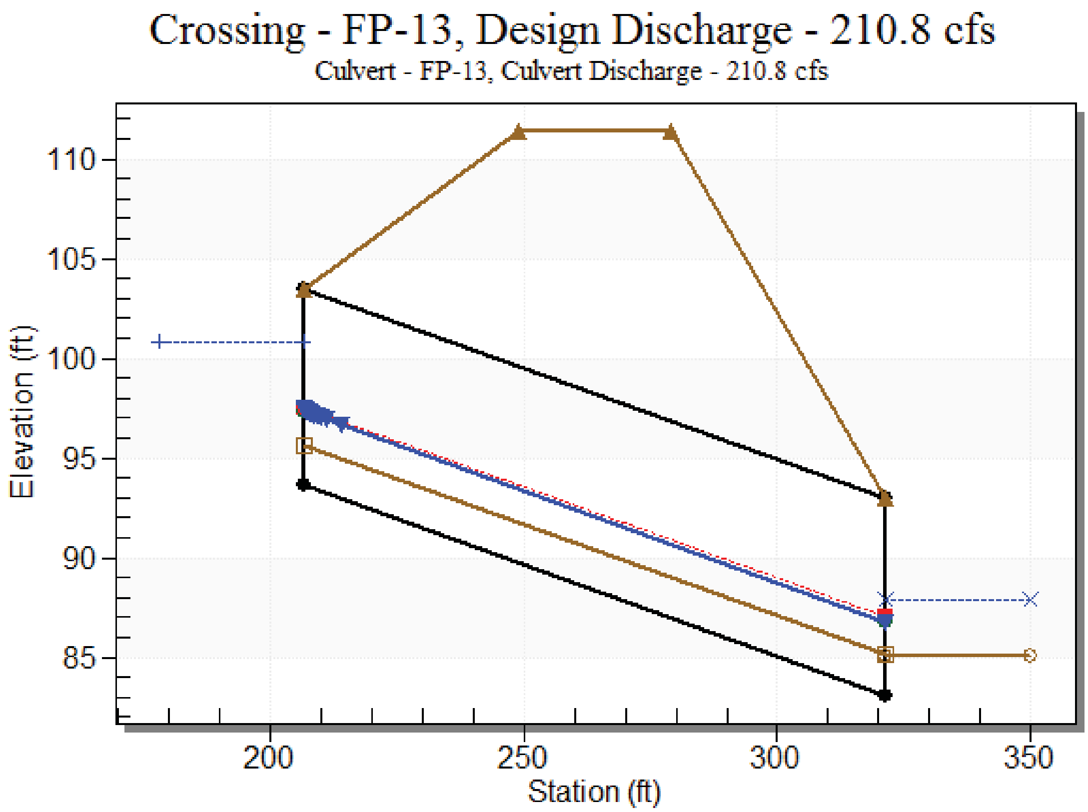
Culvert Length: 115.24 ft, Culvert Slope: 0.0913

****

Culvert Performance Curve Plot: FP-13



Water Surface Profile Plot for Culvert: FP-13



Site Data - FP-13

Site Data Option: Culvert Invert Data

Inlet Station: 206.62 ft

Inlet Elevation: 93.61 ft

Outlet Station: 321.38 ft

Outlet Elevation: 83.13 ft

Number of Barrels: 1

Culvert Data Summary - FP-13

Barrel Shape: Pipe Arch

Barrel Span: 170.60 in

Barrel Rise: 118.40 in

Barrel Material: Steel Structural Plate

Embedment: 24.00 in

Barrel Manning's n: 0.0340 (top and sides)

Manning's n: 0.0700 (bottom)

Culvert Type: Straight

Inlet Configuration: Mitered to Conform to Slope

Inlet Depression: NONE

Table 3 - Downstream Channel Rating Curve (Crossing: FP-13)

Flow (cfs)	Water Surface Elev (ft)	Depth (ft)	Velocity (ft/s)	Shear (psf)	Froude Number
39.80	86.59	1.49	5.25	6.52	1.07
65.97	86.91	1.81	5.95	7.89	1.10
92.14	87.15	2.05	6.47	8.94	1.13
118.31	87.35	2.25	6.89	9.82	1.15
144.48	87.52	2.42	7.24	10.58	1.16
170.65	87.68	2.58	7.55	11.26	1.17
196.82	87.82	2.72	7.82	11.88	1.18
210.80	87.89	2.79	7.96	12.19	1.19
249.16	88.07	2.97	8.30	12.98	1.20
275.33	88.18	3.08	8.51	13.47	1.21
301.50	88.29	3.19	8.70	13.94	1.21

Tailwater Channel Data - FP-13

Tailwater Channel Option: Triangular Channel

Side Slope (H:V): 3.40 (_:1)

Channel Slope: 0.0700

Channel Manning's n: 0.0600

Channel Invert Elevation: 85.10 ft

Roadway Data for Crossing: FP-13

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 100.00 ft

Crest Elevation: 111.43 ft

Roadway Surface: Paved

Roadway Top Width: 30.00 ft

FP-14

Crossing Discharge Data

Discharge Selection Method: Specify Minimum, Design, and Maximum Flow

Minimum Flow: 13 cfs — Q_{fish}

Design Flow: 70.5 cfs — Q_{50}

Maximum Flow: 100.6 cfs - Q_{500}

Table 40 - Summary of Culvert Flows at Crossing: FP-14

	Headwater Elevation (ft)	Total Discharge (cfs)	FP-14 Discharge (cfs)	Roadway Discharge (cfs)	Iterations
Q_{fish}	272.08	13.00	13.00	0.00	1
	272.25	21.76	21.76	0.00	1
	272.42	30.52	30.52	0.00	1
	272.58	39.28	39.28	0.00	1
	272.74	48.04	48.04	0.00	1
	272.90	56.80	56.80	0.00	1
	273.05	65.56	65.56	0.00	1
Q_{50}	273.14	70.50	70.50	0.00	1
	273.35	83.08	83.08	0.00	1
	273.49	91.84	91.84	0.00	1
	273.63	100.60	100.60	0.00	1
Q_{500}	289.41	530.28	530.28	0.00	Overtopping

$HW = 273.14' - 271.68' = 1.46'$

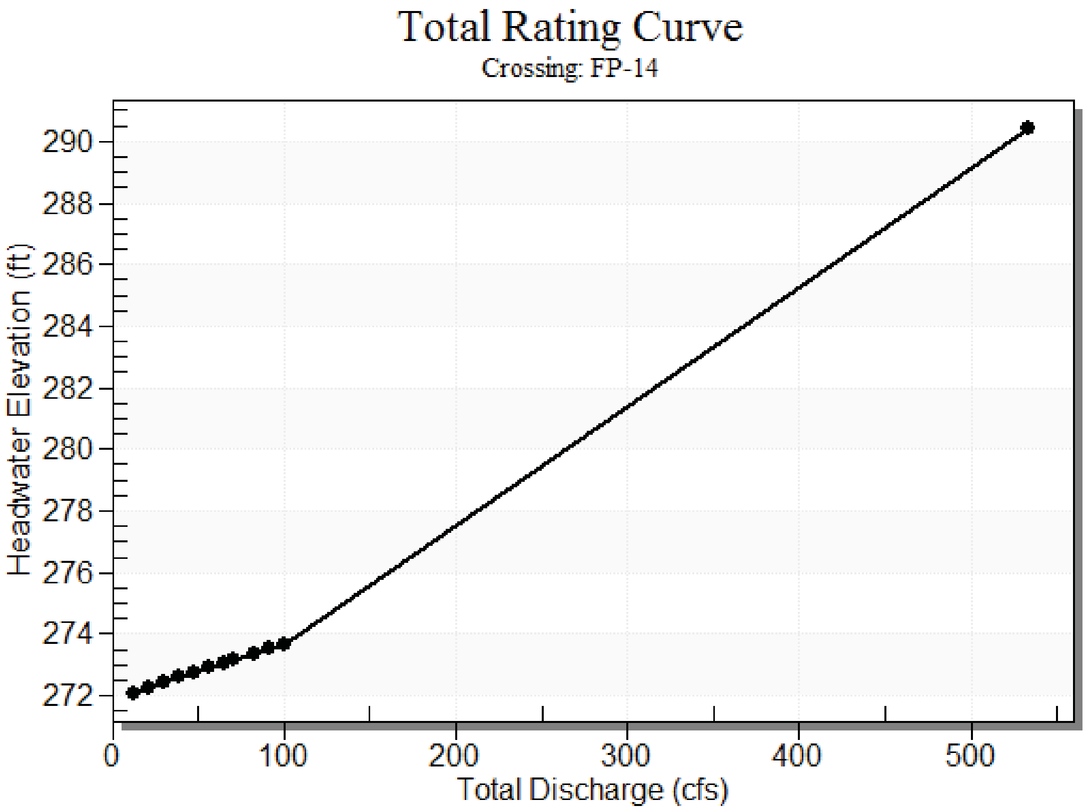
(273.14' @ Q_{50}; 271.68' INLET)

$D = 8' - 3.2' = 4.8'$

(8' Ø; 3.2' EMBED)

$HW/D = 0.30 < 1.2$

Rating Curve Plot for Crossing: FP-14



HY-8 Analysis Results

Culvert Summary Table - FP-14

Culvert Crossing: FP-14

Total Discharge (cfs)	Culvert Discharge (cfs)	Headwater Elevation (ft)	Inlet Control Depth(ft)	Outlet Control Depth(ft)	Flow Type	Normal Depth (ft)	Critical Depth (ft)	Outlet Depth (ft)	Tailwater Depth (ft)	Outlet Velocity (ft/s)	Tailwater Velocity (ft/s)
13.00	13.00	272.08	0.40	0.0*	1-S2n	0.40	0.43	0.40	0.61	3.82	3.76
21.76	21.76	272.25	0.57	0.0*	1-S2n	0.54	0.61	0.54	0.82	5.09	4.44
30.52	30.52	272.42	0.74	0.0*	1-S2n	0.67	0.77	0.67	1.00	5.79	4.93
39.28	39.28	272.58	0.90	0.0*	1-S2n	0.79	0.91	0.79	1.15	6.27	5.32
48.04	48.04	272.74	1.06	0.0*	1-S2n	0.90	1.05	0.90	1.29	6.71	5.65
56.80	56.80	272.90	1.22	0.0*	1-S2n	1.00	1.18	1.00	1.41	7.20	5.93
65.56	65.56	273.05	1.37	0.0*	1-S2n	1.09	1.29	1.09	1.53	7.61	6.18
70.50	70.50	273.14	1.46	0.0*	1-S2n	1.14	1.35	1.14	1.59	7.81	6.31
83.08	83.08	273.35	1.67	0.0*	1-S2n	1.27	1.51	1.27	1.74	8.25	6.61
91.84	91.84	273.49	1.81	0.0*	1-S2n	1.35	1.61	1.35	1.83	8.56	6.80
100.60	100.60	273.63	1.95	0.0*	1-S2n	1.43	1.71	1.43	1.93	8.88	6.97

* Full Flow Headwater elevation is below inlet invert.

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Straight Culvert

Inlet Elevation (invert): 271.70 ft,   Outlet Elevation (invert): 257.23 ft

Culvert Length: 124.81 ft,   Culvert Slope: 0.1167

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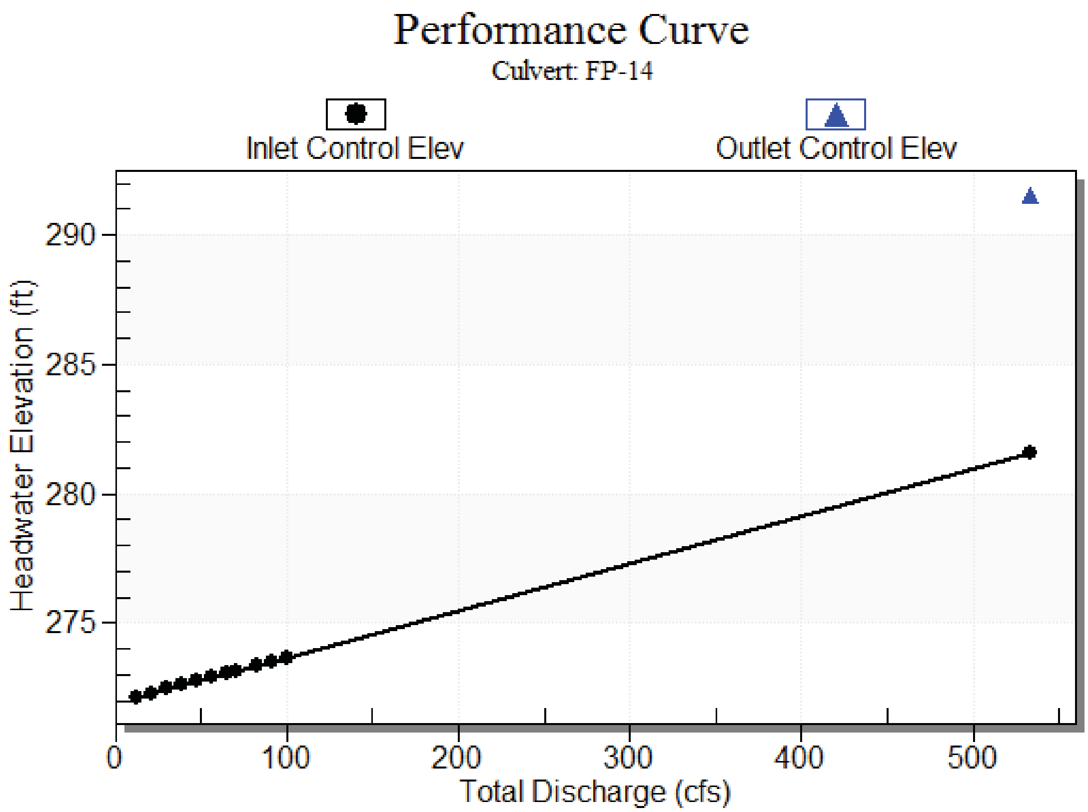
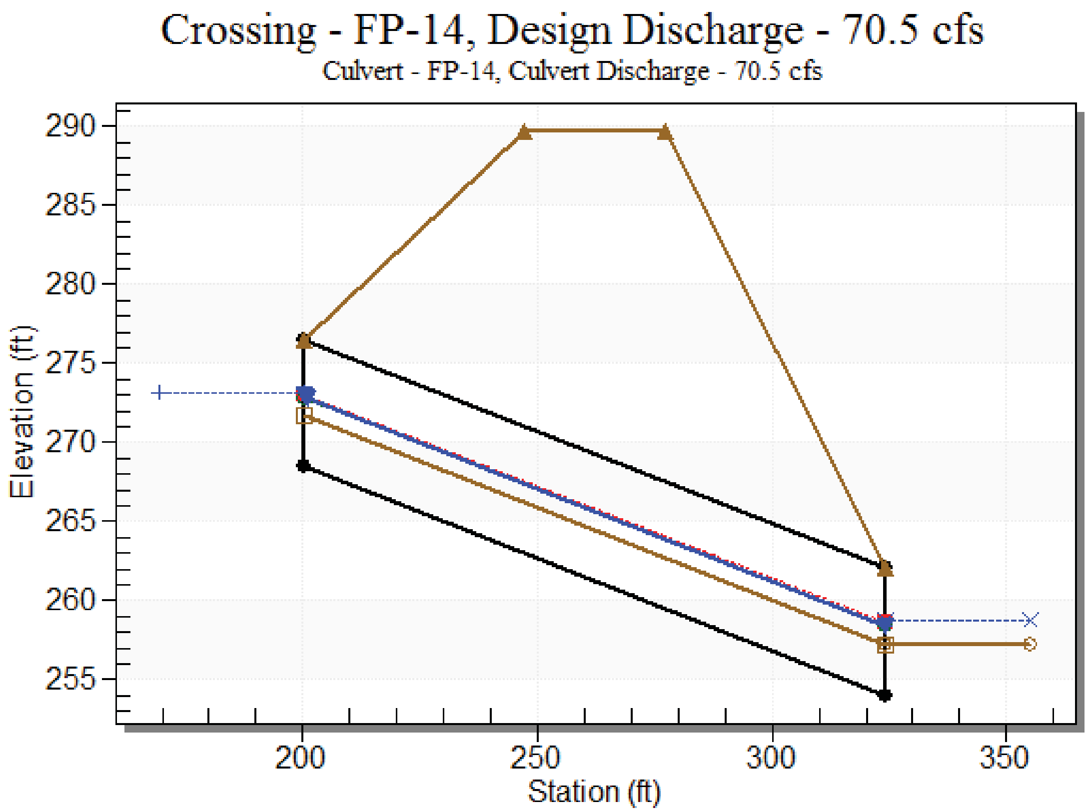
Culvert Performance Curve Plot: FP-14



Water Surface Profile Plot for Culvert: FP-14



Site Data - FP-14

Site Data Option: Culvert Invert Data

Inlet Station: 200.24 ft

Inlet Elevation: 268.50 ft

Outlet Station: 324.21 ft

Outlet Elevation: 254.03 ft

Number of Barrels: 1

Culvert Data Summary - FP-14

Barrel Shape: Circular

Barrel Diameter: 8.00 ft

Barrel Material: Corrugated Aluminum

Embedment: 38.40 in

Barrel Manning's n: 0.0310 (top and sides)

Manning's n: 0.0700 (bottom)

Culvert Type: Straight

Inlet Configuration: Mitered to Conform to Slope

Inlet Depression: NONE

Table 42 - Downstream Channel Rating Curve (Crossing: FP-14)

Flow (cfs)	Water Surface Elev (ft)	Depth (ft)	Velocity (ft/s)	Shear (psf)	Froude Number
13.00	257.81	0.61	3.76	3.01	0.91
21.76	258.02	0.82	4.44	4.06	0.94
30.52	258.20	1.00	4.93	4.92	0.96
39.28	258.35	1.15	5.32	5.67	0.98
48.04	258.49	1.29	5.65	6.35	0.99
56.80	258.61	1.41	5.93	6.96	1.00
65.56	258.73	1.53	6.18	7.53	1.01
70.50	258.79	1.59	6.31	7.84	1.01
83.08	258.94	1.74	6.61	8.57	1.02
91.84	259.03	1.83	6.80	9.04	1.03
100.60	259.13	1.93	6.97	9.49	1.03

Tailwater Channel Data - FP-14

Tailwater Channel Option: Trapezoidal Channel

Bottom Width: 4.80 ft

Side Slope (H:V): 1.40 (_:1)

Channel Slope: 0.0790

Channel Manning's n: 0.0700

Channel Invert Elevation: 257.20 ft

Roadway Data for Crossing: FP-14

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 100.00 ft

Crest Elevation: 289.75 ft

Roadway Surface: Paved

Roadway Top Width: 30.00 ft

FP-15

Crossing Discharge Data

Discharge Selection Method: Specify Minimum, Design, and Maximum Flow

Minimum Flow: 26.3 cfs – Q_{fish}

Design Flow: 138.6 cfs – Q_{50}

Maximum Flow: 198.8 cfs – Q_{500}

Table 43 - Summary of Culvert Flows at Crossing: FP-15

	Headwater Elevation (ft)	Total Discharge (cfs)	FP-15 Discharge (cfs)	Roadway Discharge (cfs)	Iterations
Q_2	318.04	26.30	26.30	0.00	1
	318.61	43.55	43.55	0.00	1
	319.51	60.80	60.80	0.00	1
	319.78	78.05	78.05	0.00	1
	319.33	95.30	95.30	0.00	1
	319.59	112.55	112.55	0.00	1
	319.85	129.80	129.80	0.00	1
Q_{50}	319.98	138.60	138.60	0.00	1
	320.36	164.30	164.30	0.00	1
	320.62	181.55	181.55	0.00	1
	320.87	198.80	198.80	0.00	1
Q_{500}	329.34	559.50	559.50	0.00	Overtopping

$HW = 319.98' - 316.62' = 3.36'$

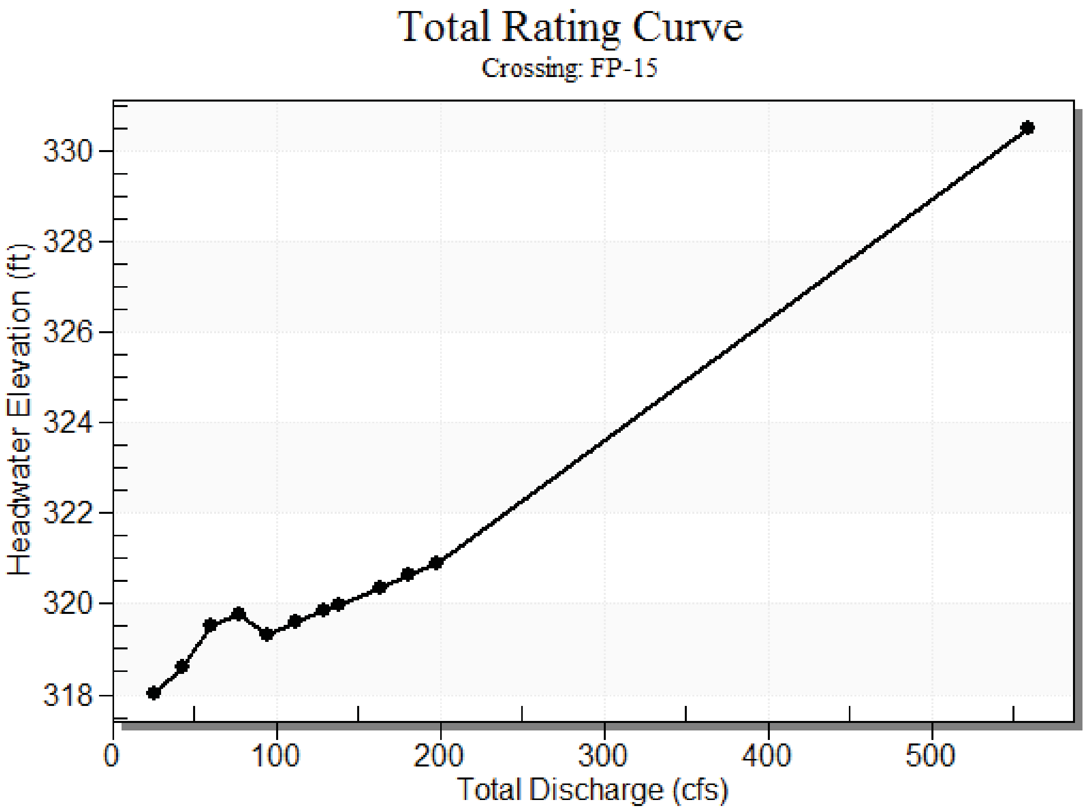
(319.98' @ Q_{50}; 316.62' INLET)

$D = 6.92' - 2' = 4.92'$

(6.92' RISE; 2' EMBED)

$HW/D = 0.68 < 1.2$ ✓

Rating Curve Plot for Crossing: FP-15



HY-8 Analysis Results

Culvert Summary Table - FP-15

Culvert Crossing: FP-15

Total Discharge (cfs)	Culvert Discharge (cfs)	Headwater Elevation (ft)	Inlet Control Depth(ft)	Outlet Control Depth(ft)	Flow Type	Normal Depth (ft)	Critical Depth (ft)	Outlet Depth (ft)	Tailwater Depth (ft)	Outlet Velocity (ft/s)	Tailwater Velocity (ft/s)
26.30	26.30	317.86	1.48	0.0*	1-S2n	0.54	0.59	0.54	0.64	4.81	4.71
43.55	43.55	318.45	2.07	0.0*	1-S2n	0.75	0.82	0.75	0.85	5.76	5.55
60.80	60.80	319.31	2.93	0.0*	1-S2n	0.93	1.04	0.93	1.03	6.46	6.16
78.05	78.05	319.61	3.23	0.0*	1-S2n	1.08	1.23	1.08	1.18	7.13	6.64
95.30	95.30	319.19	2.81	0.0*	1-S2n	1.23	1.40	1.23	1.32	7.64	7.06
112.55	112.55	319.46	3.08	0.0*	1-S2n	1.36	1.56	1.36	1.44	8.12	7.41
129.80	129.80	319.74	3.36	0.0*	1-S2n	1.49	1.72	1.49	1.56	8.58	7.73
138.60	138.60	319.89	3.51	0.0*	1-S2n	1.56	1.79	1.57	1.61	8.68	7.87
164.30	164.30	320.30	3.92	0.0*	1-S2n	1.74	2.00	1.74	1.76	9.31	8.27
181.55	181.55	320.57	4.19	0.0*	1-S2n	1.86	2.13	1.86	1.86	9.67	8.50
198.80	198.80	320.84	4.46	0.0*	1-S2n	1.97	2.26	1.97	1.95	9.99	8.73

* Full Flow Headwater elevation is below inlet invert.

****

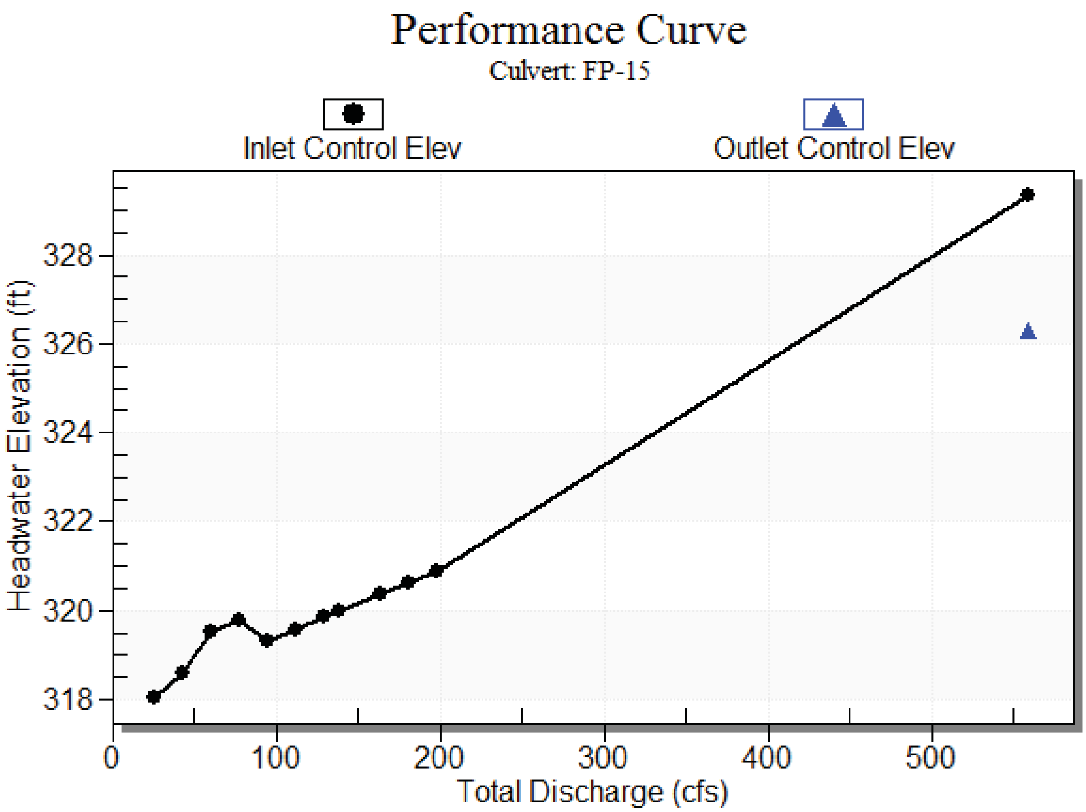
Straight Culvert

Inlet Elevation (invert): 316.62 ft,   Outlet Elevation (invert): 308.74 ft

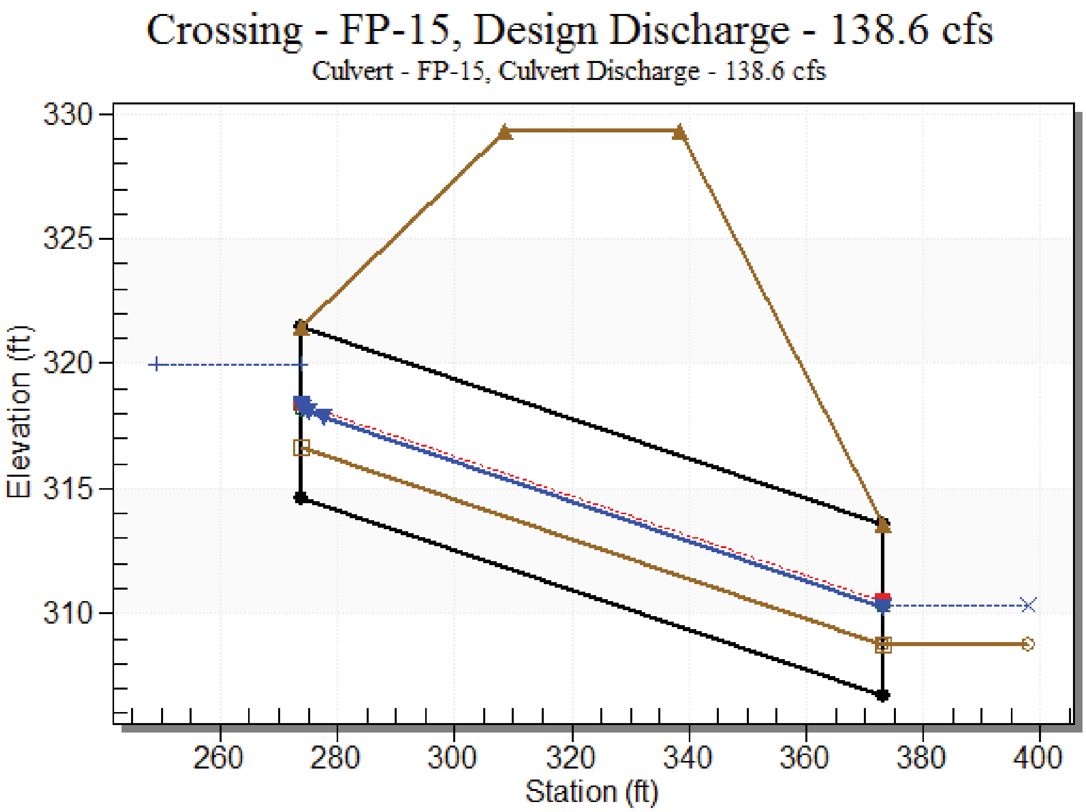
Culvert Length: 99.64 ft,   Culvert Slope: 0.0793

****

Culvert Performance Curve Plot: FP-15



Water Surface Profile Plot for Culvert: FP-15



Site Data - FP-15

Site Data Option: Culvert Invert Data

Inlet Station: 273.86 ft

Inlet Elevation: 314.62 ft

Outlet Station: 373.19 ft

Outlet Elevation: 306.74 ft

Number of Barrels: 1

Culvert Data Summary - FP-15

Barrel Shape: Pipe Arch

Barrel Span: 129.00 in

Barrel Rise: 82.00 in

Barrel Material: Aluminum Structural Plate

Embedment: 24.00 in

Barrel Manning's n: 0.0340 (top and sides)

Manning's n: 0.0600 (bottom)

Culvert Type: Straight

Inlet Configuration: Mitered

Inlet Depression: NONE

Table 45 - Downstream Channel Rating Curve (Crossing: FP-15)

Flow (cfs)	Water Surface Elev (ft)	Depth (ft)	Velocity (ft/s)	Shear (psf)	Froude Number
26.30	309.34	0.64	4.71	3.55	1.12
43.55	309.55	0.85	5.55	4.73	1.16
60.80	309.73	1.03	6.16	5.71	1.19
78.05	309.88	1.18	6.64	6.55	1.21
95.30	310.02	1.32	7.06	7.31	1.23
112.55	310.14	1.44	7.41	8.00	1.24
129.80	310.26	1.56	7.73	8.64	1.26
138.60	310.31	1.61	7.87	8.95	1.26
164.30	310.46	1.76	8.27	9.79	1.28
181.55	310.56	1.86	8.50	10.32	1.28
198.80	310.65	1.95	8.73	10.83	1.29

Tailwater Channel Data - FP-15

Tailwater Channel Option: Trapezoidal Channel

Bottom Width: 7.30 ft

Side Slope (H:V): 2.25 (_:1)

Channel Slope: 0.0890

Channel Manning's n: 0.0620

Channel Invert Elevation: 308.70 ft

Roadway Data for Crossing: FP-15

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 100.00 ft

Crest Elevation: 329.34 ft

Roadway Surface: Paved

Roadway Top Width: 30.00 ft

FP-16

Crossing Discharge Data

Discharge Selection Method: Specify Minimum, Design, and Maximum Flow

Minimum Flow: 2 cfs — Q_{fish}

Design Flow: 10.9 cfs — Q_{50}

Maximum Flow: 15.6 cfs - Q_{500}

Table 46 - Summary of Culvert Flows at Crossing: FP-16

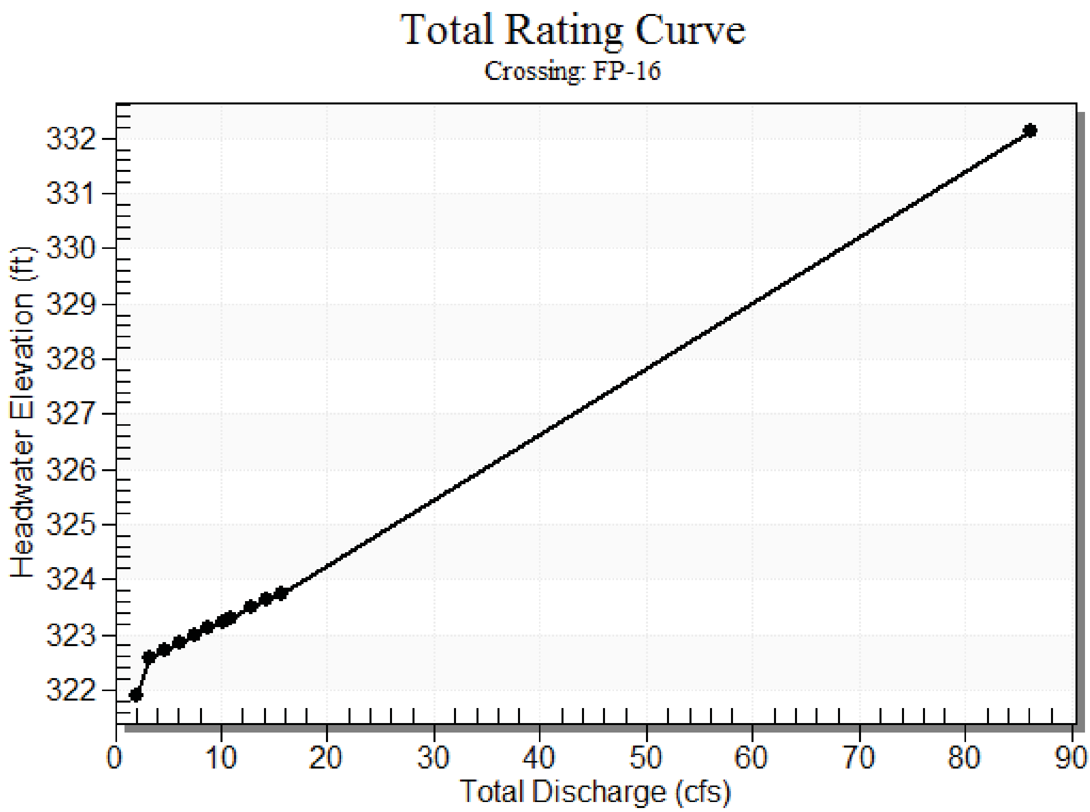
	Headwater Elevation (ft)	Total Discharge (cfs)	FP-16 Discharge (cfs)	Roadway Discharge (cfs)	Iterations
Q_{fish}	321.92	2.00	2.00	0.00	1
	322.59	3.36	3.36	0.00	1
	322.72	4.72	4.72	0.00	1
	322.85	6.08	6.08	0.00	1
	322.98	7.44	7.44	0.00	1
	323.11	8.80	8.80	0.00	1
	323.23	10.16	10.16	0.00	1
Q_{50}	323.30	10.90	10.90	0.00	1
	323.49	12.88	12.88	0.00	1
	323.62	14.24	14.24	0.00	1
	323.75	15.60	15.60	0.00	1
Q_{500}	331.97	86.74	86.74	0.00	Overtopping

HW = 323.30' (@ Q_{50}) − 321.53' (INLET) = 1.77'

D = 5' (ϕ) − 2' (EMBED) = 3'

HW/D = 0.59 < 1.5 ✓

Rating Curve Plot for Crossing: FP-16



HY-8 Analysis Results

Culvert Summary Table - FP-16

Culvert Crossing: FP-16

Total Discharge (cfs)	Culvert Discharge (cfs)	Headwater Elevation (ft)	Inlet Control Depth(ft)	Outlet Control Depth(ft)	Flow Type	Normal Depth (ft)	Critical Depth (ft)	Outlet Depth (ft)	Tailwater Depth (ft)	Outlet Velocity (ft/s)	Tailwater Velocity (ft/s)
2.00	2.00	322.46	0.32	0.93	3-M1t	0.35	0.17	2.07	2.04	0.21	0.53
3.36	3.36	322.59	0.38	1.06	3-M1t	0.48	0.24	2.18	2.15	0.33	0.64
4.72	4.72	322.70	0.43	1.17	3-M1t	0.60	0.30	2.26	2.23	0.45	0.72
6.08	6.08	322.81	0.49	1.28	3-M1t	0.70	0.36	2.34	2.31	0.57	0.79
7.44	7.44	322.91	0.54	1.38	3-M1t	0.80	0.41	2.40	2.37	0.68	0.85
8.80	8.80	323.00	0.59	1.47	3-M1t	0.89	0.45	2.47	2.44	0.79	0.91
10.16	10.16	323.09	0.64	1.56	3-M1t	0.97	0.50	2.53	2.50	0.90	0.95
10.90	10.90	323.14	0.67	1.61	3-M1t	1.02	0.52	2.56	2.53	0.96	0.98
12.88	12.88	323.27	0.75	1.74	3-M1t	1.13	0.59	2.63	2.60	1.11	1.03
14.24	14.24	323.36	0.80	1.83	3-M1t	1.21	0.64	2.68	2.65	1.21	1.07
15.60	15.60	323.44	0.84	1.91	3-M1t	1.28	0.68	2.73	2.70	1.32	1.10

****

Straight Culvert

Inlet Elevation (invert): 321.52 ft,   Outlet Elevation (invert): 320.37 ft

Culvert Length: 81.31 ft,   Culvert Slope: 0.0141

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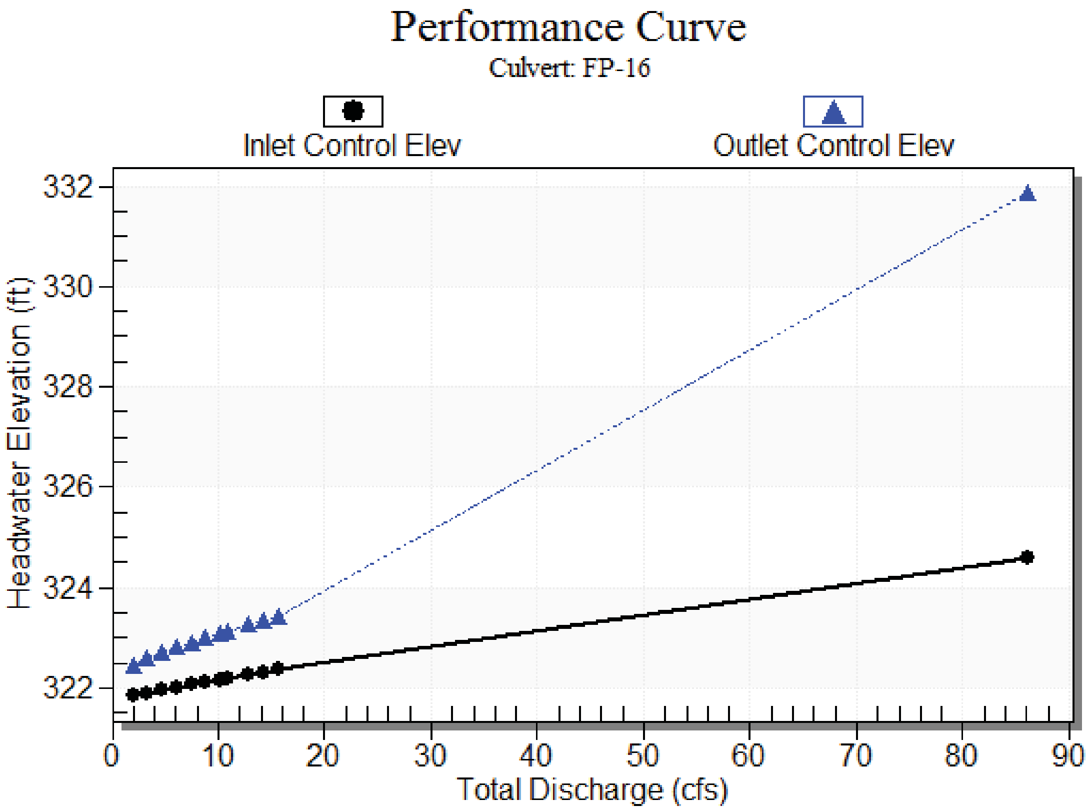
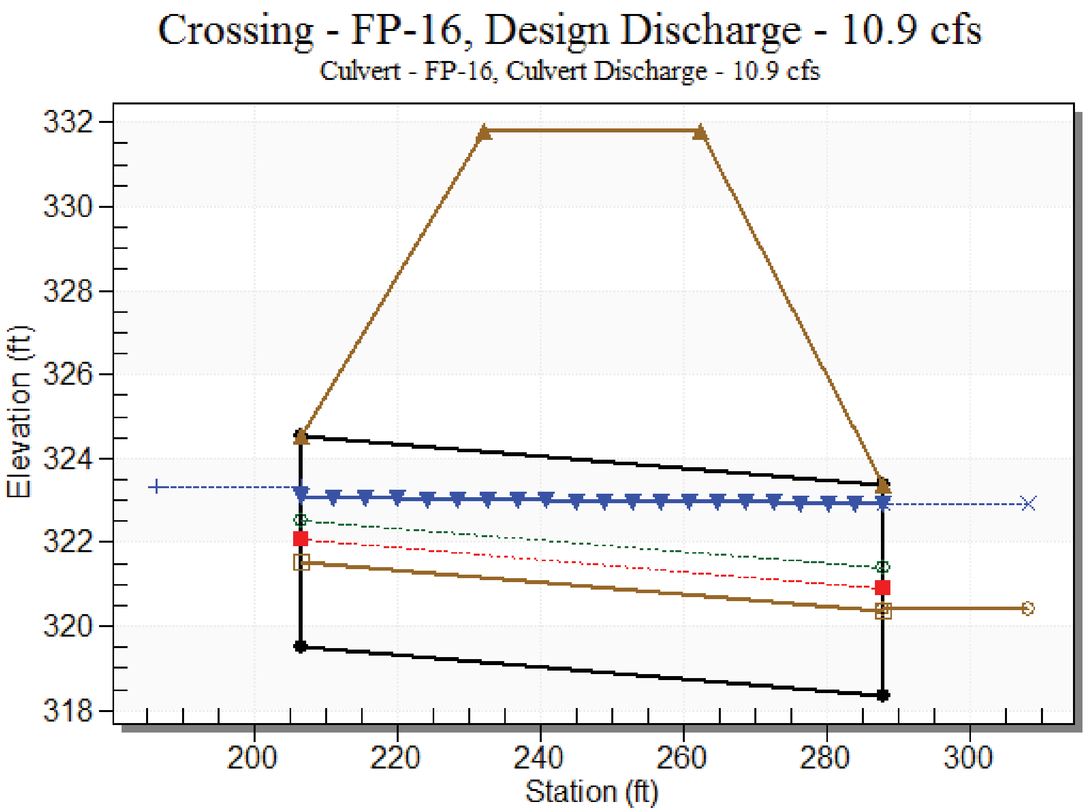
Culvert Performance Curve Plot: FP-16



Water Surface Profile Plot for Culvert: FP-16



Site Data - FP-16

Site Data Option: Culvert Invert Data

Inlet Station: 206.63 ft

Inlet Elevation: 319.52 ft

Outlet Station: 287.93 ft

Outlet Elevation: 318.37 ft

Number of Barrels: 1

Culvert Data Summary - FP-16

Barrel Shape: Circular

Barrel Diameter: 5.00 ft

Barrel Material: Corrugated Aluminum

Embedment: 24.00 in

Barrel Manning's n: 0.0310 (top and sides)

Manning's n: 0.0800 (bottom)

Culvert Type: Straight

Inlet Configuration: Mitered to Conform to Slope

Inlet Depression: NONE

Table 48 - Downstream Channel Rating Curve (Crossing: FP-16)

Flow (cfs)	Water Surface Elev (ft)	Depth (ft)	Velocity (ft/s)	Shear (psf)	Froude Number
2.00	322.44	2.04	0.53	0.76	0.18
3.36	322.55	2.15	0.64	0.80	0.19
4.72	322.63	2.23	0.72	0.84	0.19
6.08	322.71	2.31	0.79	0.86	0.20
7.44	322.77	2.37	0.85	0.89	0.20
8.80	322.84	2.44	0.91	0.91	0.21
10.16	322.90	2.50	0.95	0.93	0.21
10.90	322.93	2.53	0.98	0.95	0.21
12.88	323.00	2.60	1.03	0.97	0.21
14.24	323.05	2.65	1.07	0.99	0.22
15.60	323.10	2.70	1.10	1.01	0.22

Tailwater Channel Data - FP-16

Tailwater Channel Option: Irregular Channel

Roadway Data for Crossing: FP-16

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 100.00 ft

Crest Elevation: 331.81 ft

Roadway Surface: Paved

Roadway Top Width: 30.00 ft

FP-17

HY-8 Culvert Analysis Report

Crossing Discharge Data

Discharge Selection Method: Specify Minimum, Design, and Maximum Flow

Minimum Flow: 5.6 cfs — Q_{fish}

Design Flow: 30.3 cfs — Q_{50}

Maximum Flow: 43.4 cfs — Q_{500}

Table 1 - Summary of Culvert Flows at Crossing: FP-17

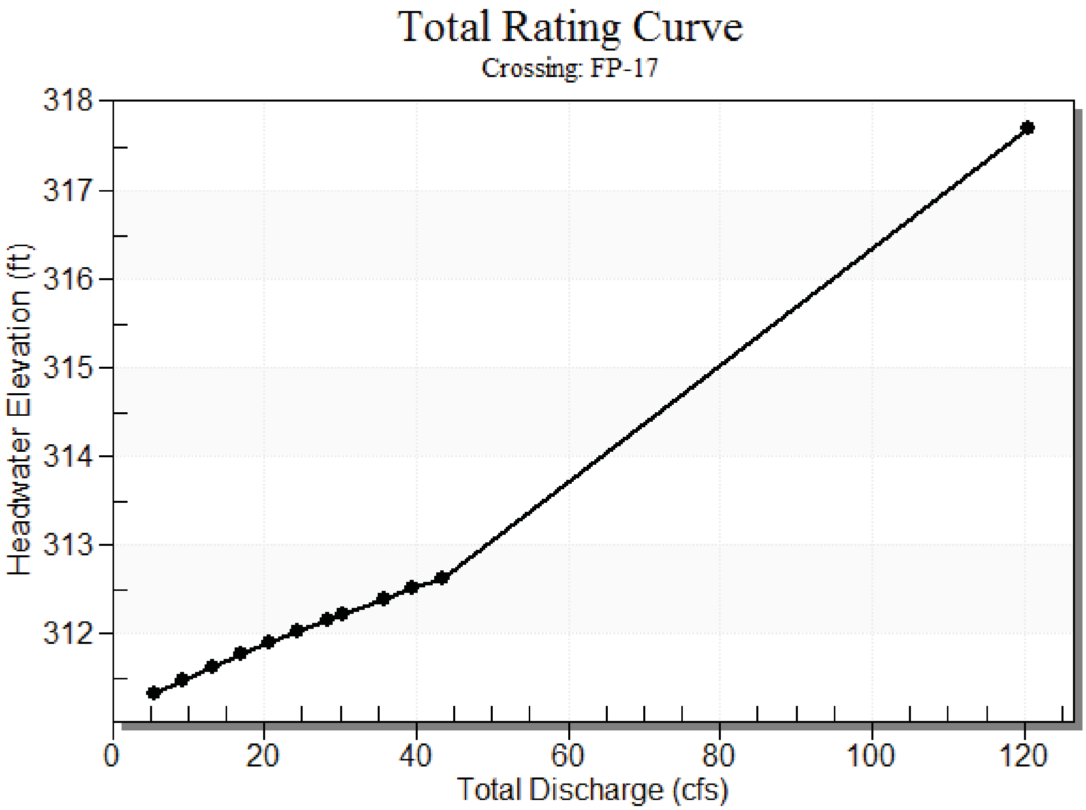
	Headwater Elevation (ft)	Total Discharge (cfs)	FP-17 Discharge (cfs)	Roadway Discharge (cfs)	Iterations
Q_{fish}	311.34	5.60	5.60	0.00	1
	311.48	9.38	9.38	0.00	1
	311.63	13.16	13.16	0.00	1
	311.76	16.94	16.94	0.00	1
	311.90	20.72	20.72	0.00	1
	312.03	24.50	24.50	0.00	1
	312.15	28.28	28.28	0.00	1
Q_{50}	312.22	30.30	30.30	0.00	1
	312.40	35.84	35.84	0.00	1
	312.52	39.62	39.62	0.00	1
	312.63	43.40	43.40	0.00	1
Q_{500}	317.41	120.64	120.64	0.00	Overtopping

HW = 312.22' (@ Q_{50}) − 310.97' (INLET) = 1.25'

D = 5' − 2' = 3'

HW/D = 0.42 < 1.5 ✓

Rating Curve Plot for Crossing: FP-17



HY-8 Analysis Results

Culvert Summary Table - FP-17

Culvert Crossing: FP-17

Total Discharge (cfs)	Culvert Discharge (cfs)	Headwater Elevation (ft)	Inlet Control Depth(ft)	Outlet Control Depth(ft)	Flow Type	Normal Depth (ft)	Critical Depth (ft)	Outlet Depth (ft)	Tailwater Depth (ft)	Outlet Velocity (ft/s)	Tailwater Velocity (ft/s)
5.60	5.60	311.34	0.37	0.0*	1-S2n	0.33	0.34	0.33	0.70	3.48	4.37
9.38	9.38	311.48	0.51	0.0*	1-S2n	0.45	0.48	0.45	0.93	4.23	5.08
13.16	13.16	311.63	0.66	0.0*	1-S2n	0.57	0.60	0.57	1.13	4.71	5.58
16.94	16.94	311.76	0.79	0.0*	1-S2n	0.66	0.72	0.66	1.34	5.22	5.68
20.72	20.72	311.90	0.93	0.0*	1-S2n	0.75	0.82	0.75	1.49	5.60	5.78
24.50	24.50	312.03	1.06	0.0*	1-S2n	0.83	0.92	0.83	1.61	5.93	5.93
28.28	28.28	312.15	1.18	0.0*	1-S2n	0.91	1.01	0.91	1.71	6.27	6.08
30.30	30.30	312.22	1.25	0.0*	1-S2n	0.95	1.05	0.95	1.76	6.44	6.16
35.84	35.84	312.40	1.43	0.0*	1-S2n	1.06	1.17	1.06	1.88	6.82	6.37
39.62	39.62	312.52	1.55	0.0*	1-S2n	1.14	1.25	1.14	1.95	7.06	6.50
43.40	43.40	312.63	1.66	0.0*	1-S2n	1.21	1.33	1.21	2.02	7.31	6.63

* Full Flow Headwater elevation is below inlet invert.

****

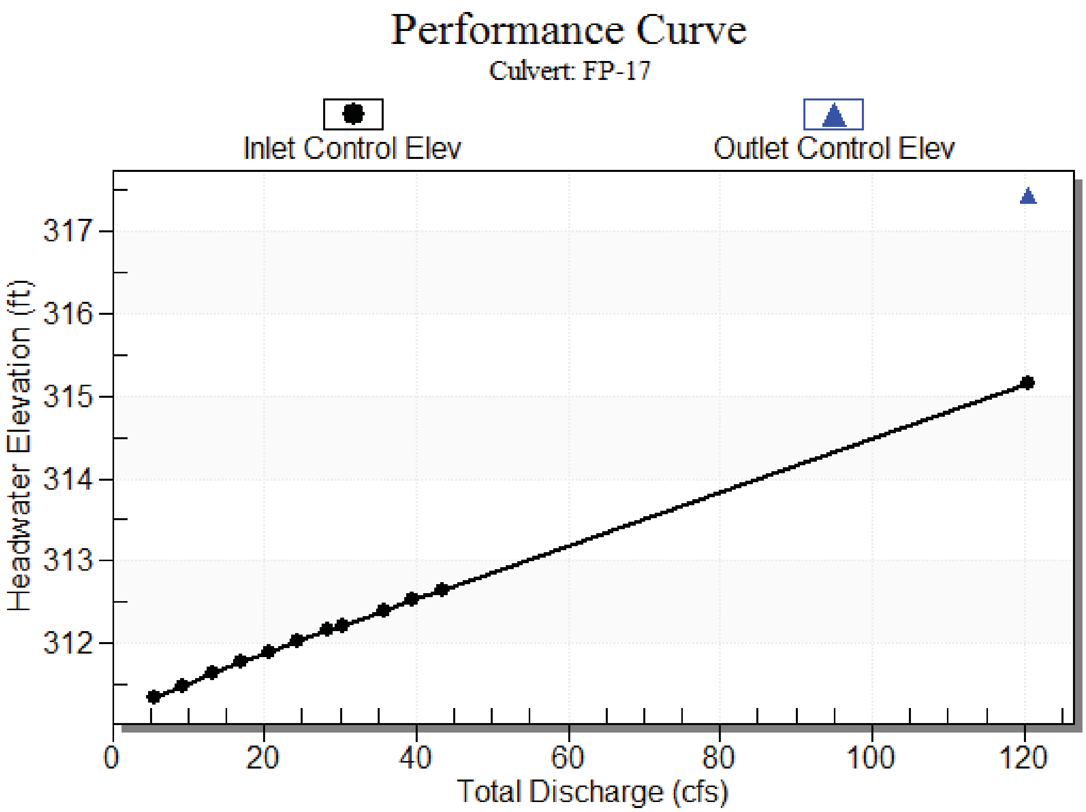
Straight Culvert

Inlet Elevation (invert): 310.97 ft,   Outlet Elevation (invert): 303.80 ft

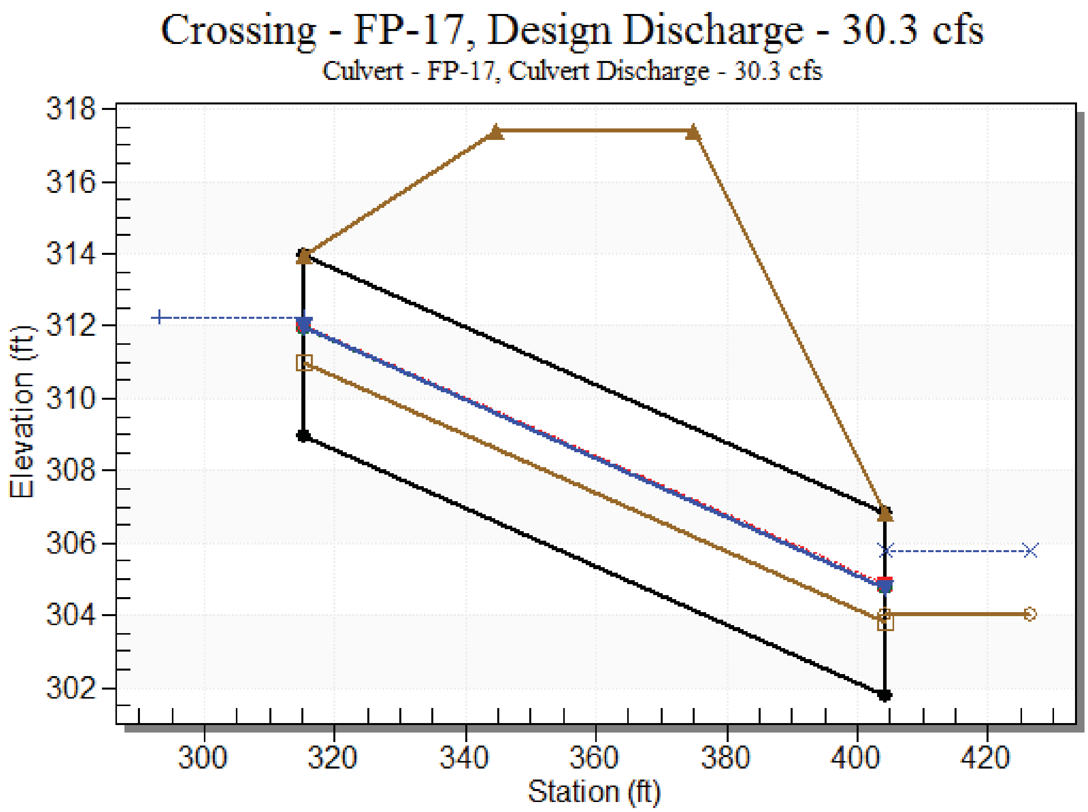
Culvert Length: 89.34 ft,   Culvert Slope: 0.0805

****

Culvert Performance Curve Plot: FP-17



Water Surface Profile Plot for Culvert: FP-17



Site Data - FP-17

Site Data Option: Culvert Invert Data

Inlet Station: 315.29 ft

Inlet Elevation: 308.97 ft

Outlet Station: 404.34 ft

Outlet Elevation: 301.80 ft

Number of Barrels: 1

Culvert Data Summary - FP-17

Barrel Shape: Circular

Barrel Diameter: 5.00 ft

Barrel Material: Corrugated Aluminum

Embedment: 24.00 in

Barrel Manning's n: 0.0310 (top and sides)

Manning's n: 0.0600 (bottom)

Culvert Type: Straight

Inlet Configuration: Mitered to Conform to Slope

Inlet Depression: NONE

Table 3 - Downstream Channel Rating Curve (Crossing: FP-17)

Flow (cfs)	Water Surface Elev (ft)	Depth (ft)	Velocity (ft/s)	Shear (psf)	Froude Number
5.60	304.70	0.70	4.37	4.78	1.06
9.38	304.93	0.93	5.08	6.32	1.05
13.16	305.13	1.13	5.58	7.67	1.04
16.94	305.34	1.34	5.68	9.11	1.08
20.72	305.49	1.49	5.78	10.16	1.11
24.50	305.61	1.61	5.93	10.97	1.14
28.28	305.71	1.71	6.08	11.65	1.16
30.30	305.76	1.76	6.16	11.98	1.17
35.84	305.88	1.88	6.37	12.79	1.19
39.62	305.95	1.95	6.50	13.27	1.20
43.40	306.02	2.02	6.63	13.72	1.21

Tailwater Channel Data - FP-17

Tailwater Channel Option: Irregular Channel

Roadway Data for Crossing: FP-17

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 100.00 ft

Crest Elevation: 317.41 ft

Roadway Surface: Paved

Roadway Top Width: 30.00 ft

AOP Structures
Streambed Stability Analysis

PND

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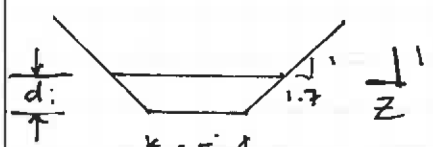
STREAMBED STABILITY ANALYSIS

PER THE ADF&G MOA AND THE PROJECT'S SOW, IT IS REQUIRED TO EVALUATE BED STABILITY WHEN SLOPES ARE GREATER THAN 6%.

NINE EMBEDDED CULVERTS ON THIS PROJECT EXCEED 6% SLOPE. STABILITY ANALYSIS WAS CONDUCTED FOLLOWING HEC 15, CHAPTER 6 (RIPRAP, COBBLE, AND GRAVEL LINING DESIGN). SEE BELOW.

FP-07



$S = 0.111$

$Q_{50} = 36.2$ cfs $V = 6.1$ fps FROM HY-8

$d = 1.095'$ (ESTIMATED / ITERATIVE – EXCEL GOALSEEK)

$A = 3.5 * 1.095' + 2 * \frac{1}{2} * (1.7 * 1.095') * 1.095'$

$= \underline{5.87\ ft^2}$

$P = 3.5 + 2\sqrt{(1.7*1.095)^2 + 1.095^2}$, TOP WIDTH $T = 3.5 + 2*1.7*1.095$

$= \underline{7.82\ ft}$ $= 7.22'$

– TRIAL d_{50} OF $15'' = 1.25'$

– $d_a = A/T = \underline{0.81'}$ = AVERAGE FLOW DEPTH

$d_a/d_{50} = \underline{0.65}$

– CALCULATE MANNING'S n

$d_a/d_{50} < 1.5$

$$n = \frac{\alpha\, d_a^{1/6}}{\sqrt{g}\, f(F_r) f(REG) f(CG)} \qquad \text{(EQN 6.2)}$$

$\alpha = 1.49$ (UNIT CONVERSION) FOR CUSTOMARY UNITS

$g = 32.2\ ft^2/s$

$f(F_r) = \left[\frac{0.28 F_r}{b}\right]^{\log\left(\frac{0.755}{b}\right)}$, $b = 1.14\left(\frac{d_{50}}{T}\right)^{0.453}\left(\frac{d_a}{d_{50}}\right)^{0.814}$ (EQN 6.4)

$= \underline{0.929}$ $= \underline{0.363}$

$F_r = V/\sqrt{gd}$

$= \underline{1.027}$ = FROUDE NUMBER

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FP-07 CONT.

$f(REG) = 13.434 \left(T/d_{50} \right)^{0.492} b^{1.025 (T/d_{50})^{0.118}}$ EQN 6.4

$= 8.87$ = ROUGHNESS ELEMENT GEOMETRY

$f(CG) = \left[T/d_a \right]^{-b}$ EQN 6.5

$= 0.452$ = CHANNEL GEOMETRY

$$n = \frac{1.49 (0.81)^{1/6}}{\sqrt{32.2}\,(0.929)(8.87)(0.452)} = 0.068$$

— CALCULATING Q USING MANNING'S EQUATION

$Q = \alpha/n \, A R^{2/3} S^{1/2}$ $R = A/P$

$= 1.49/0.068 \, (5.87) \left(\frac{5.87}{7.82} \right)^{2/3} (0.111)^{1/2}$

$= 35.36$ cfs

⇒ Q_{DESIGN} & Q_{CALC} ARE WITHIN ~5%, FLOW DEPTH (d) IS FAIRLY ACCURATE (d = 1.095')

— CALCULATING REYNOLD'S NUMBER, SHIELD'S PARAMETER (F*), AND SAFETY FACTOR (SF)

$Re = V_* d_{50} / \nu$, $V_* = \sqrt{g d S}$ = SHEAR VELOCITY

$= 2.03 \times 10^5$ $= 1.978$ fps

= REYNOLD'S NUMBER $\nu \cong 1.217 \times 10^{-5}$ ft^2/s = KINEMATIC VISCOSITY

→ USING TABLE 6.1 IN HEC 15

$Re \geq 2 \times 10^5$

⇒ $F^* = 0.15$ = SHIELDS PARAMETER

$SF = 1.5$ = SAFETY FACTOR

— CALCULATING d_{50}

$S > 10\%$, USE $d_{50} > \frac{SF\, d\, S\, \Delta}{F^* (SG - 1)}$

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FP-07 CONT.

$$d_{50} > \frac{SF\ d\ S\ \Delta}{F_*\ (SG-1)}$$, ASSUME $SG = 2.64$

$$\Delta = \frac{K_1 (1+\sin(\alpha+\beta))\tan\phi}{2(\cos\theta\tan\phi - SF\sin\theta\cos\beta)}$$ = FUNCTION OF GEOMETRY & RIPRAP SIZE

K_1 = RATIO OF CHANNEL SIDE TO BOTTOM STRESS
USE EQUATION 3.4 IN HEC-15
$= 0.066Z + 0.67$
$= \underline{0.78}$

α = ANGLE OF CHANNEL BOTTOM SLOPE
$= \tan^{-1}(0.111) = \underline{6.33°}$

β = ANGLE BETWEEN WEIGHT VECTOR & WEIGHT/DRAG RESULTANT IN THE PLANE OF THE SIDE SLOPE

$$= \tan^{-1}\left[\frac{\cos\alpha}{\frac{2\sin\theta}{\eta\tan\phi} + \sin\alpha}\right]$$

$= \underline{12.94°}$ ⟹ IN PLANE OF SIDE SLOPE $90° - 12.94° = \underline{77.06°}$

θ = ANGLE OF CHANNEL SIDE SLOPE
$= \tan^{-1}\left(\frac{1}{1.7}\right) = \underline{30.47°}$

ϕ = ANGLE OF REPOSE FOR RIPRAP
$= \underline{38°}$

η = STABILITY NUMBER
$= \tau_s / F_* (\gamma_s - \gamma) d_{50}$,
$= 0.308$

γ_s = SPECIFIC WEIGHT OF STONE (165 lb/ft³)
γ = SPECIFIC WEIGHT OF WATER (62.4 lb/ft³)
$\gamma_s - \gamma = 102.6$ USUALLY

τ_s = SHEAR STRESS
$= K_1 \gamma d S$
$= \underline{5.92\ lb/ft^2}$

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FP-07 CONT.

$$\Delta = \frac{0.78\left[1+\sin(6.33^\circ + 77.06^\circ)\right]\tan 38^\circ}{2\left(\cos 30.47^\circ \tan 38^\circ - 1.5 \sin 30.47^\circ \cos 77.06^\circ\right)}$$

$$= 1.215 / 1.006$$

$$= 1.21$$

$$d_{50} > \frac{SF\ d\ S\ \Delta}{F^* (SG-1)}$$

$$> \frac{1.5\,(1.095)(.111)(1.21)}{(.15)(2.64-1)}$$

$$> 0.89'$$

$$= 10.7''$$

— d_{50} TRIAL > d_{50} CALCULATED ✓

USE $d_{50} = 15''$

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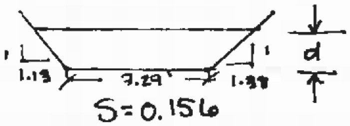
FP-09

* REFERENCE PREVIOUS PAGES FOR MORE DETAILED DESCRIPTIONS OF VARIABLES & EQUATIONS



$S = 0.156$

$Q_{50} = 92.0$ cfs
$V = 7.1$ fps
$d = 1.327$ ft
$A = (7.29 * 1.327) + \frac{1}{2}(1.13 * 1.327)(1.327) + \frac{1}{2}(1.38 * 1.327)(1.327)$
$= 11.88$ ft²
$P = 7.29 + \sqrt{(1.13 * 1.327)^2 + 1.327^2} + \sqrt{(1.38 * 1.327)^2 + 1.327^2}$
$= 11.55$ ft
$T = 7.29 + 1.13 * 1.327 + 1.38 * 1.327$
$= 10.62$ ft

– TRIAL d_{50} OF 24" = 2'

– $d_a = A/T = 1.119$
$d_a/d_{50} = 0.559$

– $d_a/d_{50} < 1.5 \Rightarrow n = \frac{\alpha d_a^{1/6}}{\sqrt{g}\, f(F_r) f(REG) f(CG)}$

$f(F_r) = \left[\frac{0.28 F_r}{b}\right]^{\log(0.755/b)}$, $b = 1.14\left(\frac{d_{50}}{T}\right)^{0.453}\left(\frac{d_a}{d_{50}}\right)^{0.814}$
$= 0.968$ $= 0.333$
$F_r = V/\sqrt{gd}$
$= 1.086$

$f(REG) = 13.434\left[T/d_{50}\right]^{0.492} b^{1.025(T/d_{50})^{0.118}}$
$= 7.74$

$f(CG) = \left[T/d_a\right]^{-b}$
$= 0.473$

$n = \frac{1.49(1.119)^{1/6}}{\sqrt{32.2}(0.968)(7.74)(.473)} = 0.0755$

– CALCULATING Q

$Q = 1.49/.0755 (11.88)\left(\frac{11.88}{11.55}\right)^{2/3}(0.156)^{1/2}$
$= 94.4$ cfs

⇒ Q CALC W/IN ~5% OF DESIGN Q_{50}
$d = 1.327'$

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FP-09 CONT.

— CALCULATING Re, F^*, & SF

$Re = V_x d_{50} / \nu = 4.2 \times 10^5$, $V_x = \sqrt{g d S} = 2.58$ fps

→ TABLE 6.1
$Re \geq 2 \times 10^5 \Rightarrow F^* = 0.15$, $SF = 1.5$

— CALCULATING d_{50}

$S > 10\%$, USE $d_{50} > \dfrac{SF\, d\, S\, \Delta}{F^* (SG-1)}$

$$\Delta = \frac{K_1 (1 + \sin(\alpha + \beta)) \tan\phi}{2(\cos\theta \tan\phi - SF \sin\theta \cos\beta)}$$

$K_1 = 0.77$ (FROM HEC 15 EQUATION 3.4)

$\alpha = \tan^{-1}(0.156) = 8.87°$

$$\beta = \tan^{-1}\left[\frac{\cos\alpha}{\frac{2\sin\theta}{\eta \tan\phi} + \sin\alpha}\right]$$

$= 11.008° \rightarrow 78.99°$

$\theta = \tan^{-1}\left(\frac{1}{1.26}\right) = 38.44°$
AVG. SIDE SLOPE

$\phi = 38°$

$\eta = \tau_s / F_* (\gamma_s - \gamma) d_{50}$
$= 0.323$

$\tau_s = K_1 \gamma d S$
$= 9.95$ lb/ft²

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FP-09 CONT.

$$\Delta = \frac{0.77\,[1+\sin(8.87^\circ + 78.99^\circ)]\tan 38^\circ}{2\,(\cos 38.44^\circ \tan 38^\circ - 1.5 \sin 38.44^\circ \cos 78.99^\circ)}$$

$$= \frac{1.203}{0.8677}$$

$$= 1.386$$

$$d_{50} > \frac{SF\ d\ S\ \Delta}{F^*\,(SG-1)}$$

$$> \frac{1.5\,(1.327)\,(0.156)(1.386)}{0.15\,(2.64-1)}$$

$$> 1.75'$$

$$= 21''$$

– d_{50} TRIAL > d_{50} CALCULATED ✓

USE $d_{50} = 24''$

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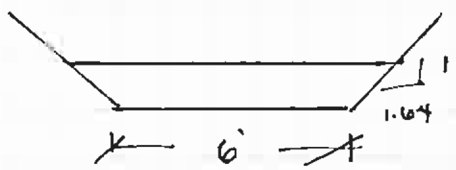
FP-10



S=0.085

$Q_{50} = 105.3$ cfs

$V = 9.1$ fps

$d = 1.533'$

$A = 6*(1.533) + 2[\frac{1}{2}(1.64*1.533)*1.533]$

$= \underline{13.052\ ft^2}$

$P = 6 + 2\sqrt{(1.64*1.533)^2 + 1.533^2}$

$= \underline{11.89\ ft}$

$T = 6' + 2*1.533'*1.64'$

$= \underline{11.03\ ft}$

— TRIAL d_{50} OF $15" = 1.25'$

— $d_a = A/T = 1.18$

$d_a/d_{50} = \underline{0.947}$

— $d_a/d_{50} < 1.5 \Rightarrow n = \dfrac{\alpha d_a^{1/6}}{\sqrt{32.2}\, f(F_r) f(REG) f(CG)}$

$f(F_r) = \left[\dfrac{0.28\,F_r}{b}\right]^{\log\left(\frac{0.755}{b}\right)}$, $b = 1.14\left(d_{50}/T\right)^{0.453}\left(d_a/d_{50}\right)^{0.814}$

$= \underline{0.970}$ $= \underline{0.407}$

$F_r = V/\sqrt{gd} = \underline{1.295}$

$f(REG) = 13.434\left(T/d_{50}\right)^{0.492} b^{1.025(T/d_{50})^{0.118}}$

$= \underline{11.914}$

$f(CG) = \left[T/d_a\right]^{-b}$

$= \underline{0.403}$

$n = \dfrac{1.49(1.18)^{1/6}}{\sqrt{32.2}(0.970)(11.914)(0.403)} = \underline{0.0580}$

— CALCULATING Q

$Q = \dfrac{1.49}{0.0580}(13.052)\left(\dfrac{13.052}{11.89}\right)^{2/3}(0.085)^{1/2}$

$= 104.10$ cfs

$\Rightarrow$ Q CALC W/IN 5% OF DESIGN Q

$d = 1.533'$

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FP-10 CONT.

– CALCULATING Re, F*, & SF

$$Re = \frac{V_x d_{50}}{\nu} = 2.1 \times 10^5$$

$$V_x = \sqrt{gdS} = 2.848 \text{ fps}$$

→ TABLE 6.1: $Re > 2 \times 10^5$

$F^* = 0.15$

$SF = 1.5$

– CALCULATING d_{50}

$5\% < S < 10\%$, CALCULATE BOTH WAYS & TAKE MAX VALUE

• EQN 6.8 ($S < 5\%$)

$$d_{50} > \frac{SF\, d\, S}{F^*(SG-1)}$$

$$> 0.79' = 9.5''$$

• EQN 6.11 ($S > 10\%$)

$$d_{50} > \frac{SF\, d\, S\Delta}{F^*(SG-1)}$$

$$\Delta = \frac{K_1 (1+\sin(\alpha+\beta))\tan\phi}{2(\cos\theta\tan\phi - SF\sin\theta\cos\beta)}$$

$$K_1 = 0.066Z + 0.67 = 0.78$$

$$\alpha = \tan^{-1}(0.085) = 4.86°$$

$$\beta = \tan^{-1}\left[\frac{\cos\alpha}{\frac{2\sin\theta}{\eta\tan\phi} + \sin\alpha}\right] = 13.57° \longrightarrow 90° - 13.57° = 76.43°$$

$$\theta = \tan^{-1}\left(\frac{1}{1.64}\right) = 31.37°$$

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FP-10 CONT.

$\phi = 38°$

$\eta = \tau_s / F_* (\gamma_s - \gamma) d_{50}$
$= 0.3296$

$\tau_s = K_1 \gamma d S$
$= 6.34 \ lb/ft^2$

$$\Delta = \frac{0.78(1 + \sin(4.86° + 76.43°)) \tan 38°}{2(\cos 31.37° \tan 38° - 1.5 \sin 31.37 \cos 76.43°)}$$

$= 1.212 / 0.968$
$= 1.252$

$$d_{50} > \frac{SF\, d\, S\, \Delta}{F_* (S_G - 1)}$$

$$> \frac{1.5(1.533)(0.085)(1.252)}{0.15\,(2.64 - 1)}$$

$> 0.989'$
$\sim 12''$ ← MAX

— d_{50} TRIAL > MAX d_{50} CALCULATED

USE $d_{50} = 15''$

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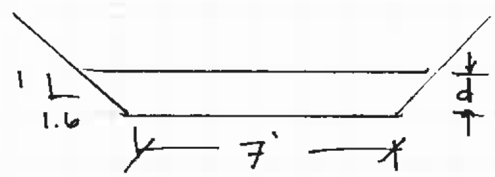
LFP-11



S=0.107

$Q_{50} = 66.4$ cfs
$V = 7.0$ fps
$d = 1.107$ ft
$A = 7(1.107) + 2(\frac{1}{2} * 1.107 * 1.6 * 1.107)$
$= \underline{9.7097\ ft^2}$
$P = 7 + 2\sqrt{(1.6 * 1.107)^2 + 1.107^2}$
$= \underline{11.177\ ft}$
$T = 7 + 2 * 1.6 * 1.107'$
$= \underline{10.542\ ft}$

— TRIAL d_{50} OF 15" = 1.25'

— $d_a = A/T = \underline{0.921}$
$d_a/d_{50} = \underline{0.737}$

— $d_a/d_{50} < 1.5 \Rightarrow n = \dfrac{\alpha d_a^{1/6}}{\sqrt{32.2}\, f(Fr) f(REG) f(CG)}$

$f(Fr) = \left[\dfrac{0.28 Fr}{b}\right]^{\log\left(\frac{0.755}{b}\right)}$, $b = 1.14\left(\dfrac{d_{50}}{T}\right)^{0.453}\left(\dfrac{d_a}{d_{50}}\right)^{0.814}$
$= \underline{0.990}$ $\qquad = \underline{0.338}$

$Fr = V/\sqrt{gd} = \underline{1.172}$

$F(REG) = 13.434(T/d_{50})^{0.492}\, b^{1.025(T/d_{50})^{0.118}}$
$= \underline{9.179}$

$F(CG) = [T/d_a]^{-b}$
$= \underline{0.439}$

$n = \dfrac{1.49(0.921)^{1/6}}{\sqrt{32.2}\,(0.990)(9.179)(0.439)} = \underline{0.0647}$

— CALCULATING Q

$Q = \dfrac{1.49}{0.0649}(9.7097)\left(\dfrac{9.7097}{11.177}\right)^{2/3}(.107)^{1/2}$
$= \underline{66.4\ cfs}$

$\Rightarrow$ Q CALC W/IN 5% OF DESIGN Q

$\underline{d = 1.107'}$

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FP-11 CONT.

– CALCULATING Re, F*, & SF

$Re = V_x d_{50} / \nu$
$= 2.01 \times 10^5$

$V_x = \sqrt{gdS}$
$= 1.953$ fps

→ TABLE 6.1 : $Re > 2 \times 10^5$
$F^* = 0.15$
$SF = 1.5$

– CALCULATING d_{50}

$S > 10\%$, USE $d_{50} > \dfrac{SF\, d\, S\, \Delta}{F^* (SG-1)}$

$$\Delta = \frac{K_1 (1+\sin(\alpha+\beta)) \tan\phi}{2 (\cos\theta \tan\phi - SF \sin\theta \cos\beta)}$$

$K_1 = 0.066Z + .67$
$= \underline{0.78}$

$\alpha = \tan^{-1}(0.107) = 6.11°$

$$\beta = \tan^{-1}\left[\frac{\cos\alpha}{\frac{2\sin\alpha}{\eta \tan\phi} + \sin\alpha}\right]$$

$= 12.11° \longrightarrow 90° - 12.11° = \underline{77.89°}$

$\theta = \tan^{-1}\left(\frac{1}{1.6}\right) = \underline{32.01°}$

$\phi = \underline{38°}$

$\eta = \tau_s / F_* (\gamma_s - \gamma) d_{50}$
$= \underline{0.300}$

$\tau_s = K_1 \gamma d S$
$= \underline{5.77}$ lb/ft²

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FP-11

$$\Delta = \frac{0.78\left[1+\sin(6.11+77.89)\right]\tan 38^\circ}{2(\cos 32.01^\circ \tan 38^\circ - 1.5\sin 32.01^\circ \cos 77.89^\circ)}$$

$$= 1.215 / 0.991$$

$$= \underline{1.23}$$

$$d_{50} > \frac{SF\,d\,S\,\Delta}{F^*(SG-1)}$$

$$> \frac{1.5\,(1.107)(0.107)(1.23)}{(0.15)\,(2.64-1)}$$

$$> 0.885'$$

$$= 10.6''$$

– d_{50} TRIAL > d_{50} CALCULATED

USE $d_{50} = 15''$

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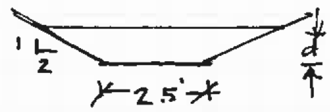
FP-12



$S = 0.118$

$Q_{50} = 22.3$ cfs
$V = 5.0$ fps
$d = 0.926'$
$A = 2.5(0.926) + 2[\frac{1}{2}(0.926 \cdot 2)(0.926)]$
$= 4.03$ ft²
$P = 2.5 + 2\sqrt{(0.926 \cdot 2)^2 + 0.926^2}$
$= 6.64$ ft
$T = 2.5 + 2 \cdot 2 \cdot 0.926$
$= 6.204$ ft

— TRIAL d_{50} OF 1'2" = 1.0'

— $d_a = A/T = 0.650'$
$d_a/d_{50} = 0.650$

— $d_a/d_{50} < 1.5 \Rightarrow n = \dfrac{\alpha d_a^{1/6}}{\sqrt{32.2}\, f(Fr) f(REG) f(CG)}$

$f(Fr) = \left[\dfrac{0.28 Fr}{b}\right]^{\log(0.755/b)}$, $b = 1.14\left(\dfrac{d_{50}}{T}\right)^{0.453}\left(\dfrac{d_a}{d_{50}}\right)^{0.814}$
$= 0.9008$ $= 0.351$

$Fr = V/\sqrt{gd} = 0.916$

$f(REG) = 13.434\left(T/d_{50}\right)^{0.492} b^{1.025(T/d_{50})^{0.118}}$
$= 8.71$

$f(CG) = [T/d_a]^{-b}$
$= 0.453$

$n = \dfrac{1.49\,(0.650)^{1/6}}{\sqrt{32.2}\,(0.9008)(8.71)(0.453)} = 0.0688$

— CALCULATING Q

$Q = \dfrac{1.49}{0.0688}(4.03)\left(\dfrac{4.03}{6.64}\right)^{2/3}(.118)^{1/2}$
$= 21.5$ cfs

$\Rightarrow$ Q CALC W/IN 5% OF DESIGN Q_{50}

$d = 0.926'$

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FP-12 CONT.

– CALCULATING R_e, F^*, & SF

$R_e = \frac{V_* d_{50}}{\nu} = \underline{1.54 \times 10^5}$

$V_* = \sqrt{gdS} = \underline{1.876 \text{ fps}}$

→ TABLE 6.1 : $4 \times 10^4 < R_e < 2 \times 10^5$ ⇒ INTERPOLATE

$F^* = \frac{(1.54 \times 10^5 - 4 \times 10^4)(0.15 - .047)}{(2 \times 10^5 - 4 \times 10^4)} + 0.047 = \underline{0.12}$

$SF = \frac{(1.54 \times 10^5 - 4 \times 10^4)(1.5 - 1.0)}{(2 \times 10^5 - 4 \times 10^4)} + 1.0 = \underline{1.36}$

– CALCULATING d_{50}

$S > 10\%$, USE $d_{50} > \frac{SF\, d\, S\, \Delta}{F^* (SG - 1)}$

$\Delta = \frac{K_1 (1 + \sin(\alpha + \beta)) \tan\phi}{2(\cos\theta \tan\phi - SF \sin\theta \cos\beta)}$

$K_1 = 0.066Z + 0.67$
$= \underline{0.80}$

$\alpha = \tan^{-1}(0.118) = \underline{6.73°}$

$\beta = \tan^{-1}\left[\frac{\cos\alpha}{\frac{2\sin\theta}{\eta \tan\phi} + \sin\alpha}\right]$

$= 20.38° \rightarrow \underline{69.62°}$

$\theta = \tan^{-1}\left(\frac{1}{2}\right) = \underline{26.26°}$

$\phi = \underline{38°}$

$\eta = \tau_s / F_* (\gamma_s - \gamma) d_{50}$
$= \underline{0.443}$

$\tau_s = K_1 \gamma d S$
$= \underline{5.45 \text{ lb/ft}^2}$

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FP-12 CONT.

$$\Delta = \frac{0.80\,[1+\sin(6.73^\circ+69.62^\circ)]\tan 38^\circ}{2\,(\cos 26.26^\circ \tan 38^\circ - 1.5 \sin 26.26^\circ \cos 69.62^\circ)}$$

$= 1.232 / 0.939$

$= 1.312$

$$d_{50} > \frac{SF\ d\ S\ \Delta}{F^*(SG-1)}$$

$$> \frac{1.36\,(0.926)(.118)(1.312)}{(0.12)(2.64-1)}$$

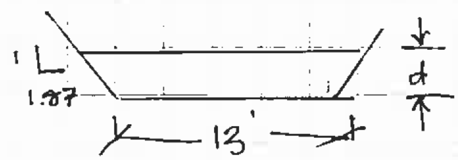
$> 0.99'$

$= 11.9''$

— d_{50} TRIAL > d_{50} CALCULATED ✓

USE $d_{50} = 12''$

FP-13



S = 0.090

$Q_{50} = 210.8$ cfs
$V = 8.0$ fps
$d = 1.565'$
$A = 13(1.565) + 2[\frac{1}{2}(1.565 * 1.87)(1.87)]$
$= 25.818\ ft^2$
$P = 13 + 2\sqrt{(1.565 * 1.87)^2 + 1.87^2}$
$= 19.95\ ft$
$T = 13 + 2 * 1.87 * 1.565'$
$= 18.85\ ft$

— TRIAL d_{50} OF 15" = 1.25'

— $d_a = A/T = 1.369'$
$d_a/d_{50} = 1.096$

— $d_a/d_{50} < 1.5 \Rightarrow n = \dfrac{\alpha d_a^{1/6}}{\sqrt{32.2}\, f(Fr) f(REG) f(CG)}$

$f(Fr) = \left[\dfrac{0.28 Fr}{b}\right]^{\log\left(\frac{0.755}{b}\right)}$
$= 0.959$

$b = 1.14\left(\dfrac{d_{50}}{T}\right)^{0.453}\left(\dfrac{d_a}{d_{50}}\right)^{0.814}$
$= 0.359$

$Fr = V/\sqrt{gd} = 1.127$

$f(REG) = 13.434(T/d_{50})^{0.492}\, b^{1.025(T/d_{50})^{0.118}}$
$= 12.019$

$f(CG) = [T/d_a]^{-b}$
$= 0.390$

$n = \dfrac{1.49\,(1.369)^{1/6}}{\sqrt{32.2}\,(0.959)(12.019)(0.390)} = 0.0616$

— CALCULATING Q

$Q = \dfrac{1.49}{0.0616}(25.818)\left(\dfrac{25.818}{19.95}\right)^{2/3}(0.090)^{1/2}$
$= 222.49$ cfs

$\Rightarrow$ Q CALC W/IN ~ 5% OF DESIGN Q_{50}

$d = 1.565'$

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FP-13 CONT.

– CALCULATING Re, F*, & SF

$$R_e = \frac{V_x d_{50}}{\nu} = 2.19 \times 10^5$$

$$V_x = \sqrt{g d S} = 2.130 \text{ fps}$$

→ TABLE 6.1 : $R_e > 2 \times 10^5$

$F_* = 0.15$

$SF = 1.5$

– CALCULATING d_{50}

5% < S < 10%, CALCULATE BOTH WAYS & TAKE MAX VALUE

• S < 5%

$$d_{50} > \frac{SF\, d\, S}{F^*(SG-1)}$$

$$> 0.859' = 10.5''$$

• S > 10%

$$d_{50} > \frac{SF\, d\, S\, \Delta}{F^*(SG-1)}$$

$$\Delta = \frac{K_1(1+\sin(\alpha+\beta))\tan\phi}{2(\cos\theta\tan\phi - SF\sin\theta\cos\beta)}$$

$$K_1 = 0.066Z + 0.67 = 0.793$$

$$\alpha = \tan^{-1}(0.090) = 5.14°$$

$$\beta = \tan^{-1}\left[\frac{\cos\alpha}{\frac{2\sin\theta}{\eta\tan\phi} + \sin\alpha}\right]$$

$$= 16.22° \longrightarrow 90° - 16.22° = 73.78°$$

$$\theta = \tan^{-1}\left(\frac{1}{1.87}\right) = 28.14°$$

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FP-13 CONT.

$\phi = 38°$

$\eta = \tau_0 / F^*(\gamma_s - \gamma) d_{50}$
$= 0.362$

$\tau_s = K_1 \gamma d S$
$= 6.97 \ lb/ft^2$

$\Delta = \dfrac{0.793 (1 + \sin(5.14° + 73.78°)) \tan 38°}{2(\cos 28.14° \tan 38° - 1.5 \sin 28.14° \cos 73.78°)}$

$= 1.228 / 0.983$

$= 1.250$

$d_{50} > \dfrac{SF \, d \, S \, \Delta}{F^* (SG - 1)}$

$> \dfrac{1.5 (1.565)(0.090)(1.25)}{0.15 \ (2.64 - 1)}$

$> 1.07'$
$= 13"$ ← MAX

— d_{50} TRIAL > MAX d_{50} CALCULATED

USE d_{50} = 15"

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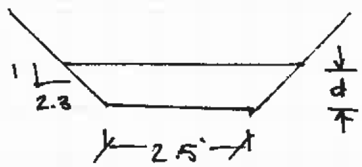
FP-14



$S = 0.116$

$Q_{50} = 70.5$ cfs

$V = 6.3$ fps

$d = 1.639'$

$A = 2.5(1.639) + 2(\frac{1}{2})(1.639)(2.3)(1.639)$

$= \underline{10.276\ ft^2}$

$P = 2.5 + 2\sqrt{(2.3 * 1.639)^2 + 1.639^2}$

$= \underline{10.721\ ft}$

$T = 2.5 + 2 * 2.3 * 1.639$

$= \underline{10.039\ ft}$

– TRIAL d_{50} OF 18" = 1.5'

– $d_a = A/T = \underline{1.024}$

$d_a/d_{50} = \underline{0.682}$

– $d_a/d_{50} < 1.5 \Rightarrow n = \alpha d_a^{1/6} / \sqrt{32.2}\, f(F_r) f(REG) f(CG)$

$f(F_r) = \left[\frac{0.28 F_r}{b}\right]^{\log\left(\frac{0.755}{b}\right)}$, $b = 1.14\left(\frac{d_{50}}{T}\right)^{.453}\left(\frac{d_a}{d_{50}}\right)^{0.814}$

$= \underline{0.884}$ $\quad = \underline{0.353}$

$F_r = V/\sqrt{gd} = \underline{0.867}$

$f(REG) = 13.434\left(\frac{T}{d_{50}}\right)^{.492} b^{1.025(T/d_{50})^{.118}}$

$= \underline{9.00}$

$f(CG) = \left[T/d_a\right]^{-b}$

$= \underline{0.447}$

$n = \frac{1.49\ (1.024)^{1/6}}{\sqrt{32.2}\ (0.884)(9.00)(0.447)} = \underline{0.0741}$

– CALCULATING Q

$Q = \frac{1.49}{0.0741}(10.276)\left(\frac{10.276}{10.721}\right)^{2/3}(0.116)^{1/2}$

$= 68.39$ cfs

$\Rightarrow$ Q CALCULATED W/IN 5% OF DESIGN Q_{50}

$\underline{d = 1.639'}$

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FP-14 CONT.

— CALCULATING Re, F*, & SF

$$Re = \frac{V_x d_{50}}{\nu} = 3.05\times10^5 \quad , \quad V_x = \sqrt{g d S} = 2.47 \text{ fps}$$

→ TABLE 6.1
$Re \geq 2\times10^5 \Rightarrow F^* = 0.15$, $SF = 1.5$

— CALCULATING d_{50}

$S > 10\%$ $\quad d_{50} > \dfrac{SF\ d\ S\ \Delta}{F^*(SG-1)}$

$$\Delta = \frac{K_1(1+\sin(\alpha+\beta))\tan\phi}{2(\cos\theta\tan\phi - SF\sin\theta\cos\beta)}$$

$K_1 = .0462 + .67 = 0.82$

$\alpha = \tan^{-1}(.116) = 6.62°$

$$\beta = \tan^{-1}\left[\frac{\cos\alpha}{\frac{2\sin\theta}{\eta\tan\phi} + \sin\alpha}\right]$$

$= 21.38° \longrightarrow 68.62°$

$\theta = \tan^{-1}\left[\frac{1}{2.3}\right] = 23.50°$

$\phi = 38°$

$$\eta = \frac{\tau_s}{F_*(\gamma_s-\gamma)d_{50}} = 0.421$$

$\tau_s = K_1 \gamma d S$
$= 9.728 \text{ lb/ft}^2$

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FP-14 CONT.

$$\Delta = \frac{0.82\,(1+\sin(6.62^\circ + 68.62^\circ))\tan 38^\circ}{2\,(\cos 23.5^\circ \tan 38^\circ - 1.5\sin 23.5^\circ \cos 68.62^\circ)}$$

$$= 1.260 / 0.997$$

$$= 1.264$$

$$d_{50} > \frac{SF\, d\, S\, \Delta}{F^*(SG-1)}$$

$$> \frac{1.5\,(1.639)(.116)(1.264)}{.15\,(2.64-1)}$$

$$> 1.47' = 17.6''$$

— d_{50} TRIAL > d_{50} CALCULATED

USE $d_{50} = 18''$

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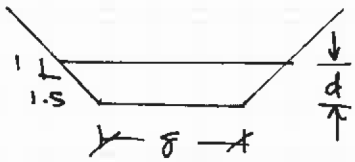
FP-15



Q_{50} = 138.6 cfs
V = 7.9 fps
d = 1.665'
A = 8(1.665) + 2(1/2)(1.665 * 1.5)(1.665)
= 17.475 ft²
P = 8 + 2√((1.5 · 1.665)² + 1.665²)
= 14.002 ft
T = 8 + 2 * 1.5 * 1.665
= 12.994 ft

— TRIAL d_{50} OF 15" = 1.25'

— $d_a = A/T = 1.345$
$d_a/d_{50} = 1.076$

— $d_a/d_{50} < 1.5 \Rightarrow n = \dfrac{\alpha\, d_a^{1/6}}{\sqrt{g}\, f(F_r) f(REG) f(CG)}$

$f(F_r) = \left[\dfrac{0.28\, F_r}{b}\right]^{\log(.755/b)}$ = 0.9197 , $b = 1.14\left(\dfrac{d_{50}}{T}\right)^{.453}\left(d_a/d_{50}\right)^{.814}$ = 0.419

$f(REG) = 13.434\,(T/d_{50})^{.492}\, b^{1.025(T/d_{50})^{.118}}$ = 13.119

$F_r = V/\sqrt{gd}$ = 1.079

$f(CG) = [T/d_a]^{-b}$ = 0.387

$n = \dfrac{1.49\,(1.345)^{1/6}}{\sqrt{32.2}\,(0.920)(13.119)(0.387)} = 0.0591$

— CALCULATING Q

$Q = \dfrac{1.49}{0.0591}(17.475)\left(\dfrac{17.475}{14.002}\right)^{2/3}(.079)^{1/2}$
= 143.6 cfs

⇒ Q_{CALC} W/IN 5% OF DESIGN Q

d = 1.665'

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FP-15 CONT.

– CALCULATING Re, F* & SF

$Re = V_x d_{50} / \nu$ $\qquad V_x = \sqrt{gdS}$

$= 4.35 \times 10^5 \qquad = 4.235$ fps

→ TABLE 6.1

$Re \geq 2 \times 10^5 \Rightarrow F^* = 0.15, \quad SF = 1.5$

– CALCULATING d_{50}

5% < S < 10% CALCULATE BOTH WAYS & TAKE MAX VALUE

- $S < 5\%$

$$d_{50} > \frac{SF\, d\, S}{F^*(SG-1)}$$

$> 0.80' = 9.6''$

- $S > 10\%$

$$d_{50} > \frac{SF\, d\, S\Delta}{F^*(SG-1)}$$

$$\Delta = \frac{K_1(1+\sin(\alpha+\beta))\tan\phi}{2(\cos\theta\tan\phi - SF\sin\theta\cos\beta)}$$

$K_1 = 0.77$

$\alpha = \tan^{-1}(0.079) = 4.52°$

$$\beta = \tan^{-1}\left[\frac{\cos\alpha}{\frac{2\sin\theta}{\eta\tan\phi} + \sin\alpha}\right]$$

$= 12.76° \longrightarrow 77.24°$

$\theta = \tan^{-1}\left(\frac{1}{1.5}\right) = 33.69°$

$\phi = 38°$

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FP-15 CONT.

$$\eta = \frac{\tau_s}{F^*(\gamma_s - \gamma) d_{50}}$$
$$= 0.329$$

$$\tau_s = K_1 \gamma d S$$
$$= 6.32 \ lb/ft^2$$

$$\Delta = \frac{0.77\left[1 + \sin(4.52^\circ + 77.24^\circ)\right]\tan 38^\circ}{2(\cos 33.69^\circ \tan 38^\circ - 1.5 \sin 33.69 \cos 77.24^\circ)}$$

$$= 1.197 / 0.933$$
$$= 1.284$$

$$d_{50} > \frac{SF d S \Delta}{F^*(SG-1)}$$

$$> \frac{1.5(1.665)(.079)(1.284)}{.15\ (2.64-1)}$$

$$> 1.03'$$
$$= 13'' \quad \leftarrow \text{MAX}$$

— d_{50} TRIAL > MAX d_{50} CALCULATED

USE $d_{50} = 15''$

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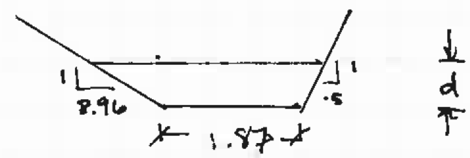
FP-17



S = 0.068

$Q_{50} = 36.3$ cfs

$V = 6.2$ fps

$d = 1.094'$

$A = 1.87 * 1.094 + \frac{1}{2}(8.96 * 1.094)(1.094) + \frac{1}{2}(0.5 * 1.094)(1.094)$
$= 7.707 \text{ ft}^2$

$P = 1.87 + \sqrt{(8.96 * 1.094)^2 + 1.094^2} + \sqrt{(0.5 * 1.094)^2 + 1.094^2}$
$= 12.956 \text{ ft}$

$T = 1.87 + 8.96(1.094) + 0.5(1.094)$
$= 12.219 \text{ ft}$

– TRIAL d_{50} OF 9" = 0.75'

– $d_a = A/T = 0.631'$

$d_a/d_{50} = 0.841$

– $d_a/d_{50} < 1.5 \Rightarrow n = \frac{\alpha d_a^{1/6}}{\sqrt{g}\, f(Fr) f(REG) f(CG)}$

$f(F_r) = \left[\frac{0.28 Fr}{b}\right]^{\log\left(\frac{0.755}{b}\right)}$
$=$

$b = 1.14 \left(\frac{d_{50}}{T}\right)^{.453} \left(\frac{d_a}{d_{50}}\right)^{.814}$
$= 0.280$

$Fr = V/\sqrt{gd} = 1.045$

$f(REG) = 13.434 (T/d_{50})^{.492} b^{1.025(T/d_{50})^{.118}}$
$= 8.646$

$f(CG) = [T/d_a]^{-b}$
$= 0.436$

$n = \frac{1.49 (0.631)^{1/6}}{\sqrt{32.2}\,(1.058)(8.646)(0.436)} = 0.0610$

– CALCULATING Q

$Q = \frac{1.49}{0.0610}(7.707)\left(\frac{7.707}{12.956}\right)^{2/3}(.068)^{1/2}$
$= 34.75$ cfs

$\Rightarrow$ Q CALC W/IN ~5% OF DESIGN Q_{50}

$d = 1.094'$

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FP-17 CONT.

— CALCULATING Re, F^*, & SF

$$Re = \frac{V_* d_{50}}{\nu}, \qquad V_* = \sqrt{gdS}$$
$$= 9.54 \times 10^4 \qquad\qquad = 1.548 \text{ fps}$$

→ TABLE 6.1

$4 \times 10^4 < Re < 2 \times 10^5$ ⟹ INTERPOLATE

$$F^* = \frac{(9.54\times10^4 - 4\times10^4)(0.15 - 0.047)}{(2\times10^5 - 4\times10^4)} + 0.047$$
$$= \underline{0.083}$$

$$SF = \frac{(9.54\times10^4 - 4\times10^4)(1.5 - 1.0)}{(2\times10^5 - 4\times10^4)} + 1.0$$
$$= \underline{1.17}$$

— CALCULATING d_{50}

5% < S < 10%, CALCULATE BOTH WAYS & TAKE MAX

- S < 5%

$$d_{50} > \frac{SF\, d\, S}{F^*(SG-1)}$$
$$> 0.64' = \underline{7.7''}$$

- S > 10%

$$d_{50} > \frac{SF\, d\, S\, \Delta}{F^*(SG-1)}$$

$$\Delta = \frac{K_1[1+\sin(\alpha+\beta)]\tan\phi}{2(\cos\theta\tan\phi - SF\sin\theta\cos\beta)}$$

$$K_1 = 0.067Z + .66$$
$$= \underline{0.977} \quad \text{(USING AVERAGE SIDE SLOPE = 4.73)}$$

$$\alpha = \tan^{-1}(.068) = \underline{3.89^\circ}$$

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EP-17 CONT.

$$\beta = \tan^{-1}\left[\frac{\cos\alpha}{\frac{2\sin\theta}{\eta\tan\phi} + \sin\alpha}\right]$$

$$= 50.80° \rightarrow \underline{39.20°}$$

$$\theta = \tan^{-1}\left[\frac{1}{4.73}\right] = \underline{11.94°}$$

$$\phi = \underline{38°}$$

$$\eta = \frac{\tau_s}{F^*(\gamma_s - \gamma)d_{50}}$$

$$= \underline{0.710}$$

$$\tau_s = K_1 \gamma d S$$

$$= \underline{4.54 \text{ lb/ft}^2}$$

$$\Delta = \frac{0.977[1 + \sin(3.89° + 39.20°)\tan 38°]}{2(\cos 11.94° \tan 38° - 1.17 \sin 11.94 \cos 39.20)}$$

$$= 1.116 / 1.154$$

$$= \underline{0.967}$$

$$d_{50} > \frac{SF\ d\ S\ \Delta}{F^*(SG-1)}$$

$$> \frac{1.17(1.094)(.068)(0.967)}{(0.083)(2.64-1)}$$

$$> 0.619'$$

$$= 7.4"$$

MAX d_{50} = 8"

- d_{50} TRIAL > MAX d_{50} CALCULATED

USE d_{50} = 9"

AOP Structures
Streambed Retention Analysis

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Project:	121088 Deweyville		
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Checked by:	AEW	Date:	3/19/13

NOTES & REFERENCES

AOP Culvert Streambed Material Retention Summary/Rock Wier Design

Purpose: Per project scope of work section 10.4.2.3:

- Substrate Material will be designed stable within culvert at all flood discharges up to and including the 50-year flood.
- Where gradients exceed 6% perform additional hydraulic analysis to ensure stability of the streambed material within the culverts.
- Design substrate retention baffles to stabilize or provide continous recuitment of bedload within culverts with slopes exceeding 3%

Analysis Procedure:
Step 1 Identify Stable Material Gradation for each Culvert

- HEC 15 - Design of Roadside Channels With Flexible Linings (Per Streambed Stability Analysis
- Identify Minimum Furinshed Streambed Material per Spec 730.20
- For Slopes >6% Verify Streambed Stability, if unstable identify methods of bed retention.

Step 2 Pipe Slopes 0-3% - Install streambed material only

- stream bed material suffient for fish passage
- install streambed transition apron not less than 8 ft from inlet and outlet of pipe.

Step 3 Pipe/Channel Slopes >3% - Create Step Pools and Retention Baffles to facilitate fish passage

- Size Streambed Boulders Spec 705.07
- 3 Methods have been utilized to approximate stable boulder size
  - Dmin = 1.5 times D100 Streambed Material (Assumed Class E Material)
  - Dmax = 1.5 to 2 times D50 (Section E.4 Stream Simulation - An Ecological Approach to Providing Passage for Aquatic Organisms at Road-Stream Crossings) D50 from HEC 11 and HEC 15 Presented
  - WSDOT Hydraulics Manual - Section 4-6.1.1 Riprap Sizing for Bank Barbs
  - Section 6.5.5.5/7.1.2.4 USACE Rip Rap Design (D84) presented in FHWAA-HIF-07-0-033
- Install Bed Retention Baffles
  - Note: Max .8 ft drop between baffles and spacing not to exceed 1.2xpipe diameter, per 7.1.2.4 FHWAA-HIF-07-0-033
  - Height = 40% Culvert Diameter and min 2-ft or 20% height for Pipe Arch

Selection of design boulder sizes based upon review of results generated by various methods utilized

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NOTES & REFERENCES

						Channel Restoration**				Retention in Pipe Culvert			
							Boulder Size (in)						
AOP Structure	MP	Design Bankfull (ft)	Slope	HEC 15 d50 (in) from stability analysis	Streambed Cobble Class	Mutilple Weir Required	Min	Max	Rock Weir Spacing	Baffle Required	Baffle Spacing (ft)	Drop (ft)	Baffle Height (ft)
FP-01	82.667	4.0	0.50%	6	Class E	No	18	24	N/A	No	N/A	N/A	N/A
FP-02	83.391	3.0	2.99%	5	Class D	Yes	15	24	26.00	No	26.00	0.8	N/A
FP-03	83.5	9.8	0.00%	2	Class A	No	6	12	N/A	No	N/A	N/A	N/A
FP-04	83.541	3.5	0.50%	2	Class A	No	6	12	N/A	No	N/A	N/A	N/A
FP-05	85.884	7.0	2.27%	6	Class E	No	18	24	N/A	No	N/A	N/A	N/A
FP-06	86.061	9.0	1.73%	4	Class C	No	12	24	N/A	No	N/A	N/A	N/A
FP-07	86.956	3.5	11.06%	15	Class E*	Yes	18	24	6.00	Yes	6.00	0.8	2.2
FP-09	87.172	6.0	13.93%	24	Class E*	Yes	18	36	5.00	Yes	5.00	0.8	3.2
FP-10	87.469	6.0	8.70%	15	Class E*	Yes	18	24	9.00	Yes	9.00	0.8	3.2
FP-11	88.386	6.0	10.00%	15	Class E*	Yes	18	24	8.00	Yes	8.00	0.8	3.2
FP-12	88.413	2.4	10.68%	12	Class E*	Yes	18	24	6.00	Yes	6.00	0.8	2
FP-13	89.035	12.6	9.13%	15	Class E*	Yes	18	30	8.00	Yes	8.00	0.8	2.0
FP-14	89.894	5.0	11.67%	18	Class E*	Yes	18	30	6.00	Yes	6.00	0.8	3.2
FP-15	90.201	8.2	7.93%	15	Class E*	Yes	18	24	8.00	Yes	8.00	0.8	2
FP-16	90.696	2.0	1.42%	4	Class C	No	12	24	N/A	No	N/A	N/A	N/A
FP-17	91.12	3.0	8.06%	9	Class E	Yes	18	24	6.00	Yes	6.00	0.8	2

* Class E material not stable.
** See details plan and profiles for locations if required
*** Location and number of baffles/rock weirs indicated on design plans
**** Spacing of baffles/rock weirs rounded down to nearest 1ft
***** Spacing of rock wiers for FP-11 U/S adjusted to 5 ft, for FP-13 adjusted to 4.5 ft

Project	121088 - Deweyville to Neck Lake Road
Description	Fish Passage Material/Retention Analysis
Date	1/28/2013 Updated 3/19/2013
By	CRW
Checked	AEW

Step 1 - HEC 15 Material Gradation Summary (See Detailed Stream Stability Analysis)

Stream Name	MP	Proposed Structure	Culvert Slope (ft/ft)	Design Bankfull	Qfish (cfs)	Q2 (cfs)	Q50 (cfs)	Tailwater Flow depth d (ft) **	HEC 15 d50 (in) from stability	Min Cobble Class	Min Boulder Size
FP-01	82.667	84"	0.50%	4.0	20.6	51.4	111.0	3.95	6	Class E	18
FP-02	83.391	72"	2.99%	3.0	2.1	5.4	11.8	1.55	5	Class D	15
FP-03	83.5	11'-10" x 7'-7"	0.00%	9.8	35.0	87.4	185.4	3.02	2	Class A	6
FP-04	83.541	66"	0.50%	3.5	2.9	7.2	15.8	1.83	2	Class A	6
FP-05	85.884	108"	2.27%	7.0	20.2	50.5	109.2	2.35	6	Class E	18
FP-06	86.061	11'-5" x 7'-3"	1.73%	9.0	25.1	62.9	135.5	2.42	4	Class C	12
FP-07	86.956	66"	11.06%	3.5	6.7	16.7	36.5	1.29	15	Class E*	18
FP-09	87.172	96"	13.93%	6.0	17.0	42.5	92.0	1.43	24	Class E*	18
FP-10	87.469	96"	8.70%	6.0	19.5	48.7	105.3	1.29	15	Class E*	18
FP-11	88.386	96"	10.00%	6.0	12.4	30.9	66.4	1.08	15	Class E*	18
FP-12	88.413	60"	10.68%	2.4	4.1	10.2	22.3	0.64	12	Class E*	18
FP-13	89.035	14'-3" x 9'-2"	9.13%	12.6	39.8	99.4	210.8	2.79	15	Class E*	18
FP-14	89.894	96"	11.67%	5.0	13.0	32.5	70.5	1.59	18	Class E*	18
FP-15	90.201	10'-8" x 6'-11"	7.93%	8.2	26.3	65.6	138.6	1.61	15	Class E*	18
FP-16	90.696	60"	1.42%	2.0	2.0	4.9	10.9	2.53	4	Class C	12
FP-17	91.12	60"	8.06%	3.0	5.6	13.9	30.3	1.76	9	Class E	18

* Class E material not stable.
** Tailwater Depth Assumed Conservative Design Value all Instances
Project Specifications for Streambed Cobbles
*** Min Boulder Size = 1/5XD100

Streambed Cobbles Gradation (Table 703-17)

Nominal Size	Percent less than the nominal Size				
	Class				
	A	B	C	D	E
12"					100
10"				100	
8"			100		65-75
6"		100		65-75	
5"			65-75		35-45
4"	100	65-75		35-45	
3"			35-45		
2"		35-45			
1.5"	35-45				
0.75"	10-15	10-15	10-15	10-15	10-15

Step 3a Streambed Boulder Analysis

WSDOT Hydraulics Manual - Section 4-6.1.1 Riprap Sizing for Bank Barbs

Stream Name	Q50 Depth at Outlet (from HY-8)	WSDOT S*D	WSDOT Boulder D50 Size (in)
FP-01	3.95	0.0198	6
FP-02	1.55	0.0463	13.2
FP-03	3.02	0.0000	6
FP-04	1.83	0.0092	6
FP-05	2.35	0.0533	13.2
FP-06	2.42	0.0419	13.2
FP-07	1.29	0.1427	26.4
FP-09	1.43	0.1992	39.6
FP-10	1.29	0.1122	26.4
FP-11	1.08	0.1080	26.4
FP-12	0.64	0.0684	13.2
FP-13	2.79	0.2547	42
FP-14	1.59	0.1856	39.6
FP-15	1.61	0.1277	26.4
FP-16	2.53	0.0359	6
FP-17	1.76	0.1419	26.4

Note: FP-13 Rock size interpolated between 3 man and 6 man stone to limit excessive rock size estimate

Riprap Gradation	D_{50}		Slope Times Flow Depth	
	English (ft)	Metric (m)	English (ft)	Metric (m)
Spalls	0.5	0.15	0.0361	0.011
Light Loose Riprap	1.1	0.32	0.0764	0.0233
Heavy Loose Riprap	2.2	0.67	0.1587	0.0484
1 Meter D50 (Three Man)[1]	3.3	1	0.2365	0.0721
2 Meter D50 (Six Man)[1]	6.6	2	0.5256	0.1602

1. See Standard Specification Section 9-13.7(1).

Riprap Sizing for In-Channel Structures

Figure 4-6.1.3

Three Man Stones For FP -09 and 14

Rock Size	Rock Weight (lbs)	Average Dimension (in.)
One Man	50 to 200	12 to 18
Two Man	200 to 700	18 to 28
Three Man	700 to 2,000	28 to 36
Four Man	2,000 to 4,000	36 to 48
Five Man	4,000 to 6,000	48 to 54
Six Man	6,000 to 8,000	54 to 60

Heavy Loose Riprap to Meet

Heavy loose riprap shall meet the following requirements for grading:

	Minimum Size	Maximum Size
40% to 90%	1 ton (½ cubic yd.)	
70% to 90%	300 lbs. (2 cu. ft.)	
10% to 30%	3 inch	50 lbs. (spalls)

Dmax = 1.5 to 2 times D50 (Section E.4 Stream Simulation - An Ecological Approach to Providing Passage for Aquatic Organisms at Road-Stream Crossings)

	HEC 11				HEC15	
Stream Name	**Q50 (cfs)**	**Velocity (ft/s) (From HY-8)**	**D50 (in)**	**Max Boulder (2x D50)**	**D50 (in)**	**Max Boulder (1.5x D50)**
FP-01	111	5.32	2.212	4	6	9
FP-02	12	2.98	0.69	1	5	7.5
FP-03	185	2.42	0.458	1	2	3
FP-04	16	1.06	0.088	0	2	3
FP-05	109	5.31	2.203	4	6	9
FP-06	135	4.20	1.379	3	4	6
FP-07	36	6.10	2.91	6	15	22.5
FP-09	92	7.06	3.90	8	24	36
FP-10	105	9.10	6.47	13	15	22.5
FP-11	66	7.03	3.86	8	15	22.5
FP-12	22	4.99	1.95	4	12	18
FP-13	211	7.96	4.95	10	15	22.5
FP-14	70	6.31	3.11	6	18	27
FP-15	139	7.87	4.84	10	15	22.5
FP-16	11	0.98	0.075	0	4	6
FP-17	30	6.16	2.97	6	9	13.5

Min boulder size taken as D50

11.3 SIZING ROCK RIPRAP AT BRIDGE PIERS

To determine the required size of stone for riprap at bridge piers, NCHRP Project 24-23 recommends using the rearranged Isbash equation from the Federal Highway Administration's Hydraulic Engineering Circular No. 23 (Second Edition) (Lagasse et al. 2001) to solve for the median stone diameter:

$$d_{50} = \frac{0.692(V_{des})^2}{(S_g - 1)2g} \qquad (11.1)$$

where:

d_{50} = Particle size for which 50% is finer by weight, ft (m)

V_{des} = Design velocity for local conditions at the pier, ft/s (m/s)

S_g = Specific gravity of riprap (usually taken as 2.65)

g = Acceleration due to gravity, 32.2 ft/s^2 (9.81 m/s^2)

●● Section 6.5.5.5/7.1.2.4 USACE Rip Rap Design (D84) presented in FHWAA-HIF-07-0-033

6.5.5.5 USACE RR

Stream Name	Design Bankfull	Culvert Slope (ft/ft)	Q50 (cfs)	Unit Discharge (ft^2/s)	D30 (in)	D84 (in)
FP-01	4.0	0.50%	111.0	28	4	6.2
FP-02	3.0	2.99%	11.8	4	3	4.5
FP-03	9.8	0.10%	185.4	19	1	2.0
FP-04	3.5	0.50%	15.8	5	1	1.8
FP-05	7.0	2.27%	109.2	16	7	9.8
FP-06	9.0	1.73%	135.5	15	5	8.2
FP-07	3.5	11.06%	36.5	10	12	18.0
FP-09	6.0	13.93%	92.0	15	18	26.5
FP-10	6.0	8.70%	105.3	18	15	22.3
FP-11	6.0	10.00%	66.4	11	12	17.7
FP-12	2.4	10.68%	22.3	9	11	16.4
FP-13	12.6	9.13%	210.8	17	15	22.2
FP-14	5.0	11.67%	70.5	14	15	22.7
FP-15	8.2	7.93%	138.6	17	14	20.7
FP-16	2.0	1.42%	10.9	5	2	3.7
FP-17	3.0	8.06%	30.3	10	10	14.8

Max boulder size taken as D84

Min boulder size taken as D50

7.1.2.4 Bed Material Gradation (for reference only)

Total Gradation for Bed Material				
D16	**D30**	**D50**	**D84**	**D100**
0.8	4.1	2.5	6.2	15.5
0.6	3.0	1.8	4.5	11.4
0.2	1.3	0.8	2.0	4.9
0.2	1.2	0.7	1.8	4.6
1.2	6.5	3.9	9.8	24.4
1.0	5.5	3.3	8.2	20.5
2.2	12.0	7.2	18.0	45.0
3.3	17.6	10.6	26.5	66.2
2.8	14.9	8.9	22.3	55.7
2.2	11.8	7.1	17.7	44.3
2.0	10.9	6.5	16.4	40.9
2.8	14.8	8.9	22.2	55.5
2.8	15.1	9.1	22.7	56.7
2.6	13.8	8.3	20.7	51.6
0.5	2.5	1.5	3.7	9.3
1.8	9.9	5.9	14.8	37.0

		Maximum Boulder Size Design Summary			
Stream Name	**MIN BOULDER SIZE**	**WDOT Method (in)**	**HEC15 (2xD50) (in)**	**USACE RR (D84) (in)**	**DESIGN MAX VALUE**
FP-01	18	6	9	6.2	24
FP-02	15	13.2	7.5	4.5	24
FP-03	6	6	3	2.0	12
FP-04	6	6	3	1.8	12
FP-05	18	13.2	9	9.8	24
FP-06	12	13.2	6	8.2	24
FP-07	18	26.4	22.5	18.0	24
FP-09	18	39.6	36.0	26.5	36
FP-10	18	26.4	22.5	22.3	24
FP-11	18	26.4	22.5	17.7	24
FP-12	18	13.2	18.0	16.4	24
FP-13	18	42.0	22.5	22.2	30
FP-14	18	39.6	27.0	22.7	30
FP-15	18	26.4	22.5	20.7	24
FP-16	12	6	6	3.7	24
FP-17	18	26.4	13.5	14.8	24

Notes:

1 HEC Results Not included due to minimal size

2 Min Boulder Size assumed to be 1.5xD100 Class E material

3 Max Boulder Size assumed dervived from results of all three methods.

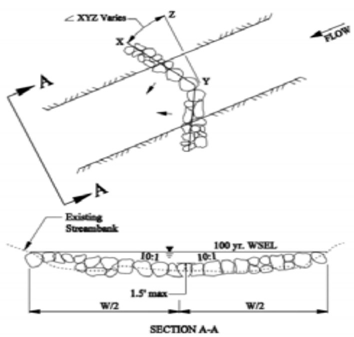
Step 3 b - Design of Bed Retention Baffles and Rock Weir Spacing

							BAFFLE/WIER SPACING				
Stream Name	Proposed Structure	Culvert Slope (ft/ft)	Culvert Length (ft)	Pipe Embedment (ft)	Channel Retention Type	Pipe Retention Type	Per Span (ft)	Per Slope Spacing (ft)	Drop	Design Spacing (ft)	Baffle Height at Flowline(ft)
FP-01	84"	0.50%	85.46	2.8	N/A	N/A	N/A	N/A	N/A	N/A	N/A
FP-02	72"	2.99%	78.64	2.4	Rock Weir	N/A	N/A	26.8	0.8	26.8	N/A
FP-03	11'-10" x 7'-7"	0.00%	78.39	2	N/A	N/A	N/A	N/A	N/A	N/A	N/A
FP-04	66"	0.50%	88.95	2.2	N/A	N/A	N/A	N/A	N/A	N/A	N/A
FP-05	108"	2.27%	70.55	3.6	N/A	N/A	N/A	N/A	N/A	N/A	N/A
FP-06	11'-5" x 7'-3"	1.73%	100.25	2	N/A	N/A	N/A	N/A	N/A	N/A	N/A
FP-07	66"	11.06%	88..25	2.2	Rock Weir	Baffles	6.60	7.2	0.8	6.6	2.20
FP-09	96"	13.93%	80.46	3.2	Rock Weir	Baffles	9.60	5.7	0.8	5.7	3.20
FP-10	96"	8.70%	96.68	3.2	Rock Weir	Baffles	9.60	9.2	0.8	9.2	3.20
FP-11	96"	10.00%	79.66	3.2	Rock Weir	Baffles	9.60	8.0	0.8	8.0	3.20
FP-12	60"	10.68%	88.33	2	Rock Weir	Baffles	6.00	7.5	0.8	6.0	2.00
FP-13	14'-3" x 9'-2"	9.13%	115.2	2.0	Rock Weir	Baffles	11.00	8.8	0.8	8.8	2.03
FP-14	96"	11.67%	124.81	3.2	Rock Weir	Baffles	9.6	6.9	0.8	6.9	3.20
FP-15	10'-8" x 6'-11"	7.93%	99.64	2	Rock Weir	Baffles	8.3	10.1	0.8	8.3	2.00
FP-16	60"	1.42%	81.31	2	N/A		N/A	N/A	N/A	N/A	N/A
FP-17	60"	8.06%	89.34	2	Rock Weir	Baffles	6.0	9.9	0.8	6.0	2.00
FP-11 U/S	-	16.00%	-	-	Rock Weir	-	-	5.0	0.8	5	-
FP-13	14'-3" x 9'-2"	16.90%	-	-	Rock Weir	-	11	4.7	0.8	4.5	-

Note: Max .8 ft drop between sills and spacing not to exceed 1.2 times pipe diameter, per 7.1.2.4 FHWAA-HIF-07-0-033

Note: Utilize same spacing in channel restoration except in the following instances

1.) For FP -07 the rock size and weir spacing provided in step 3b assumed sufficient for slight variance in channel slope
2.) For FP-11 the boulder sizes provided step 3a assumed sufficient for upstream and downstream channels
    Spacing for upstream channel modified for channel slope of 15% to
3.) For FP-13 the boulder sizes provided step 3a assumed sufficient for upstream and downstream channels
    Spacing for upstream channel modified for channel slope of 16.8% to



AOP Structures
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NOTES & REFERENCES

AOP Structure/Embedded Culvert Inlet Protection Design

Purpose: Per project scope of work section 10.4.2.2(12):

- For open bottom and embedded culverts, evaluate and design scour countermeasures base on bridge foundation design criteria outlined under FHWA PDDM, unless they can be founded on bedrock
- Utilize Design Guideline 18 Per HEC 23 (Bridge Scour and Stream Instability Countermearures)

Analysis Procedure:

18.3 RIPRAP SIZE

The results obtained from the Phase II laboratory study (Kerenyi et al. 2007) were used to develop a riprap size equation that accounts for the local velocity at the corner of the culvert entrance and the vorticity and turbulence of the flow. The equation is:

$$d_{50} = \frac{K_r y_0}{(S_g - 1)} \left(\frac{V_{AC}^2}{g y_0} \right)^{0.33} \quad (18.1)$$

where:

d_{50} = Riprap median size (50% finer) ft or m
K_r = Sizing Coefficient equal to 0.38 from the best fit lab data, 0.68 for design curve that envelops the lab data
V_{AC} = Average velocity at the culvert entrance, ft/s or m/s
y_o = Average flow depth at the culvert entrance before scour, ft or m
S_g = Riprap specific gravity
g = Acceleration of gravity ft/s^2 or m/s^2

Project	121088 - Deweyville to Neck Lake Road
Description	Design Guideline 18 - Riprap Protection for Bottomless Culverts
Date	2/20/2013 Updated 3/19/2013
By	CRW
Checked	AEW

Step 1 - FHWA DESIGN GUIDELINE 18 - RIPRAP PROTECTION FOR BOTTOMLESS CULVERTS (See Detailed Stream Stability Analysis)

Stream Name	MP	Proposed Structure	Culvert Slope (ft/ft)	Design Bankfull	Q50 (cfs)	Inlet Yo (ft)	Vac (ft/s)*	Design Guide 18 d50 (in)	Riprap Class
FP-01	82.667	84"	0.50%	4.0	111.0	2.68	4.71	4.73	1
FP-02	83.391	72"	2.99%	3.0	11.8	0.62	1.31	0.76	1
FP-03	83.5	11'-10" x 7'-7"	0.00%	9.8	185.4	3.66	5.53	6.48	2
FP-04	83.541	66"	0.50%	3.5	15.8	0.82	1.61	1.05	1
FP-05	85.884	108"	2.27%	7.0	109.2	2.31	5.91	4.97	1
FP-06	86.061	11'-5"x7'-3"	1.73%	9.0	135.5	3.2	5.51	5.91	2
FP-07	86.956	66"	11.06%	3.5	36.5	1.27	7.36	3.85	1
FP-09	87.172	96"	13.93%	6.0	92.0	1.76	9.07	5.50	2
FP-10	87.469	96"	8.70%	6.0	105.3	2.1	9.90	6.56	2
FP-11	88.386	96"	10.00%	6.0	66.4	1.41	8.08	4.39	1
FP-12	88.413	60"	10.68%	2.4	22.3	0.94	6.31	2.84	1
FP-13	89.035	14'-3" x 9'-2"	9.13%	12.6	210.8	5.22	8.99	11.33	3
FP-14	89.894	96"	11.67%	5.0	70.5	1.46	7.81	4.40	1
FP-15	90.201	10'-8" x 6'-11"	7.93%	8.2	138.6	3.51	8.68	8.49	2
FP-16	90.696	60"	1.42%	2.0	10.9	0.67	0.96	0.65	1
FP-17	91.12	60"	8.06%	3.0	30.3	1.25	6.44	3.49	1

http://www.fhwa.dot.gov/engineering/hydraulics/pubs/09112/page18.cfm

Yo	Varies from Channel Analysis
Sg	2.65
Kr	0.38
g	32.2

** Vac were conservatively taken to be outlet velocites from HY-8 analysis.*

*** FP-13 inlet is founded on bedrock, and therefore will not require large riprap protection*

18.3 RIPRAP SIZE

The results obtained from the Phase II laboratory study (Kerenyi et al. 2007) were used to develop a riprap size equation that accounts for the local velocity at the corner of the culvert entrance and the vorticity and turbulence of the flow. The equation is:

$$d_{50} = \frac{K_r y_0}{(S_g - 1)} \left(\frac{V_{AC}^2}{g y_0} \right)^{0.33} \quad (18.1)$$

where:

d_{50} = Riprap median size (50% finer) ft or m

K_r = Sizing Coefficient equal to 0.38 from the best fit lab data, 0.68 for design curve that envelops the lab data

V_{AC} = Average velocity at the culvert entrance, ft/s or m/s

y_o = Average flow depth at the culvert entrance before scour, ft or m

S_g = Riprap specific gravity

g = Acceleration of gravity ft/s^2 or m/s^2

Table 705-1
Gradation Requirements for Riprap

Class	Percent of Rock by Mass	Mass (pounds)	Approximate Cubic Dimension[(2)(3)] (inches)
1	20	22 to 33	6 to 8
	30	11 to 22	5 to 6
	40	1 to 11	2 to 5
	10 [(1)]	0 to 1	0 to 2
2	20	55 to 110	8 to 10
	30	22 to 55	6 to 8
	40	2 to 22	3 to 6
	10 [(1)]	0 to 2	0 to 3
3	20	220 to 330	14 to 16
	30	110 to 220	10 to 14
	40	11 to 110	5 to 10
	10 [(1)]	0 to 11	0 to 5
4	20	550 to 770	18 to 20
	30	220 to 550	14 to 18
	40	22 to 220	6 to 14
	10 [(1)]	0 to 22	0 to 6
5	20	1540 to 2200	26 to 28
	30	770 to 1540	20 to 26
	40	55 to 770	8 to 20
	10 [(1)]	0 to 55	0 to 8
6	20	1870 to 3530	28 to 34
	30	1100 to 1870	22 to 28
	40	110 to 1100	10 to 22
	10 [(1)]	0 to 110	0 to 10

(1) Furnish spalls and rock fragments graded to provide a stable dense mass.
(2) The volume of a rock with these cubic dimensions has a mass approximately equal to the specified rock mass.
(3) Furnish rock with breadth and thickness at least one-third its length.

P | N | D
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NOTES & REFERENCES

Culvert Outlet Protection Rock Sizing Analsyis

Purpose: Per project scope of work section 10.4.2.2(10):

- Provide scour protection to mitigate downstream erosion at culvert outlets
- Utilize Hydraulic Toolbox culvert outlet protection (HEC 14 equation 10.4)

Analysis Procedure:

The governing equation for computing riprap size for **Culvert Outlet** protection is:

$$D_{50} = 0.2\,D\left(\frac{Q}{\sqrt{g}\,D^{2.5}}\right)^{4/3}\left(\frac{D}{TW}\right)$$

HEC-14 Equation (10.4)

Stream	d50	class
FP-01	2.39	1
FP-02	0.24	1
FP-03	1.97	1
FP-04	0.44	1
FP-05	1.84	1
FP-06	1.41	1
FP-07	4.71	1
FP-09	6.86	2
FP-10	8.09	2
FP-11	4.73	1
FP-12	3.22	1
FP-13	5.87	2
FP-14	4.98	1
FP-15	6.22	2
FP-16	0.27	1
FP-17	2.98	1
C-05	4.72	1
C-08	17.8	4
C-12	4.56	1
C-13	9.07	2

Hydraulic Analysis Report

Project Data

Project Title: 121088 - Culvert Outlet Check

Designer:

Project Date: Friday, February 08, 2013

Project Units: U.S. Customary Units

Notes:

Riprap Analysis: FP-01 - Outlet - Done

Notes:

Input Parameters

Riprap Type: Culvert Outlet Protection

Flow: 111 (cfs)

Culvert Diameter: 7 (ft)

Normal Depth in Culvert: 4.2 (ft)

Tailwater Depth: 3.95 (ft)

If tailwater is unknown, use 0.4D

flow is sbcritical

Result Parameters

Tailwater Depth Used in Computations: 3.95 (ft)

Culvert Diameter Used in Computations: 7 (ft)

Computed D50: 2.39282 (in)

Riprap Analysis: FP-02 - Outlet - Done

Notes:

Input Parameters

Riprap Type: Culvert Outlet Protection

Flow: 11.8 (cfs)

Culvert Diameter: 6 (ft)

Normal Depth in Culvert: 0.64 (ft)

Tailwater Depth: 1.55 (ft)

If tailwater is unknown, use 0.4D

flow is sbcritical

Result Parameters

Tailwater Depth Used in Computations: 2.4 (ft)

Culvert Diameter Used in Computations: 6 (ft)

Computed D50: 0.243578 (in)

Riprap Analysis: FP-03 - Outlet - Done

Notes:

Input Parameters

Riprap Type: Culvert Outlet Protection

Flow: 185.4 (cfs)

Culvert Diameter: 11.82 (ft)

Normal Depth in Culvert: 1.98 (ft)

Tailwater Depth: 3.02 (ft)

If tailwater is unknown, use 0.4D

flow is sbcritical

Result Parameters

Tailwater Depth Used in Computations: 4.728 (ft)

Culvert Diameter Used in Computations: 11.82 (ft)

Computed D50: 1.97024 (in)

Riprap Analysis: FP-04 - Outlet - Done

Notes:

Input Parameters

Riprap Type: Culvert Outlet Protection

Flow: 15.8 (cfs)

Culvert Diameter: 5.5 (ft)

Normal Depth in Culvert: 1.57 (ft)

Tailwater Depth: 1.83 (ft)

If tailwater is unknown, use 0.4D

flow is sbcritical

Result Parameters

Tailwater Depth Used in Computations: 2.2 (ft)

Culvert Diameter Used in Computations: 5.5 (ft)

Computed D50: 0.440397 (in)

Hydraulic Analysis Report

Project Data

Project Title: 121088 - Culvert Outlet Check

Designer:

Project Date: Friday, February 08, 2013

Project Units: U.S. Customary Units

Notes:

Riprap Analysis: FP-05 - Outlet - Done

Notes:

Input Parameters

Riprap Type: Culvert Outlet Protection

Flow: 109.2 (cfs)

Culvert Diameter: 9 (ft)

Normal Depth in Culvert: 2.38 (ft)

Tailwater Depth: 2.35 (ft)

If tailwater is unknown, use 0.4D

flow is sbcritical

Result Parameters

Tailwater Depth Used in Computations: 3.6 (ft)

Culvert Diameter Used in Computations: 9 (ft)

Computed D50: 1.83744 (in)

Riprap Analysis: FP-06 - Outlet - Done

Notes:

Input Parameters

Riprap Type: Culvert Outlet Protection

Flow: 135.5 (cfs)

Culvert Diameter: 11.42 (ft)

Normal Depth in Culvert: 2.8 (ft)

Tailwater Depth: 2.42 (ft)

If tailwater is unknown, use 0.4D

flow is sbcritical

Result Parameters

Tailwater Depth Used in Computations: 4.568 (ft)

Culvert Diameter Used in Computations: 11.42 (ft)

Computed D50: 1.40555 (in)

Riprap Analysis: FP-07 - Outlet - Done

Notes:

Input Parameters

Riprap Type: Culvert Outlet Protection

Flow: 36.5 (cfs)

Culvert Diameter: 5.5 (ft)

Normal Depth in Culvert: 0.91 (ft)

Tailwater Depth: 1.29 (ft)

If tailwater is unknown, use 0.4D

flow is supercritical

Result Parameters

Tailwater Depth Used in Computations: 1.29 (ft)

Culvert Diameter Used in Computations: 3.205 (ft)

Computed D50: 4.71235 (in)

Riprap Analysis: FP-09 - Outlet - Done

Notes:

Input Parameters

Riprap Type: Culvert Outlet Protection

Flow: 92 (cfs)

Culvert Diameter: 8 (ft)

Normal Depth in Culvert: 1.28 (ft)

Tailwater Depth: 1.43 (ft)

If tailwater is unknown, use 0.4D

flow is supercritical

Result Parameters

Tailwater Depth Used in Computations: 1.856 (ft)

Culvert Diameter Used in Computations: 4.64 (ft)

Computed D50: 6.85998 (in)

Riprap Analysis: FP-10 - Outlet - Done

Notes:

Input Parameters

Riprap Type: Culvert Outlet Protection

Flow: 105.3 (cfs)

Culvert Diameter: 8 (ft)

Normal Depth in Culvert: 1.34 (ft)

Tailwater Depth: 1.29 (ft)

If tailwater is unknown, use 0.4D

flow is supercritical

Result Parameters

Tailwater Depth Used in Computations: 1.868 (ft)

Culvert Diameter Used in Computations: 4.67 (ft)

Computed D50: 8.09058 (in)

Riprap Analysis: FP-11 - Outlet - Done

Notes:

Input Parameters

Riprap Type: Culvert Outlet Protection

Flow: 66.4 (cfs)

Culvert Diameter: 8 (ft)

Normal Depth in Culvert: 1.03 (ft)

Tailwater Depth: 1.08 (ft)

If tailwater is unknown, use 0.4D

flow is supercritical

Result Parameters

Tailwater Depth Used in Computations: 1.806 (ft)

Culvert Diameter Used in Computations: 4.515 (ft)

Computed D50: 4.73337 (in)

Riprap Analysis: FP-12 - Outlet - Done

Notes:

Input Parameters

Riprap Type: Culvert Outlet Protection

Flow: 22.3 (cfs)

Culvert Diameter: 5 (ft)

Normal Depth in Culvert: 0.71 (ft)

Tailwater Depth: 0.64 (ft)

If tailwater is unknown, use 0.4D

flow is supercritical

Result Parameters

Tailwater Depth Used in Computations: 1.142 (ft)

Culvert Diameter Used in Computations: 2.855 (ft)

Computed D50: 3.21964 (in)

Riprap Analysis: FP-13 - Outlet - Done

Notes:

Input Parameters

Riprap Type: Culvert Outlet Protection

Flow: 210.8 (cfs)

Culvert Diameter: 14.25 (ft)

Normal Depth in Culvert: 1.68 (ft)

Tailwater Depth: 2.79 (ft)

If tailwater is unknown, use 0.4D

flow is supercritical

Result Parameters

Tailwater Depth Used in Computations: 3.186 (ft)

Culvert Diameter Used in Computations: 7.965 (ft)

Computed D50: 5.87321 (in)

Riprap Analysis: FP-14 - Outlet - Done

Notes:

Input Parameters

Riprap Type: Culvert Outlet Protection

Flow: 70.5 (cfs)

Culvert Diameter: 8 (ft)

Normal Depth in Culvert: 1.14 (ft)

Tailwater Depth: 1.59 (ft)

If tailwater is unknown, use 0.4D

flow is supercritical

Result Parameters

Tailwater Depth Used in Computations: 1.828 (ft)

Culvert Diameter Used in Computations: 4.57 (ft)

Computed D50: 4.9842 (in)

Riprap Analysis: FP-15 - Outlet - Done

Notes:

Input Parameters

Riprap Type: Culvert Outlet Protection

Flow: 138.6 (cfs)

Culvert Diameter: 10.67 (ft)

Normal Depth in Culvert: 1.56 (ft)

Tailwater Depth: 1.61 (ft)

If tailwater is unknown, use 0.4D

flow is supercritical

Result Parameters

Tailwater Depth Used in Computations: 2.446 (ft)

Culvert Diameter Used in Computations: 6.115 (ft)

Computed D50: 6.22167 (in)

Riprap Analysis: FP-16 - Outlet - Done

Notes:

Input Parameters

Riprap Type: Culvert Outlet Protection

Flow: 10.9 (cfs)

Culvert Diameter: 5 (ft)

Normal Depth in Culvert: 1.02 (ft)

Tailwater Depth: 2.53 (ft)

If tailwater is unknown, use 0.4D

flow is sbcritical

Result Parameters

Tailwater Depth Used in Computations: 2.53 (ft)

Culvert Diameter Used in Computations: 5 (ft)

Computed D50: 0.265071 (in)

Riprap Analysis: FP-17 - Outlet - Done

Notes:

Input Parameters

Riprap Type: Culvert Outlet Protection

Flow: 30.3 (cfs)

Culvert Diameter: 5 (ft)

Normal Depth in Culvert: 0.95 (ft)

Tailwater Depth: 1.76 (ft)

If tailwater is unknown, use 0.4D

flow is supercritical

Result Parameters

Tailwater Depth Used in Computations: 1.76 (ft)

Culvert Diameter Used in Computations: 2.975 (ft)

Computed D50: 2.97602 (in)

Culvert Structures
HY-8 Culvert Hydraulics

C-05

Crossing Discharge Data

Discharge Selection Method: Specify Minimum, Design, and Maximum Flow

Minimum Flow: 23.3 cfs — Q_2

Design Flow: 50.7 cfs — Q_{50}

Maximum Flow: 72.3 cfs — Q_{500}

Table 10 - Summary of Culvert Flows at Crossing: C-05

	Headwater Elevation (ft)	Total Discharge (cfs)	C-05 Discharge (cfs)	Roadway Discharge (cfs)	Iterations
Q_2	193.26	23.30	23.30	0.00	1
	193.50	28.20	28.20	0.00	1
	193.73	33.10	33.10	0.00	1
	193.95	38.00	38.00	0.00	1
	194.15	42.90	42.90	0.00	1
	194.35	47.80	47.80	0.00	1
Q_{50}	194.46	50.70	50.70	0.00	1
	194.73	57.60	57.60	0.00	1
	194.91	62.50	62.50	0.00	1
	195.10	67.40	67.40	0.00	1
	195.28	72.30	72.30	0.00	1
Q_{500}	195.96	88.74	88.74	0.00	Overtopping

HW = 194.46' − 191.36' = 3.1'

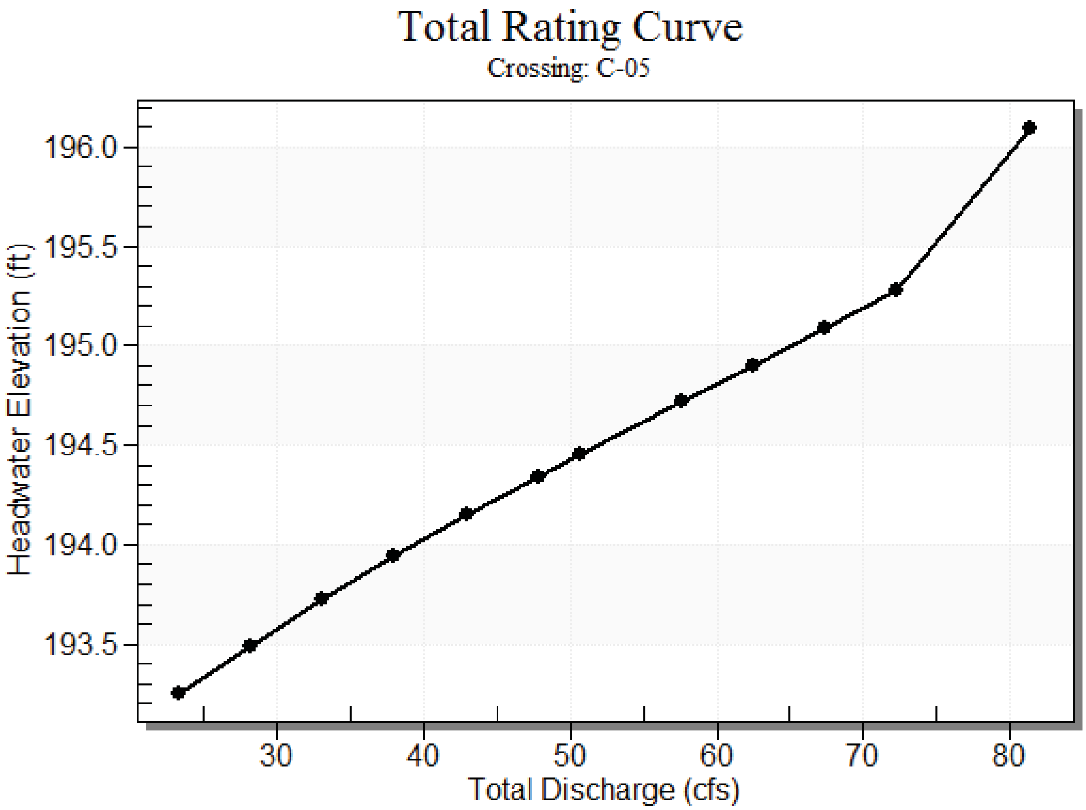
EL. @ Q_{50} — INLET EL

D = 4'

CULVERT DIAMETER

$HW/D = 0.78 < 1.5$ ✓

Rating Curve Plot for Crossing: C-05



HY-8 Analysis Results

Culvert Summary Table - C-05

Culvert Crossing: C-05

Total Discharge (cfs)	Culvert Discharge (cfs)	Headwater Elevation (ft)	Inlet Control Depth(ft)	Outlet Control Depth(ft)	Flow Type	Normal Depth (ft)	Critical Depth (ft)	Outlet Depth (ft)	Tailwater Depth (ft)	Outlet Velocity (ft/s)	Tailwater Velocity (ft/s)
23.30	23.30	193.26	1.90	0.0*	1-S2n	0.73	1.42	0.80	2.04	12.94	5.60
28.20	28.20	193.50	2.14	0.0*	1-S2n	0.79	1.57	0.89	2.19	13.42	5.88
33.10	33.10	193.73	2.37	0.0*	1-S2n	0.85	1.71	0.97	2.33	13.87	6.12
38.00	38.00	193.95	2.59	0.0*	1-S2n	0.91	1.84	1.06	2.45	14.29	6.33
42.90	42.90	194.15	2.79	0.07	1-S2n	0.97	1.96	1.13	2.56	14.69	6.53
47.80	47.80	194.35	2.99	0.25	1-S2n	1.03	2.07	1.21	2.67	14.88	6.71
50.70	50.70	194.46	3.10	0.36	1-S2n	1.07	2.13	1.25	2.73	15.02	6.81
57.60	57.60	194.73	3.37	0.62	1-S2n	1.14	2.28	1.35	2.86	15.38	7.03
62.50	62.50	194.91	3.55	0.81	1-S2n	1.19	2.38	1.42	2.95	15.64	7.17
67.40	67.40	195.10	3.74	1.01	1-S2n	1.23	2.48	1.49	3.04	15.89	7.31
72.30	72.30	195.28	3.92	1.21	1-S2n	1.28	2.57	1.55	3.12	16.04	7.44

* Full Flow Headwater elevation is below inlet invert.

****

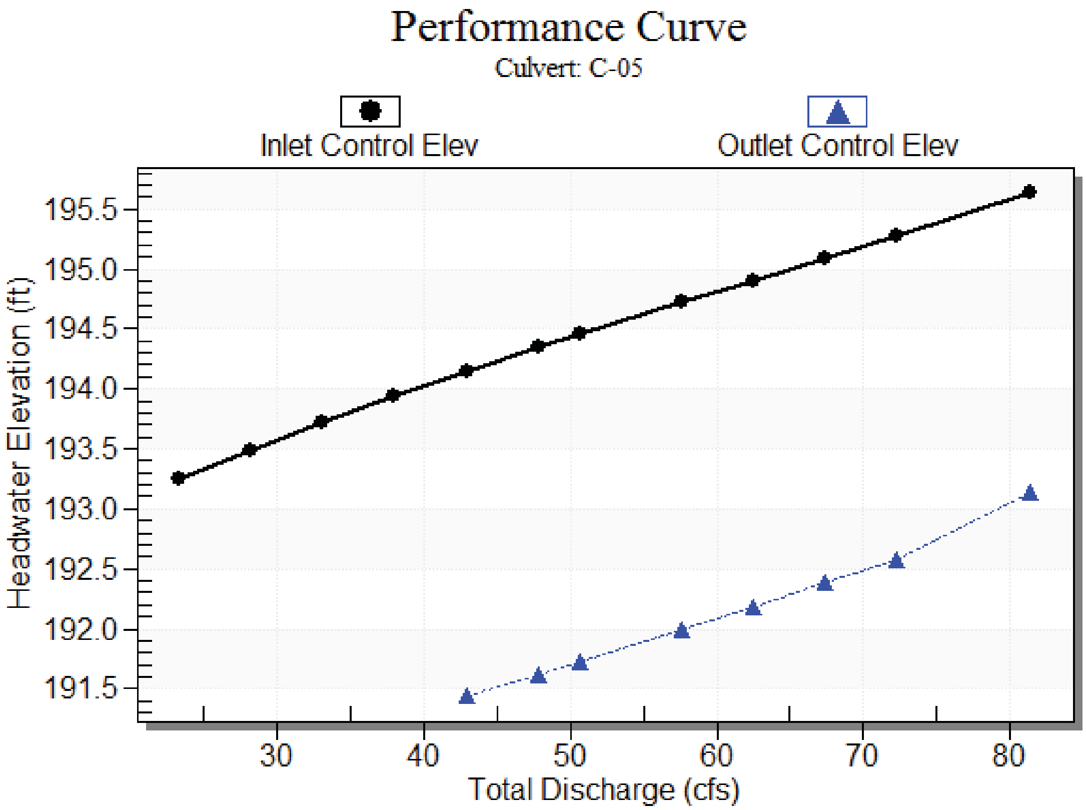
Straight Culvert

Inlet Elevation (invert): 191.36 ft,   Outlet Elevation (invert): 188.56 ft

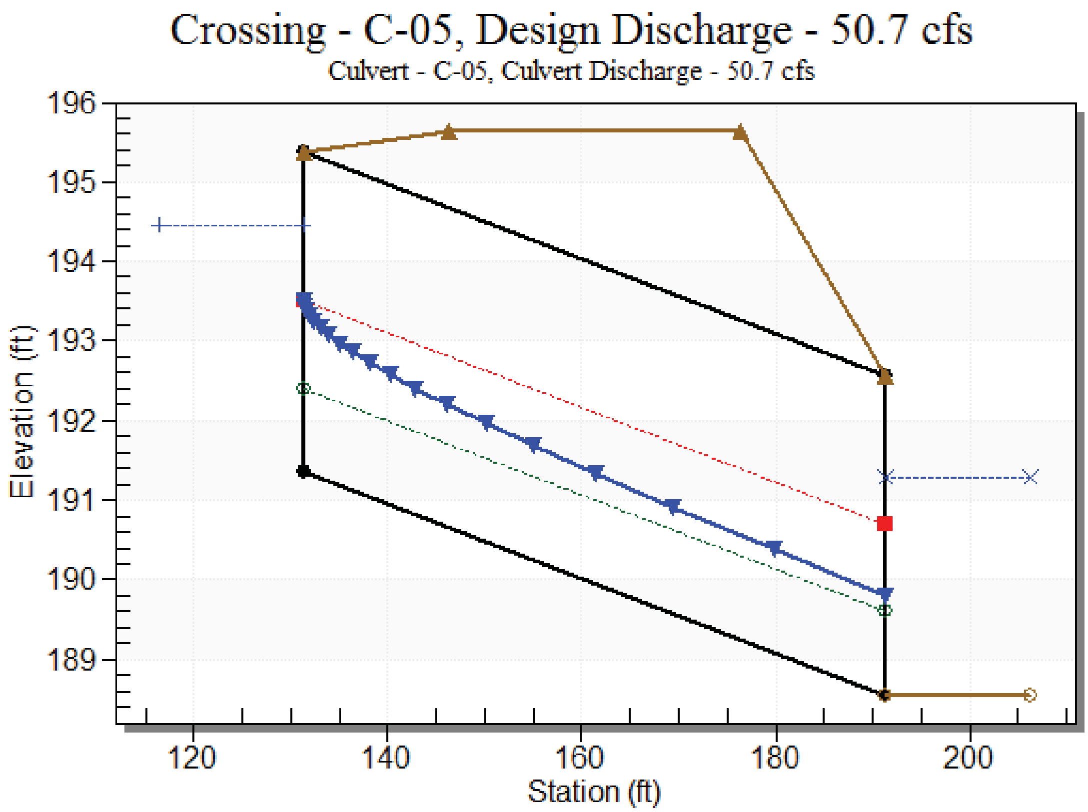
Culvert Length: 60.05 ft,   Culvert Slope: 0.0467

****

Culvert Performance Curve Plot: C-05



Water Surface Profile Plot for Culvert: C-05



Site Data - C-05

Site Data Option: Culvert Invert Data

Inlet Station: 131.38 ft

Inlet Elevation: 191.36 ft

Outlet Station: 191.36 ft

Outlet Elevation: 188.56 ft

Number of Barrels: 1

Culvert Data Summary - C-05

Barrel Shape: Circular

Barrel Diameter: 4.00 ft

Barrel Material: Smooth HDPE

Embedment: 0.00 in

Barrel Manning's n: 0.0120

Culvert Type: Straight

Inlet Configuration: Square Edge with Headwall

Inlet Depression: NONE

Table 12 - Downstream Channel Rating Curve (Crossing: C-05)

Flow (cfs)	Water Surface Elev (ft)	Depth (ft)	Velocity (ft/s)	Shear (psf)	Froude Number
23.30	190.60	2.04	5.60	7.00	0.98
28.20	190.75	2.19	5.88	7.52	0.99
33.10	190.89	2.33	6.12	7.98	1.00
38.00	191.01	2.45	6.33	8.41	1.01
42.90	191.12	2.56	6.53	8.80	1.02
47.80	191.23	2.67	6.71	9.16	1.02
50.70	191.29	2.73	6.81	9.37	1.03
57.60	191.42	2.86	7.03	9.83	1.03
62.50	191.51	2.95	7.17	10.13	1.04
67.40	191.60	3.04	7.31	10.42	1.05
72.30	191.68	3.12	7.44	10.70	1.05

Tailwater Channel Data - C-05

Tailwater Channel Option: Triangular Channel

Side Slope (H:V): 1.00 (_:1)

Channel Slope: 0.0550

Channel Manning's n: 0.0500

Channel Invert Elevation: 188.56 ft

Roadway Data for Crossing: C-05

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 100.00 ft

Crest Elevation: 195.64 ft

Roadway Surface: Paved

Roadway Top Width: 30.00 ft

C-08

HY-8 Culvert Analysis Report

Crossing Discharge Data

Discharge Selection Method: Specify Minimum, Design, and Maximum Flow

Minimum Flow: 73.6 cfs — Q_2

Design Flow: 158.5 cfs — Q_{50}

Maximum Flow: 225.9 cfs — Q_{500}

Table 1 - Summary of Culvert Flows at Crossing: C-08

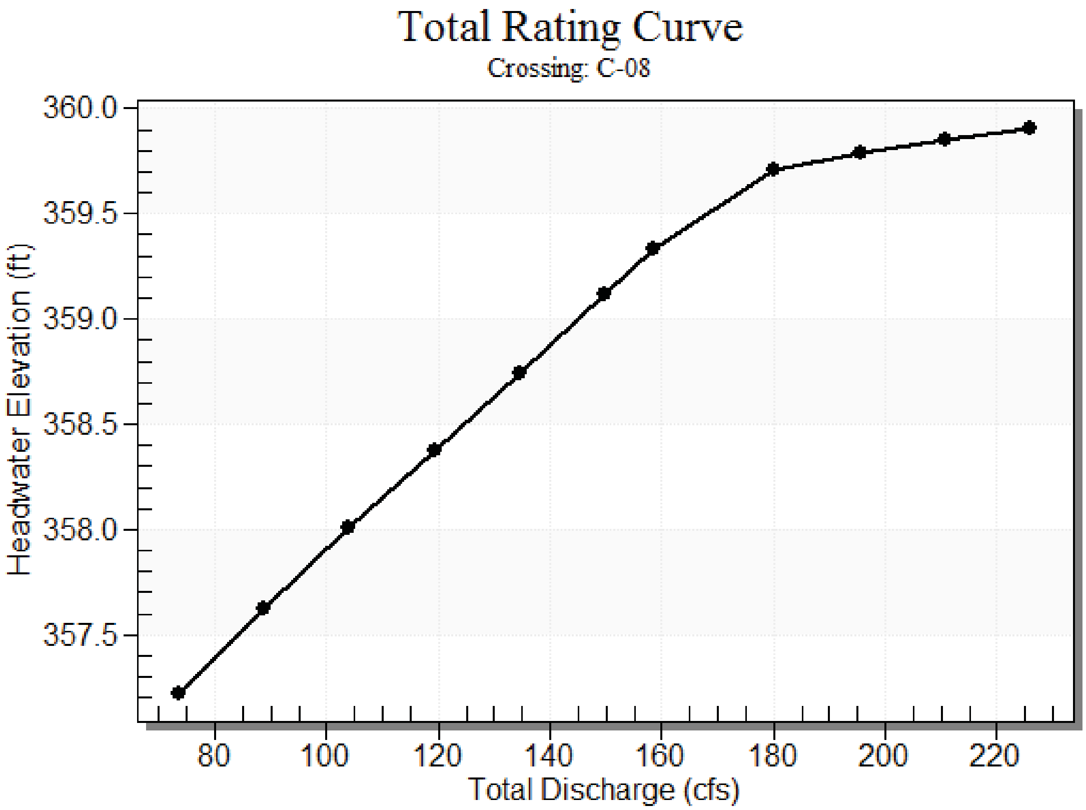
	Headwater Elevation (ft)	Total Discharge (cfs)	C-08 Discharge (cfs)	Roadway Discharge (cfs)	Iterations
Q_2	357.23	73.60	73.60	0.00	1
	357.62	88.83	88.83	0.00	1
	358.00	104.06	104.06	0.00	1
	358.38	119.29	119.29	0.00	1
	358.75	134.52	134.52	0.00	1
	359.12	149.75	149.75	0.00	1
Q_{50}	359.33	158.50	158.50	0.00	1
	359.71	180.21	173.59	6.46	12
	359.79	195.44	176.70	18.57	6
	359.85	210.67	179.22	31.29	5
	359.91	225.90	181.42	44.19	4
Q_{500}	359.63	170.47	170.47	0.00	Overtopping

HW = 359.33' (@ Q_{50}) − 354.06' (INLET) = 5.27'

D = 6'

$HW/D = 0.88 < 1.2$ ✓

Rating Curve Plot for Crossing: C-08



HY-8 Analysis Results

Culvert Summary Table - C-08

Culvert Crossing: C-08

Total Discharge (cfs)	Culvert Discharge (cfs)	Headwater Elevation (ft)	Inlet Control Depth(ft)	Outlet Control Depth(ft)	Flow Type	Normal Depth (ft)	Critical Depth (ft)	Outlet Depth (ft)	Tailwater Depth (ft)	Outlet Velocity (ft/s)	Tailwater Velocity (ft/s)
73.60	73.60	357.47	3.28	0.0*	1-S2n	1.44	2.29	1.44	1.12	13.96	6.93
88.83	88.83	357.86	3.67	0.0*	1-S2n	1.61	2.52	1.64	1.25	14.14	7.37
104.06	104.06	358.25	4.06	0.0*	1-S2n	1.74	2.75	1.79	1.37	14.65	7.76
119.29	119.29	358.62	4.43	0.0*	1-S2n	1.86	2.95	1.93	1.48	15.15	8.11
134.52	134.52	358.99	4.80	0.0*	1-S2n	1.98	3.14	2.06	1.59	15.63	8.42
149.75	149.75	359.36	5.17	0.0*	1-S2n	2.10	3.32	2.19	1.69	16.08	8.71
158.50	158.50	359.57	5.38	0.02	1-S2n	2.17	3.42	2.26	1.75	16.27	8.87
180.21	166.05	359.76	5.57	0.23	1-S2n	2.23	3.51	2.32	1.89	16.45	9.22
195.44	168.78	359.83	5.64	0.31	1-S2n	2.25	3.53	2.34	1.98	16.53	9.45
210.67	171.12	359.89	5.70	0.37	1-S2n	2.26	3.56	2.36	2.06	16.58	9.67
225.90	173.27	359.94	5.75	0.43	1-S2n	2.28	3.58	2.38	2.15	16.61	9.88

* Full Flow Headwater elevation is below inlet invert.

****

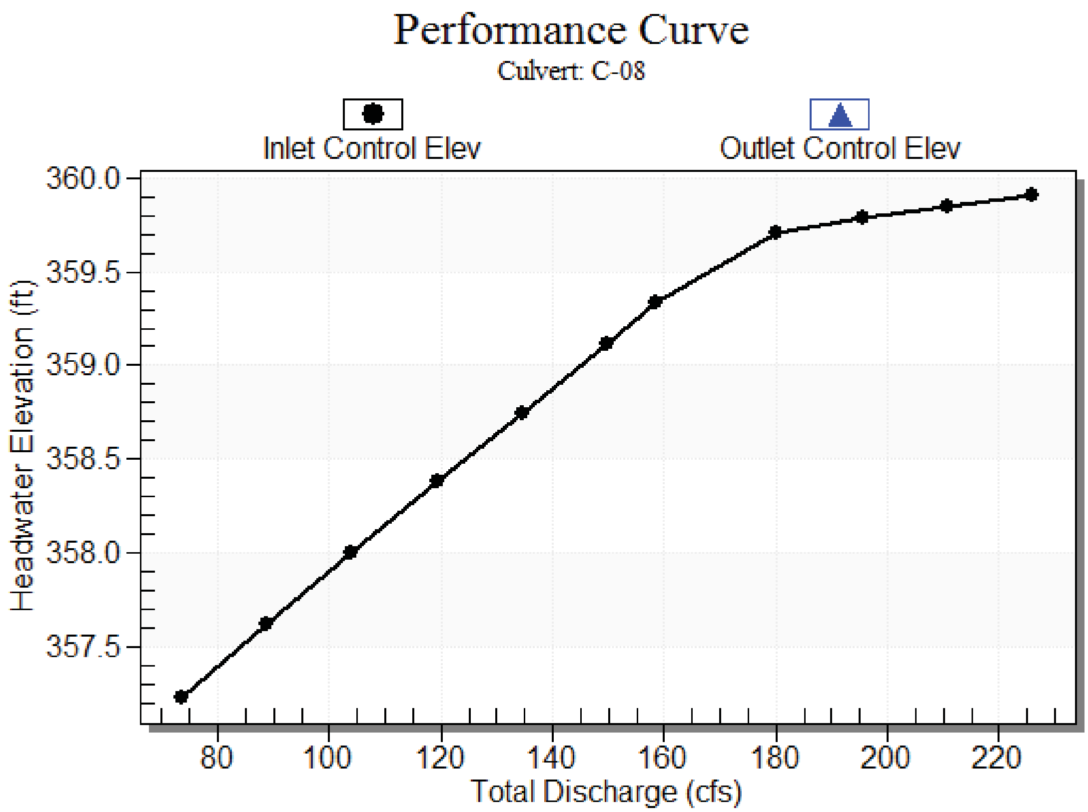
Straight Culvert

Inlet Elevation (invert): 354.06 ft,   Outlet Elevation (invert): 346.44 ft

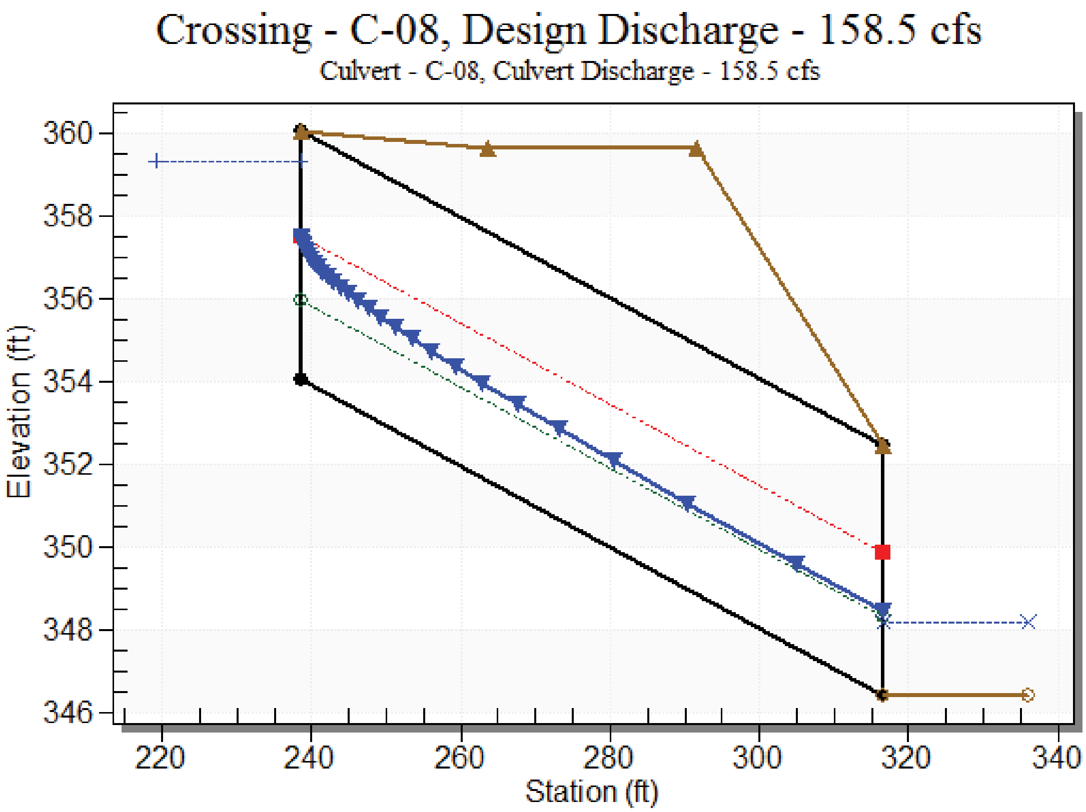
Culvert Length: 78.37 ft,   Culvert Slope: 0.0977

****

Culvert Performance Curve Plot: C-08



Water Surface Profile Plot for Culvert: C-08



Site Data - C-08

Site Data Option: Culvert Invert Data

Inlet Station: 238.62 ft

Inlet Elevation: 354.06 ft

Outlet Station: 316.62 ft

Outlet Elevation: 346.44 ft

Number of Barrels: 1

Culvert Data Summary - C-08

Barrel Shape: Circular

Barrel Diameter: 6.00 ft

Barrel Material: Corrugated Steel

Embedment: 0.00 in

Barrel Manning's n: 0.0240

Culvert Type: Straight

Inlet Configuration: Thin Edge Projecting

Inlet Depression: NONE

Table 3 - Downstream Channel Rating Curve (Crossing: C-08)

Flow (cfs)	Water Surface Elev (ft)	Depth (ft)	Velocity (ft/s)	Shear (psf)	Froude Number
73.60	347.56	1.12	6.93	6.13	1.23
88.83	347.69	1.25	7.37	6.86	1.24
104.06	347.81	1.37	7.76	7.52	1.26
119.29	347.92	1.48	8.11	8.15	1.27
134.52	348.03	1.59	8.42	8.74	1.27
149.75	348.13	1.69	8.71	9.31	1.28
158.50	348.19	1.75	8.87	9.62	1.29
180.21	348.33	1.89	9.22	10.36	1.30
195.44	348.42	1.98	9.45	10.86	1.30
210.67	348.50	2.06	9.67	11.34	1.31
225.90	348.59	2.15	9.88	11.80	1.31

Tailwater Channel Data - C-08

Tailwater Channel Option: Trapezoidal Channel

Bottom Width: 8.28 ft

Side Slope (H:V): 1.10 (_:1)

Channel Slope: 0.0880

Channel Manning's n: 0.0600

Channel Invert Elevation: 346.44 ft

Roadway Data for Crossing: C-08

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 100.00 ft

Crest Elevation: 359.63 ft

Roadway Surface: Paved

Roadway Top Width: 28.00 ft

Crossing Discharge Data

Discharge Selection Method: Specify Minimum, Design, and Maximum Flow

Minimum Flow: 56.6 cfs — Q_2

Design Flow: 122.1 cfs — Q_{50}

Maximum Flow: 174.1 cfs — Q_{500}

Table 4 - Summary of Culvert Flows at Crossing: C-12

	Headwater Elevation (ft)	Total Discharge (cfs)	C-12 Discharge (cfs)	Roadway Discharge (cfs)	Iterations
Q_2	335.99	56.60	56.60	0.00	1
	336.32	68.35	68.35	0.00	1
	336.62	80.10	80.10	0.00	1
	336.90	91.85	91.85	0.00	1
	337.16	103.60	103.60	0.00	1
	337.41	115.35	115.35	0.00	1
Q_{50} →	337.56	122.10	122.10	0.00	1
	337.91	138.85	138.85	0.00	1
	338.16	150.60	150.60	0.00	1
	338.41	162.35	162.35	0.00	1
	338.68	174.10	174.10	0.00	1
Q_{500}	338.83	180.60	180.60	0.00	Overtopping

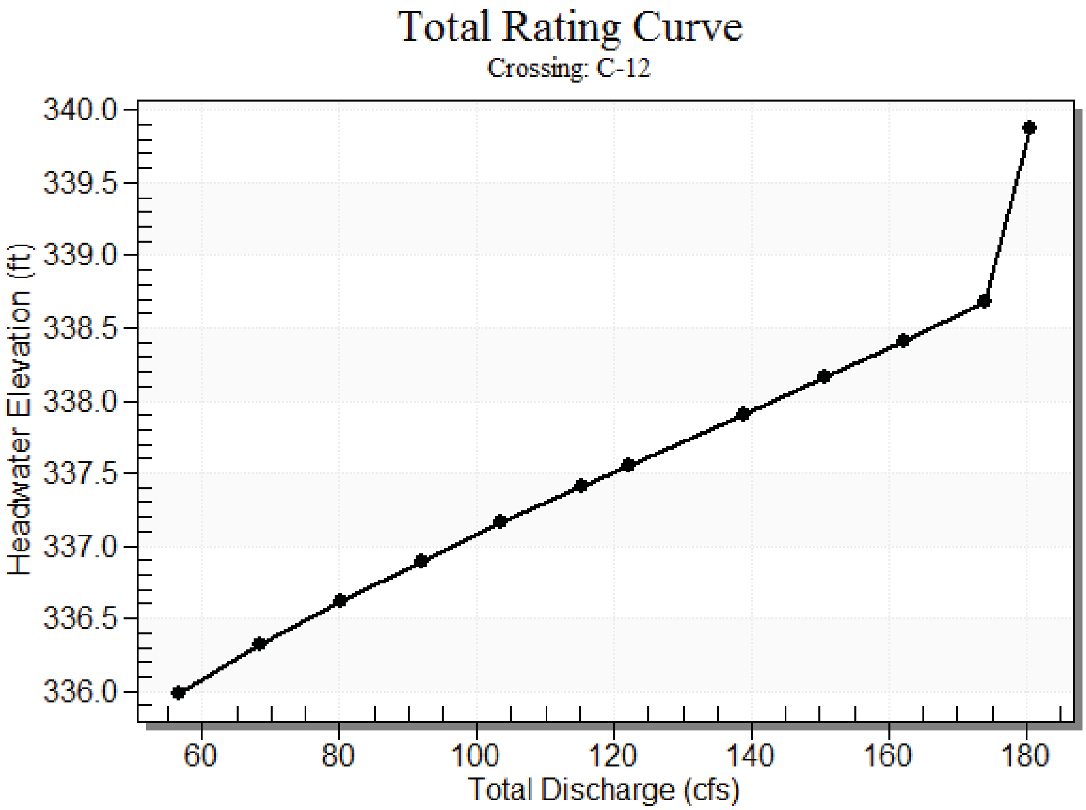
$HW = 337.56' - 332.85' = 4.71'$

@ Q_{50} — INLET

$D = 6'$ Ø

$HW/D = 0.78 < 1.2$ ✓

Rating Curve Plot for Crossing: C-12



HY-8 Analysis Results

Culvert Summary Table - C-12

Culvert Crossing: C-12

Total Discharge (cfs)	Culvert Discharge (cfs)	Headwater Elevation (ft)	Inlet Control Depth(ft)	Outlet Control Depth(ft)	Flow Type	Normal Depth (ft)	Critical Depth (ft)	Outlet Depth (ft)	Tailwater Depth (ft)	Outlet Velocity (ft/s)	Tailwater Velocity (ft/s)
56.60	56.60	335.99	3.14	0.0*	1-S2n	1.22	2.00	1.22	2.17	13.63	5.26
68.35	68.35	336.32	3.47	0.0*	1-S2n	1.34	2.20	1.39	2.33	13.62	5.52
80.10	80.10	336.62	3.77	0.0*	1-S2n	1.45	2.39	1.50	2.47	14.34	5.74
91.85	91.85	336.90	4.05	0.0*	1-S2n	1.57	2.57	1.62	2.60	14.92	5.94
103.60	103.60	337.16	4.31	0.0*	1-S2n	1.67	2.74	1.73	2.72	15.30	6.12
115.35	115.35	337.41	4.56	0.0*	1-S2n	1.76	2.90	1.83	2.83	15.69	6.29
122.10	122.10	337.56	4.71	0.0*	1-S2n	1.81	2.99	1.89	2.89	15.96	6.38
138.85	138.85	337.91	5.06	0.0*	1-S2n	1.94	3.19	2.03	3.03	16.42	6.58
150.60	150.60	338.16	5.31	0.0*	1-S2n	2.03	3.33	2.13	3.13	16.77	6.72
162.35	162.35	338.41	5.56	0.0*	1-S2n	2.12	3.46	2.22	3.22	17.09	6.85
174.10	174.10	338.68	5.83	0.01	1-S2n	2.20	3.59	2.31	3.30	17.31	6.97

* Full Flow Headwater elevation is below inlet invert.

****

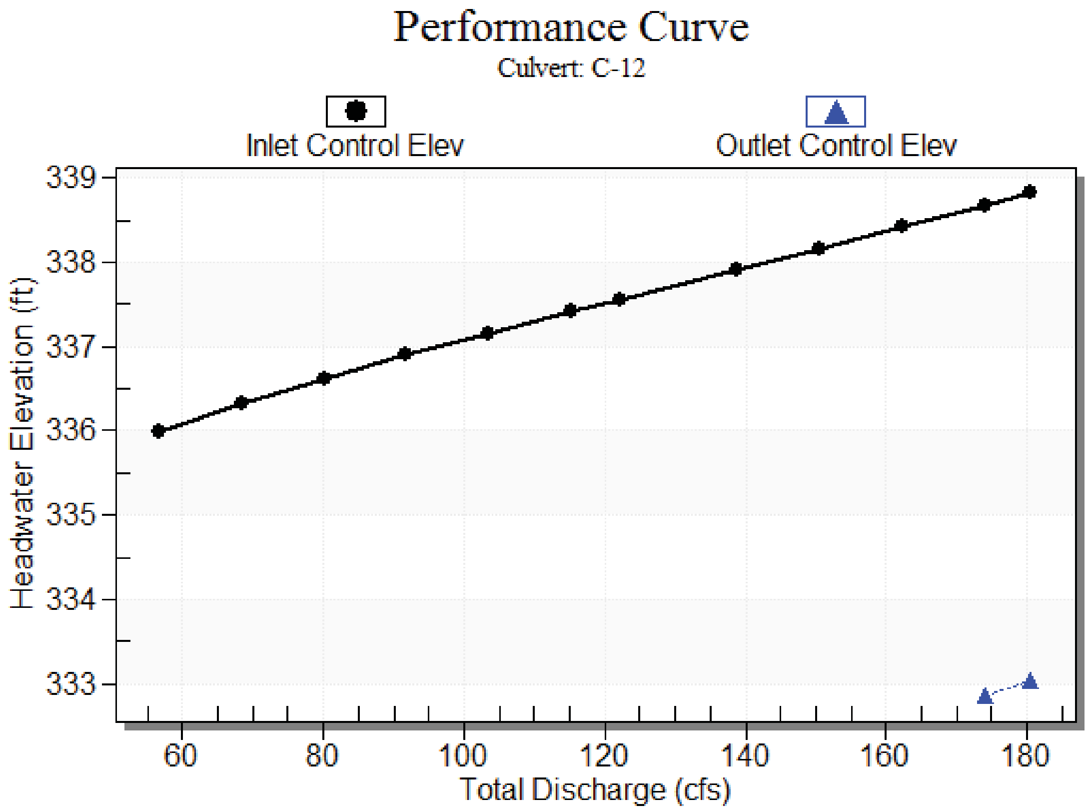
Straight Culvert

Inlet Elevation (invert): 332.85 ft, Outlet Elevation (invert): 327.85 ft

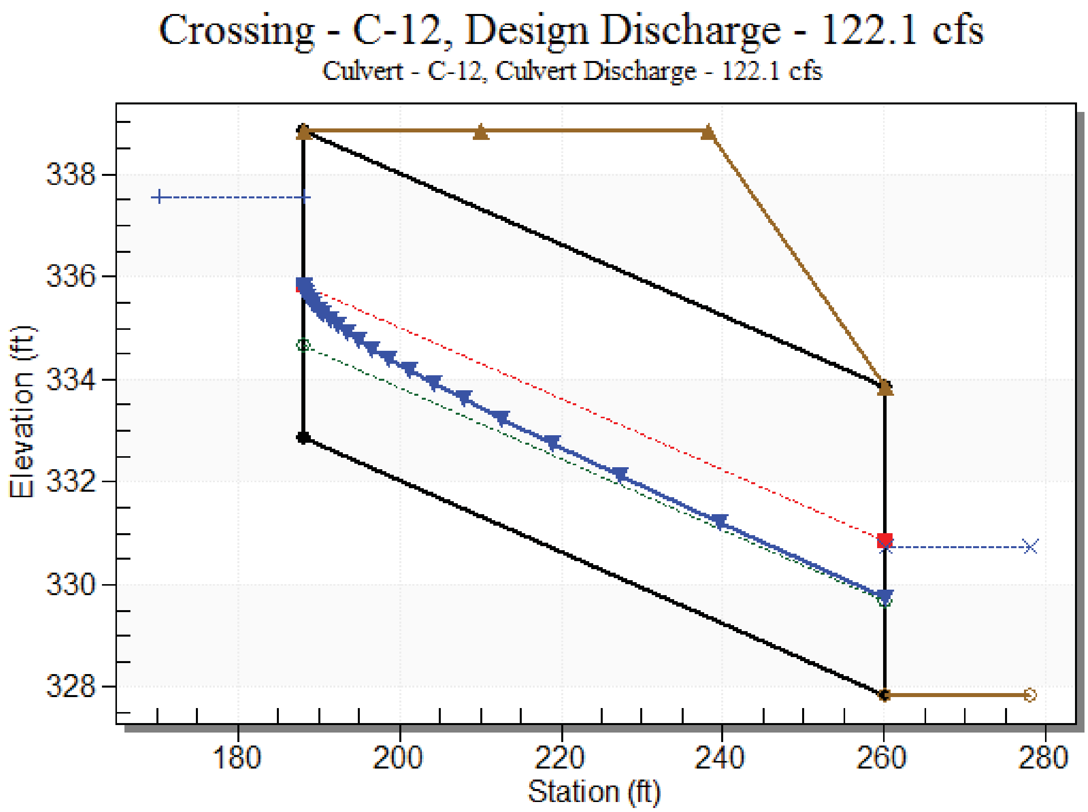
Culvert Length: 72.12 ft, Culvert Slope: 0.0695

****

Culvert Performance Curve Plot: C-12



Water Surface Profile Plot for Culvert: C-12



Site Data - C-12

Site Data Option: Culvert Invert Data

Inlet Station: 188.21 ft

Inlet Elevation: 332.85 ft

Outlet Station: 260.16 ft

Outlet Elevation: 327.85 ft

Number of Barrels: 1

Culvert Data Summary - C-12

Barrel Shape: Circular

Barrel Diameter: 6.00 ft

Barrel Material: Corrugated Steel

Embedment: 0.00 in

Barrel Manning's n: 0.0240

Culvert Type: Straight

Inlet Configuration: Mitered to Conform to Slope

Inlet Depression: NONE

Table 6 - Downstream Channel Rating Curve (Crossing: C-12)

Flow (cfs)	Water Surface Elev (ft)	Depth (ft)	Velocity (ft/s)	Shear (psf)	Froude Number
56.60	330.02	2.17	5.26	8.39	0.89
68.35	330.18	2.33	5.52	9.00	0.90
80.10	330.32	2.47	5.74	9.55	0.91
91.85	330.45	2.60	5.94	10.05	0.92
103.60	330.57	2.72	6.12	10.52	0.93
115.35	330.68	2.83	6.29	10.95	0.93
122.10	330.74	2.89	6.38	11.19	0.93
138.85	330.88	3.03	6.58	11.74	0.94
150.60	330.98	3.13	6.72	12.10	0.95
162.35	331.07	3.22	6.85	12.45	0.95
174.10	331.15	3.30	6.97	12.78	0.96

Tailwater Channel Data - C-12

Tailwater Channel Option: Triangular Channel

Side Slope (H:V): 2.29 (_:1)

Channel Slope: 0.0620

Channel Manning's n: 0.0700

Channel Invert Elevation: 327.85 ft

Roadway Data for Crossing: C-12

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 100.00 ft

Crest Elevation: 338.83 ft

Roadway Surface: Paved

Roadway Top Width: 28.00 ft

Crossing Discharge Data

Discharge Selection Method: Specify Minimum, Design, and Maximum Flow

Minimum Flow: 26.8 cfs — Q_2

Design Flow: 58.2 cfs — Q_{50}

Maximum Flow: 83.1 cfs — Q_{500}

Table 7 - Summary of Culvert Flows at Crossing: C-13

	Headwater Elevation (ft)	Total Discharge (cfs)	C-13 Discharge (cfs)	Roadway Discharge (cfs)	Iterations
Q_2	323.88	26.80	26.80	0.00	1
	324.15	32.43	32.43	0.00	1
	324.41	38.06	38.06	0.00	1
	324.66	43.69	43.69	0.00	1
	324.91	49.32	49.32	0.00	1
	325.16	54.95	54.95	0.00	1
Q_{50}	325.31	58.20	58.20	0.00	1
	325.68	66.21	66.21	0.00	1
	325.95	71.84	71.84	0.00	1
	326.24	77.47	77.47	0.00	1
	326.54	83.10	83.10	0.00	1
Q_{500}	336.52	188.75	188.75	0.00	Overtopping

$HW = 325.31' - 321.66' = 3.65'$

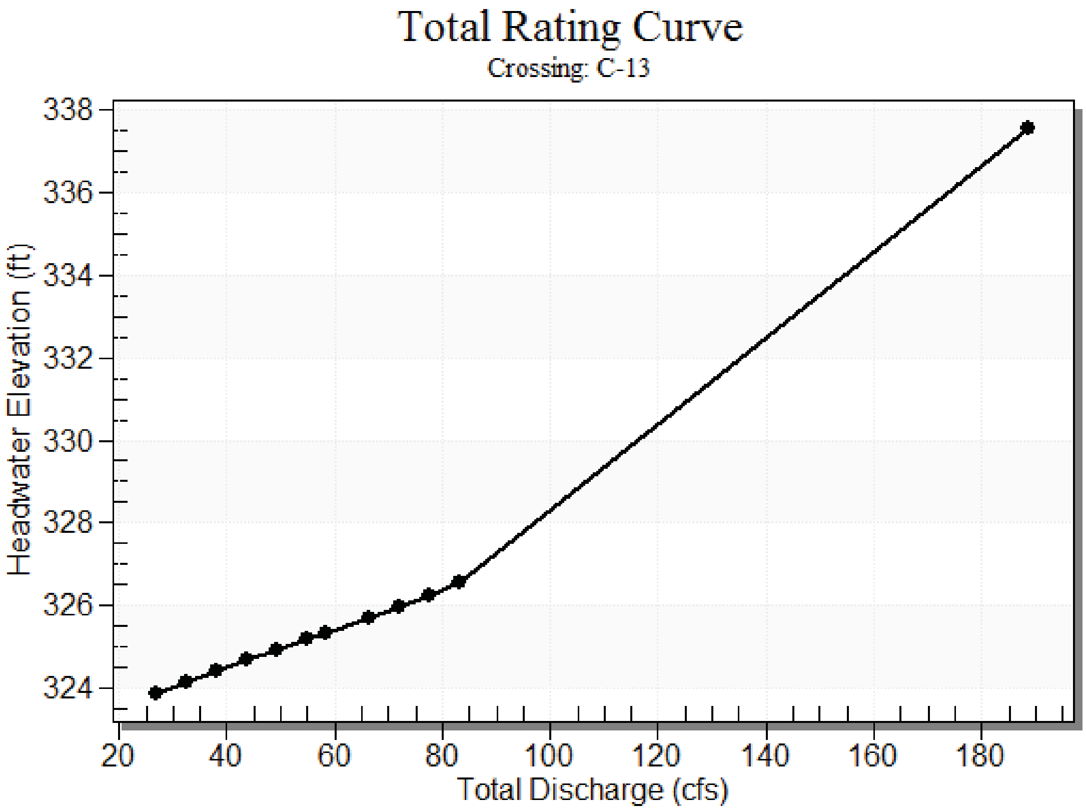
@ Q_{50} INLET

$D = 4'$

Ø

$HW/D = 0.91 < 1.5$ ✓

Rating Curve Plot for Crossing: C-13



HY-8 Analysis Results

Culvert Summary Table - C-13

Culvert Crossing: C-13

Total Discharge (cfs)	Culvert Discharge (cfs)	Headwater Elevation (ft)	Inlet Control Depth(ft)	Outlet Control Depth(ft)	Flow Type	Normal Depth (ft)	Critical Depth (ft)	Outlet Depth (ft)	Tailwater Depth (ft)	Outlet Velocity (ft/s)	Tailwater Velocity (ft/s)
26.80	26.80	323.80	2.06	0.0*	1-S2n	0.76	1.53	0.82	1.39	14.45	6.81
32.43	32.43	324.07	2.33	0.0*	1-S2n	0.83	1.69	0.90	1.45	15.11	7.27
38.06	38.06	324.33	2.59	0.0*	1-S2n	0.90	1.84	0.99	1.50	15.69	7.68
43.69	43.69	324.56	2.82	0.0*	1-S2n	0.96	1.98	1.07	1.56	16.17	8.04
49.32	49.32	324.78	3.04	0.0*	1-S2n	1.03	2.10	1.15	1.61	16.55	8.37
54.95	54.95	325.00	3.26	0.0*	1-S2n	1.10	2.23	1.22	1.65	16.87	8.68
58.20	58.20	325.12	3.38	0.0*	1-S2n	1.13	2.29	1.26	1.68	17.02	8.84
66.21	66.21	325.43	3.69	0.0*	1-S2n	1.20	2.45	1.36	1.74	17.47	9.22
71.84	71.84	325.64	3.90	0.0*	1-S2n	1.25	2.56	1.43	1.78	17.75	9.47
77.47	77.47	325.86	4.12	0.0*	5-S2n	1.30	2.66	1.50	1.82	18.03	9.70
83.10	83.10	326.09	4.35	0.0*	5-S2n	1.35	2.76	1.56	1.86	18.23	9.92

* Full Flow Headwater elevation is below inlet invert.

****

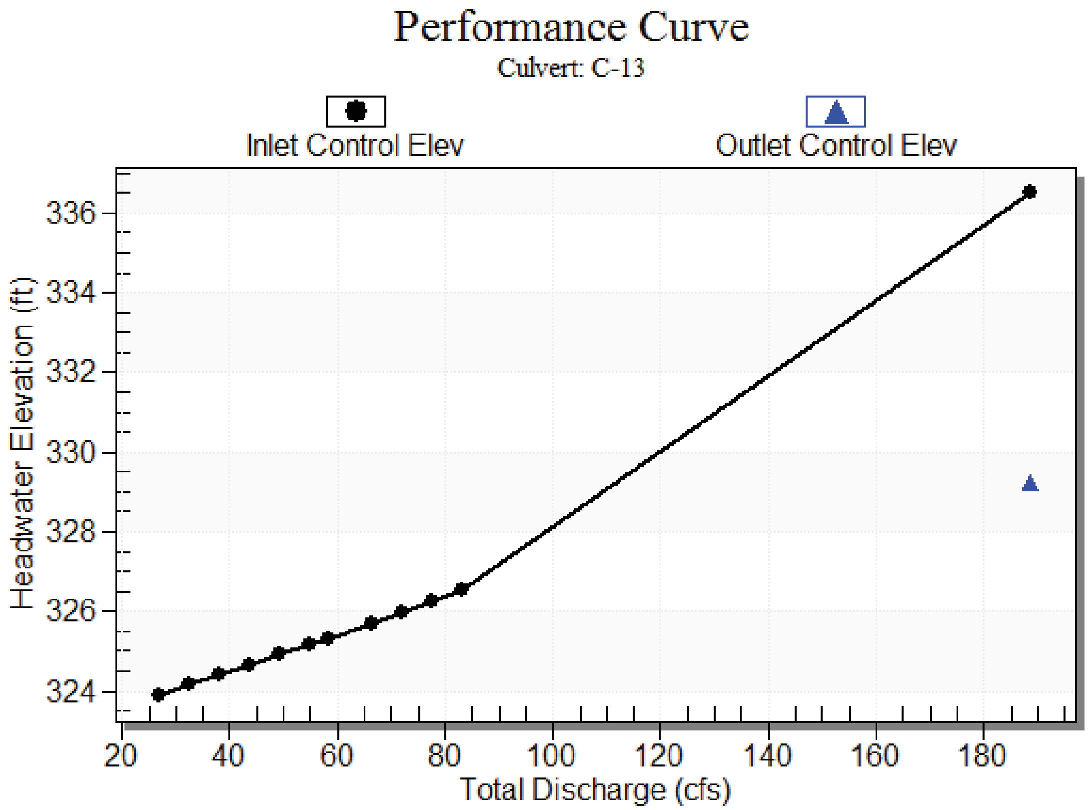
Straight Culvert

Inlet Elevation (invert): 321.66 ft,   Outlet Elevation (invert): 317.28 ft

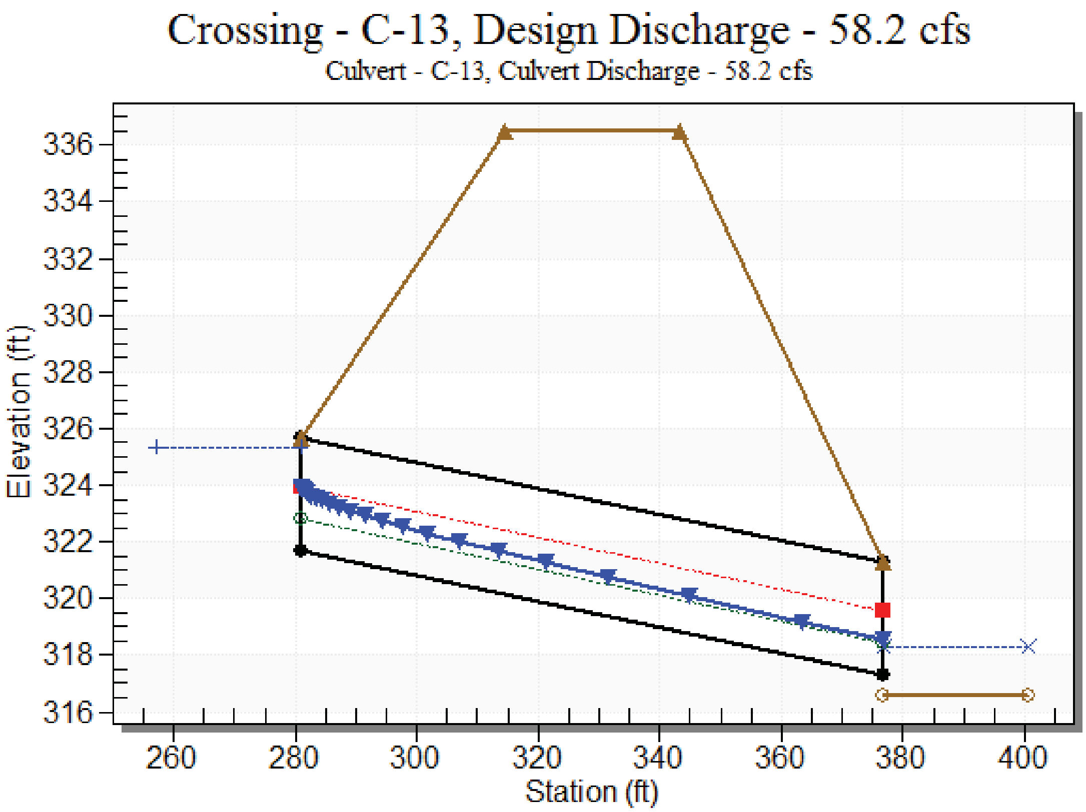
Culvert Length: 95.87 ft,   Culvert Slope: 0.0457

****

Culvert Performance Curve Plot: C-13



Water Surface Profile Plot for Culvert: C-13



Site Data - C-13

Site Data Option: Culvert Invert Data

Inlet Station: 281.02 ft

Inlet Elevation: 321.66 ft

Outlet Station: 376.79 ft

Outlet Elevation: 317.28 ft

Number of Barrels: 1

Culvert Data Summary - C-13

Barrel Shape: Circular

Barrel Diameter: 4.00 ft

Barrel Material: Smooth HDPE

Embedment: 0.00 in

Barrel Manning's n: 0.0120

Culvert Type: Straight

Inlet Configuration: Thin Edge Projecting

Inlet Depression: NONE

Table 9 - Downstream Channel Rating Curve (Crossing: C-13)

Flow (cfs)	Water Surface Elev (ft)	Depth (ft)	Velocity (ft/s)	Shear (psf)	Froude Number
26.80	317.99	1.39	6.81	16.28	1.77
32.43	318.05	1.45	7.27	16.99	1.80
38.06	318.10	1.50	7.68	17.64	1.83
43.69	318.16	1.56	8.04	18.25	1.85
49.32	318.21	1.61	8.37	18.83	1.87
54.95	318.25	1.65	8.68	19.38	1.88
58.20	318.28	1.68	8.84	19.68	1.89
66.21	318.34	1.74	9.22	20.39	1.91
71.84	318.38	1.78	9.47	20.87	1.92
77.47	318.42	1.82	9.70	21.33	1.94
83.10	318.46	1.86	9.92	21.78	1.95

Tailwater Channel Data - C-13

Tailwater Channel Option: Irregular Channel

Roadway Data for Crossing: C-13

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 100.00 ft

Crest Elevation: 336.52 ft

Roadway Surface: Paved

Roadway Top Width: 29.00 ft

Culvert Structures
Inlet & Outlet Protection

P | N | D

811 First Avenue, Suite 570
Seattle, Washington 98104
phone 206.624.1387
fax 206.624.1388

Project: 121088 Deweyville
Sheet Number: 1 Of:
Calculated by: CRW Date: 3/20/13
Checked by: AEW Date: 3/20/13

NOTES & REFERENCES

Culvert Outlet Protection Rock Sizing Analsyis

Purpose: Per project scope of work section 10.4.2.2(10):

- Provide scour protection to mitigate downstream erosion at culvert outlets
- Utilize Hydraulic Toolbox culvert outlet protection (HEC 14 equation 10.4)

Analysis Procedure:

The governing equation for computing riprap size for **Culvert Outlet** protection is:

$$D_{50} = 0.2\, D \left(\frac{Q}{\sqrt{g} D^{2.5}} \right)^{4/3} \left(\frac{D}{TW} \right)$$

HEC-14 Equation (10.4)

Stream	d50	class
FP-01	2.39	1
FP-02	0.24	1
FP-03	1.97	1
FP-04	0.44	1
FP-05	1.84	1
FP-06	1.41	1
FP-07	4.71	1
FP-09	6.86	2
FP-10	8.09	2
FP-11	4.73	1
FP-12	3.22	1
FP-13	5.87	2
FP-14	4.98	1
FP-15	6.22	2
FP-16	0.27	1
FP-17	2.98	1
C-05	4.72	1
C-08	17.8	4
C-12	4.56	1
C-13	9.07	2

Riprap Analysis: C-05 - Outlet - Done

Notes:

Input Parameters

Riprap Type: Culvert Outlet Protection

Flow: 50.7 (cfs)

Culvert Diameter: 4 (ft)

Normal Depth in Culvert: 1.07 (ft)

Tailwater Depth: 2.73 (ft)

If tailwater is unknown, use 0.4D

flow is supercritical

Result Parameters

Tailwater Depth Used in Computations: 2.73 (ft)

Culvert Diameter Used in Computations: 2.535 (ft)

Computed D50: 4.71793 (in)

Riprap Analysis: C-08 - Outlet - Done

Notes:

Input Parameters

Riprap Type: Culvert Outlet Protection

Flow: 158.5 (cfs)

Culvert Diameter: 6 (ft)

Normal Depth in Culvert: 2.17 (ft)

Tailwater Depth: 1.75 (ft)

If tailwater is unknown, use 0.4D

flow is supercritical

Result Parameters

Tailwater Depth Used in Computations: 1.75 (ft)

Culvert Diameter Used in Computations: 4.085 (ft)

Computed D50: 17.8082 (in)

Hydraulic Analysis Report

Project Data

Project Title: 121088 - Culvert Outlet Check

Designer:

Project Date: Friday, February 08, 2013

Project Units: U.S. Customary Units

Notes:

Riprap Analysis: C-12 - Outlet - Done

Notes:

Input Parameters

Riprap Type: Culvert Outlet Protection

Flow: 122.1 (cfs)

Culvert Diameter: 6 (ft)

Normal Depth in Culvert: 1.81 (ft)

Tailwater Depth: 2.89 (ft)

If tailwater is unknown, use 0.4D

flow is sbcritical

Result Parameters

Tailwater Depth Used in Computations: 2.89 (ft)

Culvert Diameter Used in Computations: 6 (ft)

Computed D50: 4.56103 (in)

Riprap Analysis: C-13 - Outlet - Done

Notes:

Input Parameters

Riprap Type: Culvert Outlet Protection

Flow: 58.2 (cfs)

Culvert Diameter: 4 (ft)

Normal Depth in Culvert: 1.13 (ft)

Tailwater Depth: 1.68 (ft)

If tailwater is unknown, use 0.4D

flow is supercritical

Result Parameters

Tailwater Depth Used in Computations: 1.68 (ft)

Culvert Diameter Used in Computations: 2.565 (ft)

Computed D50: 9.07151 (in)

Ditch Design

Ditch Design Summary

Detailed design of roadside ditch conveyance was performed in conformance with the project scope of work and design was governed by standards outlined in Chapter 7 of the PDDM, in HEC 15 "Design of Roadside Channels with Flexible Linings", and adheres to the following design criteria:

- Roadside ditches will be designed to convey the 10-year flood
- Design roadside ditches stability for the 10-year flood
- Minimum ditch slope is 0.5%. Where practical, provide a desired 1.0% minimum ditch slope
- Ditches steeper than 3% will be designed for erosion control
- Most ditches, unless otherwise noted, are designed as v-ditches with 2H:1V and 1.5H:1V side slopes on either side
- depths of most ditches are 1.25 feet, unless otherwise noted

Ditch sections were investigated and categorized by length, drainage area, and slope. Those ditches over 3% grade automatically required design of a rock lining per project scope. Several ditches with grades less than 3% were also analyzed for erosion protection.

A typical section for the majority of the ditches in the project was designed based on an average-to worst-case scenario of 10-year discharge quantities. Drainage areas were delineated around those ditches that were the longest and with the shallowest slope as those were likely to be the ditches with the largest flow depths. After obtaining Q10 values through a scaled USGS regression analysis, like that done for the culverts, the typical section was modeled in an open channel flow program, AutoCAD Civil 3D Hydraflow Express. This model outputs a flow depth and velocity based on the design geometry and a chosen Manning's n value of 0.035 was used for rock. A v-ditch with 2H:1V and 1.5H:1V side slopes and a depth of 1.25 feet was determined to be adequate for most ditches; however, there are several locations requiring a ditch along the project area (primarily those with slopes less than 1%) that are designated as "special ditches" and will be deeper. See the following table for 10-year water depths.

Ditch Designation	Ditch Slope (ft/ft)	Q10 (cfs)	Velocity (fps)	Water Depth (ft)
C-104W	0.020	5.5	3.3	0.97
C-105	0.005	5.3	2.0	1.24
C-106	0.008	11.0	2.8	1.49
C-107	0.005	6.3	2.1	1.32
C-216E	0.005	16.0	2.6	1.88
C-217	0.005	5.1	2.0	1.22
C-03	0.028	6.1	3.9	0.95
C-315	0.022	6.0	3.5	0.99
C-405	0.017	8.8	3.6	1.19
C-409	0.010	12.1	3.2	1.48
C-414	0.016	5.6	3.1	1.02
C-418	0.008	6.4	2.5	1.22
C-504	0.015	5.5	3.0	1.03

C-517	0.005	5.4	2.0	1.25
C-524	0.008	9.4	2.7	1.41
C-526	0.008	7.0	2.5	1.26
C-601	0.008	8.9	2.7	1.38
C-603	0.008	5.4	2.3	1.15
C-608	0.008	5.1	2.3	1.12
C-614	0.008	7.9	2.6	1.32
C-615	0.008	6.2	2.4	1.21
C-623	0.020	7.3	3.6	1.08
C-1399	0.012	18.7	3.7	1.69

Ditches with slopes less than 3% do not automatically require lining per project scope; however, those ditches that were close to 3% or were of a substantial length were analyzed for the adequacy of a vegetated lining. The ditches in question were modeled using HEC 15 Chapter 4. For those where vegetation was not stable, a d50 was calculated using HEC 15 Chapter 6. See the following table for a summary of the analyzed shallow ditches that require rock lining.

Ditch Designation	Ditch Slope (ft/ft)	Q10 (cfs)	Velocity (fps)	d50 (in)	Vegetated OK?
C-104W	0.020	5.5	3.3	7	No
C-105	0.005	5.3	2.0	N/A	Yes
C-106	0.008	11.0	2.8	4	No
C-107	0.005	6.3	2.1	N/A	Yes
C-216E	0.005	16.0	2.6	N/A	Yes
C-217	0.005	5.1	2.0	N/A	Yes
C-03	0.028	6.1	3.9	5	No
C-315	0.022	6.0	3.5	4	No
C-405	0.017	8.8	3.6	4	No
C-409	0.010	12.1	3.2	5	No
C-414	0.016	5.6	3.1	6	No
C-418	0.008	6.4	2.5	N/A	Yes
C-504	0.015	5.5	3.0	6	No
C-517	0.005	5.4	2.0	N/A	Yes
C-524	0.008	9.4	2.7	4	No
C-526	0.008	7.0	2.5	N/A	Yes
C-601	0.008	8.9	2.7	4	No
C-603	0.008	5.4	2.3	N/A	Yes
C-608	0.008	5.1	2.3	N/A	Yes
C-614	0.008	7.9	2.6	4	No
C-615	0.008	6.2	2.4	N/A	Yes
C-623	0.020	7.3	3.6	1	No
C-1399	0.012	18.7	3.7	7	No

For those ditches over 3% slope a worst-case scenario was investigated. Those ditches were identified by the longest distance between drainage culverts and the steepest slopes. Drainage areas were delineated, and the 10-year discharge was determined through a scaled USGS regression analysis like that done for the culverts. The ditches were modeled in the open channel flow program AutoCAD Civil 3D Hydraflow Express. Flow depths and velocities at the 10-year design event were obtained from the program and then used to determine a minimum stable d50 using HEC 15. The following table displays analysis results for the worst-case scenario ditches over 3% that require rock lining. These all fall under Class III riprap; therefore, all ditches with over a 3% slope will be lined with Class III.

Ditch Designation	Ditch Slope (ft/ft)	Q10 (cfs)	Velocity (fps)	Water Depth (ft)	d50 (in)
FP-01 to C-110	0.058	4.7	4.8	0.75	9
C-118 to FP-02	0.088	6.4	6.0	0.78	11
FP-10 to C-401	0.047	10.6	5.4	1.06	9
C-212 to C-215	0.068	9.8	6.1	0.96	10

Ditches in rock cuts were also considered. The cross-section of the ditches placed in rock cuts are set at 2H:1V and 0.25H:1V side slopes instead of the typical 2H:1V and 1.5H:1V. The steep side of the ditch is within rock, and erosion is not an issue; however, the 2H:1V side slope of the embankment is vulnerable to erosion so lining must be considered. Similar to the analyses of the other ditches, a worst-case scenario was investigated through analyzing the longest ditches with the steepest slopes. The following table displays the results.

Ditch Designation	Ditch Slope (ft/ft)	Q10 (cfs)	Velocity (fps)	Water Depth (ft)	d50 (in)
C-07 to C-501	0.081	3.0	4.7	0.75	11
C-301 to C-303	0.060	17.7	6.7	0.93	13

Channel Report

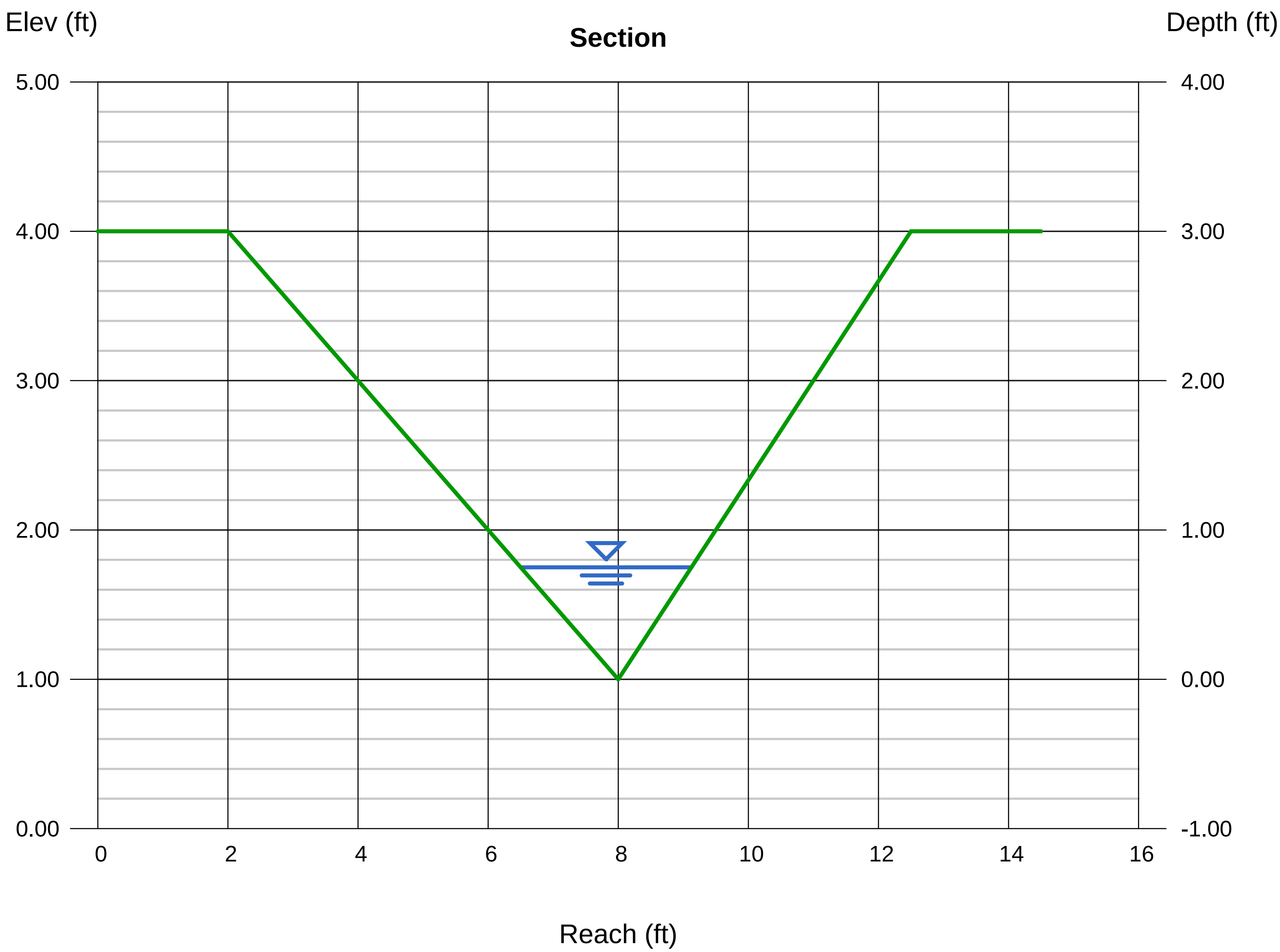
Ditch FP-01 to C-110

Triangular
Side Slopes (z:1) = 2.00, 1.50
Total Depth (ft) = 3.00

Invert Elev (ft) = 1.00
Slope (%) = 5.75
N-Value = 0.035

Calculations
Compute by: Known Q
Known Q (cfs) = 4.70

Highlighted
Depth (ft) = 0.75
Q (cfs) = 4.700
Area (sqft) = 0.98
Velocity (ft/s) = 4.77
Wetted Perim (ft) = 3.03
Crit Depth, Yc (ft) = 0.86
Top Width (ft) = 2.62
EGL (ft) = 1.10



P | N | D
1506 W. 36th Avenue
Anchorage, Alaska 99503
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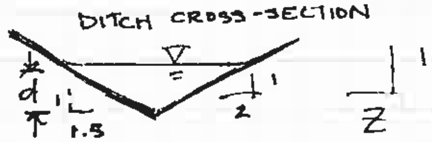
WORST-CASE DITCH LINING RIPRAP SIZE FOR SLOPES GREATER THAN 3%

DITCH BETWEEN FP-01 & DRAINAGE CULVERT C-110



$S = 0.0575$ ft/ft

$Q_{10} = 4.7$ cfs FROM REGRESSION
$V = 4.8$ fps FROM HYDRAFLOW EXPRESS
$d = 0.935$ ft ASSUMED, ITERATIVE
$A = [\frac{1}{2}(2*0.935)(0.935)] + \frac{1}{2}(1.5*0.935*0.935) = \underline{1.53\ ft^2}$
$P = \sqrt{(0.935*2)^2 + 0.935^2} + \sqrt{(0.935*1.5)^2 + 0.935^2} = \underline{3.78\ ft}$
$T = (2*0.935) + (1.5*0.935) = \underline{3.27\ ft}$

— TRIAL $d_{50} = 9" = 0.75$

— $d_a = A/T = 0.468'$
$d_a/d_{50} = 0.624$

— CALCULATING MANNING'S n

$d_a/d_{50} < 1.5 \implies n = \frac{\alpha d_a^{1/6}}{\sqrt{g}\, f(F_r) f(REG) f(CG)}$

$\alpha = 1.49$ (UNIT CONVERSION — CUSTOMARY UNITS)
$g = 32.2\ ft/s^2$ (ACCELERATION DUE TO GRAVITY)

$f(F_r) = \left[\frac{0.28 F_r}{b}\right]^{\log\left(\frac{0.755}{b}\right)} = \underline{0.874}$, $b = 1.14\left(\frac{d_{50}}{T}\right)^{0.453}\left(d_a/d_{50}\right)^{0.814} = \underline{0.399}$

$F_r = V/\sqrt{gd}$ — FROUDE NUMBER $= \underline{0.875}$

$f(REG) = 13.434\left(T/d_{50}\right)^{0.492} b^{1.025(T/d_{50})^{.118}} = \underline{9.04}$
ROUGHNESS ELEMENT GEOMETRY

$f(CG) = \left[T/d_a\right]^{-b} = \underline{0.460}$
CHANNEL GEOMETRY

• $n = \frac{1.49(0.468)^{1/6}}{\sqrt{32.2}\,(0.874)(9.04)(0.460)} = \underline{0.0636}$

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FP-01 TO C-110 CONT.

– CALCULATING Q (MANNING'S EQUATION)

$Q = \frac{\alpha}{n} A R^{2/3} S^{1/2}$ $R = A/P$

$= 1.49/.0620 (1.53)\left(\frac{1.53}{3.78}\right)^{2/3}(0.0575)^{1/2}$

$= \underline{4.70}$ cfs

⇒ Q_{DESIGN} & Q_{CALC} ARE WITHIN 5%
USE $\underline{d = 0.935 \text{ ft}}$

– CALCULATING Re, F*, & SF

$Re = \frac{V_x d_{50}}{\nu}$

$= 8.11 \times 10^4$

= REYNOLD'S NUMBER

$V_x = \sqrt{gdS}$ = SHEAR VELOCITY

$= 1.316$ fps

$\nu = 1.217 \times 10^{-5}$ ft²/s = KINEMATIC VISCOSITY

→ USING TABLE 6.1, $4\times10^4 < Re < 2\times10^5$ ⇒ INTERPOLATE

$F^* = \frac{(8.11\times10^4 - 4\times10^4)(0.15 - 0.047)}{(2\times10^5 - 4\times10^4)} + 0.047 = \underline{0.07}$

= SHIELD'S PARAMETER

$SF = \frac{(8.11\times10^4 - 4\times10^4)(1.5 - 1.0)}{(2\times10^5 - 4\times10^4)} + 1.0 = \underline{1.13}$

= SAFETY FACTOR

– CALCULATING d_{50}

5% < S < 10% CALCULATE FOR S<5% & S>10%, TAKE MAX VALUE

• S<5%

$d_{50} > \frac{SF\,d\,S}{F^*(SG-1)}$, SG = 2.64 FOR RIPRAP

$\geq \frac{1.13\,(0.935)(0.0575)}{(0.07)(2.64-1)}$

$\geq 0.53' = 6.35"$

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FP-D1 TO C-110 CONT.

- S > 10%

$$d_{50} > \frac{SF\ d\ S\ \Delta}{F_*\ (SG-1)}$$

$$\Delta = \frac{K_1(1+\sin(\alpha+\beta))\tan\phi}{2(\cos\theta\tan\phi - SF\sin\theta\cos\beta)}$$ = FUNCTION OF GEOMETRY & RIPRAP SIZE

K_1 = RATIO OF CHANNEL SIDE TO BOTTOM STRESS (EQN 3.4)
= $0.066Z + 0.67$
= 0.802 (USE Z = 2 TO BE CONSERVATIVE

α = ANGLE OF CHANNEL BOTTOM SLOPE
= $\tan^{-1}(0.0575)$
= 3.29°

β = ANGLE BETWEEN WEIGHT VECTOR & WEIGHT / DRAG RESULTANT IN PLANE OF SIDE SLOPE

$$= \tan^{-1}\left[\frac{\cos\alpha}{\frac{2\sin\theta}{\eta\tan\phi}+\sin\alpha}\right]$$

= 23.04° → IN PLANE OF SIDE SLOPE = 90° − 23.04 = 66.76°

θ = ANGLE OF CHANNEL SIDE SLOPE
= $\tan^{-1}\left(\frac{1}{2}\right)$
= 26.57°

ϕ = ANGLE OF REPOSE FOR RIPRAP
= 38°

η = STABILITY NUMBER
= $\tau_s / F_*(\gamma_s - \gamma)\,d_{50}$,
= 0.50

γ_s = SPECIFIC WEIGHT OF STONE
= 165 lb/ft³

γ = SPECIFIC WEIGHT OF WATER
= 62.4 lb/ft³

τ_s = SHEAR STRESS
= $K_1 \gamma d S$
= 2.69 lb/ft²

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FP-01 TO C-110 CONT.

$$\Delta = \frac{0.802(1+\sin(3.29° + 66.96°))\tan 38°}{2(\cos 26.57° \tan 38° - 1.13 \sin 26.57 \cos 66.96°)}$$

$$= 1.216 / 1.002$$

$$= 1.214$$

$$d_{50} > \frac{1.13(0.985)(0.0575)(1.214)}{(0.07)(2.64-1)}$$

$$> 0.64'$$

$$= 7.7''$$ ← MAX

– d_{50} TRIAL < d_{50} CALCULATED ✓

USE $d_{50} = 9''$

Channel Report

Hydraflow Express Extension for AutoCAD® Civil 3D® 2013 by Autodesk, Inc. Friday, Mar 15 2013

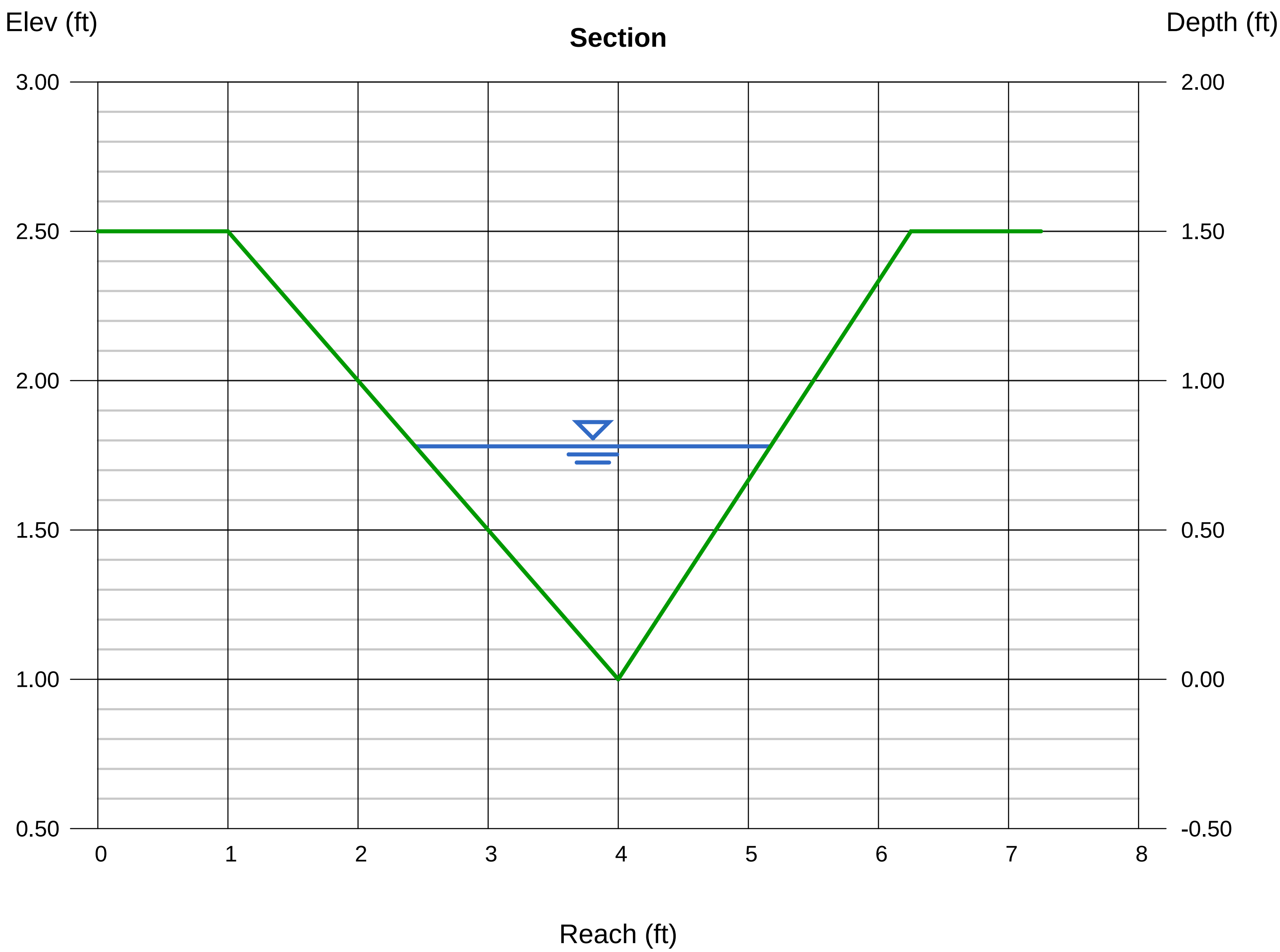
C-118 to FP-02

Triangular
Side Slopes (z:1) = 2.00, 1.50
Total Depth (ft) = 1.50

Invert Elev (ft) = 1.00
Slope (%) = 8.80
N-Value = 0.035

Calculations
Compute by: Known Q
Known Q (cfs) = 6.40

Highlighted
Depth (ft) = 0.78
Q (cfs) = 6.400
Area (sqft) = 1.06
Velocity (ft/s) = 6.01
Wetted Perim (ft) = 3.15
Crit Depth, Yc (ft) = 0.97
Top Width (ft) = 2.73
EGL (ft) = 1.34



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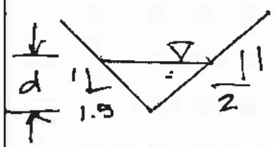
DITCH BETWEEN C-118 & FP-02



$Q_{10} = 6.4\,cfs$
$V = 6.0\,fps$
$d = 0.9771$ feet
$A = \frac{1}{2}(2*0.9771)(0.9771) + \frac{1}{2}(1.5*0.9771)(0.9771) = 1.671\,ft^2$
$P = \sqrt{(0.9771*2)^2 + 0.9771^2} + \sqrt{(0.9771*1.5)^2 + 0.9771^2} = 3.946\,ft$
$T = (2*0.9771) + (1.5*0.9771)$
$= 3.420\,ft$

$S = 8.8\%$

- TRIAL $d_{50} = 11''$
$= 0.917'$

- $d_a = A/T = 0.489$
$d_a/d_{50} = 0.533$

- CALCULATING MANNING'S n

$d_a/d_{50} < 1.5 \Rightarrow n = \dfrac{\alpha\, d_a^{1/6}}{\sqrt{g}\, f(Fr)\, f(REG)\, f(CG)}$

$\alpha = 1.49$, $g = 32.2\,ft/s^2$

$f(Fr) = \left[\dfrac{0.28\,Fr}{b}\right]^{\log\left(\frac{0.755}{b}\right)}$, $b = 1.14\left(\dfrac{d_{50}}{T}\right)^{0.453}\left(\dfrac{d_a}{d_{50}}\right)^{0.814}$
$= 0.933$ $= 0.376$

$Fr = V/\sqrt{gd}$
$= 1.070$

$f(REG) = 13.434\,(T/d_{50})^{.492}\, b^{1.025(T/d_{50})^{.118}}$
$= 7.799$

$f(CG) = [T/d_a]^{-b}$
$= 0.497$

$n = \dfrac{1.49\,(0.489)^{1/6}}{\sqrt{32.2}\,(0.933)(7.799)(0.497)}$
$= 0.0644$

- CALCULATING Q

$Q = \dfrac{\alpha}{n} A R^{2/3} S^{1/2}$
$= \dfrac{1.49}{0.0644}(1.671)\left(\dfrac{1.671}{3.946}\right)^{2/3}(.088)^{1/2}$
$= 6.47\,cfs$

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C-118 TO FP-02 CONT.

⇒ Q_{DESIGN} & Q_{CALC} WITHIN 5%
USE $d = 0.9771'$

– CALCULATING Re, F*, & SF

$Re = V_x d_{50} / \nu$
$= 1.25 \times 10^5$

$V_x = \sqrt{gdS}$
$= 1.664$ fps

⟶ USING TABLE 6.1, $4\times10^4 < Re < 2\times10^5$ ⇒ INTERPOLATE

$$F^* = \frac{(1.25\times10^5 - 4\times10^4)(0.15 - 0.047)}{(2\times10^5 - 4\times10^4)} + .047 = 0.102$$

$$SF = \frac{(1.25\times10^5 - 4\times10^4)(1.5 - 1.0)}{(2\times10^5 - 4\times10^4)} + 1.0 = 1.266$$

– CALCULATING d_{50}

5% < S < 10%

• S < 5%

$$d_{50} > \frac{SF\,d\,S}{F^*(SG-1)}$$
$$> \frac{1.266(0.9771)(0.088)}{0.102\ (2.64-1)}$$
$> 0.65'$
$> 7.8''$

• S > 10%

$$d_{50} > \frac{SF\,d\,S\,\Delta}{F^*(SG-1)}$$

$$\Delta = \frac{K_1\,(1+\sin(\alpha+\beta)\tan\phi}{2(\cos\theta\tan\phi - SF\sin\theta\cos\beta)}$$

$K_1 = 0.066\,Z + 0.67$ USE $Z = 2$
$= 0.802$

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C-118 TO FP-02 CONT.

$\alpha = \tan^{-1}(0.088)$
$= \underline{5.029°}$

$\beta = \tan^{-1}\left[\dfrac{\cos\alpha}{\dfrac{2\sin\theta}{\eta\tan\phi} + \sin\alpha}\right]$

$= 19.53° \longrightarrow 90° - 19.53° = \underline{70.46}°$

$\theta = \tan^{-1}(1/2)$
$= \underline{26.57°}$

$\phi = 38°$

$\eta = \tau_s / F_*(\gamma_s - \gamma) d_{50}$
$= \underline{0.421}$

$\tau_s = K_1 \gamma d S$
$= \underline{4.303\ lb/ft^2}$

$\Delta = \dfrac{0.802\ (1+\sin(5.029 + 70.46)\tan 38°}{2(\cos 26.57° \tan 38° - 1.246 \sin 26.57 \cos 70.46)}$

$= 1.233 / 1.019$
$= 1.2103$

$d_{50} > \dfrac{SF d S \Delta}{F_*(SG-1)}$

$> \dfrac{1.246(0.977)(.088)(1.2103)}{0.102(2.64-1)}$

$> 0.79'$
$> 9.5"$ ← MAX

— d_{50} TRIAL < d_{50} CALCULATED

USE d_{50} = 11"

Channel Report

Hydraflow Express Extension for AutoCAD® Civil 3D® 2013 by Autodesk, Inc. Friday, Mar 15 2013

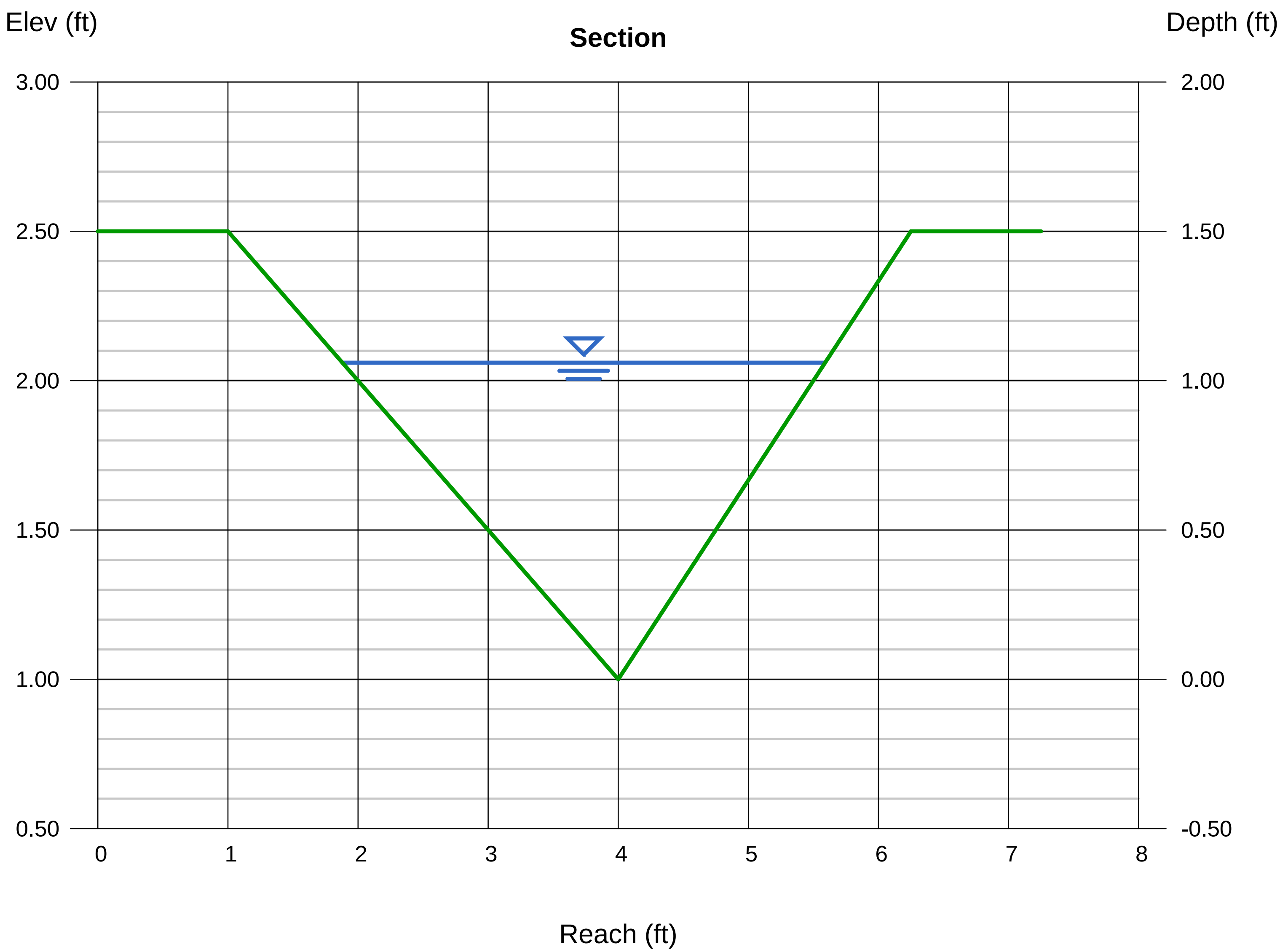
FP-10 to C-401

Triangular
Side Slopes (z:1) = 2.00, 1.50
Total Depth (ft) = 1.50

Invert Elev (ft) = 1.00
Slope (%) = 4.70
N-Value = 0.035

Calculations
Compute by: Known Q
Known Q (cfs) = 10.60

Highlighted
Depth (ft) = 1.06
Q (cfs) = 10.60
Area (sqft) = 1.97
Velocity (ft/s) = 5.39
Wetted Perim (ft) = 4.28
Crit Depth, Yc (ft) = 1.18
Top Width (ft) = 3.71
EGL (ft) = 1.51



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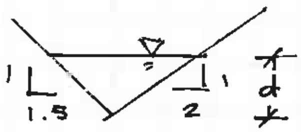
Project: 121088 DITCH DESIGN
Sheet Number: 8 Of: 20
Calculated by: AEW Date: 3/19/13
Checked by: Date:

DITCH BETWEEN FP-10 to C-401



Q_{10} = 10.6 cfs
V = 5.4 fps
d = ~~1.2428'~~ 1.2699'
A = ½(2 * ~~1.2428~~)(~~1.2428~~) + ½(1.5 * ~~1.2428~~)(~~1.2428~~) = ~~2.703 ft²~~ 2.822 ft²
P = $\sqrt{(1.2428 * 2)^2 + 1.2428^2}$ + $\sqrt{(1.2428 * 1.5)^2 + 1.2428^2}$ = ~~5.019 ft~~ 5.128 ft
T = (2 * ~~1.2428~~) + (1.5 * ~~1.2428~~) = ~~4.350 ft~~ 4.445 ft

S = 0.047 ft/ft

- TRIAL d_{50} = ~~8"~~, 9"
= ~~0.67'~~ 0.75'

- d_a = A/T = ~~0.621'~~ 0.635
d_a/d_{50} = ~~0.927~~ 0.847

- CALCULATING MANNINGS n

$d_a/d_{50} < 1.5 \Rightarrow n = \alpha d_a^{1/6} / \sqrt{g} \, f(Fr) f(REG) f(CG)$

α = 1.49, g = 32.2 ft/s²

$f(F_r) = \left[\frac{0.28 Fr}{b}\right]^{\log(0.755/b)}$
= ~~0.868~~ 0.865

$b = 1.14 (d_{50}/T)^{0.453} (d_a/d_{50})^{0.814}$
= ~~0.459~~ 0.445

$F_r = V/\sqrt{gd}$
= ~~0.854~~ 0.844

$f(REG) = 13.434 (T/d_{50})^{.492} b^{1.025 (T/d_{50})^{.118}}$
= ~~12.464~~ 11.582

$f(CG) = [T/d_a]^{-b}$
= ~~0.409~~ 0.421

- $n = 1.49 (0.621)^{1/6} / \sqrt{32.2} (0.868)(12.464)(0.409)$
= ~~0.0548~~ 0.0577

- CALCULATING Q

$Q = \alpha/n \, A R^{2/3} S^{1/2}$
= 1.49/~~0.055~~ (~~2.703~~)(~~2.703/5.019~~)$^{2/3}$ (~~0.047~~)$^{1/2}$
= ~~10.54 cfs~~
10.61 cfs ✓

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Project: 121088 DITCH DESIGN
Sheet Number: 9 Of: 20
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Checked by: Date:

FP-10 to C-401 CONT.

⟹ Q_{DESIGN} & Q_{CALC} ARE WITHIN 5% ✓

USE $d =$ ~~1.2428~~ 1.2699'

— CALCULATING Re, F*, & SF

$Re = V_x d_{50} / \nu$

$=$ ~~7.55×10^4~~ 8.5×10^5

$V_x = \sqrt{gdS}$

$=$ ~~1.37~~ fps 1.39 fps

→ USING TABLE 6.1, $4 \times 10^4 < Re < 2 \times 10^5$ ⟹ INTERPOLATE

$F^* = \frac{(7.55 \times 10^4 - 4 \times 10^4)(0.15 - 0.047)}{(2 \times 10^5 - 4 \times 10^4)} + 0.047 =$ ~~0.0648~~ 0.0760

$SF = \frac{(7.55 \times 10^4 - 4 \times 10^4)(1.5 - 1.0)}{(2 \times 10^5 - 4 \times 10^4)} + 1.0 =$ ~~1.111~~ 1.141

— CALCULATING d_{50}

$5\% < S < 10\%$

• $S < 5\%$

$d_{50} > \frac{SF\,d\,S}{F^*(SG-1)}$

$> \frac{1.111\,(1.2428)(0.047)}{(0.0648)(2.64-1)}$

$>$ ~~0.567'~~ 0.546'

$>$ ~~6.8"~~ 6.6"

• $S > 10\%$

$d_{50} > \frac{SF\,d\,S\,\Delta}{F^*(SG-1)}$

$\Delta = \frac{K_1(1+\sin(\alpha+\beta))\tan\phi}{2(\cos\theta\tan\phi - SF\sin\theta\cos\beta)}$

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FP-10 to C-401 CONT.

$K_1 = 0.066 Z + 0.067$ (USE $Z=2$)
$= 0.802$

$\alpha = \tan^{-1}(0.047)$
$= 2.69°$

$\beta = \tan^{-1}\left[\frac{\cos\alpha}{\frac{2\sin\theta}{\eta\tan\phi} + \sin\alpha}\right]$

$=$ ~~27.41°~~ 23.58° ⟶ $90° -$ ~~27.41°~~ 23.58° $=$ ~~62.59°~~ 66.42°

$\theta = \tan^{-1}(1/2)$
$= 26.57°$

$\phi = 38°$

$\eta = \tau_s / F_*(\gamma_s - \gamma) d_{50}$
$=$ ~~0.609~~ 0.511

$\tau_s = K_1 \gamma d S$
$=$ ~~2.92~~ lb/ft^2 2.987 lb/ft^2

$\Delta = \frac{0.802 (1 + \sin(2.69° + 62.59°)) \tan 38°}{2 (\cos 26.57° \tan 38° - 1.111 \sin 26.57 \cos 62.59°)}$

$=$ ~~1.196 / 0.940~~ 1.212 / 0.989
$=$ ~~1.272~~ 1.225

$d_{50} > \frac{\text{~~1.111~~ 1.141} (\text{~~1.24129~~ 1.2699})(0.047)(\text{~~1.272~~ 1.225})}{(\text{~~0.0498~~ 0.0766})(2.64 - 1)}$

$>$ ~~0.721'~~ 0.669'
$>$ ~~8.7"~~ 8.03" ⟵ MAX

– d_{50} TRIAL ≠ d_{50} CALCULATED → TRY $d_{50} = 9"$ ✓

USE $d_{50} = 9"$ ✓

Channel Report

C-212 to C-215

Triangular

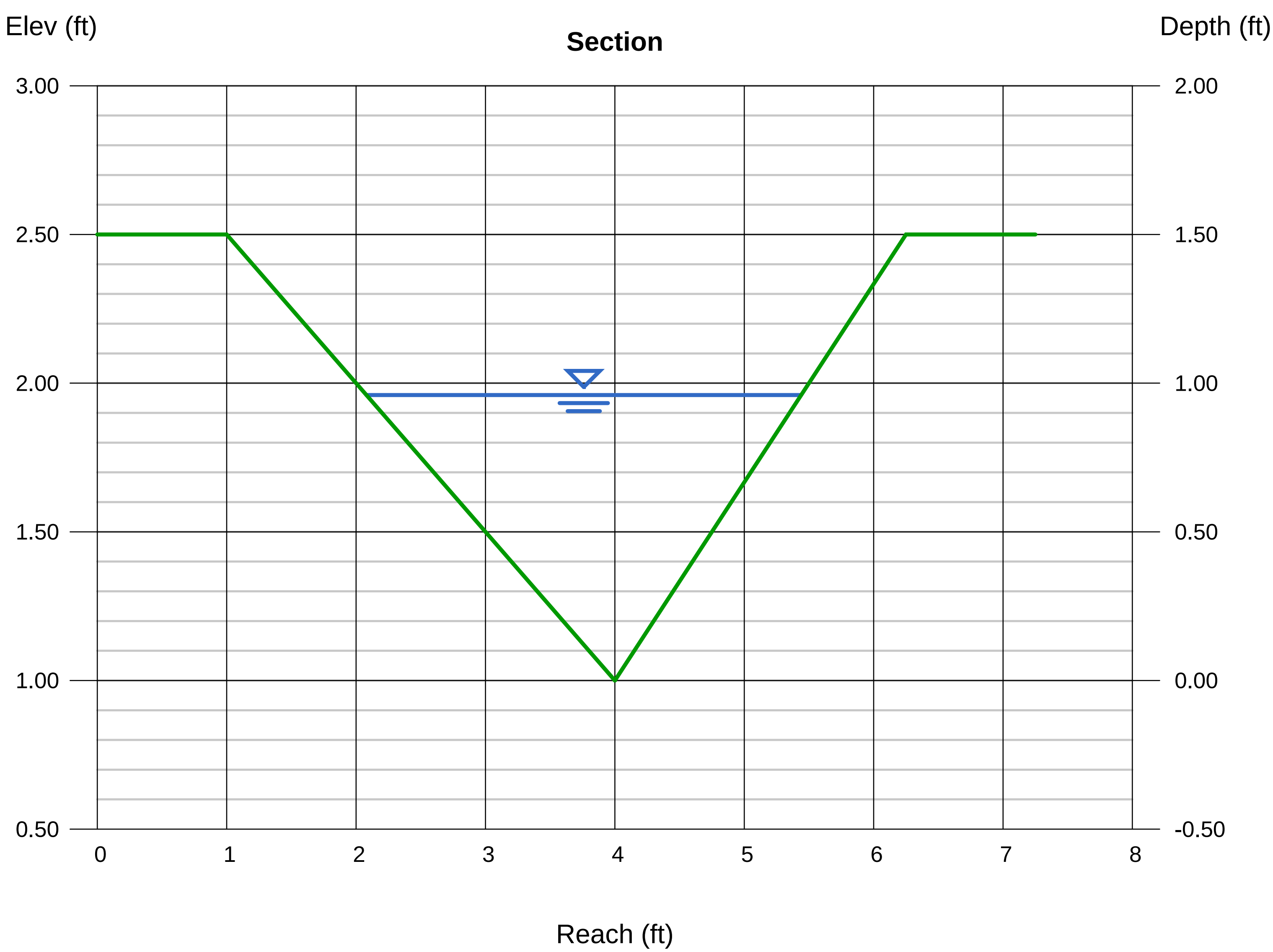
Side Slopes (z:1)	= 2.00, 1.50
Total Depth (ft)	= 1.50
Invert Elev (ft)	= 1.00
Slope (%)	= 6.80
N-Value	= 0.035

Calculations

Compute by:	Known Q
Known Q (cfs)	= 9.80

Highlighted

Depth (ft)	= 0.96
Q (cfs)	= 9.800
Area (sqft)	= 1.61
Velocity (ft/s)	= 6.08
Wetted Perim (ft)	= 3.88
Crit Depth, Yc (ft)	= 1.15
Top Width (ft)	= 3.36
EGL (ft)	= 1.53



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Project: 121088 DITCH DESIGN
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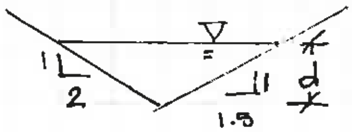
DITCH BETWEEN C-212 & C-215



$Q_{10} = 9.8$ cfs

$V = 6.1$ fps

$d =$ ~~1.1203'~~ 1.1477'

$A = \frac{1}{2}(2 * $ ~~1.1203~~ $)($~~1.1203~~$) + \frac{1}{2}(1.5 * $ ~~1.1203~~ $)($~~1.1203~~$) =$ ~~2.196 ft²~~ 2.305 ft²

$P = \sqrt{(\text{~~1.1203~~} * 2)^2 + \text{~~1.1203~~}^2} + \sqrt{(\text{~~1.1203~~} * 1.5)^2 + \text{~~1.1203~~}^2} =$ ~~4.629 ft~~ 4.635 ft

$T = (2 * $ ~~1.1203~~ $) + (1.5 * $ ~~1.1203~~ $)$
= ~~3.921 ft~~ 4.017 ft

$S = 0.068$ ft/ft

— TRIAL $d_{50} =$ ~~9"~~ 10"
= ~~0.75~~ 0.83

— $d_a = A/T =$ ~~0.560'~~ 0.574
$d_a/d_{50} =$ ~~0.747~~ 0.692

— CALCULATING MANNINGS n

$$d_a/d_{50} < 1.5 \Rightarrow n = \frac{\alpha d_a^{1/6}}{\sqrt{g}\, f(F_r) f(REG) f(CG)}$$

$\alpha = 1.49$

$g = 32.2$ ft²/s²

$$f(F_r) = \left[\frac{0.28 F_r}{b}\right]^{\log(0.755/b)}$$
= ~~0.905~~ 0.904

$$b = 1.14\left(\frac{d_{50}}{T}\right)^{0.453}\left(\frac{d_a}{d_{50}}\right)^{0.814}$$
= ~~0.425~~ 0.413

$$F_r = V/\sqrt{gd}$$
= ~~1.016~~ 1.003

$$f(REG) = 13.434\left(\frac{T}{d_{50}}\right)^{0.492} b^{1.025 (T/d_{50})^{0.118}}$$
= ~~10.438~~ 9.795

$$f(CG) = \left[T/d_a\right]^{-b}$$
= ~~0.437~~ 0.448

$$n = \frac{1.49(\text{~~0.560~~ } .574)^{1/6}}{\sqrt{32.2}\,(\text{~~0.905~~})(\text{~~10.438~~})(\text{~~0.437~~})}$$
= ~~0.0579~~
0.0603

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C-212 TO C-215 CONT.

– CALCULATING Q

$$Q = \frac{\alpha}{n} A R^{2/3} S^{1/2}$$

$$= 1.49/.058\ (2.196)\left(\frac{2.196}{4.629}\right)^{2/3}(0.068)^{1/2}$$

$= \sout{9.1}$ cfs
9.32 cfs

⇒ Q_{design} & Q_{calc} ARE WITHIN ~5%
USE $d = \sout{1.12'}$
1.1477

– CALCULATING Re, F*, & SF

$Re = V_x d_{50}/\nu$
$= \sout{9.65 \times 10^4}$
1.08×10^5

$V_x = \sqrt{g d S}$
$= \sout{1.566}$ fps
1.585

→ USING TABLE 6.1, $4\times10^4 < Re < 2\times10^5$ ⇒ INTERPOLATE

$$F^* = \frac{(9.65\times10^4 - 4\times10^4)(0.15-0.047)}{(2\times10^5 - 4\times10^4)} + 0.047 = \sout{0.08}\quad 0.09$$

$$SF = \frac{(9.65\times10^4 - 4\times10^4)(1.5-1.0)}{(2\times10^5 - 4\times10^4)} + 1.0 = \sout{1.18}\quad 1.21$$

– CALCULATING d_{50}

$5\% < S < 10\%$

• $S < 5\%$

$$d_{50} > \frac{SF\, d\, S}{F^*(S_G - 1)}$$

$$> \frac{1.18\ (1.1203)(.068)}{0.08\ (2.64-1)}$$

$> \sout{0.68'}$ 0.64'

$= \sout{8.2''}$ = 7.7"

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C-212 to C-215 CONT.

• S > 10%

$d_{50} > \frac{SF\, d\, S\, \Delta}{F^* (SG-1)}$

$\Delta = \frac{K_1 (1+\sin(\alpha+\beta))\tan\phi}{2(\cos\theta\tan\phi - SF\sin\theta\cos\beta)}$

$K_1 = 0.066Z + 0.67$ use $Z = 2$

$= \underline{0.802}$

$\alpha = \tan^{-1}(0.068)$

$= \underline{3.89°}$

$\beta = \tan^{-1}\left[\frac{\cos\alpha}{\frac{2\sin\theta}{\eta\tan\phi} + \sin\alpha}\right]$

$=$ ~~27.50°~~ 23.32° → 90° − 27.50° = ~~62.50°~~ 66.68°

$\theta = \tan^{-1}\left(\frac{1}{2}\right)$

$= \underline{26.57°}$

$\phi = \underline{38°}$

$\eta = \tau_s / F_* (\gamma_s - \gamma)\, d_{50}$

$=$ ~~0.619~~ 0.510

$\tau_s = K_1 \gamma d S$

$=$ ~~3.812~~ lb/ft² 3.906 lb/ft²

$\Delta = \frac{0.802(1+\sin(3.89° + 62.50°))\tan 38°}{2(\cos 26.57° \tan 38° - 1.18 \sin 26.57 \cos(62.50°))}$

$=$ 1.20 / 0.91 1.217 / 0.969

$=$ ~~1.32~~ 1.256

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Checked by: Date:

C-212 to C-215 CONT.

$$d_{50} > \frac{SF\, d\, S\, \Delta}{F^*(SG-1)}$$

$$> \frac{~~1.18~~\ 1.21\ (~~1.1203~~\ 1.1477)(0.068)(~~1.32~~\ 1.254)}{~~0.05~~\ 0.07\ (2.64-1)}$$

$> ~~0.9'~~\ 0.80'$

$= ~~10.85''~~$ ← MAX

9.64"

— d_{50} TRIAL $\neq$ d_{50} CALCULATED → TRY $d_{50} = 10''$ $= 0.83'$

USE $d_{50} = 10''$ ✓

Channel Report

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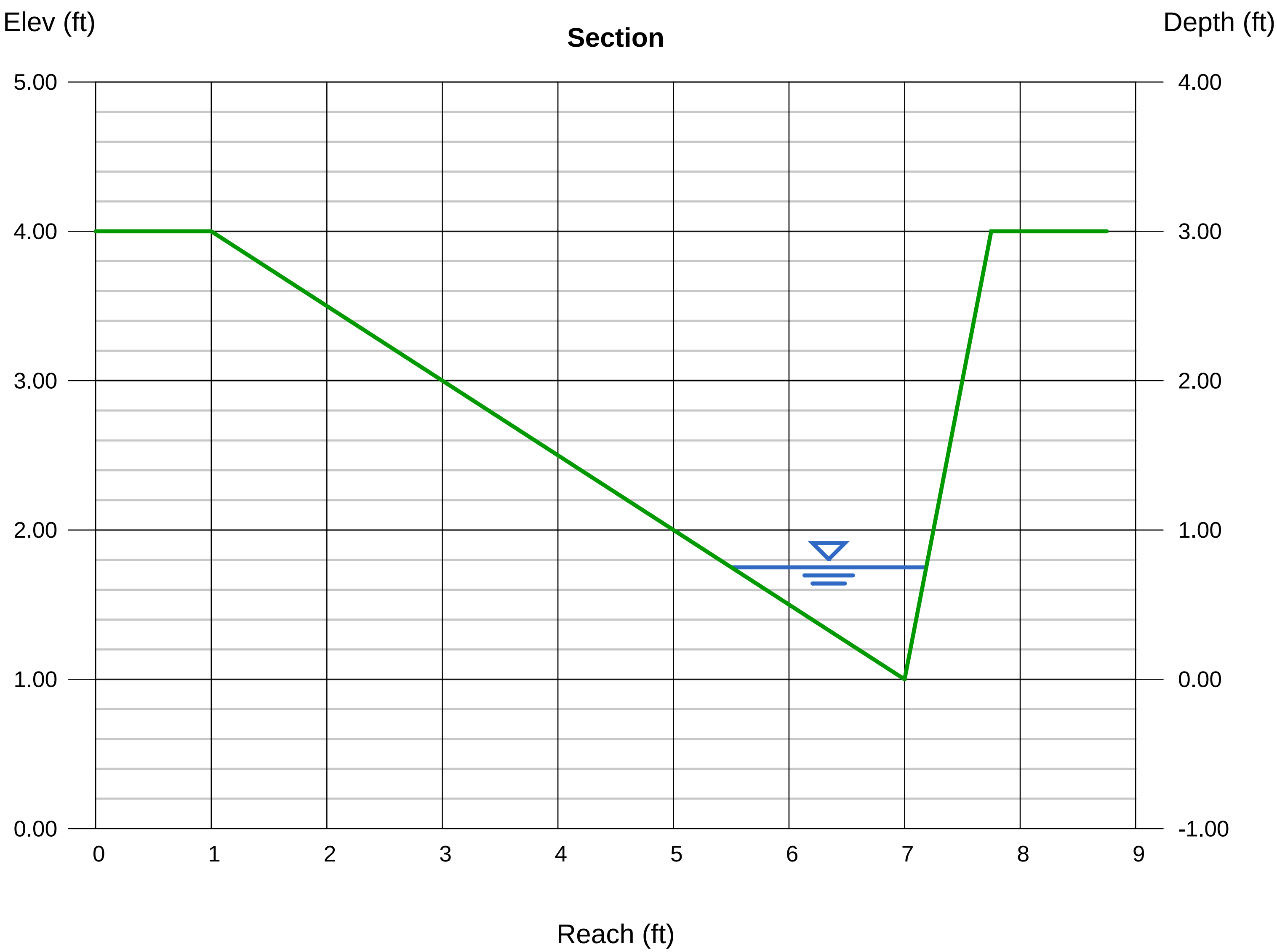
C-07 to C-501

Triangular
Side Slopes (z:1) = 2.00, 0.25
Total Depth (ft) = 3.00

Invert Elev (ft) = 1.00
Slope (%) = 8.10
N-Value = 0.035

Calculations
Compute by: Known Q
Known Q (cfs) = 3.00

Highlighted
Depth (ft) = 0.75
Q (cfs) = 3.000
Area (sqft) = 0.63
Velocity (ft/s) = 4.74
Wetted Perim (ft) = 2.45
Crit Depth, Yc (ft) = 0.85
Top Width (ft) = 1.69
EGL (ft) = 1.10



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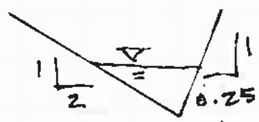
DITCH BETWEEN C-07 & C-501 — IN ROCK CUT



$S = 0.081$ ft/ft

$Q_{10} = 3$ cfs
$V = 4.74$ fps
$d = 0.9101$
$A = \frac{1}{2}(2*0.9101)(0.9101) + \frac{1}{2}(0.25*0.9101)(0.9101) = 0.932\,ft^2$
$P = \sqrt{(2*.9101)^2 + .9101^2} + \sqrt{(0.25*.9101)^2 + .9101^2} = 2.973\,ft$
$T = (2*.9101) + (0.25*.9101) = 2.0477\,ft$

– TRIAL $d_{50} = 11''$ $= 0.917$

– $d_a = A/T = 0.455$ ft
$d_a/d_{50} = 0.496$

– CALCULATING MANNING'S n

$d_a/d_{50} < 1.5 \Rightarrow n = \frac{\alpha d_a^{1/6}}{\sqrt{g}\, f(F_r) f(REG) f(CG)}$

$\alpha = 1.49, \quad g = 32.2\ ft/s^2$

$f(F_r) = \left[\frac{0.28 F_r}{b}\right]^{\log(.755/b)} = 0.872$, $\quad b = 1.14\left(\frac{d_{50}}{T}\right)^{0.453}\left(\frac{d_a}{d_{50}}\right)^{0.814} = 0.448$

$F_r = V/\sqrt{gd} = 0.8756$

$f(REG) = 13.434(T/d_{50})^{.492}\, b^{1.025(T/d_{50})^{.118}} = 8.070$

$f(CG) = [T/d_a]^{-b} = 0.510$

• $n = \frac{1.49(.455)^{1/6}}{\sqrt{32.2}\,(.872)(8.070)(.510)} = 0.0642$

– CALCULATING Q

$Q = \frac{\alpha}{n} A R^{2/3} S^{1/2}$
$= \frac{1.49}{.064}(0.932)\left(\frac{0.932}{2.973}\right)^{2/3}(0.081)^{1/2}$
$= 2.84$ cfs

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C-07 to C-501 CONT.

⇒ Q_{DESIGN} & Q_{CALC} WITHIN ~ 5%
USE d = 0.9101'

— CALCULATING Re, F*, & SF

$Re = V_x d_{50} / \nu$
$= 1.16 \times 10^5$

$V_x = \sqrt{gdS}$
$= 1.541$ fps

→ USING TABLE 6.1, $4\times10^4 < Re < 2\times10^5$ ⇒ INTERPOLATE

$$F^* = \frac{(1.16\times10^5 - 4\times10^4)(0.15 - 0.047)}{(2\times10^5 - 4\times10^4)} + 0.047 = 0.096$$

$$SF = \frac{(1.16\times10^5 - 4\times10^4)(1.5 - 1.0)}{(2\times10^5 - 4\times10^4)} + 1.0 = 1.237$$

— CALCULATING d_{50}

5% < S < 10%

- S < 5%

$$d_{50} > \frac{SF\, d\, S}{F^*(SG-1)}$$
$$> \frac{1.237(0.9101)(.081)}{(0.096)(2.64-1)}$$
$$> 0.58'$$
$$> 7''$$

- S > 10%

$$d_{50} > \frac{SF\, d\, S\, \Delta}{F^*(SG-1)}$$

$$\Delta = \frac{K_1 (1 + \sin(\alpha+\beta)\tan\phi)}{2(\cos\theta \tan\phi - SF \sin\theta \cos\beta)}$$

$K_1 = 0.066 Z + 0.67$ USE Z = 2
$= 0.802$

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C-07 to C-501 CONT.

$\alpha = \tan^{-1}(0.081)$
$= \underline{4.63^\circ}$

$\beta = \tan^{-1}\left[\dfrac{\cos\alpha}{\dfrac{2\sin\theta}{\eta\tan\phi} + \sin\alpha}\right]$

$= 19.07^\circ \longrightarrow 90^\circ - 19.07^\circ = \underline{70.93^\circ}$

$\theta = \tan^{-1}(1/2)$, LOOK AT $Z=2$ SIDE SLOPE,
$= \underline{26.57^\circ}$ OTHER SIDE IS IN ROCK & STABLE

$\phi = 38^\circ$

$\eta = \dfrac{\tau_s}{F_* (\gamma_s - \gamma) d_{50}}$
$= \underline{0.408}$

$\tau_s = K_1 \gamma d S$
$= \underline{3.689}\ \text{lb/ft}^2$

$\Delta = \dfrac{0.802\,(1 + \sin(4.63^\circ + 70.93^\circ)\tan 38^\circ)}{2\,(\cos 26.57^\circ \tan 38^\circ - 1.237 \sin 26.57^\circ \cos 70.93^\circ)}$

$= \dfrac{1.233}{1.036}$
$= \underline{1.19}$

- $d_{50} > \dfrac{SF\, d\, S\, \Delta}{F^* (SG-1)}$

$> \dfrac{1.237\,(0.9101)(.081)(1.19)}{.096\,(2.64-1)}$

$> 0.69'$
$> \underline{8.27''}$ ← MAX

- d_{50} TRIAL < d_{50} CALCULATED

<u>USE $d_{50} = 11''$</u>

Channel Report

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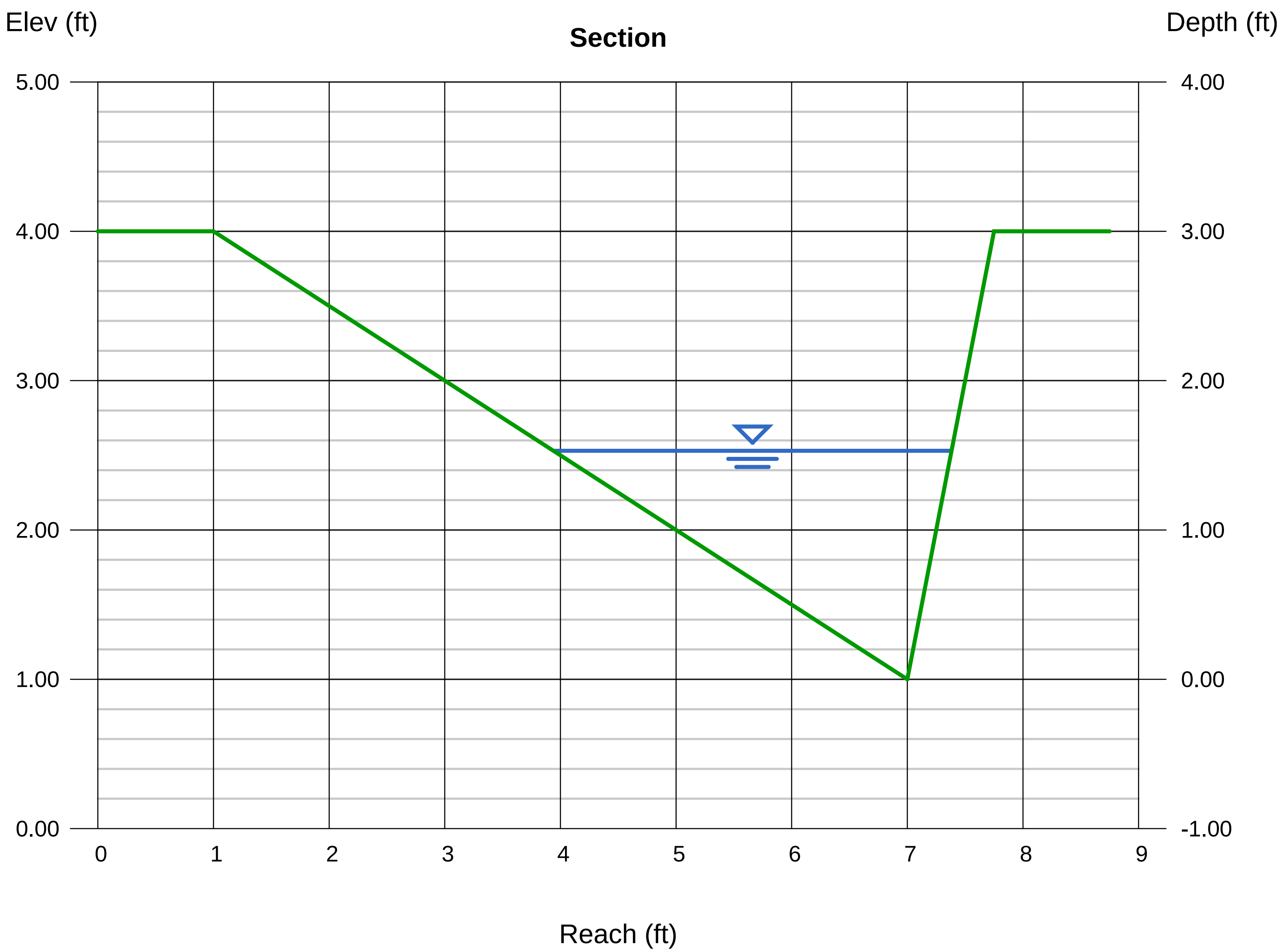
C-301 to C-303

Triangular
Side Slopes (z:1) = 2.00, 0.25
Total Depth (ft) = 3.00

Invert Elev (ft) = 1.00
Slope (%) = 6.00
N-Value = 0.035

Calculations
Compute by: Known Q
Known Q (cfs) = 17.70

Highlighted
Depth (ft) = 1.53
Q (cfs) = 17.70
Area (sqft) = 2.63
Velocity (ft/s) = 6.72
Wetted Perim (ft) = 5.00
Crit Depth, Yc (ft) = 1.73
Top Width (ft) = 3.44
EGL (ft) = 2.23



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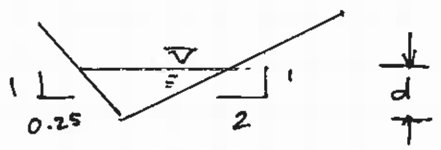
Project: 121088 DITCH DESIGN
Sheet Number: 18 Of: 20
Calculated by: AEW Date: 3/19/13
Checked by: Date:

DITCH BETWEEN C-301 to C-303 IN ROCK CUT



$S = 0.060$

$Q_{10} = 17.7$ cfs
$V = 6.7$ fps
$d = 1.7507$
$A = \frac{1}{2}(2 * 1.7507)(1.7507) + \frac{1}{2}(0.25 * 1.7507)(1.7507) = 3.448 \text{ ft}^2$
$P = \sqrt{(1.7507 * 2)^2 + 1.7507^2} + \sqrt{(1.7507 * 0.25)^2 + 1.7507^2} = 5.719 \text{ ft}$
$T = (2 * 1.7507) + (0.25 * 1.7507)$
$= 3.939 \text{ ft}$

– TRIAL $d_{50} = 13"$
$= 1.083'$

– $d_a = A/T = 0.875$
$d_a/d_{50} = 0.808$

– CALCULATING MANNING'S n

$d_a/d_{50} < 1.5 \implies n = \alpha d_a^{1/6} / \sqrt{g} f(Fr) f(REG) f(CG)$

$\alpha = 1.49, \quad g = 32.2 \text{ ft/s}^2$

$f(F_r) = \left[\frac{0.28 Fr}{b}\right]^{\log(0.755/b)}, \quad b = 1.14 (d_{50}/T)^{.453} (d_a/d_{50})^{.814}$
$= 0.892$ $\qquad = 0.334$

$F_r = V/\sqrt{gd}$
$= 0.892$

$f(REG) = 13.434 (T/d_{50})^{.492} \, b^{1.025(T/d_{50})^{.118}}$
$= 11.991$

$f(CG) = [T/d_a]^{-b}$
$= 0.448$

• $n = \dfrac{1.49(0.875)^{1/6}}{\sqrt{32.2}(0.892)(11.991)(0.448)}$
$= 0.0536$

– CALCULATING Q

$Q = \alpha/n \, A R^{2/3} S^{1/2}$
$= 1.49/0.0536 \, (3.448) \left(\frac{3.448}{5.719}\right)^{2/3} (0.060)^{1/2}$
$= 16.8$ cfs

C-301 to C-303 CONT.

⇒ Q_{DESIGN} & Q_{CALC} ARE W/IN 5%
USE $d = 1.7507'$

— CALCULATING Re, F*, & SF

$Re = V_x d_{50} / \nu$
$= 1.63 \times 10^5$

$V_x = \sqrt{g d S}$
$= 1.839$ fps

→ USING TABLE 6.1, $4 \times 10^4 < Re < 2 \times 10^5$ ⇒ INTERPOLATE

$$F^* = \frac{(1.63 \times 10^5 - 4 \times 10^4)(0.15 - 0.047)}{(2 \times 10^5 - 4 \times 10^4)} + 0.047 = 0.126$$

$$SF = \frac{(1.63 \times 10^5 - 4 \times 10^4)(1.5 - 1.0)}{(2 \times 10^5 - 4 \times 10^4)} + 1.0 = 1.384$$

— CALCULATING d_{50}

$5\% < S < 10\%$

- $S < 5\%$

$$d_{50} > \frac{SF\, d\, S}{F^* (SG - 1)}$$

$$> \frac{1.384(1.7507)(0.06)}{(0.126)(2.64 - 1)}$$

$> 0.703'$
$> 8.44''$

- $S > 10\%$

$$d_{50} > \frac{SF\, d\, S\, \Delta}{F^* (SG - 1)}$$

$$\Delta = \frac{K_1 (1 + \sin(\alpha + \beta)) \tan\phi}{2(\cos\theta \tan\phi - SF \sin\theta \cos\beta)}$$

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C-301 to C-303 CONT.

$K_1 = 0.066Z + 0.067$ (USE $Z = 2$)
$= \underline{0.802}$

$\alpha = \tan^{-1}(0.06)$
$= \underline{3.43°}$

$\beta = \tan^{-1}\left[\dfrac{\cos\alpha}{\dfrac{2\sin\theta}{\eta\tan\phi} + \sin\alpha}\right]$

$= 17.80° \longrightarrow 90° - 17.80° = \underline{72.20°}$

$\theta = \tan^{-1}(1/2)$
$= \underline{26.57°}$

$\phi = \underline{38°}$

$\eta = \tau_s / F^*(\gamma_s - \gamma)d_{50}$
$= \underline{0.375}$

$\tau_s = K_1 \gamma d S$
$= \underline{5.257}$ lb/ft²

$\Delta = \dfrac{0.802\,(1 + \sin(3.43° + 72.20°))\tan 38°}{2(\cos 26.57° \tan 38° - 1.384 \sin 26.57 \cos 72.20)}$

$= 1.234 / 1.019$
$= \underline{1.211}$

$d_{50} > \dfrac{1.384\,(1.7507)(0.060)(1.211)}{0.126\,(2.64 - 1)}$

$> 0.85'$
$> \underline{10.22''}$ ← MAX

— d_{50} TRIAL < d_{50} CALCULATED

USE $d_{50} = 13''$

Ditch Relief Culvert Design

Small Non-Fish Culvert Design Summary

Small non-fish culverts are spaced throughout the project discharging flow from ditches into natural drainage paths. These ditch relief culverts were designed in conformance with the design standards outlined in Chapter 7 of the PDDM and the requirements outlined under HDS 5.

- Design all culverts for a 50-year service life
- Design all culverts to convey the 25-year flood
- Culverts 100 feet or shorter shall be a minimum 24 inches diameter
- Culverts longer than 100 feet shall be a minimum 36 inches diameter
- Ditch relief culverts are to be installed at a minimum 3% grade
- Culvert spacing should not exceed 500 feet

Hydraulic performance for the ditch relief culverts is not seen as an issue. The majority of these culverts are 24 inches in diameter, and all are smaller than 48 inches in diameter. All minor culverts are corrugated HDPE pipe. Hydraulics for these culverts was performed in FHWA's HY-8 program. Multiple culverts with the largest flowrates and shallow slopes were analyzed and seen as a worst-case scenario for hydraulic capacity. They all passed the design 25-year flood event.

Outlet protection requirements were also investigated. A rock apron was designed for any culvert with an outlet velocity greater than 6 feet per second. A conservative design flow was used with varying culvert slopes in the HY-8 program to obtain outlet velocities. These velocities and estimated tailwater depths were used in accordance with HEC 14 to size the outlet protection. The dimensions of the rock apron are a function of the culvert diameter. The apron is designed to be 3 times the diameter of the culvert at the outlet, a length of 4 times the diameter, and tapering out at 3:1 along its length. The size of the rock to be used at any culvert requiring an apron is to be Class 1 riprap. See attached calculations, and the design plans for which culverts require outlet protection

RIPRAP APRON CALCULATION
HEC 14

L_B min = $4W_o$ = 4(6) = 24 ft, use L_B = 24 ft

$W_B = W_o + 2(L_B/3) = 6 + 2(24/3) = 22$ ft

However, since the trial D_{50} is not available, the next larger riprap size (D_{50} = 0.83 ft) would be used to line a basin with the given dimensions.

Step 4 (3rd iteration). Determine the basin exit depth, $y_B = y_c$ and exit velocity, $V_B = V_c$.

$Q^2/g = (A_c)^3/T_c = [y_c(W_B + zy_c)]^3/ (W_B + 2zy_c)$

$135^2/32.2 = 566 = [y_c(22 + 2y_c)]^3/ (22 + 4y_c)$

By trial and success, y_c = 1.02 ft, T_c =26.1 ft, A_c = 24.5 ft^2

$V_c = Q/A_c$ = 135/24.5 = 5.5 ft/s (acceptable)

Two feasible options have been identified. First, a 2.3-ft-deep, 23-ft-long pool, with an 11.5-ft-apron using D_{50} = 0.5 ft. Second, a 1.4-ft-deep, 18-ft-long pool, with a 6-ft-apron using D_{50} = 0.83 ft. The choice between these two options will likely depend on the available space and the cost of riprap.

Step 5. For the design discharge, determine if $TW/y_o \leq 0.75$

TW/y_o = 2.0/2.7 = 0.74, which satisfies $TW/y_o \leq 0.75$. No additional riprap needed.

10.2 RIPRAP APRON

The most commonly used device for outlet protection, primarily for culverts 1500 mm (60 in) or smaller, is a riprap apron. An example schematic of an apron taken from the Federal Lands Division of the Federal Highway Administration is shown in Figure 10.4.

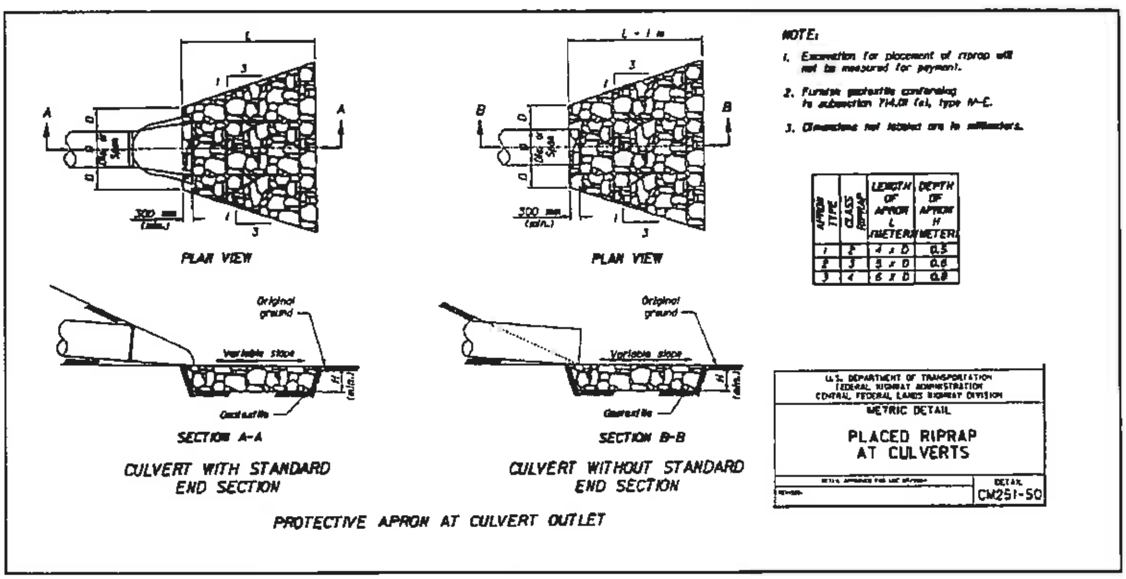

Figure 10.4. Placed Riprap at Culverts (Central Federal Lands Highway Division)

They are constructed of riprap or grouted riprap at a zero grade for a distance that is often related to the outlet pipe diameter. These aprons do not dissipate significant energy except through increased roughness for a short distance. However, they do serve to spread the flow helping to transition to the natural drainage way or to sheet flow where no natural drainage way exists. However, if they are too short, or otherwise ineffective, they simply move the location of potential erosion downstream. The key design elements of the riprap apron are the riprap size as well as the length, width, and depth of the apron.

Several relationships have been proposed for riprap sizing for culvert aprons and several of these are discussed in greater detail in Appendix D. The independent variables in these relationships include one or more of the following variables: outlet velocity, rock specific gravity, pipe dimension (e.g. diameter), outlet Froude number, and tailwater. The following equation (Fletcher and Grace, 1972) is recommended for circular culverts:

$$D_{50} = 0.2\,D\left(\frac{Q}{\sqrt{g}D^{2.5}}\right)^{4/3}\left(\frac{D}{TW}\right) \quad (10.4)$$

$$= 0.2(2')\left(\frac{17.7\ cfs}{\sqrt{32.2}\ 2^{2.5}}\right)^{4/3}\left[\frac{2}{0.4(2)}\right]$$

where,

D_{50} = riprap size, m (ft)

Q = design discharge, m^3/s (ft^3/s)

D = culvert diameter (circular), m (ft)

TW = tailwater depth, m (ft)

g = acceleration due to gravity, 9.81 m/s^2 (32.2 ft/s^2)

D_{50} = 0.45'

= 5.43"

Tailwater depth for Equation 10.4 should be limited to between 0.4D and 1.0D. If tailwater is unknown, use 0.4D.

Whenever the flow is supercritical in the culvert, the culvert diameter is adjusted as follows:

$$D' = \frac{D + y_n}{2} \quad (10.5)$$

where,

D' = adjusted culvert rise, m (ft)

y_n = normal (supercritical) depth in the culvert, m (ft)

Equation 10.4 assumes that the rock specific gravity is 2.65. If the actual specific gravity differs significantly from this value, the D_{50} should be adjusted inversely to specific gravity.

The designer should calculate D_{50} using Equation 10.4 and compare with available riprap classes. A project or design standard can be developed such as the example from the Federal Highway Administration Federal Lands Highway Division (FHWA, 2003) shown in Table 10.1 (first two columns). The class of riprap to be specified is that which has a D_{50} greater than or equal to the required size. For projects with several riprap aprons, it is often cost effective to use fewer riprap classes to simplify acquiring and installing the riprap at multiple locations. In such a case, the designer must evaluate the tradeoffs between over sizing riprap at some locations in order to reduce the number of classes required on a project.

Table 10.1. Example Riprap Classes and Apron Dimensions

Class	D_{50} (mm)	D_{50} (in)	Apron Length[1]	Apron Depth
1	125	5	4D	$3.5D_{50}$
2	150	6	4D	$3.3D_{50}$
3	250	10	5D	$2.4D_{50}$
4	350	14	6D	$2.2D_{50}$
5	500	20	7D	$2.0D_{50}$
6	550	22	8D	$2.0D_{50}$

[1]D is the culvert rise.

The apron dimensions must also be specified. Table 10.1 provides guidance on the apron length and depth. Apron length is given as a function of the culvert rise and the riprap size. Apron depth ranges from $3.5D_{50}$ for the smallest riprap to a limit of $2.0D_{50}$ for the larger riprap sizes. The final dimension, width, may be determined using the 1:3 flare shown in Figure 10.4 and should conform to the dimensions of the downstream channel. A filter blanket should also be provided as described in HEC 11 (Brown and Clyde, 1989).

For tailwater conditions above the acceptable range for Equation 10.4 (TW > 1.0D), Figure 10.3 should be used to determine the velocity downstream of the culvert. The guidance in Section 10.3 may be used for sizing the riprap. The apron length is determined based on the allowable velocity and the location at which it occurs based on Figure 10.3.

Over their service life, riprap aprons experience a wide variety of flow and tailwater conditions. In addition, the relations summarized in Table 10.1 do not fully account for the many variables in culvert design. To ensure continued satisfactory operation, maintenance personnel should inspect them after major flood events. If repeated severe damage occurs, the location may be a candidate for extending the apron or another type of energy dissipator.

Design Example: Riprap Apron (SI)

Design a riprap apron for the following CMP installation. Available riprap classes are provided in Table 10.1. Given:

Q = 2.33 m^3/s

D = 1.5 m

TW = 0.5 m

Solution

Step 1. Calculate D_{50} from Equation 10.4. First verify that tailwater is within range.

TW/D = 0.5/1.5 = 0.33. This is less than 0.4D, therefore,

use TW = 0.4D = 0.4(1.5) = 0.6 m

$$D_{50} = 0.2\,D\left(\frac{Q}{\sqrt{g}D^{2.5}}\right)^{4/3}\left(\frac{D}{TW}\right) = 0.2\,(1.5)\left(\frac{2.33}{\sqrt{9.81}(1.5)^{2.5}}\right)^{4/3}\left(\frac{1.5}{0.6}\right) = 0.13\text{ m}$$

Step 2. Determine riprap class. From Table 10.1, riprap class 2 (D_{50} = 0.15 m) is required.

APPENDIX D

Culvert Service Life & Cover

Culvert Service Life

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NOTES & REFERENCES

Steel Pipe with Metallic Coatings Service Life Analysis

Purpose: Per project scope of work section 10.4.2.2: Design all culverts and substructures for a 50 year service life with respect to corrosion. Base corrosion potential on pH and electrical resistivity tests conducted on soil, rock, and groundwater samples derived from the project site.

Per PDDM 7.3.6.2 and 7.3.6.3:

- Use a minimum wall thickness of 0.0625" [1.63 mm] for all steel and aluminum pipes. The appropriate minimum structural metal thickness will be determined from approved FLH fill height tables.
- **Corrosion -** Representative pH and resistivity determinations are required in order to specify pipe materials capable of providing a maintenance-free service life. Samples are taken in accordance with the procedures described in AASHTO T 288 and T 289.
- Samples should be taken from both the soil and water side environments to ensure that the most severe environmental conditions are selected for determining the service life of the drainage pipe.
- Soil samples should be representative of backfill material anticipated at the drainage site.
- Avoid taking water samples during flood flows or for two days following flood flows to ensure more typical readings.
- **Abrasion-** An estimate of the potential for abrasion is required in order to determine the need for invert
- **Steel Pipe with Metallic Coatings**
    - Galvanized steel (AASHTO M 218)
    - Aluminum coated steel (Type 2) (AASHTO M 274)
- **Corrosion -** Under non-abrasive and low-abrasive conditions, the service life of steel pipe with metallic coatings may be determined based upon corrosion (i.e., pH and resistivity) factors determined from Exhibit 7.3–B, which shows the relationship between service life and corrosion for plain galvanized steel pipe.
- The results included in FHWA-FLP-91-006 indicate that within the environmental range of 5.0 through 9.0 pH and resistivity equal to or greater than 1500 Ω-cm, aluminum coated steel (Type 2) can be expected to give a service life of **twice** that of plain galvanized pipe.
- Metal pipes should not be specified in moderate and severe abrasive environments where coatings are required to protect against water-side corrosion.

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NOTES & REFERENCES

Steel Pipe with Metallic Coatings Service Life Analysis

Abrasion -

- Four levels of abrasion are referred to in this guidance and the following guidelines are established for each level
  - Level 1. Nonabrasive conditions exist in areas of no bed load and very low velocities. This is the condition assumed for the soil side of drainage pipes.
  - Level 2. Low abrasive conditions exist in areas of minor bed loads of sand and velocities of 5 ft/s [1.5 m/s] or less.
  - Level 3. Moderate abrasive conditions exist in areas of moderate bed loads of sand and gravel and velocities between 5 ft/s and 15 ft/s [1.5 m/s and 4.5 m/s].
  - Level 4. Severe abrasive conditions exist in areas of heavy bed loads of sand, gravel, and rock and velocities exceeding 15 ft/s [4.5 m/s].
  - Abrasion levels are intended as guidance to help the engineer consider the impacts of bed-load wear on the invert of pipe materials.
  - The expected stream velocity should be based upon a typical flow (i.e., 2-year flow and less)

Structure	Q2 (cfs)	Outlet Velocity (ft/s)	Qfish (cfs)	Outlet Velocity (ft/s)	Notes
FP-01	51	2.88	21	1.85	-
FP-02	5	0.77	2	0.45	-
FP-03	87	3.7	35	2.39	-
FP-04	7	1.06	3	0.71	-
FP-05	51	3.58	20	2.59	-
FP-06	63	3.44	25	2.27	-
FP-07	17	5.57	7	4.15	Bedrock Channel Present
FP-09	43	6.87	17	4.97	Bedrock Channel Present
FP-10	49	7.51	19	5.71	Bedrock Channel Present
FP-11	31	6.23	12	3.8	Bedrock Channel Present
FP-12	10	4.75	4	3.09	Bedrock Channel Present
FP-13	99	6.69	40	3.85	Bedrock Channel Present
FP-14	33	5.95	13	3.82	Bedrock Channel Present
FP-15	66	6.51	26	4.81	Bedrock Channel Present
FP-16	5	0.48	2	0.21	-
FP-17	14	4.95	6	4.31	-
C-08	74	13.96	-	-	Bedrock Channel Present
C-12	57	13.62	-	-	Bedrock Channel Present

Site conditions for project culverts have been assumed to be Level 2 (Low Abrasion) based on observations during hydraulic reconnaissance of existing structures, including the predominantly bedrock stream beds and relatively low sediment transport rates, the lack of mobile sand and gravel sediments in most of the drainages, and the use of baffles and streambed materials placed within fish passage culverts, which will minimize wear on these culvert inverts.

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NOTES & REFERENCES

Steel Pipe with Metallic Coatings Service Life Analysis

ph Measurerments (waterside)

- Water side pH measurements taken at each fish stream and larger drainage streams ranged from 5 to 6.5
- A design pH of 5 has been conservatively assumed for all pipes

ph Measurerments (backfill)

- Backfill and bedding pH results have been assumed from the ARD testing
- Quarry 4 (located at Sta 930+00) sample had a pH of 8.29
- Quarry 6 (located at Sta 1154+00) had a pH of 8.71
- Quarry 4 and Quarry 6 have been sampled for pipe material testing and reported in DOWL-HKM's "Acid Rock Drainage Evaluation Report"

Resistivity

- It is assumed available native streambed material is minimal in most cases
- Nearly all of the fish pipes infill will consist of crushed rock mixed with fines per the project specifications
- Representative samples from Quarry 4 and 6
- The lowest reported design soil resistivity value of **14,400** (ohm-cm) has been assumed for analsyis of all structures
- Detailed results can be found in the attached DOWL HKM test report summary

FH43 Estimated Service Life of Galvanized Steel and Aluminized Steel Pipes

Stream Name	Proposed Structure	Wall Thickness (inches)		Material Type	Measured pH	Assumed pH	Resistivity (Ohm-cm)	Thickness Factor	Material Factor	Service Life
FP-01	84"	14 gage	0.079	Aluminized Steel Type 2	6.0	5.0	14000	1.2	2.0	82 yrs
FP-02	72"	16 gage	0.064	Aluminized Steel Type 2	6.0	5.0	14000	1	2.0	68 yrs
FP-03	11'-10" x 7'-7"	8 gage	0.168	Aluminized Steel Type 3	5.5	5.0	14000	2.6	2.0	178 yrs
FP-04	66"	16 gage	0.064	Aluminized Steel Type 2	6.0	5.0	14000	1	2.0	68 yrs
FP-05	108"	14 gage	0.079	Aluminized Steel Type 2	6.0	5.0	14000	1.2	2.0	82 yrs
FP-06	11'-5" x 7'-3"	10 gage	0.138	Aluminized Steel Type 3	6.0	5.0	14000	2.2	2.0	150 yrs
FP-07	66"	16 gage	0.064	Aluminized Steel Type 2	5.5	5.0	14000	1	2.0	68 yrs
FP-09	96"	14 gage	0.079	Aluminized Steel Type 2	5.0	5.0	14000	1.2	2.0	82 yrs
FP-10	96"	14 gage	0.079	Aluminized Steel Type 2	5.0	5.0	14000	1.2	2.0	82 yrs
FP-11	96"	14 gage	0.079	Aluminized Steel Type 2	5.0	5.0	14000	1.2	2.0	82 yrs
FP-12	60"	16 gage	0.064	Aluminized Steel Type 2	5.0	5.0	14000	1	2.0	68 yrs
FP-13	14'-3" x 9'-2"	10 gage	0.138	Aluminized Steel Type 3	5.0	5.0	14000	2.2	2.0	150 yrs
FP-14	96"	14 gage	0.079	Aluminized Steel Type 2	6.0	5.0	14000	1.2	2.0	82 yrs
FP-15	10'-8" x 6'-11"	10 gage	0.138	Aluminized Steel Type 3	5.5	5.0	14000	2.2	2.0	150 yrs
FP-16	60"	16 gage	0.064	Aluminized Steel Type 2	5.0	5.0	14000	1	2.0	68 yrs
FP-17	60"	16 gage	0.064	Aluminized Steel Type 2	6.0	5.0	14000	1	2.0	68 yrs
C-08	72"	16 gage	0.064	Aluminized Steel Type 2	5.0	5.0	14000	1	2.0	68 yrs
C-12	72"	16 gage	0.064	Aluminized Steel Type 2	6.0	5.0	14000	1	2.0	68 yrs

Notes

1. pH values were measured and reported in the Hydraulics Reconnaissance Report.
2. Soil resistivity is assumed to be the same at all pipes. 14000 ohm-cm is the lowest value measured.
3. Service Life Calculations per Exhibit 7.3-B of the PDDM

DOWL HKM

Testing Report Summary

		Date Sample Recv'd	2/28/2013
Client	PND Engineers, Inc.	W.O. #	A33576
Project	Deweyville to Neck Lake	Lab #	115-116
Location	See Below		

All results will be posted to the website for your access and convenience. Samples will be kept for 30 days before being disposed. Please contact us if you would like the remaining material returned.

Sample ID	Test Performed	Test Method	Results (ohm-cm)	
115A (Quarry 4)	Standard Method of Test for Determining Minimum Laboratory Soil Resistivity	AASHTO T288	Minimum Resistivity	14400
115B (Quarry 4)			Minimum Resistivity	14400
115C (Quarry 4)			Minimum Resistivity	17200
116A (Quarry 6)			Minimum Resistivity	29400
116B (Quarry 6)			Minimum Resistivity	25800
116C (Quarry 6)			Minimum Resistivity	25800

If you have questions regarding this summary report or the test procedures, please contact us.

Maria
Maria E. Kampsen, P.E.
Laboratory Supervisor

4040 B Street, Anchorage, Alaska 99503 -- 907-562-2000

Table 2: Summary of Acid Base Accounting Analysis Results

Sample ID	Paste pH	TIC %	CaCO3 NP	S(T) %	S(SO4) %	S(S-2) %	AP	NP	Net NP	Fizz Test	Ratio NP/AP(1)
Method Code	Sobek	CSB02V	Calc.	CSA06V	CSA07V	Calc.	Calc.	Modified	Calc.	Sobek	
LOD	0.2	0.01	#N/A	0.01	0.01	#N/A	#N/A	0.5	#N/A	#N/A	
Quarry 1	8.37	6.31	525.8	1.17	<0.01	1.17	36.6	519.5	482.9	strong	14.2
Quarry 2, C-101, C-102	8.26	6.84	570.0	0.31	<0.01	0.31	9.7	531.0	521.3	strong	54.8
Quarry 3 East Side	8.32	8.6	716.7	<0.01	<0.01	<0.01	<0.3	837.2	837.2	strong	2,790.7
Quarry 3 West,C-103,C-104	8.2	10.6	883.3	0.06	<0.01	0.06	1.9	678.1	676.3	strong	361.7
Quarry 4	8.29	11.8	983.3	<0.01	<0.01	<0.01	<0.3	932.4	932.4	strong	3,108.1
Quarry 5	8.62	0.46	38.3	0.16	<0.01	0.16	5.0	48.0	43.0	slight	9.6
Quarry 6	8.71	0.14	11.7	0.1	<0.01	0.1	3.1	21.0	17.9	slight	6.7
Quarry 7 South End	9.25	0.23	19.2	0.02	<0.01	0.02	0.6	26.5	25.9	slight	42.4
Quarry 7 North End	8.86	0.09	7.5	<0.01	<0.01	<0.01	<0.3	12.1	12.1	slight	40.2
Road cut 819+90	8.52	0.01	0.8	0.07	<0.01	0.07	2.2	7.7	5.5	none	3.5
TB-326	8.27	11.2	933.3	0.02	<0.01	0.02	0.6	898.0	897.4	strong	1,436.9
TB-342	8.31	11.1	925.0	0.03	<0.01	0.03	0.9	890.0	889.1	strong	949.4
TB-377/TB-381	8.24	10.6	883.3	0.05	<0.01	0.05	1.6	852.1	850.6	strong	545.4
TB-435	8.39	7.12	593.3	0.04	<0.01	0.04	1.3	558.7	557.4	strong	446.9
TP-317	8.45	2.69	224.2	0.93	<0.01	0.93	29.1	223.6	194.5	moderate	7.7
TP-322	8.61	1.66	138.3	0.08	<0.01	0.08	2.5	152.2	149.7	moderate	60.9
TP-333/TP-335/TP-336	8.41	0.52	43.3	0.02	<0.01	0.02	0.6	49.8	49.1	slight	79.6
TP-343/TP-349	8.23	11.8	983.3	0.11	<0.01	0.11	3.4	931.8	928.4	strong	271.1
HDTP-357/358/TP-360/362/364	8.36	10.5	875.0	0.28	<0.01	0.28	8.8	838.0	829.2	strong	95.8
TP-388/TP-389/TP-390	8.16	0.36	30.0	0.16	<0.01	0.16	5.0	31.8	26.8	slight	6.4
TP-412	8.34	0.66	55.0	0.07	<0.01	0.07	2.2	62.6	60.4	slight	28.6

Notes:

AP = Acid potential in tonnes CaCO3 equivalent per 1000 tonnes of material. AP is determined from the sulphide-sulphur content

NP = Neutralization potential in tonnes CaCO3 equivalent per 1000 tonnes of material

NET NP = NP - AP

Carbonate NP is calculated from TIC originating from carbonate minerals and is expressed in kg CaCO3/tonne

Sulphate Sulphur determined by 25% HCl with S by ICP Finish

Sulphide Sulphur determined by difference (Total S - Sulphate S)

(1) - Added to Laboratory Test Results by DOWL HKM. Note that values of <0.3 were changed to 0.3 to calculate ratios.

Culvert Cover &
Structural Calculations

FH43 Large Round Pipe Cover Check

Stream Name	Proposed Structure	Wall Thickness (inches)		Minimum Cover (in)	Plan Minimum (in)	Check Min	Max Cover (ft)	Plan Max (ft)	Check Max
FP-01	84"	14	0.079	12	97	OK	43	11	OK
FP-02	72"	16	0.064	12	17	OK	40	5	OK
FP-03	11'-10" x 7'-7"	8	0.168	24	28	OK	16	6	OK
FP-04	66"	16	0.064	12	88	OK	44	10	OK
FP-05	108"	14	0.079	18	23	OK	47	5	OK
FP-06	11'-5" x 7'-3"	10	0.138	24	136	OK	16	14	OK
FP-07	66"	16	0.064	12	32	OK	44	10	OK
FP-09	96"	14	0.079	12	41	OK	38	9	OK
FP-10	96"	14	0.079	12	55	OK	38	10	OK
FP-11	96"	14	0.079	12	18	OK	38	9	OK
FP-12	60"	16	0.064	12	54	OK	49	10	OK
FP-13	14'-3" x 9'-2"	10	0.138	24	109	OK	19	18	OK
FP-14	96"	14	0.079	12	207	OK	38	22	OK
FP-15	10'-8" x 6'-11"	10	0.138	24	124	OK	16	14	OK
FP-16	60"	16	0.064	12	98	OK	49	10	OK
FP-17	60"	16	0.064	12	45	OK	49	9	OK
C-05	48	-	1.477	12	18	OK	27	3.92	OK
C-08	72"	16	0.064	12	19	OK	40	6	OK
C-12	72"	16	0.064	12	18	OK	40	4	OK
C-13	48	-	1.477	12	146	OK	49	15	OK

Notes

1. Max Cover for FP-13 Calculated per depth of cover 19ft assumed ok for actual 18 ft.

2.) Measurements performed in AutoCAD Civil 3d 2013 edition

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Project: 121088 - DEWEYVILLE
Sheet Number: 1 Of: 11
Calculated by: MTB Date: 2/20/13
Checked by: CRW Date: 3/18/13

PIPE ARCH CHECK FOR 19' EMBEDMENT

→ A PIPE ARCH CULVERT IS PLANNED FOR INSTALLATION WITH A FILL DEPTH 19.03' MTB THE PROPOSED STRUCTURE IS NOT SPECIFIED ON THE US DOT FHWA STANDARD DWG. 603-2. THEREFORE, CALCULATIONS ARE REQUIRED TO VERIFY THAT THE PIPE ARCH PROVIDES ADEQUATE CAPACITY TO SUPPORT THE LOADS AT THE INSTALLED DEPTH. THE FOLLOWING CALCULATIONS PROVIDE THE NECESSARY CHECKS IN ACCORDANCE WITH AASHTO LRFD BRIDGE DESIGN.

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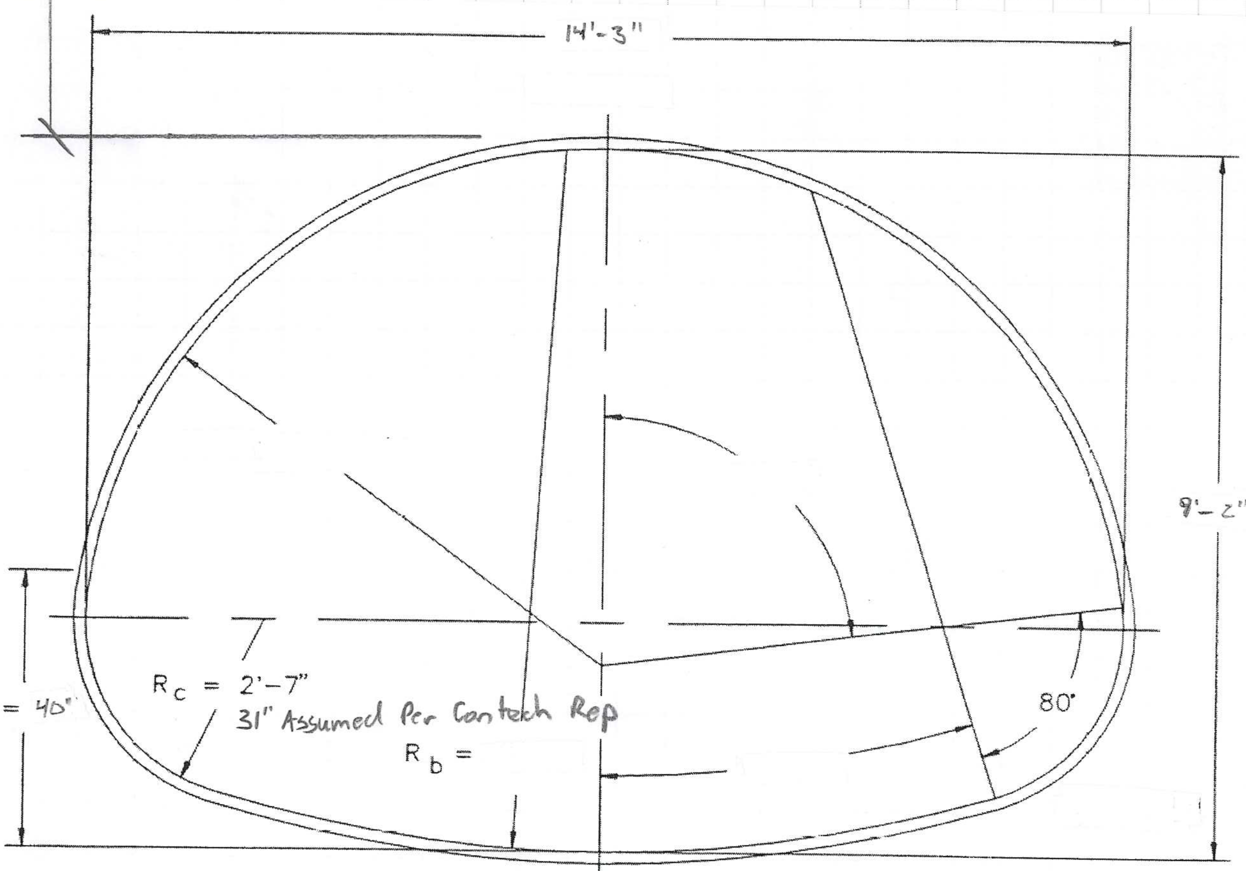
AASHTO LRFD BRIDGE DESIGN 19.03' EMBEDMENT CHECK

FP-13

$\gamma = 120pcf$
$\phi = 40$ Assumed

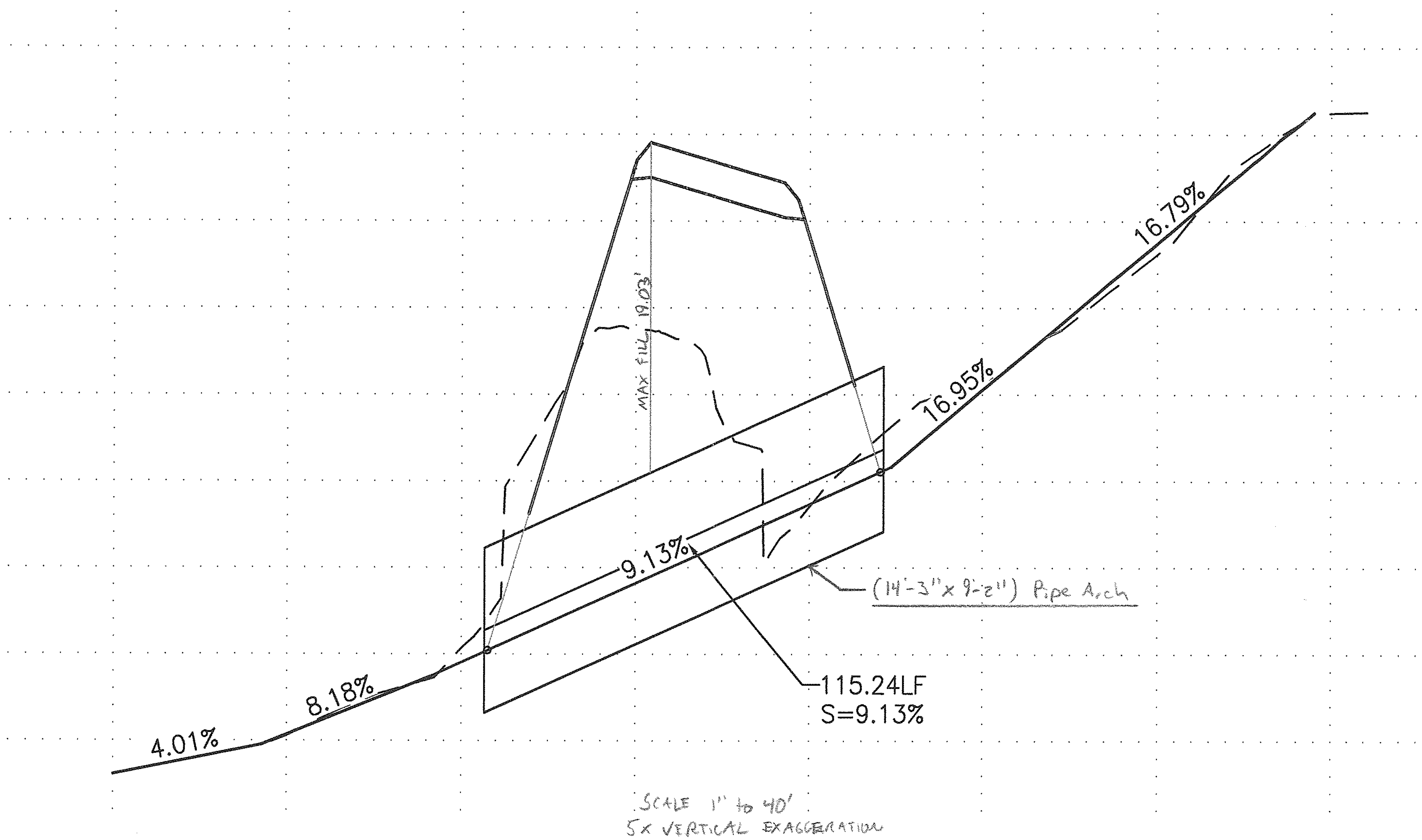
H= 19' FILL DEPTH

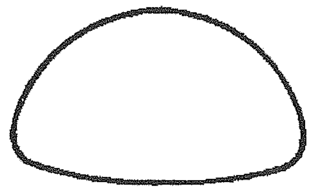


BASE IMAGE
CONTECH MULTIPLATE PRODUCT MANUAL

3 x 1 corrugations

NOTE: DOCUMENT HEIGHTS OF COVER BASED ON 2 TONS/FT² OF CORNER BEARING PRESSURE Per Corrugated Steel Pipe Design Manual, 2008 Edi NEED TO VERIFY PER AASHTO GUIDELINES


4.01%
8.18%
9.13%
MAX FILL 19.03'
16.95%
16.79%
(14'-3" x 9'-2") Pipe Arch
115.24LF
S=9.13%
SCALE 1" to 40'
5x VERTICAL EXAGGERATION



AISI-11

Height-of-Cover Limits for Corrugated Steel Pipe Arch
H20 or H25 Live Load • 5 x 1 in. and 3 x 1 in. Corrugations

Span & Rise in.	Minimum Specified Thickness Required 3 x 1 in.	Minimum Specified Thickness Required 5 x 1** in.	Minimum* Cover in.	Maximum Cover (ft) Over Pipe Arch for Soil Corner Bearing Capacity of 2 tons/ft²
53 x 41	0.079	0.109	12	25
60 x 46	0.079	0.109	15	25
66 x 51	0.079	0.109	15	25
73 x 55	0.079	0.109	18	24
81 x59	0.079	0.109	18	21
87 x 63	0.079	0.109	18	20
95 x 67	0.079	0.109	18	20
103 x 71	0.079	0.109	18	20
112 x 75	0.079	0.109	21	20
117 x 79	0.109	0.109	21	19
128 x 83	0.109	0.109	24	19
137 x 87	0.109	0.109	24	19
142 x 91	0.138	0.138	24	19
150 x 96	0.138	0.138	30	19
157 x 101	0.138	0.138	30	19
164 x 105	0.138	0.138	30	19
171 x 110	0.138	0.138	30	19

ASSUMED ALLOWABLE BEARING PRESSURE

FP-13

MAX COVER

Notes:

1. Soil bearing capacity refers to the soil in the region of the pipe corners. See Chapter 10 for design of pipe envelope at pipe corners. The remaining backfill around the pipe arch must be compacted to a specified AASHTO T-99 density of 90%
2. Use reasonable care in handling and installation.
3. Pipe arches are typically used where the cover does not exceed 15 feet.

* Minimum covers are for H20 and H25 loads. See Table 10.1 for construction load requirements. Minimum covers are measured from top of pipe to bottom of flexible pave-ment or top of pipe to top of rigid pavement. Minimum cover must be maintained in unpaved traffic areas.

** Same thicknesses as specified for 3 x 1 may be provided when the corner radius meets the requirements of ASTM A760.

CORRUGATED STEEL PIPE DESIGN MANUAL, 2008

pg 4 of 11

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LOADS ON PIPE ARCH CULVERT

- PER ARTICLE 12.5.4, BURIED STRUCTURES SHALL BE CONSIDERED NON-REDUNDANT UNDER EARTH FILL & REDUNDANT UNDER LIVE LOAD.

$\eta_r = 1.05$ FOR EARTH FILL

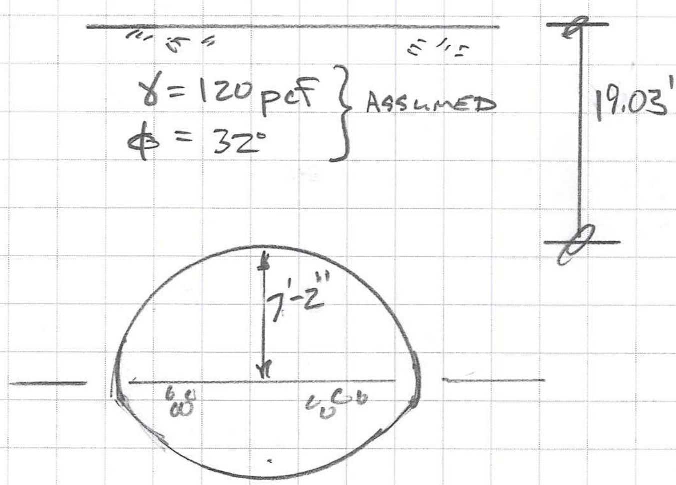
- PER ARTICLE 3.6.1.2.6: "FOR SINGLE-SPAN CULVERTS, THE EFFECTS OF LIVE LOAD MAY BE NEGLECTED WHERE THE DEPTH OF FILL IS MORE THAN 8-ft & EXCEEDS THE SPAN LENGTH." MTB ✓

IN OUR CASE THE DEPTH OF FILL IS 19.3' & THE SPAN LENGTH OF THE CULVERT IS 14'-3" SO THE EFFECTS FROM LIVE LOAD WILL BE NEGLECTED.

→ EARTH FILL PRESSURE:

$\gamma_p = 1.95$ (TABLE 3.4.1-2)

$EV = 120\,pcf \times 19.03 = 2284\,psf$ MTB ✓



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CHECK CAPACITY OF PIPE ARCH CULVERT

→ CHECK CULVERT PER AASHTO. CHECK PER ARTICLES 12.5.2 & 12.5.3, SERVICE LIMIT STATE & STRENGTH LIMIT STATE RESPECTIVELY.

12.5.2 - SERVICE LIMIT STATE - SERVICE LOAD COMBO #1

- DEFLECTION CHECK

12.5.3 - STRENGTH LIMIT STATE - STR LOAD COMBO #1

- WALL AREA
- BUCKLING
- SEAM FAILURE → N/A NO SEAMS MTB ✓
- FLEXIBILITY LIMIT FOR CONSTRUCTION

  ↳ N/A AS THIS IS NOT AFFECTED BY DEPTH (ASSUMED CHECKED)

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CHECK CAPACITY OF PIPE ARCH CULVERT

12.7.2.2 - THRUST

$$T_L = P_L\left(\frac{S}{24}\right)$$

WHERE $P_L = \eta_r \gamma_p (2.3^{ksf}) = (1.05)(1.95)(2.3^{ksf})$ MTB ✓

$= 4.71^{ksf}$

$S = 14'-3'' = 171''$ MTB ✓

$$T_L = (4.71^{ksf})\left(\frac{171}{24}\right) = 33.6^{k/ft}$$ MTB ✓

12.7.2.3 - WALL RESISTANCE

FACTORED AXIAL RESISTANCE w/o CONSIDERATION OF BUCKLING:

$$\phi R_n = \phi F_y A = (1.0)(33^{ksi})(2.008^{in^2/ft}) = 66.3^{k/ft}$$

A for 0.138 of 3x1 = 2.008 per table 2.6 CSPDM
Assumed conservative thickness

12.7.2.4 - RESISTANCE TO BUCKLING

$$\frac{r}{k}\sqrt{\frac{24E_m}{F_u}} = \frac{0.682}{0.22}\sqrt{\frac{24(29000)}{45}} = 386$$

$$S = 171'' < 386 \rightarrow f_{cr} = F_u - \frac{\left[\frac{F_u k S}{r}\right]^2}{48E_m}$$

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CHECK CAPACITY OF PIPE ARCH CULVERT

12.7.2.4 - RESISTANCE TO BUCKLING CONT...

$$f_{cr} = 45^{ksi} - \frac{\left[\frac{(45^{ksi})(6.22)(171)}{0.3472}\right]^2}{48(29000)} = 27.9^{ksi}$$

MTB ✓

$f_{cr} < F_y$ so BUCKLING DOES CONTROL

$\therefore \phi R_n = \phi F_{cr} A = 56.0\ k/ft \geq T_L$ OK ✓

MTB ✓

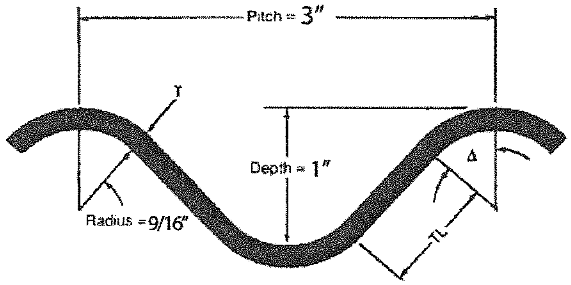

Table 2.6

Sectional properties of 3 x 1 in. (Annular or Helical)

Specified Thickness	Uncoated Thickness *T*	Area of Section *A*	Tangent Length *TL*	Tangent Angle *Δ*	Moment of Inertia *I*	Section Modulus *S*	Radius of Gyration *r*	Developed Width Factor
(in.)	(in.)	($in.^2/ft$)	(in.)	(Degrees)	($in.^4/in$)	($in.^3/ft$)	(in.)	
0.040*	0.0359	0.534	0.963	44.19	0.0052	0.1194	0.3403	1.239
0.052	0.0478	0.711	0.951	44.39	0.0069	0.1578	0.3410	1.240
0.064	0.0598	0.890	0.938	44.60	0.0087	0.1961	0.3417	1.240
0.079	0.0747	1.113	0.922	44.87	0.0109	0.2431	0.3427	1.241
0.109	0.1046	1.560	0.889	45.42	0.0146	0.3358	0.3448	1.243
0.138	0.1345	2.008	0.855	46.02	0.0202	0.4269	0.3472	1.244
0.168	0.1644	2.458	0.819	46.65	0.0251	0.5170	0.3499	1.246

* Thickness not commonly available. Information only.

Notes: 1. Per foot of projection about the neutral axis. To obtain *A* or *S* per *inch* of width, divide the above values by 12.

2. Developed width factor measures the increase in profile length due to corrugating. Dimensions are subject to manufacturing tolerances.

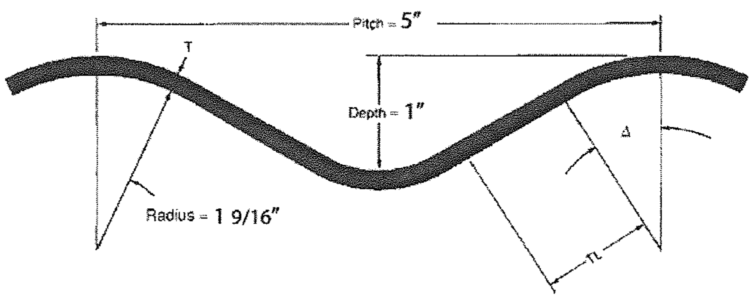

Table 2.7

Sectional properties of 5 x 1 in. (Helical)

Specified Thickness	Uncoated Thickness *T*	Area of Section *A*	Tangent Length *TL*	Tangent Angle *Δ*	Moment of Inertia *I*	Section Modulus *S*	Radius of Gyration *r*	Developed Width Factor
(in.)	(in.)	($in.^2/ft$)	(in.)	(Degrees)	($in.^4/in$)	($in.^3/ft$)	(in.)	
0.064	0.0598	0.794	0.730	35.58	0.0089	0.1960	0.3657	1.106
0.079	0.0747	0.992	0.708	35.80	0.0111	0.2423	0.3663	1.107
0.109	0.1046	1.390	0.664	36.30	0.0156	0.3330	0.3677	1.107
0.138	0.1345	1.788	0.616	36.81	0.0203	0.4210	0.3693	1.108
0.168	0.1644	2.186	0.564	37.39	0.0250	0.5069	0.3711	1.108

Notes: 1. Per foot of projection about the neutral axis. To obtain *A* or *S* per *inch* of width, divide the above values by 12.

2. Developed width factor measures the increase in profile. Dimensions are subject to manufacturing tolerances.

3. Actual Pitch = 4.9213 in. and Actual Depth = 1.0236 in. Dimensions shown on sketch are nominal.

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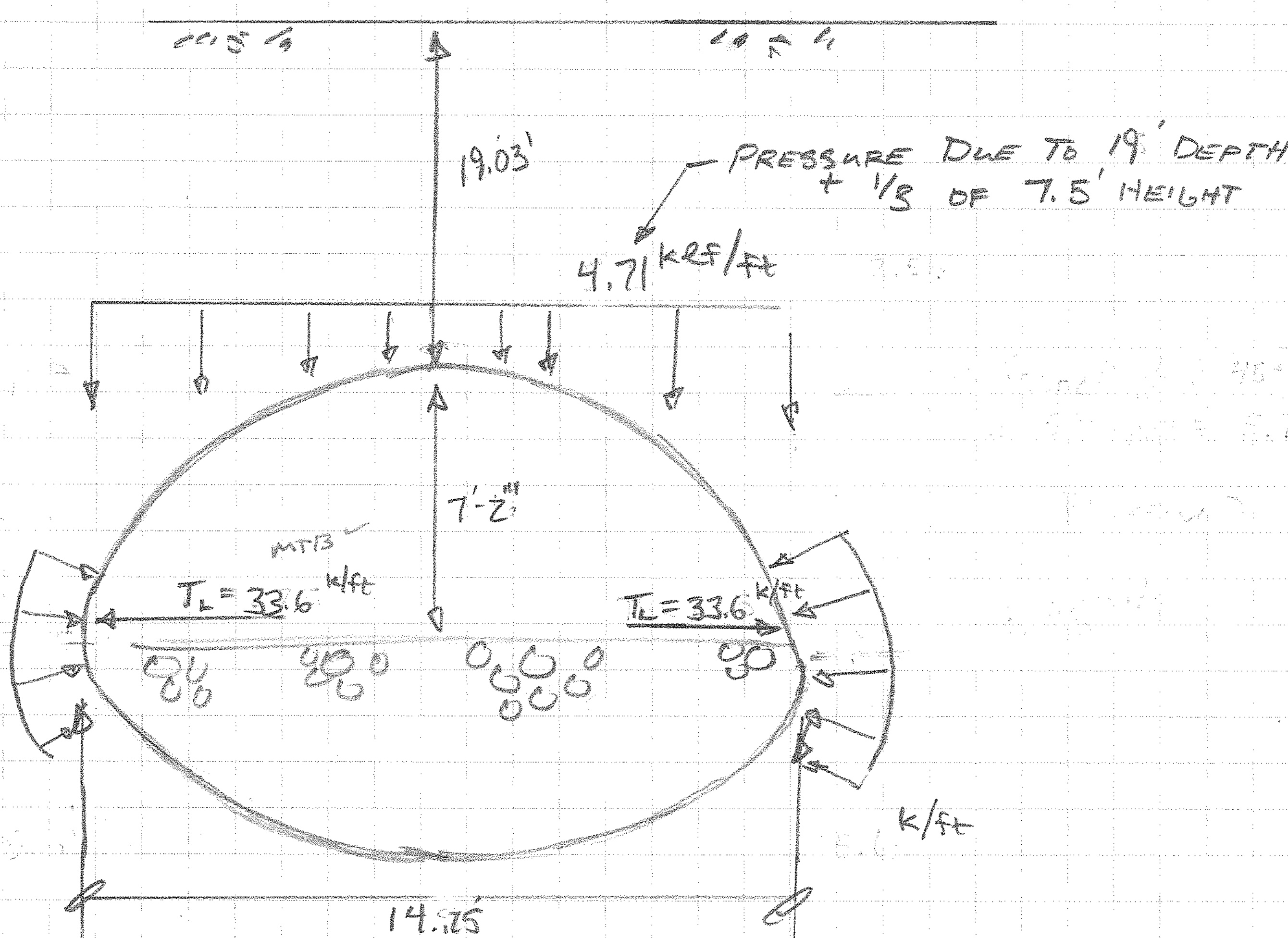
Loads on Pipe Arch Culvert



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Notes & Ref

Dead Load Corner Bearing Pressure

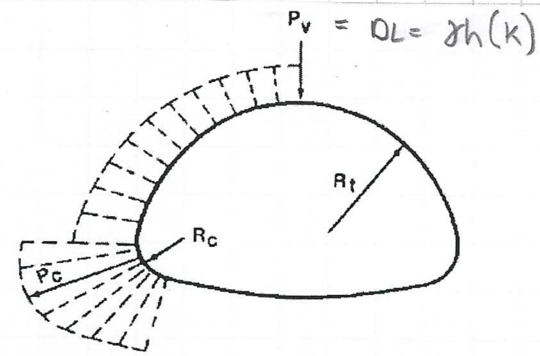

Figure 7.11 The pressure on a pipe arch varies with location and radius, being greatest at the corners.

P_{CDL} = Pipe Thrust T_L / CORNER RADIUS — PER 12.6.3.2

FACTORED P_{CDL} = (33.6 k/ft) / 2'-7"

F P_{CDL} = 13.0 KSF

SAFETY AGAINST STRUCTURAL FAILURE - SOIL ENVELOP DESIGN

Per 12.8.5.3

d= required envelop width ADJACENT to the structure

$d = \frac{T}{P_{Brg}} - R_c$

P_{BRG} = ALLOWABLE BEARING CAPACITY (KSF)

R_c = corner Radius

T= Pipe thrust

Conservative Assume Embankment ALLOWABLE BEARING CAPACITY = 2TSF ✓

Bedrock channel below PIPE Assumed Bearing Capacity >> 2TSF

d= (33.6k/ft)/(4ksf) - 2'7" ✓

d = 5.82'

d provided = 9'-2" OR PIPE HEIGHT ✓

STD DWG 602-3 ✓

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