Lee's Ferry Access Road
Glen Canyon National Recreation Area
AZ PRA GLCA 5(2)

Final
Drainage Report

Federal Highway Administration
Central Federal Lands Highway Division

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1. INTRODUCTION

1.1. Scope and Purpose

This report summarizes the hydrologic and hydraulic analyses performed for the Lee's Ferry Access Road, project number AZ PRA GLCA 5(2), on the Glen Canyon National Recreation Area near Page, AZ.

The drainage design for this project was prepared in accordance with the Federal Lands Highway Project Development and Design Manual, Hydrology and Hydraulics, April 2011.

1.2. Project Location

Lee's Ferry Access Road (AZ PRA GLCA 5(2) begins at the intersection of US 89A and proceeds northward for approximately 5.8 miles. The route is entirely within the Glen Canyon National Recreational Area in Coconino County.

1.3. Project Description

The proposed road reconstruction will consist of replacing/rehabilitating the existing roadway surface by pulverize and repaving. Erosion is a concern along the roadside and will be addressed with roadside paved ditches, revet mattress slope protection and minor ditch profiles. The project includes minimal roadside grading, drainage structures, replacing paved ditch and curb, placement of pulverized base and asphalt pavement, locations of subgrade repair, minor signing, striping, and other safety related features necessary to meet current design practice.

2. HYDROLOGY

2.1 Drainage Basin Descriptions

Basin areas within the Lees Ferry study are typically sparse with vegetation and contain very loose soil. The soil components are predominately made up channery, sandy loam, and cobbles. The soil is classified as primarily a Type D soil that is well drained and with a high runoff potential. Slopes within the basins average from 5% to 40%. High plateaus, rolling foothills, and mild sloped plains are prevalent. Average elevations and areas varied widely throughout with the region with a 1475' divergence in average elevation. A flash flood event with high runoff and high sediment transport loads are likely. Soil Classifications and Descriptions are located in **Appendix A.**

2.2 Prediction of Design Discharge

2.2.1 Regression Analysis

Design discharges were developed with the indirect equations and methods found in the "Methods for Estimating Magnitude and Frequency of Floods in the Southwestern

United States", United States Geological Survey Water-Supply Paper 2433 (USGS WSP 2433). Drainage basin areas were determined from best available data (USGS topographic mapping and aerial imaging). Based on the USGS flood region mapping the delineated basin area is in within Flood Region 8. USGS Regional Regression Equations for Region 8 were used to calculate the 2-, 5-, 10-, 25-, 50-, and 100-year flows. The applicable drainage area for the Region 8 regression equations is 1.0 square miles. The regression equations were utilized for drainage areas greater than 1.0 square miles.

Table 1 is a summary of the basin areas and calculated peak flows based on regression analysis. Hydrologic calculations are presented in **Appendix B**.

Station	Area (Sq Mi)	2-Year flow (CFS)	5-Year flow (CFS)	10-Year flow (CFS)	25-Year flow (CFS)	50-Year flow (CFS)	100-Year flow (CFS)
Sta 155+31 (D4)	0.014	Drainage area less than 1 sq mi. Refer to rational method calculations.					
Sta 158+35 (D5)	0.010	Drainage area less than 1 sq mi. Refer to rational method calculations.					
Sta 164+80 (D6)	0.013	Drainage area less than 1 sq mi. Refer to rational method calculations.					
Sta 170+00 (Slope Protection)	0.49	110	355	626	1,117	1,608	2,213
Sta 173+91 (Rundown) (D7)	0.010	Drainage area less than 1 sq mi. Refer to rational method calculations.					
Sta 174+48 (D7)	5.55	275	727	1,167	1,924	2,646	3,478
Sta 243+29 (D11)	2.79	198	543	887	1,486	2,063	2,738
Sta 287+75 (D13)	0.141	Drainage area less than 1 sq mi. Refer to rational method calculations.					
Sta 290+40 (Rdwy Overtopping)	0.038	Drainage area less than 1 sq mi. Refer to rational method calculations.					
Sta 335+49 (Gabion Wall)	0.040	Drainage area less than 1 sq mi. Refer to rational method calculations.					
Sta 356+00 (D16)	0.072	Drainage area less than 1 sq mi. Refer to rational method calculations.					
Sta 403+08	0.390	Drainage area less than 1 sq mi. Refer to rational method calculations.					

Table 1 – Basin Areas and Regression Analysis Discharge at Selected Locations on Lees Ferry Access Road

2.2.2 Rational Method

The Rational Method was used to compute peak flows for drainage areas less than 1 square mile. The analysis presented with this submittal uses site specific Intensity-Duration Frequency (I-D-F) curves for the 10-year and 50-year design storms. The new *Point Precipitation Frequency Estimates from NOAA Atlas 14* were used to develop rainfall intensities for the drainage design and are shown in Appendix B. The Rational Method is based on the following.

$$Q = C\ i\ A$$

where Q = the peak discharge in cfs

C = runoff coefficient

i = the average rainfall intensity, in inches/hour (in/hr) for the selected rainfall return period

A = the contributing drainage area in acres

The following values of "C" are used with a 25-year and 100-year design storm events for a desert environment assuming 10% vegetation cover:

- 25-year – 0.41
- 100-year – 0.53

The rainfall intensity is estimated based upon the time of concentration at the point being analyzed. The time of concentration is calculated as follows:

$$T_c = 11.4 \quad L^{0.5} \quad K_b^{0.52} \quad S^{-031} \quad I^{-0.38}$$

Where T_c = time of concentration in hours

L = the length of the longest flow path in miles

K_b = the watershed resistance coefficient

S = the slope of the longest flow path in ft/mile

I = the average rainfall intensity in in/hr

Defining the time of concentration and resulting rainfall intensity is an iterative procedure. The procedure begins by assuming an initial time of concentration, identifying the corresponding rainfall intensity from the IDF graph and calculating the time of concentration using the equation presented above. The computed time of concentration is then compared with the assumed time of concentration. If the two values differ significantly, a new time of concentration and corresponding rainfall intensity are assumed and the time of concentration is calculated. This process is repeated until an acceptable convergence is achieved. The resulting time of concentration then defines the rainfall intensity for input into the Rational Method equation. This procedure typically defaults to the minimum 10-minute time of concentration for most roadway catch basins. Drainage areas, which include shoulders, median and side slopes, are identified by examination of the roadway plan and profile.

Station	Area (Acres)	25-Year flow (CFS)	100-Year flow (CFS)
Sta 155+31 (D4)	9.3	11	21
Sta 158+35 (D5)	6.3	7	14
Sta 164+80 (D6)	8.7	10	20
Sta 170+00 (Slope Protection)	315.4	Refer to regression calculations.	
Sta 173+91 (Rundown) (D7)	6.6	8	15
Sta 174+48 (D7)	3553.6	Refer to regression calculations.	
Sta 243+29 (D11)	1786.2	Refer to regression calculations.	
Sta 287+75 (D13)	90.5	59	130
Sta 290+40 (Rdwy Overtopping)	24.5	28	56
Sta 335+49 (Gabion Wall)	25.6	30	58
Sta 356+00 (D16)	46.1	45	97
Sta 403+08	249.6	216	470

Table 2 – Basin Areas and Rational Method Discharge at Selected Locations on Lees Ferry Access Road

2.3 Existing Drainage Features

Due to the erosive nature of soils within the Lee's Ferry study area several of the roadside culverts are partially plugged with sediment and debris. Capacity has been reduced and conditions at the inlets and outlets have deteriorated.

Erosion of the roadway embankments is also prevalent in selected areas. Southwest of Cathedral Wash is an unnamed wash traverses from south to north along the access roadway from approximately Sta 167+55 to Sta 170+37. The existing roadway embankment along the wash is eroding and migrating towards the back of curb along the access road. There are two existing spur dikes located within the wash at Sta 164+35 and Sta 165+12. Both features are showing signs of erosion and have failed to improve the conditions developing along the embankment. The unnamed wash converges with Cathedral Wash and is discharged across the alignment through a 12X12 RCBC. The 12X12 RCBC at Sta 175+00 is for Cathedral Wash, the largest of the delineated basins. The fill surrounding the outlet apron has extreme degradation associated "head cutting" from the discharge. A roadside ditch discharging southeast of the outlet apron has also eroded into a well incised channel and continues to degrade the roadway embankment.

At approximately Sta 243+31 there are two 48" pipes conveying No Name Wash discharge across the access roadway. Both pipes are undersized for the design storm and offset from the natural flow path of the existing wash.

At Sta 323+50 there is a 72” diameter pipe that is failing. Under current conditions, the existing culvert crosses under Lees Ferry Access Road with a single 72” diameter corrugated metal pipe (CMP) pipe with concrete headwalls. There is an existing overflow pipe located approximately 50’ west of the 72” culvert. The downstream end (outlet) of the overflow pipe is buried by soil dumped over it. Recommendations for the existing 72” culvert repair is documented in the technical memorandum dated November 28, 2011.

The final technical memorandum is presented in **Appendix F**.

Sta 335+49 along the access road the existing wash is also indicating signs lateral migration towards the roadway. Regression equations and preliminary HEC-RAS models were developed to assess existing hydrologic and hydraulic conditions. **Table 3** is a list of existing structures**.**

ID No.	Station Feature	Existing Feature	Upstream Invert (ft)	Downstream invert (ft)	Length (ft)	Plan Designation	Action
1	Sta 101+77	8X8 Box Culvert	3542.78	3541.80	75	---	Leave as-is
2	Sta 106+38	18”X30” Elliptical Pipe	3558.64	3557.18	40	---	Leave as-is
3	Sta 124+14	18”X20” Elliptical Pipe	3556.64	3555.95	40	D1	Replace in kind
4	Sta 128+13	24” CMP	3543.26	3542.40	40	D2	Replace in kind
4a	Sta 131+13	24” CMP	3537.60	3535.84	18	---	Leave as-is
5	Sta 132+88	18”X30” Elliptical CMP	3542.00	3541.36	40	D3	Replace in kind
6	**Sta 155+31**	**18”X30” Elliptical CMP**	**3503.84**	**3504.54**	**51**	**D4**	**Evaluate design**
7	**Sta 158+35**	**18”X30” Elliptical CMP**	**3485.16**	**3486.82**	**52**	**D5**	**Evaluate design**
8	**Sta 164+80**	**21”X36” Elliptical CMP**	**3458.10**	**3458.84**	**48**	**D6**	**Evaluate design**
9	**Sta 174+48**	**12X12 Box Culvert**	**3419.49**	**3418.64**	**43**	**D7**	**Leave as-is. Eval. Outlet**

Table 3 – Existing Culvert Summary

ID No.	Station Feature	Existing Feature	Upstream Invert (ft)	Downstream invert (ft)	Length (ft)	Plan Designation	Action
10	Sta 184+54	UNKNOWN	3407.99	3406.81	46	---	Leave as-is
11	Sta 186+83	2- 36" CMP	3409.13	3407.23	45	---	Leave as-is
12	Sta 189+65	18"X30" Elliptical CMP	3422.21	3418.96	47	---	Leave as-is
13	Sta 192+33	24" CMP	3429.64	3428.78	43	---	Leave as-is
14	Sta 201+53	12"X21" Elliptical CMP	3442.23	3441.56	43	---	Leave as-is
15	Sta 211+60	12"X21" Elliptical CMP	3442.18	3441.52	43	D8	Replace in kind
16	Sta 218+36	12"X21" Elliptical CMP	3423.14	3422.17	43	D9	Replace in kind
17	Sta 222+25	12"X21" Elliptical CMP	3413.06	3412.47	43	D10	Replace in kind
18	Sta 226+21	12"X21" Elliptical CMP	3406.86	3404.94	43	---	Leave as-is
19	**Sta 243+29**	**2 – 48" CMP**	**3342.99**	**3342.32**	**40**	**D11**	**Evaluate design**
20	Sta 247+24	12"X21" Elliptical CMP	3350.32	3349.61	47	D12	Replace in kind
21	Sta 255+92	12"X21" Elliptical CMP	3354.48	3353.36	38	---	Leave as-is
22	Sta 258+07	12"X21" Elliptical CMP	3354.67	3352.96	43	---	Leave as-is
23	Sta 262+96	12"X21" Elliptical CMP	3354.72	3353.84	43	---	Leave as-is
24	Sta 266+61	12"X21" Elliptical CMP	3354.12	3352.65	43	---	Leave as-is
25	Sta 272+22	12"X21" Elliptical CMP	3352.13	3351.48	43	---	Leave as-is

Table 3 – Existing Culvert Summary (Cont.)

ID No.	Station Feature	Existing Feature	Upstream Invert (ft)	Downstream invert (ft)	Length (ft)	Plan Designation	Action
26	Sta 281+00	18”X30” Elliptical CMP	3337.74	3336.84	43	---	Leave as-is
27	Sta 284+71	36” CMP	3329.41	3327.55	57	---	Extend Culvert
28	Sta 285+68	2 – 48” CMP	3328.36	3327.11	42	---	Leave as-is
29	**Sta 287+75**	**12”X21” Elliptical CMP**	**3331.72**	**3330.59**	**45**	**D13**	**Evaluate design**
30	Sta 299+20	12”X21” Elliptical CMP	3293.58	3299.90	59	---	Leave as-is
31	Sta 301+70	12”X21” Elliptical CMP	3291.14	3291.39	39	---	Leave as-is
32	Sta 308+45	60” CMP	3243.57	3241.65	71	---	Leave as-is
33	**Sta 323+04**	**57”x38” CMP**	**3166.60**	**3163.37**	**55**	**---**	**Refer to Appendix F**
34	Sta 323+54	72” CMP	3149.38	3142.84	169	---	Refer to Appendix F
35	Sta 331+24	18” CMP	3183.43	3181.42	41	---	Replace in kind
36	Sta 333+03	18” CMP	3178.21	3175.43	83	---	Replace in kind
37	Sta 335+43	18” CMP	3184.43	3180.99	65	---	Replace in kind
38	Sta 340+60	18” CMP	3194.73	3189.58	75	---	Replace in kind
38a	Sta 345+28	18” CMP	3226.53	3221.90	75	---	Leave as-is
39	Sta 355+86	24” CMP	3238.59	3207.31	112	---	Replace in kind
40	Sta 356+47	42”X29” Elliptical CMP	3240.95	3233.88	65	---	Leave as-is
41	Sta 371+95	24” CMP	3134.53	3118.09	84	---	Leave as-is
42	Sta 371+95	36” CMP	3134.24	3118.87	84	---	Leave as-is
43	**Sta 403+08**	**2-48” CMP**	**3128.41**	**3126.31**	**73**	**---**	**Evaluate design**

Table 3 – Existing Culvert Summary (Cont.)

3. DESIGN DISCUSSION

3.1. Design Criteria

The design of the roadway hydraulic structures was based on the Low-Standard roadway classification per the Federal Lands Highway Project Development and Design Manual (PDDM).

The following table lists the design storm values used for the project.

Roadway Hydraulic Design Storm Values		
	FLH Standard	**Used on This Project**
Culvert Design	25-year storm	25-year storm
Roadside Ditch Design	10-year storm	10-year storm
Pavement Drainage Design	10-year storm 50-year storm in sumps	10-year storm 50-year storm in sumps
Storm Drain Design	10-year storm 50-year storm in sumps	N/A
Floodplain Encroachment Design	100-year storm	N/A
Bridge Design Flood	50-year storm	N/A
Longitudinal Embankment Design	25-year storm	25-year storm
Retaining Wall Design	25-year storm	25-year storm
Channel Changes	25-year storm	25-year storm

Table 4 – Roadway Hydraulic Design Storm Values

3.2. Hydraulic Analysis

The following is a summary of the hydraulic analysis evaluation for the design of the various roadway hydraulic structures for the project.

3.2.1. Culverts

For culvert crossings, an existing condition model and a proposed condition model were generated for the 25-year storm event. The existing condition model was used to determine the existing capacity of the culverts. The proposed culvert recommendations will be designed to either meet or exceed the existing capacity based on the calculated design flows.

During the week of June 18, 2012 the Central Federal Lands Highways Division (CFLHD) inspection team visited the Lees Ferry Access Road to perform a culvert assessment of all the culverts along the 5.7 mile route. The culvert assessment report provided recommendations for various culverts. Those recommendations from the CFLHD culvert assessment report were implemented and are summarized in the following table.

Table 5 is a list of the proposed culverts with the replacement recommendations**.** CFLHD Culvert Assessment Report is provided in **Appendix H**.

Table 5 is a list of replacement recommendations for the proposed culverts locations**.**

ID No.	Station Feature	Existing Feature	Plan Designation	Replacement Recommendation	Upstream Invert (ft)	Downstream invert (ft)	Length (ft)
3	Sta 124+14	18"X20" Elliptical Pipe	D1	**24" Pipe Culvert**	3557.67	3556.55	56
4	Sta 128+13	24" CMP	D2	**24" Pipe Culvert**	3543.13	3541.05	67
5	Sta 132+88	18"X30" Elliptical CMP	D3	**36" Pipe Culvert**	3452.43	3540.27	61
6*	Sta 155+31	18"X30" Elliptical CMP	D4	**Eliminate Culvert**	N/A	N/A	N/A
7*	Sta 158+35	18"X30" Elliptical CMP	D5	**Eliminate Culvert**	N/A	N/A	N/A
8*	Sta 164+80	21"X36" Elliptical CMP	D6	**Eliminate Culvert**	N/A	N/A	N/A
9	Sta 174+48	12X12 Box Culvert	D7	**Keep existing RCBC. Provide outlet protection.**	N/A	N/A	N/A
15	Sta 211+60	12"X21" Elliptical CMP	D8	**24" Pipe Culvert**	3442.27	3441.05	61
16	Sta 218+36	12"X21" Elliptical CMP	D9	**24" Pipe Culvert**	3422.33	3421.21	50
17	Sta 222+25	12"X21" Elliptical CMP	D10	**24" Pipe Culvert**	3412.90	3412.45	48
19	Sta 243+29	2 – 48" CMP	D11	**3 Barrel 10' span by 5' high RCBC**	3343.52	3342.47	53
20*	Sta 247+24	12"X21" Elliptical CMP	D12	**Eliminate Culvert**	3350.57	3349.67	45
29	Sta 287+75	12"X21" Elliptical CMP	D13	**2 Barrel 36" Pipe Culvert**	3330.84	3329.89	48
n/a	Sta 292+50	n/a	NEW	**24" Pipe Culvert**	3331.74	3330.24	51
35*	Sta 331+24	18" CMP	NEW	**24" Pipe Culvert**	3182.65	3181.21	48
36*	Sta 333+03	18" CMP	NEW	**36" Pipe Culvert**	3178.43	3173.34	97
37*	Sta 335+43	18" CMP	NEW	**36" Pipe Culvert**	3184.92	3177.76	68
38*	Sta 340+60	18" CMP	NEW	**36" Pipe Culvert**	3194.42	3190.11	72
39*	Sta 355+86	24" CMP	NEW	**24" Pipe Culvert**	3233.60	3230.87	68
43*	Sta 403+08	2 – 48" CMP	NEW	**2-48" Pipe Culvert**	3227.72	3225.36	75

* Culvert recommendations from CFLHD culvert assessment report.

Table 5 – Proposed Culvert Replacement Recommendations

Culvert hydraulics was calculated with Federal Highway Administration HY-8 program, version 8.7.2.

The summary of the existing and proposed culvert analysis is presented in **Appendix C**.

3.2.2. Ditches

The roadside ditches were evaluated using rating curve for a general ditch typical section for the corridor. The rating curve plotted the water surface elevation versus the ditch slope by varying the discharge. The rating curve is used to determine the capacity of the roadside ditch based on the varying site conditions along the corridor.

Ditch hydraulics was calculated with Bentley's *Flowmaster*. The program was also used to generate the rating curves.

The ditch hydraulic analysis is shown in **Appendix D**.

3.2.3. Culvert Materials and End Treatment

New culverts and culverts that will be replaced in kind shall be the type of material that will meet or exceed the existing service life of the culvert it's replacing. The proposed culverts shall provide a beveled entrance treatment that will provide improved hydraulic efficiency.

3.2.4. Outlet Protection

The riprap outlet protection as shown in the project plans shall be provided to protect the drainage facility and mitigate long-term degradation.

3.2.5. Channels

The low-standard roadway criteria for a 25-year storm shall be used to evaluate the channel hydraulics. An existing and proposed channel model will be used to verify if the existing freeboard is either met or exceeded.

Channels were analyzed using the U.S. Army Corps of Engineers River Analysis System (HEC-RAS) program, Version 4.1.0 along with Bentley's *Flowmaster* and *CulvertMaster*. Cross sections for the HEC-RAS models were developed with topographic and digital terrain model (DTM) information obtained from a field survey dated March 2011. Ineffective flow areas associated with obstructions within cross-section were placed at a 1:1 ratio upstream and a 2:1 ratio downstream. Similarly, ineffective areas associated with culverts were also placed within model cross-sections. Each location was modeled and analyzed for both existing and proposed conditions. Models were reviewed at the design flow, 25-year event, and the channel forming events (2-year to 5-year). The 50-year model was used as the check storm.

The channel hydraulic analysis is shown in **Appendix E**.

4. RECOMMENDED DESIGN

4.1. Culverts

The existing drainage culvert crossing for the Lee's Ferry Access Road were evaluated and based on field recommendations the culverts fell into the following categories:

- Leave as is: Based on field recommendations, the culvert will remain with no drainage improvements proposed.

- Replace in kind: The existing drainage culverts often plug with sediment. Since the project is located in a sediment rich environment, this issue may not be completely solvable. Replacing the existing culverts with a larger cross culvert and/or installing additional cross culverts may mitigate this situation. Adjusting the skew angle to increase the gradient of the pipe can also increase the self cleaning velocity. No hydrology or hydraulics was preformed for the culverts replaced in kind.

- Evaluate design: Culverts identified to be evaluated were determined based on field recommendations. Hydrology and hydraulics analysis were performed to evaluate the existing condition and proposed condition. The models were used to verify that the existing capacity is either met or exceeded and improve the hydraulic performance of the crossing. Due to the sediment rich environment, the culverts are still susceptible to plugging.

Refer to **Table 3 & Table 5** for a list of the existing and proposed culverts with the recommended action.

4.1.1. Sta 155+31, Sta 158+35, Sta 164+80 – Eliminate Culverts

Per the CFLHD culvert assessment report recommendations, three proposed culverts replacements were eliminated. These culverts are subject to sediment laden runoff which is a recurring maintenance problem. The culvert assessment report recommended expanding the roadside paved ditch in this reach to capture and divert the runoff into Cathedral Wash rather than under the roadway. The runoff contributing to the three eliminated culverts were combined to size the revet mattress rundown at Cathedral Wash. The revet mattress rundown is sized adequately to accommodate the increased runoff. Ditch analysis is evaluated using a rating curve as discussed in this report. The paved ditch will see is significant sediment load from the runoff. The paved ditch will help mitigate the sediment load due to the increased ditch velocity but will not prevent it.

4.1.2. Sta 243+29 – No Name Wash

At No Name Wash, due to the undersized existing culverts the stream crossing overtops several times per year, during which the roadway must be closed. The existing alignment of the drainage crossing is offset from the natural flow path of the wash. A 3 barrel 10’ wide by 5’ high concrete box culvert is proposed at this location. The new box culvert will be realigned to closely match the natural flow path of the wash. A graded ditch northeast of the proposed box culvert will be used to convey the roadside ditch drainage into the existing wash. Channel grading for both the inlet and outlet end of the box culvert will be required.

4.1.3. Sta 324+00 - 72” Culvert Repair

Within the project limits there is a 72” culvert crossing that is in need of repair. A technical memorandum that documents various repair alternatives was developed. The repair to the existing 72” culvert would be made separate from the Lee’s Ferry roadway project.

A copy of the final technical memorandum is presented in **Appendix F**.

4.1.4. Sta 331+24 to Sta 403+08 – Culvert Replacements

Additional culvert replacements where added based on the CFLHD culvert assessment report. The culverts were either upsized based on the available pipe cover for replaced in kind. No hydrology or hydraulics was performed for the culvert replacements with the exception of the culvert recommendation at Sta 403+08. The analysis showed that the 2-48” culverts were adequate for the 25-year design storm.

4.1.5. Various Locations – Culvert Cleaning

Based on site visits and the culvert assessment report, locations of culverts that were in need of cleaning were denoted in the project plans.

4.2. Ditches

The paved roadside ditches were evaluated using a rating curve. Two general roadside ditch typical sections were evaluated for the corridor:

- Typical Roadway Paved Ditch Section: This section evaluates the ditch capacity for the 6:1 paved ditch section. The width of the paved ditch section is 6’ with a concrete curb to convey the drainage.
- Full Roadway Ditch Section: This section evaluates the ditch capacity for the 6:1 paved ditch section along with the adjacent roadside cut ditch. This typical section would apply in areas of higher flows where the paved ditch would both be utilized.

The existing paved ditches along Lee's Ferry Access Road are generally a "U" shape. The "U" ditches will be replaced with a paved "V" ditch with concrete curb to provide better access to cleaning the ditches after larger storm events. Due to the high sediment load in the area, the paved ditches will be susceptible to being plugged. The "V" ditch will allow improved equipment access for cleaning versus the "U" shaped channel.

4.3. Culvert Materials and End Treatment

Beveled edges should be used on all headwalls. Flared end sections shall be used on 48" culverts or smaller.

There are areas where an existing drop inlet is located inside the roadway clear zone. The existing drop inlets have limited capacity due to clogging. It is recommended that the drop inlets be replaced with a flared end section increase capacity and allow for improved sediment transport.

4.4. Outlet Protection

4.4.1. Sta 174+48 – Cathedral Wash (12'x12' Outlet)

Geotechnical reports for the region indicate conditions within the Lee's Ferry area are characterized as very loose soil with sparse vegetation. The channel dynamics of Cathedral Wash combined with a 20' high bluff immediately downstream of the 12'X12' RCBC outfall have compounded these conditions to produce extreme erosion within the region. Head cutting has migrated back to the outlet apron and surrounding embankment. The existing conditions model indicates that the culvert is under inlet control and velocities increase over 50% at the outlet.

The final design will entail a concrete pad immediately downstream of the outlet with a head cut wall doweled into the existing outlet apron. The depth of void from the face of the existing outlet apron is an average of 2'. This shall be filled used in the construction of the head cut wall. The eroded embankment, which is nearly vertical, will be retrofitted with gabion basket walls. The walls will be placed on either side of the outlet to protect the headwalls and apron from further erosion.

One hundred feet southwest of the 12'X12' RCBC outlet a roadside ditch has eroded into a well incised 4' to 8' ditch. Embankment soil has begun to slough off into the ditch and is in need of repair. The incised roadside ditch outlets along the previously mention bluff and will also continue to degrade.

Final design incorporated templates developed with InRoads XM software. The roadside ditch rundown vertical and geometric parameters were adjusted to control the depth and velocity within the ditch. A gabion basket wall opening at the outlet will further dissipate hydraulic energy before the discharge into Cathedral Wash. The entire system will work as a preventative maintenance from further degradation of the existing conditions.

The scour at the outlet was evaluated using HY-8 and was based on the available soil, flow and culvert geometry data. The soils information was obtained from the “Geotechnical and Pavement Design Report-Lee’s Ferry Access Road Improvements” dated October 27th, 2011 prepared by Yeh and Associates, Inc. The report did not have any soil borings in Cathedral Wash. Based on the available boring information, the nearest boring location to the area of interest was assumed in the scour calculations. The calculated scour depth is 10.6’. Based on field observations, there is evidence of rock outcroppings within Cathedral Wash that may prevent the scour from reaching that depth.

4.4.2. Sta 290+29 – Access Road Overtopping

This area is currently seeing erosion from sheet flow across the roadway. The sheet flow has caused erosion of the fill slopes in this area. A revet mattress is proposed to protect the roadway fill slope from erosion.

4.4.3. Various Locations – Outlet Protection

Based on site visits and the culvert assessment report, locations of additional outlet protection were denoted in the project plans.

4.5. Channels

The selected locations were modeled and analyzed for both existing and proposed conditions. A summary of the findings is as follows:

4.5.1. Sta 163+68 to Sta 170+76 – Tributary to Cathedral Wash

The existing conditions model indicates roadway overtopping at the furthest upstream dike during the design storm event and that both spur dikes are overtopped. The spur dikes will continue to erode with each storm event. Further downstream the thalweg velocity increases an additional 2 ft/s as the wash shifts from the right bank (embankment toe). Based on the existing conditions model the channel will continue to migrate into the embankment and the existing spur dikes will become ineffective. Two alternatives to mitigate existing conditions were presented during the initial design phase; an updated spur dike design utilizing gabion baskets or a fully lined revet mattress embankment. The final recommendation was to go with a fully lined revet mattress embankment.

The revet mattress design is retrofitted embankment protection at 2:1 slope with 4’ of bank protection. The toe of the embankment will be armored with 1 course of gabion baskets for toe down protection. Existing spur dikes will be removed. Cross sections of the existing model were updated with additional roughness (n = 0.050) and modified slopes to emulate the revet mattress design and removal of the existing spur dikes. Based on assessment velocities along the armored embankment are reduced from 10% - 30%. Furthermore, velocity distributions indicate that discharge momentum is shifted back towards the central portion of the wash, away from the armored embankment.

4.5.2. Sta 340+00 to Sta 345+00 – Embankment Erosion

The unnamed wash is pinched between the roadway embankment and the existing terrain. The wash has begun to lateral migrate into the embankment. In order to contain the migration, a gabion basket wall will be placed as a permanent structure in the region. Velocities still remain high in the region as per modeling output but the permanent structure will reduce the lateral migration of the bed stream.

5. SUMMARY

The Lee’s Ferry region is geotechnically characterized as very loose soils with sparse vegetation. Site photos also indicate is little to no vegetative matter or material providing cohesive strength to the soil. These conditions would relate to the embankments ability to withstand shear stresses associated with the discharge forces present in stream beds. Preliminary evaluation of the hydraulic conditions within the stream beds in the surrounding area have indicated a very dynamic or live bed with potential for scour and lateral migration along the embankments. Channel restoration and scour protection measures will minimize the impacts associated with these existing conditions.

During the 25-year storm event there is potential roadway overtopping and further degradation to the spur dikes. The channel will continue to migrate towards the back of curb. Removal of the existing spur dikes and providing a revet mattress lining along the unnamed wash from Sta 163+70 to 170+32 will mitigate the lateral migration and restore channel momentum to the center of the channel. The proposed lengthened turnout within the region will not adversely affect the channel dynamics since conveyance capacity will still be available.

The 12X12 RCBC outlet apron at Sta 174+48 is in need of immediate repair. If the head cutting continues to migrate within the region there could be permanent structural damage to the outlet and embankment failure. Reinforced concrete and gabion basket walls will mitigate potential erosion concerns at the outlet. The permanent structure will allow the discharge to dissipate its energy. The gabion wall will mitigate the potential of head cut migration. The roadside ditch improvement will be interconnected into the outlet protection to armor the entire region and mitigate further erosion to the region.

At approximately Sta 340+00, stream bed migration into the embankment has also become visible. The “pinch” point along the stream bed has reduced the conveyance capacity and increased velocities. As the velocities increase the lateral migration has also increased. In order to maximize the channel capacity and reduce the impact to the area, a gabion basket wall is proposed to mitigate further erosion of the roadway embankment.

6. REFERENCE

Central Federal Lands Highway Division, "Project Development and Design Manual", Chapter 7 Hydrology and Hydraulics, Draft April 2011.

U.S. Army Corps of Engineers, HEC-RAS Computer Program, Version 4.1.0.

U.S. Department of Agriculture, "NRCS-Web Soil Survey", December 2011.

U.S. Department of Transportation, Federal Highway Administration, "Hydraulics of Bridge Waterways", Hydraulic Design Series No. 1, May 2005.

U.S. Department of Transportation, Federal Highway Administration, "Hydraulic Design of Highway Culverts", Hydraulic Design Series No. 5, May 2005.

U.S. Department of Transportation, Federal Highway Administration, "Design of Riprap Revetment", Hydraulic Engineering Circular No. 11, March 1989.

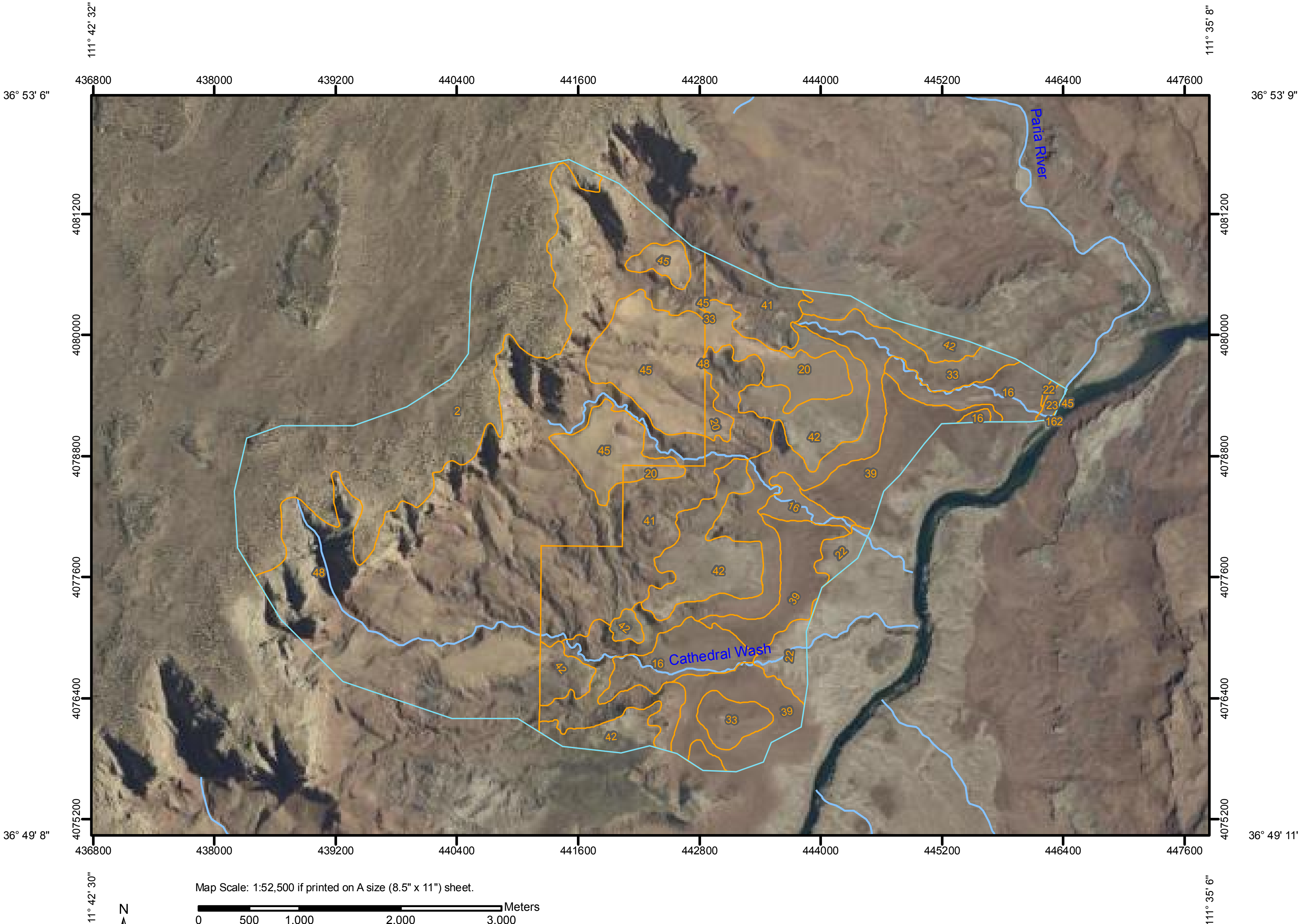
U.S. Department of Transportation, Federal Highway Administration, "Hydraulic Design of Energy Dissipaters for Culverts and Channels", Hydraulic Engineering Circular No. 14, July 2006.

U.S. Department of Transportation, Federal Highway Administration, "Design of Roadside Channel with Flexible Linings", Hydraulic Engineering Circular No. 15, September 2005.

U.S. Department of Transportation, Federal Highway Administration, "Stream Stability at Highway Structures", Hydraulic Engineering Circular No. 20, March 2001.

U.S. Geological Survey, U.S. Department of the Interior, “Methods for Estimating Magnitude and Frequency of Floods in the Southwestern United States”, Water-Supply Paper 2433, 1997.

Appendix A – Soil Classifications and Descriptions



Map Scale: 1:52,500 if printed on A size (8.5" x 11") sheet.

Meters: 0, 500, 1,000, 2,000, 3,000

Feet: 0, 2,500, 5,000, 10,000, 15,000

MAP LEGEND

Area of Interest (AOI)

Area of Interest (AOI)

Soils

Soil Map Units

Special Point Features

- Blowout
- Borrow Pit
- Clay Spot
- Closed Depression
- Gravel Pit
- Gravelly Spot
- Landfill
- Lava Flow
- Marsh or swamp
- Mine or Quarry
- Miscellaneous Water
- Perennial Water
- Rock Outcrop
- Saline Spot
- Sandy Spot
- Severely Eroded Spot
- Sinkhole
- Slide or Slip
- Sodic Spot
- Spoil Area
- Stony Spot
- Very Stony Spot
- Wet Spot
- Other

Special Line Features

- Gully
- Short Steep Slope
- Other

Political Features

- Cities

Water Features

- Streams and Canals

Transportation

- Rails
- Interstate Highways
- US Routes
- Major Roads
- Local Roads

MAP INFORMATION

Map Scale: 1:52,500 if printed on A size (8.5" × 11") sheet.

The soil surveys that comprise your AOI were mapped at 1:24,000.

Please rely on the bar scale on each map sheet for accurate map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL: http://websoilsurvey.nrcs.usda.gov
Coordinate System: UTM Zone 12N NAD83

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Coconino County Area, Arizona, North Kaibab Part
Survey Area Data: Version 8, May 2, 2011

Soil Survey Area: Glen Canyon National Recreation Area
Survey Area Data: Version 1, Oct 7, 2010

Soil Survey Area: Grand Canyon Area, Arizona, Parts of Coconino and Mohave Counties
Survey Area Data: Version 7, May 2, 2011

Your area of interest (AOI) includes more than one soil survey area. These survey areas may have been mapped at different scales, with a different land use in mind, at different times, or at different levels of detail. This may result in map unit symbols, soil properties, and interpretations that do not completely agree across soil survey area boundaries.

Date(s) aerial images were photographed: 6/12/2007; 6/8/2007

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Map Unit Legend

Coconino County Area, Arizona, North Kaibab Part (AZ629)			
Map Unit Symbol	**Map Unit Name**	**Acres in AOI**	**Percent of AOI**
2	Arches-Pensom complex, 4 to 12 percent slopes	999.7	15.1%
45	Sheppard loamy fine sand, 5 to 15 percent slopes	456.0	6.9%
48	Torriorthents-Rock outcrop complex, 25 to 65 percent slopes	2,114.3	32.0%
Subtotals for Soil Survey Area		**3,570.1**	**54.1%**
Totals for Area of Interest		**6,604.4**	**100.0%**

Glen Canyon National Recreation Area (UT689)			
Map Unit Symbol	**Map Unit Name**	**Acres in AOI**	**Percent of AOI**
16	Myton very gravelly sandy loam, 5 to 18 percent slopes, very bouldery	326.1	4.9%
20	Pagina-Denazar complex, 2 to 14 percent slopes	181.6	2.8%
22	Pennell cobbly loam, 3 to 10 percent slopes	107.2	1.6%
23	Razito-Riverwash complex, 1 to 4 percent slopes, rarely flooded	12.3	0.2%
33	Rock outcrop-Torriorthents complex, 20 to 65 percent slopes, extremely bouldery	671.9	10.2%
39	Somorent family-Rock outcrop complex, 5 to 12 percent slopes	509.6	7.7%
41	Torriorthents-Rock outcrop-Badland complex, 4 to 70 percent slopes, extremely bouldery	595.8	9.0%
42	Tsaya-Rock outcrop complex, 2 to 18 percent slopes	629.7	9.5%
45	Water	0.1	0.0%
Subtotals for Soil Survey Area		**3,034.2**	**45.9%**
Totals for Area of Interest		**6,604.4**	**100.0%**

Grand Canyon Area, Arizona, Parts of Coconino and Mohave Counties (AZ701)			
Map Unit Symbol	**Map Unit Name**	**Acres in AOI**	**Percent of AOI**
162	Water	0.1	0.0%
Subtotals for Soil Survey Area		**0.1**	**0.0%**
Totals for Area of Interest		**6,604.4**	**100.0%**

RUSLE2 Related Attributes

This report summarizes those soil attributes used by the Revised Universal Soil Loss Equation Version 2 (RUSLE2) for the map units in the selected area. The report includes the map unit symbol, the component name, and the percent of the component in the map unit. Soil property data for each map unit component include the hydrologic soil group, erosion factors Kf for the surface horizon, erosion factor T, and the representative percentage of sand, silt, and clay in the surface horizon.

Report—RUSLE2 Related Attributes

RUSLE2 Related Attributes– Glen Canyon National Recreation Area								
Map symbol and soil name	Pct. of map unit	Slope length (ft)	Hydrologic group	Kf	T factor	Representative value		
						% Sand	% Silt	% Clay
16—Myton very gravelly sandy loam, 5 to 18 percent slopes, very bouldery								
Myton	95	16	A	.20	5	75.0	13.0	12.0
22—Pennell cobbly loam, 3 to 10 percent slopes								
Pennell	85	56	D	.43	1	44.0	41.0	15.0
33—Rock outcrop-Torriorthents complex, 20 to 65 percent slopes, extremely bouldery								
Rock outcrop	60	—	—	—	—	—	—	—
Torriorthents	40	16	D	.37	2	43.0	39.0	18.0
39—Somorent family-Rock outcrop complex, 5 to 12 percent slopes								
Somorent family	85	56	D	.24	1	70.0	13.0	17.0
Rock outcrop	10	—	—	—	—	—	—	—
42—Tsaya-Rock outcrop complex, 2 to 18 percent slopes								
Tsaya	65	56	D	.20	1	60.0	9.0	31.0
Rock outcrop	20	—	—	—	—	—	—	—

Data Source Information

Soil Survey Area: Glen Canyon National Recreation Area
Survey Area Data: Version 1, Oct 7, 2010

Glen Canyon National Recreation Area

33—Rock outcrop-Torriorthents complex, 20 to 65 percent slopes, extremely bouldery

Map Unit Setting

Elevation: 3,120 to 4,200 feet
Mean annual precipitation: 6 to 10 inches
Mean annual air temperature: 54 to 57 degrees F
Frost-free period: 150 to 180 days

Map Unit Composition

Rock outcrop: 60 percent
Torriorthents and similar soils: 40 percent

Description of Torriorthents

Setting

Landform: Plateaus
Landform position (two-dimensional): Footslope
Landform position (three-dimensional): Base slope
Down-slope shape: Convex
Across-slope shape: Linear
Parent material: Sandy and gravelly talus derived from sandstone and shale

Properties and qualities

Slope: 20 to 65 percent
Surface area covered with cobbles, stones or boulders: 15.0 percent
Depth to restrictive feature: 4 to 20 inches to paralithic bedrock
Drainage class: Somewhat excessively drained
Capacity of the most limiting layer to transmit water (Ksat): Very low to moderately high (0.00 to 0.20 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum content: 5 percent
Maximum salinity: Nonsaline (0.0 to 2.0 mmhos/cm)
Sodium adsorption ratio, maximum: 1.0
Available water capacity: Very low (about 1.4 inches)

Interpretive groups

Land capability (nonirrigated): 7c
Ecological site: Talus Slope (Blackbrush-Shadscale) (R035XY018UT)

Typical profile

0 to 2 inches: Channery loam
2 to 10 inches: Very flaggy coarse sandy loam
10 to 17 inches: Extremely parachannery coarse sandy loam

17 to 27 inches: Bedrock

Data Source Information

Soil Survey Area: Coconino County Area, Arizona, North Kaibab Part
Survey Area Data: Version 8, May 2, 2011

Soil Survey Area: Glen Canyon National Recreation Area
Survey Area Data: Version 1, Oct 7, 2010

Soil Survey Area: Grand Canyon Area, Arizona, Parts of Coconino and Mohave Counties
Survey Area Data: Version 7, May 2, 2011

Glen Canyon National Recreation Area

39—Somorent family-Rock outcrop complex, 5 to 12 percent slopes

Map Unit Setting

Elevation: 3,120 to 4,000 feet
Mean annual precipitation: 6 to 10 inches
Mean annual air temperature: 54 to 57 degrees F
Frost-free period: 150 to 180 days

Map Unit Composition

Somorent family and similar soils: 85 percent
Rock outcrop: 10 percent

Description of Somorent Family

Setting

Landform: Plateaus
Landform position (two-dimensional): Summit
Landform position (three-dimensional): Interfluve
Down-slope shape: Linear
Across-slope shape: Concave
Parent material: Eolian sands and/or residuum weathered from sandstone and shale

Properties and qualities

Slope: 5 to 12 percent
Depth to restrictive feature: 7 to 15 inches to paralithic bedrock
Drainage class: Somewhat excessively drained
Capacity of the most limiting layer to transmit water (Ksat): Very low to moderately high (0.00 to 0.20 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum content: 5 percent
Gypsum, maximum content: 5 percent
Maximum salinity: Nonsaline (0.0 to 2.0 mmhos/cm)
Sodium adsorption ratio, maximum: 1.0
Available water capacity: Very low (about 0.7 inches)

Interpretive groups

Land capability (nonirrigated): 7c
Ecological site: Desert Shallow Sandy Loam (Shadscale) (R035XY130UT)

Typical profile

0 to 2 inches: Channery sandy loam
2 to 7 inches: Parachannery sandy loam

7 to 17 inches: Bedrock

Data Source Information

Soil Survey Area: Coconino County Area, Arizona, North Kaibab Part
Survey Area Data: Version 8, May 2, 2011

Soil Survey Area: Glen Canyon National Recreation Area
Survey Area Data: Version 1, Oct 7, 2010

Soil Survey Area: Grand Canyon Area, Arizona, Parts of Coconino and Mohave Counties
Survey Area Data: Version 7, May 2, 2011

Glen Canyon National Recreation Area

16—Myton very gravelly sandy loam, 5 to 18 percent slopes, very bouldery

Map Unit Setting

Elevation: 3,150 to 4,000 feet
Mean annual precipitation: 6 to 10 inches
Mean annual air temperature: 54 to 57 degrees F
Frost-free period: 150 to 180 days

Map Unit Composition

Myton and similar soils: 95 percent

Description of Myton

Setting

Landform: Plateaus
Landform position (two-dimensional): Footslope
Landform position (three-dimensional): Base slope
Down-slope shape: Linear
Across-slope shape: Concave
Parent material: Colluvium and/or slope alluvium derived from sandstone and shale

Properties and qualities

Slope: 5 to 18 percent
Surface area covered with cobbles, stones or boulders: 4.0 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Somewhat excessively drained
Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.60 to 2.00 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum content: 5 percent
Maximum salinity: Nonsaline (0.0 to 2.0 mmhos/cm)
Sodium adsorption ratio, maximum: 1.0
Available water capacity: Low (about 3.2 inches)

Interpretive groups

Land capability (nonirrigated): 7c
Ecological site: Desert Stony Loam (Shadscale-Bud Sagebrush) (R035XY136UT)

Typical profile

0 to 2 inches: Very gravelly sandy loam
2 to 7 inches: Gravelly sandy loam
7 to 30 inches: Extremely gravelly loamy sand
30 to 47 inches: Very gravelly loamy coarse sand
47 to 60 inches: Very gravelly loam

60 to 64 inches: Very stony sandy loam

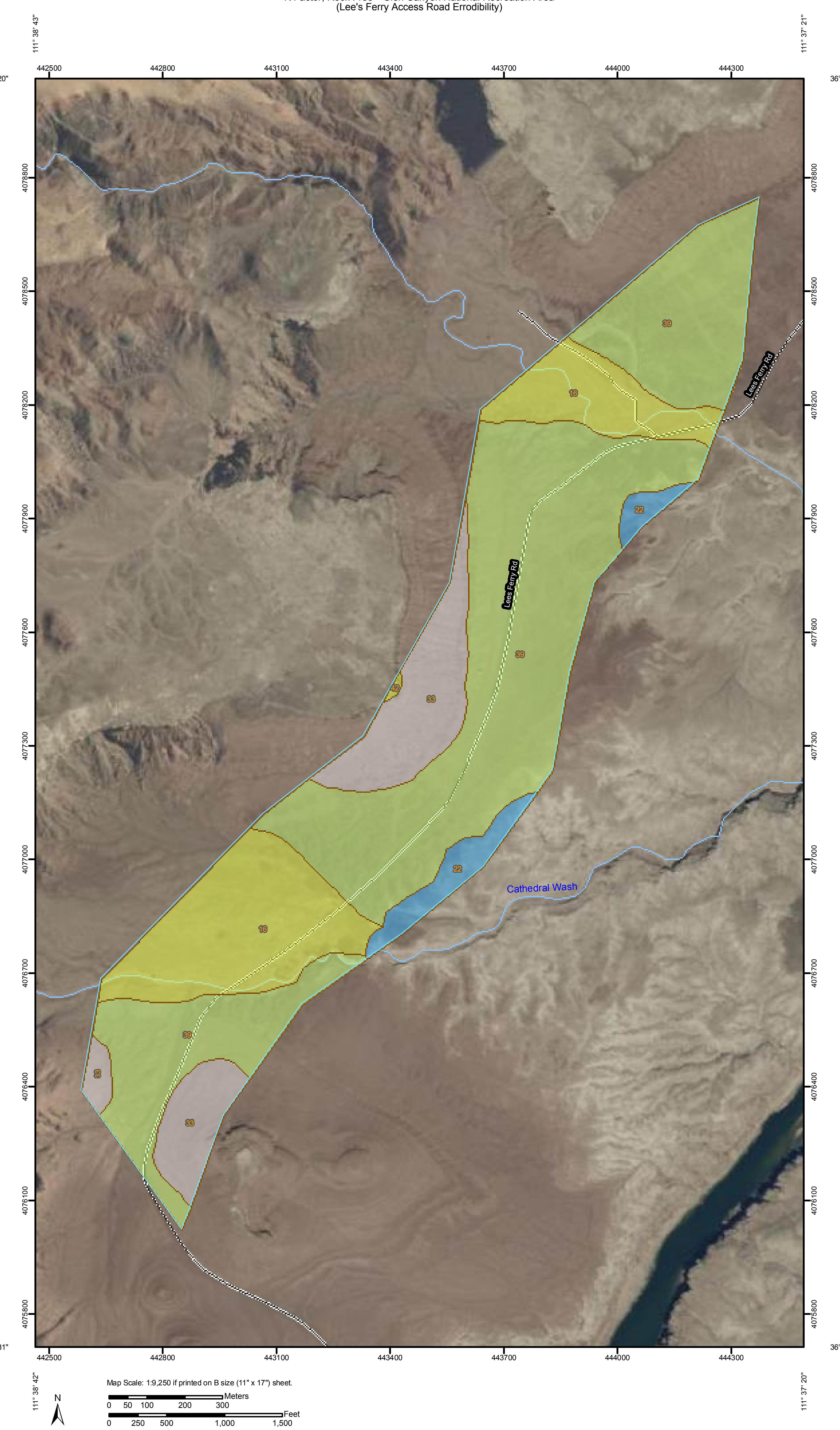
Data Source Information

Soil Survey Area: Coconino County Area, Arizona, North Kaibab Part
Survey Area Data: Version 8, May 2, 2011

Soil Survey Area: Glen Canyon National Recreation Area
Survey Area Data: Version 1, Oct 7, 2010

Soil Survey Area: Grand Canyon Area, Arizona, Parts of Coconino and Mohave Counties
Survey Area Data: Version 7, May 2, 2011

K Factor, Rock Free—Glen Canyon National Recreation Area
(Lee's Ferry Access Road Errodibility)



Map Scale: 1:9,250 if printed on B size (11" x 17") sheet.

N

Meters: 0 50 100 200 300

Feet: 0 250 500 1,000 1,500

MAP LEGEND

Area of Interest (AOI)

Area of Interest (AOI)

Soils

Soil Map Units

Soil Ratings

.02

.05

.10

.15

.17

.20

.24

.28

.32

.37

.43

.49

.55

.64

Not rated or not available

Political Features

Cities

Water Features

Streams and Canals

Transportation

Rails

Interstate Highways

US Routes

Major Roads

Local Roads

MAP INFORMATION

Map Scale: 1:9,250 if printed on B size (11" × 17") sheet.

The soil surveys that comprise your AOI were mapped at 1:24,000.

Warning: Soil Map may not be valid at this scale.

Enlargement of maps beyond the scale of mapping can cause misunderstanding of the detail of mapping and accuracy of soil line placement. The maps do not show the small areas of contrasting soils that could have been shown at a more detailed scale.

Please rely on the bar scale on each map sheet for accurate map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL: http://websoilsurvey.nrcs.usda.gov
Coordinate System: UTM Zone 12N NAD83

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Glen Canyon National Recreation Area
Survey Area Data: Version 1, Oct 7, 2010

Date(s) aerial images were photographed: 6/12/2007; 6/8/2007

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

K Factor, Rock Free

K Factor, Rock Free— Summary by Map Unit — Glen Canyon National Recreation Area (UT689)				
Map unit symbol	**Map unit name**	**Rating**	**Acres in AOI**	**Percent of AOI**
16	Myton very gravelly sandy loam, 5 to 18 percent slopes, very bouldery	.20	66.7	21.1%
22	Pennell cobbly loam, 3 to 10 percent slopes	.43	12.5	3.9%
33	Rock outcrop-Torriorthents complex, 20 to 65 percent slopes, extremely bouldery		41.1	13.0%
39	Somorent family-Rock outcrop complex, 5 to 12 percent slopes	.24	195.8	61.9%
42	Tsaya-Rock outcrop complex, 2 to 18 percent slopes	.20	0.4	0.1%
Totals for Area of Interest			**316.4**	**100.0%**

Description

Erosion factor K indicates the susceptibility of a soil to sheet and rill erosion by water. Factor K is one of six factors used in the Universal Soil Loss Equation (USLE) and the Revised Universal Soil Loss Equation (RUSLE) to predict the average annual rate of soil loss by sheet and rill erosion in tons per acre per year. The estimates are based primarily on percentage of silt, sand, and organic matter and on soil structure and saturated hydraulic conductivity (Ksat). Values of K range from 0.02 to 0.69. Other factors being equal, the higher the value, the more susceptible the soil is to sheet and rill erosion by water.

"Erosion factor Kf (rock free)" indicates the erodibility of the fine-earth fraction, or the material less than 2 millimeters in size.

Rating Options

Aggregation Method: Dominant Condition

Aggregation is the process by which a set of component attribute values is reduced to a single value that represents the map unit as a whole.

A map unit is typically composed of one or more "components". A component is either some type of soil or some nonsoil entity, e.g., rock outcrop. For the attribute being aggregated, the first step of the aggregation process is to derive one attribute value for each of a map unit's components. From this set of component attributes, the next step of the aggregation process derives a single value that represents the map unit as a whole. Once a single value for each map unit is derived, a thematic map for soil map units can be rendered. Aggregation must be done because, on any soil map, map units are delineated but components are not.

For each of a map unit's components, a corresponding percent composition is recorded. A percent composition of 60 indicates that the corresponding component typically makes up approximately 60% of the map unit. Percent composition is a critical factor in some, but not all, aggregation methods.

The aggregation method "Dominant Condition" first groups like attribute values for the components in a map unit. For each group, percent composition is set to the sum of the percent composition of all components participating in that group. These groups now represent "conditions" rather than components. The attribute value associated with the group with the highest cumulative percent composition is returned. If more than one group shares the highest cumulative percent composition, the corresponding "tie-break" rule determines which value should be returned. The "tie-break" rule indicates whether the lower or higher group value should be returned in the case of a percent composition tie.

The result returned by this aggregation method represents the dominant condition throughout the map unit only when no tie has occurred.

Component Percent Cutoff: *None Specified*

Components whose percent composition is below the cutoff value will not be considered. If no cutoff value is specified, all components in the database will be considered. The data for some contrasting soils of minor extent may not be in the database, and therefore are not considered.

Tie-break Rule: Higher

The tie-break rule indicates which value should be selected from a set of multiple candidate values, or which value should be selected in the event of a percent composition tie.

Layer Options: Surface Layer

For an attribute of a soil horizon, a depth qualification must be specified. In most cases it is probably most appropriate to specify a fixed depth range, either in centimeters or inches. The Bottom Depth must be greater than the Top Depth, and the Top Depth can be greater than zero. The choice of "inches" or "centimeters" only applies to the depth of soil to be evaluated. It has no influence on the units of measure the data are presented in.

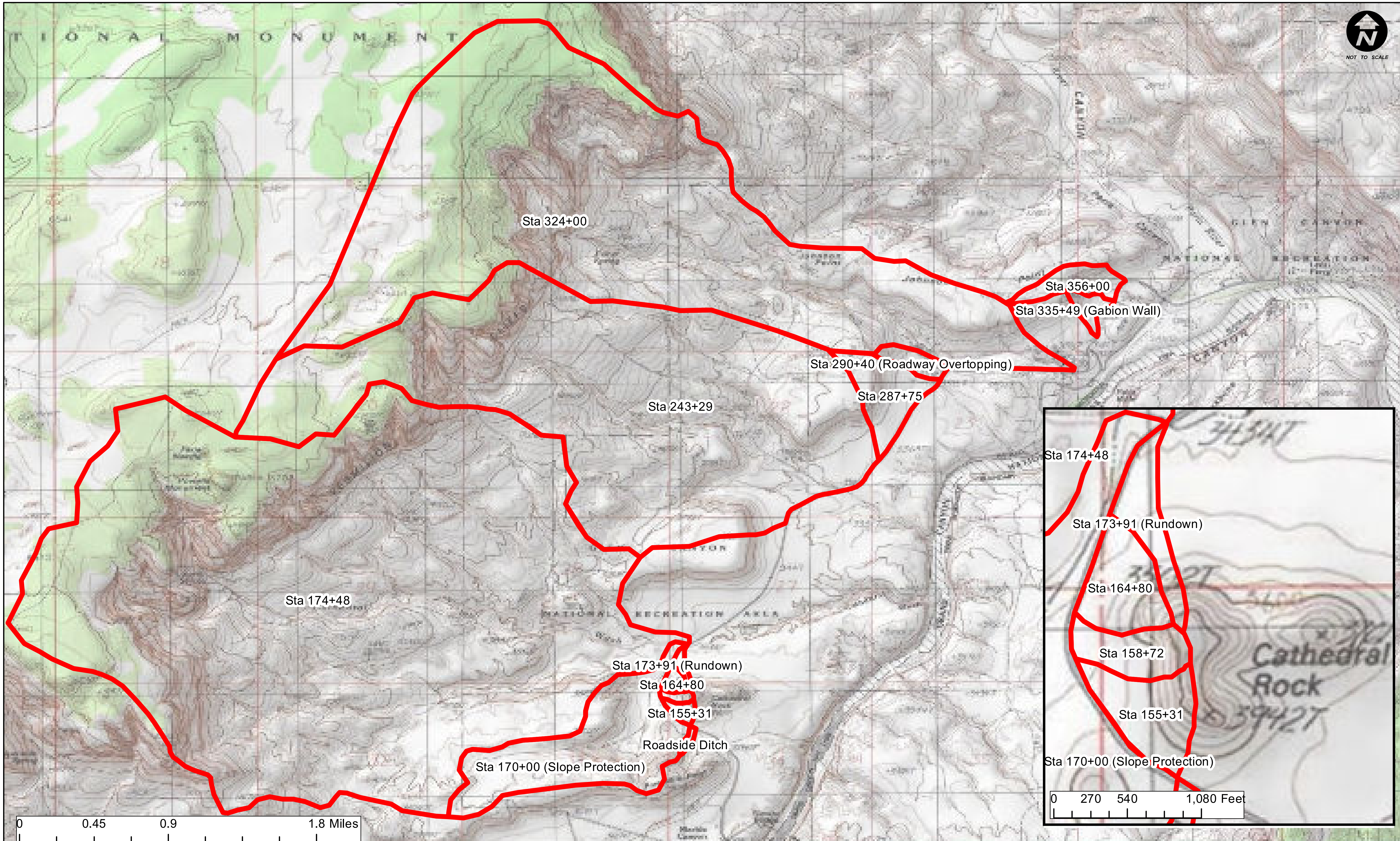
When "Surface Layer" is specified as the depth qualifier, only the surface layer or horizon is considered when deriving a value for a component, but keep in mind that the thickness of the surface layer varies from component to component.

When "All Layers" is specified as the depth qualifier, all layers recorded for a component are considered when deriving the value for that component.

Whenever more than one layer or horizon is considered when deriving a value for a component, and the attribute being aggregated is a numeric attribute, a weighted average value is returned, where the weighting factor is the layer or horizon thickness.

Appendix B – Hydrologic Calculations

Lee's Ferry Access Road Project



Legend

Delineations

HDR

HDR PROJECT NO. 160338
MAY 2012

Regression 93-419 Blakemore et al. (1994) **Region 08**

COLUMN FORMAT Data From HUC-8: h5080302

A Area (sq mi) Part 1= 0.49281

H Height or Elevation diffe Hi= 4000 Lo= 3432

Height Average Have 3716.0

Watershed Name	Recurrence Interval, Years	A	White Paper	ADOT Average Stnd Error in %	Low Adjustment (-) for Stnd Error	USGS Average Stnd Error in %	High Adjustment (-) for Stnd Error
Lee's Ferry Sta 170+00 Cathedral Wash Slope Protection	2	0.493	110	70%	33	72%	187
	5	0.493	355	60%	142	62%	569
	10	0.493	626	55%	282	57%	970
	25	0.493	1,117	52%	536	54%	1697
	50	0.493	1,608	51%	788	53%	2428
	100	0.493	2,213	51%	1085	53%	3342

Regression 93-419 Blakemore et al. (1994) **Region 08**

COLUMN FORMAT Data From HUC-8: h5080302

A Area (sq mi) Part 1= 5.55247

H Height or Elevation diffe Hi= 6500 Lo= 3432

Height Average Have 4966.0

Watershed Name	Recurrence Interval, Years	A	White Paper	ADOT Average Stnd Error in %	Low Adjustment (-) for Stnd Error	USGS Average Stnd Error in %	High Adjustment (-) for Stnd Error
Lee's Ferry Sta 174+48 Culvert (D7)	2	5.552	275	70%	83	72%	468
	5	5.552	727	60%	291	62%	1164
	10	5.552	1,167	55%	525	57%	1809
	25	5.552	1,924	52%	923	54%	2924
	50	5.552	2,646	51%	1297	53%	3996
	100	5.552	3,478	51%	1704	53%	5252

Regression 93-419 Blakemore et al. (1994) **Region 08**

COLUMN FORMAT Data From HUC-8: h5080302

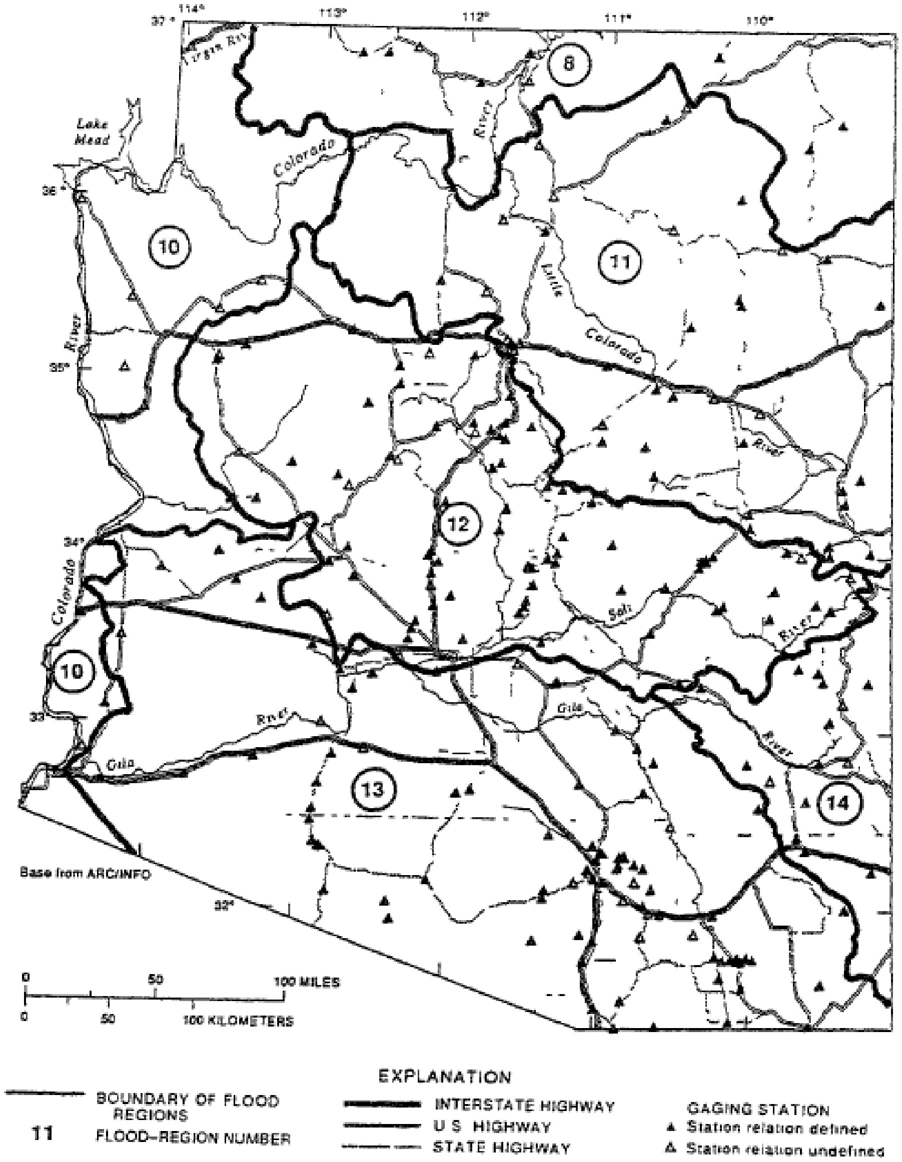
A Area (sq mi) Part 1= 2.79089

H Height or Elevation diffe Hi= 6460 Lo= 3348

Height Average Have 4904.0

Watershed Name	Recurrence Interval, Years	A	White Paper	ADOT Average Stnd Error in %	Low Adjustment (-) for Stnd Error	USGS Average Stnd Error in %	High Adjustment (-) for Stnd Error
Lee's Ferry Sta 243+29 Culvert (D11)	2	2.791	198	70%	59	72%	336
	5	2.791	543	60%	217	62%	868
	10	2.791	887	55%	399	57%	1374
	25	2.791	1,486	52%	713	54%	2258
	50	2.791	2,063	51%	1011	53%	3115
	100	2.791	2,738	51%	1342	53%	4134

FIGURE 10-9
FLOOD REGIONS IN ARIZONA



HDR Engineering, Inc.

3200 E. Camelback Road
Suite 350
Phoenix, AZ 85018-2311

Phone (602) 522-7700
Fax (602) 522-7707
www.hdrinc.com

FIGURE 10-14

SCATTER DIAGRAM OF INDEPENDENT VARIABLES FOR R8 REGRESSION EQUATIO

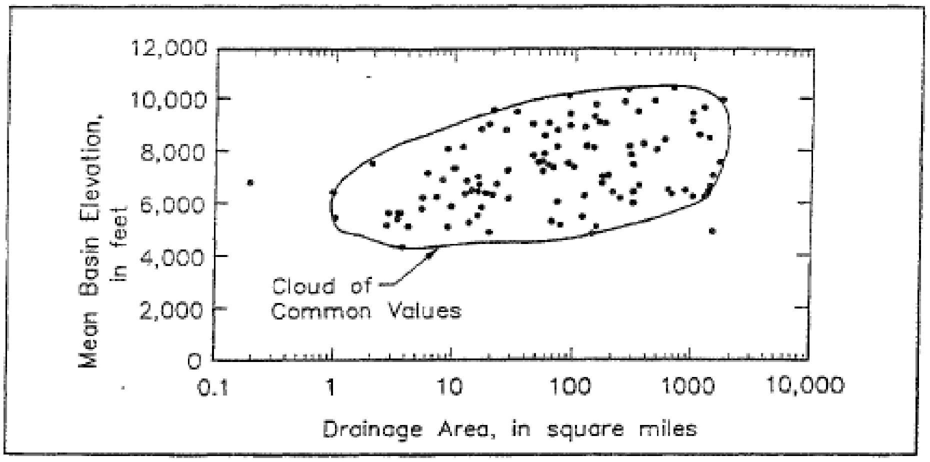
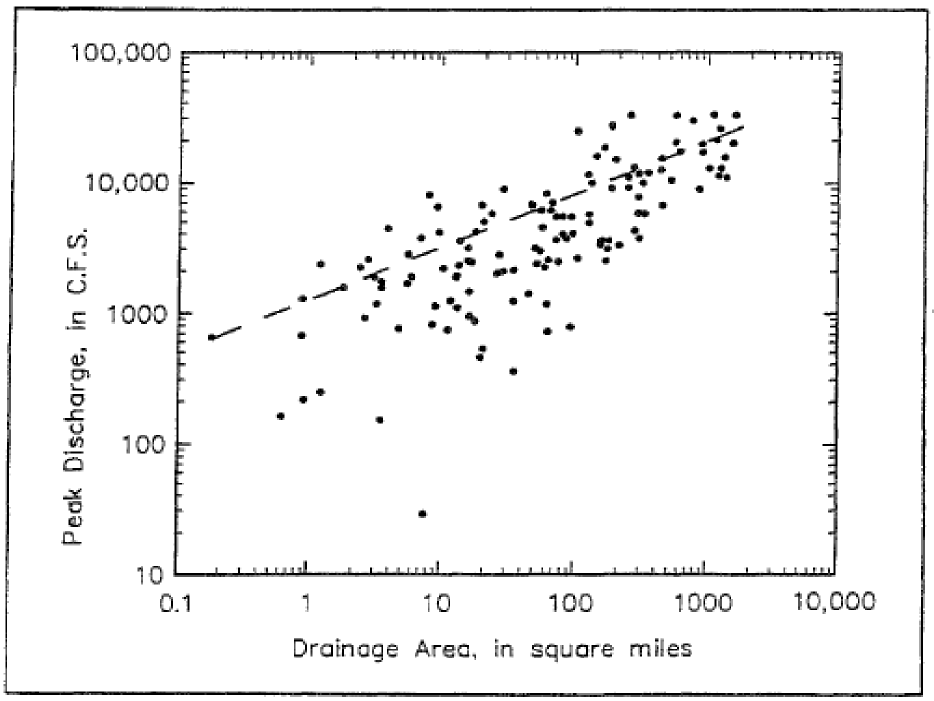


FIGURE 10-15

Q_{100} DATA POINTS AND 100-YEAR PEAK DISCHARGE RELATION FOR R8



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www.hdrinc.com

TABLE 10-3

FLOOD MAGNITUDE-FREQUENCY RELATIONS FOR THE FOUR CORNERS REGION (R8)

Equation: Q, peak discharge, in cubic feet per second; AREA, drainage area, in square miles; and ELEV, mean basin elevation, in feet divided by 1,000.

Recurrence interval, in years	Equation	Average standard error of model, in percent
2	$Q = 598\ AREA^{0.501}\ ELEV^{-1.02}$	70
5	$Q = 2{,}620\ AREA^{0.449}\ ELEV^{-1.28}$	60
10	$Q = 5{,}310\ AREA^{0.425}\ ELEV^{-1.40}$	55
25	$Q = 10{,}500\ AREA^{0.403}\ ELEV^{-1.49}$	52
50	$Q = 16{,}000\ AREA^{0.390}\ ELEV^{-1.54}$	51
100	$Q = 23{,}300\ AREA^{0.377}\ ELEV^{-1.59}$	51

Job No 160338

Computation

Project: Central Federal Lands - Lees Ferry	Computed: JM	Date: 7/12/2012
Subject: Rational Method	Checked: RC	
Task: IDF		

HYDROLOGY

I-D-F EQUATION PARAMETERS-STEEL FORMULA

$$i = a / (D + b)$$

i	the desired intensity for a given duration and frequency
a	I-D-F equation parameter
D	duration in hours
b	I-D-F equation parameter

DURATION		*SITE SPECIFIC INTENSITY*					*IDF EQUATION PARAMETERS*									
							2-year		*10-year*		*25-year*		*50-year*		*100-year*	
D		i_{2}	i_{10}	i_{25}	i_{50}	i_{100}	*a*	*b*	*a*	*b*	*a*	*b*	*a*	*b*	*a*	*b*
min.	*hours*	*in/hr*	*in/hr*	*in/hr*	*in/hr*	*in/hr*	*in/hr*	*in/hr*	*in/hr*	*in/hr*	*in/hr*	*in/hr*	*in/hr*	*in/hr*	*in/hr*	*in/hr*
5	0.08	1.54	2.74	3.71	4.60	5.64										
10	0.17	1.16	2.08	2.82	3.49	4.30	0.39	0.17	0.72	0.18	0.98	0.18	1.21	0.18	1.51	0.18
15	0.25	0.96	1.72	2.33	2.89	3.55	0.48	0.24	0.83	0.23	1.12	0.23	1.40	0.23	1.70	0.23
30	0.50	0.65	1.16	1.57	1.94	2.39	0.50	0.27	0.89	0.27	1.20	0.27	1.48	0.26	1.83	0.27
60	1.00	0.40	0.72	0.97	1.20	1.48	0.53	0.31	0.94	0.31	1.27	0.31	1.57	0.31	1.94	0.31

Computation

Project: Central Federal Lands - Lees Ferry	Computed: JM	Date: 7/12/2012
Subject: Rational Method	Checked: RC	
Task: Calculate 25-year time of concentration		

Time of Concentration: Tc=11.4*(L^0.5)*(Kb^0.52)*(S^-0.31)*(i^-0.38)

Basin ID	Area	Storm Event	Assumed Tc	Intensity	Length	Kb*	Upstream	Downstream	Slope	Calculated Tc	
	(sqmi)		(min)	(in/hr)	(mi)		**Elevation**	**Elevation**	(ft/mile)	(hr)	(min)
Roadside Ditch	0.006	25yr	5.0	3.71	0.194	0.10	3900.0	3550.0	1804.12	0.09	5.4
Sta 155+00	0.014	25yr	7.4	3.22	0.303	0.10	3900.0	3525.0	1237.62	0.13	8.0
Sta 158+72	0.010	25yr	5.3	3.64	0.218	0.10	3900.0	3500.0	1834.86	0.10	5.7
Sta 165+00	0.014	25yr	6.6	3.37	0.275	0.10	3850.0	3450.0	1454.55	0.12	7.1
Sta 174+59 (New Ditch)	0.010	25yr	8.0	3.12	0.342	0.10	3850.0	3440.0	1198.83	0.15	8.7
Sta 288+00	0.141	25yr	27.2	1.67	1.210	0.10	3800.0	3333.0	385.95	0.49	29.5
Sta 290+40	0.038	25yr	8.5	3.04	0.379	0.10	3800.0	3334.0	1229.55	0.15	9.2
Sta 335+49	0.028	25yr	7.4	3.22	0.334	0.10	3675.0	3200.0	1422.16	0.13	8.1
Sta 356+00	0.072	25yr	13.1	2.49	0.620	0.10	3750.0	3230.0	838.71	0.24	14.3
Sta 403+08	0.390	25yr	18.3	2.11	1.265	0.10	5000.0	3150.0	1462.45	0.30	18.3

* Table 2-1 from ADOT Highway Drainage Design Manual Hydrology dated March 1993

Job No. 160338

Computation

Project: Central Federal Lands - Lees Ferry	Computed: JM	Date: 7/12/2012
Subject: Rational Method	Checked: RC	
Task: Calculate 100-year time of concentration		

Time of Concentration: Tc=11.4*(L^0.5)*(Kb^0.52)*(S^-0.31)*(i^-0.38)

Basin ID	Area	Storm Event	Assumed Tc	Intensity	Length	Kb*	Upstream	Downstream	Slope	Calculated Tc	
	(sqmi)		(min)	(in/hr)	(mi)		**Elevation**	**Elevation**	(ft/mile)	(hr)	(min)
Roadside Ditch	0.006	100yr	4.6	5.78	0.194	0.10	3900.0	3550.0	1804.12	0.08	4.6
Sta 155+00	0.014	100yr	6.7	5.10	0.303	0.10	3900.0	3525.0	1237.62	0.11	6.7
Sta 158+72	0.010	100yr	4.8	5.71	0.218	0.10	3900.0	3500.0	1834.86	0.08	4.8
Sta 165+00	0.014	100yr	6.0	5.31	0.275	0.10	3850.0	3450.0	1454.55	0.10	6.0
Sta 174+59 (New Ditch)	0.010	100yr	7.3	4.93	0.342	0.10	3850.0	3440.0	1198.83	0.12	7.3
Sta 288+00	0.141	100yr	24.5	2.72	1.210	0.10	3800.0	3333.0	385.95	0.41	24.5
Sta 290+40	0.038	100yr	7.7	4.83	0.379	0.10	3800.0	3334.0	1229.55	0.13	7.7
Sta 335+49	0.028	100yr	6.8	5.07	0.334	0.10	3675.0	3200.0	1422.16	0.11	6.8
Sta 356+00	0.072	100yr	11.9	3.98	0.620	0.10	3750.0	3230.0	838.71	0.20	11.9
Sta 403+08	0.390	100yr	15.0	3.55	1.265	0.10	5000.0	3150.0	1462.45	0.25	15.0

* Table 2-1 from ADOT Highway Drainage Design Manual Hydrology dated March 1993

Job No. 160338

Computation

Project: Central Federal Lands - Lees Ferry	Computed: JM	Date: 7/12/2012
Subject: Rational Method	Checked: RC	
Task: Calculate 25-year flow		

Basin ID	Storm Event	Area (Acres)	L_0 (ft)	T_i (min.)	T_t (min.)	i_{25} (in/hr)	C	Q (cfs)
Roadside Ditch	25yr	3.8	1024	5.4	10.0	2.82	0.41	4
Sta 155+00	25yr	9.3	1600	8.0	10.0	2.82	0.41	11
Sta 158+72	25yr	6.3	1151	5.7	10.0	2.82	0.41	7
Sta 165+00	25yr	8.7	1452	7.1	10.0	2.82	0.41	10
Sta 174+59 (New Ditch)	25yr	6.6	1806	8.7	10.0	2.82	0.41	8
Sta 288+00	25yr	90.5	6389	29.5	29.5	1.59	0.41	59
Sta 290+40	25yr	24.5	2001	9.2	10.0	2.82	0.41	28
Sta 335+49	25yr	17.9	1764	8.1	10.0	2.82	0.41	21
Sta 356+00	25yr	46.1	3274	14.3	14.3	2.39	0.41	45
Sta 403+08	25yr	249.6	6679	18.3	18.3	2.11	0.41	216

Job No. 160338

Computation

Project: Central Federal Lands - Lees Ferry	Computed: JM	Date: 7/12/2012
Subject: Rational Method	Checked: RC	
Task: Calculate 100-year flow		

Basin	Storm	Area	L_0	T_i	T_t	i_{100}	C	Q
ID	Event	(Acres)	(ft)	(min.)	(min.)	(in/hr)		(cfs)
Roadside Ditch	100yr	3.8	1024	4.6	10.0	4.30	0.53	9
Sta 155+00	100yr	9.3	1600	6.7	10.0	4.30	0.53	21
Sta 158+72	100yr	6.3	1151	4.8	10.0	4.30	0.53	14
Sta 165+00	100yr	8.7	1452	6.0	10.0	4.30	0.53	20
Sta 174+59 (New Ditch)	100yr	6.6	1806	7.3	10.0	4.30	0.53	15
Sta 288+00	100yr	90.5	6389	24.5	24.5	2.71	0.53	130
Sta 290+40	100yr	24.5	2001	7.7	10.0	4.30	0.53	56
Sta 335+49	100yr	17.9	1764	6.8	10.0	4.30	0.53	41
Sta 356+00	100yr	46.1	3274	11.9	11.9	3.97	0.53	97
Sta 403+08	100yr	249.6	6679	15.0	15.0	3.55	0.53	470

FIGURE 2-4
RATIONAL "C" COEFFICIENT
DESERT
(CACTUS, GRASS & BRUSH)

AS A FUNCTION OF RAINFALL DEPTH, HYDROLOGIC SOIL GROUP (HSG), AND % OF VEGETATION COVER.

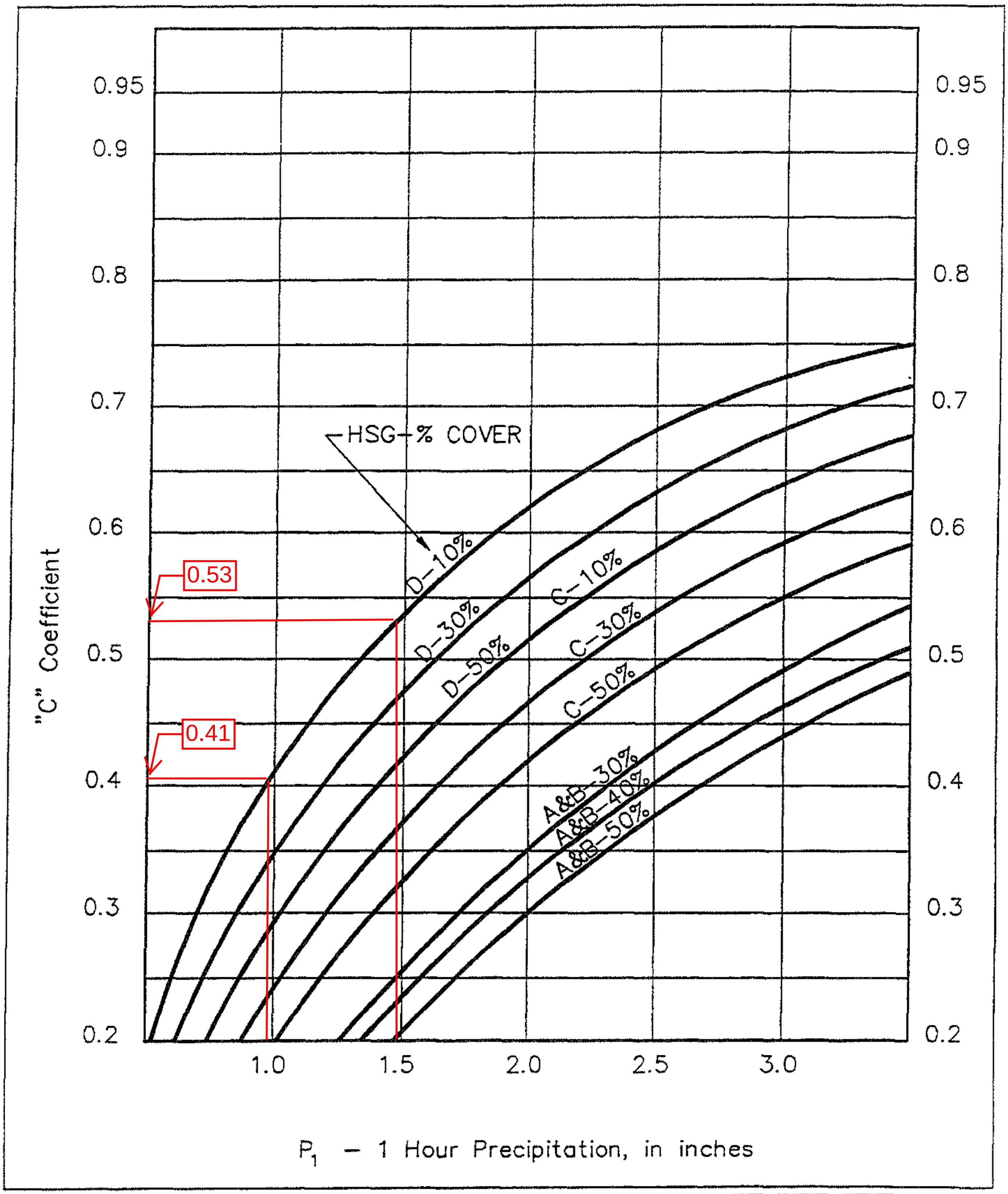


TABLE 2-1
RESISTANCE COEFFICIENT (K_b) FOR USE WITH THE RATIONAL METHOD T_c EQUATION

Description of Landform	K_b	
	Defined Drainage Network	Overland Flow Only
Mountain, with forest and dense ground cover (overland slopes - 50% or greater)	0.15	0.30
Mountain, with rough rock and boulder cover (overland slopes - 50% or greater)	0.12	0.25
Foothills (overland slopes - 10% to 50%)	0.10	0.20
Alluvial fans, Pediments and Rangeland (overland slopes - 10% or less)	0.05	0.10
Irrigated Pasture [a]	—	0.20
Tilled Agricultural Fields [a]	—	0.08
URBAN		
Residential, L is less than 1,000 ft[b]	0.04	—
Residential, L is greater than 1,000 ft[b]	0.025	—
Grass; parks, cemeteries, etc. [a]	—	0.20
Bare ground; playgrounds, etc. [a]	—	0.08
Paved; parking lots, etc. [a]	—	0.02

Notes: a - No defined drainage network.
b - L is length in the T_c equation. Streets serve as drainagae network.

iTouchMap.com Mobile and Desktop Maps

Maps | **Country - State** | **Places** | **Google Earth** | **Cities** | **Earthquakes** | **I Am Here** | **Lat - Long**

Home » Latitude and Longitude of a Point

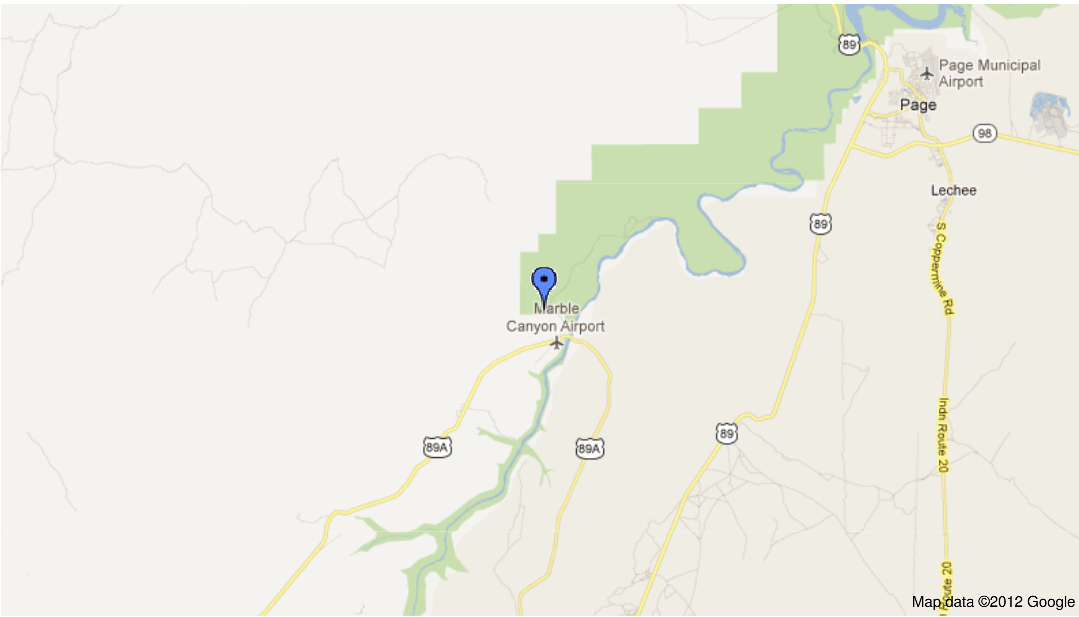
To find the latitude and longitude of a point **Click** on the map, **Drag** the marker, or enter the...

Address: 123 Street, City State/Country Go

Map Center: Get Address - Land Plat Size - Street View - Google Earth 3D - Area Photographs

Try out the Google Earth Plug-in. Google Earth gives you a 3D look of the area around the center of the map, which is usually your last click point, and includes latitude, longitude and elevation information.

Latitude and Longitude of a Point



Note: Right click on a **blue marker** to remove it.

Clear/Reset All Markers | Center Red Marker

Get the Latitude and Longitude of a Point

When you click on the map, move the marker or enter an address the latitude and longitude coordinates of the point are inserted in the boxes below.

Latitude: 20.000000

Longitude: -10.000000

	Degrees	Minutes	Seconds
Latitude:	20	0	0
Longitude:	-10	0	0

Show Point from Latitude and Longitude

Use this if you know the latitude and longitude coordinates of a point and want to see where on the map the point is.

Use: + for *N* Lat or *E* Long **-** for *S* Lat or *W* Long.
Example: +40.689060 -74.044636
Note: Your entry should not have any embedded spaces.

Decimal Deg. Latitude: 36.828524

Decimal Deg. Longitude: -111.644440

Show Point

Example: **+34 40 50.12** for *34N 40' 50.12"*

	Degrees	Minutes	Seconds
Latitude:			
Longitude:			

Show Point

NOAA Atlas 14, Volume 1, Version 5
Location name: MARBLE CANYON, Arizona, US*
Coordinates: 36.8285, -111.6444
Elevation: 3549ft*
* source: Google Maps

POINT PRECIPITATION FREQUENCY ESTIMATES

Sanja Perica, Sarah Dietz, Sarah Heim, Lillian Hiner, Kazungu Maitaria, Deborah Martin, Sandra Pavlovic, Ishani Roy, Carl Trypaluk, Dale Unruh, Fenglin Yan, Michael Yekta, Tan Zhao, Geoffrey Bonnin, Daniel Brewer, Li-Chuan Chen, Tye Parzybok, John Yarchoan

NOAA, National Weather Service, Silver Spring, Maryland

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	1.20 (0.972–1.48)	1.54 (1.25–1.90)	2.15 (1.74–2.66)	2.74 (2.18–3.40)	3.71 (2.88–4.61)	4.60 (3.50–5.66)	5.64 (4.21–7.02)	6.89 (4.97–8.65)	8.87 (6.13–11.2)	10.6 (7.10–13.7)
10-min	0.912 (0.738–1.12)	1.16 (0.954–1.45)	1.64 (1.33–2.03)	2.08 (1.66–2.58)	2.82 (2.20–3.50)	3.49 (2.67–4.31)	4.30 (3.20–5.34)	5.24 (3.78–6.58)	6.75 (4.66–8.56)	8.09 (5.41–10.4)
15-min	0.756 (0.612–0.928)	0.964 (0.784–1.20)	1.35 (1.10–1.68)	1.72 (1.37–2.13)	2.33 (1.82–2.90)	2.89 (2.20–3.56)	3.55 (2.64–4.41)	4.33 (3.13–5.44)	5.58 (3.86–7.07)	6.69 (4.47–8.60)
30-min	0.508 (0.412–0.626)	0.650 (0.530–0.806)	0.910 (0.738–1.13)	1.16 (0.924–1.44)	1.57 (1.22–1.95)	1.94 (1.49–2.40)	2.39 (1.78–2.97)	2.92 (2.11–3.66)	3.76 (2.60–4.76)	4.50 (3.01–5.79)
60-min	0.315 (0.255–0.387)	0.402 (0.328–0.498)	0.564 (0.457–0.699)	0.718 (0.572–0.889)	0.971 (0.756–1.21)	1.20 (0.920–1.48)	1.48 (1.10–1.84)	1.81 (1.30–2.27)	2.33 (1.61–2.95)	2.79 (1.86–3.58)
2-hr	0.192 (0.161–0.230)	0.243 (0.202–0.291)	0.331 (0.274–0.396)	0.414 (0.338–0.496)	0.548 (0.440–0.656)	0.672 (0.526–0.807)	0.821 (0.626–0.995)	0.998 (0.737–1.23)	1.28 (0.906–1.60)	1.54 (1.05–1.95)
3-hr	0.142 (0.122–0.167)	0.180 (0.153–0.213)	0.240 (0.205–0.283)	0.295 (0.247–0.347)	0.378 (0.312–0.446)	0.454 (0.368–0.542)	0.550 (0.435–0.669)	0.669 (0.513–0.824)	0.862 (0.633–1.08)	1.04 (0.739–1.31)
6-hr	0.082 (0.072–0.095)	0.103 (0.090–0.119)	0.134 (0.116–0.155)	0.160 (0.139–0.185)	0.200 (0.171–0.231)	0.234 (0.197–0.274)	0.277 (0.229–0.339)	0.339 (0.268–0.418)	0.437 (0.332–0.544)	0.526 (0.389–0.664)
12-hr	0.050 (0.045–0.057)	0.063 (0.056–0.071)	0.080 (0.071–0.090)	0.094 (0.083–0.106)	0.113 (0.099–0.129)	0.129 (0.111–0.147)	0.145 (0.124–0.170)	0.170 (0.142–0.210)	0.219 (0.170–0.273)	0.264 (0.198–0.333)
24-hr	0.031 (0.028–0.035)	0.039 (0.036–0.044)	0.051 (0.046–0.057)	0.060 (0.054–0.067)	0.073 (0.066–0.081)	0.084 (0.075–0.094)	0.095 (0.084–0.107)	0.107 (0.093–0.121)	0.123 (0.106–0.141)	0.137 (0.115–0.169)
2-day	0.017 (0.015–0.019)	0.021 (0.019–0.024)	0.027 (0.025–0.030)	0.033 (0.029–0.036)	0.040 (0.035–0.044)	0.045 (0.040–0.051)	0.052 (0.045–0.058)	0.058 (0.050–0.066)	0.068 (0.057–0.078)	0.075 (0.062–0.087)
3-day	0.012 (0.011–0.013)	0.015 (0.014–0.017)	0.019 (0.017–0.021)	0.023 (0.021–0.025)	0.028 (0.025–0.030)	0.031 (0.028–0.035)	0.036 (0.031–0.040)	0.040 (0.035–0.045)	0.046 (0.039–0.053)	0.052 (0.043–0.060)
4-day	0.009 (0.009–0.010)	0.012 (0.011–0.013)	0.015 (0.014–0.017)	0.018 (0.016–0.020)	0.021 (0.019–0.024)	0.025 (0.022–0.027)	0.028 (0.024–0.031)	0.031 (0.027–0.035)	0.036 (0.030–0.041)	0.040 (0.033–0.046)
7-day	0.006 (0.005–0.007)	0.007 (0.007–0.008)	0.010 (0.009–0.011)	0.011 (0.010–0.012)	0.013 (0.012–0.015)	0.015 (0.014–0.017)	0.017 (0.015–0.019)	0.019 (0.017–0.022)	0.022 (0.019–0.025)	0.024 (0.020–0.028)
10-day	0.005 (0.004–0.005)	0.006 (0.005–0.006)	0.007 (0.007–0.008)	0.009 (0.008–0.010)	0.010 (0.009–0.012)	0.012 (0.011–0.013)	0.013 (0.012–0.015)	0.015 (0.013–0.017)	0.017 (0.015–0.020)	0.019 (0.016–0.022)
20-day	0.003 (0.003–0.003)	0.003 (0.003–0.004)	0.004 (0.004–0.005)	0.005 (0.005–0.006)	0.006 (0.006–0.007)	0.007 (0.006–0.008)	0.008 (0.007–0.009)	0.009 (0.008–0.010)	0.010 (0.009–0.012)	0.011 (0.009–0.013)
30-day	0.002 (0.002–0.002)	0.003 (0.003–0.003)	0.003 (0.003–0.004)	0.004 (0.004–0.004)	0.005 (0.004–0.005)	0.005 (0.005–0.006)	0.006 (0.005–0.006)	0.006 (0.006–0.007)	0.007 (0.006–0.008)	0.008 (0.007–0.009)
45-day	0.002 (0.002–0.002)	0.002 (0.002–0.002)	0.003 (0.002–0.003)	0.003 (0.003–0.003)	0.004 (0.003–0.004)	0.004 (0.004–0.005)	0.005 (0.004–0.005)	0.005 (0.004–0.006)	0.006 (0.005–0.006)	0.006 (0.005–0.007)
60-day	0.001 (0.001–0.002)	0.002 (0.002–0.002)	0.002 (0.002–0.002)	0.003 (0.002–0.003)	0.003 (0.003–0.003)	0.004 (0.003–0.004)	0.004 (0.004–0.004)	0.004 (0.004–0.005)	0.005 (0.004–0.005)	0.005 (0.004–0.006)

[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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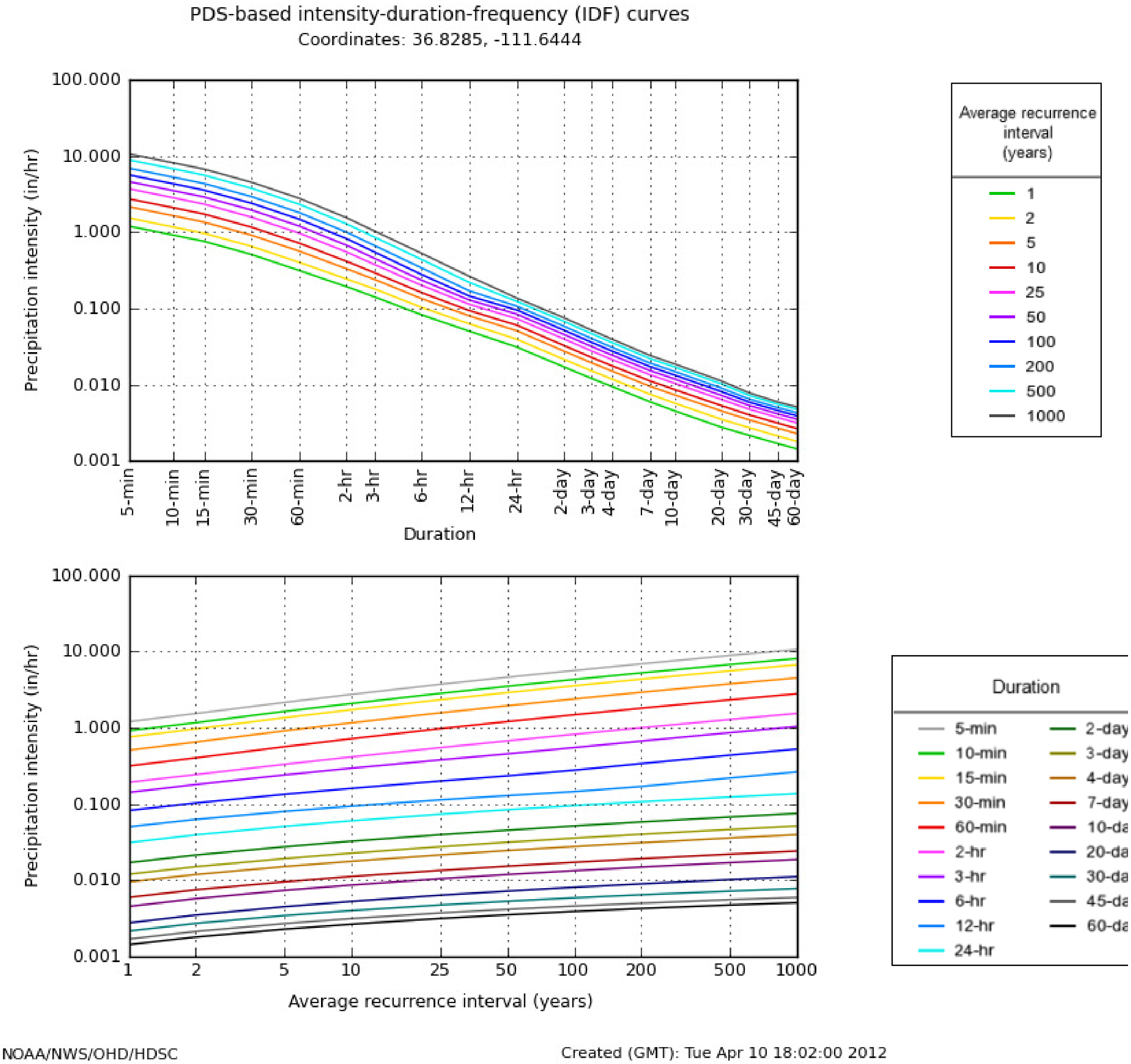
PF graphical



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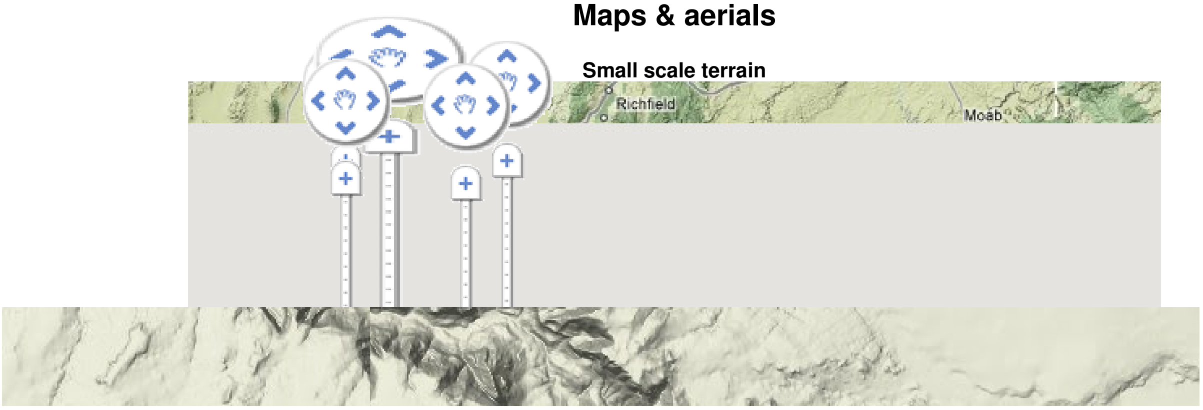
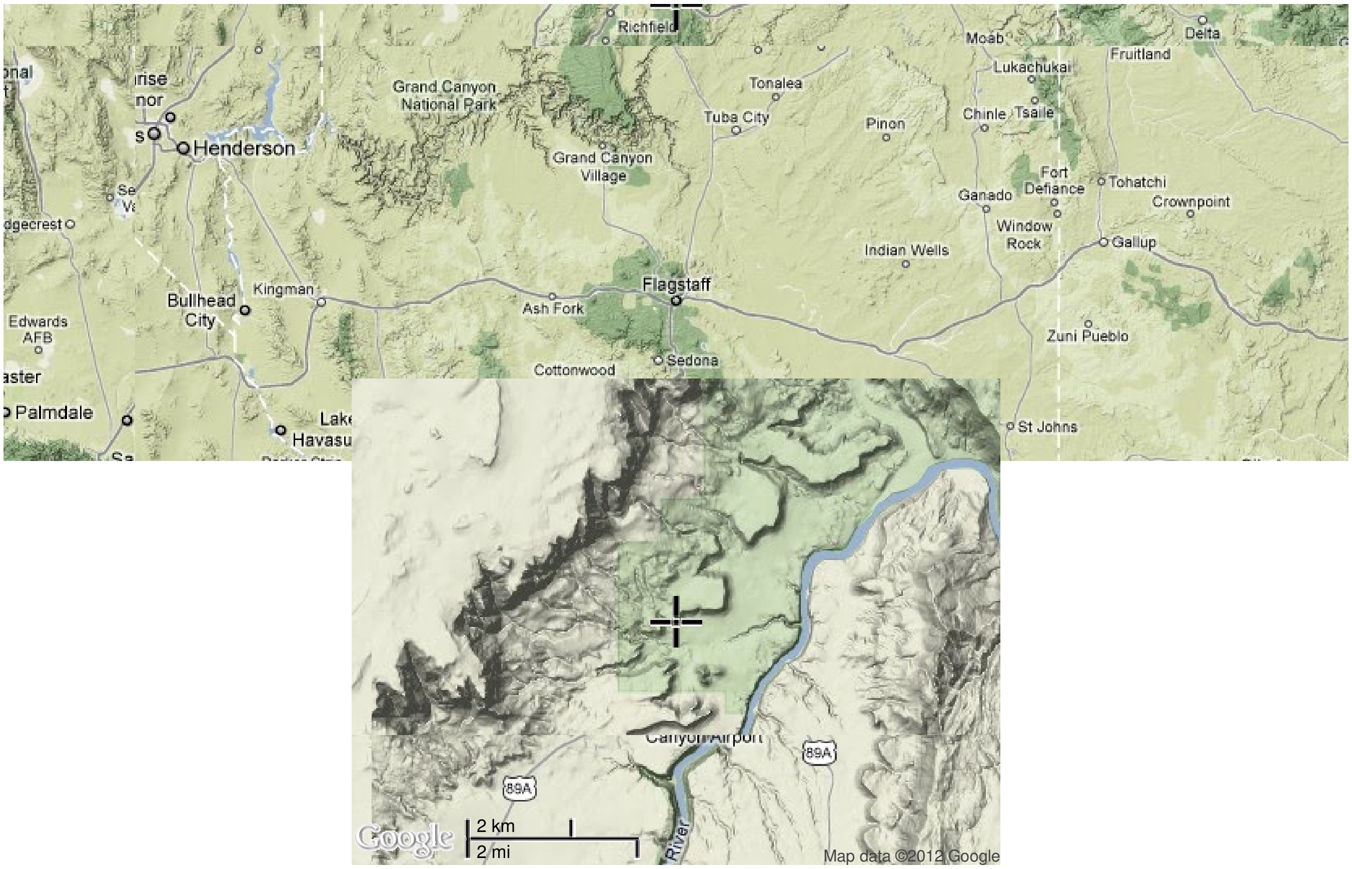
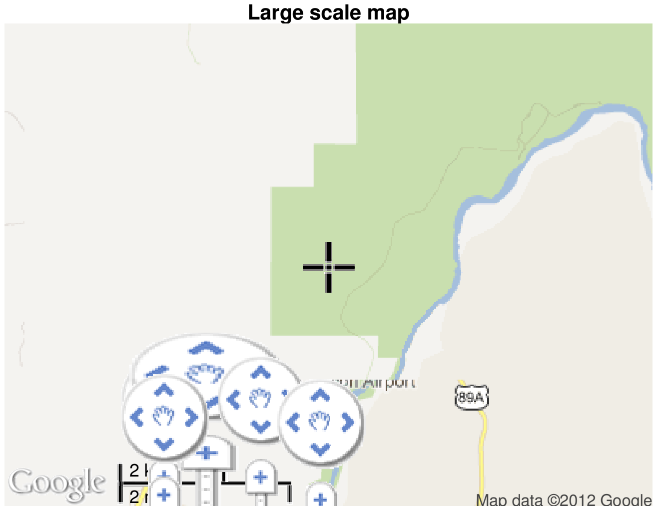
Maps & aerials

Small scale terrain

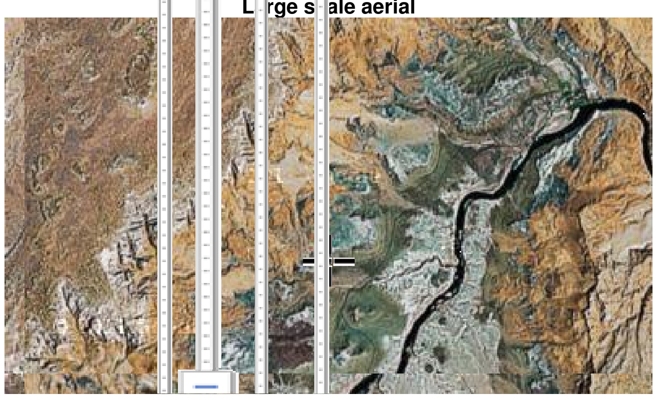


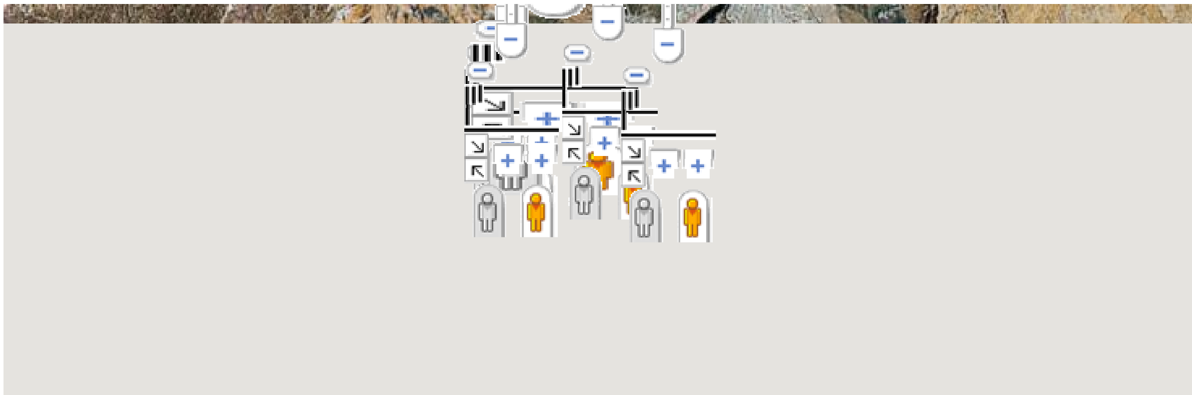


Large scale map



Large scale aerial





Questions?: HDSC.Questions@noaa.gov

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NOAA Atlas 14, Volume 1, Version 5
Location name: MARBLE CANYON, Arizona, US*
Coordinates: 36.8285, -111.6444
Elevation: 3549ft*
* source: Google Maps

POINT PRECIPITATION FREQUENCY ESTIMATES

Sanja Perica, Sarah Dietz, Sarah Heim, Lillian Hiner, Kazungu Maitaria, Deborah Martin, Sandra Pavlovic, Ishani Roy, Carl Trypaluk, Dale Unruh, Fenglin Yan, Michael Yekta, Tan Zhao, Geoffrey Bonnin, Daniel Brewer, Li-Chuan Chen, Tye Parzybok, John Yarchoan

NOAA, National Weather Service, Silver Spring, Maryland

PF tabular | PF graphical | Maps & aerials

PF tabular

PDS-based point precipitation frequency estimates with 90% confidence intervals

Duration	Average recurrence interval(years)							
	1	2	5	10	25	50	100	200
5-min	0.100 (0.081–0.123)	0.128 (0.104–0.158)	0.179 (0.145–0.222)	0.228 (0.182–0.283)	0.309 (0.240–0.384)	0.383 (0.292–0.472)	0.470 (0.351–0.585)	0.574 (0.414–0.721)
10-min	0.152 (0.123–0.187)	0.194 (0.159–0.241)	0.273 (0.221–0.338)	0.347 (0.277–0.430)	0.470 (0.366–0.584)	0.582 (0.445–0.718)	0.716 (0.534–0.890)	0.874 (0.630–1.10)
15-min	0.189 (0.153–0.232)	0.241 (0.196–0.299)	0.338 (0.274–0.419)	0.431 (0.343–0.533)	0.582 (0.454–0.725)	0.722 (0.551–0.890)	0.887 (0.661–1.10)	1.08 (0.782–1.36)
30-min	0.254 (0.206–0.313)	0.325 (0.265–0.403)	0.455 (0.369–0.565)	0.580 (0.462–0.718)	0.784 (0.611–0.976)	0.972 (0.743–1.20)	1.20 (0.891–1.49)	1.46 (1.05–1.83)
60-min	0.315 (0.255–0.387)	0.402 (0.328–0.498)	0.564 (0.457–0.699)	0.718 (0.572–0.889)	0.971 (0.756–1.21)	1.20 (0.920–1.48)	1.48 (1.10–1.84)	1.81 (1.30–2.27)
2-hr	0.385 (0.322–0.460)	0.486 (0.404–0.582)	0.662 (0.548–0.793)	0.828 (0.675–0.991)	1.10 (0.880–1.31)	1.35 (1.05–1.61)	1.64 (1.25–1.99)	2.00 (1.47–2.45)
3-hr	0.426 (0.365–0.503)	0.541 (0.460–0.640)	0.722 (0.615–0.850)	0.885 (0.741–1.04)	1.14 (0.937–1.34)	1.36 (1.11–1.63)	1.65 (1.31–2.01)	2.01 (1.54–2.48)
6-hr	0.492 (0.431–0.570)	0.616 (0.538–0.712)	0.802 (0.697–0.928)	0.961 (0.830–1.11)	1.20 (1.02–1.38)	1.40 (1.18–1.64)	1.66 (1.37–2.03)	2.03 (1.60–2.50)
12-hr	0.605 (0.537–0.687)	0.757 (0.672–0.860)	0.962 (0.852–1.09)	1.13 (0.995–1.28)	1.36 (1.19–1.55)	1.55 (1.34–1.77)	1.75 (1.50–2.05)	2.05 (1.71–2.53)
24-hr	0.747 (0.677–0.831)	0.945 (0.855–1.05)	1.22 (1.11–1.36)	1.45 (1.31–1.60)	1.76 (1.58–1.95)	2.02 (1.79–2.24)	2.29 (2.01–2.56)	2.57 (2.23–2.90)
2-day	0.817 (0.741–0.905)	1.03 (0.932–1.14)	1.32 (1.20–1.46)	1.56 (1.41–1.73)	1.90 (1.70–2.11)	2.18 (1.94–2.43)	2.48 (2.17–2.78)	2.79 (2.41–3.17)
3-day	0.864 (0.786–0.955)	1.09 (0.985–1.20)	1.39 (1.26–1.53)	1.63 (1.48–1.80)	1.98 (1.78–2.19)	2.27 (2.01–2.52)	2.57 (2.25–2.87)	2.89 (2.50–3.26)
4-day	0.911 (0.831–1.00)	1.14 (1.04–1.26)	1.45 (1.32–1.60)	1.70 (1.54–1.87)	2.06 (1.85–2.27)	2.35 (2.09–2.60)	2.66 (2.34–2.96)	2.98 (2.58–3.35)
7-day	1.00 (0.915–1.11)	1.26 (1.15–1.39)	1.60 (1.46–1.77)	1.88 (1.71–2.08)	2.26 (2.05–2.51)	2.57 (2.30–2.86)	2.89 (2.56–3.25)	3.23 (2.82–3.67)
10-day	1.09 (0.995–1.20)	1.38 (1.25–1.51)	1.77 (1.61–1.95)	2.08 (1.89–2.29)	2.51 (2.26–2.77)	2.85 (2.54–3.16)	3.21 (2.84–3.57)	3.58 (3.12–4.03)
20-day	1.32 (1.21–1.45)	1.68 (1.54–1.84)	2.16 (1.98–2.37)	2.54 (2.31–2.78)	3.06 (2.77–3.35)	3.46 (3.11–3.81)	3.88 (3.45–4.30)	4.31 (3.79–4.81)
30-day	1.55 (1.43–1.69)	1.96 (1.80–2.13)	2.48 (2.28–2.69)	2.88 (2.65–3.13)	3.42 (3.12–3.73)	3.82 (3.47–4.19)	4.24 (3.81–4.67)	4.65 (4.14–5.15)
45-day	1.83 (1.68–1.99)	2.30 (2.12–2.51)	2.92 (2.68–3.17)	3.39 (3.10–3.69)	4.02 (3.66–4.37)	4.48 (4.06–4.89)	4.95 (4.45–5.43)	5.41 (4.82–5.98)

60-day	**2.06** (1.90–2.26)	**2.59** (2.39–2.83)	**3.28** (3.02–3.57)	**3.82** (3.51–4.15)	**4.53** (4.14–4.93)	**5.07** (4.60–5.53)	**5.61** (5.04–6.15)	**6.14** (5.48–6.80)	(

[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 frec duration and average recurrence interval) will be greater than the upper bound (or less than the lower bound) is 5%. Estimates at upper b 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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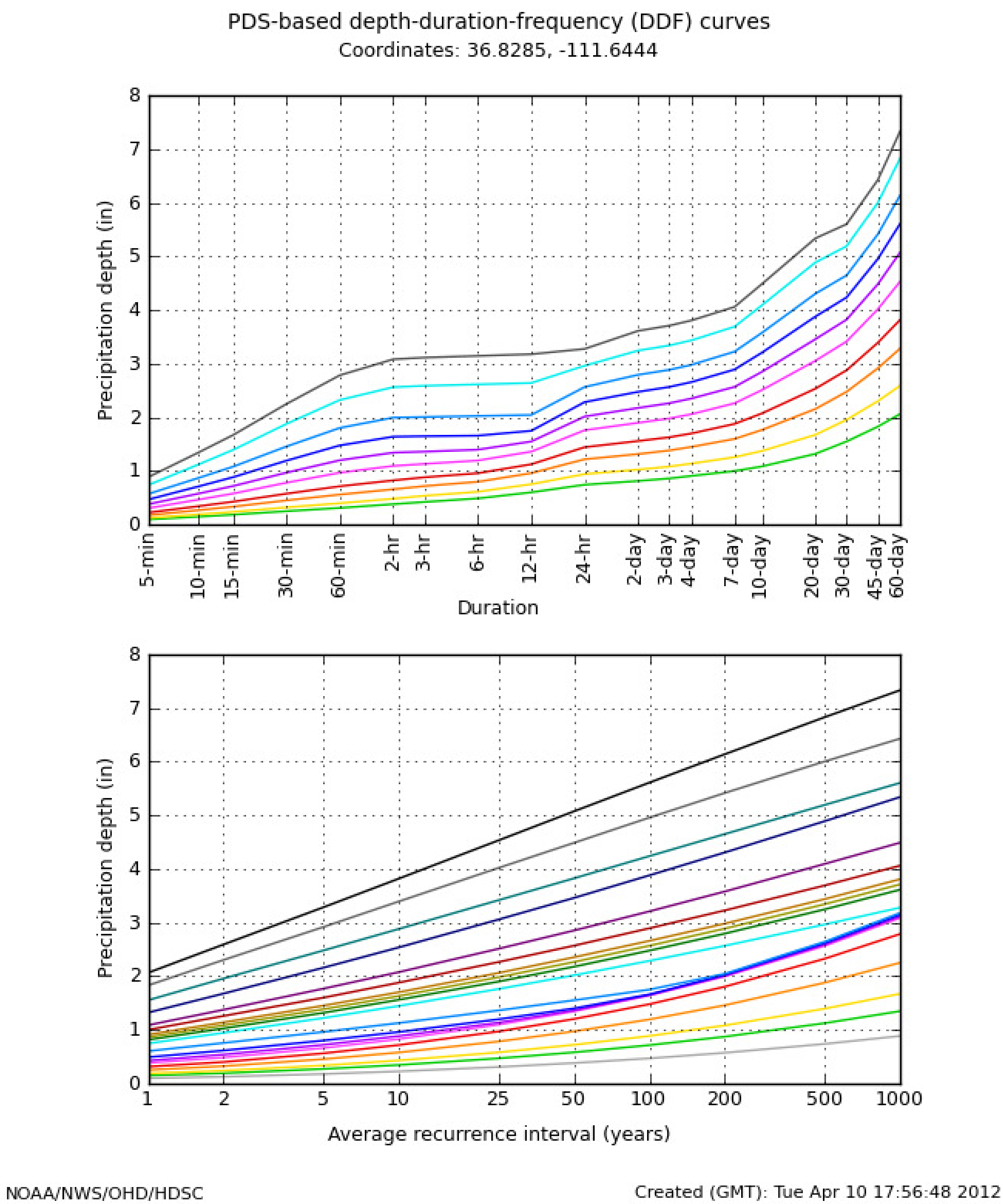
PF graphical



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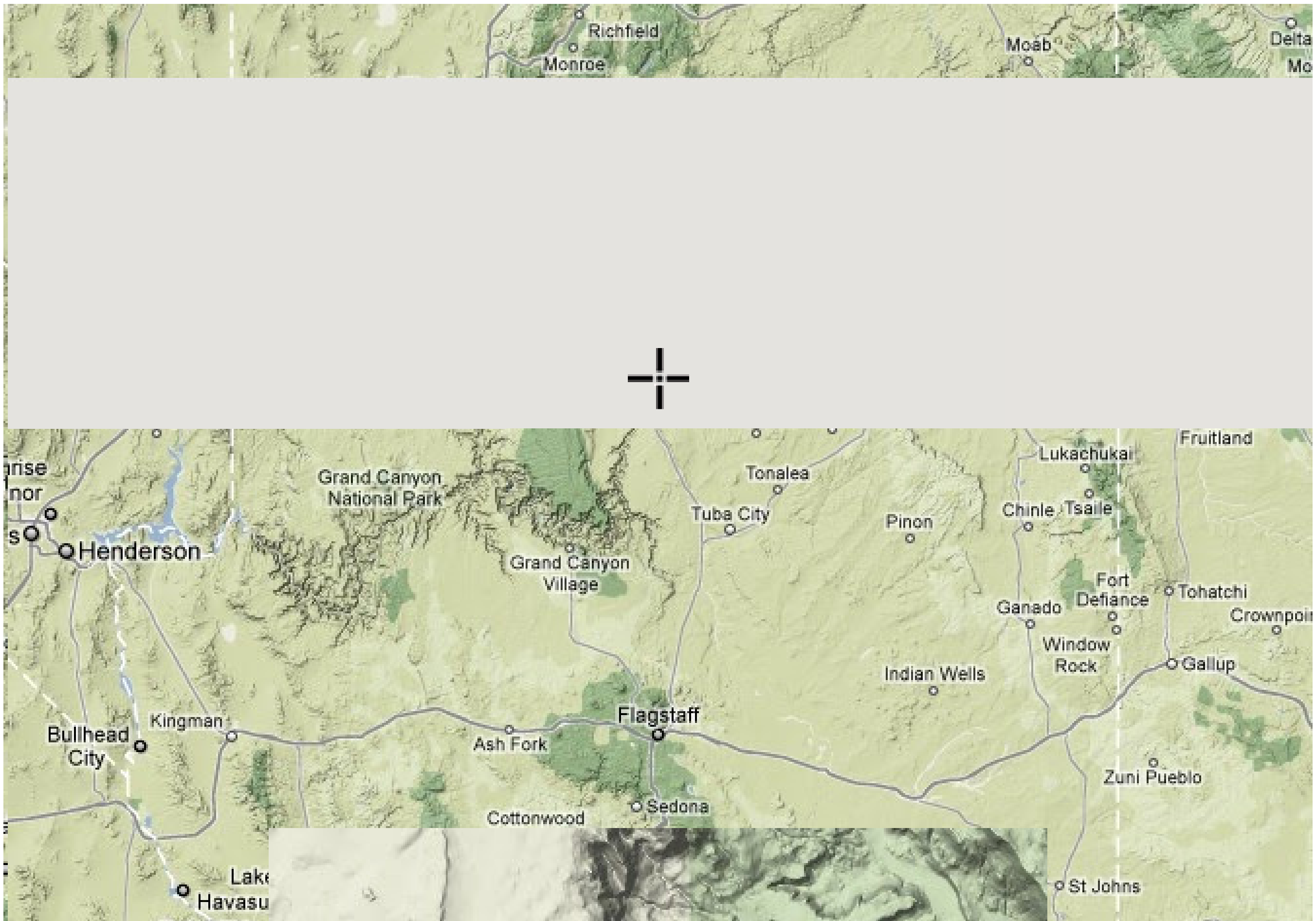
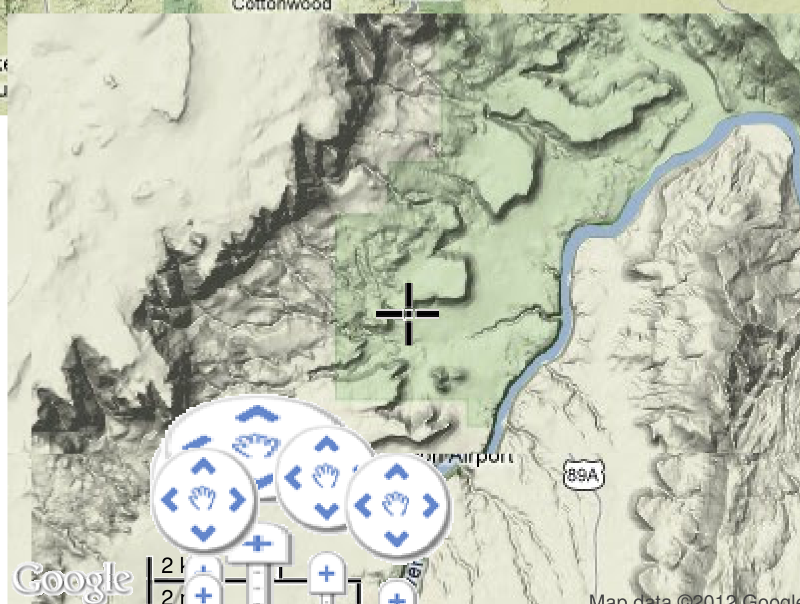
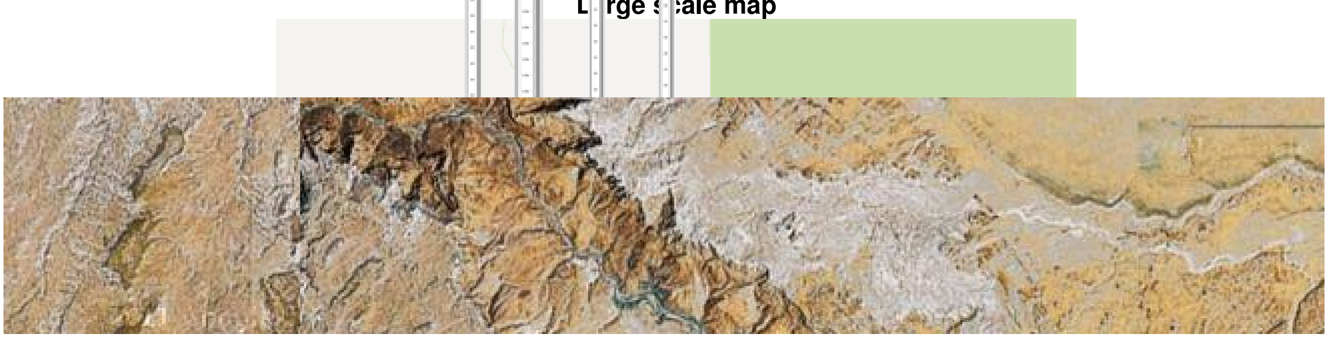
Maps & aerials

Small scale terrain





Large scale map



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Appendix C – Culvert Crossing Hydraulic Analysis

Table 6 - Summary of Culvert Flows at Crossing: D4-exst pipe culvert

Headwater Elevation (ft)	Total Discharge (cfs)	Exst Culvert D4 Discharge (cfs)	Roadway Discharge (cfs)	Iterations
3504.54	0.00	0.00	0.00	1
3505.18	2.10	2.10	0.00	1
3505.51	4.20	4.20	0.00	1
3505.79	6.30	6.30	0.00	1
3506.02	8.40	8.40	0.00	1
3506.26	10.50	10.50	0.00	1
3506.32	11.00	11.00	0.00	1
3506.75	14.70	14.70	0.00	1
3507.22	16.80	16.80	0.00	1
3507.82	18.90	18.90	0.00	1
3508.45	21.00	21.00	0.00	1
3508.84	22.19	22.19	0.00	Overtopping

Table 5 - Culvert Summary Table: Exst Culvert D4

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)
0.00	0.00	3504.54	0.000	0.0*	0-NF	0.000	0.000	0.000	0.000	0.000	0.000
2.10	2.10	3505.18	0.591	0.645	2-M2c	0.383	0.370	0.374	0.187	3.108	2.990
4.20	4.20	3505.51	0.885	0.973	2-M2c	0.569	0.547	0.550	0.275	3.877	3.719
6.30	6.30	3505.79	1.146	1.248	2-M2c	0.733	0.692	0.694	0.343	4.443	4.201
8.40	8.40	3506.02	1.381	1.484	2-M2c	0.892	0.817	0.819	0.400	4.937	4.570
10.50	10.50	3506.26	1.619	1.722	2-M2c	1.058	0.929	0.931	0.449	5.385	4.873
11.00	11.00	3506.32	1.679	1.775	2-M2c	1.100	0.955	0.957	0.460	5.488	4.937
14.70	14.70	3506.75	2.185	2.214	2-M2c	1.667	1.128	1.130	0.534	6.224	5.357
16.80	16.80	3507.22	2.539	2.676	7-M2c	1.667	1.213	1.217	0.572	6.649	5.559
18.90	18.90	3507.82	2.950	3.279	7-M2c	1.667	1.291	1.295	0.606	7.090	5.743
21.00	21.00	3508.45	3.418	3.909	7-M2c	1.667	1.358	1.364	0.639	7.556	5.911

Water Surface Profile Plot for Culvert: Exst Culvert D4

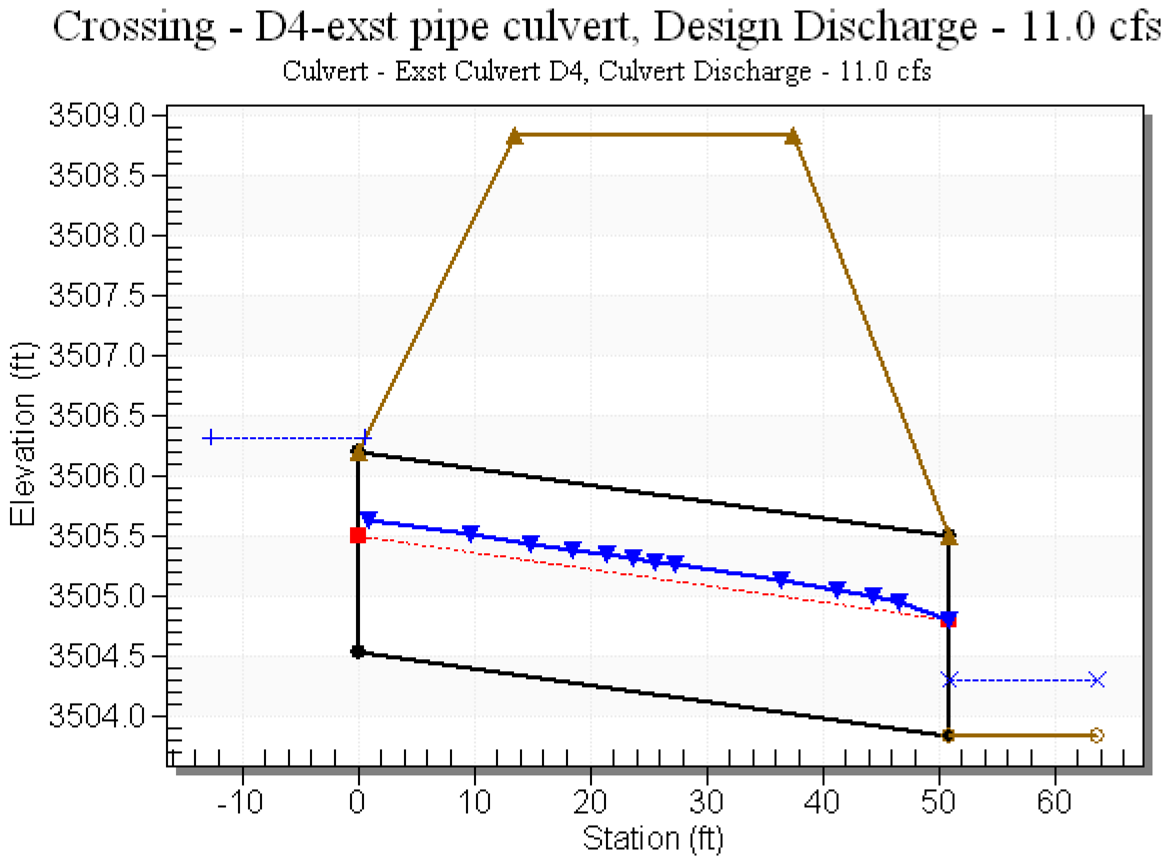


Table 4 - Summary of Culvert Flows at Crossing: D4-pipe culvert

Headwater Elevation (ft)	Total Discharge (cfs)	Culvert D4 Discharge (cfs)	Roadway Discharge (cfs)	Iterations
3504.53	0.00	0.00	0.00	1
3505.29	2.10	2.10	0.00	1
3505.64	4.20	4.20	0.00	1
3505.92	6.30	6.30	0.00	1
3506.18	8.40	8.40	0.00	1
3506.44	10.50	10.50	0.00	1
3506.50	11.00	11.00	0.00	1
3507.11	14.70	14.70	0.00	1
3507.55	16.80	16.80	0.00	1
3508.02	18.90	18.90	0.00	1
3508.53	21.00	21.00	0.00	1
3511.06	29.55	29.55	0.00	Overtopping

Table 3 - Culvert Summary Table: Culvert D4

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)
0.00	0.00	3504.53	0.000	0.0*	0-NF	0.000	0.000	0.000	0.000	0.000	0.000
2.10	2.10	3505.29	0.670	0.764	2-M2c	0.668	0.494	0.503	0.187	3.393	2.990
4.20	4.20	3505.64	0.970	1.108	2-M2c	0.986	0.713	0.719	0.275	4.131	3.719
6.30	6.30	3505.92	1.244	1.393	2-M2c	1.273	0.884	0.888	0.343	4.674	4.201
8.40	8.40	3506.18	1.475	1.654	2-M2c	1.598	1.030	1.033	0.400	5.134	4.570
10.50	10.50	3506.44	1.679	1.912	2-M2c	2.000	1.158	1.161	0.449	5.554	4.873
11.00	11.00	3506.50	1.725	1.972	2-M2c	2.000	1.188	1.189	0.460	5.650	4.937
14.70	14.70	3507.11	2.065	2.583	7-M2c	2.000	1.380	1.381	0.534	6.350	5.357
16.80	16.80	3507.55	2.268	3.020	7-M2c	2.000	1.472	1.478	0.572	6.752	5.559
18.90	18.90	3508.02	2.486	3.495	7-M2c	2.000	1.560	1.565	0.606	7.168	5.743
21.00	21.00	3508.53	2.722	3.998	7-M2c	2.000	1.634	1.642	0.639	7.609	5.911

Water Surface Profile Plot for Culvert: Culvert D4

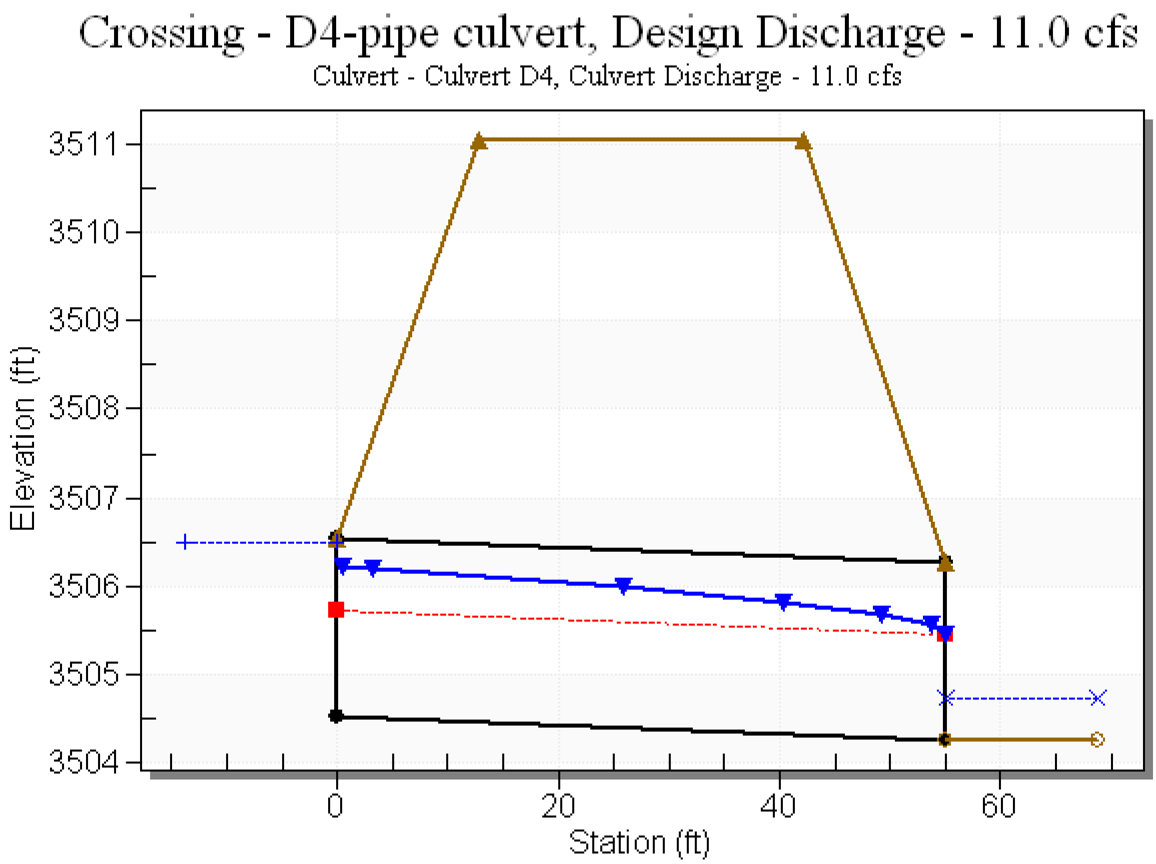


Table 10 - Summary of Culvert Flows at Crossing: D5-exst pipe culvert

Headwater Elevation (ft)	Total Discharge (cfs)	Exst Culvert D5 Discharge (cfs)	Roadway Discharge (cfs)	Iterations
3486.82	0.00	0.00	0.00	1
3487.28	1.40	1.40	0.00	1
3487.50	2.80	2.80	0.00	1
3487.69	4.20	4.20	0.00	1
3487.87	5.60	5.60	0.00	1
3488.03	7.00	7.00	0.00	1
3488.19	8.40	8.40	0.00	1
3488.34	9.80	9.80	0.00	1
3488.51	11.20	11.20	0.00	1
3488.69	12.60	12.60	0.00	1
3488.88	14.00	14.00	0.00	1
3490.41	21.77	21.77	0.00	Overtopping

Table 9 - Culvert Summary Table: Exst Culvert D5

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)
0.00	0.00	3486.82	0.000	0.0*	0-NF	0.000	0.000	0.000	0.000	0.000	0.000
1.40	1.40	3487.28	0.458	0.0*	1-S2n	0.241	0.293	0.243	0.163	3.548	2.717
2.80	2.80	3487.50	0.682	0.0*	1-S2n	0.358	0.433	0.362	0.240	4.334	3.374
4.20	4.20	3487.69	0.870	0.0*	1-S2n	0.445	0.547	0.446	0.298	4.979	3.811
5.60	5.60	3487.87	1.048	0.0*	1-S2n	0.527	0.646	0.527	0.348	5.437	4.142
7.00	7.00	3488.03	1.210	0.0*	1-S2n	0.601	0.734	0.603	0.390	5.808	4.414
8.40	8.40	3488.19	1.366	0.0*	1-S2n	0.673	0.817	0.674	0.429	6.127	4.648
9.80	9.80	3488.34	1.522	0.0*	1-S2n	0.743	0.892	0.745	0.464	6.389	4.851
11.20	11.20	3488.51	1.688	0.0*	5-S2n	0.812	0.965	0.814	0.496	6.625	5.034
12.60	12.60	3488.69	1.867	0.0*	5-S2n	0.882	1.033	0.882	0.526	6.833	5.199
14.00	14.00	3488.88	2.064	0.0*	5-S2n	0.952	1.096	0.955	0.555	7.003	5.351

Water Surface Profile Plot for Culvert: Exst Culvert D5

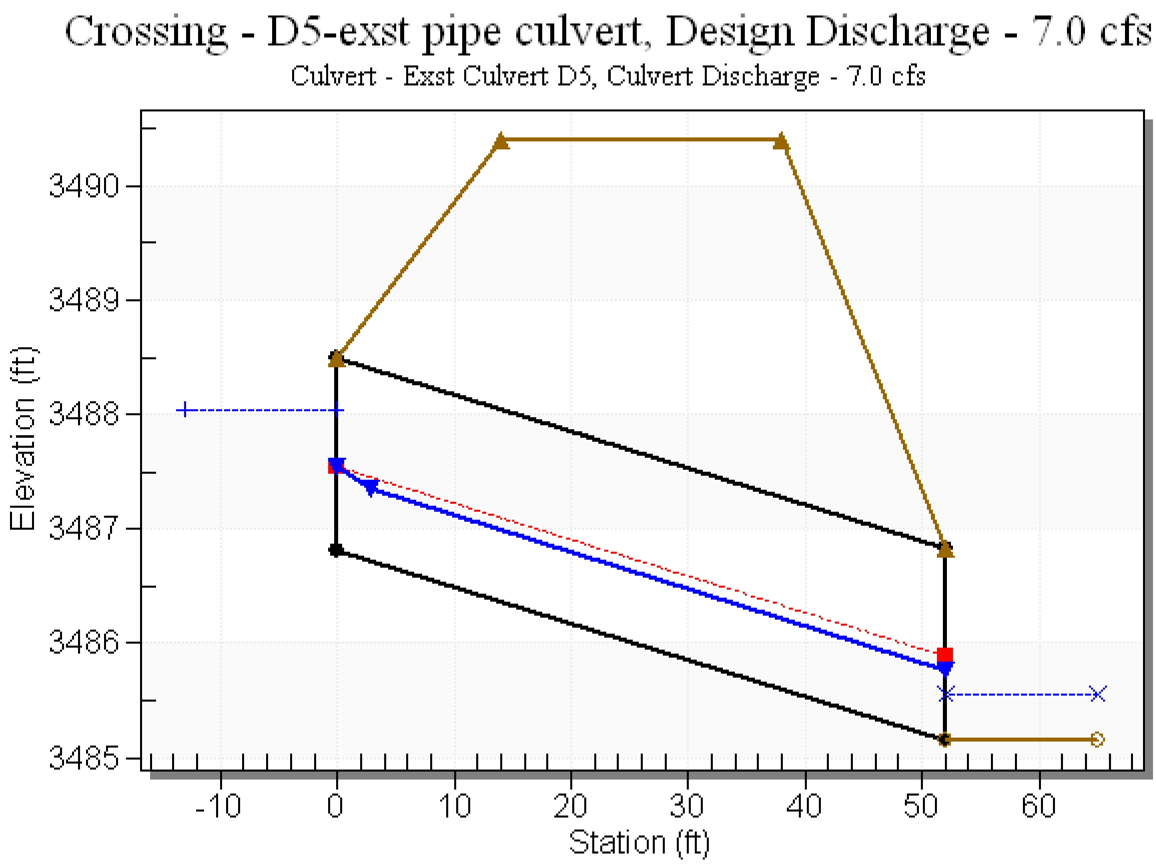


Table 8 - Summary of Culvert Flows at Crossing: D5-pipe culvert

Headwater Elevation (ft)	Total Discharge (cfs)	Culvert D5 Discharge (cfs)	Roadway Discharge (cfs)	Iterations
3489.17	0.00	0.00	0.00	1
3489.69	1.40	1.40	0.00	1
3489.92	2.80	2.80	0.00	1
3490.10	4.20	4.20	0.00	1
3490.27	5.60	5.60	0.00	1
3490.44	7.00	7.00	0.00	1
3490.59	8.40	8.40	0.00	1
3490.73	9.80	9.80	0.00	1
3490.86	11.20	11.20	0.00	1
3490.99	12.60	12.60	0.00	1
3491.12	14.00	14.00	0.00	1
3492.14	23.47	23.47	0.00	Overtopping

Table 7 - Culvert Summary Table: Culvert D5

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)
0.00	0.00	3489.17	0.000	0.0*	0-NF	0.000	0.000	0.000	0.000	0.000	0.000
1.40	1.40	3489.69	0.522	0.0*	1-S2n	0.278	0.407	0.297	0.163	4.645	2.717
2.80	2.80	3489.92	0.748	0.0*	1-S2n	0.411	0.580	0.413	0.240	6.004	3.374
4.20	4.20	3490.10	0.927	0.0*	1-S2n	0.497	0.713	0.503	0.298	6.715	3.811
5.60	5.60	3490.27	1.103	0.0*	1-S2n	0.584	0.833	0.586	0.348	7.294	4.142
7.00	7.00	3490.44	1.270	0.0*	1-S2n	0.654	0.935	0.658	0.390	7.759	4.414
8.40	8.40	3490.59	1.420	0.0*	1-S2n	0.720	1.030	0.720	0.429	8.220	4.648
9.80	9.80	3490.73	1.558	0.0*	1-S2n	0.786	1.115	0.787	0.464	8.525	4.851
11.20	11.20	3490.86	1.689	0.0*	1-S2n	0.846	1.200	0.849	0.496	8.836	5.034
12.60	12.60	3490.99	1.817	0.0*	1-S2n	0.903	1.272	0.911	0.526	9.035	5.199
14.00	14.00	3491.12	1.945	0.0*	1-S2n	0.960	1.344	0.963	0.555	9.349	5.351

Water Surface Profile Plot for Culvert: Culvert D5

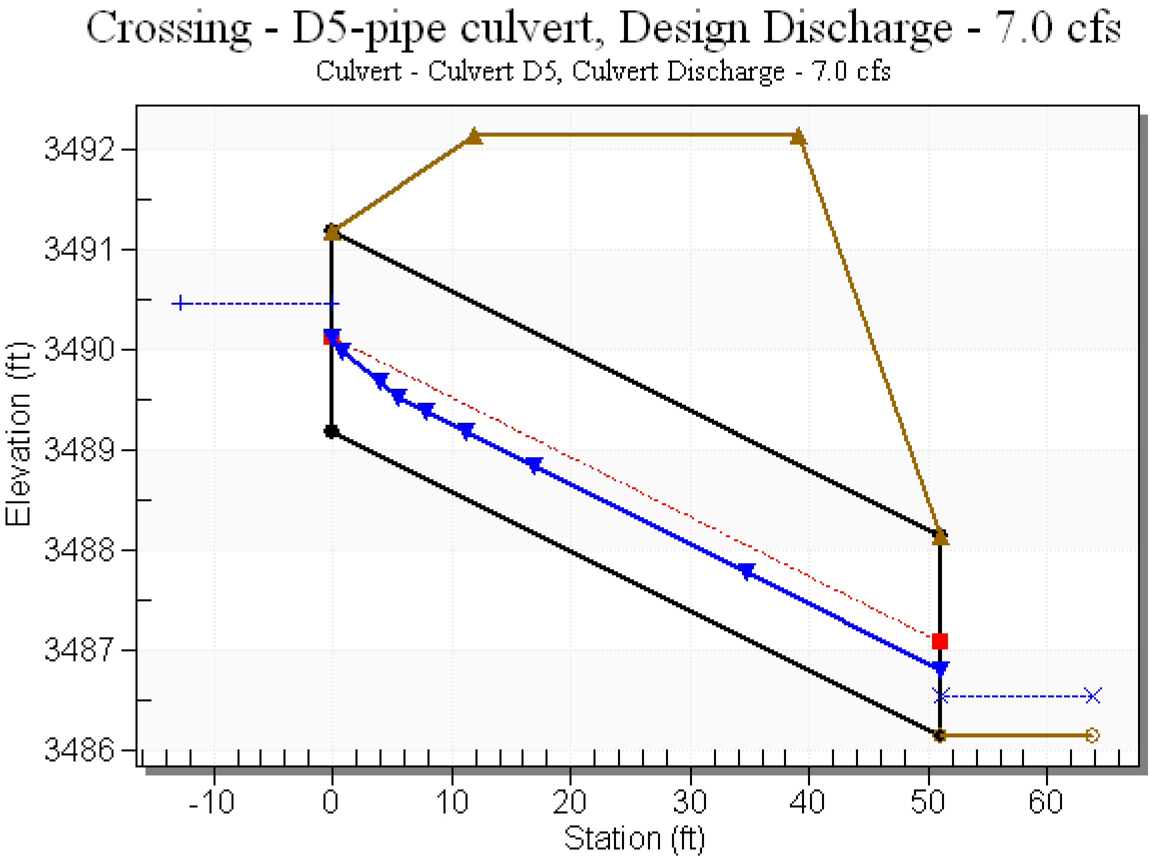


Table 14 - Summary of Culvert Flows at Crossing: D6-exst pipe culvert

Headwater Elevation (ft)	Total Discharge (cfs)	Exst Culvert D6 Discharge (cfs)	Roadway Discharge (cfs)	Iterations
3459.29	0.00	0.00	0.00	1
3459.80	2.00	2.00	0.00	1
3460.05	4.00	4.00	0.00	1
3460.26	6.00	6.00	0.00	1
3460.45	8.00	8.00	0.00	1
3460.63	10.00	10.00	0.00	1
3460.79	12.00	12.00	0.00	1
3460.96	14.00	14.00	0.00	1
3461.12	16.00	16.00	0.00	1
3461.29	18.00	18.00	0.00	1
3461.47	20.00	20.00	0.00	1
3463.28	33.89	33.89	0.00	Overtopping

Table 13 - Culvert Summary Table: Exst Culvert D6

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)
0.00	0.00	3459.29	0.000	0.0*	0-NF	0.000	0.000	0.000	0.000	0.000	0.000
2.00	2.00	3459.80	0.514	0.0*	1-S2n	0.301	0.324	0.314	0.049	3.100	1.075
4.00	4.00	3460.05	0.763	0.0*	1-S2n	0.445	0.482	0.451	0.074	3.933	1.415
6.00	6.00	3460.26	0.967	0.0*	1-S2n	0.557	0.613	0.562	0.095	4.506	1.662
8.00	8.00	3460.45	1.162	0.0*	1-S2n	0.657	0.718	0.657	0.112	4.976	1.863
10.00	10.00	3460.63	1.339	0.0*	1-S2n	0.751	0.820	0.754	0.128	5.298	2.036
12.00	12.00	3460.79	1.505	0.0*	1-S2n	0.841	0.907	0.841	0.143	5.608	2.188
14.00	14.00	3460.96	1.667	0.0*	1-S2n	0.927	0.993	0.932	0.157	5.828	2.325
16.00	16.00	3461.12	1.831	0.0*	1-S2n	1.014	1.070	1.014	0.170	6.065	2.453
18.00	18.00	3461.29	2.002	0.0*	5-S2n	1.103	1.145	1.104	0.183	6.248	2.568
20.00	20.00	3461.47	2.184	0.0*	5-S2n	1.192	1.218	1.193	0.194	6.404	2.679

Water Surface Profile Plot for Culvert: Exst Culvert D6

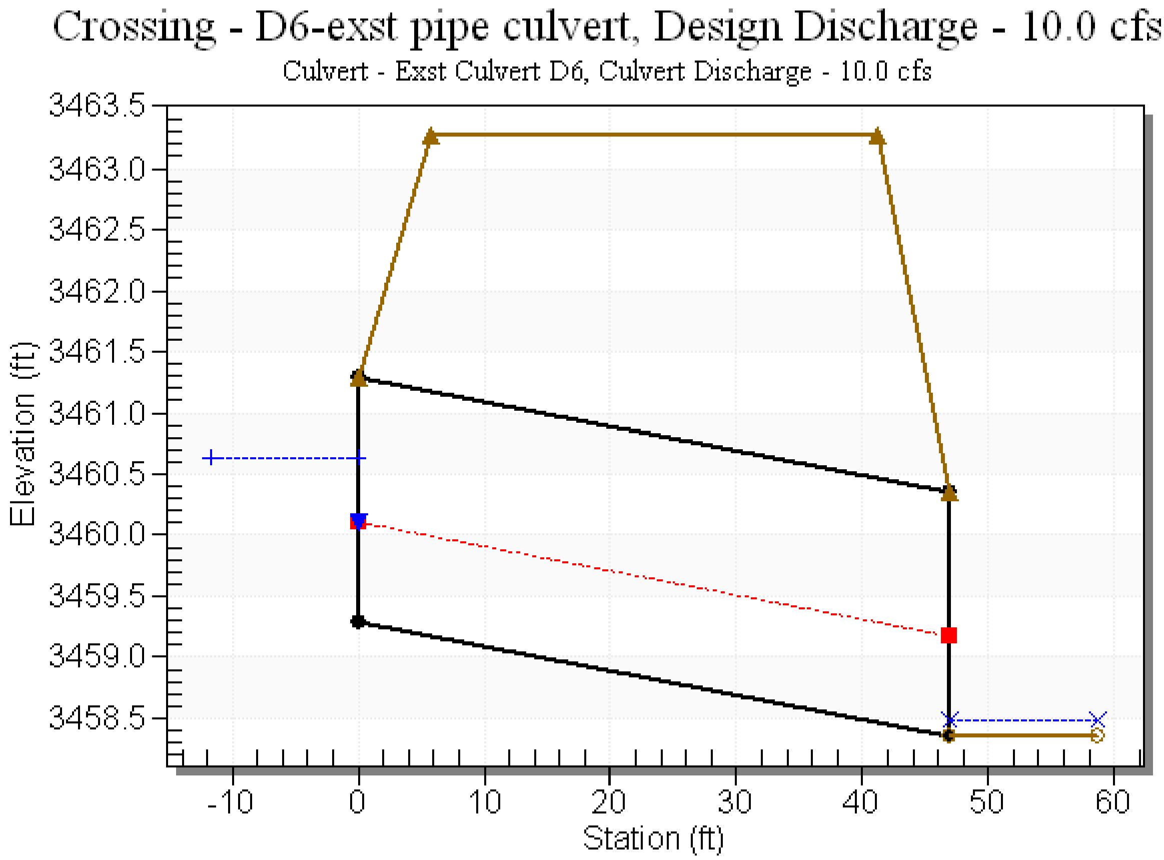


Table 12 - Summary of Culvert Flows at Crossing: D6-pipe culvert

Headwater Elevation (ft)	Total Discharge (cfs)	Culvert D6 Discharge (cfs)	Roadway Discharge (cfs)	Iterations
3459.29	0.00	0.00	0.00	1
3459.93	2.00	2.00	0.00	1
3460.22	4.00	4.00	0.00	1
3460.48	6.00	6.00	0.00	1
3460.71	8.00	8.00	0.00	1
3460.91	10.00	10.00	0.00	1
3461.09	12.00	12.00	0.00	1
3461.35	14.00	14.00	0.00	1
3461.54	16.00	16.00	0.00	1
3461.75	18.00	18.00	0.00	1
3462.13	20.00	20.00	0.00	1
3463.28	24.59	24.59	0.00	Overtopping

Table 11 - Culvert Summary Table: Culvert D6

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)
0.00	0.00	3459.29	0.000	0.0*	0-NF	0.000	0.000	0.000	0.000	0.000	0.000
2.00	2.00	3459.93	0.645	0.0*	1-S2n	0.452	0.481	0.460	0.049	3.625	1.075
4.00	4.00	3460.22	0.933	0.0*	1-S2n	0.651	0.695	0.654	0.074	4.467	1.415
6.00	6.00	3460.48	1.192	0.0*	1-S2n	0.813	0.862	0.814	0.095	5.003	1.662
8.00	8.00	3460.71	1.419	0.0*	1-S2n	0.955	1.006	0.955	0.112	5.399	1.863
10.00	10.00	3460.91	1.617	0.0*	1-S2n	1.092	1.128	1.097	0.128	5.673	2.036
12.00	12.00	3461.09	1.802	0.0*	1-S2n	1.228	1.241	1.228	0.143	5.931	2.188
14.00	14.00	3461.35	1.985	2.065	2-M2c	1.368	1.344	1.347	0.157	6.218	2.325
16.00	16.00	3461.54	2.174	2.251	2-M2c	1.527	1.438	1.442	0.170	6.598	2.453
18.00	18.00	3461.75	2.375	2.460	2-M2c	1.746	1.523	1.528	0.183	6.987	2.568
20.00	20.00	3462.13	2.592	2.838	7-M2c	2.000	1.605	1.606	0.194	7.395	2.679

Water Surface Profile Plot for Culvert: Culvert D6

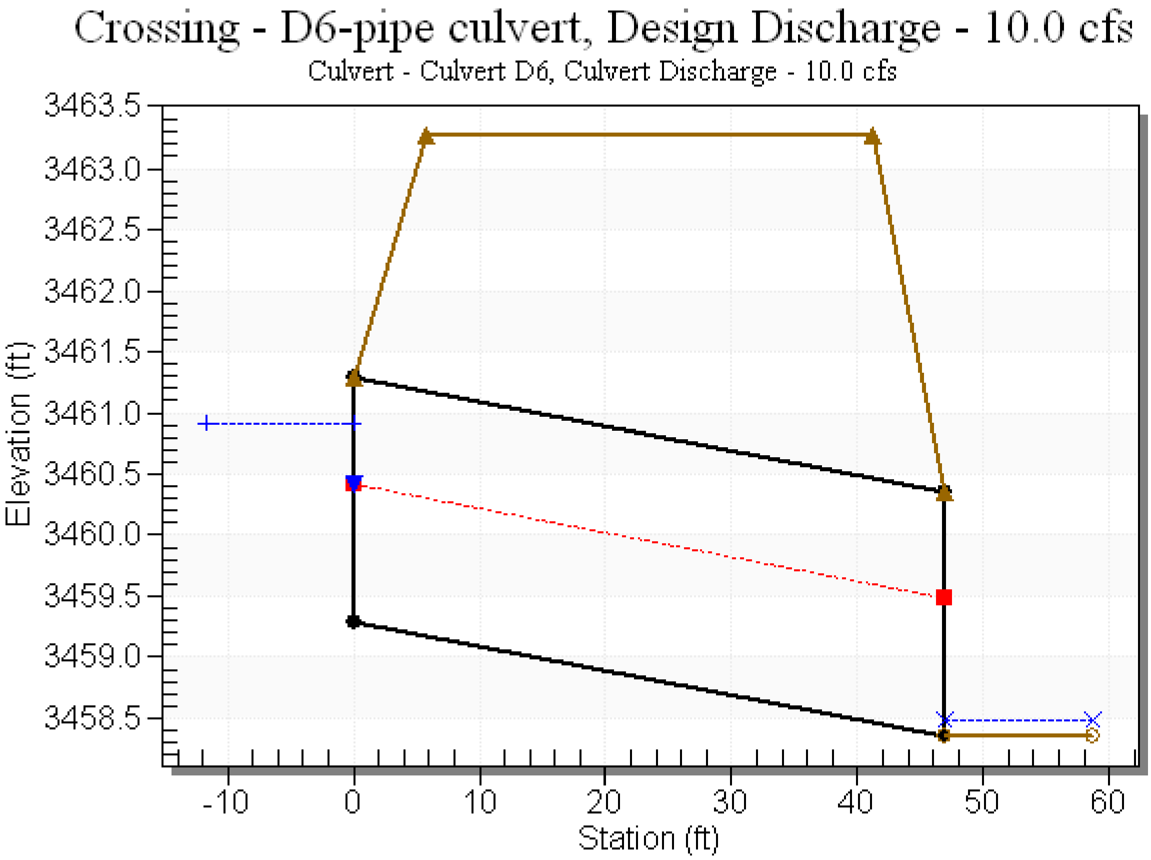


Table 1 - Summary of Culvert Flows at Crossing: D7-exst box culvert

Headwater Elevation (ft)	Total Discharge (cfs)	Exst Culvert D7 Discharge (cfs)	Roadway Discharge (cfs)	Iterations
3419.36	0.00	0.00	0.00	1
3423.10	264.60	264.60	0.00	1
3425.30	529.20	529.20	0.00	1
3427.21	793.80	793.80	0.00	1
3428.90	1058.40	1058.40	0.00	1
3430.50	1323.00	1323.00	0.00	1
3432.11	1587.60	1587.60	0.00	1
3433.84	1852.20	1852.20	0.00	1
3434.33	1924.00	1924.00	0.00	1
3434.72	2381.40	1979.08	400.31	7
3434.82	2646.00	1992.90	652.20	5
3434.46	1941.95	1941.95	0.00	Overtopping

Table 2 - Culvert Summary Table: Exst Culvert D7

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)
0.00	0.00	3419.36	0.000	0.0*	0-NF	0.000	0.000	0.000	0.000	0.000	0.000
264.60	264.60	3423.10	3.743	0.0*	1-S2n	1.317	2.477	1.760	0.792	12.529	9.393
529.20	529.20	3425.30	5.941	0.0*	1-S2n	2.078	3.932	2.966	1.196	14.869	12.162
793.80	793.80	3427.21	7.851	0.0*	1-S2n	2.757	5.152	4.012	1.520	16.487	14.100
1058.40	1058.40	3428.90	9.539	0.0*	1-S2n	3.378	6.242	4.972	1.801	17.741	15.628
1323.00	1323.00	3430.50	11.137	0.0*	1-S2n	3.958	7.243	5.863	2.053	18.806	16.907
1587.60	1587.60	3432.11	12.755	0.0*	5-S2n	4.516	8.179	6.706	2.285	19.730	18.014
1852.20	1852.20	3433.84	14.478	0.0*	5-S2n	5.058	9.064	7.504	2.500	20.569	18.995
1924.00	1924.00	3434.33	14.973	0.0*	5-S2n	5.200	9.297	7.717	2.556	20.778	19.244
2381.40	1979.08	3434.72	15.362	0.0*	5-S2n	5.309	9.473	7.882	2.893	20.923	20.686
2646.00	1992.90	3434.82	15.461	0.0*	5-S2n	5.336	9.517	7.917	3.075	20.976	21.429

Water Surface Profile Plot for Culvert: Exst Culvert D7

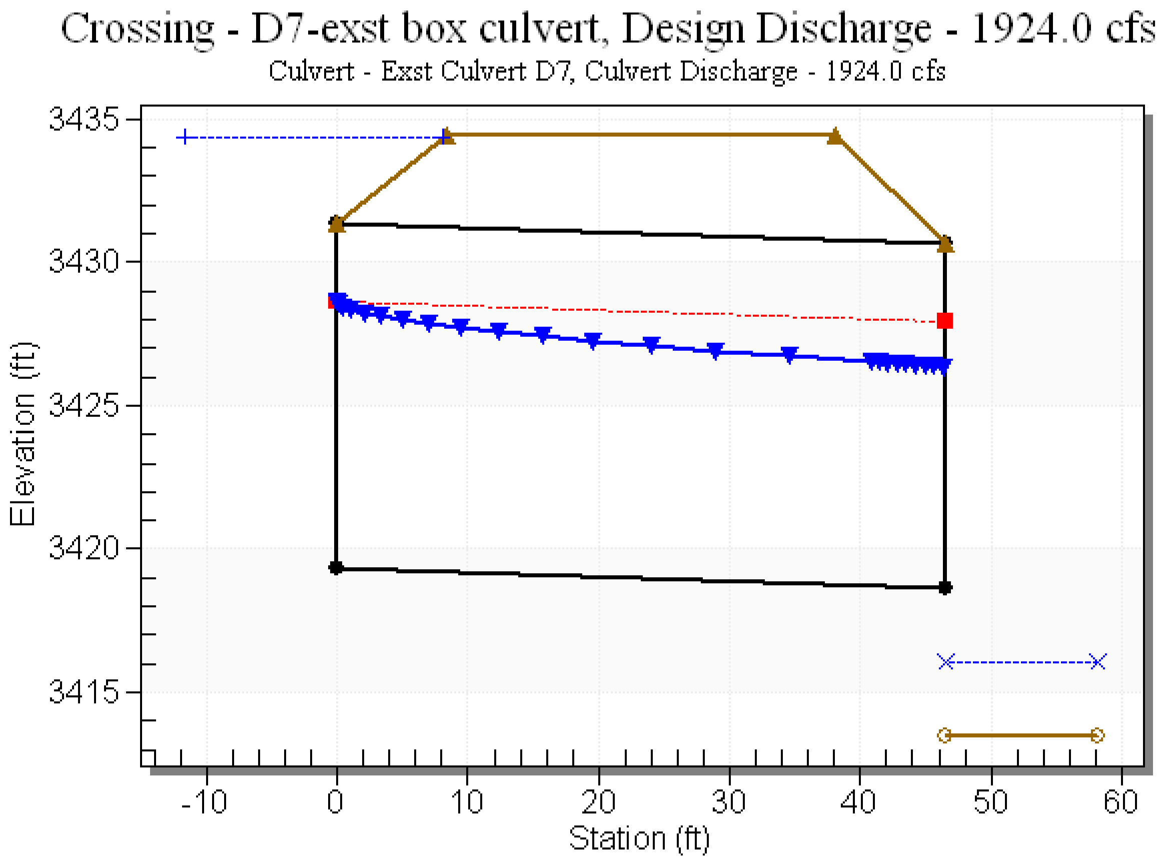


Table 2 - Summary of Culvert Flows at Crossing: D11-exst pipe culvert

Headwater Elevation (ft)	Total Discharge (cfs)	Exst 2-48" culvert Discharge (cfs)	Roadway Discharge (cfs)	Iterations
3342.99	0.00	0.00	0.00	1
3348.32	206.30	206.30	0.00	1
3350.49	412.60	278.75	133.38	9
3350.81	618.90	287.66	330.77	6
3351.04	825.20	293.91	530.75	5
3351.23	1031.50	299.03	732.13	5
3351.40	1237.80	303.51	933.18	4
3351.56	1444.10	307.57	1136.02	4
3351.59	1486.00	308.34	1176.95	3
3351.84	1856.70	314.72	1541.84	4
3351.97	2063.00	317.92	1744.76	3
3349.92	261.87	261.87	0.00	Overtopping

Table 1 - Culvert Summary Table: Exst 2-48" culvert

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)
0.00	0.00	3342.99	0.000	0.0*	0-NF	0.000	0.000	0.000	0.000	0.000	0.000
206.30	206.30	3348.32	5.330	0.624	5-S2n	2.084	3.065	2.475	1.294	12.645	4.531
412.60	278.75	3350.49	7.500	1.251	5-S2n	2.527	3.483	2.963	1.921	13.995	5.700
618.90	287.66	3350.81	7.818	1.739	5-S2n	2.583	3.529	3.021	2.409	14.156	6.481
825.20	293.91	3351.04	8.047	0.0*	5-S2n	2.622	3.562	3.061	2.822	14.271	7.082
1031.50	299.03	3351.23	8.239	0.0*	5-S2n	2.654	3.589	3.094	3.186	14.362	7.576
1237.80	303.51	3351.40	8.410	0.0*	5-S2n	2.683	3.612	3.121	3.513	14.446	7.997
1444.10	307.57	3351.56	8.567	0.0*	5-S2n	2.708	3.633	3.146	3.814	14.520	8.367
1486.00	308.34	3351.59	8.598	0.0*	5-S2n	2.713	3.637	3.151	3.872	14.532	8.437
1856.70	314.72	3351.84	8.850	7.782	4-FFf	2.753	3.670	2.753	4.353	17.073	8.997
2063.00	317.92	3351.97	8.979	8.112	4-FFf	2.773	3.687	2.773	4.598	17.104	9.272

Water Surface Profile Plot for Culvert: Exst 2-48" culvert

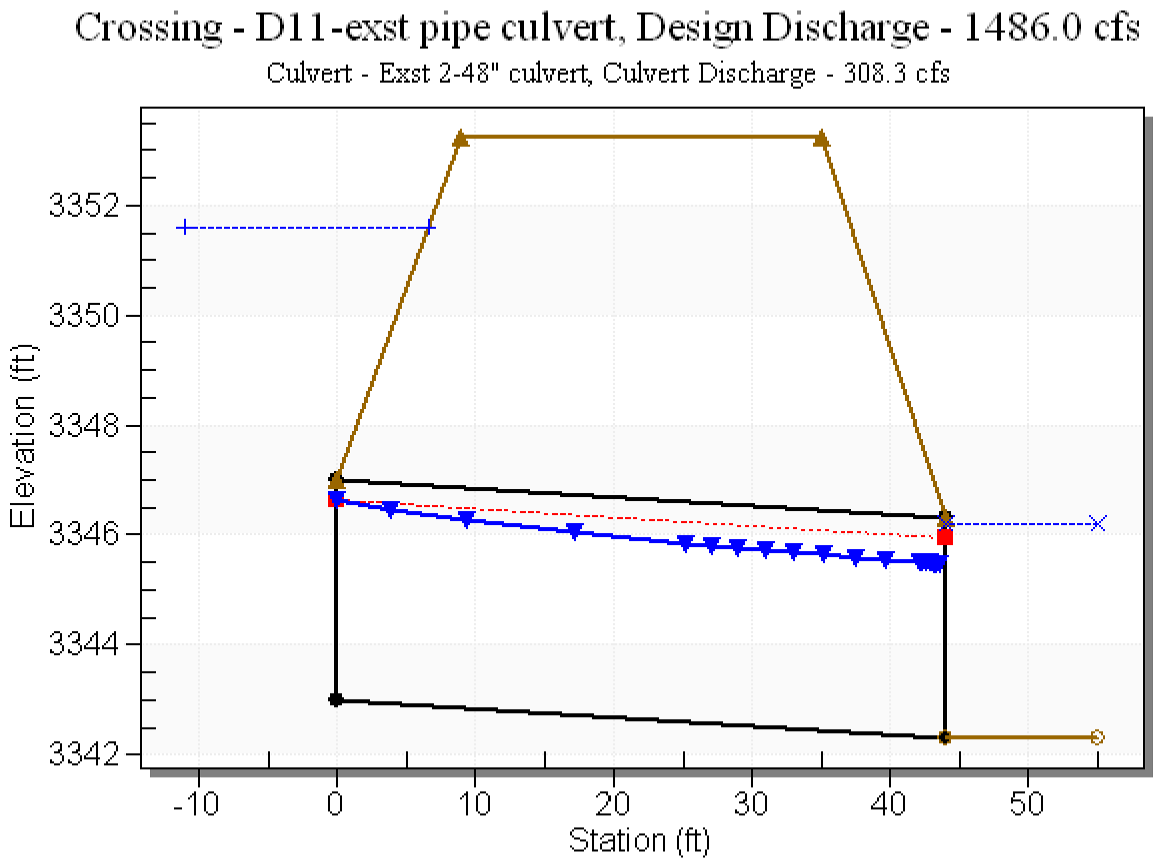


Table 22 - Summary of Culvert Flows at Crossing: D11-box culvert (3 barrel)

Headwater Elevation (ft)	Total Discharge (cfs)	Box Culvert Discharge (cfs)	Roadway Discharge (cfs)	Iterations
3342.99	0.00	0.00	0.00	1
3344.71	206.30	206.30	0.00	1
3345.73	412.60	412.60	0.00	1
3346.60	618.90	618.90	0.00	1
3347.36	825.20	825.20	0.00	1
3348.08	1031.50	1031.50	0.00	1
3348.78	1237.80	1237.80	0.00	1
3349.50	1444.10	1444.10	0.00	1
3349.65	1486.00	1486.00	0.00	1
3350.51	1856.70	1713.91	142.45	4
3350.75	2063.00	1774.20	287.79	5
3349.92	1560.27	1560.27	0.00	Overtopping

Table 21 - Culvert Summary Table: Box Culvert

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)
0.00	0.00	3342.99	0.000	0.0*	0-NF	0.000	0.000	0.000	0.000	0.000	0.000
206.30	206.30	3344.71	1.719	0.0*	1-S2n	0.630	1.139	0.747	1.294	9.204	4.531
412.60	412.60	3345.73	2.736	0.0*	1-S2n	1.008	1.808	1.255	1.921	10.957	5.700
618.90	618.90	3346.60	3.605	0.0*	1-S2n	1.302	2.369	1.703	2.409	12.111	6.481
825.20	825.20	3347.36	4.372	0.0*	1-S2n	1.582	2.870	2.115	2.822	13.003	7.082
1031.50	1031.50	3348.08	5.085	0.0*	5-S2n	1.836	3.331	2.501	3.186	13.749	7.576
1237.80	1237.80	3348.78	5.786	0.0*	5-S2n	2.081	3.761	2.867	3.513	14.390	7.997
1444.10	1444.10	3349.50	6.505	0.0*	5-S2n	2.310	4.168	3.217	3.814	14.962	8.367
1486.00	1486.00	3349.65	6.656	0.0*	5-S2n	2.357	4.249	3.287	3.872	15.071	8.437
1856.70	1713.91	3350.51	7.518	0.0*	5-S2n	2.604	4.673	3.653	4.353	15.641	8.997
2063.00	1774.20	3350.75	7.760	0.0*	5-S2n	2.666	4.782	3.752	4.598	15.764	9.272

Water Surface Profile Plot for Culvert: Box Culvert

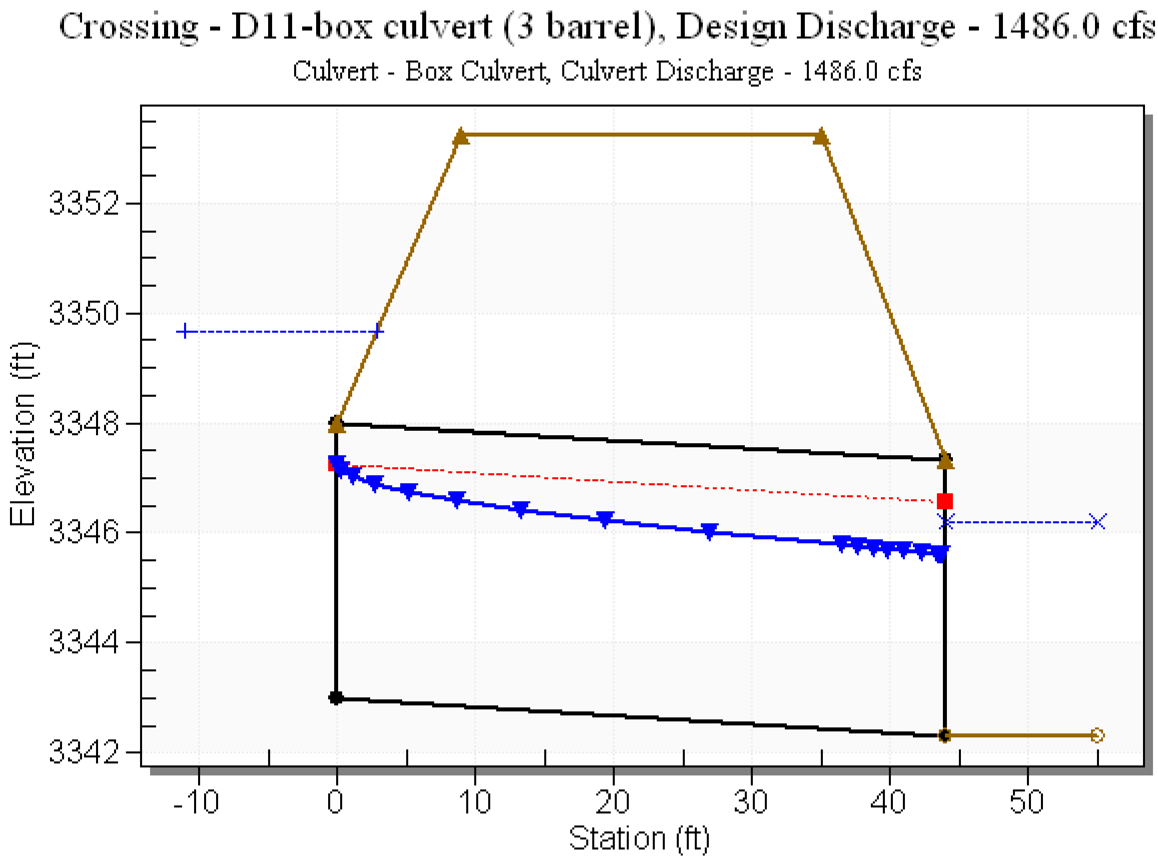


Table 20 - Summary of Culvert Flows at Crossing: D13-exst pipe culvert

Headwater Elevation (ft)	Total Discharge (cfs)	Exst Culvert D13 Discharge (cfs)	Roadway Discharge (cfs)	Iterations
3331.72	0.00	0.00	0.00	1
3334.95	13.00	11.27	1.60	82
3334.97	26.00	11.31	14.50	6
3334.98	39.00	11.34	27.32	4
3335.00	52.00	11.36	40.50	4
3335.00	59.00	11.37	47.37	3
3335.02	78.00	11.39	66.28	3
3335.03	91.00	11.40	79.47	3
3335.04	104.00	11.41	91.67	2
3335.05	117.00	11.32	105.64	3
3335.06	130.00	11.23	118.50	2
3334.94	11.26	11.26	0.00	Overtopping

Table 19 - Culvert Summary Table: Exst Culvert D13

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)
0.00	0.00	3331.72	0.000	0.0*	0-NF	0.000	0.000	0.000	0.000	0.000	0.000
13.00	11.27	3334.95	2.958	3.227	7-M2c	1.250	1.056	1.064	0.368	6.928	3.730
26.00	11.31	3334.97	2.974	3.249	7-M2c	1.250	1.058	1.066	0.545	6.945	4.683
39.00	11.34	3334.98	2.984	3.264	7-M2c	1.250	1.059	1.067	0.683	6.956	5.319
52.00	11.36	3335.00	2.993	3.278	7-M2c	1.250	1.059	1.068	0.800	6.965	5.808
59.00	11.37	3335.00	2.998	3.284	7-M2c	1.250	1.060	1.068	0.856	6.970	6.032
78.00	11.39	3335.02	3.009	3.300	7-M2c	1.250	1.061	1.069	0.994	6.981	6.551
91.00	11.40	3335.03	3.013	3.310	7-M2t	1.250	1.061	1.079	1.079	6.944	6.852
104.00	11.41	3335.04	3.017	3.319	7-M2t	1.250	1.062	1.157	1.157	6.654	7.119
117.00	11.32	3335.05	2.979	3.329	7-M2t	1.250	1.058	1.230	1.230	6.433	7.363
130.00	11.23	3335.06	2.943	3.338	4-FFf	1.250	1.055	1.250	1.299	6.363	7.586

Water Surface Profile Plot for Culvert: Exst Culvert D13

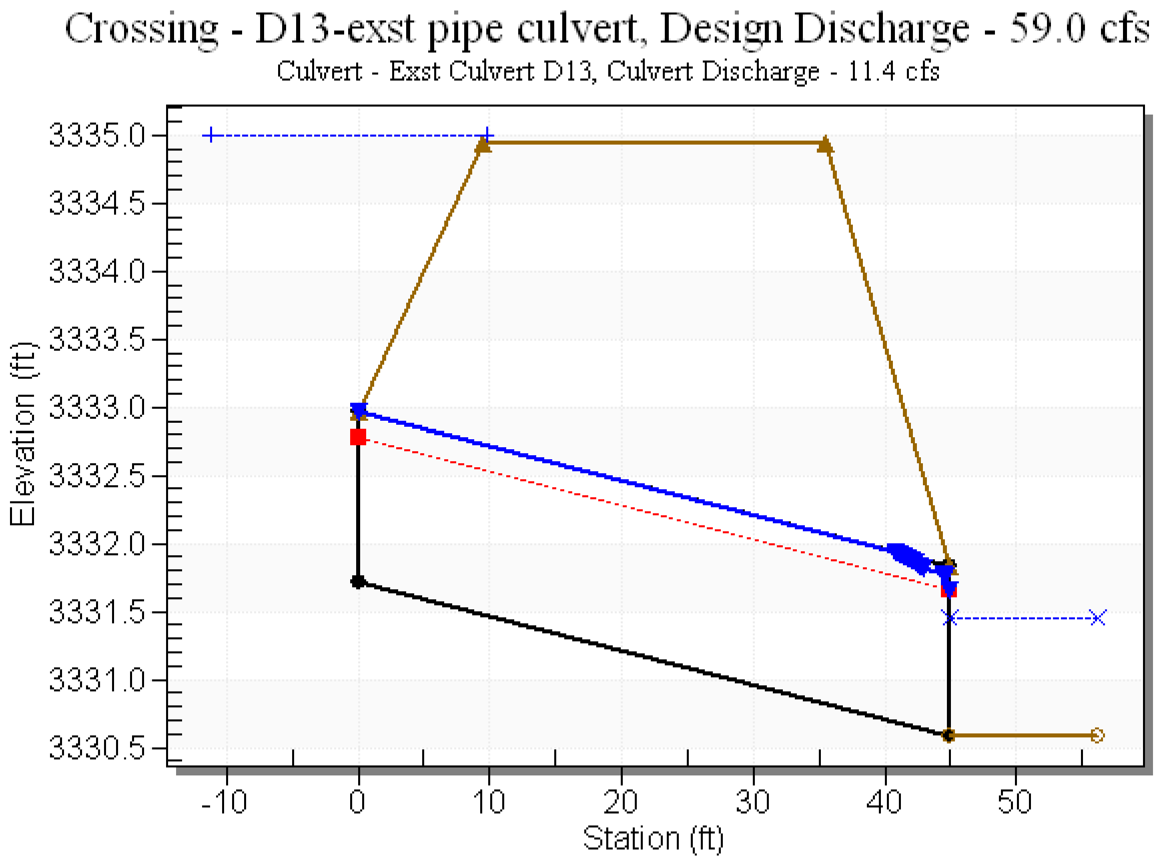


Table 18 - Summary of Culvert Flows at Crossing: D13-pipe culvert

Headwater Elevation (ft)	Total Discharge (cfs)	Culvert D13 Discharge (cfs)	Roadway Discharge (cfs)	Iterations
3330.84	0.00	0.00	0.00	1
3332.16	13.00	13.00	0.00	1
3332.76	26.00	26.00	0.00	1
3333.23	39.00	39.00	0.00	1
3333.66	52.00	52.00	0.00	1
3333.88	59.00	59.00	0.00	1
3334.46	78.00	78.00	0.00	1
3334.94	91.00	90.03	0.12	67
3334.97	104.00	90.58	12.67	5
3334.98	117.00	90.91	25.66	4
3335.00	130.00	91.19	38.05	3
3334.94	90.01	90.01	0.00	Overtopping

Table 17 - Culvert Summary Table: Culvert D13

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)
0.00	0.00	3330.84	0.000	0.0*	0-NF	0.000	0.000	0.000	0.000	0.000	0.000
13.00	13.00	3332.16	1.164	1.320	2-M2c	0.814	0.789	0.801	0.368	4.288	3.730
26.00	26.00	3332.76	1.699	1.921	2-M2c	1.185	1.140	1.146	0.545	5.237	4.683
39.00	39.00	3333.23	2.166	2.393	2-M2c	1.490	1.410	1.416	0.683	5.940	5.319
52.00	52.00	3333.66	2.612	2.825	2-M2c	1.778	1.640	1.646	0.800	6.545	5.808
59.00	59.00	3333.88	2.857	3.037	2-M2c	1.938	1.756	1.759	0.856	6.851	6.032
78.00	78.00	3334.46	3.576	3.621	2-M2c	2.440	2.028	2.032	0.994	7.651	6.551
91.00	90.03	3334.94	4.101	4.040	2-M2c	3.000	2.179	2.186	1.079	8.175	6.852
104.00	90.58	3334.97	4.127	4.083	2-M2c	3.000	2.185	2.192	1.157	8.199	7.119
117.00	90.91	3334.98	4.142	4.105	2-M2c	3.000	2.189	2.196	1.230	8.214	7.363
130.00	91.19	3335.00	4.155	4.113	2-M2c	3.000	2.192	2.200	1.299	8.226	7.586

Water Surface Profile Plot for Culvert: Culvert D13

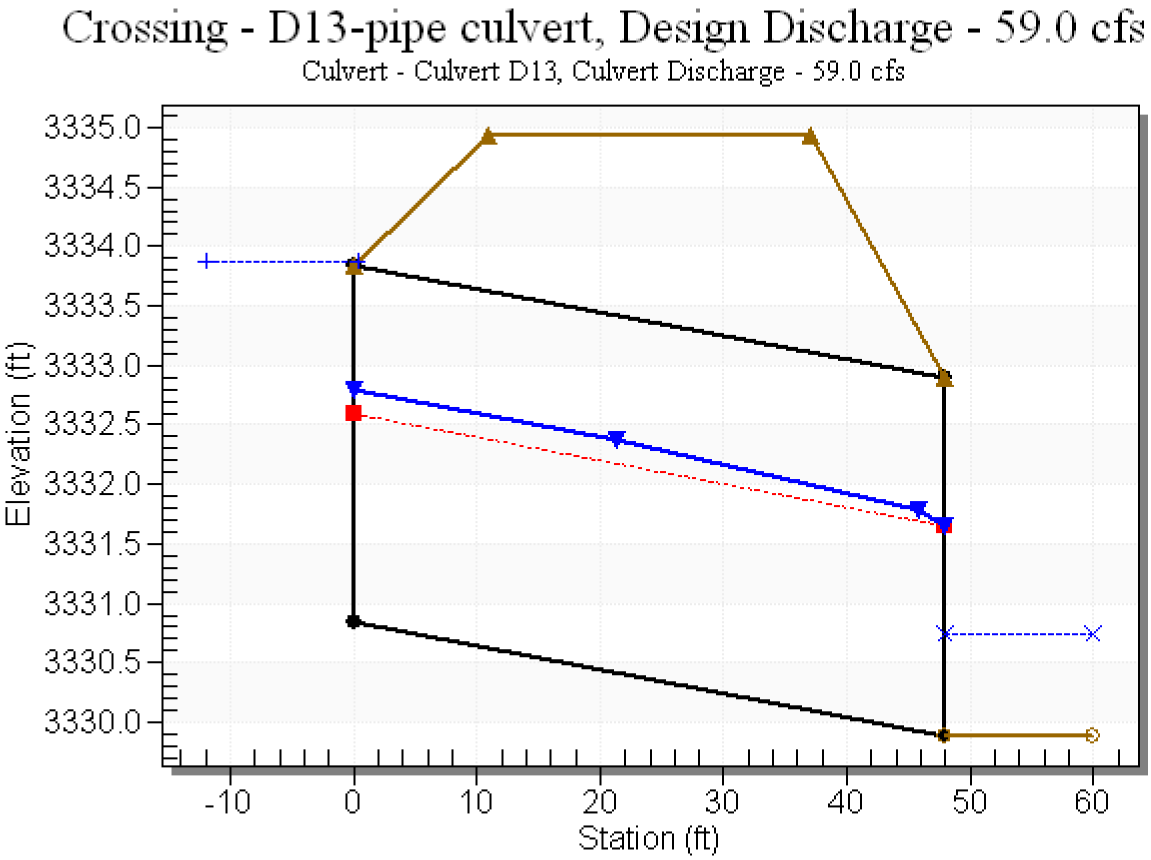


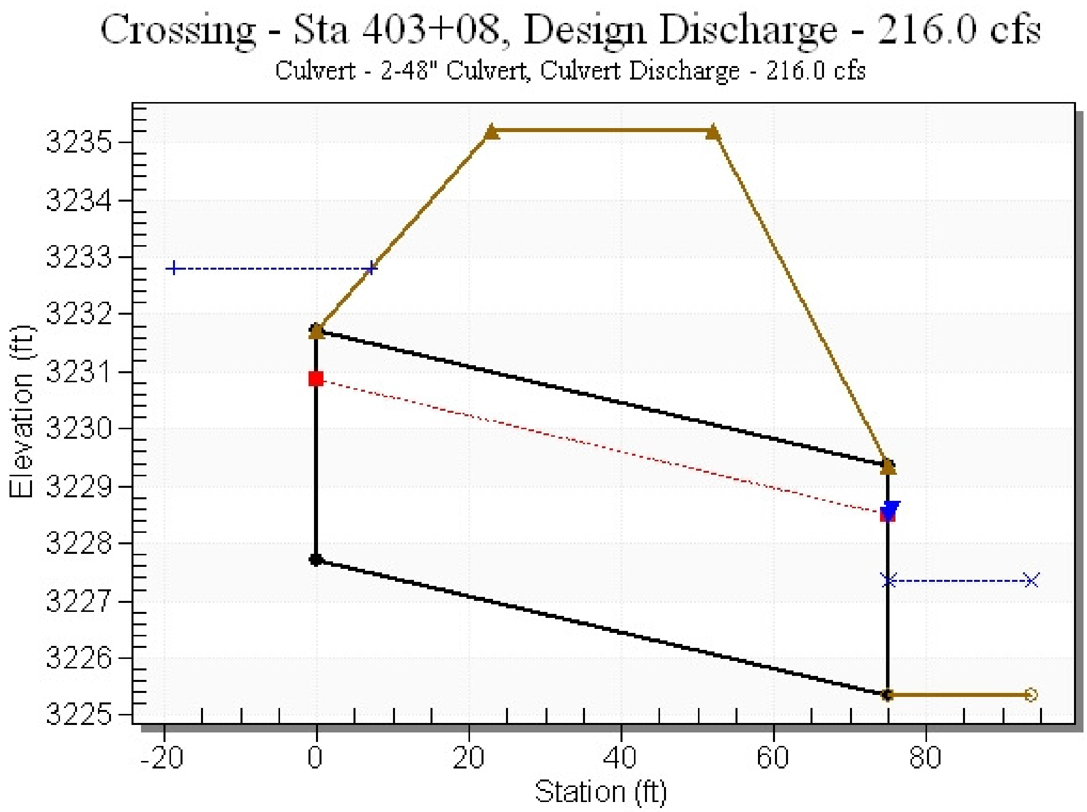
Table 1 - Summary of Culvert Flows at Crossing: Sta 403+08

Headwater Elevation (ft)	Total Discharge (cfs)	2-48" Culvert Discharge (cfs)	Roadway Discharge (cfs)	Iterations
3227.72	0.00	0.00	0.00	1
3229.61	47.00	47.00	0.00	1
3230.60	94.00	94.00	0.00	1
3231.39	141.00	141.00	0.00	1
3232.17	188.00	188.00	0.00	1
3232.80	216.00	216.00	0.00	1
3235.25	282.00	274.73	6.44	37
3235.33	329.00	276.43	51.90	6
3235.38	376.00	277.61	98.04	5
3235.43	423.00	278.60	143.89	4
3235.47	470.00	279.49	190.28	4
3235.22	274.16	274.16	0.00	Overtopping

Table 2 - Culvert Summary Table: 2-48" Culvert

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)
0.00	0.00	3227.72	0.000	0.0*	0-NF	0.000	0.000	0.000	0.000	0.000	0.000
47.00	47.00	3229.61	1.886	0.0*	1-S2n	1.267	1.418	1.268	0.840	6.852	4.792
94.00	94.00	3230.60	2.878	0.0*	1-S2n	1.850	2.050	1.859	1.250	8.214	6.014
141.00	141.00	3231.39	3.665	0.0*	1-S2n	2.369	2.530	2.369	1.571	9.096	6.828
188.00	188.00	3232.17	4.446	0.0*	5-S2n	2.916	2.929	2.919	1.843	9.586	7.453
216.00	216.00	3232.80	4.960	5.081	2-M2c	3.341	3.137	3.143	1.989	10.195	7.768
282.00	274.73	3235.25	6.208	7.527	7-M2c	4.000	3.462	3.488	2.299	11.814	8.400
329.00	276.43	3235.33	6.248	7.608	7-M2c	4.000	3.471	3.496	2.498	11.865	8.783
376.00	277.61	3235.38	6.276	7.664	7-M2c	4.000	3.477	3.498	2.682	11.909	9.125
423.00	278.60	3235.43	6.299	7.711	7-M2c	4.000	3.482	3.503	2.854	11.940	9.434
470.00	279.49	3235.47	6.320	7.754	7-M2c	4.000	3.487	3.507	3.017	11.967	9.718

Water Surface Profile Plot for Culvert: 2-48" Culvert



Site Data - 2-48" Culvert

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 3227.72 ft

Outlet Station: 75.00 ft

Outlet Elevation: 3225.36 ft

Number of Barrels: 2

Culvert Data Summary - 2-48" Culvert

Barrel Shape: Circular

Barrel Diameter: 4.00 ft

Barrel Material: Corrugated Aluminum

Embedment: 0.00 in

Barrel Manning's n: 0.0310

Inlet Type: Conventional

Inlet Edge Condition: Beveled Edge (1.5:1)

Inlet Depression: NONE

Appendix D – Ditch Hydraulic Analysis

Cross Section for Full Roadway Ditch Section

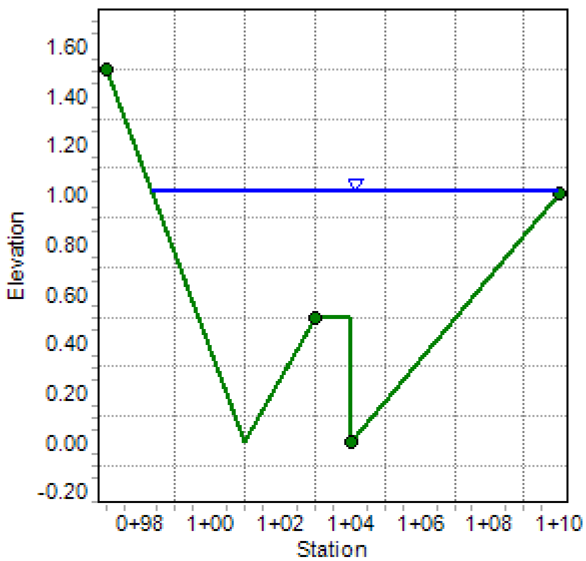
Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Channel Slope	0.01000	ft/ft
Normal Depth	1.01	ft
Discharge	35.00	ft³/s

Cross Section Image



Worksheet for Full Roadway Ditch Section

Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Channel Slope	0.01000	ft/ft
Discharge	35.00	ft^3/s

Section Definitions

Station (ft)	Elevation (ft)
1+10	1.00
1+04	0.00
1+04	0.50
1+03	0.50
1+01	0.00
0+97	1.50

Roughness Segment Definitions

Start Station & Elevation	End Station & Elevation	Roughness Coefficient
(1+10, 1.00)	(1+04, 0.00)	0.016
(1+04, 0.00)	(1+03, 0.50)	0.013
(1+03, 0.50)	(0+97, 1.50)	0.020

Options

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

Results

Normal Depth	1.01	ft
Elevation Range	0.00 to 1.50 ft	
Flow Area	6.40	ft^2
Wetted Perimeter	12.52	ft
Hydraulic Radius	0.51	ft

Worksheet for Full Roadway Ditch Section

Results

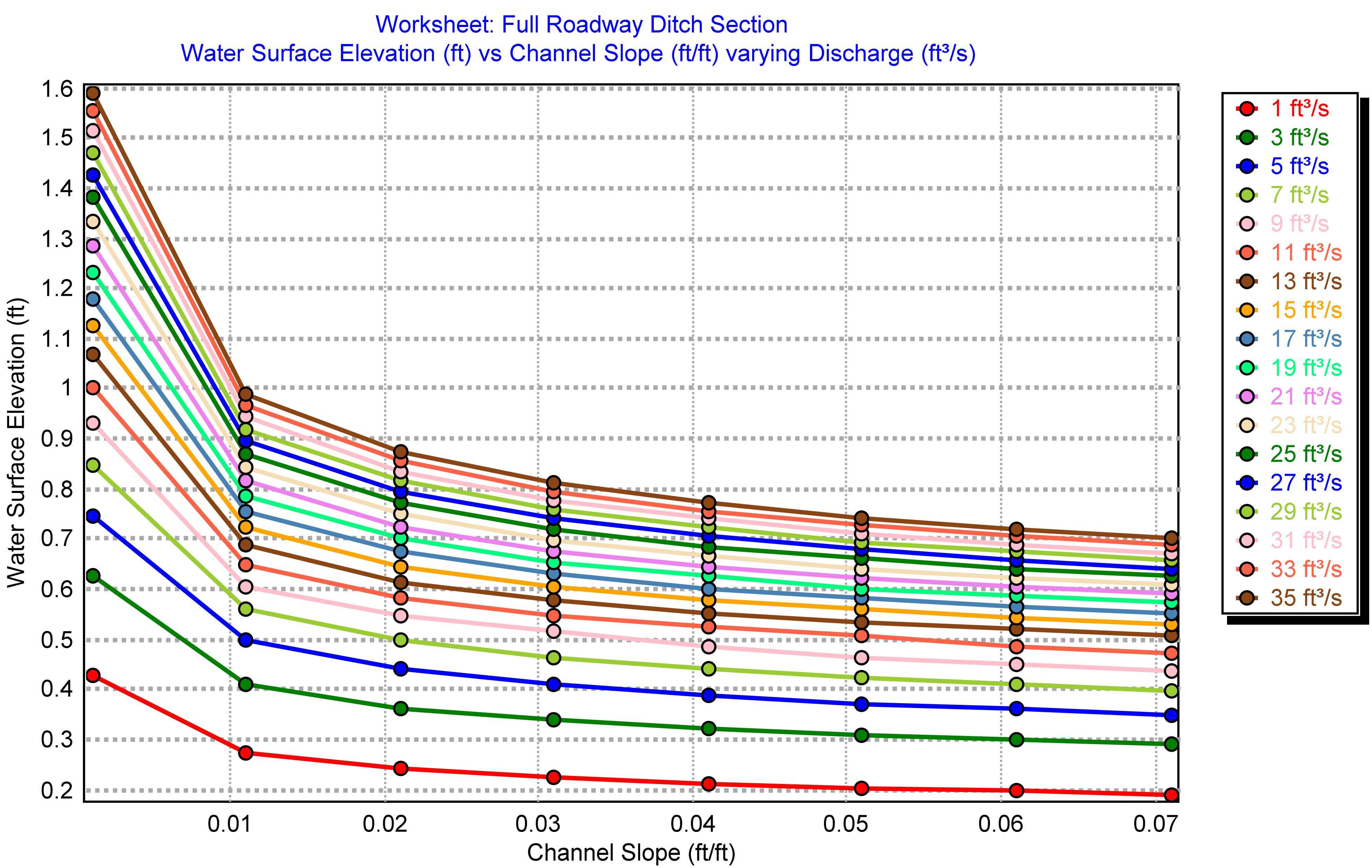
Top Width		11.68	ft
Normal Depth		1.01	ft
Critical Depth		1.12	ft
Critical Slope		0.00566	ft/ft
Velocity		5.47	ft/s
Velocity Head		0.46	ft
Specific Energy		1.47	ft
Froude Number		1.30	
Flow Type	Supercritical		

GVF Input Data

Downstream Depth	0.00	ft
Length	0.00	ft
Number Of Steps	0	

GVF Output Data

Upstream Depth	0.00	ft
Profile Description		
Profile Headloss	0.00	ft
Downstream Velocity	Infinity	ft/s
Upstream Velocity	Infinity	ft/s
Normal Depth	1.01	ft
Critical Depth	1.12	ft
Channel Slope	0.01000	ft/ft
Critical Slope	0.00566	ft/ft


Worksheet: Full Roadway Ditch Section
Water Surface Elevation (ft) vs Channel Slope (ft/ft) varying Discharge (ft³/s)
Water Surface Elevation (ft)
Channel Slope (ft/ft)
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
1.1
1.2
1.3
1.4
1.5
1.6
0.01
0.02
0.03
0.04
0.05
0.06
0.07
1 ft³/s
3 ft³/s
5 ft³/s
7 ft³/s
9 ft³/s
11 ft³/s
13 ft³/s
15 ft³/s
17 ft³/s
19 ft³/s
21 ft³/s
23 ft³/s
25 ft³/s
27 ft³/s
29 ft³/s
31 ft³/s
33 ft³/s
35 ft³/s

Cross Section for Typical Roadway Ditch Section

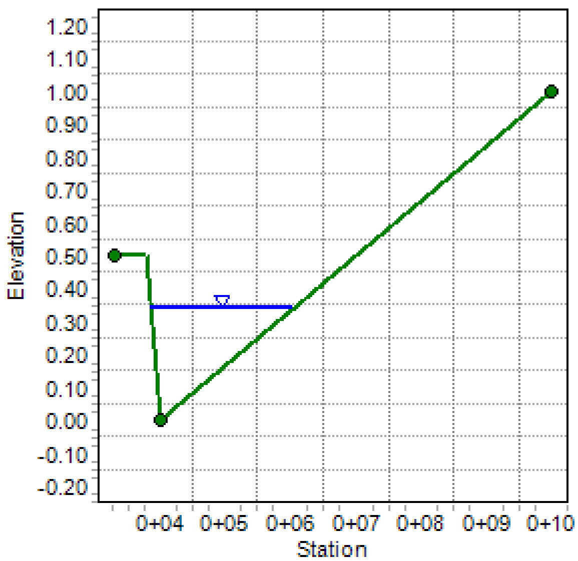
Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Channel Slope	0.01000	ft/ft
Normal Depth	0.34	ft
Discharge	1.00	ft³/s

Cross Section Image



Worksheet for Typical Roadway Ditch Section

Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Channel Slope	0.01000	ft/ft
Discharge	1.00	ft³/s
Section Definitions		

Station (ft)	Elevation (ft)
0+10	1.00
0+04	0.00
0+04	0.50
0+03	0.50

Roughness Segment Definitions

Start Station & Elevation	End Station & Elevation	Roughness Coefficient
(0+10, 1.00)	(0+04, 0.00)	0.016
(0+04, 0.00)	(0+03, 0.50)	0.013

Options

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

Results

Normal Depth	0.34	ft
Elevation Range	0.00 to 1.00 ft	
Flow Area	0.37	ft²
Wetted Perimeter	2.43	ft
Hydraulic Radius	0.15	ft
Top Width	2.18	ft
Normal Depth	0.34	ft
Critical Depth	0.36	ft

Worksheet for Typical Roadway Ditch Section

Results

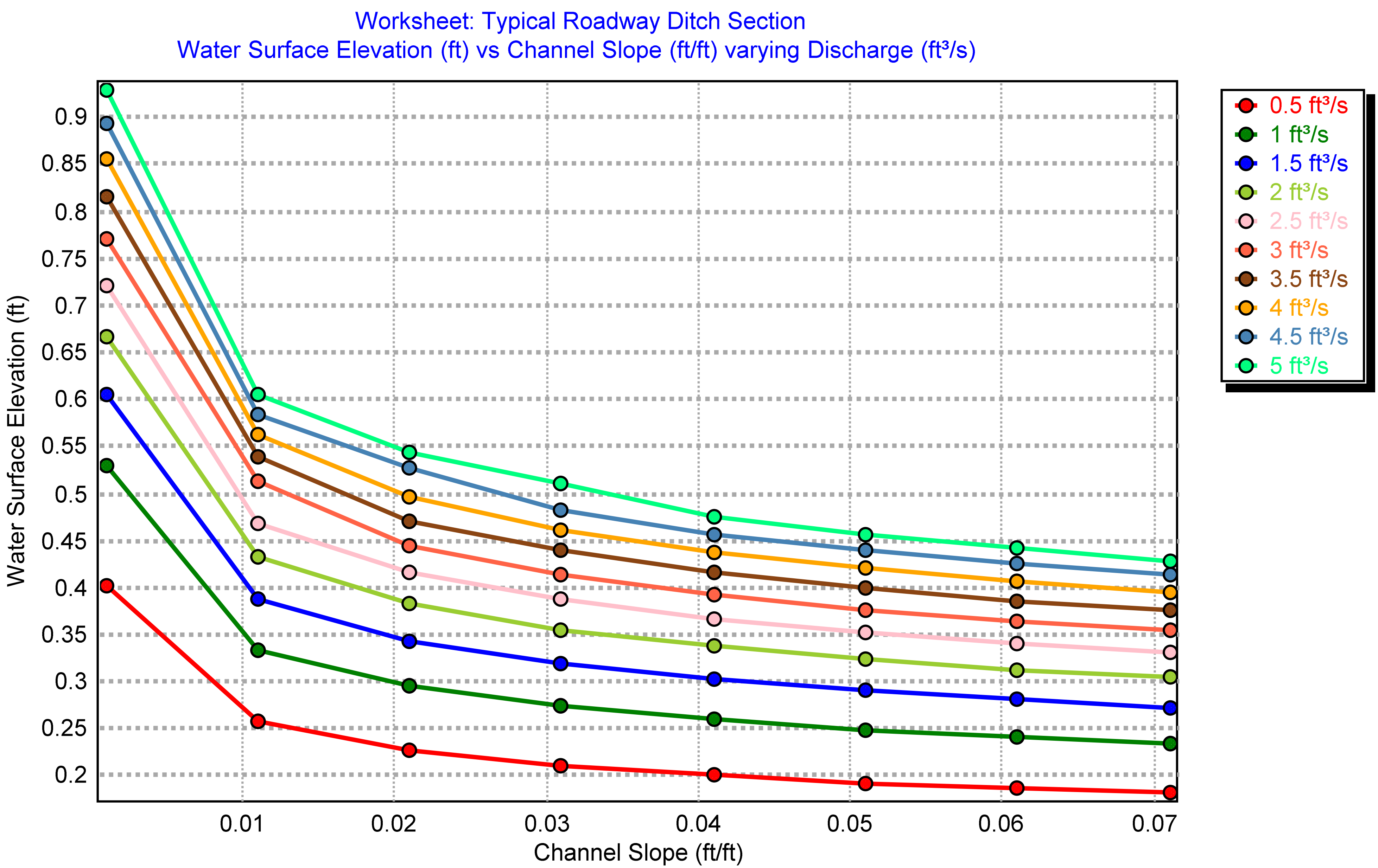
Critical Slope		0.00726	ft/ft
Velocity		2.71	ft/s
Velocity Head		0.11	ft
Specific Energy		0.45	ft
Froude Number		1.16	
Flow Type	Supercritical		

GVF Input Data

Downstream Depth	0.00	ft
Length	0.00	ft
Number Of Steps	0	

GVF Output Data

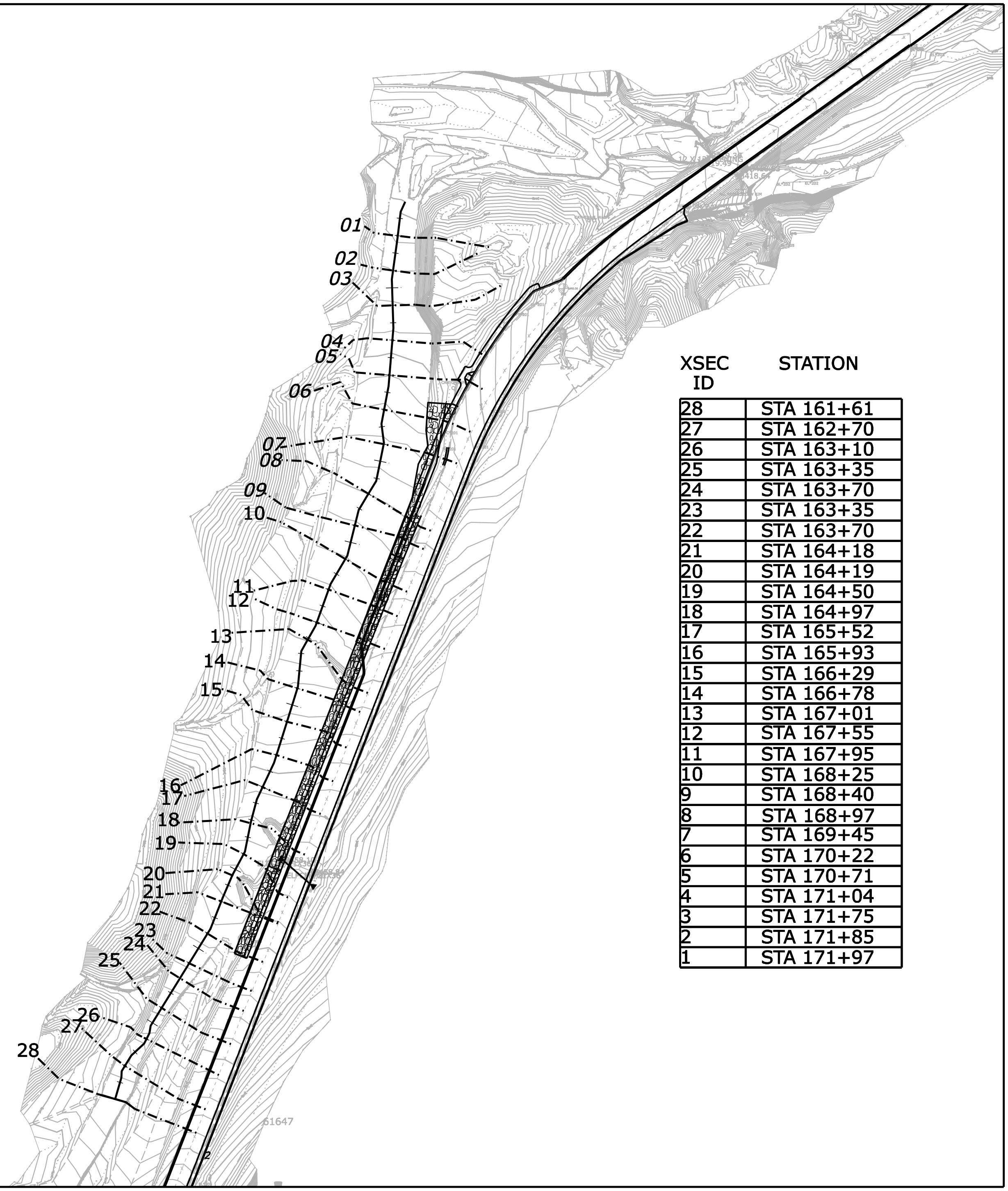
Upstream Depth	0.00	ft
Profile Description		
Profile Headloss	0.00	ft
Downstream Velocity	Infinity	ft/s
Upstream Velocity	Infinity	ft/s
Normal Depth	0.34	ft
Critical Depth	0.36	ft
Channel Slope	0.01000	ft/ft
Critical Slope	0.00726	ft/ft


Worksheet: Typical Roadway Ditch Section
Water Surface Elevation (ft) vs Channel Slope (ft/ft) varying Discharge (ft³/s)
Water Surface Elevation (ft)
Channel Slope (ft/ft)
0.9
0.85
0.8
0.75
0.7
0.65
0.6
0.55
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.5 ft³/s
1 ft³/s
1.5 ft³/s
2 ft³/s
2.5 ft³/s
3 ft³/s
3.5 ft³/s
4 ft³/s
4.5 ft³/s
5 ft³/s

Appendix E – Channel Hydraulic Analysis

Channel Hydraulic HEC-RAS Analysis – Sta 163+68 to Sta 170+76 (Tributary to Cathedral Wash Existing Model)

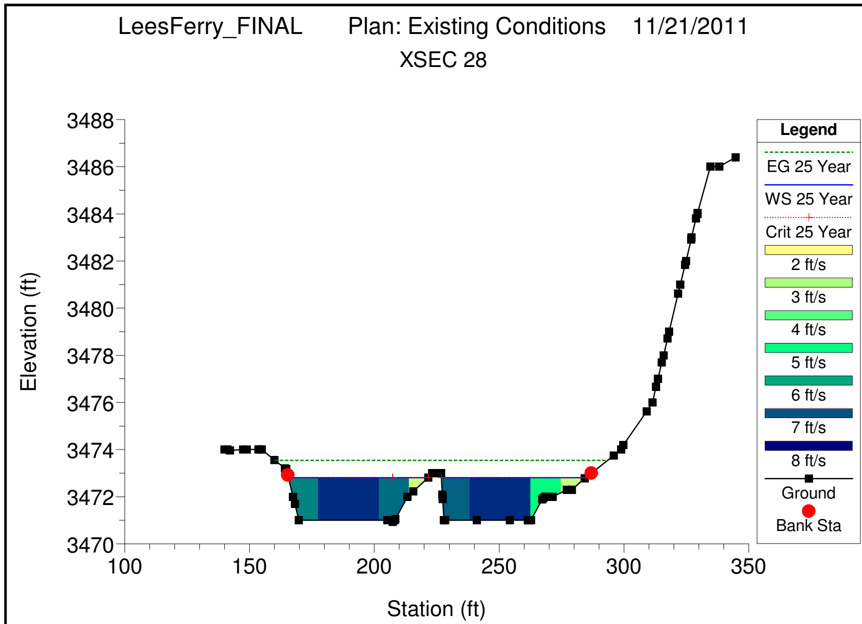
Hec-Ras Cross Sections
Cathedral Wash
Revet Mattress

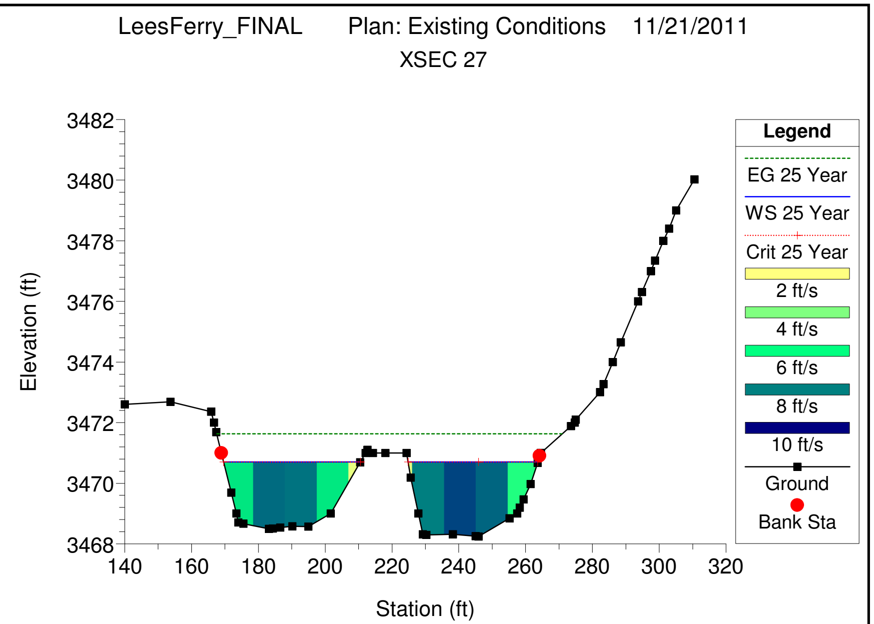


XSEC ID	STATION
28	STA 161+61
27	STA 162+70
26	STA 163+10
25	STA 163+35
24	STA 163+70
23	STA 163+35
22	STA 163+70
21	STA 164+18
20	STA 164+19
19	STA 164+50
18	STA 164+97
17	STA 165+52
16	STA 165+93
15	STA 166+29
14	STA 166+78
13	STA 167+01
12	STA 167+55
11	STA 167+95
10	STA 168+25
9	STA 168+40
8	STA 168+97
7	STA 169+45
6	STA 170+22
5	STA 170+71
4	STA 171+04
3	STA 171+75
2	STA 171+85
1	STA 171+97

HEC-RAS Plan: Ex Cond River: RIVER-1 Reach: Reach-1 Profile: 25 Year

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Reach-1	28	25 Year	1117.00	3470.93	3472.81	3472.81	3473.54	0.013667	6.84	163.35	113.82	1.01
Reach-1	27	25 Year	1117.00	3468.24	3470.70	3470.70	3471.63	0.012798	7.72	144.68	79.73	1.01
Reach-1	26	25 Year	1117.00	3466.39	3469.43	3469.43	3470.36	0.012590	7.71	144.85	78.57	1.00
Reach-1	25	25 Year	1117.00	3466.00	3468.52	3468.52	3469.47	0.012406	7.82	142.91	75.25	1.00
Reach-1	24	25 Year	1117.00	3463.90	3466.26	3466.26	3467.19	0.012686	7.72	144.64	79.36	1.01
Reach-1	23	25 Year	1117.00	3463.00	3465.42	3465.42	3466.40	0.012466	7.97	140.20	72.13	1.01
Reach-1	22	25 Year	1117.00	3461.50	3464.41		3465.00	0.005800	6.20	180.10	76.52	0.71
Reach-1	21	25 Year	1117.00	3461.00	3464.51	3463.12	3464.79	0.001800	4.20	265.77	103.46	0.46
Reach-1	20	25 Year	1117.00	3460.00	3463.57	3463.57	3464.39	0.012920	7.27	153.68	94.23	1.00
Reach-1	19	25 Year	1117.00	3458.19	3462.31	3460.93	3462.71	0.002323	5.03	222.24	83.41	0.48
Reach-1	18	25 Year	1388.00	3457.07	3460.65	3460.65	3462.04	0.011125	9.44	147.07	53.90	1.01
Reach-1	17	25 Year	1388.00	3455.75	3458.44	3458.44	3459.58	0.011168	8.54	162.48	83.84	0.99
Reach-1	16	25 Year	1388.00	3454.32	3457.04	3457.04	3458.01	0.012105	7.92	175.18	90.36	1.00
Reach-1	15	25 Year	1388.00	3453.00	3455.43	3455.43	3456.27	0.012979	7.36	188.51	114.13	1.01
Reach-1	14	25 Year	1388.00	3452.00	3454.54		3455.16	0.007514	6.33	219.39	110.96	0.79
Reach-1	13	25 Year	1388.00	3450.90	3453.59	3453.59	3454.48	0.012603	7.57	183.27	104.26	1.01
Reach-1	12	25 Year	1388.00	3448.61	3451.91	3451.91	3453.02	0.011233	8.45	164.37	99.00	0.99
Reach-1	11	25 Year	1388.00	3447.40	3450.04	3450.04	3451.00	0.012409	7.86	176.52	93.57	1.01
Reach-1	10	25 Year	1388.00	3446.89	3448.97	3448.97	3449.89	0.012450	7.72	179.90	98.39	1.01
Reach-1	9	25 Year	1388.00	3446.00	3448.08	3448.08	3448.92	0.012574	7.33	189.25	112.70	1.00
Reach-1	8	25 Year	1388.00	3444.83	3446.81	3446.81	3447.54	0.013522	6.88	201.79	140.05	1.01
Reach-1	7	25 Year	1388.00	3443.00	3444.88	3444.88	3445.61	0.013531	6.87	202.13	140.69	1.01
Reach-1	6	25 Year	1388.00	3441.40	3443.57	3443.57	3444.33	0.013348	6.99	198.45	132.87	1.01
Reach-1	5	25 Year	1388.00	3439.30	3442.70		3443.20	0.004027	5.64	245.88	91.29	0.61
Reach-1	4	25 Year	1388.00	3439.30	3441.87	3441.87	3442.88	0.012187	8.08	171.88	85.91	1.01
Reach-1	3	25 Year	1388.00	3438.00	3440.91		3441.71	0.007785	7.16	193.78	82.15	0.82
Reach-1	2	25 Year	1388.00	3436.96	3440.02	3440.02	3441.29	0.011352	9.05	153.34	60.76	1.00
Reach-1	1	25 Year	1388.00	3436.00	3439.67	3439.07	3440.54	0.006002	7.50	184.95	59.71	0.75


LeesFerry_FINAL Plan: Existing Conditions 11/21/2011
XSEC 28
Legend
EG 25 Year
WS 25 Year
Crit 25 Year
2 ft/s
3 ft/s
4 ft/s
5 ft/s
6 ft/s
7 ft/s
8 ft/s
Ground
Bank Sta
Elevation (ft)
Station (ft)
3470
3472
3474
3476
3478
3480
3482
3484
3486
3488
100
150
200
250
300
350


LeesFerry_FINAL Plan: Existing Conditions 11/21/2011
XSEC 27
Legend
EG 25 Year
WS 25 Year
Crit 25 Year
2 ft/s
4 ft/s
6 ft/s
8 ft/s
10 ft/s
Ground
Bank Sta
Elevation (ft)
Station (ft)
3468
3470
3472
3474
3476
3478
3480
3482
140
160
180
200
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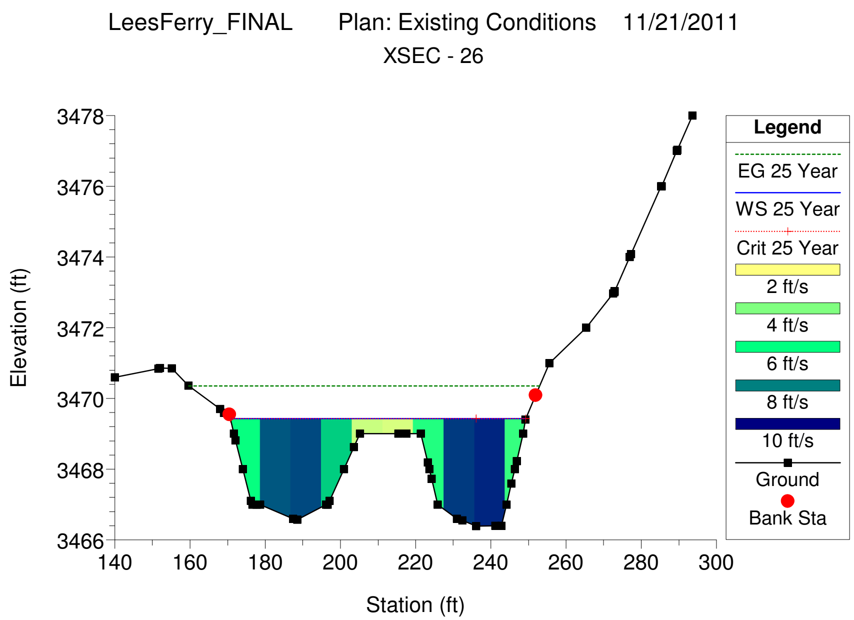
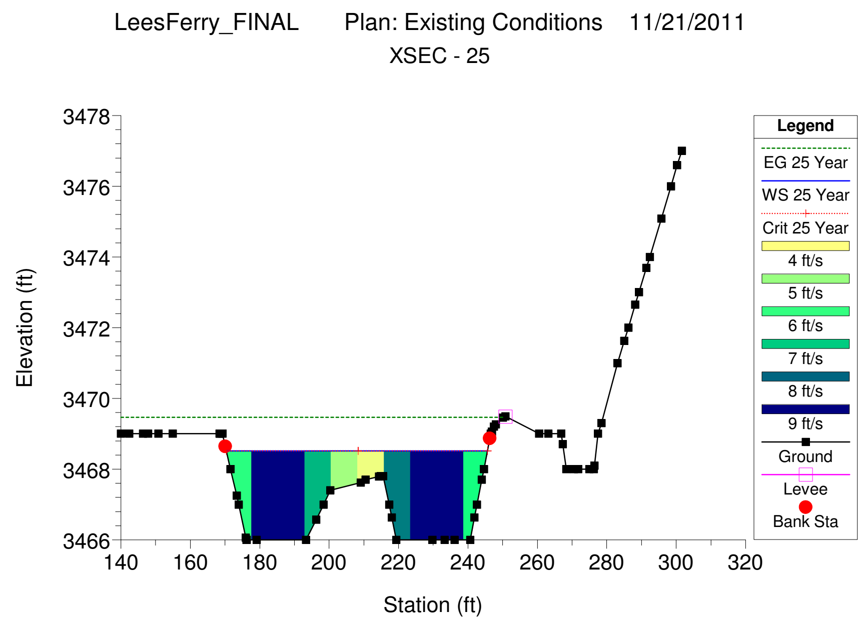
240
260
280
300
320


LeesFerry_FINAL Plan: Existing Conditions 11/21/2011
XSEC - 26
Legend
EG 25 Year
WS 25 Year
Crit 25 Year
2 ft/s
4 ft/s
6 ft/s
8 ft/s
10 ft/s
Ground
Bank Sta
Elevation (ft)
Station (ft)
3466
3468
3470
3472
3474
3476
3478
140
160
180
200
220
240
260
280
300


LeesFerry_FINAL Plan: Existing Conditions 11/21/2011
XSEC - 25
Legend
EG 25 Year
WS 25 Year
Crit 25 Year
4 ft/s
5 ft/s
6 ft/s
7 ft/s
8 ft/s
9 ft/s
Ground
Levee
Bank Sta
Elevation (ft)
Station (ft)
3466
3468
3470
3472
3474
3476
3478
140
160
180
200
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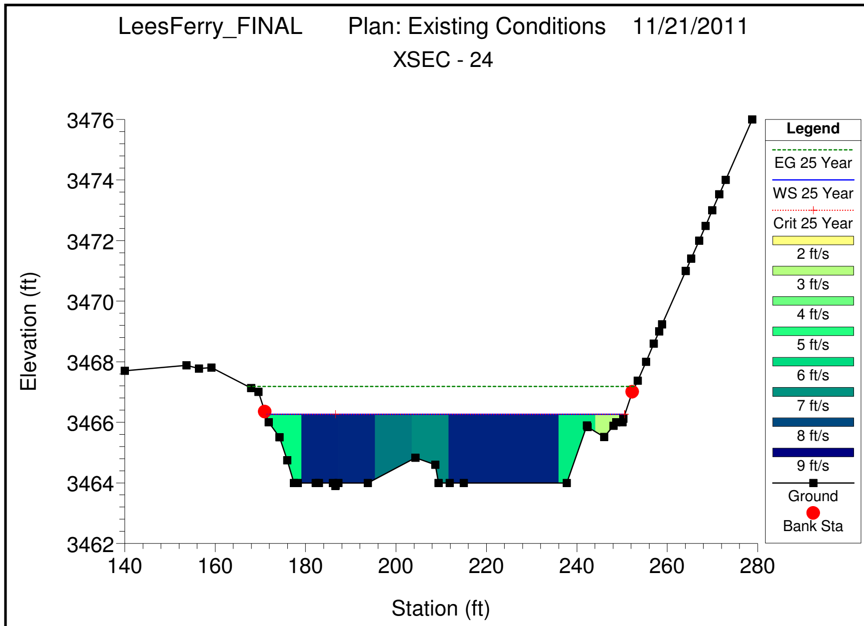
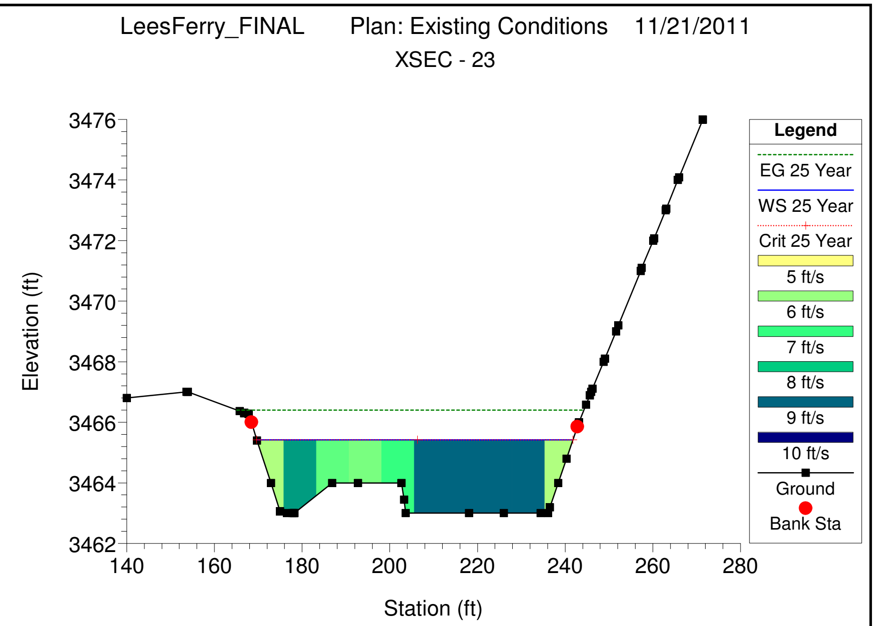
240
260
280
300
320


LeesFerry_FINAL Plan: Existing Conditions 11/21/2011
XSEC - 24
Elevation (ft)
Station (ft)
Legend
EG 25 Year
WS 25 Year
Crit 25 Year
2 ft/s
3 ft/s
4 ft/s
5 ft/s
6 ft/s
7 ft/s
8 ft/s
9 ft/s
Ground
Bank Sta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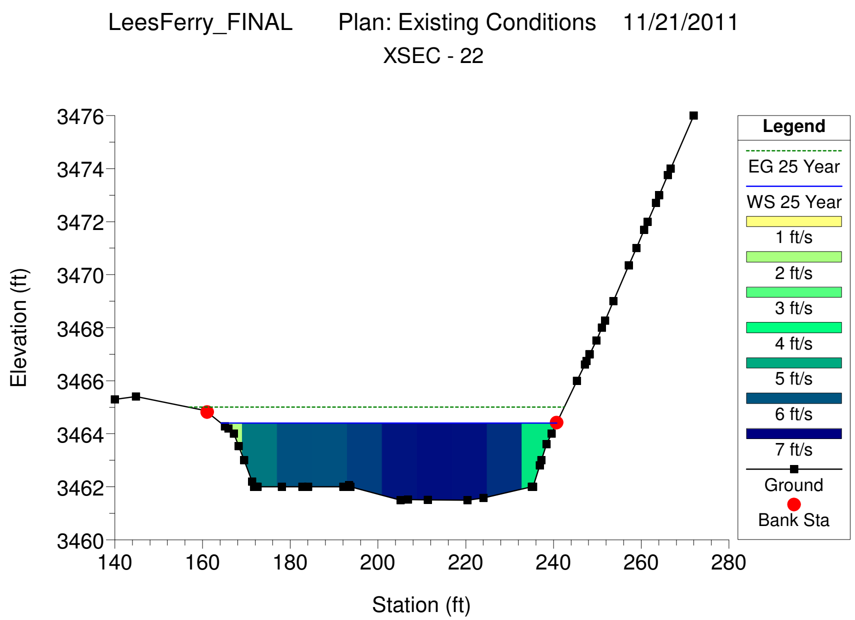
XSEC - 23
Elevation (ft)
Station (ft)
Legend
EG 25 Year
WS 25 Year
Crit 25 Year
5 ft/s
6 ft/s
7 ft/s
8 ft/s
9 ft/s
10 ft/s
Ground
Bank Sta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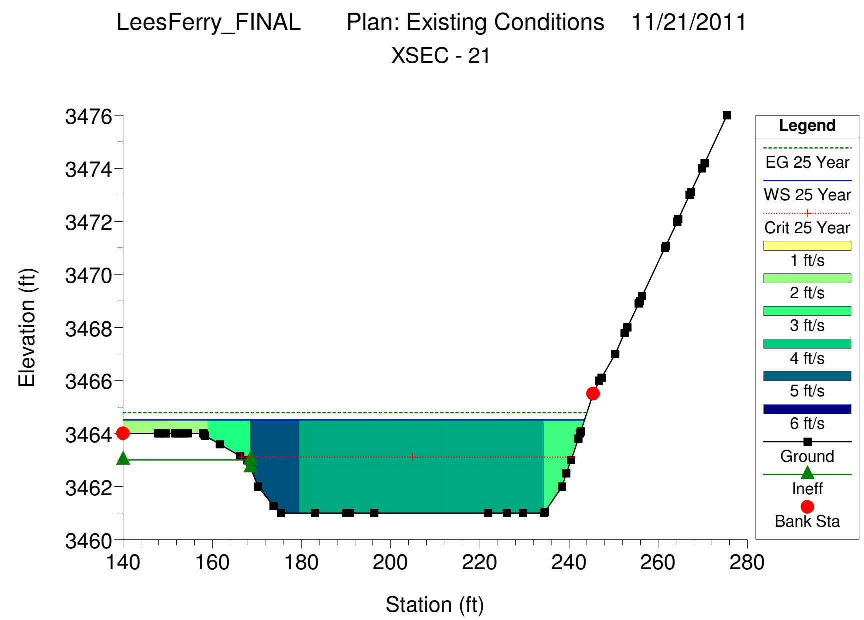
XSEC - 22
Elevation (ft)
Station (ft)
Legend
EG 25 Year
WS 25 Year
1 ft/s
2 ft/s
3 ft/s
4 ft/s
5 ft/s
6 ft/s
7 ft/s
Ground
Bank Sta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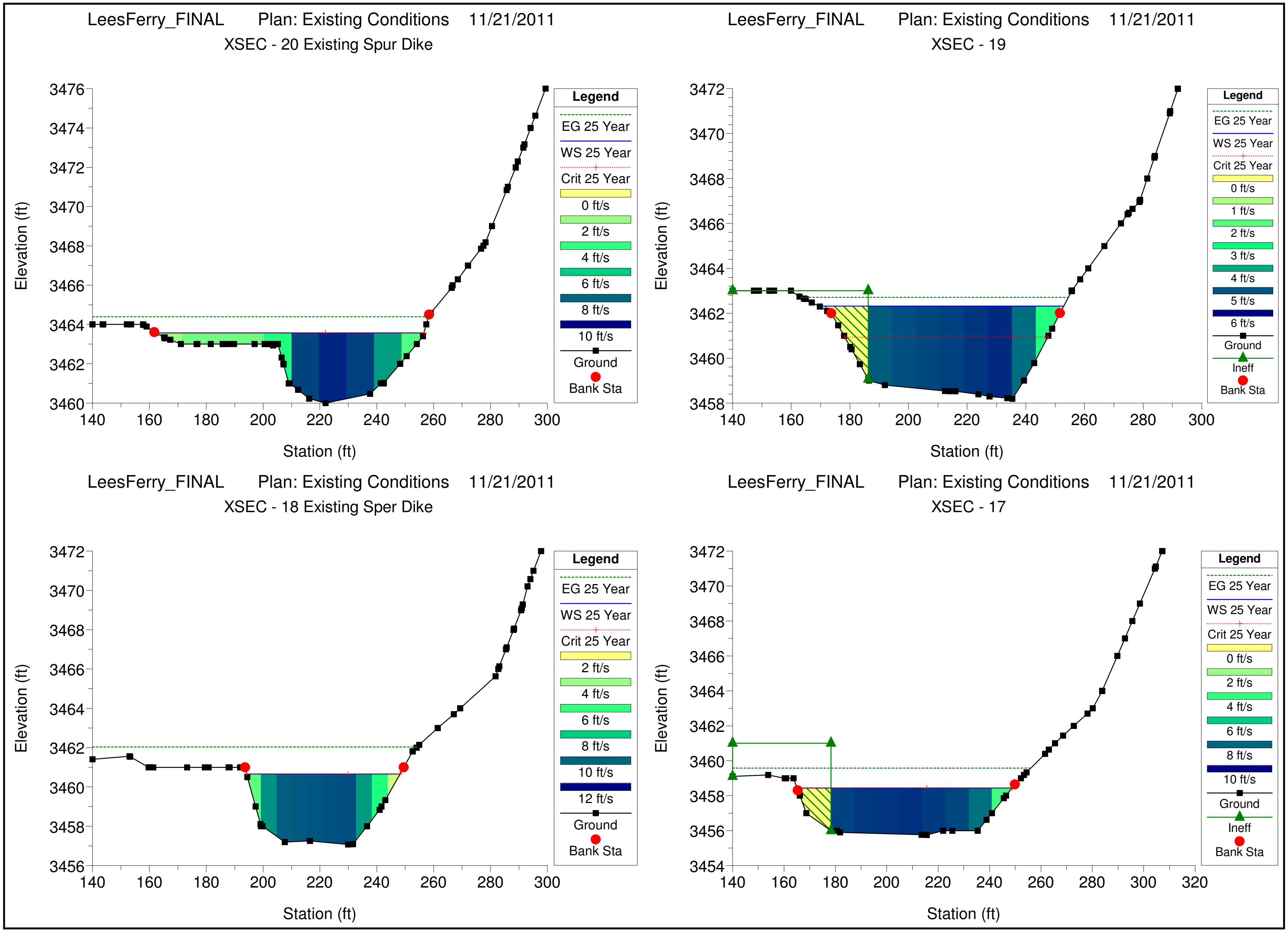
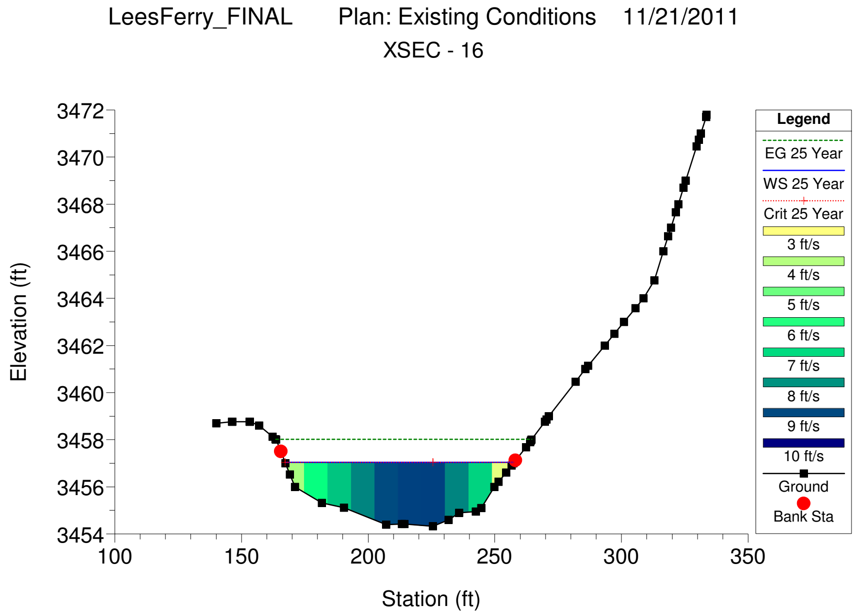
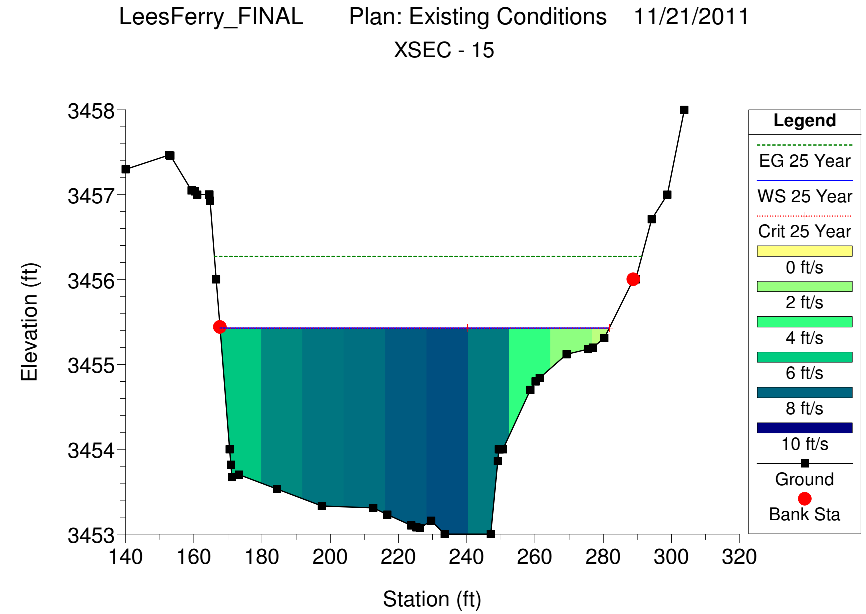
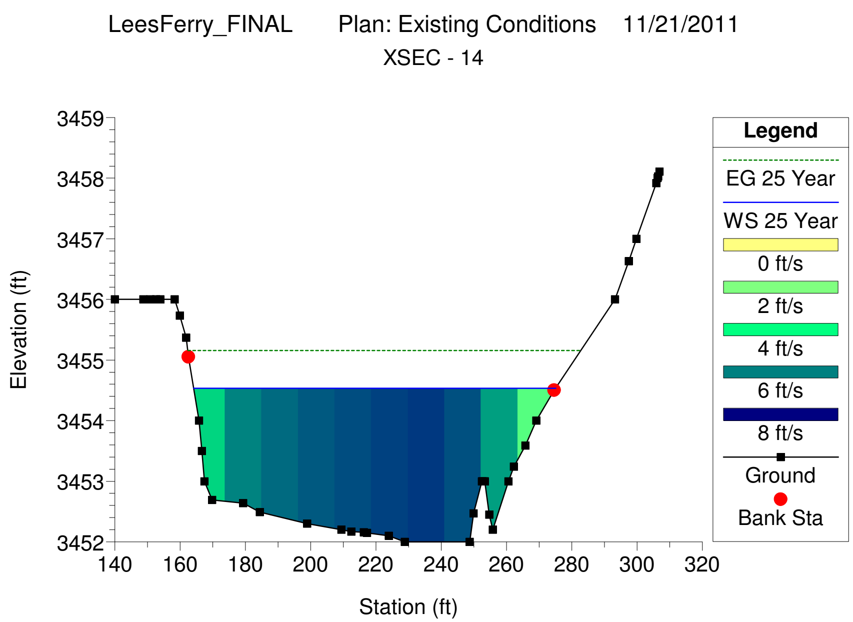
XSEC - 21
Elevation (ft)
Station (ft)
Legend
EG 25 Year
WS 25 Year
Crit 25 Year
1 ft/s
2 ft/s
3 ft/s
4 ft/s
5 ft/s
6 ft/s
Ground
Ineff
Bank Sta

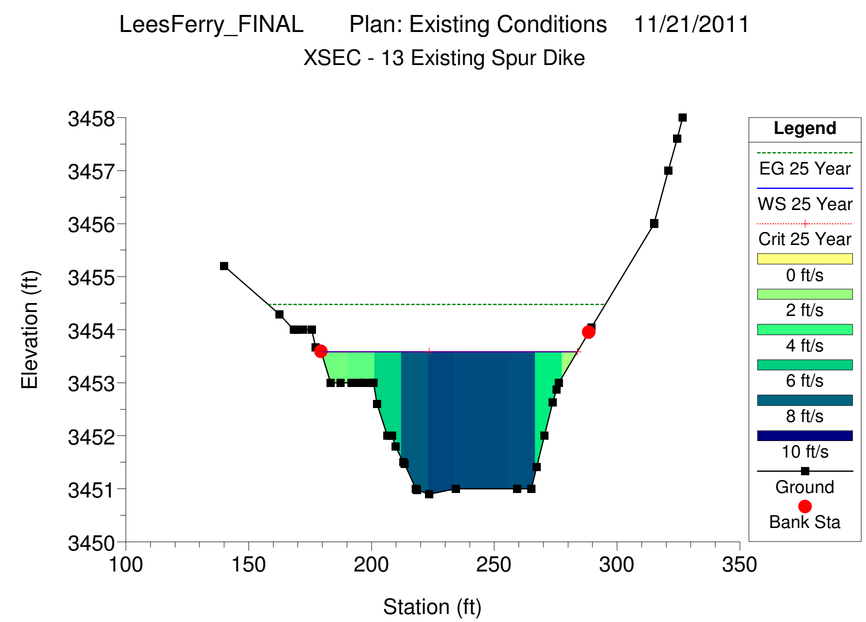


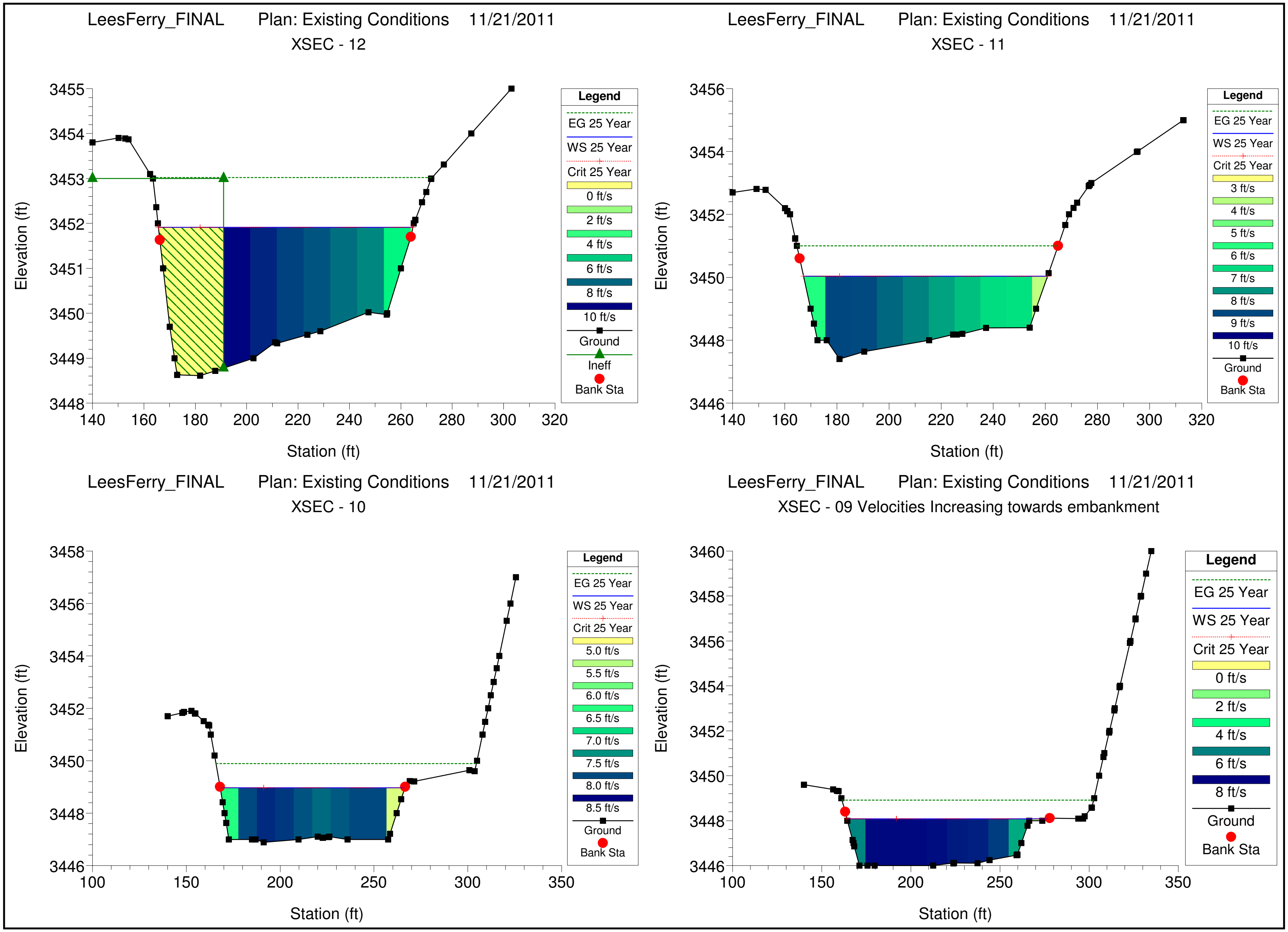
LeesFerry_FINAL Plan: Existing Conditions 11/21/2011
XSEC - 20 Existing Spur Dike
Elevation (ft)
Station (ft)
Legend
EG 25 Year
WS 25 Year
Crit 25 Year
0 ft/s
2 ft/s
4 ft/s
6 ft/s
8 ft/s
10 ft/s
Ground
Bank Sta
LeesFerry_FINAL Plan: Existing Conditions 11/21/2011
XSEC - 19
Elevation (ft)
Station (ft)
Legend
EG 25 Year
WS 25 Year
Crit 25 Year
0 ft/s
1 ft/s
2 ft/s
3 ft/s
4 ft/s
5 ft/s
6 ft/s
Ground
Ineff
Bank Sta
LeesFerry_FINAL Plan: Existing Conditions 11/21/2011
XSEC - 18 Existing Sper Dike
Elevation (ft)
Station (ft)
Legend
EG 25 Year
WS 25 Year
Crit 25 Year
2 ft/s
4 ft/s
6 ft/s
8 ft/s
10 ft/s
12 ft/s
Ground
Bank Sta
LeesFerry_FINAL Plan: Existing Conditions 11/21/2011
XSEC - 17
Elevation (ft)
Station (ft)
Legend
EG 25 Year
WS 25 Year
Crit 25 Year
0 ft/s
2 ft/s
4 ft/s
6 ft/s
8 ft/s
10 ft/s
Ground
Ineff
Bank Sta

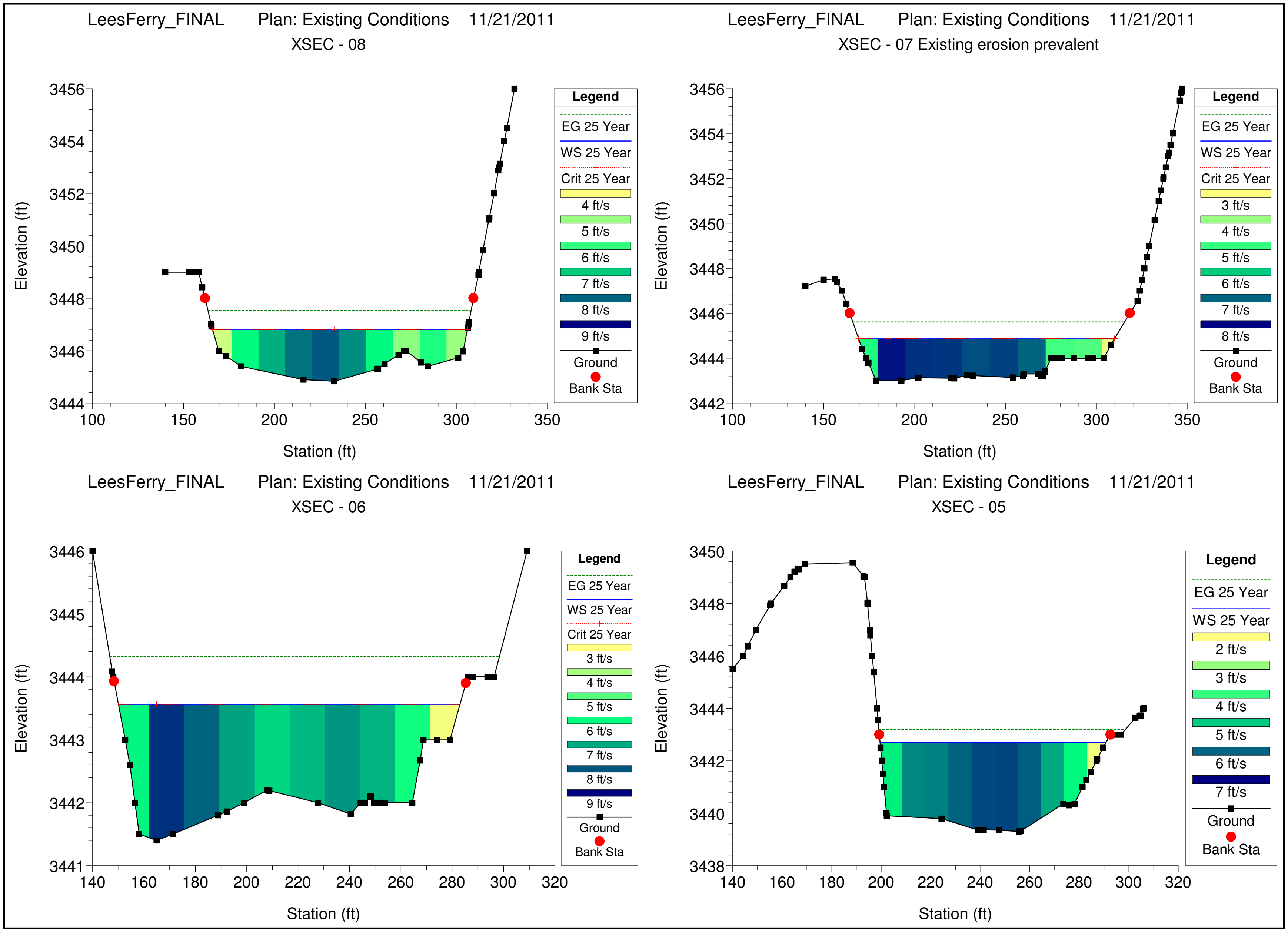

LeesFerry_FINAL Plan: Existing Conditions 11/21/2011
XSEC - 16
Legend
EG 25 Year
WS 25 Year
Crit 25 Year
3 ft/s
4 ft/s
5 ft/s
6 ft/s
7 ft/s
8 ft/s
9 ft/s
10 ft/s
Ground
Bank Sta
Elevation (ft)
Station (ft)
3454
3456
3458
3460
3462
3464
3466
3468
3470
3472
100
150
200
250
300
350


LeesFerry_FINAL Plan: Existing Conditions 11/21/2011
XSEC - 15
Legend
EG 25 Year
WS 25 Year
Crit 25 Year
0 ft/s
2 ft/s
4 ft/s
6 ft/s
8 ft/s
10 ft/s
Ground
Bank Sta
Elevation (ft)
Station (ft)
3453
3454
3455
3456
3457
3458
140
160
180
200
220
240
260
280
300
320

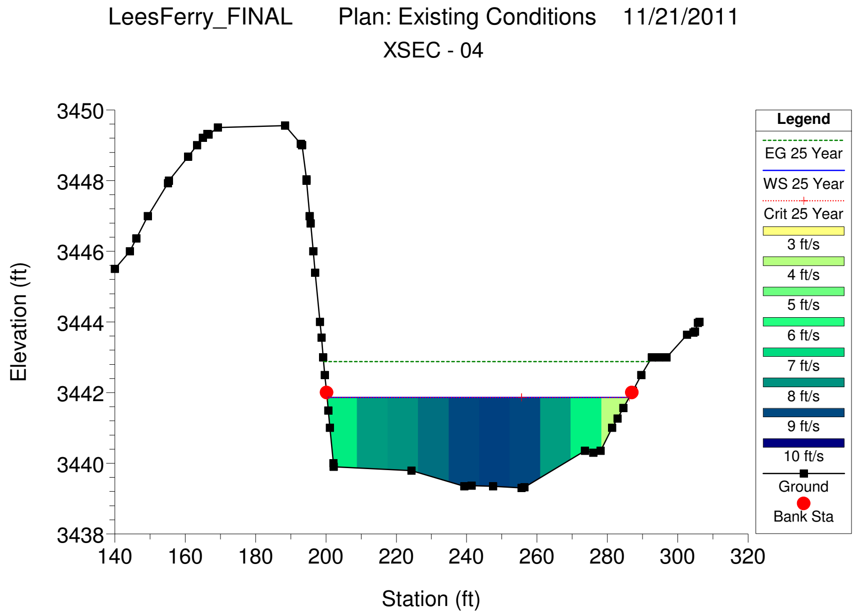

LeesFerry_FINAL Plan: Existing Conditions 11/21/2011
XSEC - 14
Legend
EG 25 Year
WS 25 Year
0 ft/s
2 ft/s
4 ft/s
6 ft/s
8 ft/s
Ground
Bank Sta
Elevation (ft)
Station (ft)
3452
3453
3454
3455
3456
3457
3458
3459
140
160
180
200
220
240
260
280
300
320

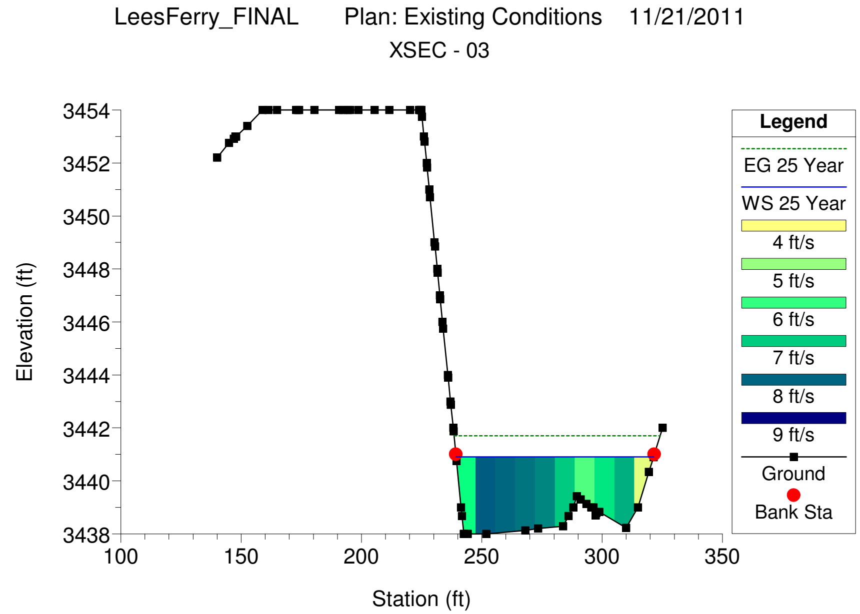

LeesFerry_FINAL Plan: Existing Conditions 11/21/2011
XSEC - 13 Existing Spur Dike
Legend
EG 25 Year
WS 25 Year
Crit 25 Year
0 ft/s
2 ft/s
4 ft/s
6 ft/s
8 ft/s
10 ft/s
Ground
Bank Sta
Elevation (ft)
Station (ft)
3450
3451
3452
3453
3454
3455
3456
3457
3458
100
150
200
250
300
350

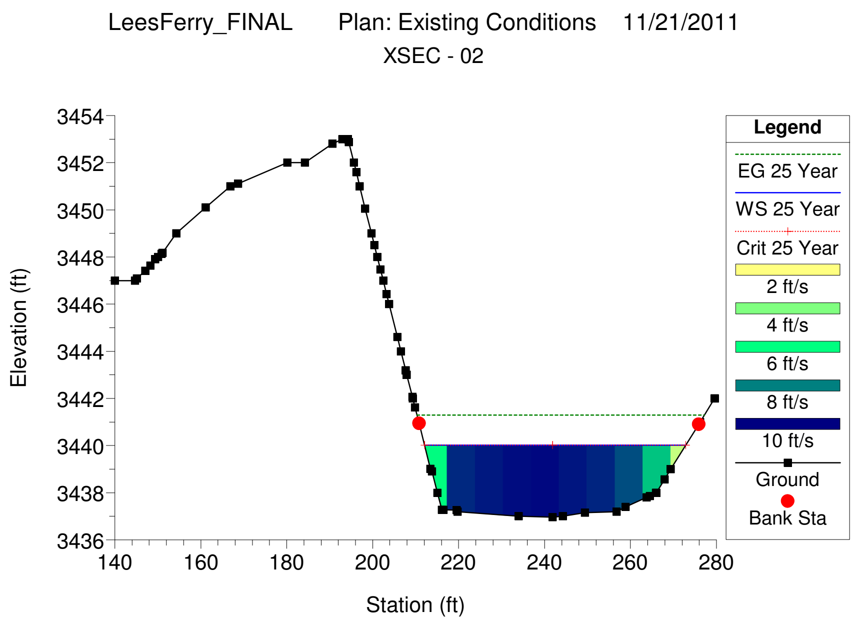

LeesFerry_FINAL Plan: Existing Conditions 11/21/2011
XSEC - 12
Elevation (ft)
Station (ft)
Legend
EG 25 Year
WS 25 Year
Crit 25 Year
0 ft/s
2 ft/s
4 ft/s
6 ft/s
8 ft/s
10 ft/s
Ground
Ineff
Bank Sta
LeesFerry_FINAL Plan: Existing Conditions 11/21/2011
XSEC - 11
Elevation (ft)
Station (ft)
Legend
EG 25 Year
WS 25 Year
Crit 25 Year
3 ft/s
4 ft/s
5 ft/s
6 ft/s
7 ft/s
8 ft/s
9 ft/s
10 ft/s
Ground
Bank Sta
LeesFerry_FINAL Plan: Existing Conditions 11/21/2011
XSEC - 10
Elevation (ft)
Station (ft)
Legend
EG 25 Year
WS 25 Year
Crit 25 Year
5.0 ft/s
5.5 ft/s
6.0 ft/s
6.5 ft/s
7.0 ft/s
7.5 ft/s
8.0 ft/s
8.5 ft/s
Ground
Bank Sta
LeesFerry_FINAL Plan: Existing Conditions 11/21/2011
XSEC - 09 Velocities Increasing towards embankment
Elevation (ft)
Station (ft)
Legend
EG 25 Year
WS 25 Year
Crit 25 Year
0 ft/s
2 ft/s
4 ft/s
6 ft/s
8 ft/s
Ground
Bank Sta

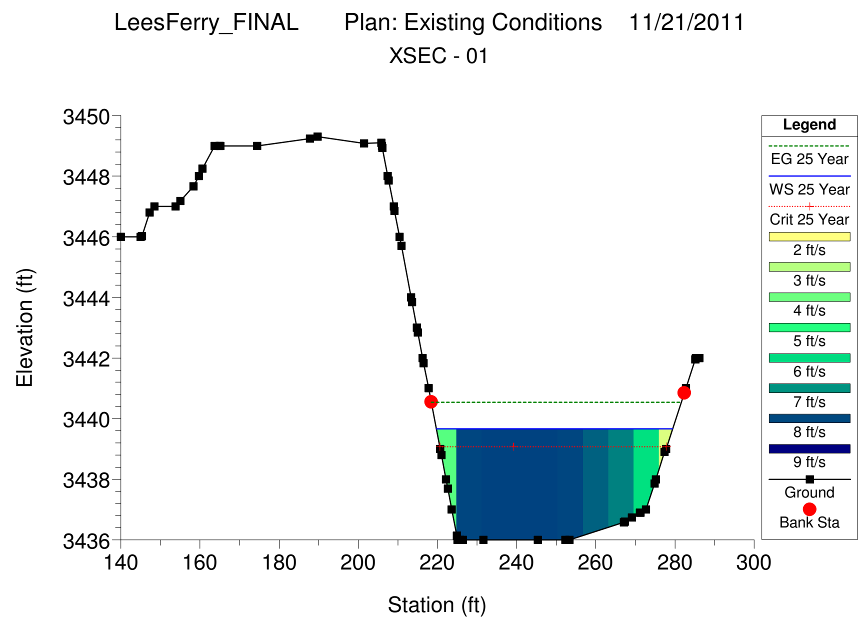


LeesFerry_FINAL Plan: Existing Conditions 11/21/2011
XSEC - 08
Elevation (ft)
Station (ft)
3456
3454
3452
3450
3448
3446
3444
100
150
200
250
300
350
Legend
EG 25 Year
WS 25 Year
Crit 25 Year
4 ft/s
5 ft/s
6 ft/s
7 ft/s
8 ft/s
9 ft/s
Ground
Bank Sta
LeesFerry_FINAL Plan: Existing Conditions 11/21/2011
XSEC - 07 Existing erosion prevalent
Elevation (ft)
Station (ft)
3456
3454
3452
3450
3448
3446
3444
3442
100
150
200
250
300
350
Legend
EG 25 Year
WS 25 Year
Crit 25 Year
3 ft/s
4 ft/s
5 ft/s
6 ft/s
7 ft/s
8 ft/s
Ground
Bank Sta
LeesFerry_FINAL Plan: Existing Conditions 11/21/2011
XSEC - 06
Elevation (ft)
Station (ft)
3446
3445
3444
3443
3442
3441
140
160
180
200
220
240
260
280
300
320
Legend
EG 25 Year
WS 25 Year
Crit 25 Year
3 ft/s
4 ft/s
5 ft/s
6 ft/s
7 ft/s
8 ft/s
9 ft/s
Ground
Bank Sta
LeesFerry_FINAL Plan: Existing Conditions 11/21/2011
XSEC - 05
Elevation (ft)
Station (ft)
3450
3448
3446
3444
3442
3440
3438
140
160
180
200
220
240
260
280
300
320
Legend
EG 25 Year
WS 25 Year
2 ft/s
3 ft/s
4 ft/s
5 ft/s
6 ft/s
7 ft/s
Ground
Bank Sta


LeesFerry_FINAL Plan: Existing Conditions 11/21/2011
XSEC - 04
Elevation (ft)
Station (ft)
Legend
EG 25 Year
WS 25 Year
Crit 25 Year
3 ft/s
4 ft/s
5 ft/s
6 ft/s
7 ft/s
8 ft/s
9 ft/s
10 ft/s
Ground
Bank Sta

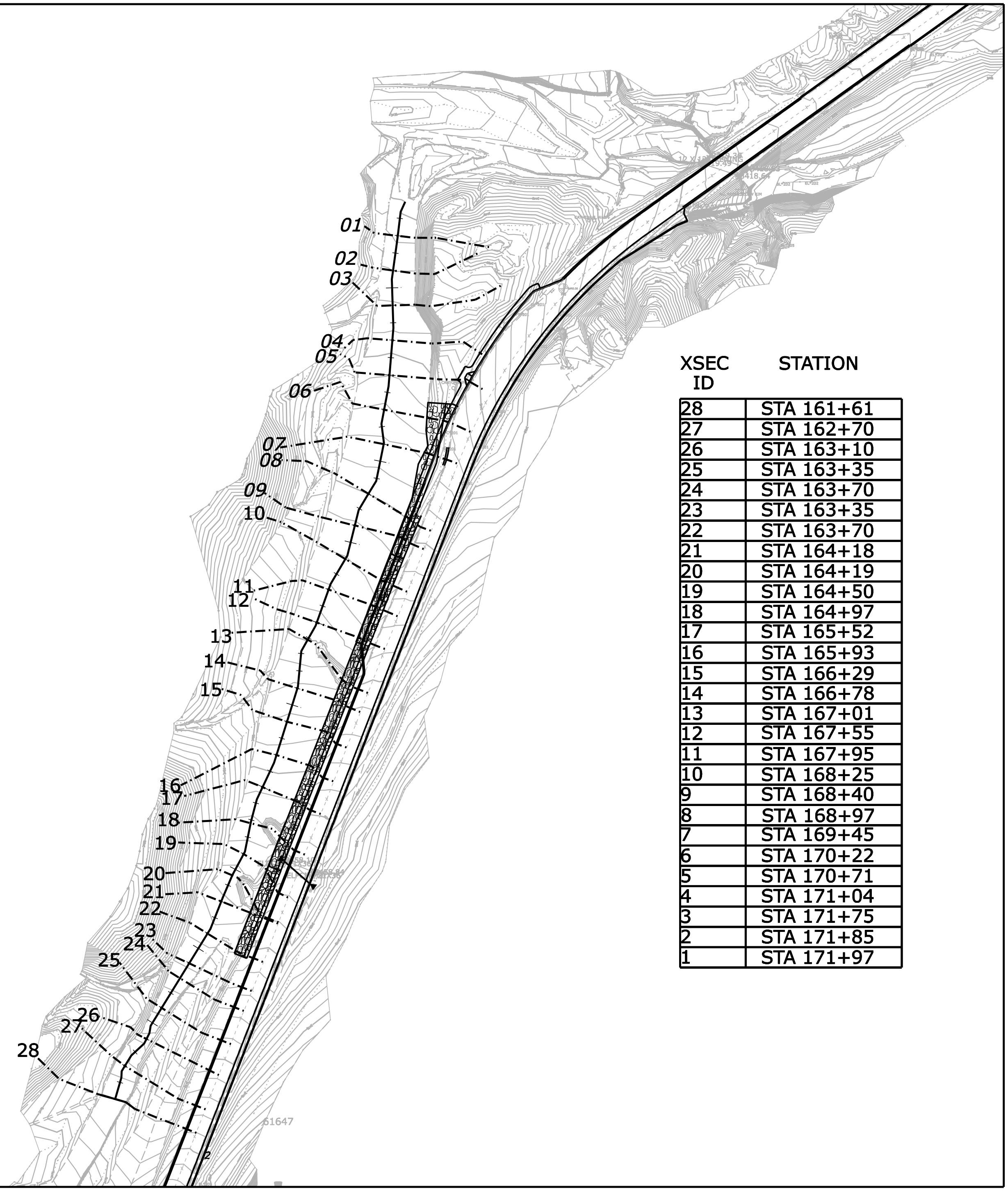

LeesFerry_FINAL Plan: Existing Conditions 11/21/2011
XSEC - 03
Elevation (ft)
Station (ft)
Legend
EG 25 Year
WS 25 Year
4 ft/s
5 ft/s
6 ft/s
7 ft/s
8 ft/s
9 ft/s
Ground
Bank Sta


LeesFerry_FINAL Plan: Existing Conditions 11/21/2011
XSEC - 02
Elevation (ft)
Station (ft)
Legend
EG 25 Year
WS 25 Year
Crit 25 Year
2 ft/s
4 ft/s
6 ft/s
8 ft/s
10 ft/s
Ground
Bank Sta


LeesFerry_FINAL Plan: Existing Conditions 11/21/2011
XSEC - 01
Elevation (ft)
Station (ft)
Legend
EG 25 Year
WS 25 Year
Crit 25 Year
2 ft/s
3 ft/s
4 ft/s
5 ft/s
6 ft/s
7 ft/s
8 ft/s
9 ft/s
Ground
Bank Sta

Channel Hydraulic HEC-RAS Analysis – Sta 163+68 to Sta 170+76 (Tributary to Cathedral Wash Proposed Model)

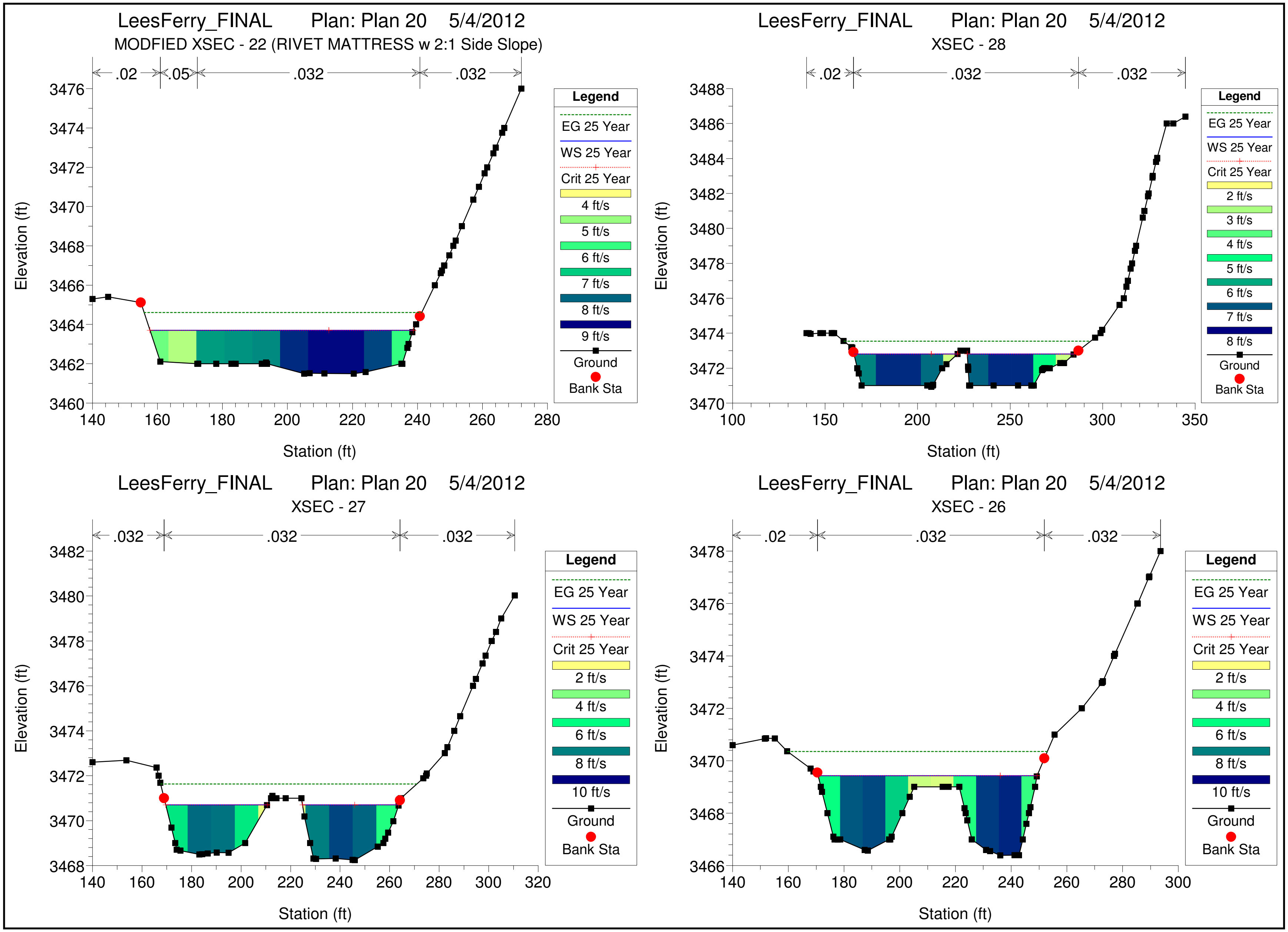
Hec-Ras Cross Sections
Cathedral Wash
Revet Mattress



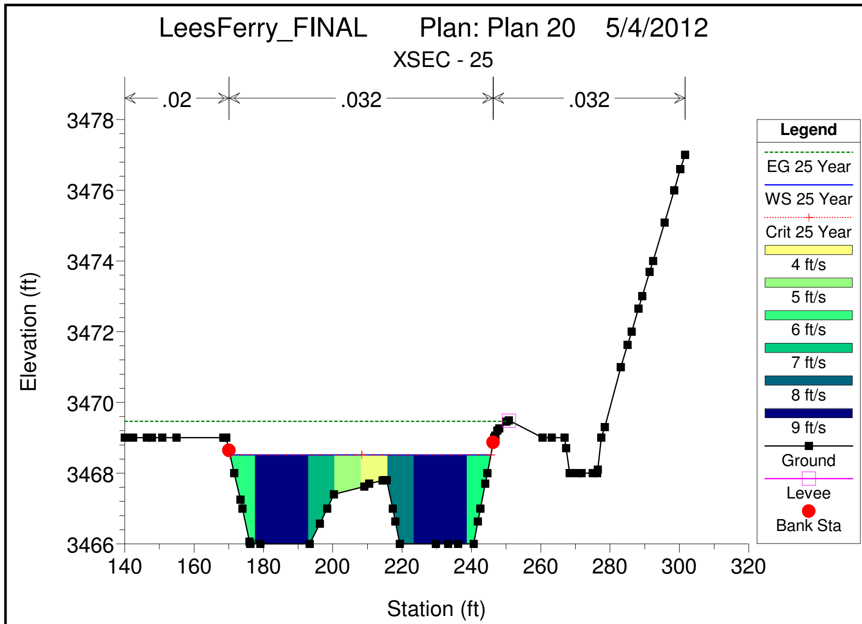
XSEC ID	STATION
28	STA 161+61
27	STA 162+70
26	STA 163+10
25	STA 163+35
24	STA 163+70
23	STA 163+35
22	STA 163+70
21	STA 164+18
20	STA 164+19
19	STA 164+50
18	STA 164+97
17	STA 165+52
16	STA 165+93
15	STA 166+29
14	STA 166+78
13	STA 167+01
12	STA 167+55
11	STA 167+95
10	STA 168+25
9	STA 168+40
8	STA 168+97
7	STA 169+45
6	STA 170+22
5	STA 170+71
4	STA 171+04
3	STA 171+75
2	STA 171+85
1	STA 171+97

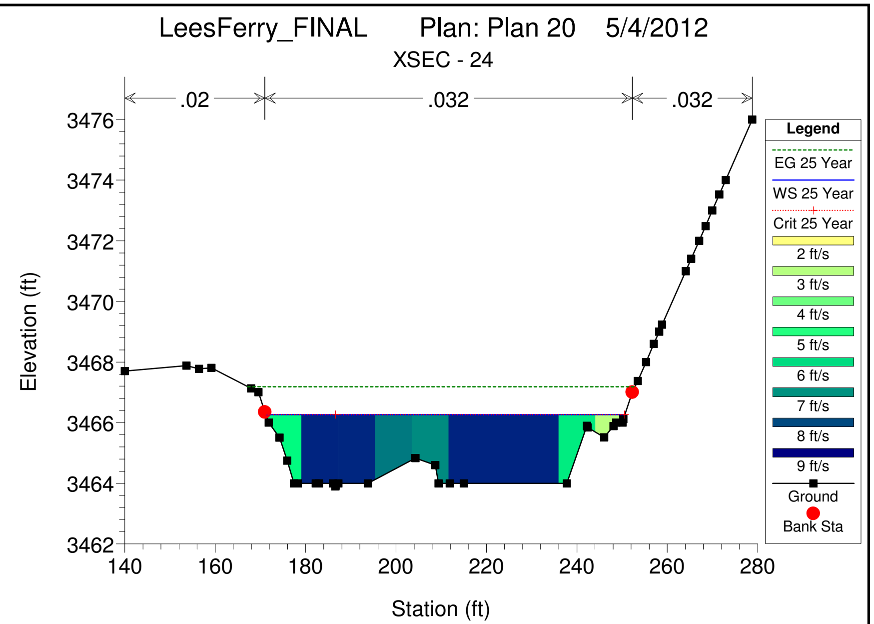
HEC-RAS Plan: Modified Turnout River: RIVER-1 Reach: Reach-1 Profile: 25 Year

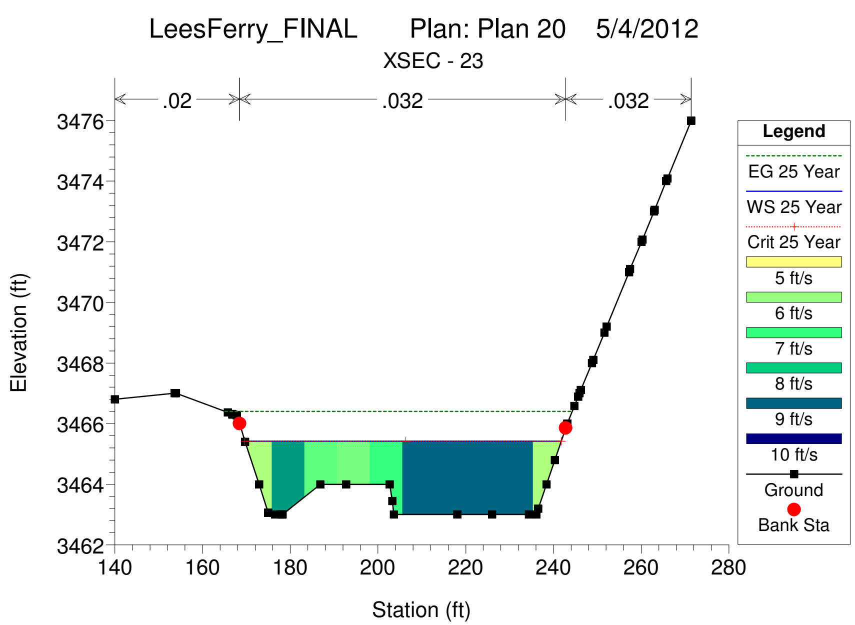
Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Reach-1	28	25 Year	1117.00	3470.93	3472.81	3472.81	3473.54	0.013667	6.84	163.35	113.82	1.01
Reach-1	27	25 Year	1117.00	3468.24	3470.70	3470.70	3471.63	0.012798	7.72	144.68	79.73	1.01
Reach-1	26	25 Year	1117.00	3466.39	3469.43	3469.43	3470.36	0.012590	7.71	144.85	78.57	1.00
Reach-1	25	25 Year	1117.00	3466.00	3468.52	3468.52	3469.47	0.012406	7.82	142.91	75.25	1.00
Reach-1	24	25 Year	1117.00	3463.90	3466.26	3466.26	3467.19	0.012686	7.72	144.64	79.36	1.01
Reach-1	23	25 Year	1117.00	3463.00	3465.42	3465.42	3466.40	0.012471	7.97	140.18	72.13	1.01
Reach-1	22	25 Year	1117.00	3461.50	3463.70	3463.70	3464.61	0.014550	7.67	145.68	81.03	1.01
Reach-1	21	25 Year	1117.00	3461.00	3463.08	3463.08	3464.05	0.003810	7.90	141.44	73.38	1.00
Reach-1	20	25 Year	1117.00	3460.00	3462.09	3462.09	3463.02	0.013399	7.71	144.82	79.36	1.01
Reach-1	19	25 Year	1117.00	3458.19	3460.72	3460.72	3461.69	0.013407	7.90	141.37	74.11	1.01
Reach-1	18	25 Year	1388.00	3457.07	3459.80	3459.80	3460.87	0.012630	8.27	167.77	79.49	1.00
Reach-1	17	25 Year	1388.00	3455.75	3458.20	3458.20	3459.24	0.012935	8.19	169.38	82.21	1.01
Reach-1	16	25 Year	1388.00	3454.32	3456.95	3456.95	3457.92	0.012901	7.91	175.37	91.37	1.01
Reach-1	15	25 Year	1388.00	3453.00	3455.43	3455.43	3456.27	0.013522	7.36	188.62	114.14	1.01
Reach-1	14	25 Year	1388.00	3452.00	3454.57	3454.57	3455.60	0.012814	8.15	170.43	84.17	1.00
Reach-1	13	25 Year	1388.00	3450.90	3453.26	3453.26	3454.30	0.012605	8.19	169.89	84.66	1.00
Reach-1	12	25 Year	1388.00	3448.61	3451.52	3451.52	3452.55	0.030182	8.15	170.38	84.28	1.01
Reach-1	11	25 Year	1388.00	3447.40	3450.24	3450.24	3451.29	0.029743	8.19	169.40	82.66	1.01
Reach-1	10	25 Year	1388.00	3446.89	3449.14	3449.14	3450.14	0.011988	8.01	173.36	88.48	1.00
Reach-1	9	25 Year	1388.00	3446.00	3448.33	3448.33	3449.18	0.012314	7.42	190.58	121.89	0.96
Reach-1	8	25 Year	1388.00	3444.83	3446.88	3446.88	3447.66	0.013734	7.12	194.85	126.00	1.01
Reach-1	7	25 Year	1388.00	3443.00	3444.95	3444.95	3445.72	0.015104	7.04	197.16	130.45	1.01
Reach-1	6	25 Year	1388.00	3441.80	3443.95	3443.95	3444.83	0.014499	7.52	184.54	107.37	1.01
Reach-1	5	25 Year	1388.00	3439.30	3442.70		3443.20	0.004027	5.64	245.88	91.29	0.61
Reach-1	4	25 Year	1388.00	3439.30	3441.87	3441.87	3442.88	0.012187	8.08	171.88	85.91	1.01
Reach-1	3	25 Year	1388.00	3438.00	3440.91		3441.71	0.007785	7.16	193.78	82.15	0.82
Reach-1	2	25 Year	1388.00	3436.96	3440.02	3440.02	3441.29	0.011352	9.05	153.34	60.76	1.00
Reach-1	1	25 Year	1388.00	3436.00	3439.67	3439.07	3440.54	0.006002	7.50	184.95	59.71	0.75

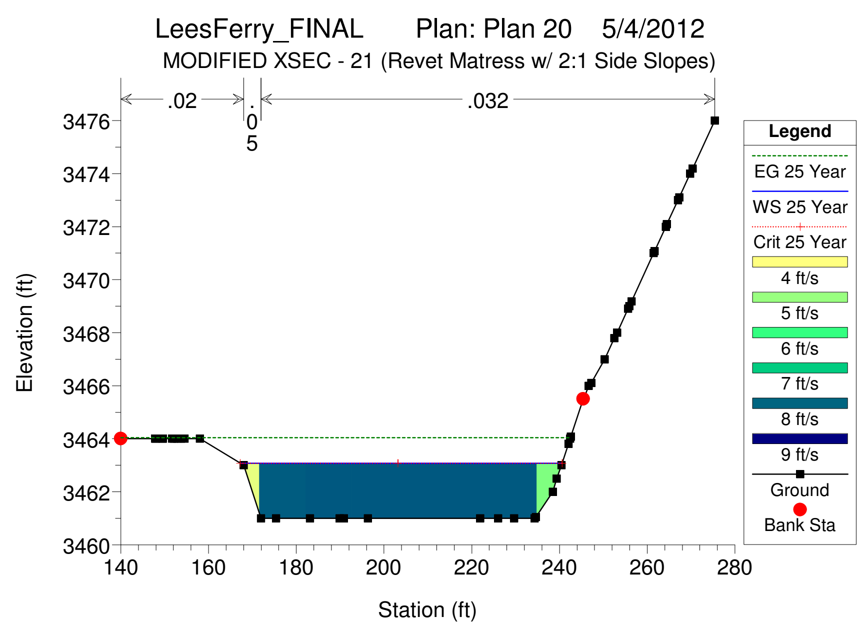


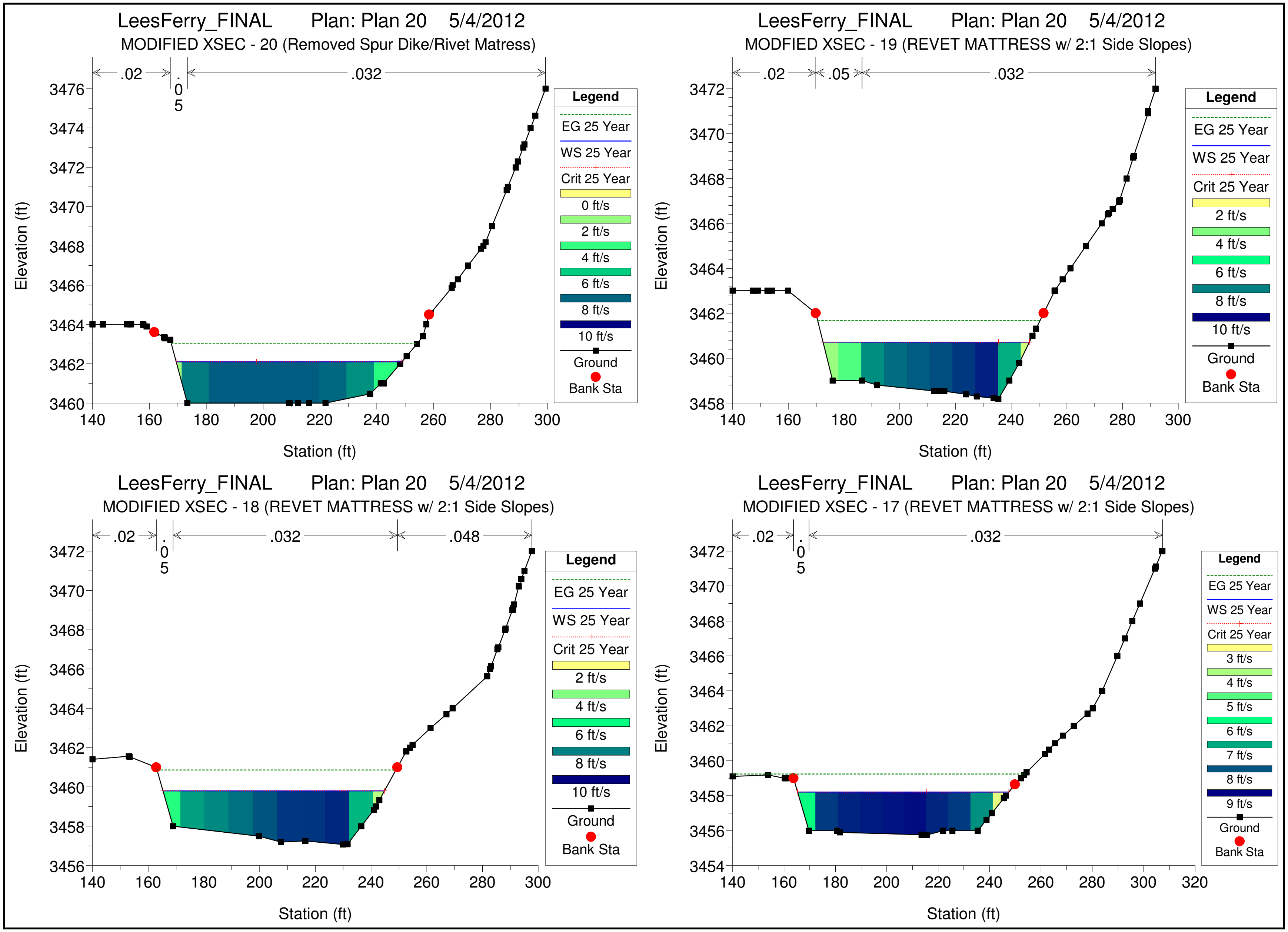
LeesFerry_FINAL Plan: Plan 20 5/4/2012
MODFIED XSEC - 22 (RIVET MATTRESS w 2:1 Side Slope)
.02 .05 .032 .032
Elevation (ft)
Station (ft)
Legend
EG 25 Year
WS 25 Year
Crit 25 Year
4 ft/s
5 ft/s
6 ft/s
7 ft/s
8 ft/s
9 ft/s
Ground
Bank Sta
LeesFerry_FINAL Plan: Plan 20 5/4/2012
XSEC - 28
.02 .032 .032
Elevation (ft)
Station (ft)
Legend
EG 25 Year
WS 25 Year
Crit 25 Year
2 ft/s
3 ft/s
4 ft/s
5 ft/s
6 ft/s
7 ft/s
8 ft/s
Ground
Bank Sta
LeesFerry_FINAL Plan: Plan 20 5/4/2012
XSEC - 27
.032 .032 .032
Elevation (ft)
Station (ft)
Legend
EG 25 Year
WS 25 Year
Crit 25 Year
2 ft/s
4 ft/s
6 ft/s
8 ft/s
10 ft/s
Ground
Bank Sta
LeesFerry_FINAL Plan: Plan 20 5/4/2012
XSEC - 26
.02 .032 .032
Elevation (ft)
Station (ft)
Legend
EG 25 Year
WS 25 Year
Crit 25 Year
2 ft/s
4 ft/s
6 ft/s
8 ft/s
10 ft/s
Ground
Bank Sta

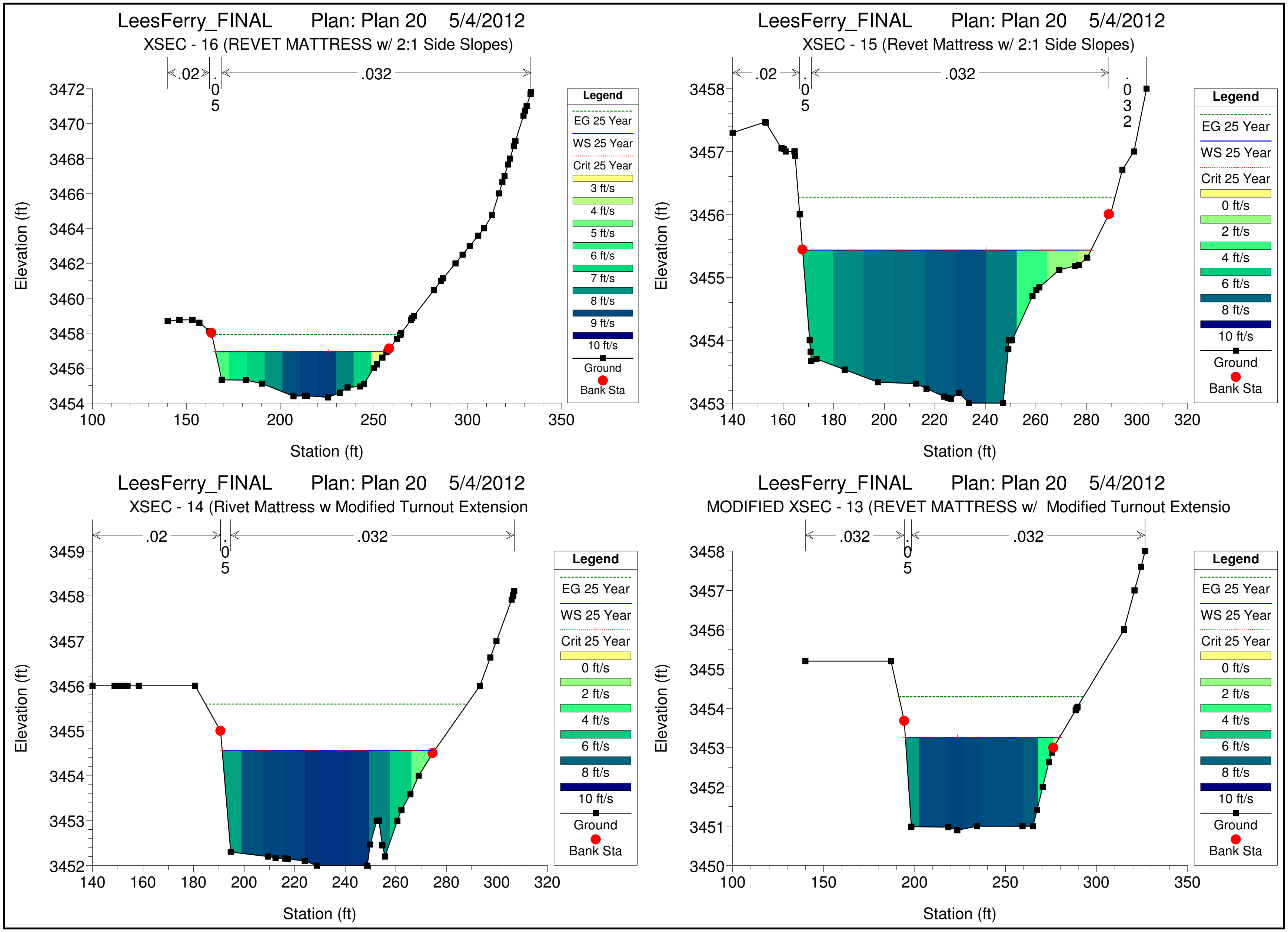

LeesFerry_FINAL Plan: Plan 20 5/4/2012
XSEC - 25
.02
.032
.032
Elevation (ft)
Station (ft)
Legend
EG 25 Year
WS 25 Year
Crit 25 Year
4 ft/s
5 ft/s
6 ft/s
7 ft/s
8 ft/s
9 ft/s
Ground
Levee
Bank Sta

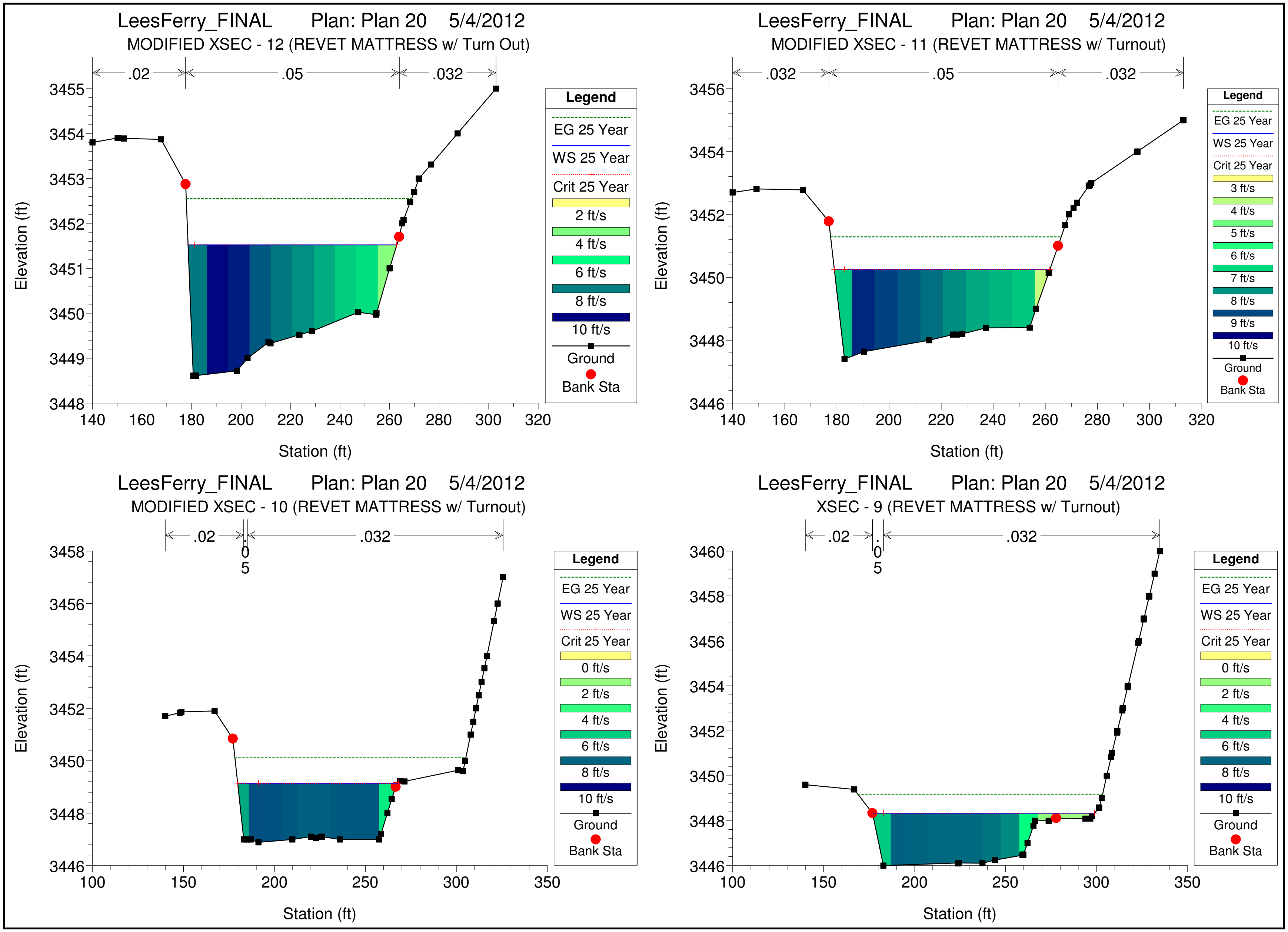

LeesFerry_FINAL Plan: Plan 20 5/4/2012
XSEC - 24
.02
.032
.032
Elevation (ft)
Station (ft)
Legend
EG 25 Year
WS 25 Year
Crit 25 Year
2 ft/s
3 ft/s
4 ft/s
5 ft/s
6 ft/s
7 ft/s
8 ft/s
9 ft/s
Ground
Bank Sta

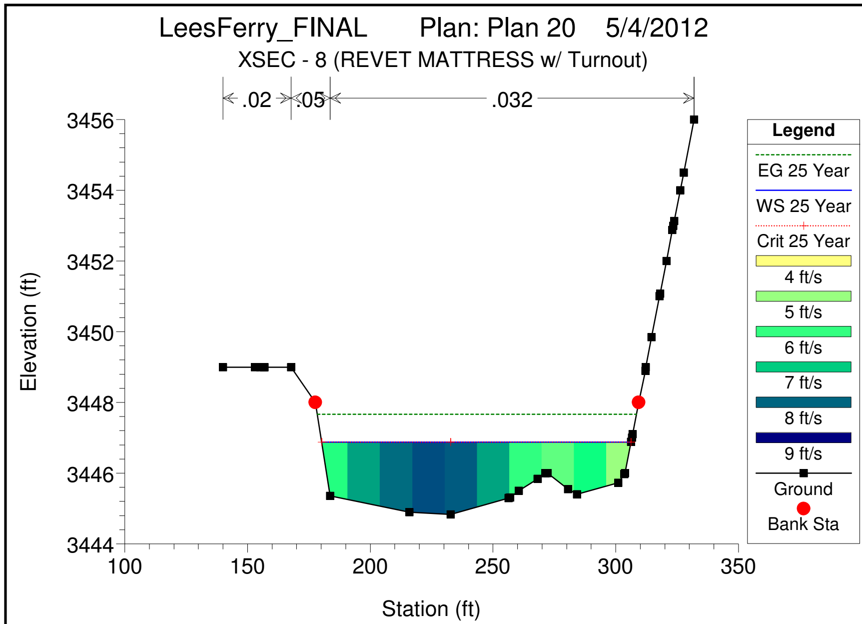

LeesFerry_FINAL Plan: Plan 20 5/4/2012
XSEC - 23
.02
.032
.032
Elevation (ft)
Station (ft)
Legend
EG 25 Year
WS 25 Year
Crit 25 Year
5 ft/s
6 ft/s
7 ft/s
8 ft/s
9 ft/s
10 ft/s
Ground
Bank Sta

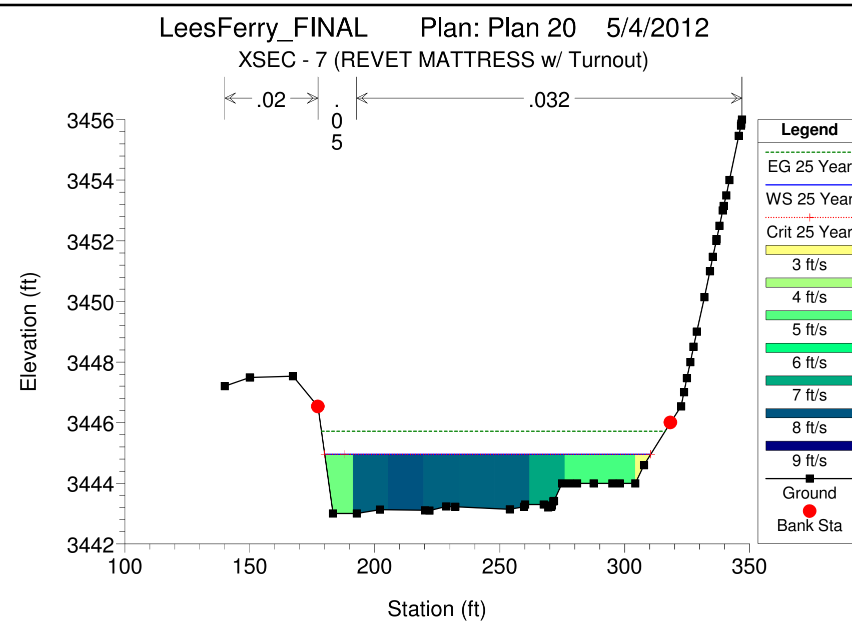

LeesFerry_FINAL Plan: Plan 20 5/4/2012
MODIFIED XSEC - 21 (Revet Matress w/ 2:1 Side Slopes)
.02
.05
.032
Elevation (ft)
Station (ft)
Legend
EG 25 Year
WS 25 Year
Crit 25 Year
4 ft/s
5 ft/s
6 ft/s
7 ft/s
8 ft/s
9 ft/s
Ground
Bank Sta

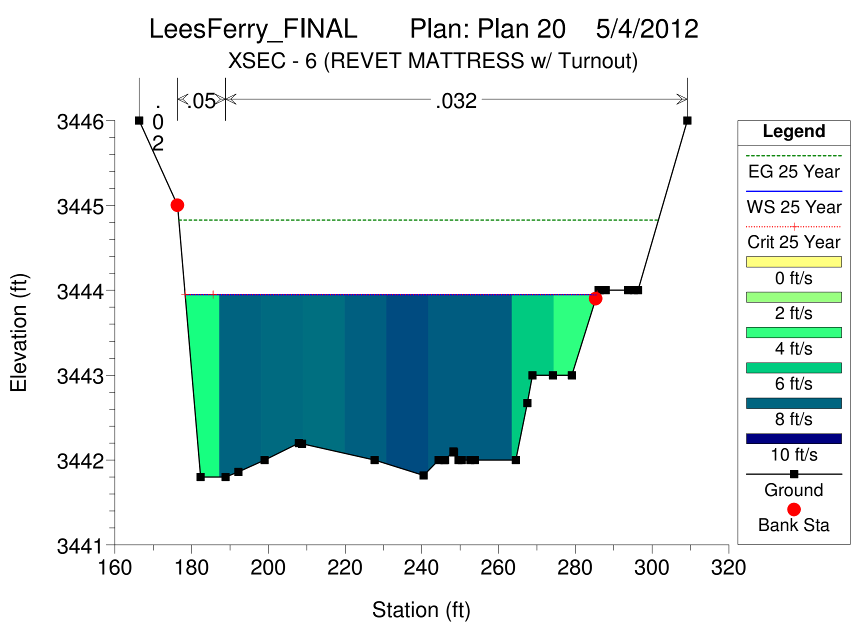

LeesFerry_FINAL Plan: Plan 20 5/4/2012
MODIFIED XSEC - 20 (Removed Spur Dike/Rivet Matress)
.02
.05
.032
Elevation (ft)
Station (ft)
Legend
EG 25 Year
WS 25 Year
Crit 25 Year
0 ft/s
2 ft/s
4 ft/s
6 ft/s
8 ft/s
10 ft/s
Ground
Bank Sta
LeesFerry_FINAL Plan: Plan 20 5/4/2012
MODFIED XSEC - 19 (REVET MATTRESS w/ 2:1 Side Slopes)
.02
.05
.032
Elevation (ft)
Station (ft)
Legend
EG 25 Year
WS 25 Year
Crit 25 Year
2 ft/s
4 ft/s
6 ft/s
8 ft/s
10 ft/s
Ground
Bank Sta
LeesFerry_FINAL Plan: Plan 20 5/4/2012
MODIFIED XSEC - 18 (REVET MATTRESS w/ 2:1 Side Slopes)
.02
.05
.032
.048
Elevation (ft)
Station (ft)
Legend
EG 25 Year
WS 25 Year
Crit 25 Year
2 ft/s
4 ft/s
6 ft/s
8 ft/s
10 ft/s
Ground
Bank Sta
LeesFerry_FINAL Plan: Plan 20 5/4/2012
MODIFIED XSEC - 17 (REVET MATTRESS w/ 2:1 Side Slopes)
.02
.05
.032
Elevation (ft)
Station (ft)
Legend
EG 25 Year
WS 25 Year
Crit 25 Year
3 ft/s
4 ft/s
5 ft/s
6 ft/s
7 ft/s
8 ft/s
9 ft/s
Ground
Bank Sta

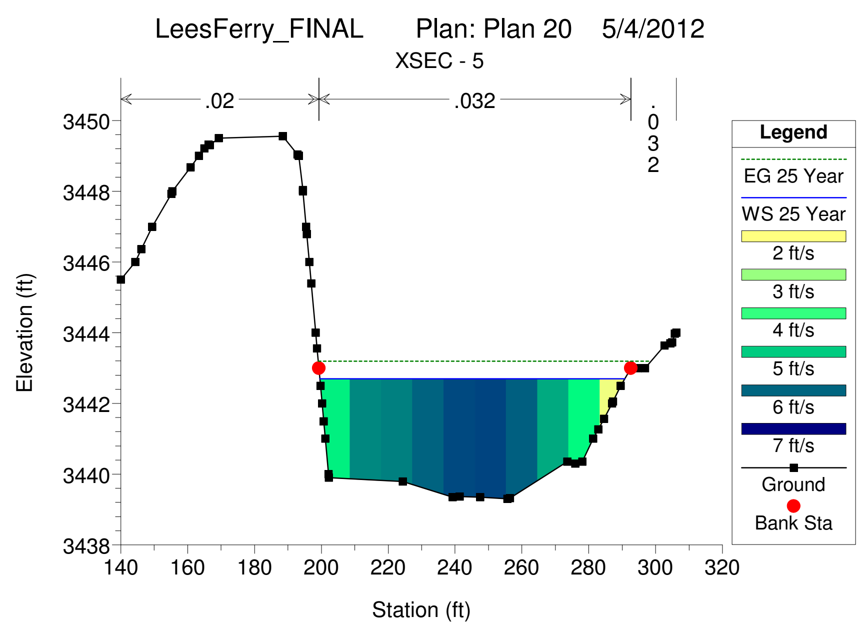

LeesFerry_FINAL Plan: Plan 20 5/4/2012
XSEC - 16 (REVET MATTRESS w/ 2:1 Side Slopes)
.02
.032
Elevation (ft)
Station (ft)
Legend
EG 25 Year
WS 25 Year
Crit 25 Year
3 ft/s
4 ft/s
5 ft/s
6 ft/s
7 ft/s
8 ft/s
9 ft/s
10 ft/s
Ground
Bank Sta
LeesFerry_FINAL Plan: Plan 20 5/4/2012
XSEC - 15 (Revet Mattress w/ 2:1 Side Slopes)
.02
.032
Elevation (ft)
Station (ft)
Legend
EG 25 Year
WS 25 Year
Crit 25 Year
0 ft/s
2 ft/s
4 ft/s
6 ft/s
8 ft/s
10 ft/s
Ground
Bank Sta
LeesFerry_FINAL Plan: Plan 20 5/4/2012
XSEC - 14 (Rivet Mattress w Modified Turnout Extension
.02
.032
Elevation (ft)
Station (ft)
Legend
EG 25 Year
WS 25 Year
Crit 25 Year
0 ft/s
2 ft/s
4 ft/s
6 ft/s
8 ft/s
10 ft/s
Ground
Bank Sta
LeesFerry_FINAL Plan: Plan 20 5/4/2012
MODIFIED XSEC - 13 (REVET MATTRESS w/ Modified Turnout Extensio
.032
.032
Elevation (ft)
Station (ft)
Legend
EG 25 Year
WS 25 Year
Crit 25 Year
0 ft/s
2 ft/s
4 ft/s
6 ft/s
8 ft/s
10 ft/s
Ground
Bank Sta

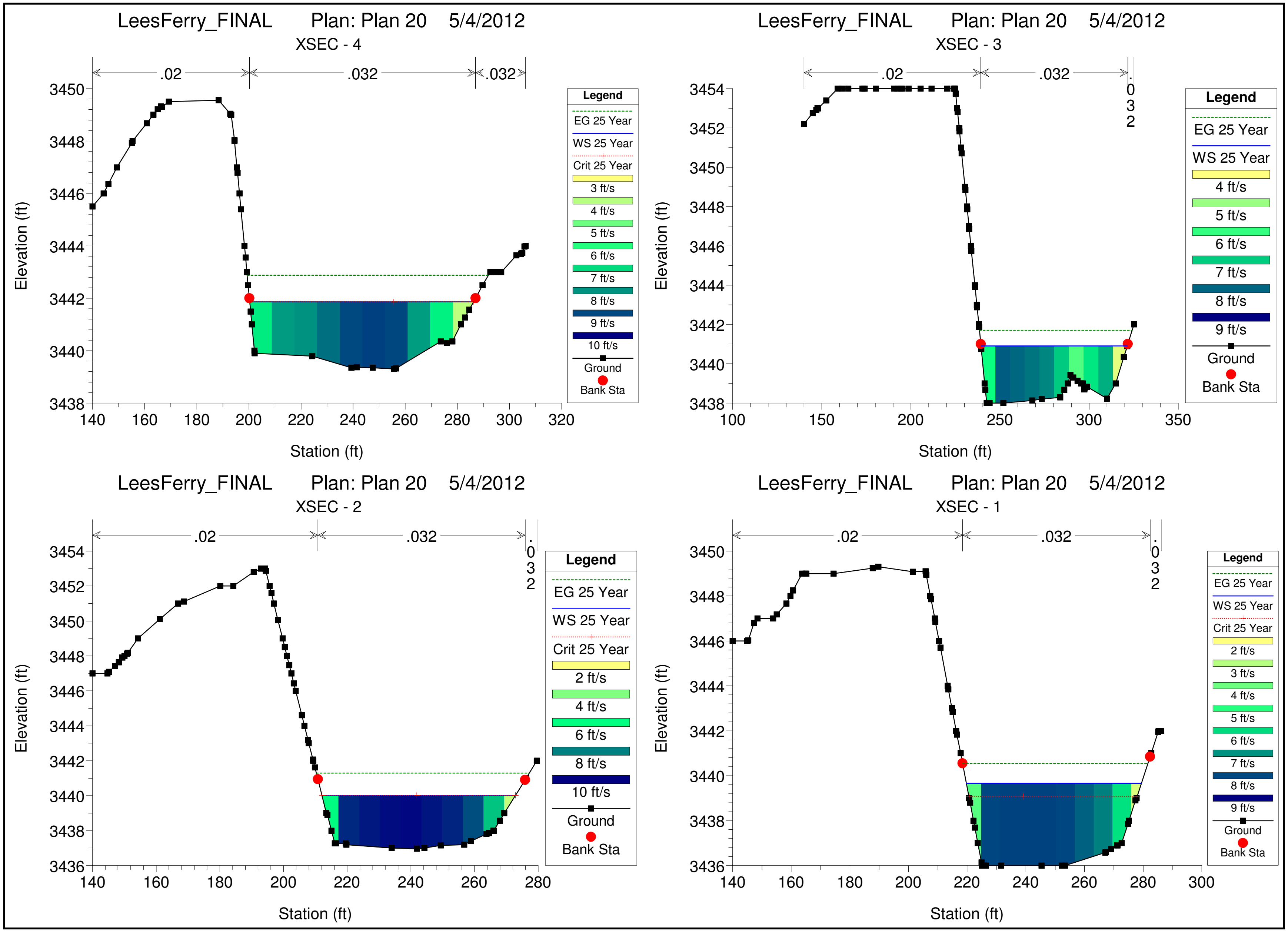

LeesFerry_FINAL Plan: Plan 20 5/4/2012
MODIFIED XSEC - 12 (REVET MATTRESS w/ Turn Out)
.02
.05
.032
Elevation (ft)
Station (ft)
Legend
EG 25 Year
WS 25 Year
Crit 25 Year
2 ft/s
4 ft/s
6 ft/s
8 ft/s
10 ft/s
Ground
Bank Sta
LeesFerry_FINAL Plan: Plan 20 5/4/2012
MODIFIED XSEC - 11 (REVET MATTRESS w/ Turnout)
.032
.05
.032
Elevation (ft)
Station (ft)
Legend
EG 25 Year
WS 25 Year
Crit 25 Year
3 ft/s
4 ft/s
5 ft/s
6 ft/s
7 ft/s
8 ft/s
9 ft/s
10 ft/s
Ground
Bank Sta
LeesFerry_FINAL Plan: Plan 20 5/4/2012
MODIFIED XSEC - 10 (REVET MATTRESS w/ Turnout)
.02
.032
Elevation (ft)
Station (ft)
Legend
EG 25 Year
WS 25 Year
Crit 25 Year
0 ft/s
2 ft/s
4 ft/s
6 ft/s
8 ft/s
10 ft/s
Ground
Bank Sta
LeesFerry_FINAL Plan: Plan 20 5/4/2012
XSEC - 9 (REVET MATTRESS w/ Turnout)
.02
.032
Elevation (ft)
Station (ft)
Legend
EG 25 Year
WS 25 Year
Crit 25 Year
0 ft/s
2 ft/s
4 ft/s
6 ft/s
8 ft/s
10 ft/s
Ground
Bank Sta


LeesFerry_FINAL Plan: Plan 20 5/4/2012
XSEC - 8 (REVET MATTRESS w/ Turnout)
.02
.05
.032
Elevation (ft)
Station (ft)
Legend
EG 25 Year
WS 25 Year
Crit 25 Year
4 ft/s
5 ft/s
6 ft/s
7 ft/s
8 ft/s
9 ft/s
Ground
Bank Sta


LeesFerry_FINAL Plan: Plan 20 5/4/2012
XSEC - 7 (REVET MATTRESS w/ Turnout)
.02
.05
.032
Elevation (ft)
Station (ft)
Legend
EG 25 Year
WS 25 Year
Crit 25 Year
3 ft/s
4 ft/s
5 ft/s
6 ft/s
7 ft/s
8 ft/s
9 ft/s
Ground
Bank Sta

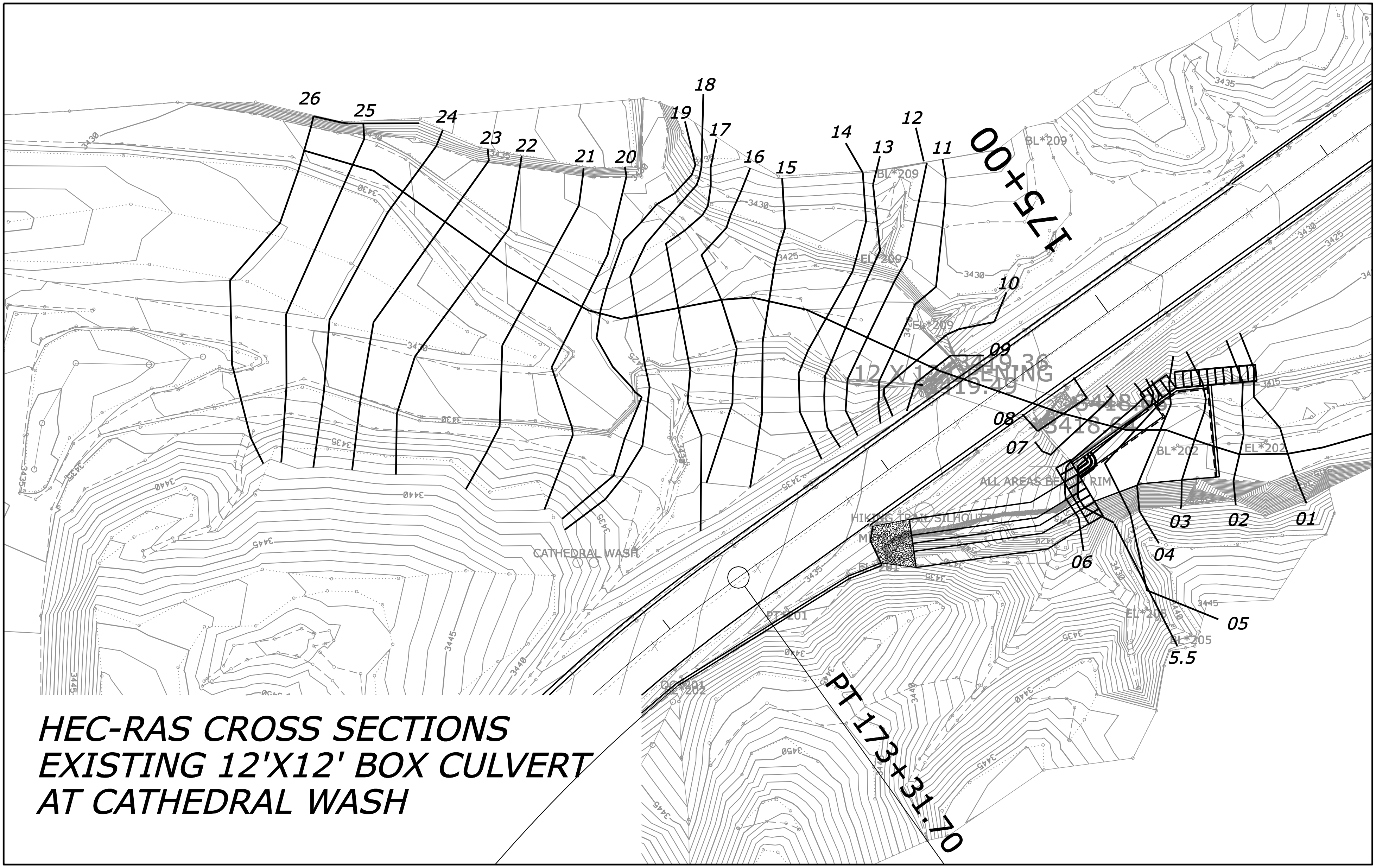

LeesFerry_FINAL Plan: Plan 20 5/4/2012
XSEC - 6 (REVET MATTRESS w/ Turnout)
.02
.05
.032
Elevation (ft)
Station (ft)
Legend
EG 25 Year
WS 25 Year
Crit 25 Year
0 ft/s
2 ft/s
4 ft/s
6 ft/s
8 ft/s
10 ft/s
Ground
Bank Sta


LeesFerry_FINAL Plan: Plan 20 5/4/2012
XSEC - 5
.02
.032
.032
Elevation (ft)
Station (ft)
Legend
EG 25 Year
WS 25 Year
2 ft/s
3 ft/s
4 ft/s
5 ft/s
6 ft/s
7 ft/s
Ground
Bank Sta



LeesFerry_FINAL Plan: Plan 20 5/4/2012
XSEC - 4
.02
.032
.032
Elevation (ft)
Station (ft)
Legend
EG 25 Year
WS 25 Year
Crit 25 Year
3 ft/s
4 ft/s
5 ft/s
6 ft/s
7 ft/s
8 ft/s
9 ft/s
10 ft/s
Ground
Bank Sta
LeesFerry_FINAL Plan: Plan 20 5/4/2012
XSEC - 3
.02
.032
.032
Elevation (ft)
Station (ft)
Legend
EG 25 Year
WS 25 Year
4 ft/s
5 ft/s
6 ft/s
7 ft/s
8 ft/s
9 ft/s
Ground
Bank Sta
LeesFerry_FINAL Plan: Plan 20 5/4/2012
XSEC - 2
.02
.032
.032
Elevation (ft)
Station (ft)
Legend
EG 25 Year
WS 25 Year
Crit 25 Year
2 ft/s
4 ft/s
6 ft/s
8 ft/s
10 ft/s
Ground
Bank Sta
LeesFerry_FINAL Plan: Plan 20 5/4/2012
XSEC - 1
.02
.032
.032
Elevation (ft)
Station (ft)
Legend
EG 25 Year
WS 25 Year
Crit 25 Year
2 ft/s
3 ft/s
4 ft/s
5 ft/s
6 ft/s
7 ft/s
8 ft/s
9 ft/s
Ground
Bank Sta

Channel Hydraulic HEC-RAS Analysis – Cathedral Wash Existing Model

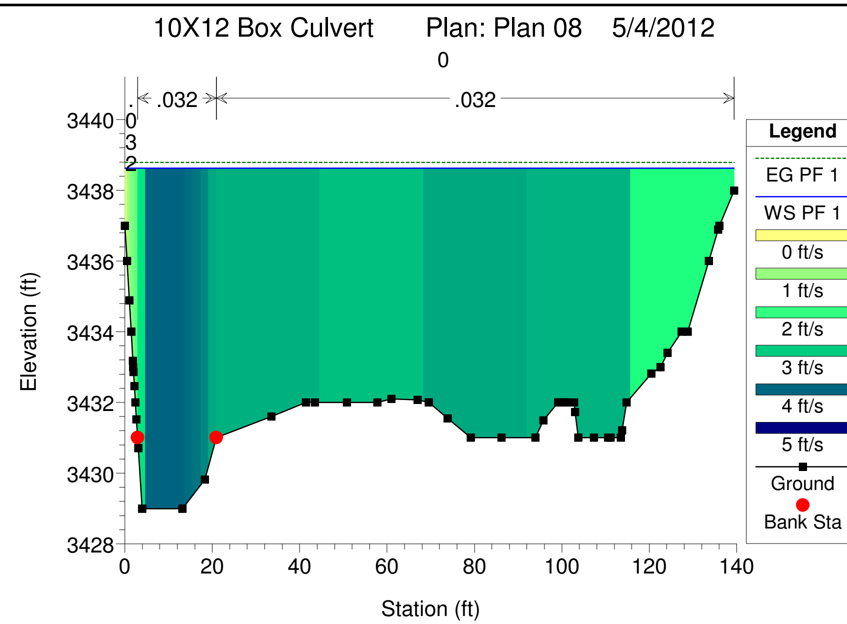


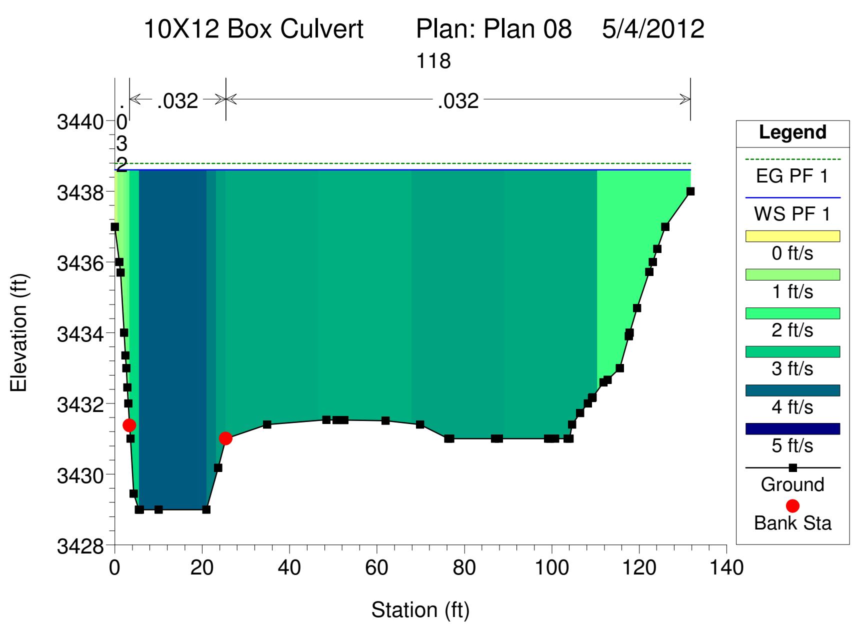
HEC-RAS CROSS SECTIONS
EXISTING 12'X12' BOX CULVERT
AT CATHEDRAL WASH

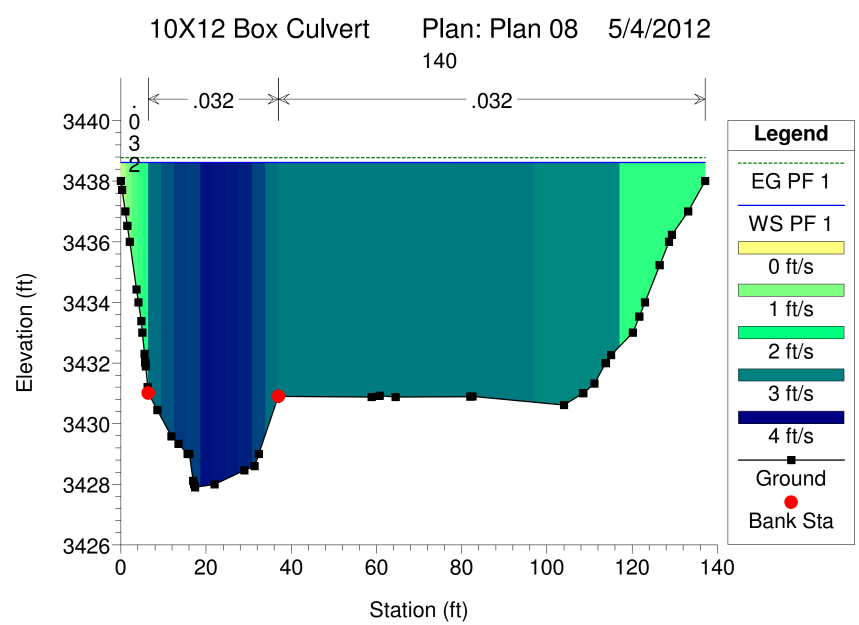
HEC-RAS Plan: Drop Final River: RIVER-1 Reach: Reach-1 Profile: PF 1

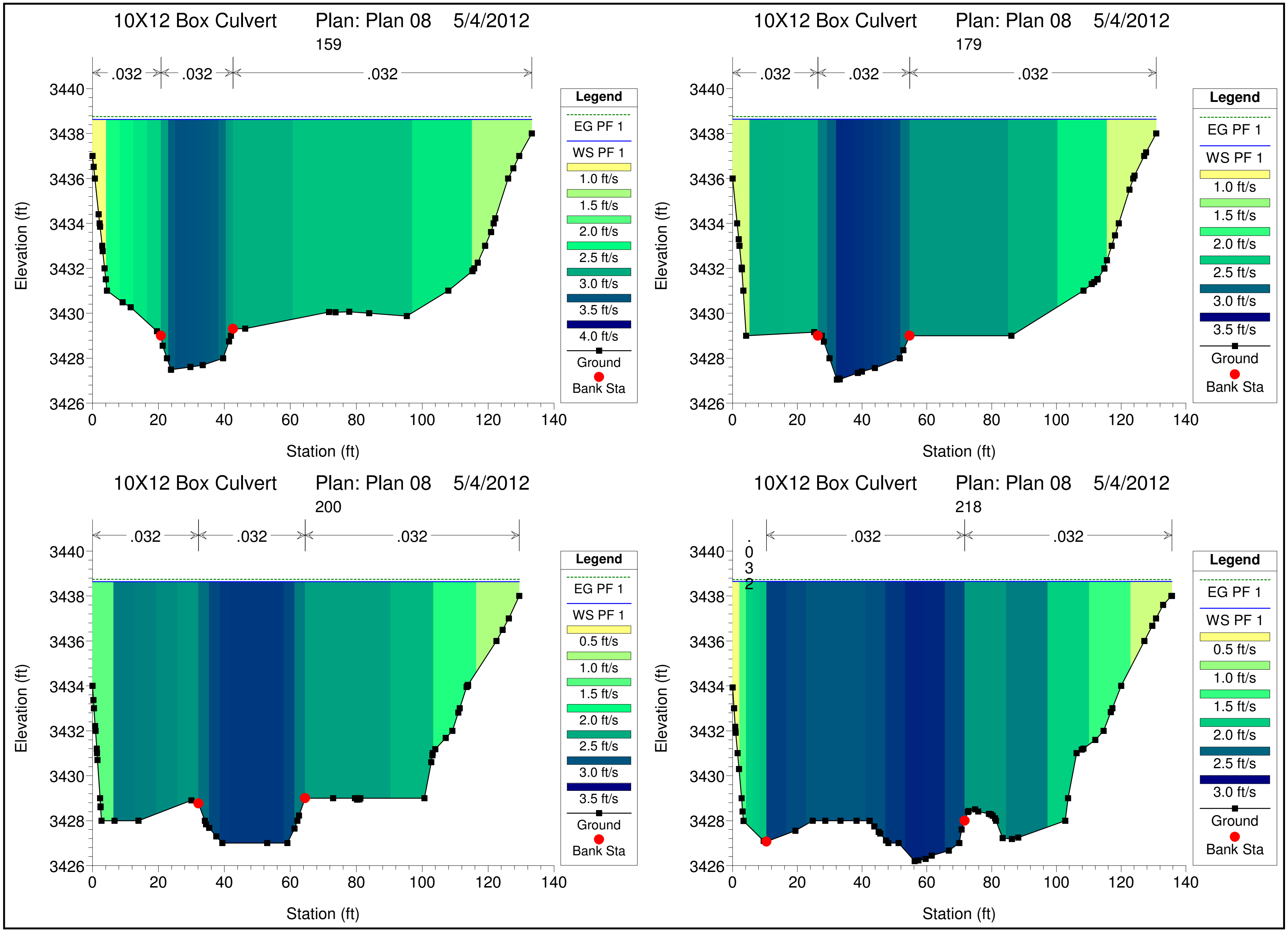
Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Reach-1	27	PF 1	3041.00	3429.00	3438.63		3438.79	0.000381	3.78	949.10	139.38	0.22
Reach-1	26	PF 1	3041.00	3429.00	3438.61		3438.78	0.000397	3.90	913.19	131.71	0.23
Reach-1	25	PF 1	3041.00	3427.90	3438.62		3438.77	0.000302	3.57	1000.31	137.12	0.20
Reach-1	24	PF 1	3041.00	3427.49	3438.63		3438.76	0.000234	3.39	1081.63	133.22	0.18
Reach-1	23	PF 1	3041.00	3427.04	3438.64		3438.75	0.000197	3.16	1138.63	130.82	0.17
Reach-1	22	PF 1	3041.00	3427.00	3438.64		3438.75	0.000178	3.08	1173.09	129.41	0.16
Reach-1	21	PF 1	3041.00	3426.20	3438.65		3438.74	0.000131	2.67	1297.50	135.71	0.14
Reach-1	20	PF 1	3041.00	3426.00	3438.66		3438.73	0.000082	2.17	1563.13	160.38	0.11
Reach-1	19	PF 1	3041.00	3425.10	3438.65		3438.72	0.000096	2.40	1468.17	155.64	0.12
Reach-1	18	PF 1	3041.00	3424.00	3438.65		3438.72	0.000088	2.47	1493.76	143.76	0.12
Reach-1	17	PF 1	3041.00	3423.00	3438.64		3438.72	0.000090	2.62	1416.02	125.82	0.12
Reach-1	16	PF 1	3041.00	3422.00	3438.62		3438.71	0.000100	2.81	1315.66	115.69	0.13
Reach-1	15	PF 1	3041.00	3422.00	3438.62		3438.71	0.000101	2.84	1315.43	115.69	0.13
Reach-1	14	PF 1	3041.00	3421.00	3438.62		3438.71	0.000089	2.68	1358.36	113.45	0.12
Reach-1	13	PF 1	3041.00	3421.00	3438.61		3438.70	0.000095	2.80	1297.76	103.26	0.12
Reach-1	12	PF 1	3041.00	3421.00	3438.60		3438.70	0.000094	2.74	1323.00	107.89	0.12
Reach-1	11	PF 1	3041.00	3421.00	3438.57		3438.68	0.000124	3.10	1202.17	104.83	0.13
Reach-1	10	PF 1	3041.00	3421.00	3438.36		3438.66	0.000307	4.85	758.85	59.81	0.21
Reach-1	9	PF 1	3041.00	3421.00	3437.37	3431.18	3438.55	0.002472	9.22	372.84	38.36	0.41
Reach-1	8.9		Culvert									
Reach-1	8	PF 1	3041.00	3418.94	3429.10	3429.10	3434.03	0.019107	17.81	170.74	17.40	1.00
Reach-1	7	PF 1	3041.00	3418.46	3427.85	3427.85	3430.99	0.008638	14.88	226.87	39.20	0.88
Reach-1	6	PF 1	3041.00	3417.81	3423.66	3423.66	3425.54	0.009046	11.80	292.31	77.34	0.96
Reach-1	5	PF 1	3041.00	3412.75	3420.25		3421.46	0.002916	8.89	350.98	54.06	0.59
Reach-1	4	PF 1	3041.00	3412.10	3419.67		3421.38	0.004946	10.49	290.96	47.05	0.73
Reach-1	3	PF 1	3041.00	3411.31	3419.52		3421.31	0.004465	10.86	290.75	45.74	0.71
Reach-1	2	PF 1	3041.00	3411.00	3418.26	3418.26	3421.09	0.009368	13.51	226.71	41.14	0.99
Reach-1	1	PF 1	3041.00	3411.00	3417.99	3417.99	3420.72	0.009998	13.28	230.10	44.17	1.01

No Data for Plot

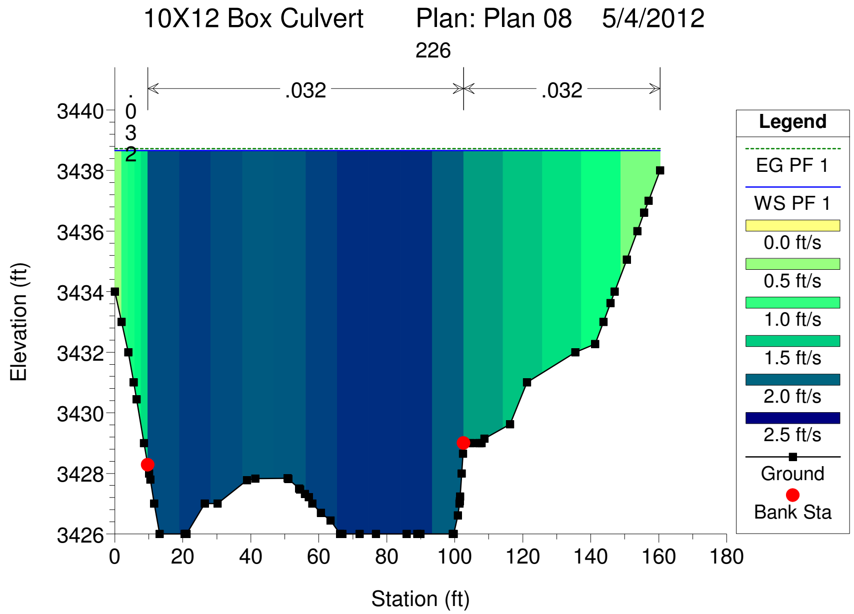


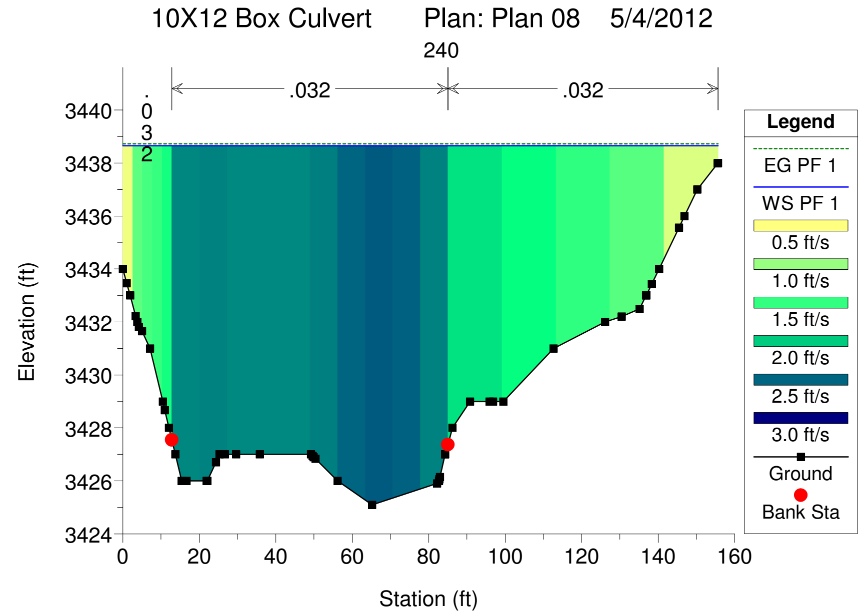


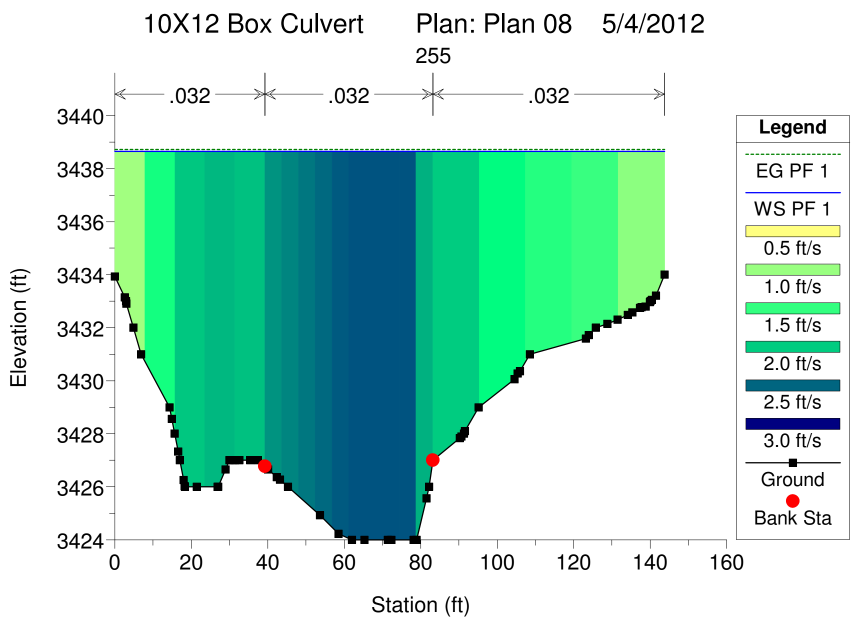


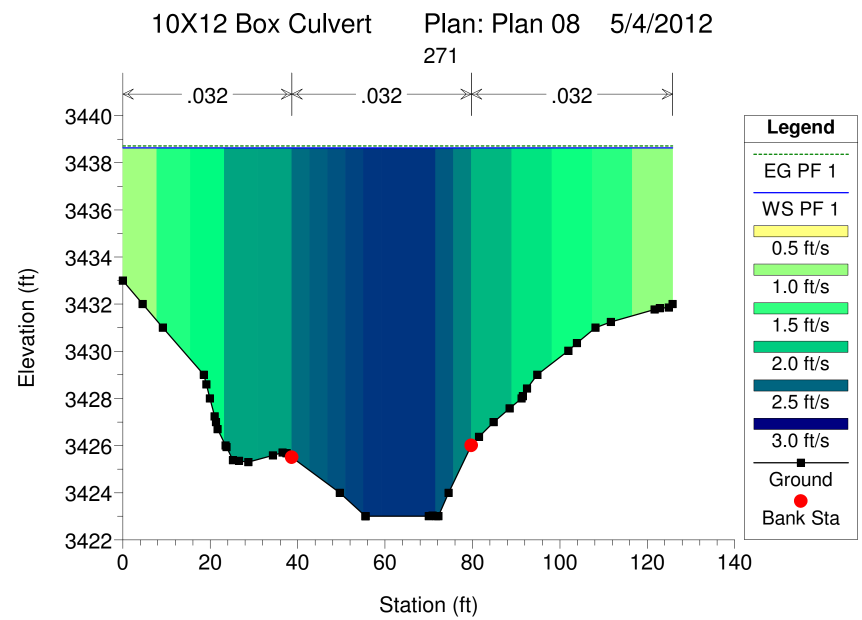


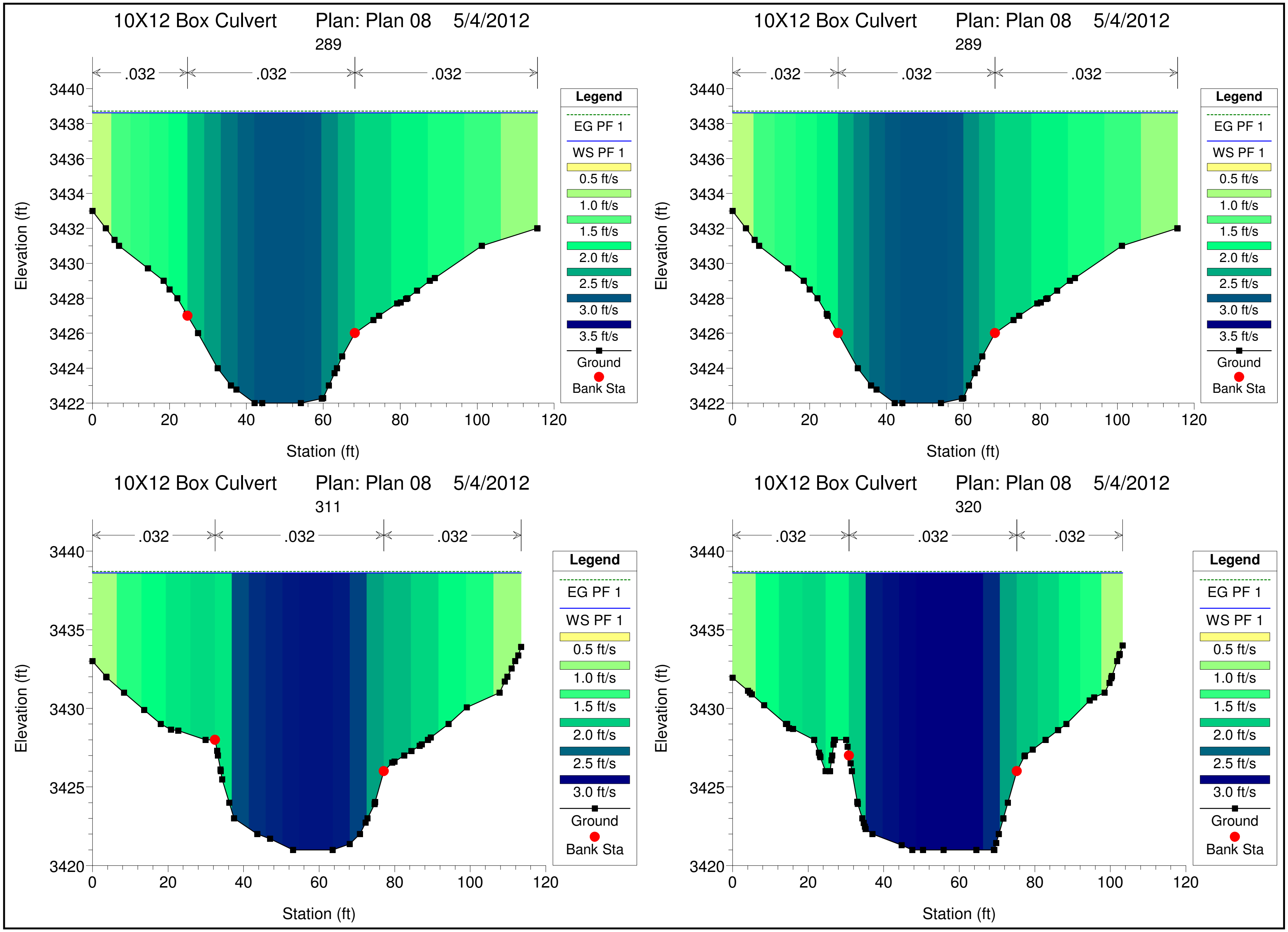
10X12 Box Culvert Plan: Plan 08 5/4/2012
159
.032
.032
.032
Legend
EG PF 1
WS PF 1
1.0 ft/s
1.5 ft/s
2.0 ft/s
2.5 ft/s
3.0 ft/s
3.5 ft/s
4.0 ft/s
Ground
Bank Sta
Elevation (ft)
Station (ft)
10X12 Box Culvert Plan: Plan 08 5/4/2012
179
.032
.032
.032
Legend
EG PF 1
WS PF 1
1.0 ft/s
1.5 ft/s
2.0 ft/s
2.5 ft/s
3.0 ft/s
3.5 ft/s
Ground
Bank Sta
Elevation (ft)
Station (ft)
10X12 Box Culvert Plan: Plan 08 5/4/2012
200
.032
.032
.032
Legend
EG PF 1
WS PF 1
0.5 ft/s
1.0 ft/s
1.5 ft/s
2.0 ft/s
2.5 ft/s
3.0 ft/s
3.5 ft/s
Ground
Bank Sta
Elevation (ft)
Station (ft)
10X12 Box Culvert Plan: Plan 08 5/4/2012
218
.032
.032
.032
Legend
EG PF 1
WS PF 1
0.5 ft/s
1.0 ft/s
1.5 ft/s
2.0 ft/s
2.5 ft/s
3.0 ft/s
Ground
Bank Sta
Elevation (ft)
Station (ft)


10X12 Box Culvert Plan: Plan 08 5/4/2012
226
.032
.032
.032
Elevation (ft)
Station (ft)
Legend
EG PF 1
WS PF 1
0.0 ft/s
0.5 ft/s
1.0 ft/s
1.5 ft/s
2.0 ft/s
2.5 ft/s
Ground
Bank Sta

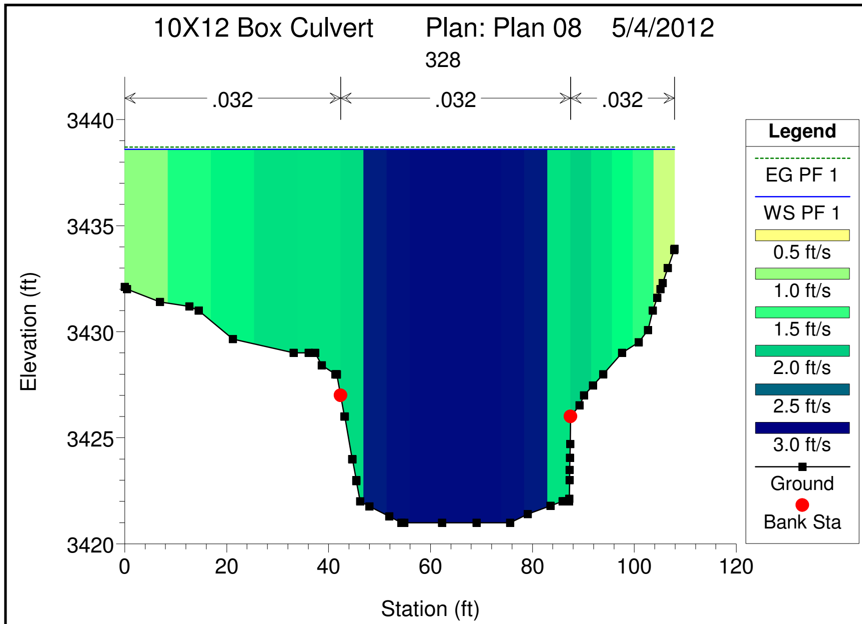

10X12 Box Culvert Plan: Plan 08 5/4/2012
240
.032
.032
.032
Elevation (ft)
Station (ft)
Legend
EG PF 1
WS PF 1
0.5 ft/s
1.0 ft/s
1.5 ft/s
2.0 ft/s
2.5 ft/s
3.0 ft/s
Ground
Bank Sta

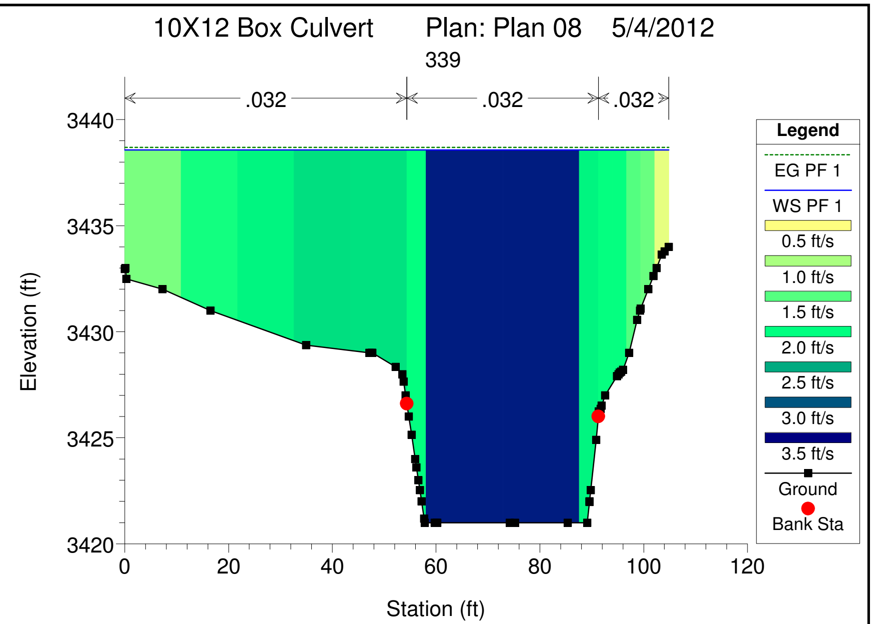

10X12 Box Culvert Plan: Plan 08 5/4/2012
255
.032
.032
.032
Elevation (ft)
Station (ft)
Legend
EG PF 1
WS PF 1
0.5 ft/s
1.0 ft/s
1.5 ft/s
2.0 ft/s
2.5 ft/s
3.0 ft/s
Ground
Bank Sta

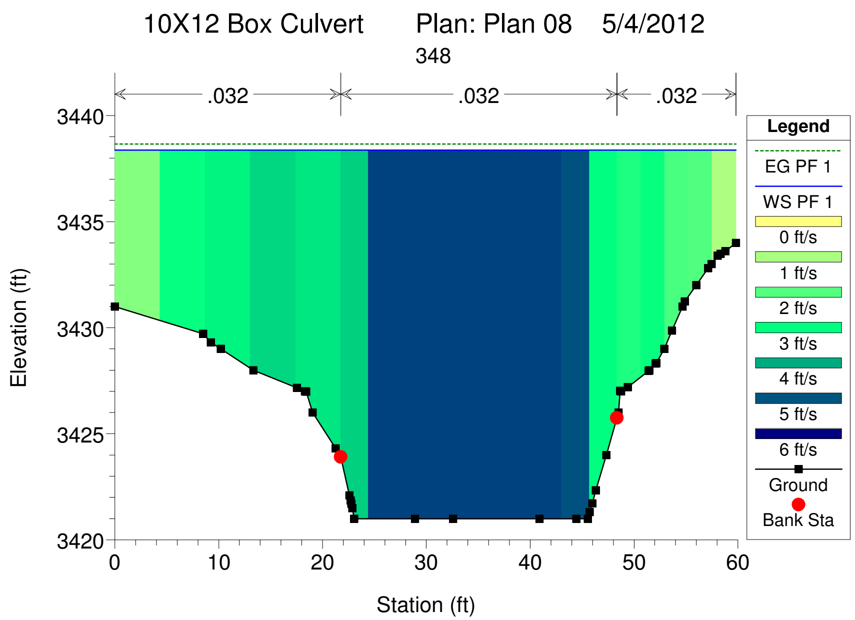

10X12 Box Culvert Plan: Plan 08 5/4/2012
271
.032
.032
.032
Elevation (ft)
Station (ft)
Legend
EG PF 1
WS PF 1
0.5 ft/s
1.0 ft/s
1.5 ft/s
2.0 ft/s
2.5 ft/s
3.0 ft/s
Ground
Bank Sta

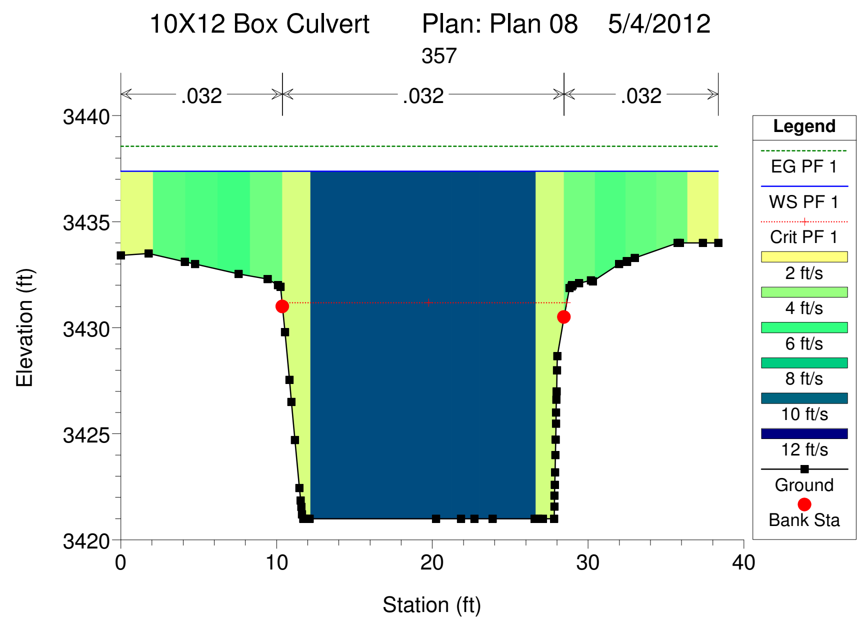


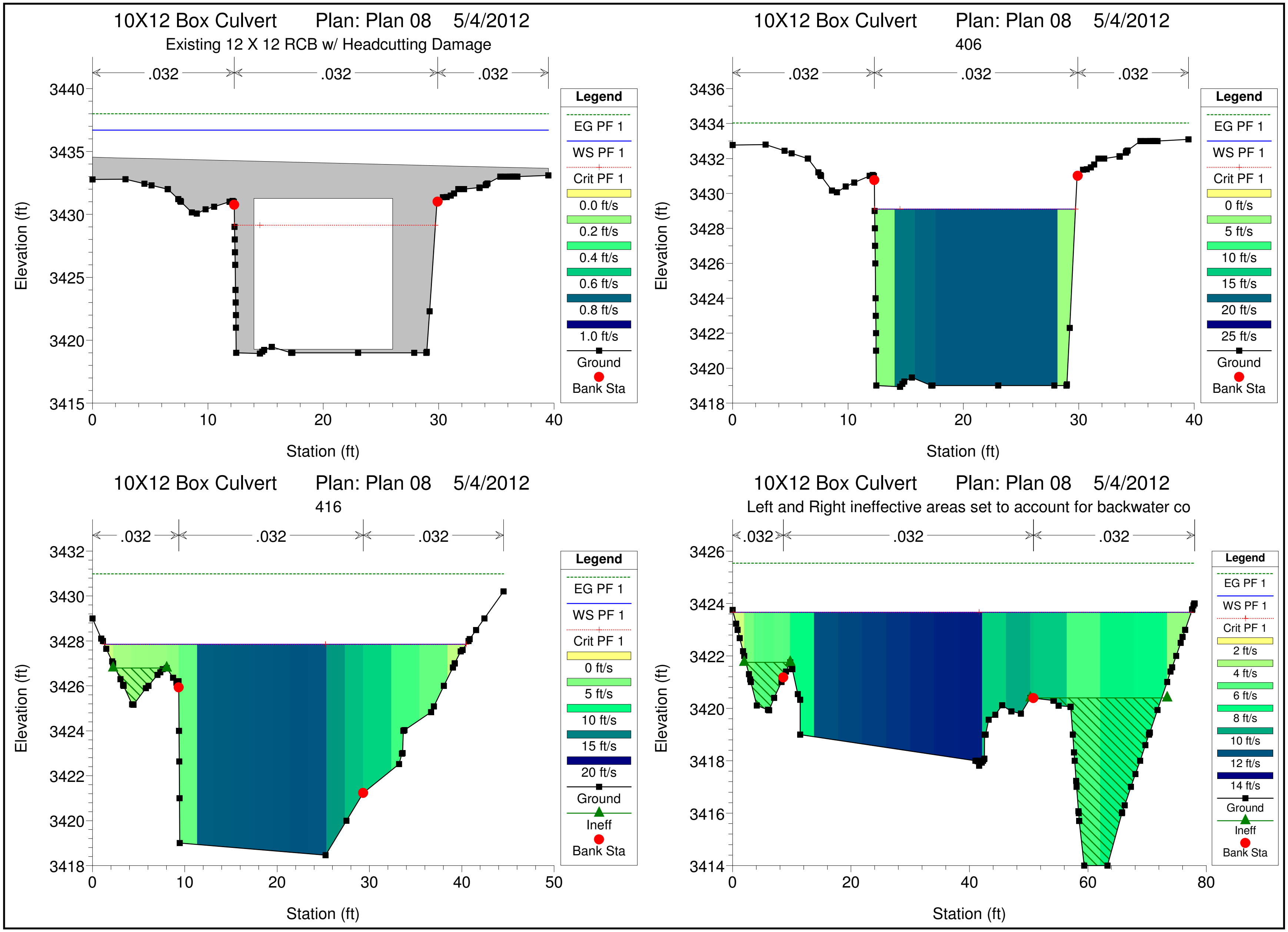
10X12 Box Culvert Plan: Plan 08 5/4/2012
289
.032
.032
.032
Legend
EG PF 1
WS PF 1
0.5 ft/s
1.0 ft/s
1.5 ft/s
2.0 ft/s
2.5 ft/s
3.0 ft/s
3.5 ft/s
Ground
Bank Sta
Elevation (ft)
Station (ft)
10X12 Box Culvert Plan: Plan 08 5/4/2012
289
.032
.032
.032
Legend
EG PF 1
WS PF 1
0.5 ft/s
1.0 ft/s
1.5 ft/s
2.0 ft/s
2.5 ft/s
3.0 ft/s
3.5 ft/s
Ground
Bank Sta
Elevation (ft)
Station (ft)
10X12 Box Culvert Plan: Plan 08 5/4/2012
311
.032
.032
.032
Legend
EG PF 1
WS PF 1
0.5 ft/s
1.0 ft/s
1.5 ft/s
2.0 ft/s
2.5 ft/s
3.0 ft/s
Ground
Bank Sta
Elevation (ft)
Station (ft)
10X12 Box Culvert Plan: Plan 08 5/4/2012
320
.032
.032
.032
Legend
EG PF 1
WS PF 1
0.5 ft/s
1.0 ft/s
1.5 ft/s
2.0 ft/s
2.5 ft/s
3.0 ft/s
Ground
Bank Sta
Elevation (ft)
Station (ft)

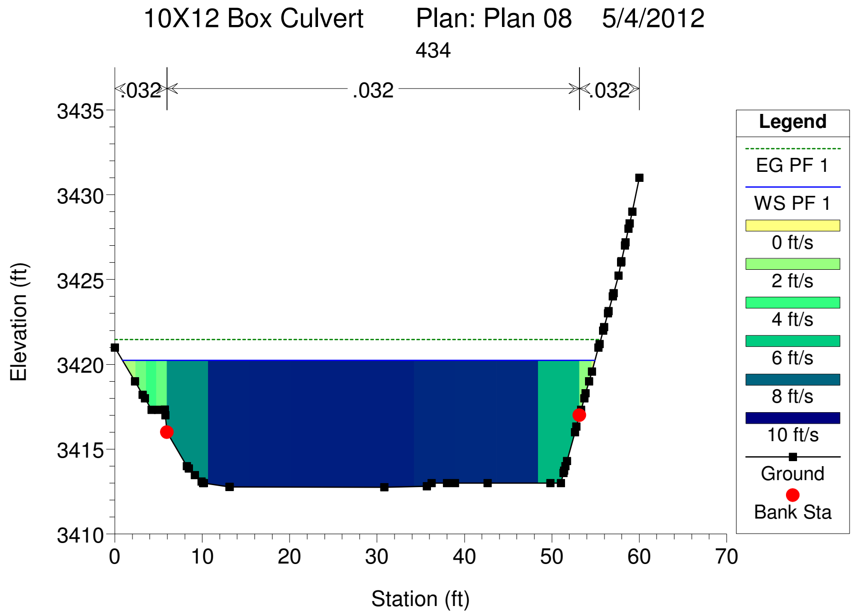

10X12 Box Culvert Plan: Plan 08 5/4/2012
328
.032
.032
.032
Elevation (ft)
Station (ft)
3420
3425
3430
3435
3440
0
20
40
60
80
100
120
Legend
EG PF 1
WS PF 1
0.5 ft/s
1.0 ft/s
1.5 ft/s
2.0 ft/s
2.5 ft/s
3.0 ft/s
Ground
Bank Sta

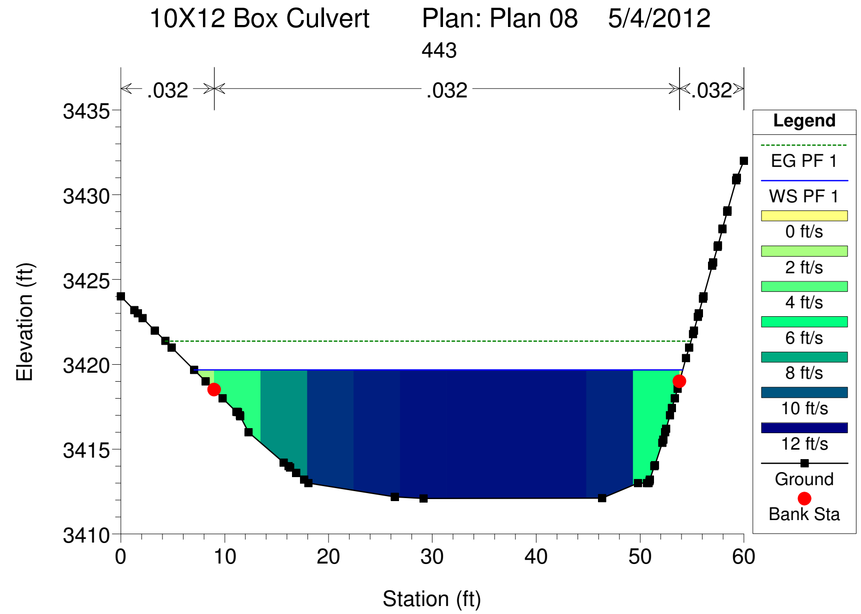

10X12 Box Culvert Plan: Plan 08 5/4/2012
339
.032
.032
.032
Elevation (ft)
Station (ft)
3420
3425
3430
3435
3440
0
20
40
60
80
100
120
Legend
EG PF 1
WS PF 1
0.5 ft/s
1.0 ft/s
1.5 ft/s
2.0 ft/s
2.5 ft/s
3.0 ft/s
3.5 ft/s
Ground
Bank Sta

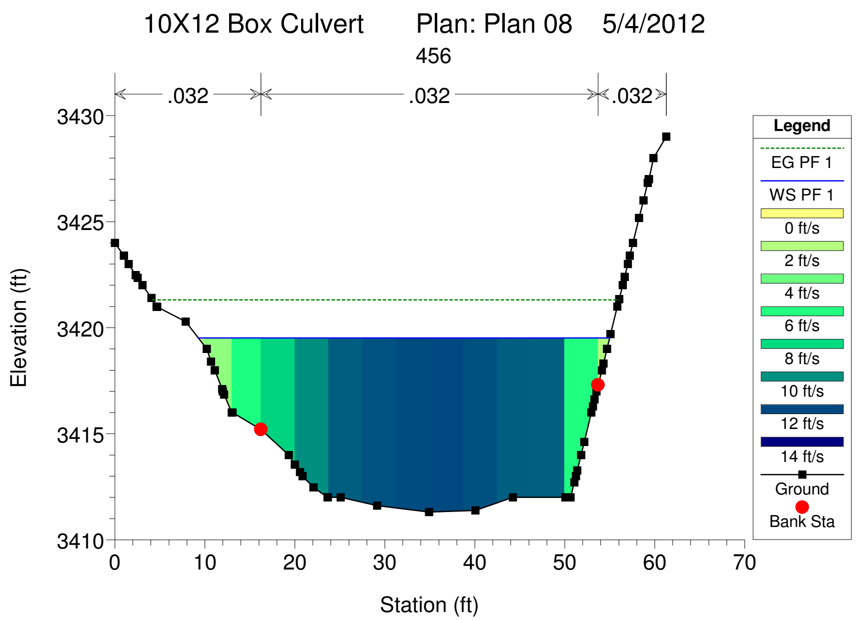

10X12 Box Culvert Plan: Plan 08 5/4/2012
348
.032
.032
.032
Elevation (ft)
Station (ft)
3420
3425
3430
3435
3440
0
10
20
30
40
50
60
Legend
EG PF 1
WS PF 1
0 ft/s
1 ft/s
2 ft/s
3 ft/s
4 ft/s
5 ft/s
6 ft/s
Ground
Bank Sta

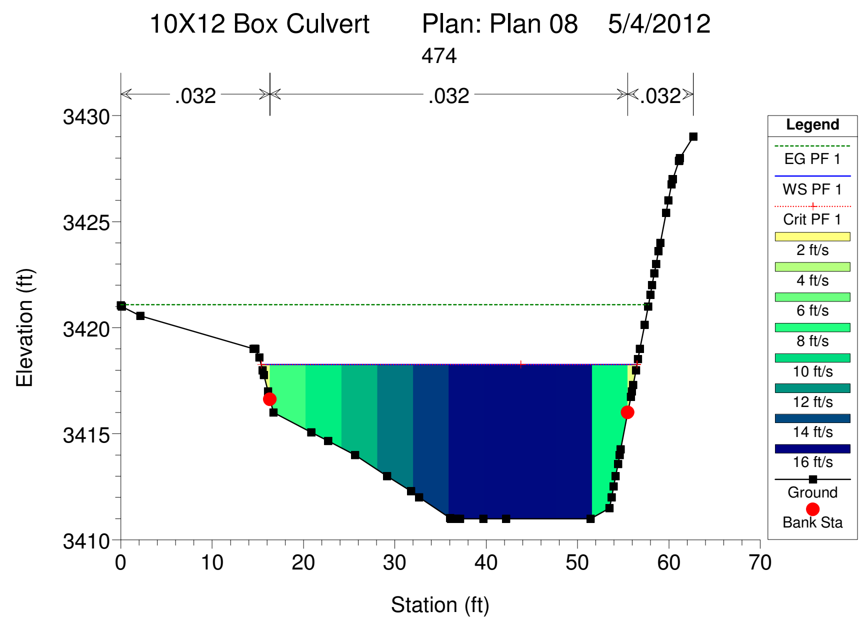

10X12 Box Culvert Plan: Plan 08 5/4/2012
357
.032
.032
.032
Elevation (ft)
Station (ft)
3420
3425
3430
3435
3440
0
10
20
30
40
Legend
EG PF 1
WS PF 1
Crit PF 1
2 ft/s
4 ft/s
6 ft/s
8 ft/s
10 ft/s
12 ft/s
Ground
Bank Sta

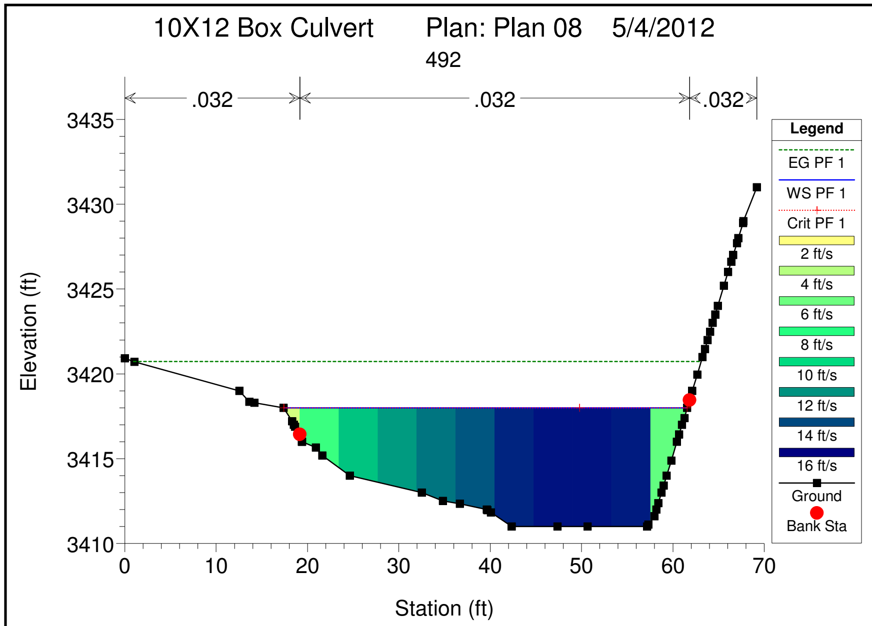

10X12 Box Culvert Plan: Plan 08 5/4/2012
Existing 12 X 12 RCB w/ Headcutting Damage
.032 .032 .032
Legend
EG PF 1
WS PF 1
Crit PF 1
0.0 ft/s
0.2 ft/s
0.4 ft/s
0.6 ft/s
0.8 ft/s
1.0 ft/s
Ground
Bank Sta
Elevation (ft)
Station (ft)
10X12 Box Culvert Plan: Plan 08 5/4/2012
406
.032 .032 .032
Legend
EG PF 1
WS PF 1
Crit PF 1
0 ft/s
5 ft/s
10 ft/s
15 ft/s
20 ft/s
25 ft/s
Ground
Bank Sta
Elevation (ft)
Station (ft)
10X12 Box Culvert Plan: Plan 08 5/4/2012
416
.032 .032 .032
Legend
EG PF 1
WS PF 1
Crit PF 1
0 ft/s
5 ft/s
10 ft/s
15 ft/s
20 ft/s
Ground
Ineff
Bank Sta
Elevation (ft)
Station (ft)
10X12 Box Culvert Plan: Plan 08 5/4/2012
Left and Right ineffective areas set to account for backwater co
.032 .032 .032
Legend
EG PF 1
WS PF 1
Crit PF 1
2 ft/s
4 ft/s
6 ft/s
8 ft/s
10 ft/s
12 ft/s
14 ft/s
Ground
Ineff
Bank Sta
Elevation (ft)
Station (ft)


10X12 Box Culvert Plan: Plan 08 5/4/2012
434
.032
.032
.032
Elevation (ft)
Station (ft)
Legend
EG PF 1
WS PF 1
0 ft/s
2 ft/s
4 ft/s
6 ft/s
8 ft/s
10 ft/s
Ground
Bank Sta


10X12 Box Culvert Plan: Plan 08 5/4/2012
443
.032
.032
.032
Elevation (ft)
Station (ft)
Legend
EG PF 1
WS PF 1
0 ft/s
2 ft/s
4 ft/s
6 ft/s
8 ft/s
10 ft/s
12 ft/s
Ground
Bank Sta

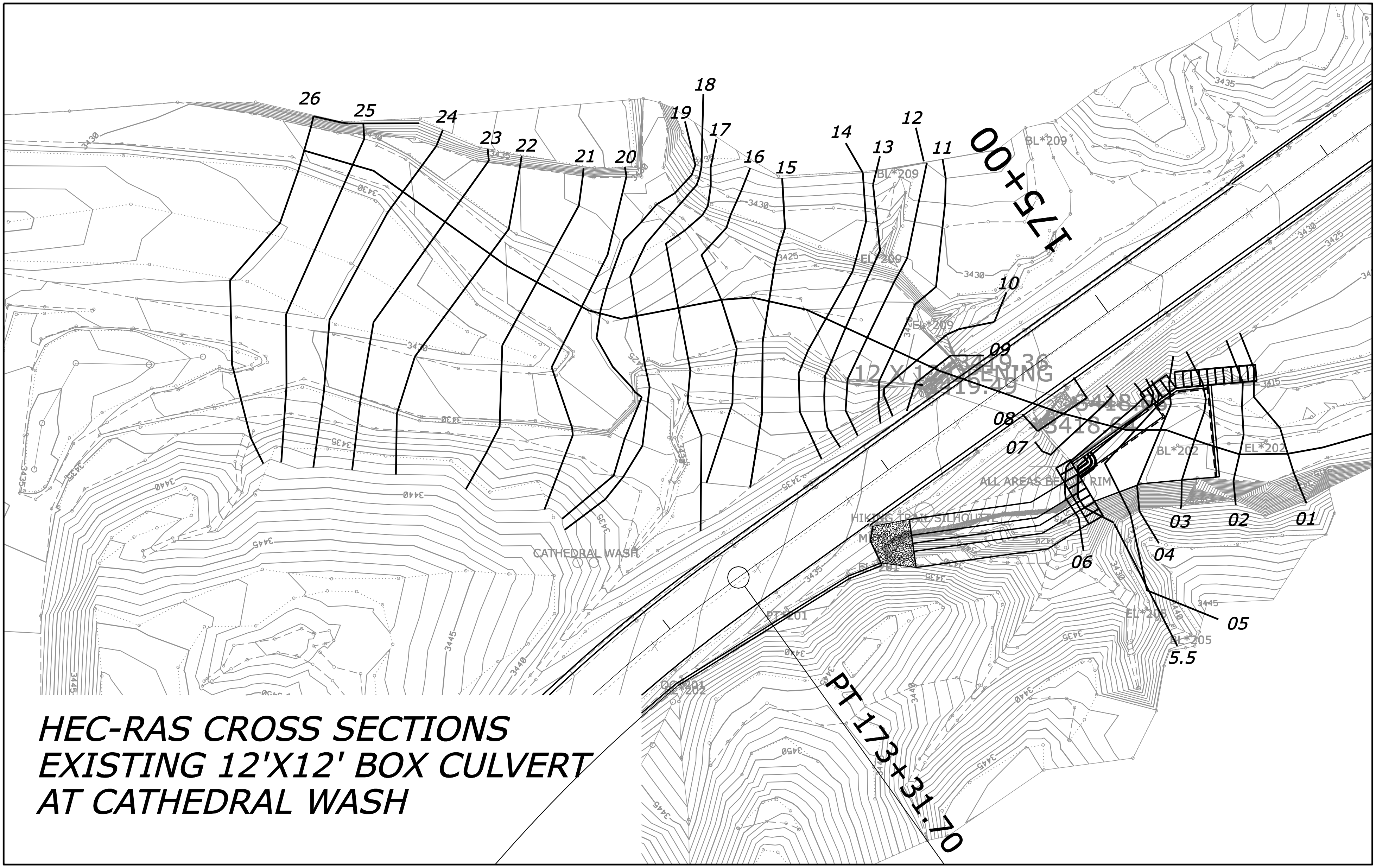

10X12 Box Culvert Plan: Plan 08 5/4/2012
456
.032
.032
.032
Elevation (ft)
Station (ft)
Legend
EG PF 1
WS PF 1
0 ft/s
2 ft/s
4 ft/s
6 ft/s
8 ft/s
10 ft/s
12 ft/s
14 ft/s
Ground
Bank Sta


10X12 Box Culvert Plan: Plan 08 5/4/2012
474
.032
.032
.032
Elevation (ft)
Station (ft)
Legend
EG PF 1
WS PF 1
Crit PF 1
2 ft/s
4 ft/s
6 ft/s
8 ft/s
10 ft/s
12 ft/s
14 ft/s
16 ft/s
Ground
Bank Sta



10X12 Box Culvert Plan: Plan 08 5/4/2012
492
.032
.032
.032
Legend
EG PF 1
WS PF 1
Crit PF 1
2 ft/s
4 ft/s
6 ft/s
8 ft/s
10 ft/s
12 ft/s
14 ft/s
16 ft/s
Ground
Bank Sta
Elevation (ft)
3410
3415
3420
3425
3430
3435
0
10
20
30
40
50
60
70
Station (ft)

Channel Hydraulic HEC-RAS Analysis – Cathedral Wash Proposed Model

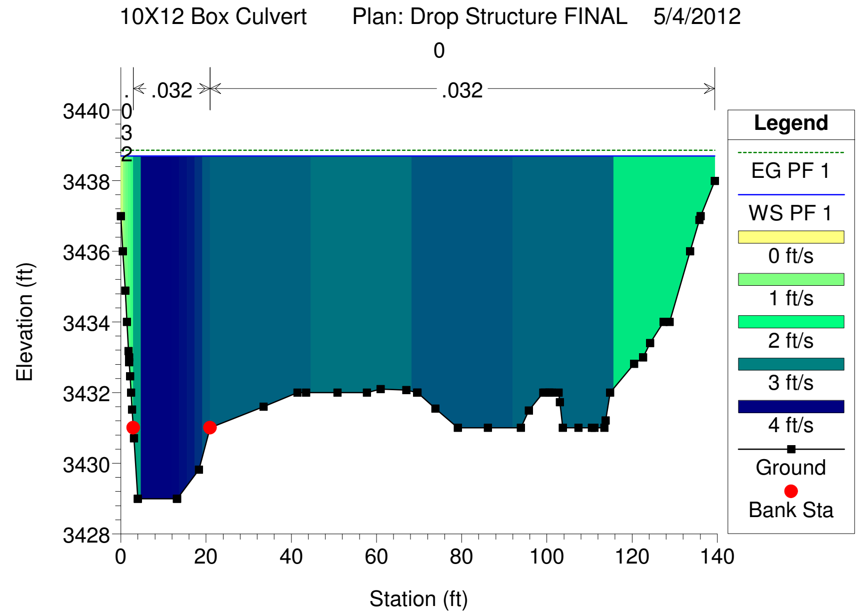


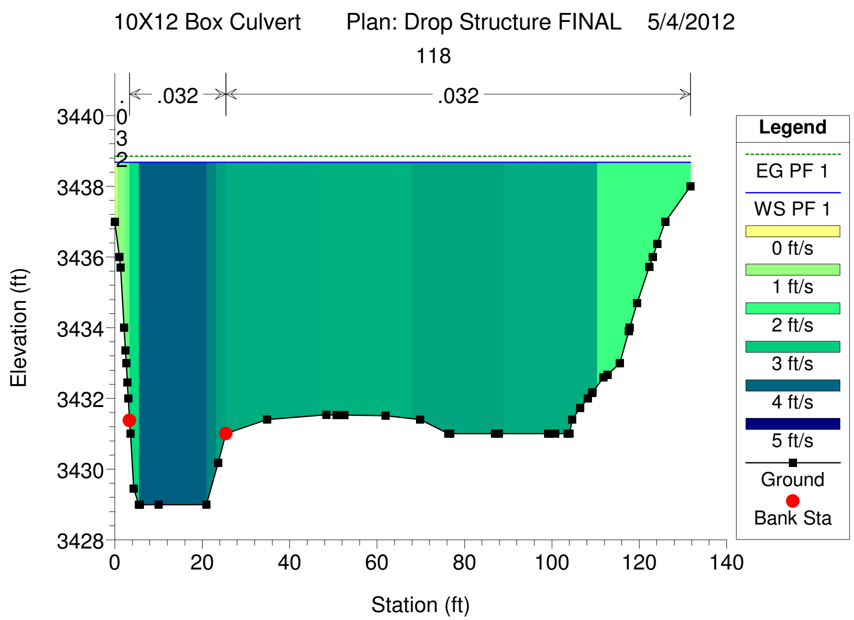
HEC-RAS CROSS SECTIONS
EXISTING 12'X12' BOX CULVERT
AT CATHEDRAL WASH

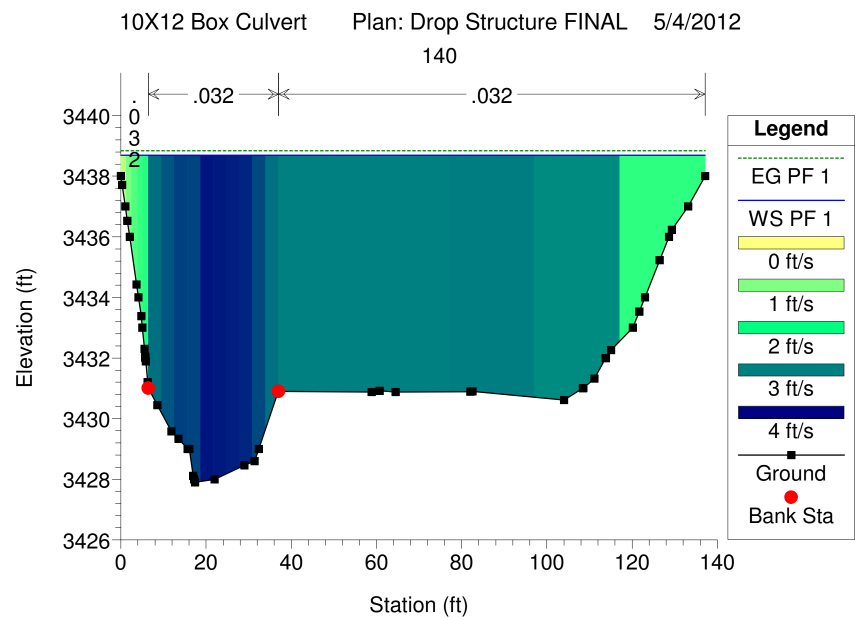
HEC-RAS Plan: Drop Final River: RIVER-1 Reach: Reach-1 Profile: PF 1

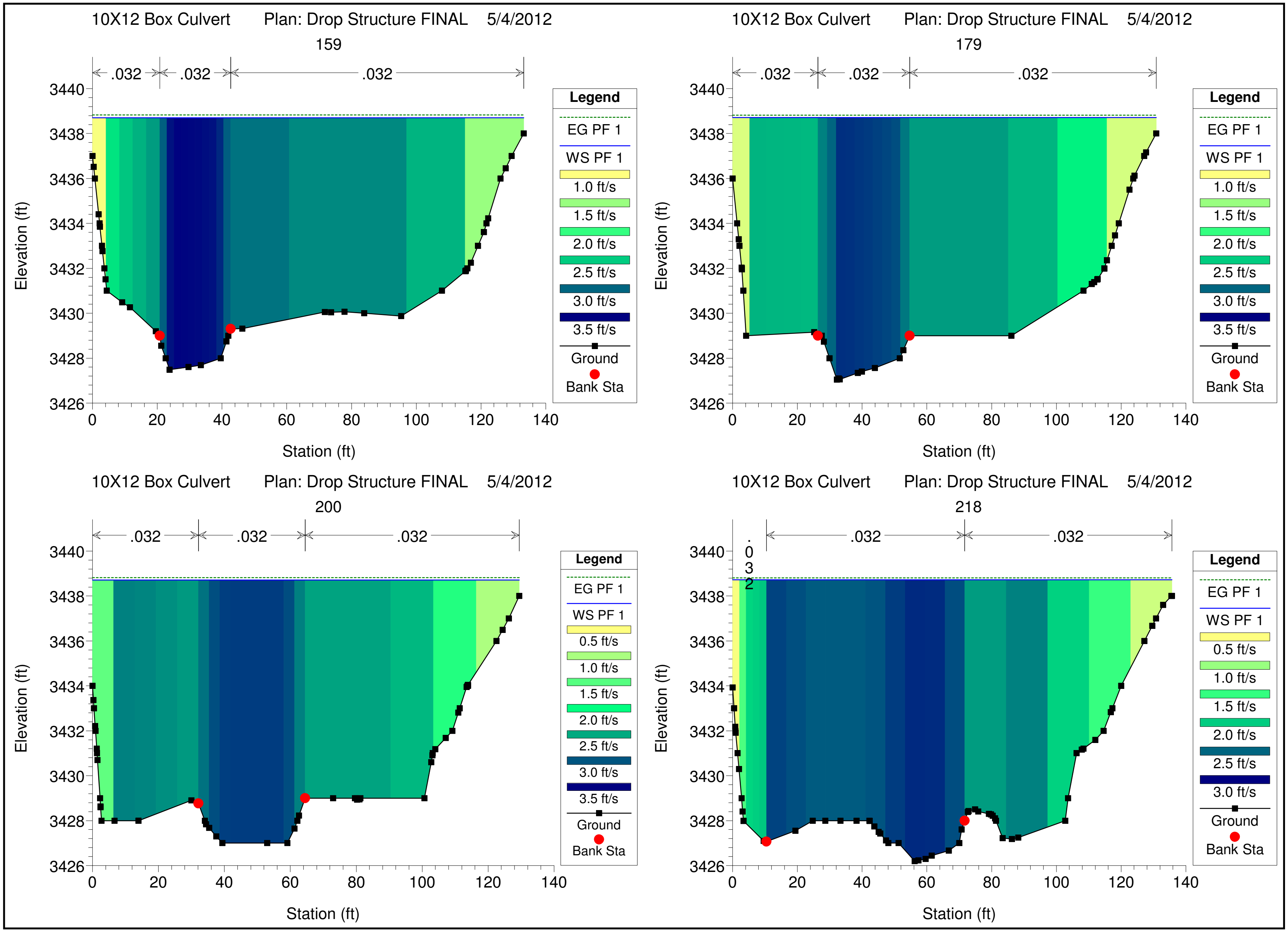
Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Reach-1	27	PF 1	3041.00	3429.00	3438.70		3438.86	0.000369	3.74	959.14	139.38	0.22
Reach-1	26	PF 1	3041.00	3429.00	3438.68		3438.85	0.000384	3.86	922.74	131.71	0.22
Reach-1	25	PF 1	3041.00	3427.90	3438.69		3438.84	0.000293	3.53	1010.25	137.12	0.20
Reach-1	24	PF 1	3041.00	3427.49	3438.70		3438.83	0.000228	3.36	1091.25	133.22	0.18
Reach-1	23	PF 1	3041.00	3427.04	3438.71		3438.82	0.000192	3.13	1148.09	130.82	0.17
Reach-1	22	PF 1	3041.00	3427.00	3438.71		3438.82	0.000173	3.06	1182.41	129.41	0.16
Reach-1	21	PF 1	3041.00	3426.20	3438.72		3438.81	0.000128	2.65	1307.28	135.71	0.14
Reach-1	20	PF 1	3041.00	3426.00	3438.73		3438.80	0.000080	2.15	1574.65	160.38	0.11
Reach-1	19	PF 1	3041.00	3425.10	3438.72		3438.79	0.000093	2.39	1479.38	155.64	0.12
Reach-1	18	PF 1	3041.00	3424.00	3438.72		3438.79	0.000086	2.45	1504.08	143.76	0.12
Reach-1	17	PF 1	3041.00	3423.00	3438.71		3438.79	0.000088	2.61	1425.08	125.82	0.12
Reach-1	16	PF 1	3041.00	3422.00	3438.69		3438.78	0.000099	2.79	1324.05	115.69	0.13
Reach-1	15	PF 1	3041.00	3422.00	3438.69		3438.78	0.000099	2.82	1323.82	115.69	0.13
Reach-1	14	PF 1	3041.00	3421.00	3438.69		3438.78	0.000087	2.67	1366.59	113.45	0.12
Reach-1	13	PF 1	3041.00	3421.00	3438.68		3438.78	0.000093	2.79	1305.25	103.26	0.12
Reach-1	12	PF 1	3041.00	3421.00	3438.67		3438.77	0.000093	2.72	1330.82	107.89	0.12
Reach-1	11	PF 1	3041.00	3421.00	3438.64		3438.76	0.000122	3.08	1209.79	104.83	0.13
Reach-1	10	PF 1	3041.00	3421.00	3438.44		3438.73	0.000302	4.82	763.35	59.81	0.21
Reach-1	9	PF 1	3041.00	3421.00	3437.05	3431.48	3438.59	0.003447	10.37	328.80	38.36	0.48
Reach-1	8.9		Culvert									
Reach-1	8	PF 1	3041.00	3418.94	3429.12	3429.12	3434.07	0.012607	17.86	170.25	17.41	1.00
Reach-1	7	PF 1	3041.00	3418.46	3427.85	3427.85	3430.99	0.008638	14.88	226.87	39.20	0.88
Reach-1	6	PF 1	3041.00	3417.81	3423.85	3423.85	3425.82	0.009119	12.15	306.62	77.72	0.97
Reach-1	5.5	PF 1	3041.00	3411.00	3421.36		3421.62	0.000907	4.20	744.92	78.04	0.23
Reach-1	5	PF 1	3041.00	3411.00	3420.87		3421.56	0.003108	6.71	461.84	55.11	0.39
Reach-1	4	PF 1	3041.00	3411.00	3420.43		3421.49	0.005968	8.26	370.57	48.64	0.51
Reach-1	3	PF 1	3041.00	3411.00	3420.14		3421.39	0.006671	9.07	342.62	47.22	0.55
Reach-1	2	PF 1	3041.00	3411.00	3418.26	3418.26	3421.09	0.009368	13.51	226.71	41.14	0.99
Reach-1	1	PF 1	3041.00	3411.00	3417.99	3417.99	3420.72	0.009998	13.28	230.10	44.17	1.01

No Data for Plot

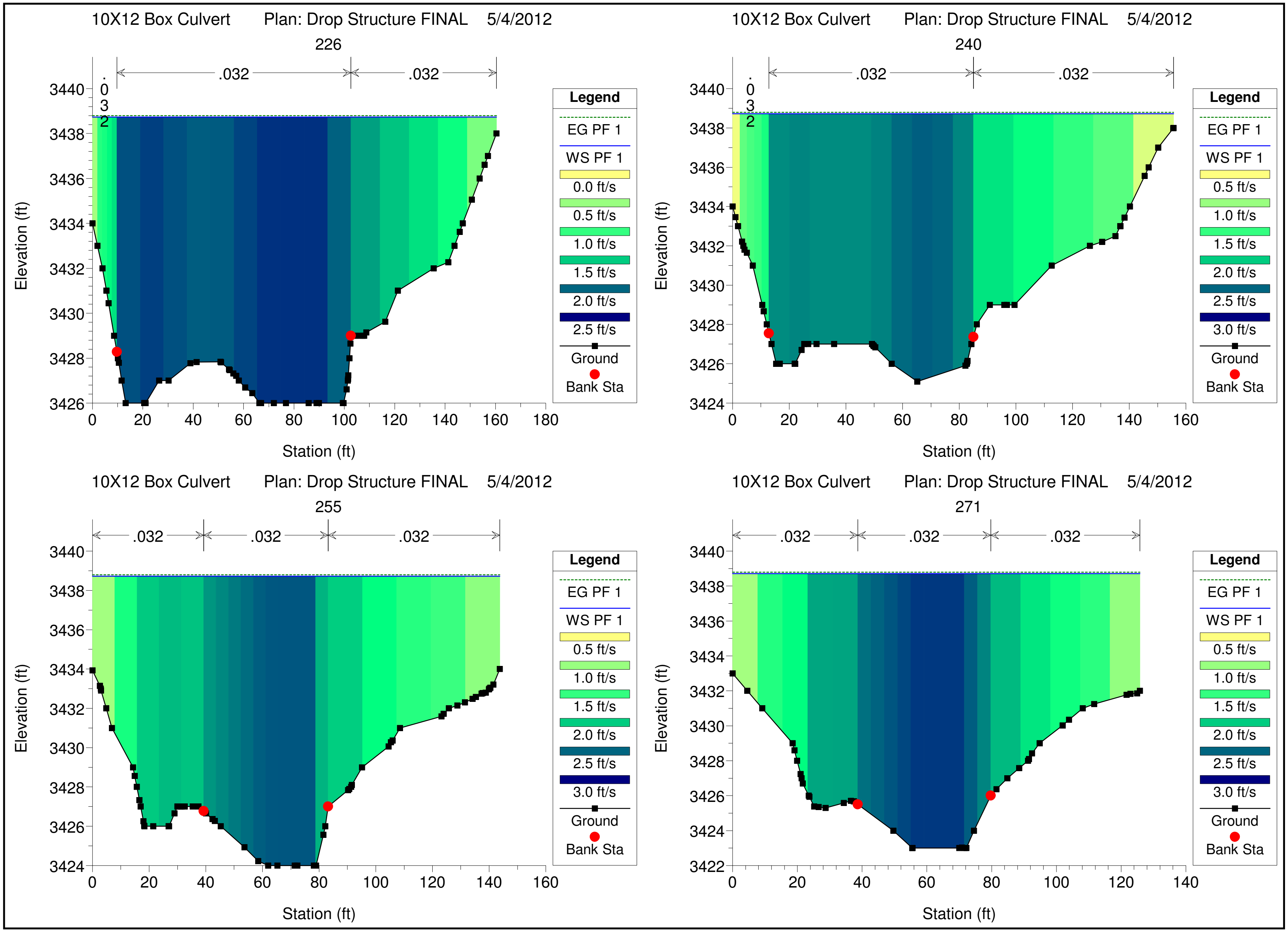


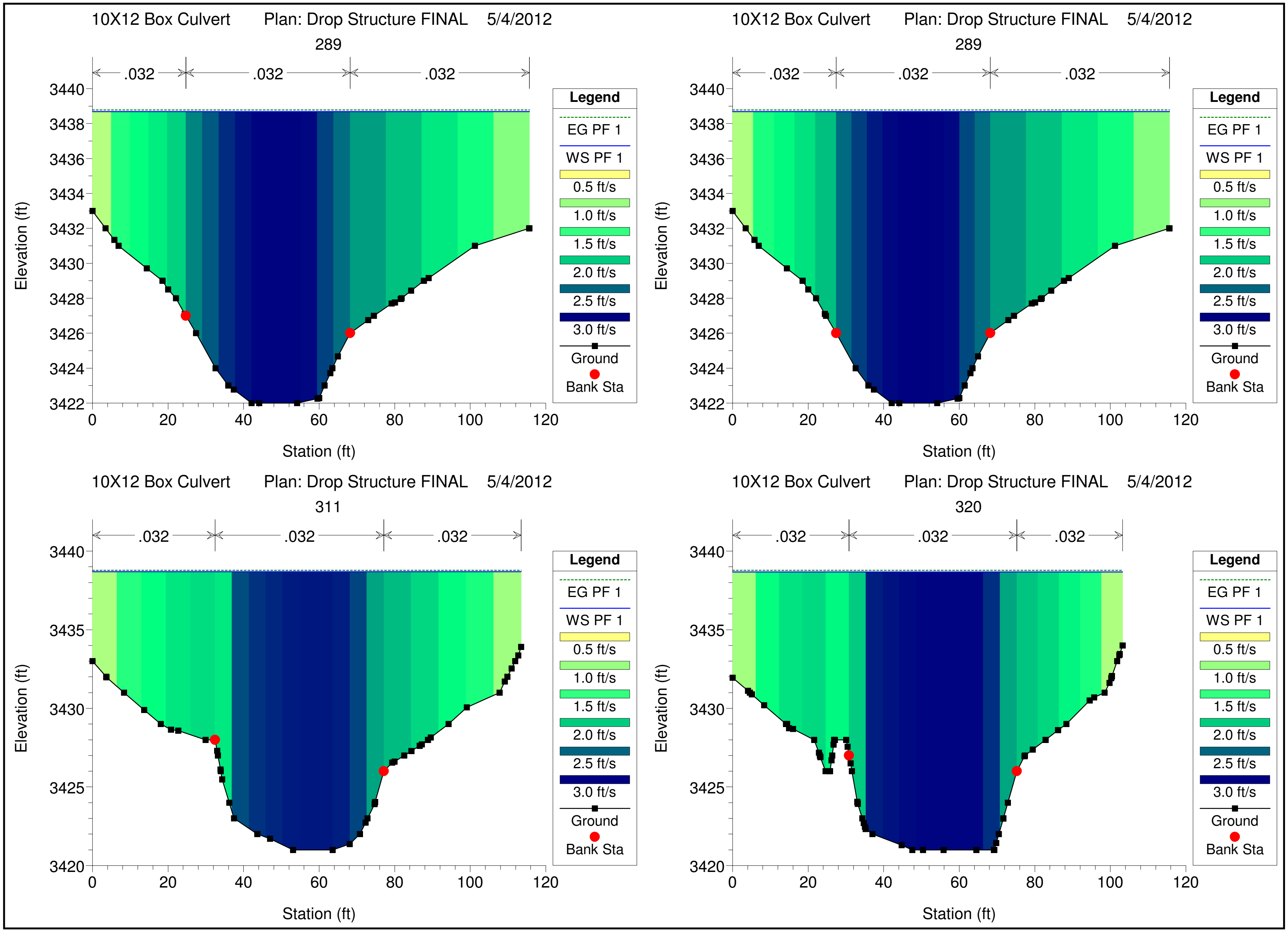


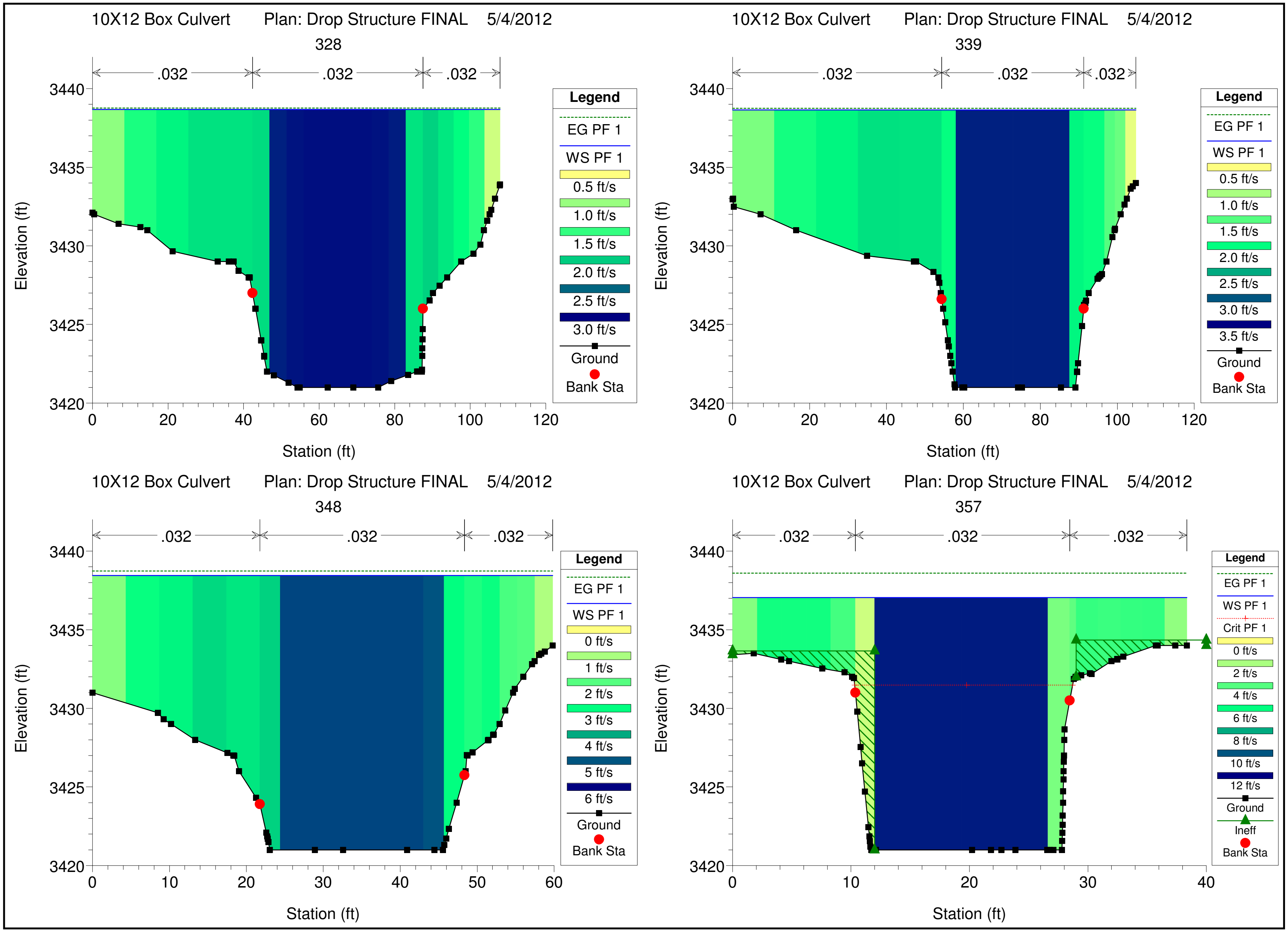


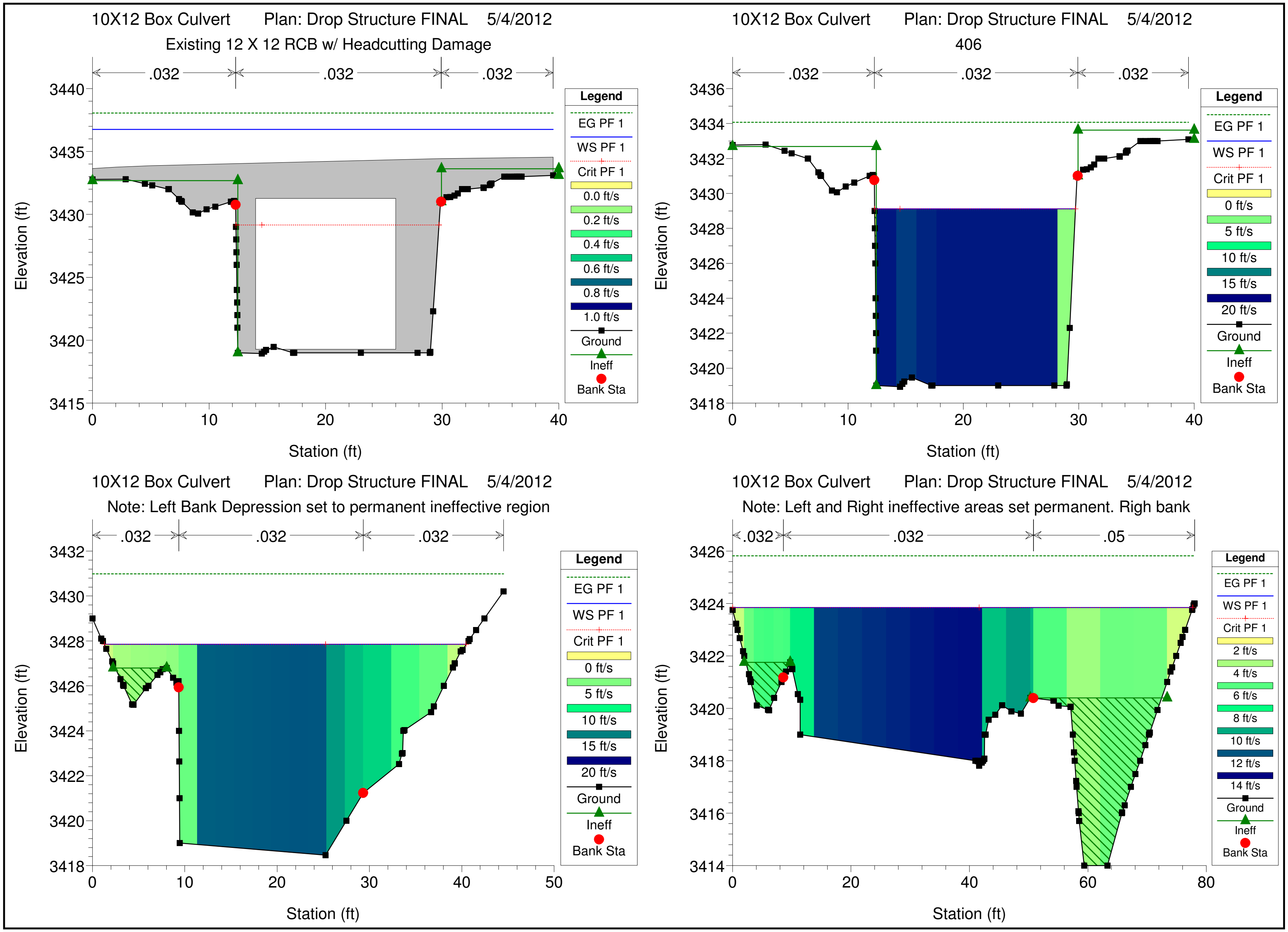


10X12 Box Culvert
Plan: Drop Structure FINAL
5/4/2012
159
.032
.032
.032
Elevation (ft)
Station (ft)
Legend
EG PF 1
WS PF 1
1.0 ft/s
1.5 ft/s
2.0 ft/s
2.5 ft/s
3.0 ft/s
3.5 ft/s
Ground
Bank Sta
10X12 Box Culvert
Plan: Drop Structure FINAL
5/4/2012
179
.032
.032
.032
Elevation (ft)
Station (ft)
Legend
EG PF 1
WS PF 1
1.0 ft/s
1.5 ft/s
2.0 ft/s
2.5 ft/s
3.0 ft/s
3.5 ft/s
Ground
Bank Sta
10X12 Box Culvert
Plan: Drop Structure FINAL
5/4/2012
200
.032
.032
.032
Elevation (ft)
Station (ft)
Legend
EG PF 1
WS PF 1
0.5 ft/s
1.0 ft/s
1.5 ft/s
2.0 ft/s
2.5 ft/s
3.0 ft/s
3.5 ft/s
Ground
Bank Sta
10X12 Box Culvert
Plan: Drop Structure FINAL
5/4/2012
218
.032
.032
.032
Elevation (ft)
Station (ft)
Legend
EG PF 1
WS PF 1
0.5 ft/s
1.0 ft/s
1.5 ft/s
2.0 ft/s
2.5 ft/s
3.0 ft/s
Ground
Bank Sta

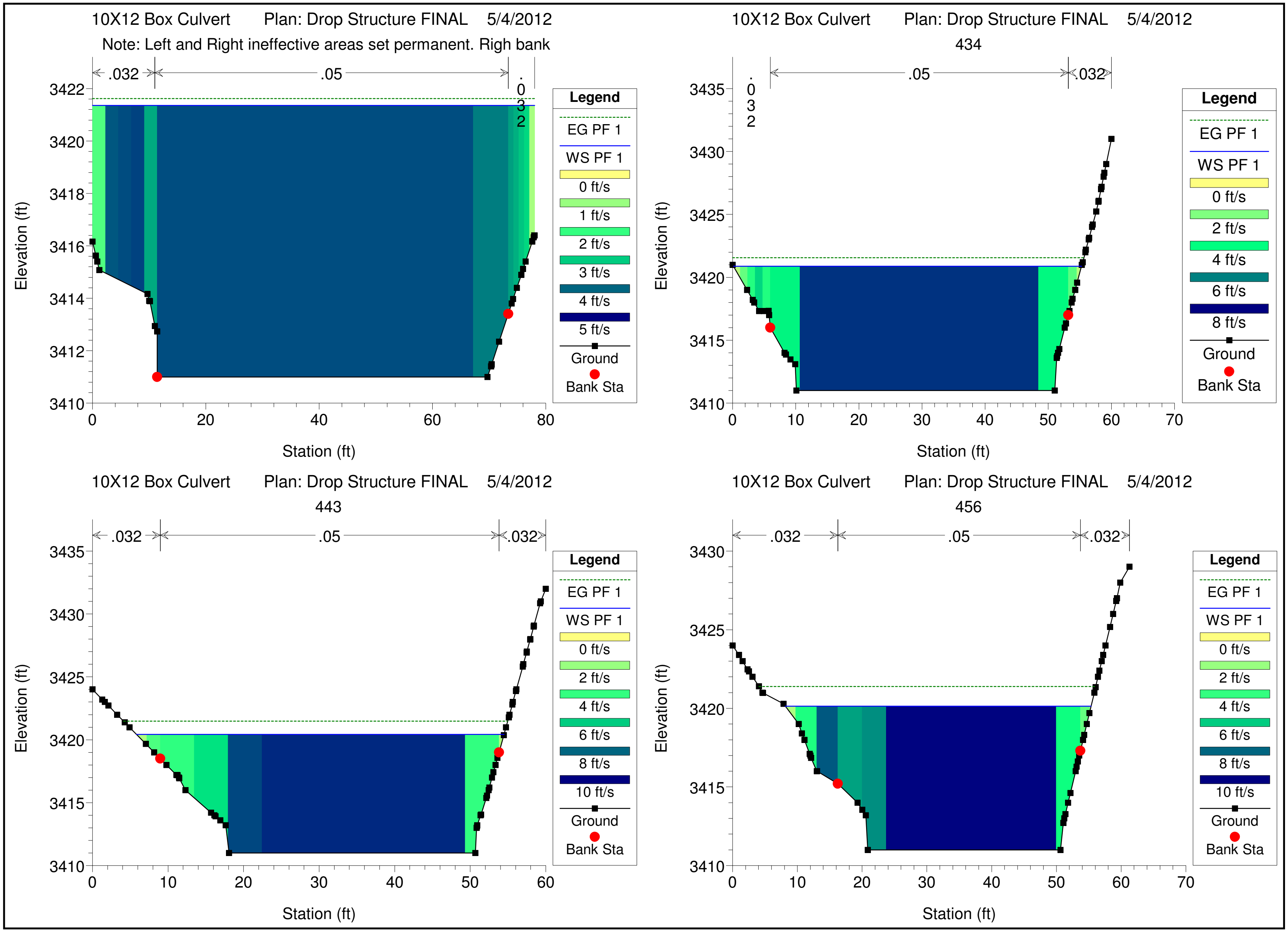

10X12 Box Culvert Plan: Drop Structure FINAL 5/4/2012
226
.032
.032
Elevation (ft)
Station (ft)
Legend
EG PF 1
WS PF 1
0.0 ft/s
0.5 ft/s
1.0 ft/s
1.5 ft/s
2.0 ft/s
2.5 ft/s
Ground
Bank Sta
10X12 Box Culvert Plan: Drop Structure FINAL 5/4/2012
240
.032
.032
Elevation (ft)
Station (ft)
Legend
EG PF 1
WS PF 1
0.5 ft/s
1.0 ft/s
1.5 ft/s
2.0 ft/s
2.5 ft/s
3.0 ft/s
Ground
Bank Sta
10X12 Box Culvert Plan: Drop Structure FINAL 5/4/2012
255
.032
.032
.032
Elevation (ft)
Station (ft)
Legend
EG PF 1
WS PF 1
0.5 ft/s
1.0 ft/s
1.5 ft/s
2.0 ft/s
2.5 ft/s
3.0 ft/s
Ground
Bank Sta
10X12 Box Culvert Plan: Drop Structure FINAL 5/4/2012
271
.032
.032
.032
Elevation (ft)
Station (ft)
Legend
EG PF 1
WS PF 1
0.5 ft/s
1.0 ft/s
1.5 ft/s
2.0 ft/s
2.5 ft/s
3.0 ft/s
Ground
Bank Sta

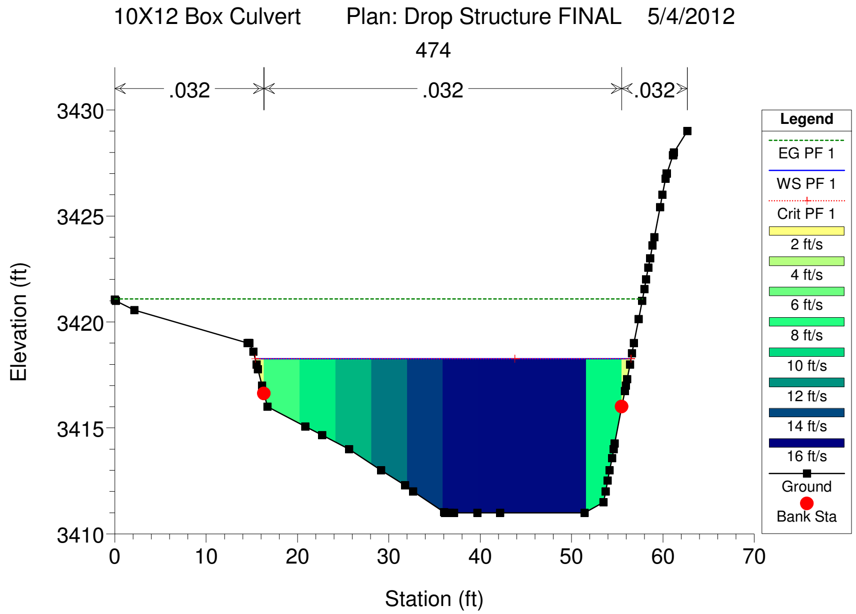

10X12 Box Culvert Plan: Drop Structure FINAL 5/4/2012
289
.032
.032
.032
Elevation (ft)
Station (ft)
Legend
EG PF 1
WS PF 1
0.5 ft/s
1.0 ft/s
1.5 ft/s
2.0 ft/s
2.5 ft/s
3.0 ft/s
Ground
Bank Sta
10X12 Box Culvert Plan: Drop Structure FINAL 5/4/2012
289
.032
.032
.032
Elevation (ft)
Station (ft)
Legend
EG PF 1
WS PF 1
0.5 ft/s
1.0 ft/s
1.5 ft/s
2.0 ft/s
2.5 ft/s
3.0 ft/s
Ground
Bank Sta
10X12 Box Culvert Plan: Drop Structure FINAL 5/4/2012
311
.032
.032
.032
Elevation (ft)
Station (ft)
Legend
EG PF 1
WS PF 1
0.5 ft/s
1.0 ft/s
1.5 ft/s
2.0 ft/s
2.5 ft/s
3.0 ft/s
Ground
Bank Sta
10X12 Box Culvert Plan: Drop Structure FINAL 5/4/2012
320
.032
.032
.032
Elevation (ft)
Station (ft)
Legend
EG PF 1
WS PF 1
0.5 ft/s
1.0 ft/s
1.5 ft/s
2.0 ft/s
2.5 ft/s
3.0 ft/s
Ground
Bank Sta


10X12 Box Culvert Plan: Drop Structure FINAL 5/4/2012
328
.032 .032 .032
Legend
EG PF 1
WS PF 1
0.5 ft/s
1.0 ft/s
1.5 ft/s
2.0 ft/s
2.5 ft/s
3.0 ft/s
Ground
Bank Sta
Elevation (ft)
Station (ft)
10X12 Box Culvert Plan: Drop Structure FINAL 5/4/2012
339
.032 .032 .032
Legend
EG PF 1
WS PF 1
0.5 ft/s
1.0 ft/s
1.5 ft/s
2.0 ft/s
2.5 ft/s
3.0 ft/s
3.5 ft/s
Ground
Bank Sta
Elevation (ft)
Station (ft)
10X12 Box Culvert Plan: Drop Structure FINAL 5/4/2012
348
.032 .032 .032
Legend
EG PF 1
WS PF 1
0 ft/s
1 ft/s
2 ft/s
3 ft/s
4 ft/s
5 ft/s
6 ft/s
Ground
Bank Sta
Elevation (ft)
Station (ft)
10X12 Box Culvert Plan: Drop Structure FINAL 5/4/2012
357
.032 .032 .032
Legend
EG PF 1
WS PF 1
Crit PF 1
0 ft/s
2 ft/s
4 ft/s
6 ft/s
8 ft/s
10 ft/s
12 ft/s
Ground
Ineff
Bank Sta
Elevation (ft)
Station (ft)

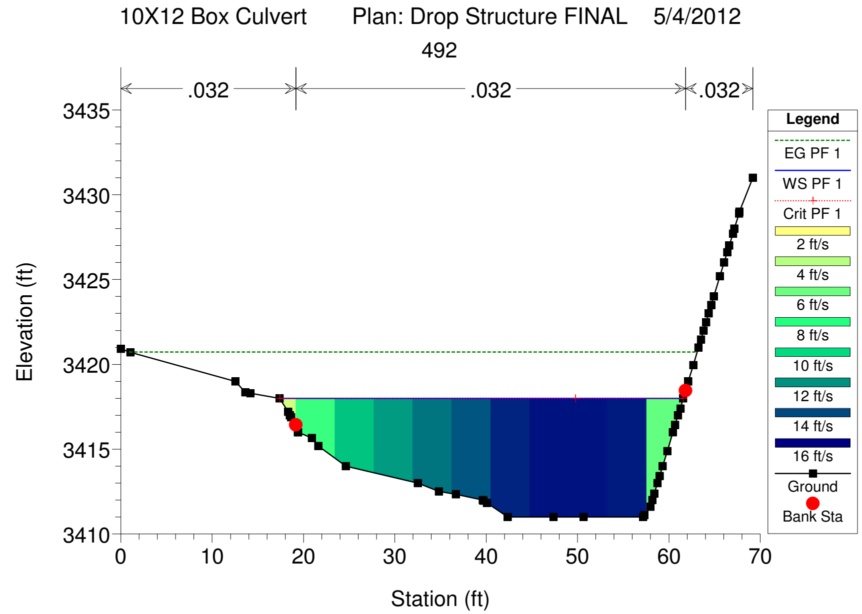


10X12 Box Culvert Plan: Drop Structure FINAL 5/4/2012
Existing 12 X 12 RCB w/ Headcutting Damage
.032 .032 .032
Legend
EG PF 1
WS PF 1
Crit PF 1
0.0 ft/s
0.2 ft/s
0.4 ft/s
0.6 ft/s
0.8 ft/s
1.0 ft/s
Ground
Ineff
Bank Sta
Elevation (ft)
Station (ft)
10X12 Box Culvert Plan: Drop Structure FINAL 5/4/2012
406
.032 .032 .032
Legend
EG PF 1
WS PF 1
Crit PF 1
0 ft/s
5 ft/s
10 ft/s
15 ft/s
20 ft/s
Ground
Ineff
Bank Sta
Elevation (ft)
Station (ft)
10X12 Box Culvert Plan: Drop Structure FINAL 5/4/2012
Note: Left Bank Depression set to permanent ineffective region
.032 .032 .032
Legend
EG PF 1
WS PF 1
Crit PF 1
0 ft/s
5 ft/s
10 ft/s
15 ft/s
20 ft/s
Ground
Ineff
Bank Sta
Elevation (ft)
Station (ft)
10X12 Box Culvert Plan: Drop Structure FINAL 5/4/2012
Note: Left and Right ineffective areas set permanent. Righ bank
.032 .032 .05
Legend
EG PF 1
WS PF 1
Crit PF 1
2 ft/s
4 ft/s
6 ft/s
8 ft/s
10 ft/s
12 ft/s
14 ft/s
Ground
Ineff
Bank Sta
Elevation (ft)
Station (ft)


10X12 Box Culvert Plan: Drop Structure FINAL 5/4/2012
Note: Left and Right ineffective areas set permanent. Righ bank
.032
.05
.032
Elevation (ft)
Station (ft)
Legend
EG PF 1
WS PF 1
0 ft/s
1 ft/s
2 ft/s
3 ft/s
4 ft/s
5 ft/s
Ground
Bank Sta
10X12 Box Culvert Plan: Drop Structure FINAL 5/4/2012
434
.032
.05
.032
Elevation (ft)
Station (ft)
Legend
EG PF 1
WS PF 1
0 ft/s
2 ft/s
4 ft/s
6 ft/s
8 ft/s
Ground
Bank Sta
10X12 Box Culvert Plan: Drop Structure FINAL 5/4/2012
443
.032
.05
.032
Elevation (ft)
Station (ft)
Legend
EG PF 1
WS PF 1
0 ft/s
2 ft/s
4 ft/s
6 ft/s
8 ft/s
10 ft/s
Ground
Bank Sta
10X12 Box Culvert Plan: Drop Structure FINAL 5/4/2012
456
.032
.05
.032
Elevation (ft)
Station (ft)
Legend
EG PF 1
WS PF 1
0 ft/s
2 ft/s
4 ft/s
6 ft/s
8 ft/s
10 ft/s
Ground
Bank Sta

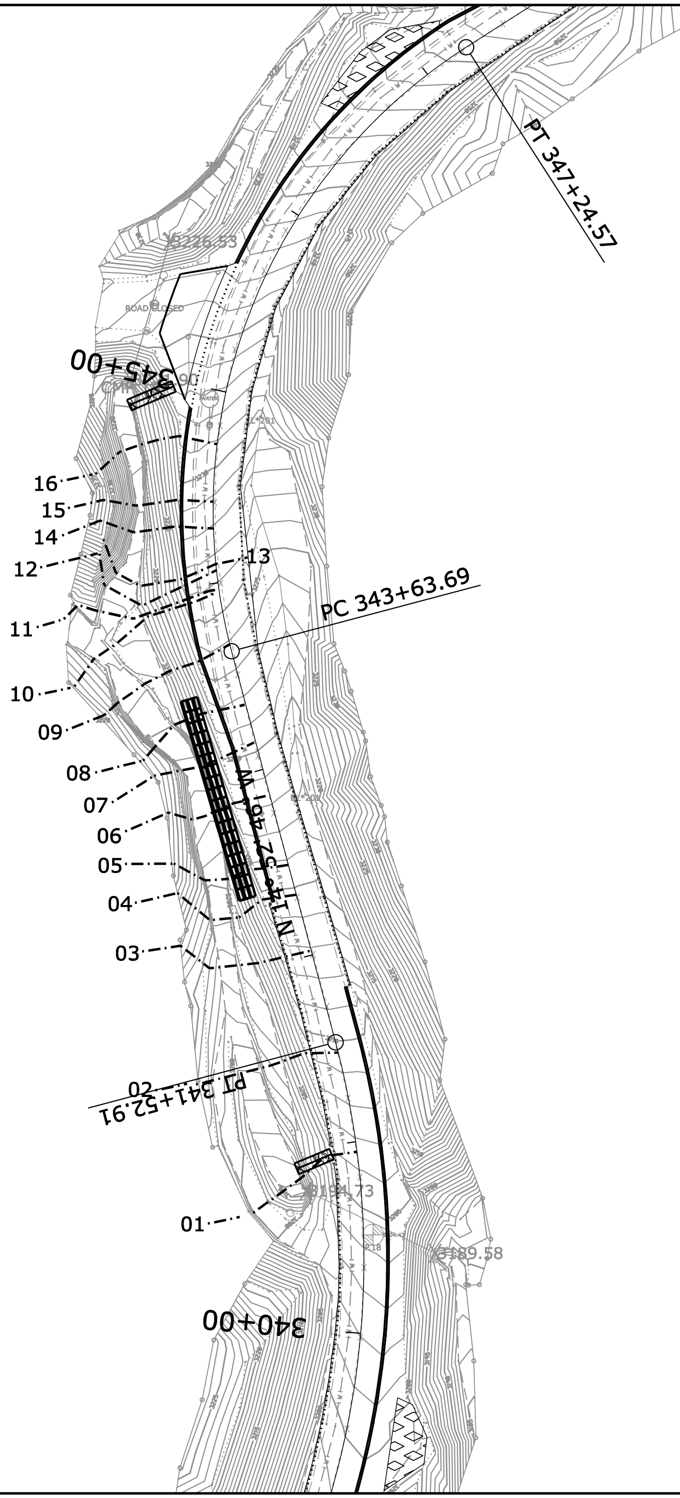


10X12 Box Culvert Plan: Drop Structure FINAL 5/4/2012
474
.032
.032
.032
Legend
EG PF 1
WS PF 1
Crit PF 1
2 ft/s
4 ft/s
6 ft/s
8 ft/s
10 ft/s
12 ft/s
14 ft/s
16 ft/s
Ground
Bank Sta
Elevation (ft)
3410
3415
3420
3425
3430
Station (ft)
0
10
20
30
40
50
60
70



10X12 Box Culvert Plan: Drop Structure FINAL 5/4/2012
492
.032
.032
.032
Legend
EG PF 1
WS PF 1
Crit PF 1
2 ft/s
4 ft/s
6 ft/s
8 ft/s
10 ft/s
12 ft/s
14 ft/s
16 ft/s
Ground
Bank Sta
Elevation (ft)
3410
3415
3420
3425
3430
3435
Station (ft)
0
10
20
30
40
50
60
70

Channel Hydraulic HEC-RAS Analysis – Sta 340+00 to Sta 345+00
(Embankment Erosion Existing Model)

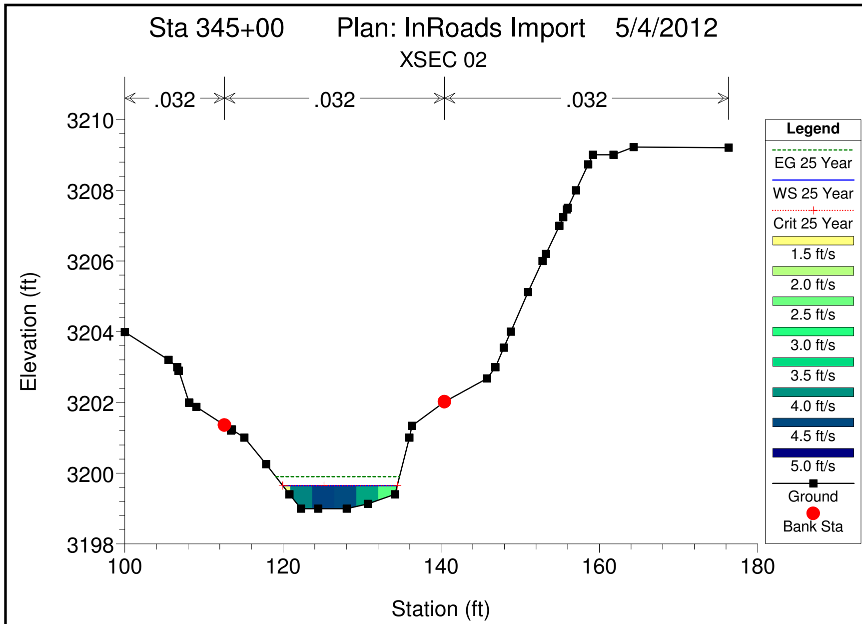


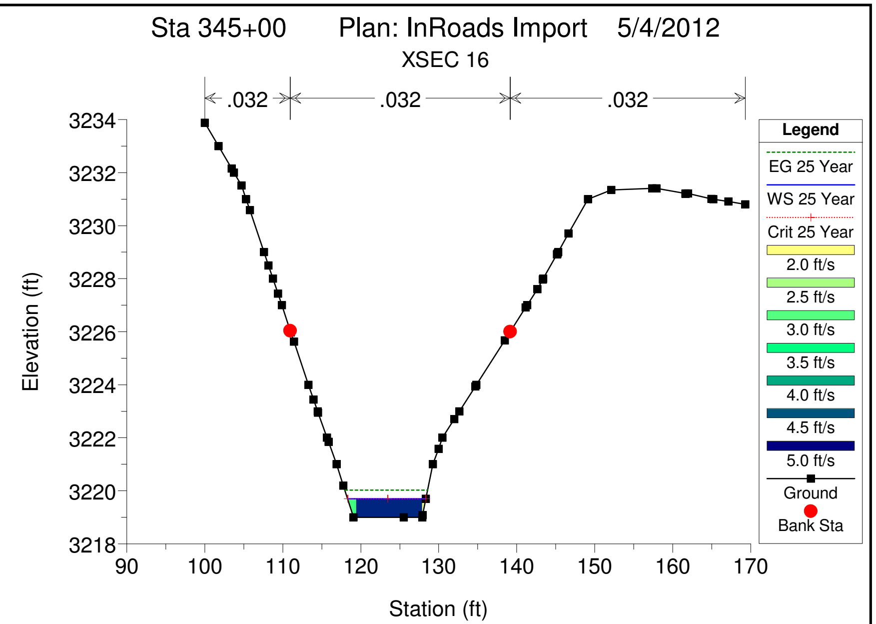
XSEC ID	STATION
16	STA 344+72
15	STA 344+42
14	STA 344+29
13	STA 344+10
12	STA 344+07
11	STA 343+97
10	STA 343+95
9	STA 343+68
8	STA 343+35
7	STA 343+15
6	STA 342+86
5	STA 342+49
4	STA 342+33
3	STA 342+02
2	STA 341+48
1	STA 340+95

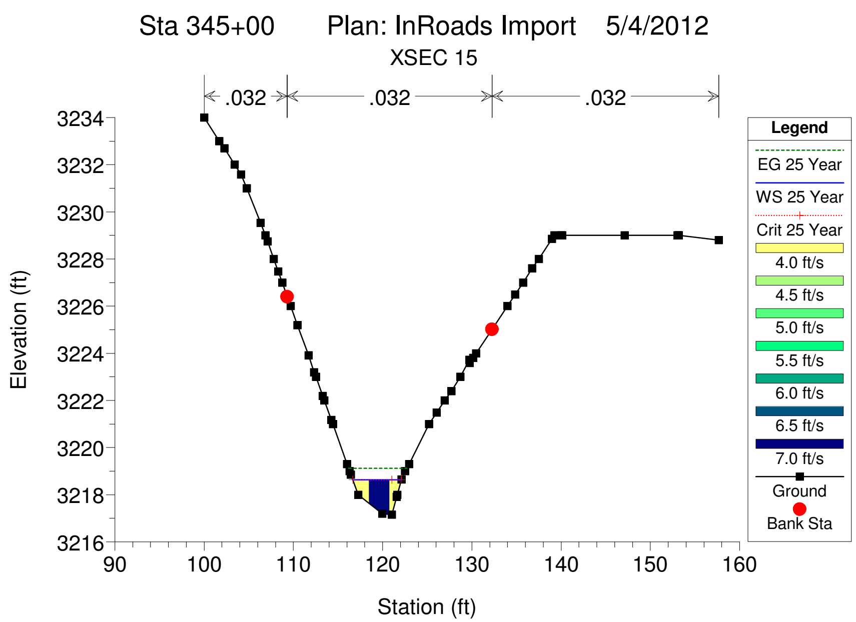
Hec-Ras Cross Sections
Sta 340+00 - Gabion Wall

HEC-RAS Plan: InRoads Import   River: RIVER-1   Reach: Reach-1   Profile: 25 Year

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Reach-1	16	25 Year	30.00	3219.00	3219.70	3219.70	3220.02	0.018652	4.58	6.55	10.02	1.00
Reach-1	15	25 Year	30.00	3217.15	3218.63	3218.63	3219.13	0.019853	5.67	5.29	5.42	1.01
Reach-1	14	25 Year	30.00	3216.50	3217.63	3217.63	3218.03	0.018734	5.07	5.92	7.52	1.01
Reach-1	13	25 Year	30.00	3216.00	3216.50	3216.50	3216.74	0.019613	3.91	7.67	16.13	1.00
Reach-1	12	25 Year	30.00	3214.88	3215.76	3215.76	3215.99	0.020348	3.82	7.85	17.80	1.01
Reach-1	11	25 Year	30.00	3214.00	3214.47	3214.47	3214.69	0.019889	3.69	8.12	19.04	1.00
Reach-1	10	25 Year	30.00	3212.56	3213.36	3213.36	3213.64	0.018546	4.24	7.08	12.66	1.00
Reach-1	9	25 Year	30.00	3211.40	3212.08	3212.08	3212.31	0.020202	3.83	7.84	17.52	1.01
Reach-1	8	25 Year	30.00	3211.00	3211.50	3211.50	3211.74	0.019952	3.96	7.57	15.58	1.00
Reach-1	7	25 Year	30.00	3209.00	3209.67	3209.67	3210.00	0.019107	4.58	6.56	10.06	1.00
Reach-1	6	25 Year	30.00	3207.20	3208.05	3208.05	3208.35	0.019660	4.40	6.82	11.74	1.02
Reach-1	5	25 Year	30.00	3206.00	3206.59	3206.59	3206.88	0.019472	4.30	6.97	12.19	1.00
Reach-1	4	25 Year	30.00	3204.43	3205.59	3205.59	3205.89	0.018778	4.42	6.79	11.45	1.01
Reach-1	3	25 Year	30.00	3202.60	3203.31	3203.31	3203.60	0.018968	4.27	7.02	12.65	1.01
Reach-1	2	25 Year	30.00	3199.00	3199.65	3199.65	3199.90	0.019210	4.07	7.37	14.48	1.00
Reach-1	1	25 Year	30.00	3196.00	3196.51	3196.51	3196.76	0.019928	3.98	7.55	15.66	1.01


Sta 345+00 Plan: InRoads Import 5/4/2012
XSEC 02
.032
.032
.032
Elevation (ft)
Station (ft)
Legend
EG 25 Year
WS 25 Year
Crit 25 Year
1.5 ft/s
2.0 ft/s
2.5 ft/s
3.0 ft/s
3.5 ft/s
4.0 ft/s
4.5 ft/s
5.0 ft/s
Ground
Bank Sta


Sta 345+00 Plan: InRoads Import 5/4/2012
XSEC 16
.032
.032
.032
Elevation (ft)
Station (ft)
Legend
EG 25 Year
WS 25 Year
Crit 25 Year
2.0 ft/s
2.5 ft/s
3.0 ft/s
3.5 ft/s
4.0 ft/s
4.5 ft/s
5.0 ft/s
Ground
Bank Sta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Elevation (ft)
Station (ft)
Legend
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WS 25 Year
Crit 25 Year
4.0 ft/s
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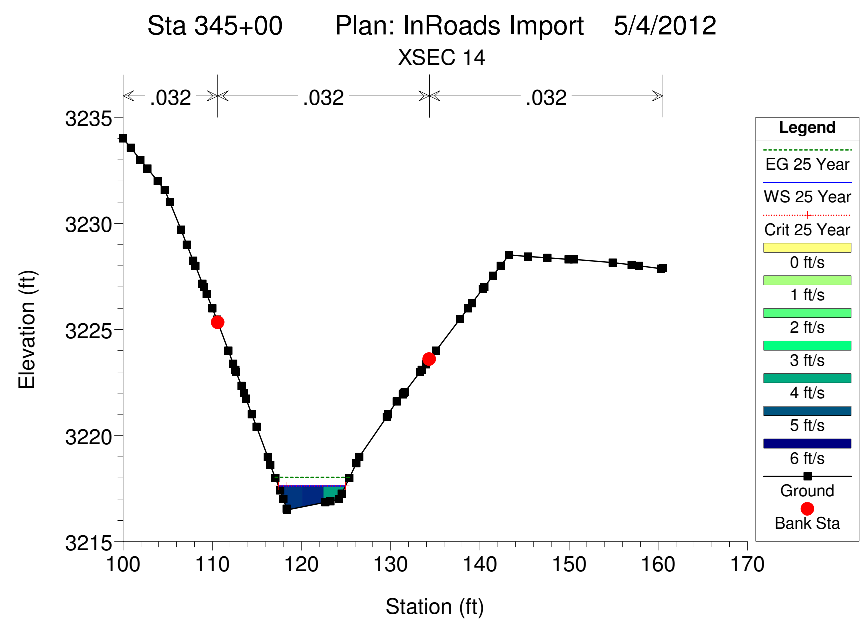
5.0 ft/s
5.5 ft/s
6.0 ft/s
6.5 ft/s
7.0 ft/s
Ground
Bank Sta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Station (ft)
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WS 25 Year
Crit 25 Year
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2 ft/s
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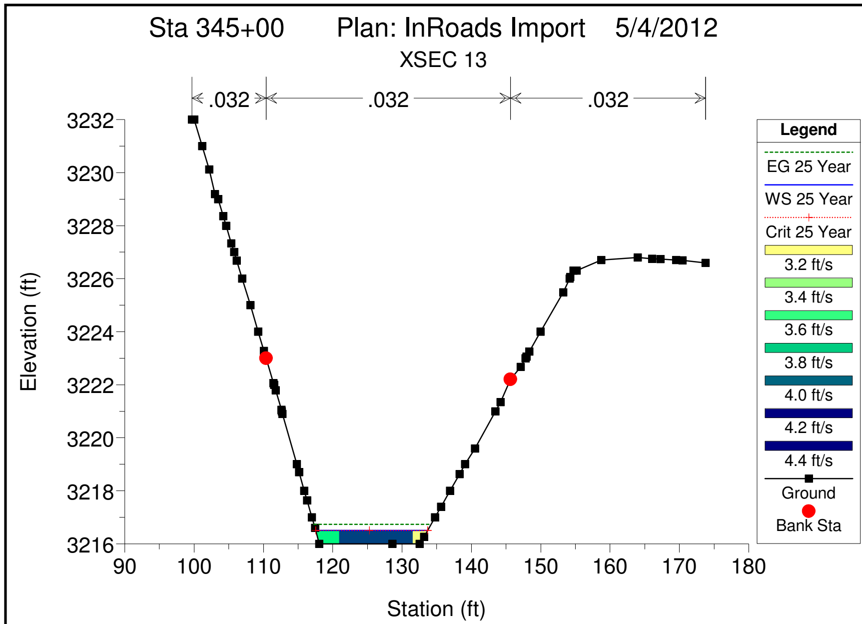
4 ft/s
5 ft/s
6 ft/s
Ground
Bank Sta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WS 25 Year
Crit 25 Year
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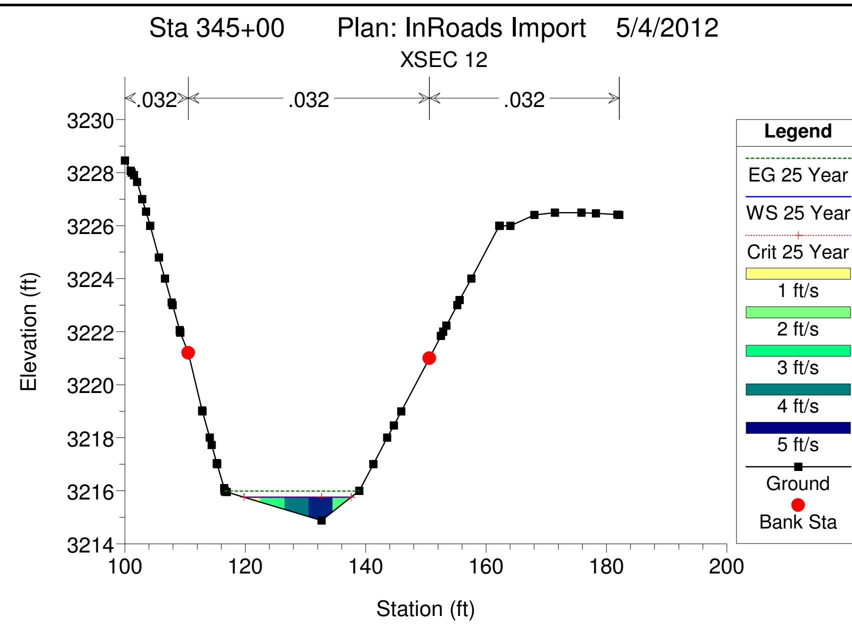
3.6 ft/s
3.8 ft/s
4.0 ft/s
4.2 ft/s
4.4 ft/s
Ground
Bank Sta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Crit 25 Year
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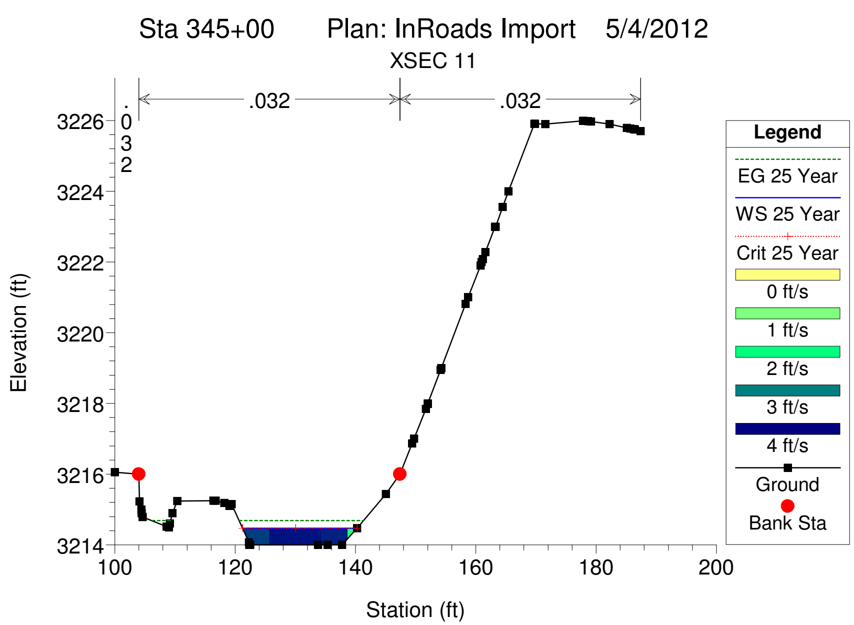
5 ft/s
Ground
Bank Sta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Crit 25 Year
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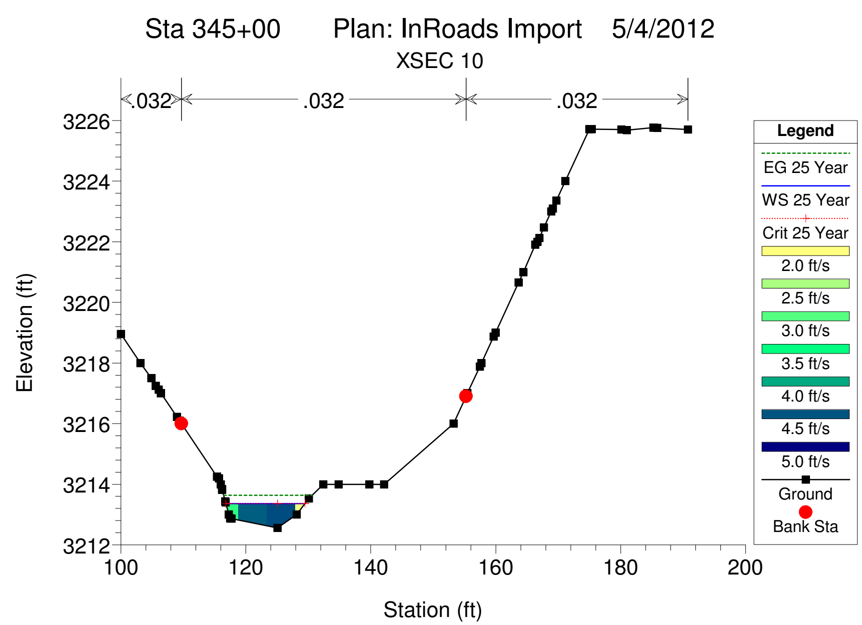
Ground
Bank Sta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Station (ft)
Legend
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Crit 25 Year
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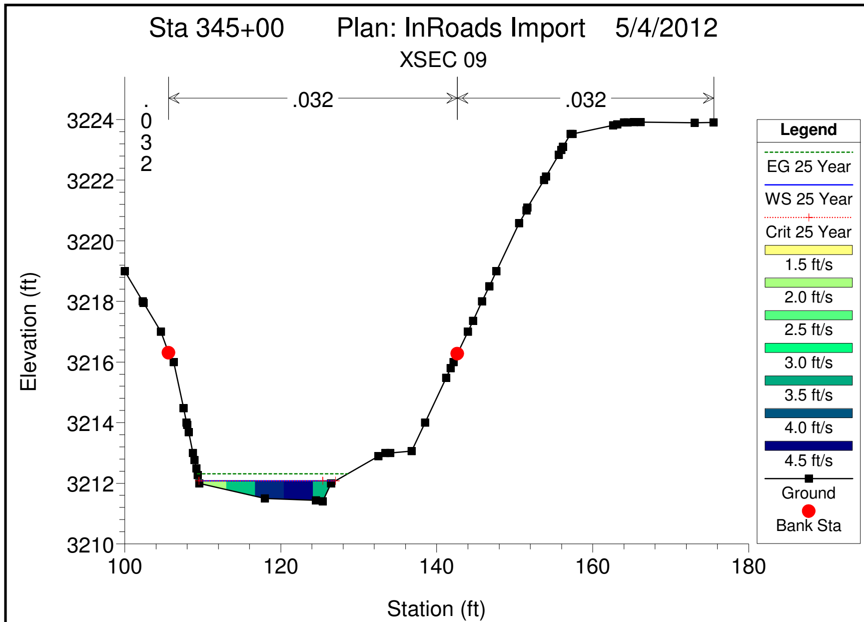
Ground
Bank Sta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Crit 25 Year
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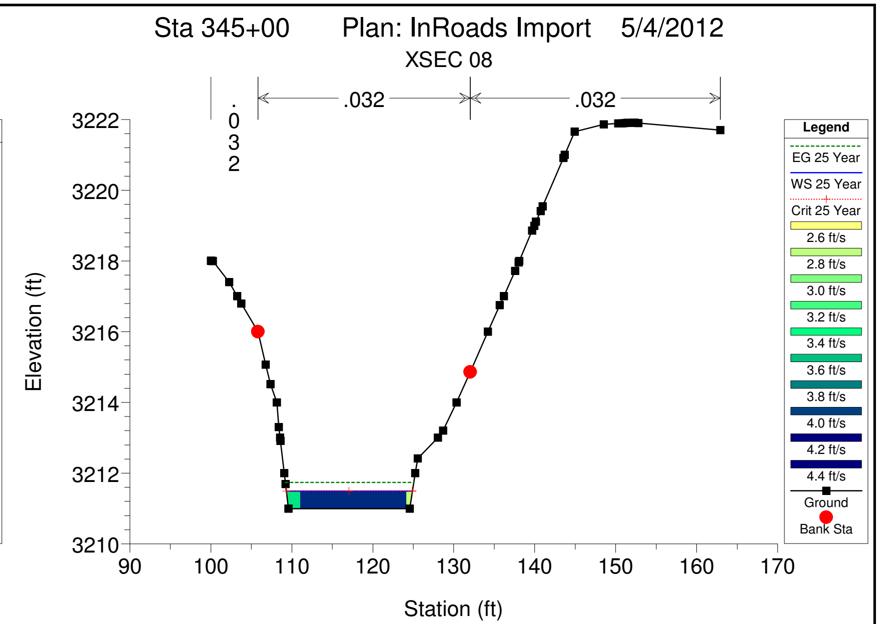
Ground
Bank Sta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3.0 ft/s
3.2 ft/s
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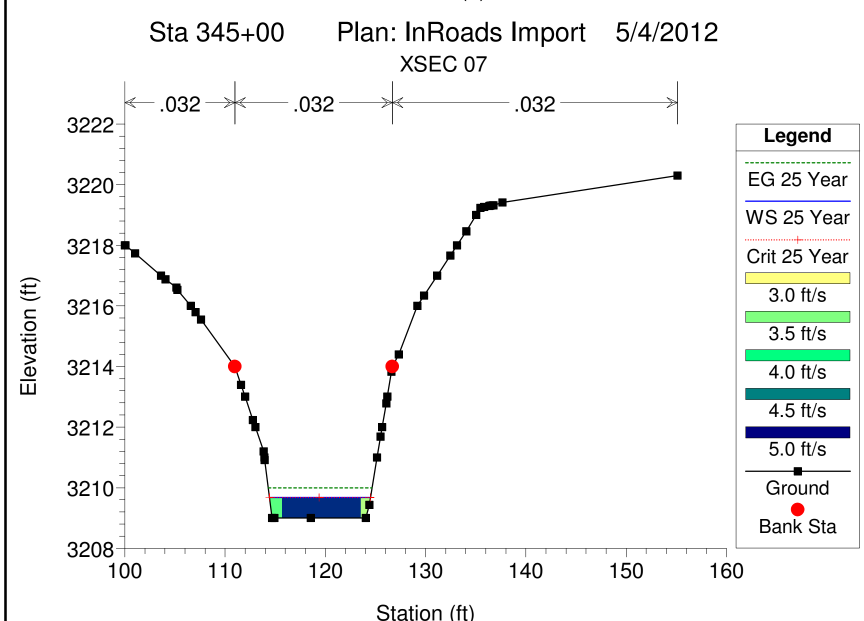
4.2 ft/s
4.4 ft/s
Ground
Bank Sta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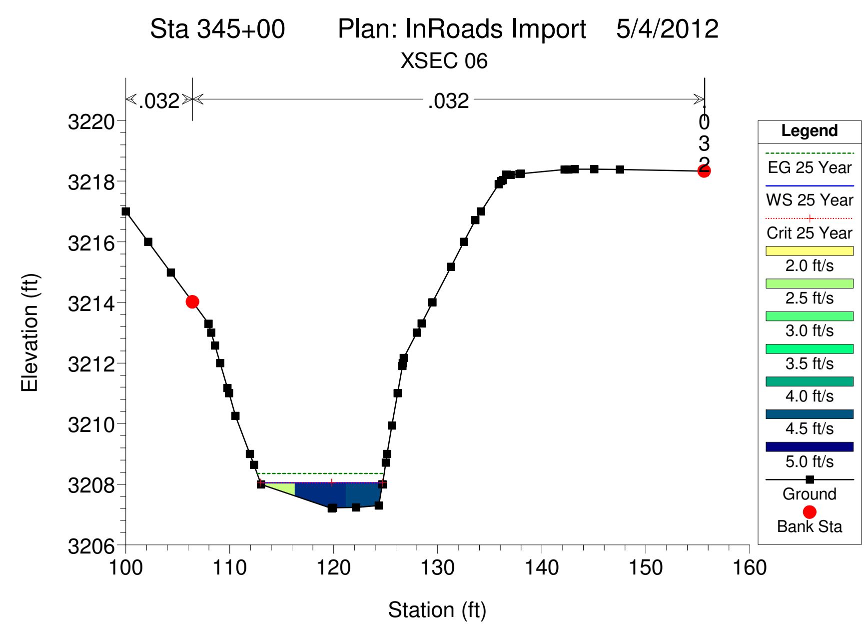
5.0 ft/s
Ground
Bank Sta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Station (ft)
Legend
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Crit 25 Year
2.0 ft/s
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3.5 ft/s
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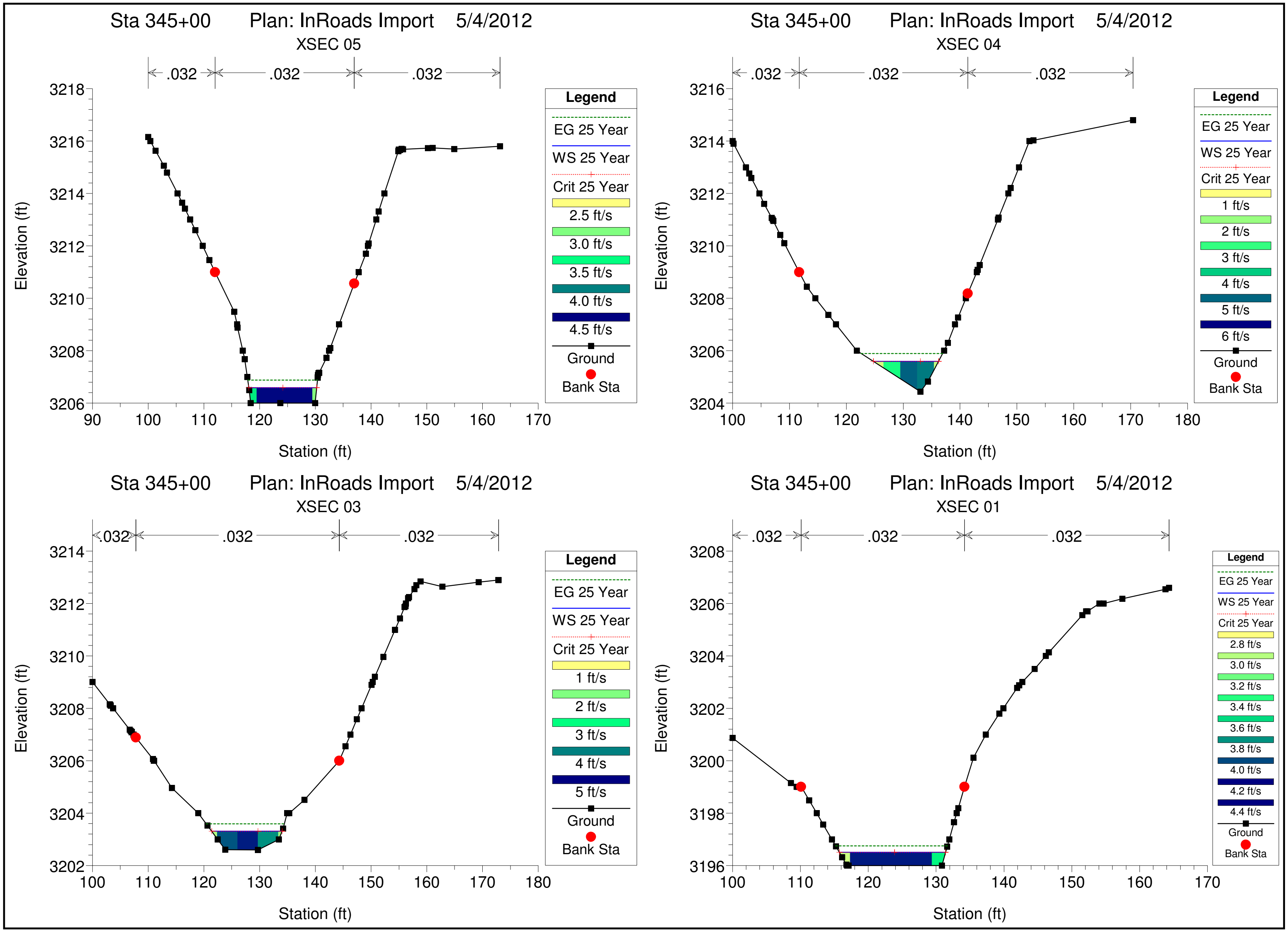
4.5 ft/s
5.0 ft/s
Ground
Bank Sta



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3212
3210
3208
3206
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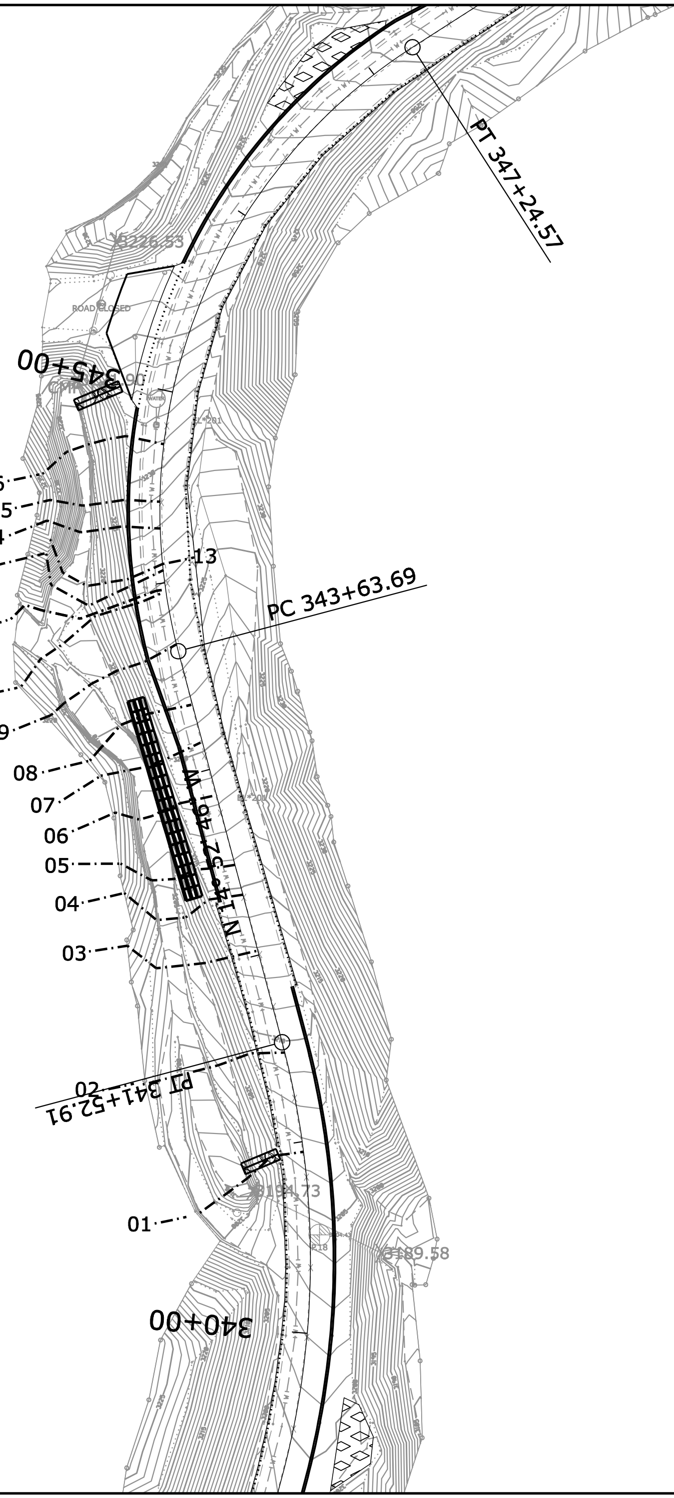
100
110
120
130
140
150
160
170
Legend
EG 25 Year
WS 25 Year
Crit 25 Year
2.5 ft/s
3.0 ft/s
3.5 ft/s
4.0 ft/s
4.5 ft/s
Ground
Bank Sta
Sta 345+00 Plan: InRoads Import 5/4/2012
XSEC 04
.032
.032
.032
Elevation (ft)
Station (ft)
3216
3214
3212
3210
3208
3206
3204
100
110
120
130
140
150
160
170
180
Legend
EG 25 Year
WS 25 Year
Crit 25 Year
1 ft/s
2 ft/s
3 ft/s
4 ft/s
5 ft/s
6 ft/s
Ground
Bank Sta
Sta 345+00 Plan: InRoads Import 5/4/2012
XSEC 03
.032
.032
.032
Elevation (ft)
Station (ft)
3214
3212
3210
3208
3206
3204
3202
100
110
120
130
140
150
160
170
180
Legend
EG 25 Year
WS 25 Year
Crit 25 Year
1 ft/s
2 ft/s
3 ft/s
4 ft/s
5 ft/s
Ground
Bank Sta
Sta 345+00 Plan: InRoads Import 5/4/2012
XSEC 01
.032
.032
.032
Elevation (ft)
Station (ft)
3208
3206
3204
3202
3200
3198
3196
100
110
120
130
140
150
160
170
Legend
EG 25 Year
WS 25 Year
Crit 25 Year
2.8 ft/s
3.0 ft/s
3.2 ft/s
3.4 ft/s
3.6 ft/s
3.8 ft/s
4.0 ft/s
4.2 ft/s
4.4 ft/s
Ground
Bank Sta

Channel Hydraulic HEC-RAS Analysis – Sta 340+00 to Sta 345+00 (Embankment Erosion Proposed Model)



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11	STA 343+97
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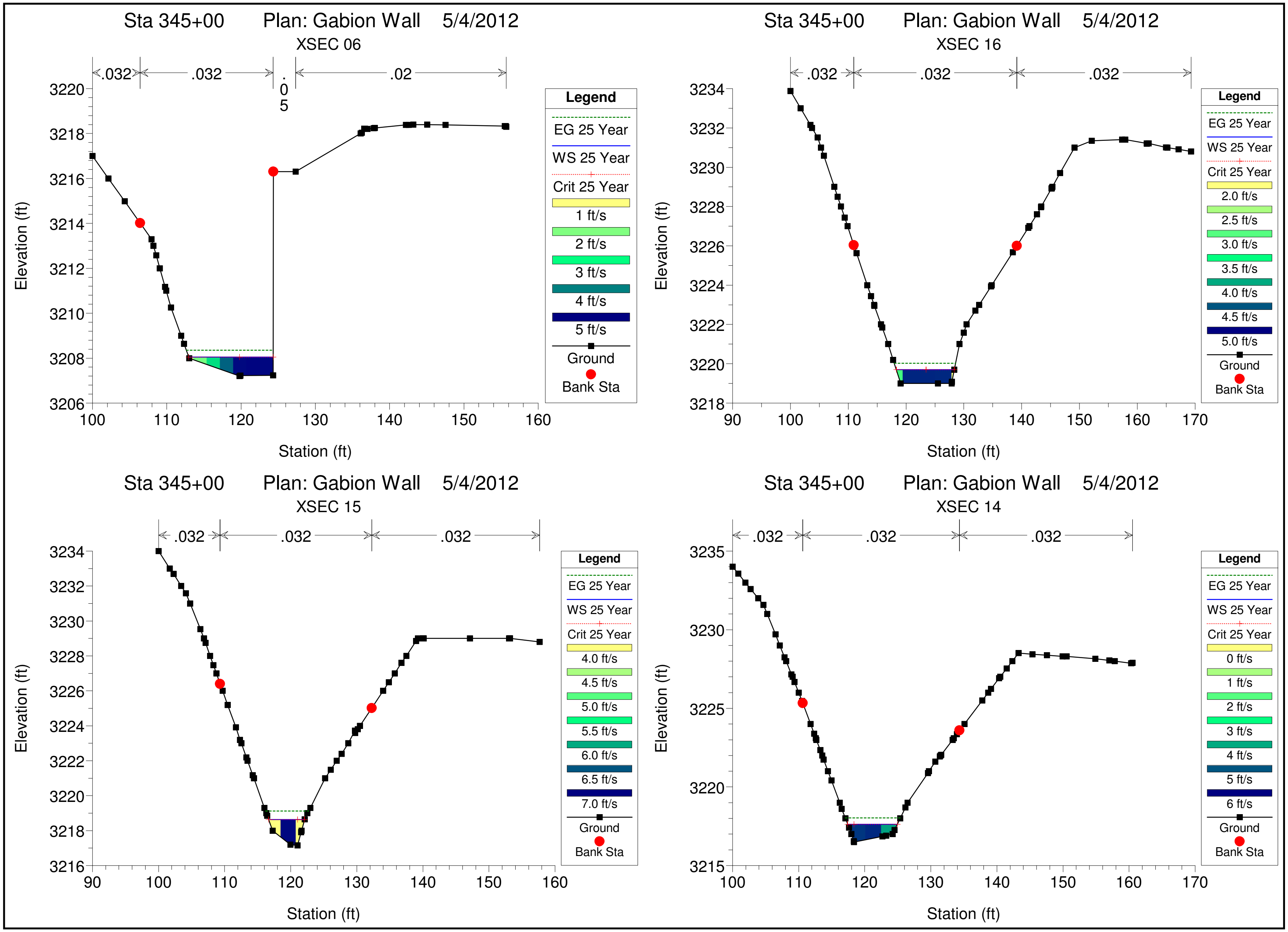
9	STA 343+68
8	STA 343+35
7	STA 343+15
6	STA 342+86
5	STA 342+49
4	STA 342+33
3	STA 342+02
2	STA 341+48
1	STA 340+95

Hec-Ras Cross Sections
Sta 340+00 - Gabion Wall

HEC-RAS Plan: Gabion River: RIVER-1 Reach: Reach-1 Profile: 25 Year

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Reach-1	16	25 Year	30.00	3219.00	3219.70	3219.70	3220.02	0.018652	4.58	6.55	10.02	1.00
Reach-1	15	25 Year	30.00	3217.15	3218.63	3218.63	3219.13	0.019853	5.67	5.29	5.42	1.01
Reach-1	14	25 Year	30.00	3216.50	3217.63	3217.63	3218.03	0.018734	5.07	5.92	7.52	1.01
Reach-1	13	25 Year	30.00	3216.00	3216.50	3216.50	3216.74	0.019613	3.91	7.67	16.13	1.00
Reach-1	12	25 Year	30.00	3214.88	3215.76	3215.76	3215.99	0.020348	3.82	7.85	17.80	1.01
Reach-1	11	25 Year	30.00	3214.00	3214.47	3214.47	3214.69	0.019889	3.69	8.12	19.04	1.00
Reach-1	10	25 Year	30.00	3212.56	3213.36	3213.36	3213.64	0.018546	4.24	7.08	12.66	1.00
Reach-1	9	25 Year	30.00	3211.40	3212.08	3212.08	3212.31	0.020202	3.83	7.84	17.52	1.01
Reach-1	8	25 Year	30.00	3211.00	3211.40	3211.40	3211.60	0.022047	3.61	8.32	20.95	1.01
Reach-1	7	25 Year	30.00	3209.00	3209.68	3209.68	3210.02	0.021534	4.66	6.44	9.61	1.00
Reach-1	6	25 Year	30.00	3207.20	3208.05	3208.05	3208.36	0.021802	4.43	6.77	11.37	1.01
Reach-1	5	25 Year	30.00	3206.00	3206.52	3206.52	3206.78	0.021456	4.10	7.33	14.39	1.01
Reach-1	4	25 Year	30.00	3204.43	3205.59	3205.59	3205.89	0.018778	4.42	6.79	11.45	1.01
Reach-1	3	25 Year	30.00	3202.60	3203.31	3203.31	3203.60	0.018968	4.27	7.02	12.65	1.01
Reach-1	2	25 Year	30.00	3199.00	3199.65	3199.65	3199.90	0.019210	4.07	7.37	14.48	1.00
Reach-1	1	25 Year	30.00	3196.00	3196.51	3196.51	3196.76	0.019928	3.98	7.55	15.66	1.01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Station (ft)
Legend
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WS 25 Year
Crit 25 Year
1 ft/s
2 ft/s
3 ft/s
4 ft/s
5 ft/s
Ground
Bank Sta
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Station (ft)
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EG 25 Year
WS 25 Year
Crit 25 Year
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4.0 ft/s
4.5 ft/s
5.0 ft/s
Ground
Bank Sta
Sta 345+00 Plan: Gabion Wall 5/4/2012
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Elevation (ft)
Station (ft)
Legend
EG 25 Year
WS 25 Year
Crit 25 Year
4.0 ft/s
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5.0 ft/s
5.5 ft/s
6.0 ft/s
6.5 ft/s
7.0 ft/s
Ground
Bank Sta
Sta 345+00 Plan: Gabion Wall 5/4/2012
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Elevation (ft)
Station (ft)
Legend
EG 25 Year
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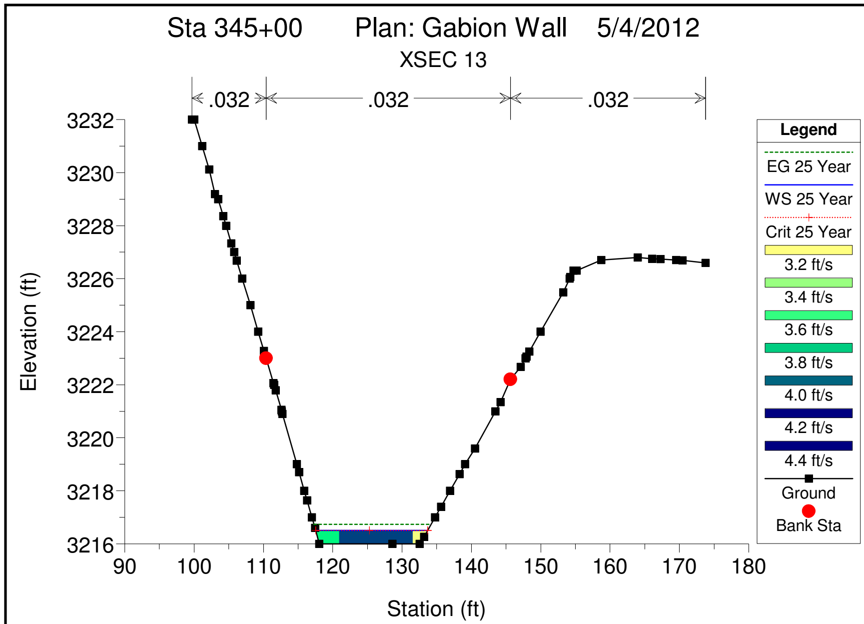
Ground
Bank Sta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Crit 25 Year
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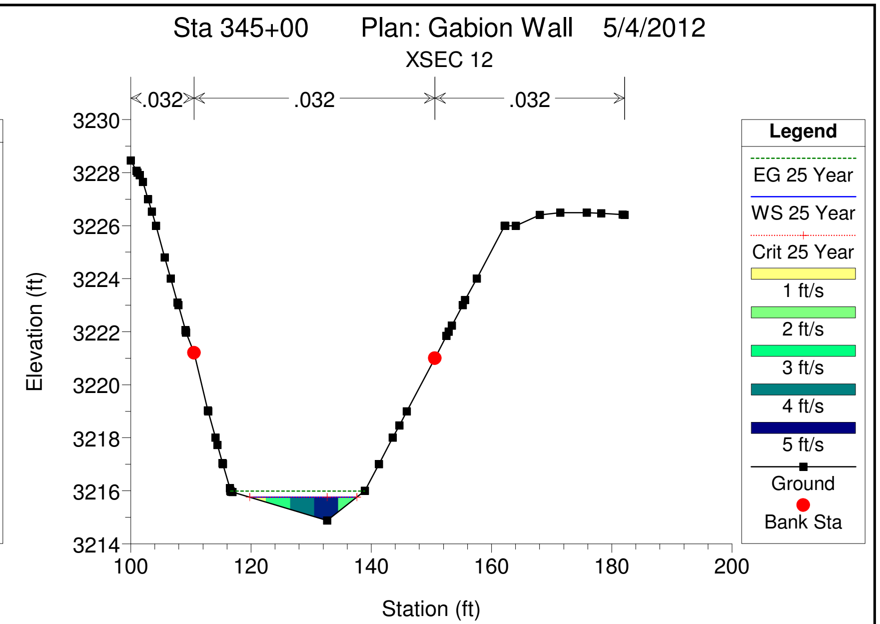
4.4 ft/s
Ground
Bank Sta
Elevation (ft)
Station (ft)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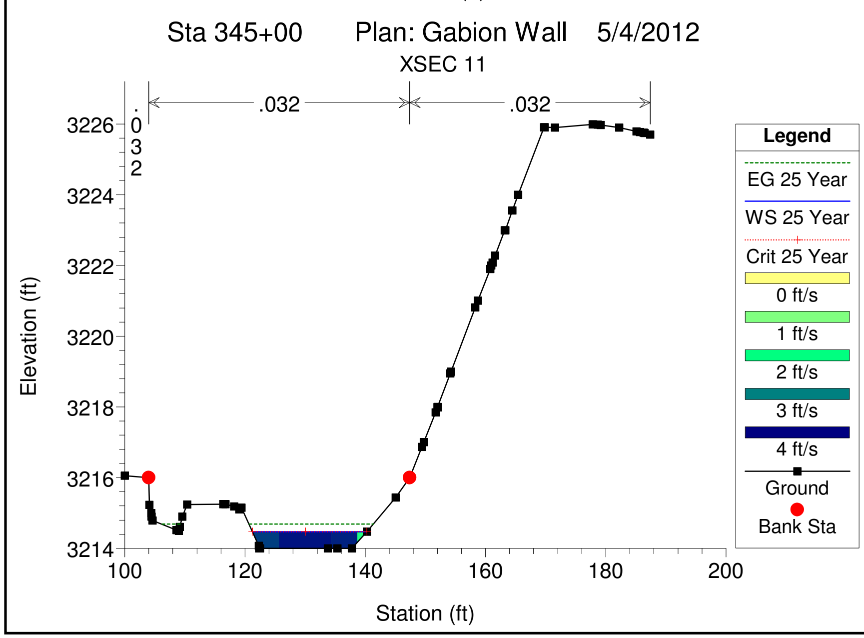
Ground
Bank Sta
Elevation (ft)
Station (ft)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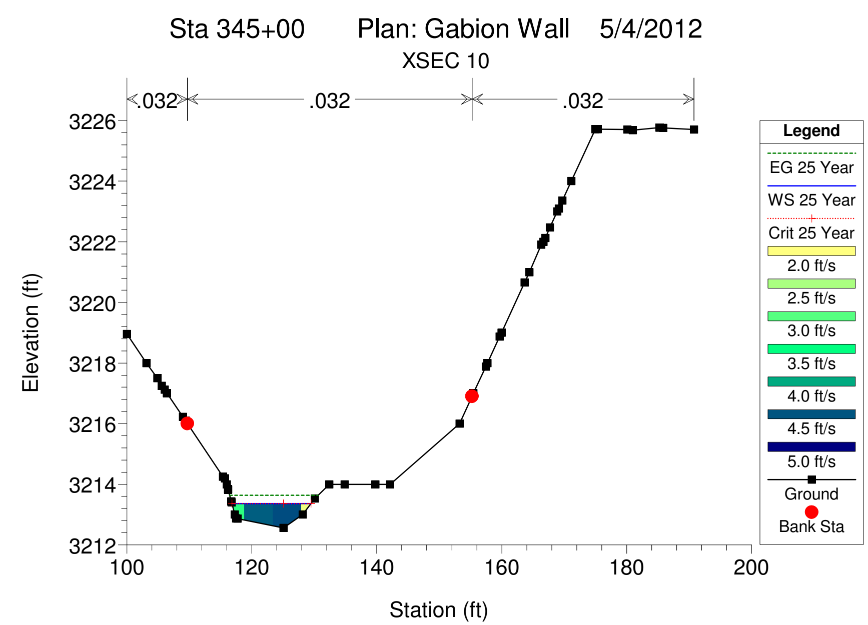
3 ft/s
4 ft/s
Ground
Bank Sta
Elevation (ft)
Station (ft)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4.5 ft/s
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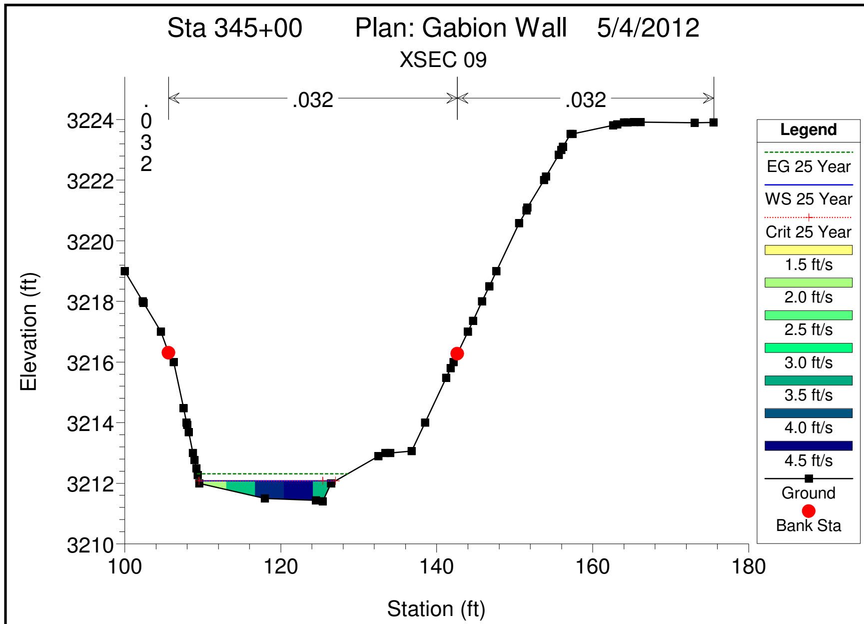
Ground
Bank Sta
Elevation (ft)
Station (ft)



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Crit 25 Year
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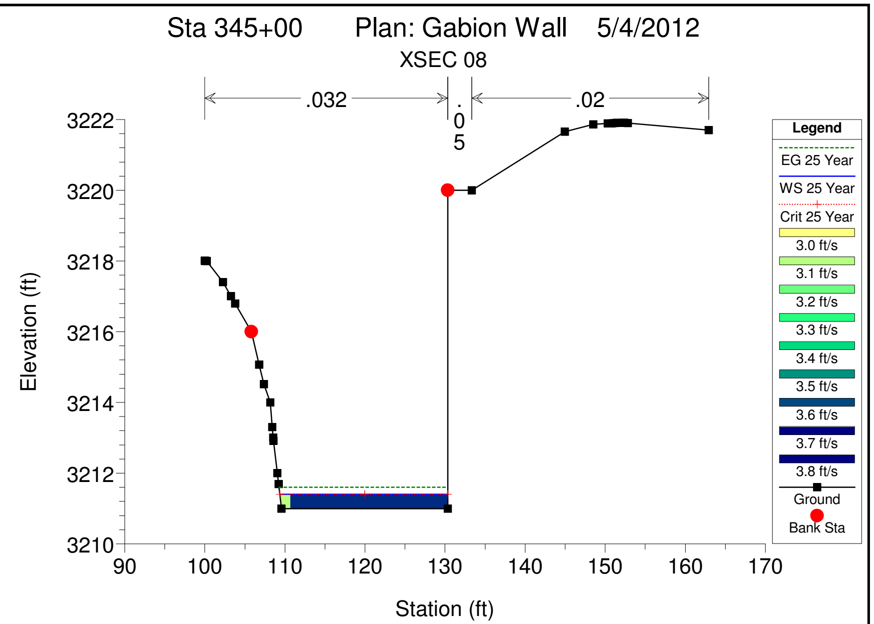
Ground
Bank Sta
Elevation (ft)
Station (ft)



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Crit 25 Year
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3.1 ft/s
3.2 ft/s
3.3 ft/s
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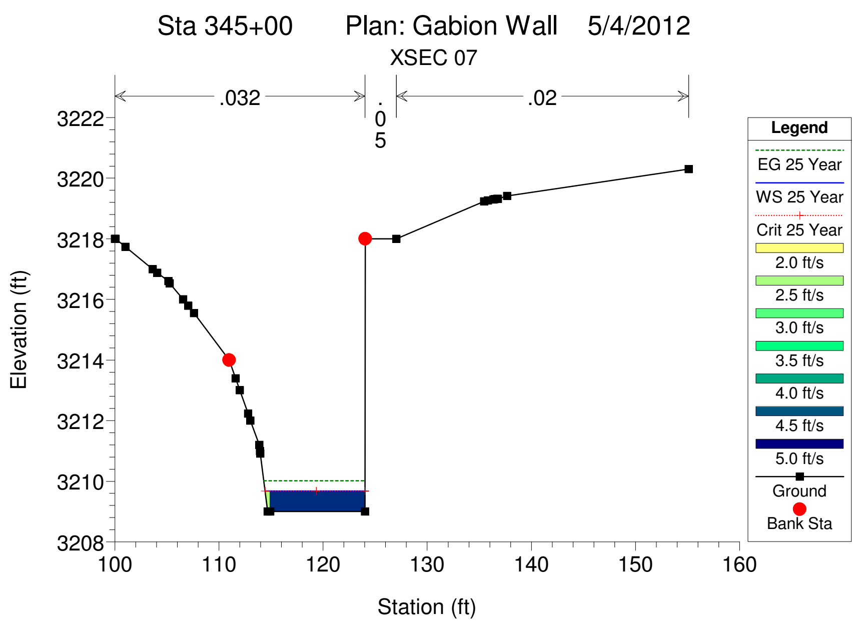
Ground
Bank Sta
Elevation (ft)
Station (ft)



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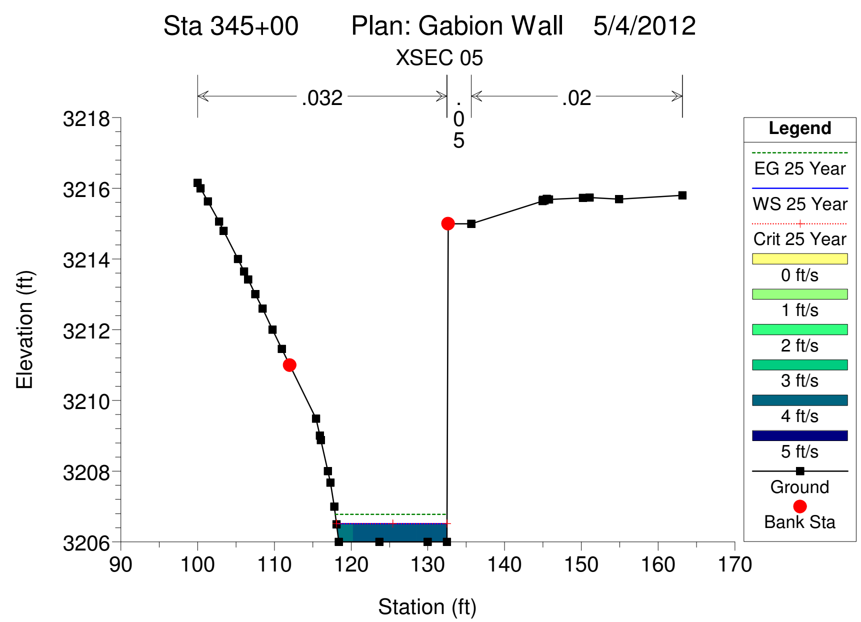
Station (ft)



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Crit 25 Year
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1 ft/s
2 ft/s
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Ground
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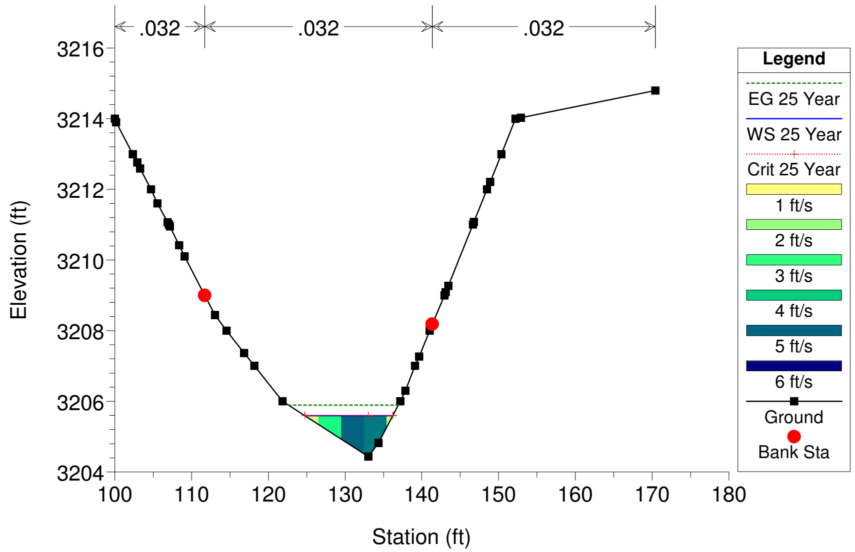
Elevation (ft)
Station (ft)

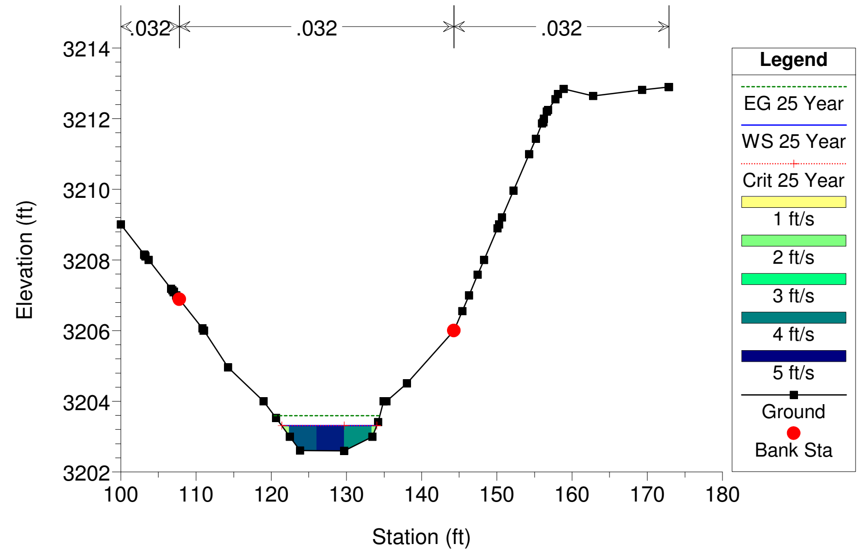
Sta 345+00 Plan: Gabion Wall 5/4/2012

XSEC 04



Sta 345+00 Plan: Gabion Wall 5/4/2012

XSEC 03



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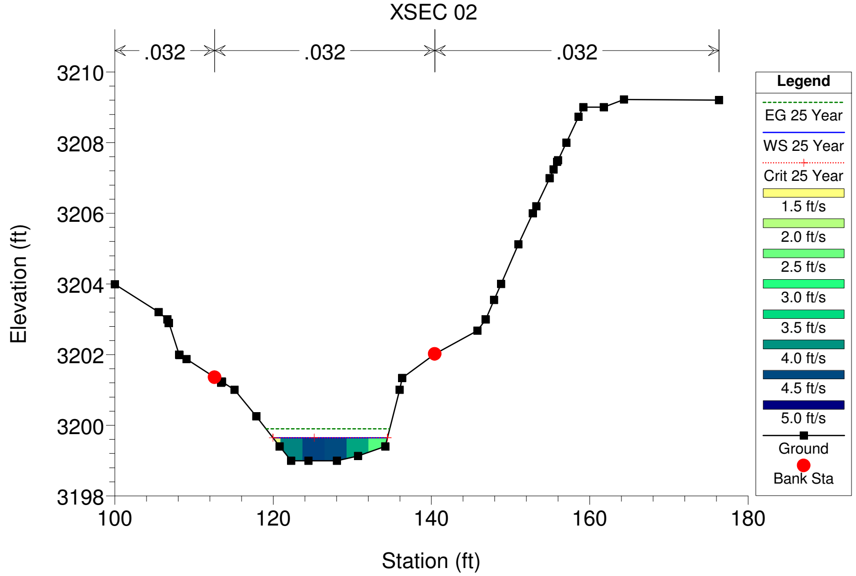

Sta 345+00 Plan: Gabion Wall 5/4/2012

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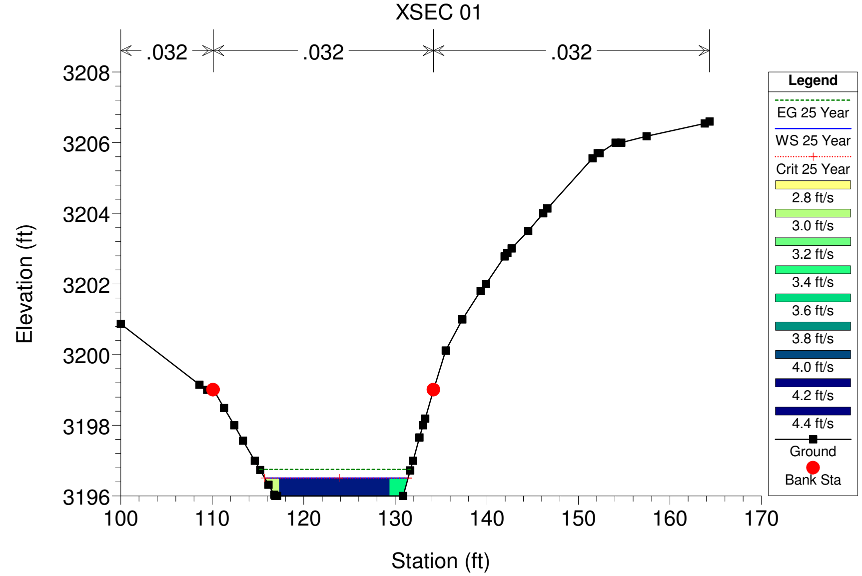

Appendix F – 72” Culvert Repair Technical Memorandum

Memo

To:	Mr. Matthew Ambroziak Central Federal Lands Highway Division		
From:	Ray P. Carranza, P.E.	Project:	AZ PRA GLCA 5(2) Lees Ferry Access Road
CC:	Doug Emmons/HDR, Darin Lockhart/HDR		
Date:	November 28, 2011	Job No:	147602

RE: Lees Ferry Access Road – Existing 72" Culvert Repair

This memo documents the hydrologic and hydraulic analyses performed at the existing 72" culvert crossing (approx. Sta 323+50) of the Lees Ferry Access Road on the Glen Canyon National Recreation Area near Page, Arizona. HDR was contracted by the Federal Highway Administration, Central Federal Lands Highway Division (CFLHD) to perform an evaluation and provide alternatives for the repair of the existing culvert crossing. The purpose of this memo is to document the hydrologic and hydraulic analysis performed on four (4) proposed culvert repair alternatives for a cost estimate.

Existing Conditions

Under current conditions, the existing culvert crosses under Lees Ferry Access Road with a single 72" diameter corrugated metal pipe (CMP) pipe with a concrete headwall only at the inlet; the outlet is bevel cut to approximately match the fill slope. There is an existing overflow pipe located approximately 50' west of the 72" culvert. The downstream end (outlet) of the overflow pipe is buried by soil dumped over it. The 72" existing culvert is in need of repair due to evidence of pitting within the walls and displacement of the pipe at the distressed (failed) point with accumulated sediment upstream. As one progresses downstream, the deposition increases again through the outlet. Based on observations from a site visit on August 12, 2011, the downstream end of the existing culvert appears to be constricted for an undetermined length (see photo below on right). This section of pipe was repaired and is approximately dimensioned at 60" to 62" horizontally and 60" to 68" vertically. The existing invert elevation upstream is 3,149.38' and downstream is 3,142.84', based on survey data performed in March 2011. The depth of the existing 72" culvert is approximately 25' below existing ground. There is an existing drainage crossing approximately 600' downstream, SW from the 72" culvert outlet.

72" Culvert Inlet

72" Culvert Repaired Joint

Hydrologic Analysis

Design discharges were developed with the indirect equations and methods found in the "Methods for Estimating Magnitude and Frequency of Floods in the Southwestern United States", United States Geological Survey Water-Supply Paper 2433 (USGS WSP 2433). Drainage basin delineation for the 72" culvert crossing was determined from best available data (USGS topographic mapping and aerial imaging). The watershed area was determined to be approximately 3.31 square miles. Based on the USGS flood region mapping the delineated basin area is in within Flood Region 8. USGS Regional Regression Equations for Region 8 were used to calculate the 2-, 5-, 10-, 25-, 50-, and 100-year flows. The calculated 25yr event at Sta 323+50 has a range from 755 – 2526 cfs.

Hydrologic calculations are presented in Appendix A, and summarized in Table 1, below.

RETURN INTERVAL	FLOW (CFS)	Average Stnd Error in %
2-Year	220	72%
5-Year	601	62%
10-Year	981	57%
25-Year	1,640	54%
50-Year	2,275	53%
100-Year	3,016	53%

Table 1 – Flows at Lees Ferry Access Road Sta 323+50 Culvert Crossing

The calculated peak flows were compared with the methods developed in "Analysis of the Magnitude and Frequency of Peak Discharge and Maximum Observed Peak Discharge in New Mexico and Surrounding Areas", Scientific Investigations Report 2008-5119 (USGS). While there was some variance between the two calculated peaks, the flow values were within a relatively similar threshold.

The reports cited indicate the characteristic of the drainage basin is among the low threshold of statistical "outliers" when compared against the available data for gauged watersheds within the region and it is below the estimated elevation threshold for large flood events in the southwest. However, as a conservative estimate the flows calculated with the standard methods will be used for the design of alternatives at the crossing.

Hydraulic Analysis

The four (4) proposed culvert alternatives were analyzed using the Bentley CulvertMaster program, Version 3.1. Topographic and digital terrain model (DTM) information was obtained from a field survey dated March 2011. The design of the roadway hydraulic structures was based on the Low-Standard roadway classification per the Federal Lands Highway Project Development and Design Manual (PDDM). Five (5) separate models were generated (one for the existing condition and four proposed culvert alternatives) for the 25-year storm event. The existing condition model was used to determine the existing capacity of the 72" culvert. The alternatives developed will be designed to either meet or exceed the existing capacity based on the calculated design flows. The 50-year flows were set as a check storm to evaluate potential adverse impacts and not used for design of the culverts. The allowable headwater elevation that was used in the analysis was 3170' based on the shoulder hinge point from the DTM. No analysis was performed at the drainage crossing located approximately 600' downstream, SW of the existing 72" culvert outlet to determine the effects of the various culvert alternatives. The existing condition and proposed culvert alternatives are summarized below:

> **Existing Condition – Damaged 72" culvert with no overflow pipe**: Evaluation of the existing culvert shows that for the 25-year event, the 72" culvert has a capacity of 609 cfs. The existing overflow pipe is ineffective since the outlet is plugged on the outlet end.

Alternative #1 – Repair of 72" culvert with a 60" I.D. (63" O.D.) HDPE liner and install a 48" overflow pipe: This alternative requires a 48" overflow pipe approximately 14' above the existing 72" culvert invert, which would replace the existing overflow pipe at Sta 323+00. This alternative has the largest design headwater elevations compared to the other alternatives. Armoring the roadway embankment is recommended due to the high headwater. The analysis of the 60" HDPE liner assumes that there will be a beveled ring end with an entrance loss coefficient of 0.2 to increase the capacity of the culvert. Analysis of the 60" HDPE liner with a headwall and no beveled ring will increase the headwater. The 48" overflow pipe was analyzed with a beveled ring at the culvert entrance. Erosion protection would be required for the 48" overflow pipe to have the flows run down to the existing wash. This alternative will also provide the smallest excavation footprint compared to the other alternatives.

Alternative #2 – Repair of 72" culvert with a 60" HDPE liner and install an additional 60" culvert: The analysis of the 2-60" culverts includes a beveled ring for the entrance inlet type. This alternative requires excavation in order to construct an additional culvert. Impacts to the existing roadway elements would have to be reconstructed due to the excavation limits. The limits of disturbance are shown in Appendix C. Armoring of the roadway embankment may be considered due to the headwater. The overflow pipe would not be required for this alternative.

Alternative #3 – Replacement of 72" culvert with 12' span by 10' high concrete box culvert: This alternative had the most favorable hydraulic results. The design headwater is reduced with this alternative, therefore armoring of the roadway embankment would not be necessary. Impacts to the existing roadway elements would have to be reconstructed due to the box culvert excavation limits. The overflow pipe would not be required for this alternative.

Alternative #4 – Replacement of 72" culvert with 120" culvert: This alternative produced similar results to Alternative #3. The analysis of the 120" culvert includes a beveled ring for the entrance inlet type. The design headwater is reduced with this alternative, therefore armoring of the roadway embankment would not be necessary. Impacts to the existing roadway elements would have to be reconstructed due to the culvert excavation limits. The overflow pipe would not be required for this alternative.

Hydraulic calculations are presented in Appendix B, and summarized in Table 2, below.

Alternative #	Description	Q_{25}	$Q_{max\ capacity}$[1]	Design Q_{25} HW
Existing	72" CMP	1,640 cfs	609 cfs	3171.49'
1	72" Culvert Repair with 60" Liner / 48" Culvert	1,640 cfs	631.0 cfs	3171.48'
2	72" Culvert Repair with Add'l 60" Culvert	1,640 cfs	1056.0 cfs	3171.33'
3	12' x 10' Box	1,640 cfs	2342.5 cfs	3164.26'
4	120" Culvert	1,640 cfs	1722 cfs	3169.66'

[1] Maximum capacity of culvert before overtopping the roadway.

Table 2 – (25-year) Headwater Depths for the Existing and Proposed Culvert Alternatives

Cost Estimate

Alternative #	Description	Estimated Construction Cost [1]
Existing	72" CMP	N/A
1	72" Culvert Repair / 48" Culvert	$292,000
1.01	72" Culvert Repair / 48" Culvert – Jack and Bore Option	$330,000
2	72" Culvert Repair with Add'l 60" Culvert	$395,000
2.01	72" Culvert Repair with Add'l 60" Culvert – Jack and Bore Option	$473,000
3	12' x 10' Box	$760,000
4	120" Culvert	$365,000
[1] 14% added to the material cost to include miscellaneous items. 6% was also applied for construction contingencies.		

Table 3 - Estimated Construction Cost Summary

The cost shown in Table 3 reflects the construction cost of the hydraulic structure. The estimated cost for roadway earthwork, removals, erosion mitigation, mobilization, traffic control or any other related roadway items that may be impacted due to the installation of the hydraulic structures was approximated using 14% of the material cost. Additional construction cost estimates were developed for Alternatives 1 and 2 to look at a jack and boring operation to install the new culverts. Alternatives 1 and 2 assume pipe excavation and backfill to install the new culverts. Alternatives 1.01 and 2.01 assume that the new culverts will be installed via jacking and boring. If jacking and boring is the preferred construction method, a subsurface investigation should be considered to examine soil conditions, identify potential obstructions and impacts to surface activities. Additional subsurface investigations were not included in the alternatives cost estimate.

Several cost saving measures can be implemented in final design. The headwalls can be eliminated if it is not required to retain the roadway embankment. Eliminating or reducing the amount of slope armoring can be evaluated. Less expensive slope armoring alternatives can be considered and evaluated for feasibility. Based on field observations, the outlet end is on a rock ledge. Riprap may not be required to prevent erosion at the outlet.

The cost estimate is presented in Appendix E along with an additional cost breakdown of alternatives.

Conclusions

Initial evaluation of the existing 72" culvert shows that 1024 cfs will overtop the roadway and 616 cfs will pass through the culvert for the 25-year storm event. Based on the flow hydrologic calculations shown in this report, the existing 72" culvert is not adequately sized for the 25-year event. The existing culvert can adequately pass the 5-year storm event. The existing 72" culvert constriction will either need to be removed and replaced with a new culvert section or have a lining transition what will adequately line the entire length of culvert. Lining the existing 72" CMP with a smooth liner will increase the outlet velocities approximately by 10% to 20%.

Installation of various outlet protection measures would need to be evaluated due to the increased velocities. A lined 72" culvert will have an effect of increasing the velocities due to the reduced roughness in the pipe. Increased velocities could have a beneficial effect of clearing some of the current build-up of sediment now deposited at the outlet. Base on site conditions, the existing pipe outlets to a bedrock surface. Riprap protection at the outlet was assumed to be not required due to the existing bedrock surface at the outlet. Armoring the roadway embankment would mitigate potential erosion due to the rise and fall of the upstream headwater. In overtopping situations, armoring the roadway embankment on the downstream side would

mitigate potential erosion from the roadway sheet flow. Installation of an overflow pipe will require erosion protection measures for the rundown to the existing wash.
Riprap was sized for the various alternatives. The riprap sizing and quantity backup calculations are presented in this Appendix D.

Based on the calculated design flows for the 25-year event, Alternative #1 adds an additional 22 cfs of flow capacity and 996 cfs overtopping the roadway; Alternative #2 adds an additional 447 cfs of flow capacity and 575 cfs overtopping the roadway; Alternative #3 adds an additional 1733 cfs of flow capacity and is adequate in passing the 25-year design flow below the low point of the shoulder hinge; Alternative #4 adds an additional 1113 cfs of flow capacity and is adequate in passing the 25-year design flow below the low point of the shoulder hinge. Each alternative with the exception of Alternative #3 will have overtopping during a 50-year storm event. The impacts to the roadway due to excavation for Alternatives #2, 3 and 4 would have a much larger footprint than Alternative #1. Alternative #1 requires excavation to replace the existing culvert at Sta 323+00 with a 48" culvert which is approximately 10' below existing ground. An exhibit showing the limits of disturbance for Alternative #2 is included in this memorandum. Alternatives #3 and #4 may have similar excavation limits depending on final design of the drainage structure.

The existing 72" CMP has an average fill height of 25'. In order to maintain the structural integrity of the lining, the minimum grout strength and soil modulus must be met for the burial depth. Refer to manufacturers specifications for maximum burial depths for various fill heights.

Leaving the existing 72" CMP in place as-is will increase the pitting within the pipe walls. The high headwater would overtime degrade the roadway embankment slopes as the storm event passes and the headwater elevation decreases. Overtopping of the roadway would introduce slope degradation on the downstream end of the roadway embankment as water flows over the roadway and down the embankment.

Recommendations

The ultimate recommended alternative is Alternative #1. This alternative was shown to exceed the capacity of the existing 72" culvert. Based on the 25-year design storm event, this alternative will overtop the roadway but the amount of flow is reduced compared to the existing condition. The repair of the 72" culvert with a liner will provide a trenchless solution to provide minimal to no impact to the existing roadway. The decrease in 72" culvert capacity will require a 48" overflow pipe. The overflow pipe will have an effect of minimizing the possibility of ultimate embankment failure. If an immediate repair is to be made separate from the Lee's Ferry roadway project, the work on the two culverts should be conducted in two phases. Alternative #1A would repair the 72" culvert with a slip liner. Alternative #1B would install the overflow pipe during pavement reconstruction for Lees Ferry Access Road. Alternative #1A is recommended to be constructed at this time and Alternative #1B shall be constructed as part of the Lee's Ferry roadway project. Please note that Alternative #1A is not a permanent solution as it does not provide capacity beyond the 5-year storm event, but will address the structural deficiencies associated with the existing culvert. The cost estimate for Alternative 1 was broken down to estimate a construction cost for each phase. The estimated construction cost for repairing the 72" culvert in the first phase would be approximately $182,000 as shown in Appendix E. Limits of disturbance associated with the overflow culvert excavation will be evaluated during final design to allow traffic to pass at all times with reasonable delays. The jack and bore method may need to be considered for installation of the 48" overflow pipe if reasonable delays would be exceeded by other means of construction. The other alternatives which required deep excavations and full roadway closures were dismissed as the road is not conducive to full or long term one lane road closures. A beveled entrance is recommended for both the 72" culvert repair and 48" overflow pipe to increase capacity.

APPENDICIES

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APPENDIX A
HYDROLOGIC CALCULATIONS

Project No. AZ PRA GLCA 5(2)

Subject: Federal Highways Division - Central Federal Lands

Lees Ferry Access Road

Culvert Analysis Summary

Computed By: DAP **Checked By:** RPC

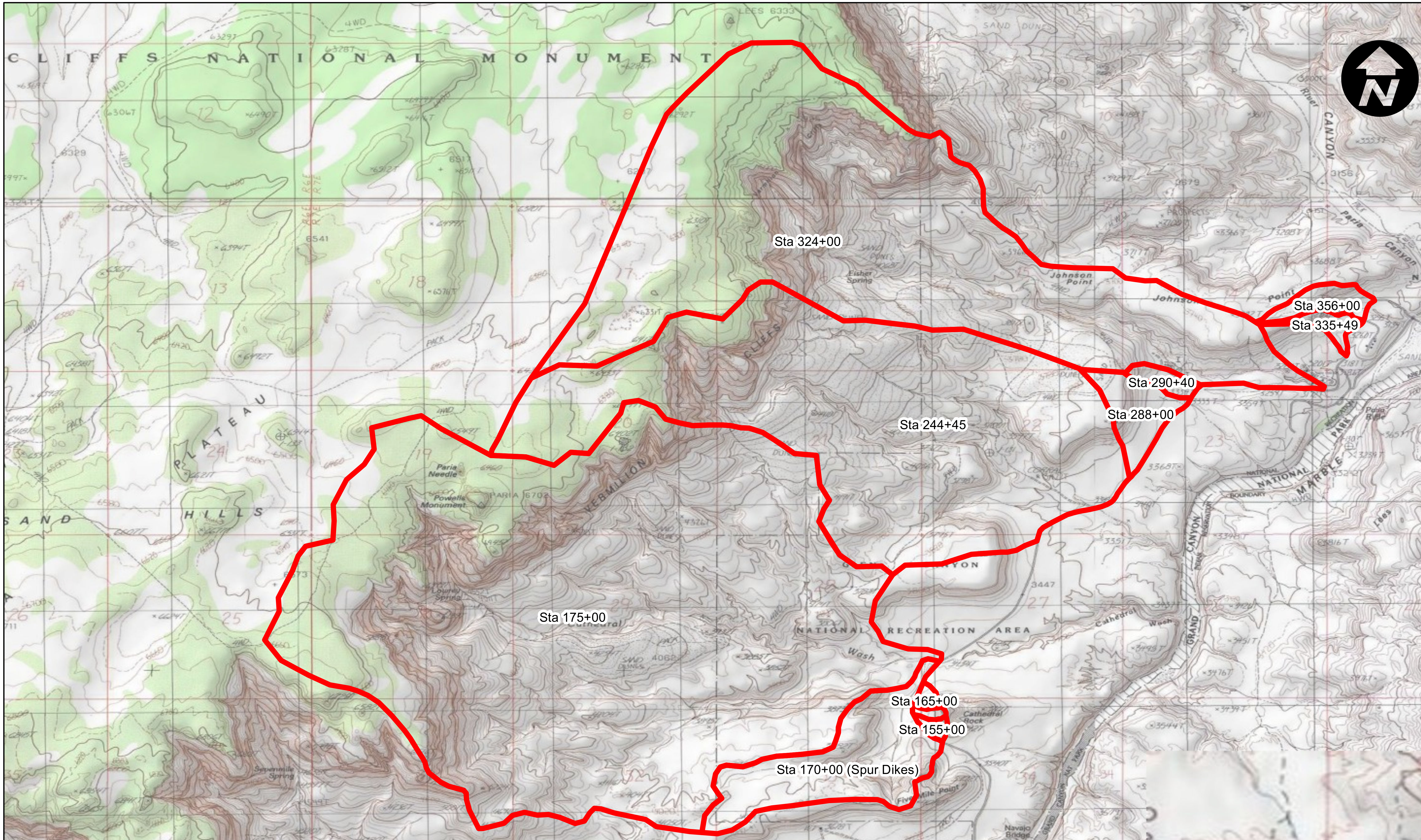
Regression 93-419 Blakemore et al. (1994) **Region 08**

COLUMN FORMAT Data From HUC-8: h5080302

A Area (sq mi) Part 1= 3.3077

H Height or Elevation difference (ft) Hi= 6437 Lo= 3172

Watershed Name	Recurrence Interval, Years	A (sq mi)	93-419	ADOT Average Stnd Error in %	Adjusted (-) for Stnd Error	USGS Average Stnd Error in %
Lee's Ferry Sta 323+00	2	3.308	220	70%	66	72%
Lee's Ferry Sta 323+00	5	3.308	601	60%	241	62%
Lee's Ferry Sta 323+00	10	3.308	981	55%	441	57%
Lee's Ferry Sta 323+00	25	3.308	1,640	52%	787	54%
Lee's Ferry Sta 323+00	50	3.308	2,275	51%	1115	53%
Lee's Ferry Sta 323+00	100	3.308	3,016	51%	1478	53%

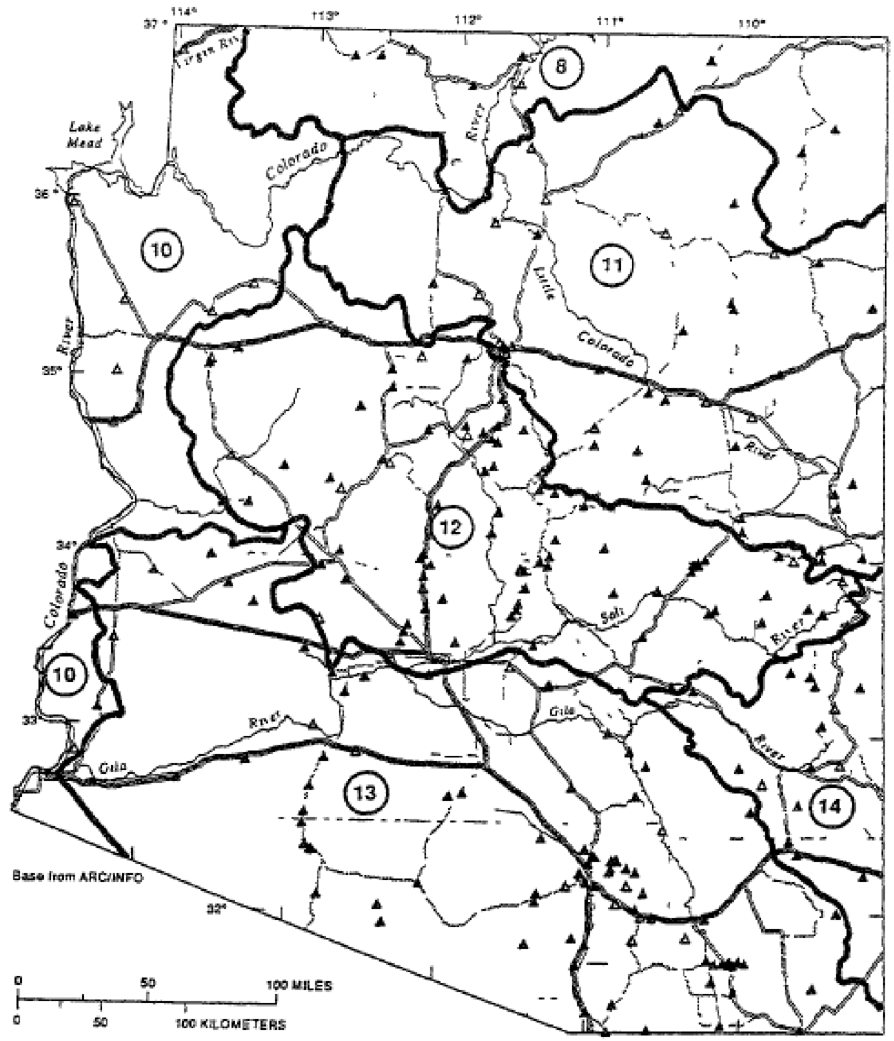


Legend

Delineations

0 1,500 3,000 6,000 Feet

FIGURE 10-9
FLOOD REGIONS IN ARIZONA



EXPLANATION

BOUNDARY OF FLOOD REGIONS	INTERSTATE HIGHWAY	GAGING STATION
11 FLOOD-REGION NUMBER	U S HIGHWAY	▲ Station relation defined
	STATE HIGHWAY	△ Station relation undefined

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FIGURE 10-14

SCATTER DIAGRAM OF INDEPENDENT VARIABLES FOR R8 REGRESSION EQUATIO'

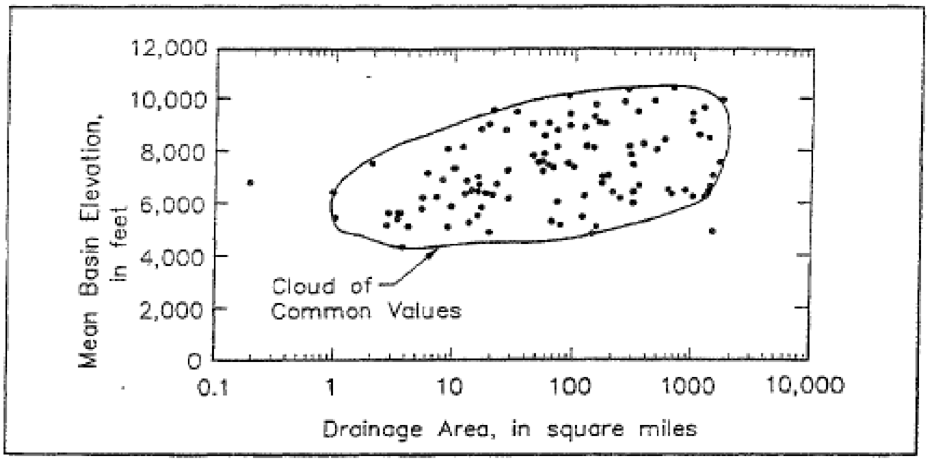

FIGURE 10-15

Q_{100} DATA POINTS AND 100-YEAR PEAK DISCHARGE RELATION FOR R8

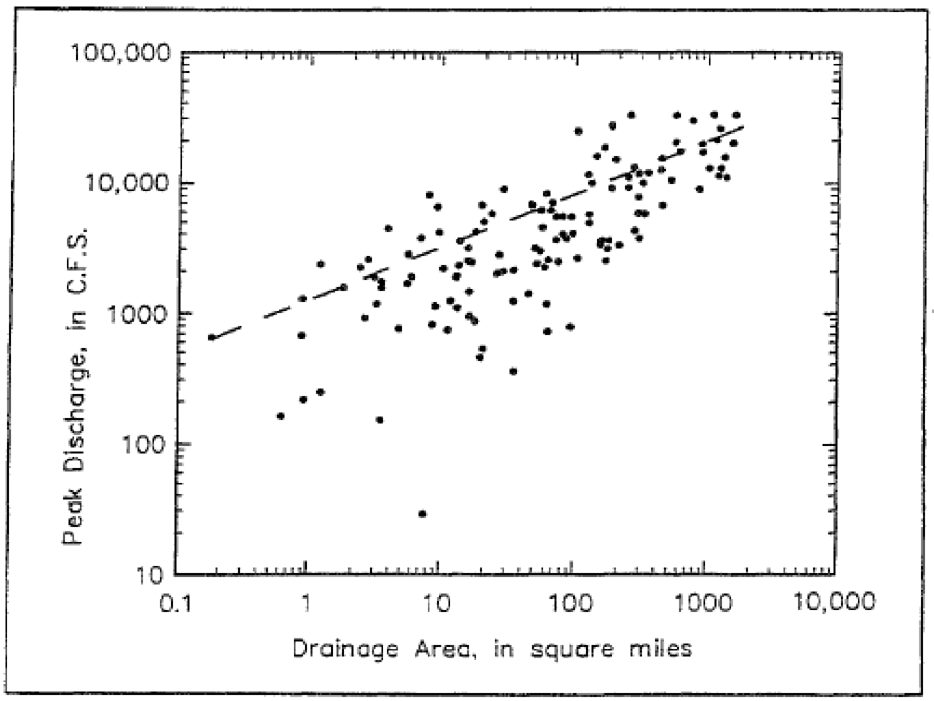

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TABLE 10-3

FLOOD MAGNITUDE-FREQUENCY RELATIONS FOR THE FOUR CORNERS REGION (R8)

Equation: Q, peak discharge, in cubic feet per second; AREA, drainage area, in square miles; and ELEV, mean basin elevation, in feet divided by 1,000.

Recurrence interval, in years	Equation	Average standard error of model, in percent
2	$Q = 598\ AREA^{0.501}\ ELEV^{-1.02}$	70
5	$Q = 2{,}620\ AREA^{0.449}\ ELEV^{-1.28}$	60
10	$Q = 5{,}310\ AREA^{0.425}\ ELEV^{-1.40}$	55
25	$Q = 10{,}500\ AREA^{0.403}\ ELEV^{-1.49}$	52
50	$Q = 16{,}000\ AREA^{0.390}\ ELEV^{-1.54}$	51
100	$Q = 23{,}300\ AREA^{0.377}\ ELEV^{-1.59}$	51

APPENDIX B
HYDRAULIC CALCULATIONS

Project No.	AZ PRA GLCA 5(2)
Subject:	Federal Highways Division - Central Federal Lands
	Lees Ferry Access Road
	Culvert Analysis Summary
Computed By:	RPC **Checked By:** DAP

				Invert Elevation (ft)				Discharge		Headwater Elevation		
Alternative	**Station**	**Culvert No.**	**Culvert Size (in)**	**U/S**	**D/S**	**Length (ft)**	**Slope (ft/ft)**	**25-Year**	**Culvert Capacity**	**Overtopping**	**Allowable**	**Design Flow**
Existing	323+50	Exst CMP	72	3149.38	3142.84	160.64	0.0407	**1640.00**	609	3171.1	3170.0	3171.5
1	323+50	CMP Repair	60	3149.38	3142.84	160.64	0.0407	**1640.00**	481	3171.1	3170.0	3171.5
			48	3163.85	3161.16	77.93	0.0345		149			
2	323+50	CMP Repair	2-60	3149.38	3142.84	160.64	0.0407	**1640.00**	1056.02	3171.1	3170.0	3171.3
3	323+50	Box Culvert	12' x 10'	3149.38	3142.84	160.51	0.0407	**1640.00**	2342.53	3171.1	3170.0	3164.3
4	323+50	Culvert	120	3149.38	3142.84	160.51	0.0407	**1640.00**	1722	3171.1	3170.0	3169.7

		INLET ENTRANCE
Alternative	**Culvert Size**	**TYPE**
Existing	72"	Headwall
1	60" Repair	Bevel Ring
	48" Overflow	Bevel Ring
2	2-60"	Bevel Ring
3	12' x 10' Box	30 to 75 Wingwall Flare
4	120"	Bevel Ring

Project No.	AZ PRA GLCA 5(2)
Subject:	Federal Highways Division - Central Federal Lands
	Lees Ferry Access Road
	Culvert Analysis Summary
Computed By:	RPC **Checked By:** DAP

Alternative	Station	Culvert No.	Culvert Size (in)	Berm Elev. (as req.)	Control HW Elevation (ft) Inlet	Control HW Elevation (ft) Outlet	Control Depth (ft) Inlet	Control Depth (ft) Outlet	D (ft)	HW (ft)	HW/D	Outlet Velocity (fps)
Existing	323+50	Exst CMP	72		3171.50		22.12		6	22.12	3.69	21.96
1	323+50	CMP Repair	60		3171.50		22.12		5	22.12	4.42	28.44
			48		3171.50		7.65		4	7.65	1.91	13.12
2	323+50	CMP Repair	2-60		3171.33		21.95		5	21.92	4.38	28.39
3	323+50	Box Culvert	12' x 10'		3164.26		14.88		10	14.92	1.49	28.26
4	323+50	Culvert	120		3169.66		20.28		10	20.32	2.03	25.11

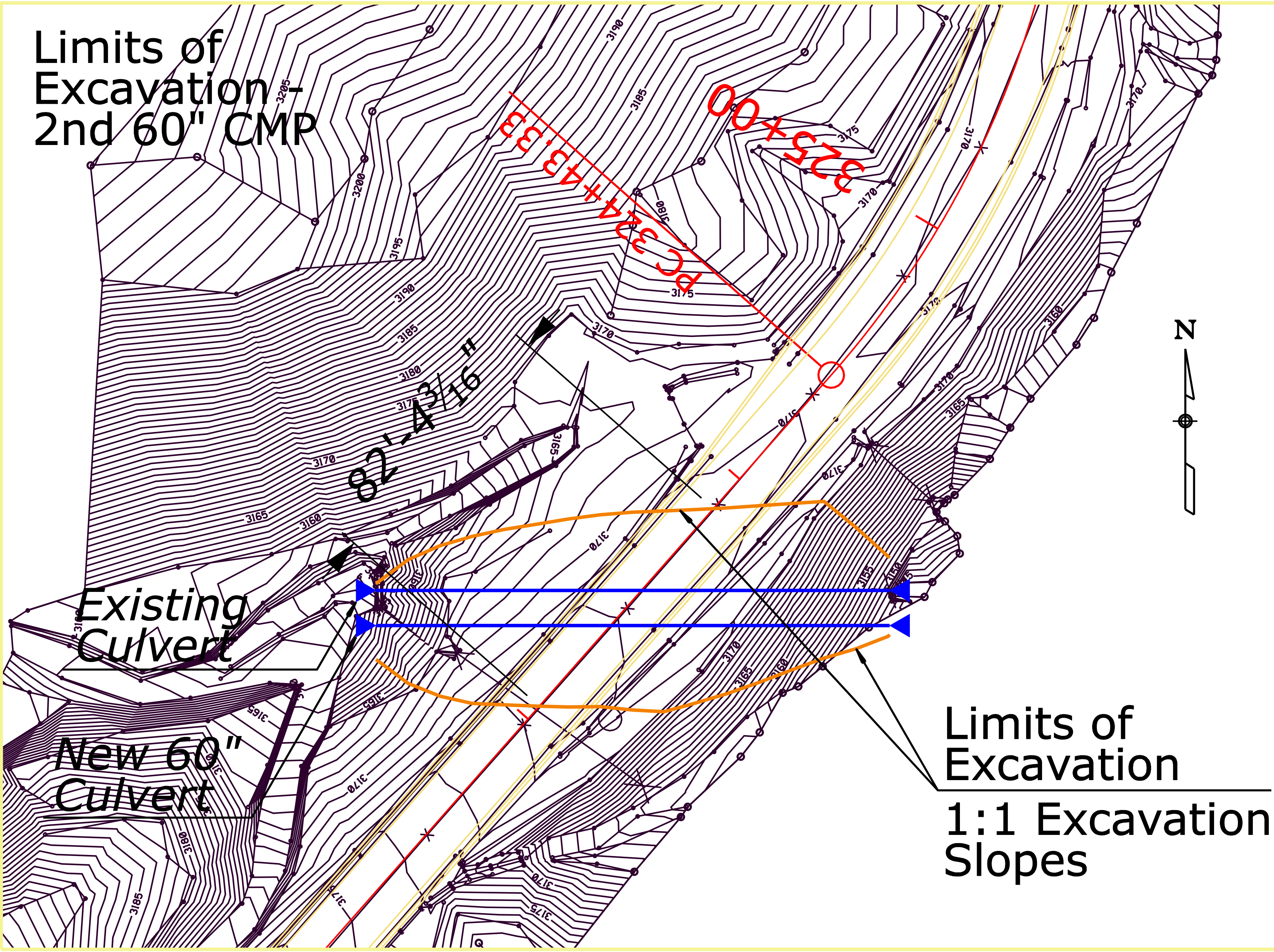
Alternative	Culvert Size	INLET ENTRANCE TYPE
Existing	72"	Headwall
1	60" Repair	Bevel Ring
	48" Overflow	Bevel Ring
2	2-60"	Bevel Ring
3	12' x 10' Box	30 to 75 Wingwall Flare
4	120"	Bevel Ring

Project No.	AZ PRA GLCA 5(2)
Subject:	Federal Highways Division - Central Federal Lands
	Lees Ferry Access Road
	Culvert Analysis Summary
Computed By:	RPC **Checked By:** DAP

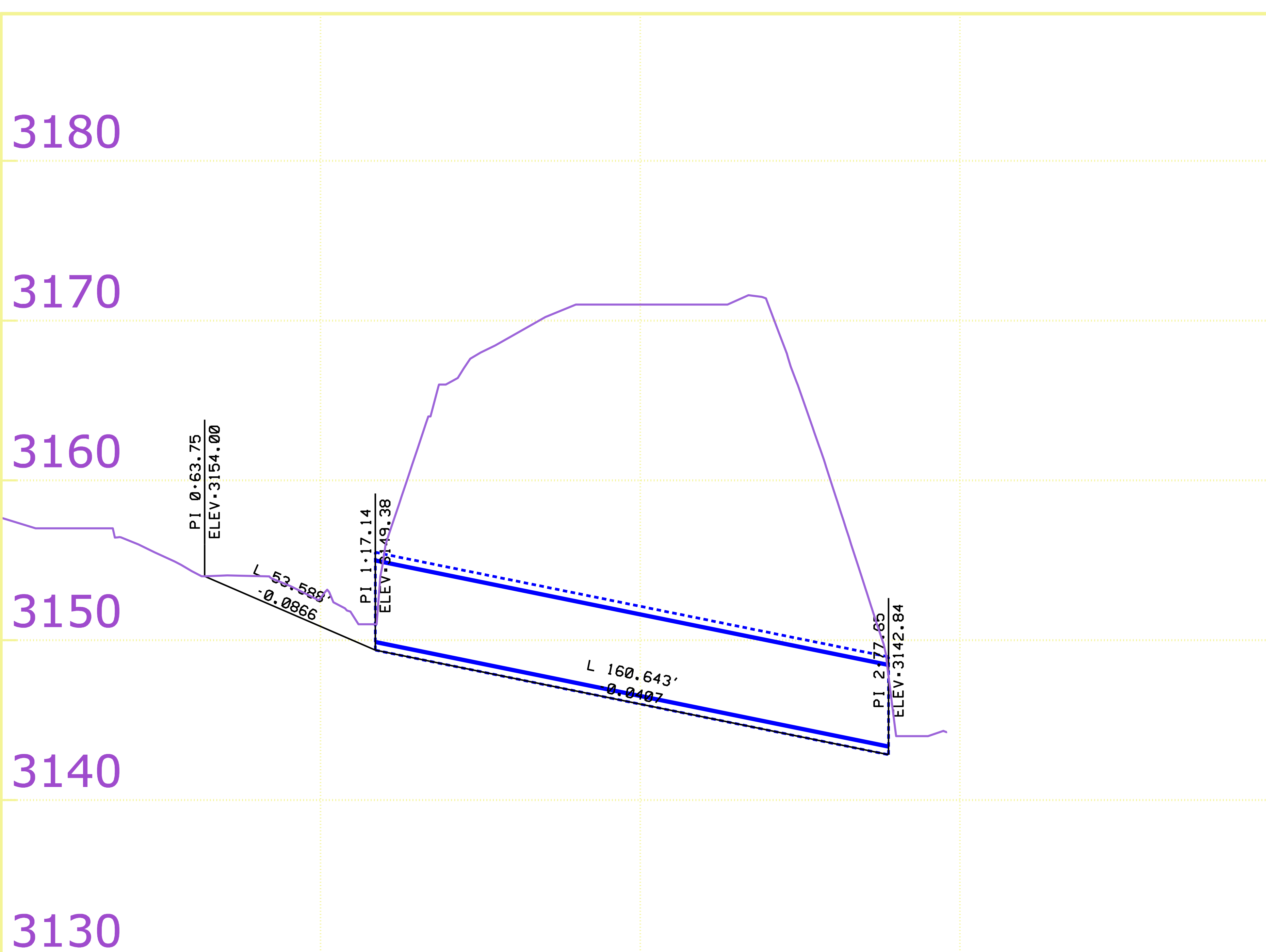
Alternative	Station	Culvert No.	Culvert Size (in)	Tailwater Velocity (fps)	V_{out}/V_{Tw}	Q_{exit}	Outlet Depth (ft)
Existing	323+50	Exst CMP	72	39.57	0.55	616.80	5.85
1	323+50	CMP Repair	60	30.59	0.93	487.60	4.08
			48	30.59	0.43	158.00	3.65
2	323+50	CMP Repair	2-60	30.59	0.93	1066.00	4.56
3	323+50	Box Culvert	12' x 10'	30.59	0.92	1640.00	4.84
4	323+50	Culvert	120	30.59	0.82	1640.00	7.75

Alternative	Culvert Size	INLET ENTRANCE TYPE
Existing	72"	Headwall
1	60" Repair	Bevel Ring
	48" Overflow	Bevel Ring
2	2-60"	Bevel Ring
3	12' x 10' Box	30 to 75 Wingwall Flare
4	120"	Bevel Ring

APPENDIX C
ALTERNATIVE #2 LIMITS OF DISTURBANCE EXHIBIT



Limits of Excavation - 2nd 60" CMP
325+00
PC 324+43.33
82'-4 3/16"
N
Existing Culvert
New 60" Culvert
Limits of Excavation
1:1 Excavation Slopes



3180
3170
3160
3150
3140
3130
PI 0·63.75
ELEV·3154.00
L 53.588'
-0.0866
PI 1·17.14
ELEV·3149.38
L 160.643'
-0.0407
PI 2·77.85
ELEV·3142.84

APPENDIX D
RIPRAP SIZING CALCULATIONS

S.O. No.
Subject: Riprap Quantities
Lees Ferry Access Road **Sheet No.**
Drawing No.
Computed By RPC **Checked By** DAP **Date** Oct-11

Pipe Ref No.	**I.D. (in)**	**I.D. (ft)**	**25-year Q (cfs)**	**TW (ft)**	**D_{50} [1] (ft)** Calc	**D_{50} [2a] (ft)** Calc	**D_{50} [2b] (ft)** Calc	**Riprap Class[3]**	**D_{50} (in)** Avg	**D_{50} (in)** Used	**Barrel**	**X (ft)** 3*I.D.	**L (ft)**	**W (ft)**	**T (ft)**	**Volume (CY)**
Alternative No. 1	63	5.25	512	4.21	1.28	2.13	2.11	6	22.06	22	1	15.75	42	43.75	3.67	250
Alternative No. 1	48	4	119	2.77	0.53	0.67	0.66	3	7.42	10	1	12	20	25.33	2.00	38
																287
Alternative No. 2	63	5.25	631	3.11	2.26	3.81	3.77	6	39.38	22	2	31.5	42	59.50	3.67	339
Alternative No. 3	144	12	631	2.23	2.63	1.77	1.75	6	24.57	22	1	36	96	100.00	3.67	1304
Alternative No. 4	120	10	631	3.60	1.56	1.40	1.38	5	17.35	20	1	30	70	76.67	3.33	663

Reference: Hydraulic Engineering Circular No 14, Third Edition: Hydraulic Design of Energy Dissipators for Culverts and Channels. July 2006.

[1]: Riprap sizing based on Urban Drainage and Flood Control District in Denver Colorado (UD & FCD, 2004), Eq D.1a from HEC 14

[2a]: Riprap sizing based on Fletcher and Grace (1972), Eq D.5 from HEC 14

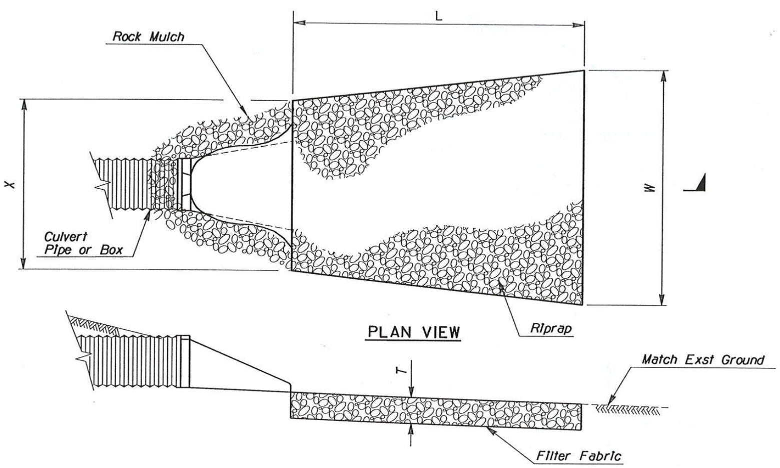
[2b]: Riprap sizing based on Fletcher and Grace (1972), Eq 10.4 for circular culverts from HEC 14

[3]: Riprap Class taken from Table 10.1 of Hydraulic Engineering Circular No 14, Third Edition: Hydraulic Design of Energy Dissipators for Culverts and Channels. July 2006

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.



APPENDIX E
COST ESTIMATE FOR ALTERNATIVES

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FEDERAL HIGHWAYS DIVISION
CENTRAL FEDERAL LANDS
72 INCH CULVERT REPAIR
CONSTRUCTION COST ESTIMATE

ROUTE: Lees Ferry Access Road
LOCATION: Sta 323+50, 72 inch culvert
LENGTH:

PROJECT DESCRIPTION: LEES FERRY ACCESS ROAD - 72 INCH CULVERT REPAIR ALTERNATIVES
ESTIMATE SUMMARY LEVEL: Conceptual
DATE: October 2011

ITEM	MAJOR ITEM DESCRIPTION	UNIT	ALT 1 QUANTITY	ALT 1.01 QUANTITY	ALT 2 QUANTITY	ALT 2.01 QUANTITY	ALT 3 QUANTITY	ALT 4 QUANTITY	UNIT COST	ALT 1 COST	ALT 1.01 COST	ALT 2 COST	ALT 2.01 COST	ALT 3 COST	ALT 4 COST
	EARTHWORK														
	DRAINAGE EXCAVATION														
	PIPE EXCAVATION	CUYD	400	0	2,050	0	4,100	4,100	$30	$12,000	$0	$61,500	$0	$123,000	$123,000
	TOTAL ITEM									$12,000	$0	$61,500	$0	$123,000	$123,000
	DRAINAGE														
	ON-SITE & OFF-SITE DRAINAGE														
	JACK AND BORE PIPE	LNFT		78		160			$1,000	$0	$78,000	$0	$160,000	$0	$0
	CONCRETE HEADWALL FOR 48-INCH PIPE CULVERT	EACH	1	1					$6,000	$6,000	$6,000	$0	$0	$0	$0
	CONCRETE HEADWALL FOR 120-INCH PIPE CULVERT	EACH						2	$17,000	$0	$0	$0	$0	$0	$34,000
	REVET MATTRESS/EMBANKMENT SPILLWAYS	SQYD	53	53					$150	$8,000	$8,000	$0	$0	$0	$0
	REVET MATTRESS/EMBANKMENT (slope armouring)	SQYD	100	100	100	100			$150	$15,000	$15,000	$15,000	$15,000	$0	$0
	12'X10' CONCRETE BOX CULVERT (CONCRETE)	CUYD					407		$800	$0	$0	$0	$0	$325,600	$0
	12'X10' CONCRETE BOX CULVERT (STEEL)	LBS					62,351		$1.10	$0	$0	$0	$0	$68,586	$0
	PLACED RIPRAP, CLASS 3 (outlet protection)	CUYD	0	0	0	0	652	332	$120	$0	$0	$0	$0	$78,240	$39,780
	48-INCH PIPE CULVERT	LNFT	78	78					$200	$15,600	$15,600	$0	$0	$0	$0
	60-INCH PIPE CULVERT	LNFT			160	160			$285	$0	$0	$45,600	$45,600	$0	$0
	120-INCH PIPE CULVERT	LNFT						160	$450	$0	$0	$0	$0	$0	$72,000
	CULVERT LINING REPAIR (63" OD)														
	BEVELED ENTRANCE FOR 60-INCH PIPE CULVERT	EACH	1	1	2	2			$20,000	$20,000	$20,000	$40,000	$40,000	$0	$0
	CULVERT LINING INSTALLED	LNFT	162	162	162	162			$808	$130,896	$130,896	$130,896	$130,896	$0	$0
	ROADWAY														
	FLEXIBLE PAVEMENT, FULL DEPTH PATCH, TYPE 1	SQYD	280		280		280	280	$120	$33,600	$0	$33,600	$0	$33,600	$33,600
	TOTAL ITEM									$229,096	$273,496	$265,096	$391,496	$506,026	$179,380
	SUBTOTAL A (ITEMS 100 THRU 200)									**$241,000**	**$273,000**	**$327,000**	**$391,000**	**$629,000**	**$302,000**
	UNIDENTIFIED ITEMS (14% OF SUBTOTAL A) (traffic control, erosion and sediment control, mobilization)									34,000	38,000	46,000	55,000	88,000	42,000
	SUBTOTAL B (SUBTOTAL A PLUS UNIDENTIFIED ITEMS)									**$275,000**	**$311,000**	**$373,000**	**$446,000**	**$717,000**	**$344,000**
	CONSTRUCTION CONTINGENCIES (6% OF SUBTOTAL B)									$17,000	$19,000	$22,000	$27,000	$43,000	$21,000
	TOTAL ESTIMATED CONSTRUCTION COST									**$292,000**	**$330,000**	**$395,000**	**$473,000**	**$760,000**	**$365,000**

FEDERAL HIGHWAYS DIVISION
CENTRAL FEDERAL LANDS
72 INCH CULVERT REPAIR
CONSTRUCTION COST ESTIMATE

ROUTE: Lees Ferry Access Road
LOCATION: Sta 323+50, 72 inch culvert
LENGTH:

PROJECT DESCRIPTION: LEES FERRY ACCESS ROAD - 72 INCH CULVERT REPAIR (PHASED CONSTRUCTION)
ESTIMATE SUMMARY LEVEL: Conceptual
DATE: November 2011

ITEM	MAJOR ITEM DESCRIPTION	UNIT	ALT 1 QUANTITY	ALT 1A QUANTITY	ALT 1B QUANTITY	UNIT COST	ALT 1 COST	ALT 1A COST	ALT 1B COST
	EARTHWORK								
	DRAINAGE EXCAVATION								
	PIPE EXCAVATION	CUYD	400		400	$30	$12,000	$0	$12,000
	TOTAL ITEM						$12,000	$0	$12,000
	DRAINAGE								
	ON-SITE & OFF-SITE DRAINAGE								
	JACK AND BORE PIPE	LNFT				$1,000	$0	$0	$0
	CONCRETE HEADWALL FOR 48-INCH PIPE CULVERT	EACH	1		1	$6,000	$6,000	$0	$6,000
	CONCRETE HEADWALL FOR 120-INCH PIPE CULVERT	EACH				$17,000	$0	$0	$0
	REVET MATTRESS/EMBANKMENT SPILLWAYS	SQYD	53		53	$150	$8,000	$0	$7,950
	REVET MATTRESS/EMBANKMENT (slope armouring)	SQYD	100		100	$150	$15,000	$0	$15,000
	12'X10' CONCRETE BOX CULVERT (CONCRETE)	CUYD				$800	$0	$0	$0
	12'X10' CONCRETE BOX CULVERT (STEEL)	LBS				$1.10	$0	$0	$0
	PLACED RIPRAP, CLASS 3 (outlet protection)	CUYD	0	0	0	$120	$0	$0	$0
	48-INCH PIPE CULVERT	LNFT	78		78	$200	$15,600	$0	$15,600
	60-INCH PIPE CULVERT	LNFT				$285	$0	$0	$0
	120-INCH PIPE CULVERT	LNFT				$450	$0	$0	$0
	CULVERT LINING REPAIR (63" OD)								
	BEVELED ENTRANCE FOR 60-INCH PIPE CULVERT	EACH	1	1		$20,000	$20,000	$20,000	$0
	CULVERT LINING INSTALLED	LNFT	162	162		$808	$130,896	$130,896	$0
	ROADWAY								
	FLEXIBLE PAVEMENT, FULL DEPTH PATCH, TYPE 1	SQYD	280		280	$120	$33,600	$0	$33,600
	TOTAL ITEM						$229,096	$150,896	$78,150
	SUBTOTAL A (ITEMS 100 THRU 200)						**$241,000**	**$151,000**	**$90,000**
	UNIDENTIFIED ITEMS (14% OF SUBTOTAL A) (traffic control, erosion and sediment control, mobilization)						34,000	21,000	13,000
	SUBTOTAL B (SUBTOTAL A PLUS UNIDENTIFIED ITEMS)						**$275,000**	**$172,000**	**$103,000**
	CONSTRUCTION CONTINGENCIES (6% OF SUBTOTAL B)						$17,000	$10,000	$6,000
	TOTAL ESTIMATED CONSTRUCTION COST						**$292,000**	**$182,000**	**$109,000**

Appendix G – Cathedral Wash Outlet Scour Hole Geometry Summary

HY-8 Energy Dissipation Report

Scour Hole Geometry

Parameter	Value	Units
Select Culvert and Flow		
Crossing	Crossing 1	
Culvert	Culvert 1	
Flow	1924.00	cfs
Culvert Data		
Culvert Width (including multiple barrels)	12.0	ft
Culvert Height	12.0	ft
Outlet Depth	6.38	ft
Outlet Velocity	22.87	ft/s
Froude Number	1.60	
Tailwater Depth	8.33	ft
Tailwater Velocity	5.03	ft/s
Tailwater Slope (SO)	0.0366	
Scour Data		
Time to Peak		
Note:	if Time to Peak is unknown, enter 30 min	
Time to Peak	30.00	min
Cohesion	Noncohesive	
D16 Value	0.10	mm
D84 Value	4.00	mm
Tailwater Flow Depth after Culvert Outlet	Normal Depth	
Results		
Assumptions		
Soil Sigma	6.32	
Scour Hole Dimensions		
Length	99.813	ft
Width	53.509	ft
Depth	10.614	ft
Volume	62341.505	ft^3
DS at .4(LS)	39.925	ft
Tailwater Depth (TW)	8.333	ft
Velocity with TW and WS	2.640	ft/s

YEH AND ASSOCIATES, INC.
GEOTECHNICAL ENGINEERING CONSULTANTS

Project: Lees Ferry Access Road
Project Number: 211-052 Date: 5/3/11

Boring: **P-7**
Sheet 1 of 1

Boring Began: 5/3/2011
Drilling Method: Hollow-Stem Auger
Drill: CME 75
Driller: Enviro-Drill - Jeff
Logged By: T. Allen
Final By: T. Allen
Inclination: Vertical

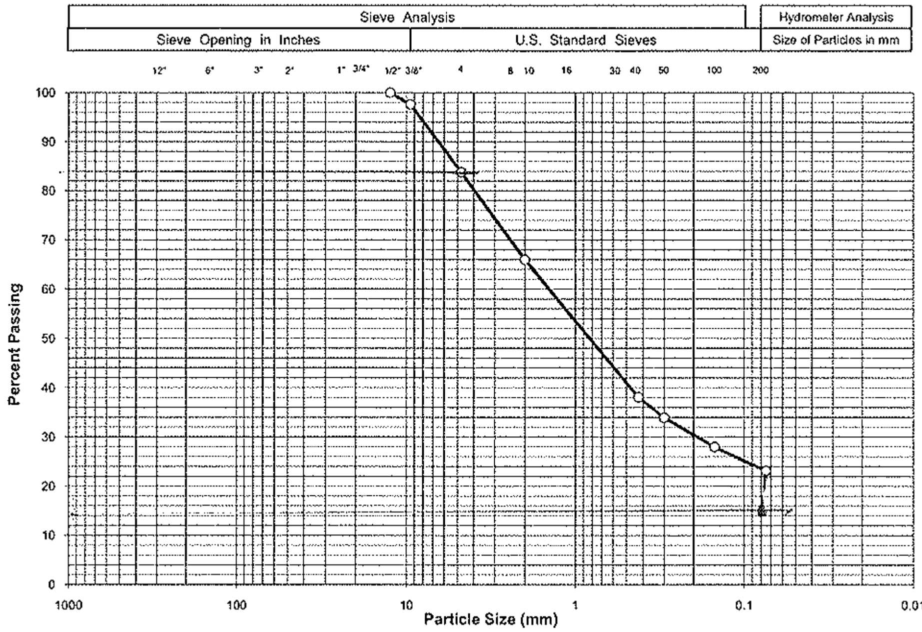
Completed: 5/3/2011
Drill Bit:
Casing:
Weather:

Total Depth: 3.0 ft
Ground Elevation:
Location:
Coordinates: N: E:

Ground Water Notes:

Depth	-	-	-	-
Date	-	-	-	-
Time	-	-	-	-

Elevation (feet)	Depth (feet)	Run / Sample Type	Recovery (%)	Rock RQD	Soil Samples Blows per 6 in	Soil Samples N	Lithology	Material Description	Field Notes and Lab Tests
								0.0 - 0.3 ft. Asphalt.	
								0.3 - 0.6 ft. 4.5" ABC.	
								0.6 - 1.0 ft. silty SAND.	
					10/17/38	55		**1.0 - 3.0 ft.** Weathered Shale, red-brown, moist to damp, hard.	MC= 5.5% #4= 16% #200= 23.2% LL= 22 PL= 17 PI= 5 AASHTO: A-1-b USCS: SM-SC
								Bottom of Hole at 3.0 ft.	Refusal on Sandstone at 3 feet



Sieve Size	% Passing
3"	-
2 ½"	-
2"	-
1 ½"	-
1"	-
¾"	-
½"	100
⅜"	98
#4	84
#10	66
#40	38
#200	23.2

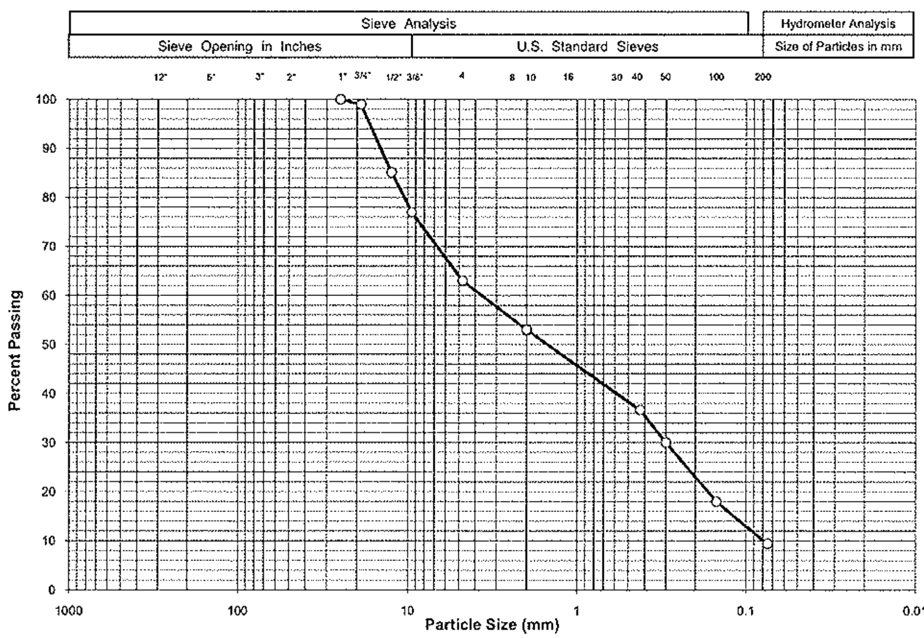
Gravel (%)	16	LL	22	Project Name:	Lee's Ferry Road
Sand (%)	61	PL	17	Boring:	P-7
Fines (%)	23	PI	5	Sample Depth (ft):	6"-2'
Sample Description:	silty sand	SM-SC		A-1-b	(0)

Yeh & Associates, Inc.
Geotechnical Engineering Consultants

SIEVE ANALYSIS

Drawn By:	FJP	Project No.:	211-052
Checked By:	TLA	Figure No.:	-
Date:	05/10/11		

Revised 04/27/2004



Sieve Size	% Passing
3"	-
2 ½"	-
2"	-
1 ½"	-
1"	100
¾"	99
½"	85
⅜"	77
#4	63
#10	53
#40	37
#200	9.4

Gravel (%)	37	LL	NV	Project Name:	Lee's Ferry Road
Sand (%)	54	PL	NP	Boring:	P-8
Fines (%)	9	PI	NP	Sample Depth (ft):	ABC 4"-6"
Sample Description:	poorly-graded sand with silt	SP-SM		A-1-b	(0)

Yeh & Associates, Inc.
Geotechnical Engineering Consultants

SIEVE ANALYSIS

Drawn By:	FJP	Project No.:	211-052
Checked By:	TLA	Figure No.:	-
Date:	05/10/11		

Revised 04/27/2004

Appendix H – Central Federal Lands Highway Division – Culvert Assessment Report (Dated: June 18-20, 2012)

<table>
<tr><td colspan="3">U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION

CULVERT ASSESSMENT REPORT</td></tr>
<tr><td>REGION NO.
INTER MTN</td><td>REPORT ON: AZ PRA GLCA 5(2)
Lee's Ferry Access Road</td><td>DIVISION:
CFLHD</td></tr>
<tr><td>DATE:
June 18-20, 2012</td><td>INSPECTION MADE BY:
Scott Hogan (Hydraulic Engineer, CFLHD)</td><td>PROJECT NO.:
AZ PRA GLCA 5(2)</td></tr>
<tr><td colspan="3">IN COMPANY WITH:
Melanie Monarco (Roadway Designer, CFLHD) Tim Windle (Civil Engineer, GCNRA)</td></tr>
</table>

During the week of June 18, 2012 the CFLHD inspection team visited the Lees Ferry Access Road to perform a culvert assessment of all culverts along the 5.7 mile route. The access road extends from US-89A at Marble Canyon (Project Station 100+00 ft) northeast along the Colorado River to the Lees Ferry Boat Launch (Sta 403+07). The team was equipped with the Federal Lands culvert rover to support detailed culvert inspection as necessary, and were accompanied at several of the culvert assessments by Tim Windle. All station references are based on the 95% project plans for Lee's Ferry Access Road & Paria Bridge, dated May 2012.

A total of 43 culverts were assessed in accordance with the procedures outlined in the "FHWA FLH Culvert Assessment and Decision-Making Procedures Manual" (April 2010). Basic site data were collected at each culvert crossing, including; culvert type, size, length, skew, approximate cover, pipe material, end treatment type, and other noted key features. The initial assessment involved a visual inspection of both ends of the culvert and subsequently the rover was deployed if problems were detected or if the midsection of the culvert was not visible from either end. Photos of the rover and typical setup are attached.

Elements reviewed during the assessment included invert deterioration, joint condition, cross section deformation, corrosion, cracking, end treatment condition, amount of debris and sediment blockage, and scour protection. Each element was assigned a condition rating code based on the observations. The overall rating for each culvert was assigned based on the lowest individual element rating. A summary of the codes along with their description and recommended action is provided below.

Culvert Assessment Rating Codes

Code	Description
Good	Like new, with little or no deterioration, structurally sound and functionally adequate
Fair	Some deterioration, but structurally sound and functionally adequate
Poor	Significant deterioration and/or functional inadequacy, requiring repair action that should, if possible, be incorporated into the planned roadway project
Critical	Very poor condition that indicates possible imminent failure that could threaten public safety, requiring immediate repair action
Unknown	All or part of the culvert is inaccessible for assessment or a rating cannot be assigned

A summary listing of all culverts, with basic assessment data, overall rating, and recommendations is provided as an attachment. There is a significant range in culvert sizes, from a 21"x15" Arch CMP to a 12 ft x 12 ft concrete box culvert. Most of the CMP culverts are rated in fair condition primarily because the original bituminous lining included on the culverts is cracked and flaking off. These culverts are still in adequate condition, but the linings are no longer effective. The majority of the small CMP culverts (less than 48”) appeared to have bituminous linings (inside and outside surfaces), except for the 18” CMPs near the campground. As shown in the attached typical photos, these culverts exhibited extensive corrosion and are recommended for replacement. The double 48” CMPs at Sta 403+08 also showed a moderate level of corrosion and perforation and should be considered for replacement. A close-fit culvert liner could be an option at this crossing, but since the culverts are shallow, the cost of replacement would be comparable to the lining cost (not including the cost of the two headwalls). Based on the corrosion potential that was observed, we recommend that all new culverts include an abrasion and corrosion resistant lining, preferably a polymeric coating. One example of this type of lining is the Contech Trenchcoat product line.

The 72” CMP at Sta 324+54 is the only culvert rated in the critical category. The invert has failed and buckled due to abrasion and corrosion. As a result, one of the downstream joints failed and was bent inwards from recent high flows, exposing the embankment to subsequent flows. This failure was identified during a previous site visit and has been temporarily mitigated by Park staff. The exposed edges of the culvert joint were removed and the voids have been filled with concrete. The culvert remains in critical condition, since much of the invert has been compromised. The repair, involving a 60” slip lining, is planned for this fall.

Several culverts that have been filled with sediment deposition during recent storm events, or have been covered by roadway operations, are in need of cleaning, as specified on the attached culvert summary. These should be addressed by the Park or included in the project construction contract.

Four of the culverts that are completely filled with sediment appear to be a significant, recurring maintenance problem that may warrant an alternative drainage solution. Three of these culverts are located on the road grade that is adjacent to Cathedral Wash from Sta 155+31 to 164+80. Expanding the roadside ditch in this reach to capture and divert the sediment laden runoff into Cathedral Wash rather than under the roadway, near Sta 174+49, would be worth evaluating as an alternative. The improved ditch would discharge into Cathedral Wash downstream of the 12ft x 12ft box culvert. Similarly, the culvert at Sta 247+25 may be eliminated if the tributary drainage could be diverted to the upstream end of the proposed box culvert at Sta 243+30

Recommendations

Following is a summary of the recommendations from the culvert assessment. Specific locations and details are provided in the attached culvert summary.

- Eliminate three proposed culvert replacements (Sta 155+31 to 164+80) and expand the roadside ditch to outlet at the downstream end of the 12x12 box culvert at Sta 174+49
- Eliminate the proposed culvert replacement at Sta 247+25 and divert flows through the roadside ditch to the new box culvert at Sta 243+40
- Replace six culverts in addition to those identified for replacement on the current project plans (See attached culvert summary)
- Add a slip-lining to the 72” CMP at Sta 323+54 (currently included in the project plans)
- Add outlet protection at thirteen culverts (a few are undermined and require a gabion drop in addition to a revet mattress or riprap) (see attached culvert summary)
- Clean four culverts (includes inlet, barrel, and outlet, and vegetation removal) (see attached culvert summary)

Please contact me if you have any questions, (720) 963-3742.

APPROVED FOR DISTRIBUTION

7/9/12

Matt Ambroziak Date
Project Manager

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FLH Culvert Rover

Typical rover operations set-up

Sta 324+54 72” CMP corrosion and perforation and invert deterioration

Sta 324+54 72” CMP failed joint (view upstream) before temporary repair (left) and after repair (right)

Typical corrosion observed in the 18” CMPs near the campground (Sta 331+24 through Sta 340+60)

Typical corrosion and invert deterioration observed in the two 48” CMPs at Sta 403+08 (end of project near the boat launch)

Typical culvert outlet where a gabion drop and
revet mattress are recommended for erosion protection

Culvert Assessment Data and Recommendations

AZ GLCA 5(2) Lees Ferrry Road
Culvert Assessment
Performed 6/18-21/2012

End Treatments

P = Projecting — H/W = Headwall & Wingwalls
M =Mitered — E = End Section
H = Headwall — DI = Drop Inlet

ID No.	Stationing on CFL Tioga Rd Plans	Approximate Length (ft)	Skew (deg.)	Approximate Cover (ft)		Culvert Size & Type	End Treatments		Overall Rating	Clean Culvert	Add Outlet Protection	Repair Culvert	Replace Culvert	Add culvert lining	Fold n Form Lining	Notes
				U.S	D.S		Inlet	Outlet								
1	101+76	75	0	12	15	8'x8' RCBC	H/W	H/W	Good							
2	106+38	40	0	4	5	28"x20" ACMP	E	E	Good							
3	124+14	40	0	4	5	28"x20" ACMP	DI	E	Fair				X			Current design specifies this culvert to be replaced.
4	128+13	39	0	2	4	24" CMP	DI	E	Fair				X			Current design specifies this culvert to be replaced.
5	132+88	40	0	2	4	28"x20" ACMP	DI	E	Good				X			Current design specifies this culvert to be replaced.
6	155+31	43	0	2	5	28"x20" ACMP	DI	E	Unknown							Recommend eliminating culvert and expanding roadside ditch
7	158+35	43	0	2	4	28"x20" ACMP	DI	E	Unknown							Recommend eliminating culvert and expanding roadside ditch
8	164+80	36	0	2	3	35"x24" ACMP	DI	E	Unknown							Recommend eliminating culvert and expanding roadside ditch
9	174+49	47	10	2	2	12'x12' RCBC	H/W	H/W	Poor		X					Undermined at outlet, add gabion drop at oulet and revet mattress
10	184+54	51	10	3	4	36" CMP	E	E	Fair							
11	186+82	49	0	4	5	2 x36" CMP	E	E	Fair							
12	189+82	49	35	1.5	5	28"x20" ACMP	E	E	Fair		X					
13	192+42	40	0	3	4	24" CMP	H/W	E	Fair	X						
14	201+32	42	0	2	5	21"x15" ACMP	H/W	E	Fair	X						Culvert undersized, replace with larger pipe
15	211+60	38	0	1.5	3	21"x15" ACMP	H/W	E	Fair				X			Current design specifies this culvert to be replaced.
16	218+36	36	0	1.5	3	21"x15" ACMP	P	E	Poor				X			Current design specifies this culvert to be replaced.
17	222+25	36	0	2	4	21"x15" ACMP	H/W	E	Fair							Current design specifies this culvert to be replaced.
18	226+26	39	10	2	3	21"x15" ACMP	H/W	E	Poor		X					Replace end section and add outlet scour protection
19	243+30	39	10	1.5	3	48" CMP	H/W	H/W	Fair				X			Insufficient capacity noted, specfied to be replaced with current project
20	247+25	36	0	2	4	21"x15" ACMP	DI	P	Unknown							Consider eliminating and redirecting flows via ditch to Sta 243+30
21	255+91	36	0	2	2.5	21"x15" ACMP	E	E	Fair		X					
22	258+08	36	0	2	3	28"x20" ACMP	E	E	Fair		X					
23	262+97	40	0	2	4	21"x15" ACMP	DI	E	Fair		X					
24	266+60	40	0	2	4	21"x15" ACMP	H/W	E	Fair							
25	272+21	36	0	1.5	3	21"x15" ACMP	H/W	E	Fair							
26	281+00	36	0	1.5	3	28"x20" ACMP	E	E	Fair		X					
27	284+73	57	30	4	8	36" CMP	E	E	Fair		X					Add gabion drop at oulet and revet mattress
28	285+69	40	0	1.5	2	2 X 48" CMP	H/W	H/W	Fair		X					Add revet mattress approx 12' long x 15' wide
29	287+76	37	0	1.5	3	21"x15" ACMP	E	E	Fair		X		X			Current design specifies this culvert to be replaced.
30	299+21	60	0	6	15	21"x15" ACMP	E	E	Fair		X					Add gabion drop at outlet and revet mattress
31	301+71	36	0	1	4	21"x15" ACMP	DI	E	Fair							
32	308+44	71	40	7	9	60" CMP	H/W	H/W	Fair		X					
33	323+04	55	10	2	5	57"x38" ACMP	M	?	Fair	X	X					Keep existing pipe, excavate outlet and add rundown
34	323+54	165	0	12	17	72" CMP	H/W	M	Critical					X		Add sliplining

ID No.	Stationing on CFL Tioga Rd Plans	Approximate Length (ft)	Skew (deg.)	Approximate Cover (ft)		Culvert Size & Type	End Treatments		Overall Rating	Clean Culvert	Add Outlet Protection	Repair Culvert	Replace Culvert	Add culvert lining	Fold n Form Lining	Notes
				U.S	D.S		Inlet	Outlet								
35	331+24	37	0	1.5	5	18" CMP	E	E	Poor				X			Replace due to deformation and corrossion, due to debris potential replace with larger culvert
36	333+04	76	10	10	12	18" CMP	P	E	Poor				X			Replace due to corrossion, due to debris potential replace with larger culvert
37	335+42	68	0	7	10	18" CMP	E	P	Poor				X			Replace due to corrossion, due to debris potential replace with larger culvert
38	340+60	72	10	10	15	18" CMP	P	E	Poor				X			Replace due to corrossion, due to debris potential replace with larger culvert
39	355+86	70+	0	12	20	24" CMP	?	P	Poor				X			Abandon existing, add new culvert with rundown higher in embankment
40	356+47	65	0	4	4	42" x 29" ACMP	?	P	Fair	X						Excavate inlet
41	371+65	75	0	1	4	24" CMP	H/W	P	Good							
42	371+65	75	0	1.5	4	36" CMP	H/W	P	Good							
43	403+08	73	0	2	3	2 x 48" CMP	H/W	H/W	Poor				X			Corrosion will limit the life of the culverts. Compare cost of lining vs. replacement

Additional notes:

1) Based on the observed potential for corrosion caused by the native backfill materials we recommend that all new culverts include a polymeric coating (inside and out)

2) Culverts identified in fair condition should have significant project life remaining, with only minor flaws noted.

Culverts in poor condition should be replaced with the upcoming road project. The culvert in critical condition should be addressed as soon as possible.