RJH CONSULTANTS, INC.

GEOTECHNICAL AND
WATER RESOURCES ENGINEERING

BREACH INUNDATION MAPPING REPORT

FISH CREEK DAM

ROUTT COUNTY, COLORADO

Submitted to
City of Steamboat Springs
P.O. Box 775088
Steamboat Springs, Colorado 80477

Submitted by
RJH Consultants, Inc.
9800 Mt. Pyramid Court, Suite 330
Englewood, Colorado 80112
303-225-4611
www.rjh-consultants.com

December 2013
Project 13117

G. George Solvensky, P.E.
Project Manager

TABLE OF CONTENTS

List of Tables

List of Figures

Appendices

SECTION 1 - INTRODUCTION

1.1 Purpose

The purpose of this Breach Inundation Mapping Report (Report) is to present the results of the dam breach analysis and inundation limits for a simulated failure of Fish Creek Dam (Project). This evaluation was prepared in accordance with the Colorado Office of the State Engineer (SEO) *Rules and Regulations for Dam Safety and Construction* (Rules) (SEO, 2007) and *Guidelines for Dam Breach Analysis* (Guidelines) (SEO, 2010).

The simulated breach analysis was performed to support inundation mapping for the Fish Creek Dam Emergency Action Plan (EAP) and these analytical methods are only appropriate for these purposes. The actual flood inundation limits from a dam breach of Fish Creek Dam depend on actual dam failure flood conditions and may differ from areas shown on the Report mapping. The models documented in this Report should not be used for other purposes.

1.2 Objectives

The objectives of this simulated dam breach analysis are as follows:

- Develop dam breach parameters and a dam breach hydrograph for a "sunny-day" failure event.
- Route the dam breach hydrograph through the downstream drainage.
- Develop dam breach inundation limits.
- Evaluate dam breach inundation parameters (i.e., depth, velocity, etc.) at critical locations throughout the downstream drainage.

1.3 Project Location and Background

Fish Creek Dam is located approximately 8 miles east of Steamboat Springs in Routt County, Colorado. The site is located in Section 10 and 15, Township 6 North, Range 83 West of the 6th Principal Meridian. The dam is located on Middle Fork Fish Creek and impounds a reservoir with a storage capacity of approximately 4,150 acre-feet (ac-ft), and is supplied by direct inflow from Middle Fork Fish Creek. The Project location is shown on Figure 1.1.

According to design documents provided by the SEO, the dam was originally constructed in 1954 and consisted of an earthen embankment dam with a sand filter drain at the downstream toe, and a 24-inch-diameter steel outlet works conduit extending through approximately the center of the dam embankment. A large rehabilitation project was completed in 1972 and consisted of raising the dam by about 11 feet, extending the filter drain, extending the outlet works conduit, and constructing a new saddle dam and 80-foot-wide rockcut spillway along the north side of the reservoir. The saddle dam consisted of an earthen embankment with clay core and was about 15 feet high. The spillway discharges to an unnamed tributary, which joins Middle Fork Fish Creek about 0.5 mile downstream of the main dam.

An additional rehabilitation project was completed in 1997 and consisted of raising the main dam by about 20.5 feet, extending the existing outlet works conduit with an 18-inch-diameter steel pipe, lining the existing outlet works conduit with an 18-inch-diameter steel pipe, installing a new 36-inch-diameter steel upper-level outlet works conduit, raising the saddle dam by about 22.0 feet, and installing a 10-foot-wide, riprap-lined low-flow channel along the spillway. The new outlet works conduit extends through the left portion of the main dam and into the left abutment before discharging to Middle Fork Fish Creek, near the downstream toe of the dam.

Based on the location of the Project and review of available data, the flood routing model and inundation mapping were developed using 2-foot topography provided the City of Steamboat Springs (Steamboat Springs), 3-meter Digital Elevation Mapping (DEM) topographic data provided by the Steamboat Springs Fire District, and cross section data from the Federal Emergency Management Agency (FEMA) Flood Insurance Study (FIS) effective hydraulic models (FEMA, 2005). Further discussion of topographic data is provided in Section 4.4.

Inundation mapping for this Report was developed using National Agriculture Imagery Program (NAIP) 1-meter resolution aerial photography as figure backgrounds.

1.4 Scope of Services

RJH Consultants, Inc. (RJH) performed the following tasks for this evaluation:

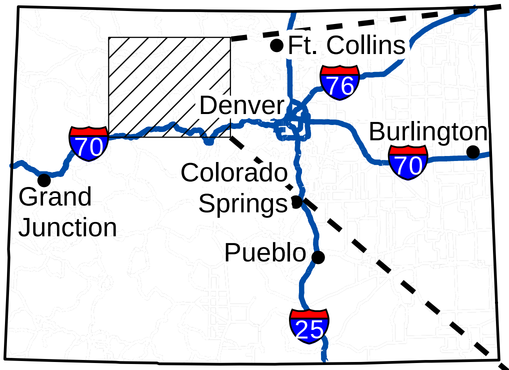
- Obtained digital topographic data, aerial photographs, and other information that describes the downstream drainage.
- Developed dam breach parameters for a simulated failure of Fish Creek Dam.

- Developed a hydrologic model to evaluate the attenuation of the dam breach hydrograph through the downstream drainage.
- Developed a hydraulic model to evaluate dam breach water surface elevations, velocities, and inundation limits in the downstream drainage.
- Developed inundation maps.
- Prepared this Report.

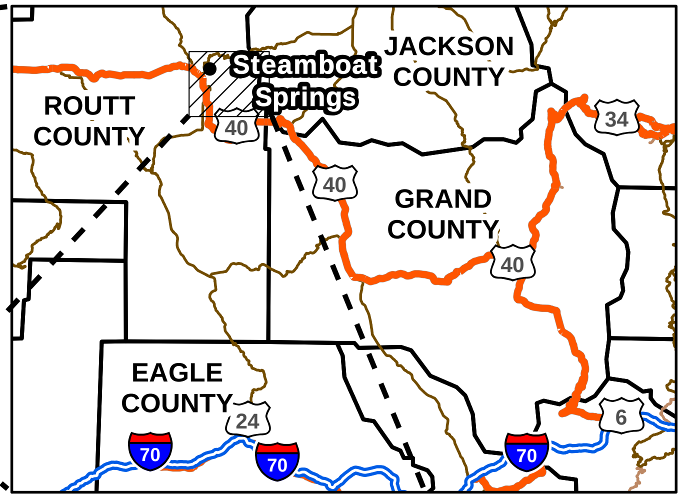
1.5 Authorization and Project Personnel

RJH performed the work described in this Report in accordance with the terms and conditions of the contract between RJH and Steamboat Springs for Engineering Services for Dam Inundation Mapping dated September 4, 2013. The following RJH personnel are responsible for the work described in this Report:

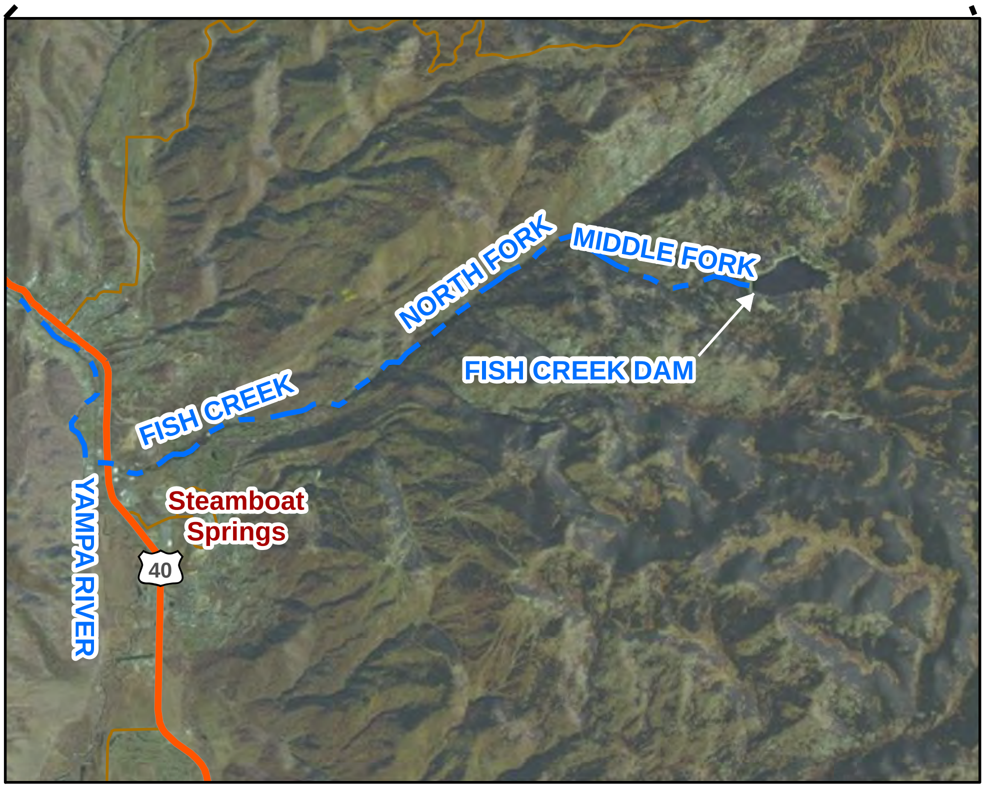
Project Manager	George Slovensky, P.E.
Project Engineer	Eric Hahn, P.E.
Technical Review	Korey Kadrmas, P.E.



PROJECT VICINITY MAP
(NOT TO SCALE)



PROJECT LOCATION MAP
(NOT TO SCALE)



SITE LOCATION MAP
(NOT TO SCALE)

RJH CONSULTANTS, INC.	FISH CREEK DAM BREACH INUNDATION MAPPING REPORT	SITE LOCATION AND VICINITY MAPS
	PROJECT NO. 13117	DECEMBER 2013 **Figure 1.1**

P:\13117 - Steamboat\Engineering\GIS\Fish Creek\13117_Site_Location.mxd

SECTION 2 - PROJECT DESCRIPTION

2.1 Dam and Reservoir Characteristics

Fish Creek Dam is a large, high hazard, earth embankment dam with a crest at about elevation (El.) 9894.0. The upstream slope is about 3 horizontal to 1 vertical (H:V) and the downstream slope is about 2H:1V. The crest is approximately 868 feet long. The reservoir has a storage capacity of about 4,150 ac-ft at about maximum normal pool El. 9886.0. The maximum normal pool of the reservoir is controlled by a rockcut spillway channel that discharges to an unnamed tributary of Middle Fork Fish Creek, located to the north of the reservoir.

Key characteristics of the dam and reservoir are provided in Table 2.1.

TABLE 2.1
DAM AND RESERVOIR CHARACTERISTICS

Active Storage Volume	4,150 ac-ft
Surface Area at Normal Pool	139 acres
Dam Crest Elevation	9894.0 feet
Natural Ground Elevation Below Crest	9820.0 feet (approx.)
Spillway Crest Elevation	9886.0 feet
Maximum Normal Water Surface Elevation	9886.0 feet

2.2 Drainage Characteristics

Fish Creek Dam is located on Middle Fork Fish Creek about 2 miles upstream of its confluence with North Fork Fish Creek. North Fork Fish Creek then discharges to Fish Creek, which subsequently discharges to the Yampa River, near the south end of Steamboat Springs. The Yampa River then flows generally northwest through Steamboat Springs. The following stream reaches in downstream order would be impacted by a failure of Fish Creek Dam:

- Middle Fork Fish Creek (approximately 2 miles).
- North Fork Fish Creek (approximately 2.3 miles).
- Fish Creek (approximately 3.8 miles).
- Yampa River (approximately 14.6 miles).

Additional information regarding the drainage characteristics of the downstream channels is provided in Section 4.2.

SECTION 3 - BREACH HYDROGRAPH ESTIMATION

3.1 General

A simulated dam breach was evaluated for a "sunny-day" scenario with the reservoir at maximum normal pool elevation with no base flow. The "sunny-day" failure was assumed to result from a piping failure. No base flow was included because anticipated base flows would be negligible compared to peak breach flows. RJH developed the breach analysis using the "simple" level of breach analysis structure in accordance with the SEO Guidelines. The simple approach was selected because it a) generally produces conservative flood limits that are appropriate for an EAP, and b) the results of the breach analysis are not anticipated to change the hazard classification. The simple breach analysis approach consists of the following components:

- Breach Parameter Estimate: Empirical methods.
- Breach Hydrograph Estimation: Parametric hydrologic model (HEC-HMS).
- Breach Hydrograph Routing: Hydrologic model (HEC-HMS).
- Hydraulics at Critical Sections: Steady state hydraulics (HEC-RAS).

3.2 Breach Parameter Estimation Methods

RJH evaluated breach parameters using the Froelich (2008) method and time to failure using the Washington State method in accordance with recommendations in the SEO Guidelines for a large-size dam with a "high" storage intensity. RJH initially considered using the Froelich method to estimate time to failure; however, in our opinion, this resulted in an unrealistically short time to failure for a large, earthen embankment designed to modern standards. The Washington State method for cohesionless soils was selected because it accounts for the embankment geometry and volume of eroded material. The "cohesionless" soils classification was selected because available data was insufficient to classify the material as having significant cohesion. Input parameters were developed based on available data from the design drawings and previous SEO inspections. Documentation of this analysis is provided in Appendix A and the results are summarized in Table 3.1.

TABLE 3.1
SUMMARY OF BREACH PARAMETER ESTIMATES – SUNNY-DAY FAILURE

Average Breach Width, B_{avg}	140 feet
Bottom Breach Width, B_b	90 feet
Breach Formation Time, t_f	1.0 hours
Breach Side Slopes, z (ZH:1V)	0.7

3.3 Breach Hydrograph Development

The simulated dam breach hydrograph was developed using the U.S. Army Corps of Engineers' (USACE) HEC-HMS Version 3.5 computer software (USACE, 2009). The dam breach parameters shown in Table 3.1 were used in the HEC-HMS program to model the temporal development of the breach and resulting outflow. The HEC-HMS breach hydrograph model resulted in a peak breach outflow of 72,100 cubic feet per second (cfs) and a total breach volume of 4,120 ac-ft. HEC-HMS model input/output, including the breach hydrograph, is provided in Appendix B.

SECTION 4 - DAM BREACH FLOOD ROUTING

4.1 General

RJH performed dam breach analyses to support the development of maps that identify potential inundation limits for the simulated failure of Fish Creek Dam. The breach flow hydrograph was routed downstream a sufficient distance to the point on the Yampa River, where attenuated breach flows become less than the FEMA FIS 100-year discharge. During an actual dam failure, flooding will vary depending on actual conditions including the location, size, depth, and rate of breach development; downstream backwater; local flood conditions; and seasonal variations within the channel including erosion resistance. Because of these and other factors, actual inundation limits may vary from those shown on the referenced inundation figures.

4.2 Roughness Values

Manning's "n" values are a measure of channel roughness and resistance to flow and will impact the routing of the dam breach hydrograph. Manning's "n" values also vary depending on the roughness of the channel and overbanks, and with the depth of flow and type of flow event. Deeper flows will be less affected by a given obstruction than shallower flows. RJH assigned roughness values to representative sections of the floodplain downstream based on a) Manning's "n" values used in the FEMA FIS, b) field visit observations, c) aerial photography, d) published references that provide a description and pictures of stream channels with a recommended typical "n" value, and e) engineering experience and judgment.

RJH divided the downstream drainage into three segments with relatively homogenous hydraulic roughness characteristics (XS = river cross section):

- **XS -0.0 TO XS -5.013 (MIDDLE FORK FISH CREEK, NORTH FORK FISH CREEK, AND FISH CREEK):** The main channel of this stream reach generally consists of a steep mountain stream with large boulders and minimal vegetation. A Manning's "n" value of 0.08 was selected for the main channel, based on the FEMA FIS effective model and confirmed with field visit observations and published references for similar stream channels. The overbanks consist of some areas with thick pine trees and brush and areas of rock, gravel, and short native grasses. A Manning's "n" value of 0.08 was selected for the overbanks, based primarily on aerial photography, field visit observations, and published references for similar overbank areas.

- **XS -5.013 TO XS -8.05 (FISH CREEK):** The main channel of this stream reach generally consists of a steep mountain stream with gravel, cobbles, some boulders, and minimal vegetation. A Manning's "n" value of 0.06 was selected for the main channel, based on the FEMA FIS effective model and confirmed with field visit observations and published references for similar stream channels. The overbanks vary between a) areas with thick pine trees and brush, b) commercial/residential developed areas, and c) a golf course area. Manning's "n" values between 0.08 to 0.10 were selected for the thick pine tree and brush areas, based primarily on field visit observations and published references for similar overbank areas. A Manning's "n" value of 0.06 was selected for the developed areas, based on the FEMA FIS effective model and confirmed with field visit observations. A Manning's "n" value of 0.05 was selected for the golf course areas based on field visit observations and published references for similar overbank areas.
- **XS -8.05 TO XS -22.72 (YAMPA RIVER):** The main channel of this stream reach generally consists of an intermountain valley river that is relatively clean (i.e., no significant boulders or vegetation) with some gentle meandering. Manning's "n" values between 0.04 to 0.045 were selected for the main channel, based on the FEMA FIS effective model and confirmed with field visit observations and published references for similar stream channels. The overbanks vary between a) pasture areas, b) native areas with short grass and some trees, c) native areas with dense trees, and d) commercial/residential developed areas. A Manning's "n" value of 0.05 was selected for the pasture areas, based on the FEMA FIS effective model and confirmed with field visit observations and published references for similar overbank areas. A Manning's "n" value of 0.06 was selected for the native areas with short grass, based on the FEMA FIS effective model and confirmed with field visit observations and published references for similar overbank areas. A Manning's "n" value of 0.10 was selected for native areas with dense trees, based on the FEMA FIS effective model and confirmed with field visit observations and published references for similar overbank areas. Manning's "n" values between 0.05 to 0.06 were selected for the developed areas, based on the FEMA FIS effective model and confirmed with field visit observations.

Documentation of the Manning's "n" analysis is provided in Appendix C.

4.3 Dam Breach Flood Routing

The dam breach hydrograph will attenuate as it travels downstream because of the effects of storage and dispersion within the downstream channel. Attenuation of the dam breach hydrograph was modeled using the HEC-HMS computer software. The Muskingum-Cunge method was selected for channel routing along Middle Fork Fish Creek, North Fork Fish Creek, and Fish Creek because it is a physically based model with input parameters that are simple to define and it compares well against unsteady flow equations, when substantial backwater effects are not anticipated (HEC-HMS User's Manual (USACE, 2009). In RJH's opinion, backwater effects should not be significant in these stream reaches because of the relative uniformity of the channel geometry, overall steepness of the channel, and minimal amount of major flow obstructions.

The Muskingum-Cunge method requires the input of reach length, slope, and geometry. RJH developed channel routing reaches for three relatively homogenous (i.e., similar channel geometry, slope, and roughness characteristics) channel reaches. Values for reach length and slope were obtained from the 2-foot topography. A representative cross section was also developed for each routing reach using the 2-foot topography. Cross sections were selected to approximately represent the typical channel geometry of the reach.

The Modified Puls method was selected for channel routing along the Yampa River. The Modified Puls method is based on level-pool routing concepts and is typically used for channels with significant floodplain storage or backwater effects. RJH developed channel routing reaches for three relatively homogeneous reaches along the Yampa River.

The Modified Puls method requires the determination of storage-discharge relationships for channel reaches. Storage-discharge relationships were estimated for each channel reach by using the HEC-RAS hydraulic model (see Section 4.4). The HEC-RAS model was used to calculate water surface profiles for a range of discharges. For each discharge, the model calculated the flow area at each cross section. Using the average-end area method, the storage was then calculated for each channel reach.

The results of the HEC-HMS breach hydrograph routing are presented in Table 4.1 and model input/output is provided in Appendix B.

TABLE 4.1
HEC-HMS DAM BREACH HYDROGRAPH ROUTING RESULTS

Distance Downstream from Dam (miles)	Sunny-Day Failure	
	Flow (cfs)	Volume (ac-ft)
Fish Creek Dam	72,100	4120.2
2.151	71,651	4126.4
5.013	71,472	4124.8
8.056	70,597	4138.1
11.390	37,573	4138.1
14.317	22,163	4138.1
17.200	15,127	4138.1
22.722	8,203	4132.6

4.4 Dam Breach Flood Hydraulic Analysis and Routing

Dam breach and inundation limits were delineated using the USACE HEC-RAS Version 4.1.0 computer software. A steady flow HEC-RAS model was developed to perform downstream hydraulic analysis of the dam breach flows. The peak dam breach flows shown in Table 4.1 were utilized in the HEC-RAS model and corresponding water surface elevations and velocities were computed at each cross section.

A total of 109 cross sections were used to model Middle Fork Fish Creek, North Fork Fish Creek, Fish Creek, and the Yampa River. Cross sections are labeled as the distance (river miles) from Fish Creek Dam downstream to each cross section. For example, XS -0.857 is located 0.857 mile downstream from the toe of the dam.

The HEC-RAS hydraulic model and inundation mapping were developed using 2-foot topography provided by Steamboat Springs generally within the vicinity of the city limits and 3-meter DEM topographic data provided by the Steamboat Springs Fire District elsewhere. The topographic data was supplemented with surveyed topographic data from the FEMA FIS hydraulic models, where available, to better define the main river channel.

RJH identified the following crossing structures using 2011 aerial photography, FEMA FIS modeling, and limited field observations:

- **STEAMBOAT BOULEVARD BRIDGE (XS -5.47):** Bridge data obtained from field measurements by RJH.

- **PEDESTRIAN BRIDGE (XS -5.518):** Bridge data obtained from field measurements by RJH.
- **ROLLINGSTONE DRIVE BRIDGE (XS -7.60):** Bridge data obtained from field measurements by RJH.
- **HIGHWAY 40 BRIDGE (XS -7.81):** Bridge data obtained from FEMA effective model.
- **RAILROAD BRIDGE (XS -7.93):** Bridge data obtained from FEMA effective model.
- **RAILROAD BRIDGE (XS -8.91):** Bridge data obtained from FEMA effective model.
- **5TH STREET BRIDGE (XS -9.42):** Bridge data obtained from FEMA effective model.
- **13TH STREET BRIDGE (XS -10.06):** Bridge data obtained from FEMA effective model.
- **YAMPA CORE TRAIL PEDESTRIAN BRIDGE (XS -10.52):** Bridge data obtained from FEMA effective model.
- **SHIELD DRIVE BRIDGE (XS -11.1):** Bridge data obtained from FEMA effective model.
- **STEAMBOAT CAMPGROUND BRIDGE (XS -12.4):** Bridge data obtained from FEMA effective model.
- **RAILROAD BRIDGE (XS -14.2):** Bridge data obtained from FEMA effective model.
- **COUNTY ROAD 33B BRIDGE (XS -16.72):** Bridge data obtained from FEMA effective model.
- **RAILROAD BRIDGE (XS -20.6):** Bridge data obtained from FEMA effective model.
- **COUNTY ROAD 179 BRIDGE (XS -21.21):** Bridge data obtained from FEMA effective model.

RJH assumed that the two most upstream bridges (i.e., Steamboat Boulevard bridge and downstream pedestrian bridge) would be blocked with dam breach debris and overtop. RJH did not include the small pedestrian bridges located near XS -7.3, XS -9.1, and XS -9.7, because we concluded that these structures would likely be washed away by the large breach flows. RJH did not include the railroad bridge near XS -9.0, because the bridge is generally oriented parallel to the overall flow lines of the floodplain and we concluded that it would have a minimal impact on flood elevations. All other identified crossings were included in the HEC-RAS model.

4.5 Results

RJH estimated flood inundation limits for the "sunny-day" failure event as shown on Figures 4.1 through 4.15. Hydraulic modeling output is provided in Appendix D. The floodwave was mapped to just upstream of County Road 205 where the peak breach flow becomes less than the estimated 100-year flow of 14,520 cfs in the Yampa River. At this location breach flows would be contained within the regulatory 100-year floodplain.

Table 4.2 presents the following floodwave information for the simulated "sunny-day" failure at specific cross section (stream miles) locations: peak floodwave discharge, peak floodwave velocity, maximum water surface elevation (stage), and peak floodwave arrival time (elapsed time for the peak breach flow to travel from the dam to the referenced cross section).

TABLE 4.2
SIMULATED SUNNY-DAY FAILURE

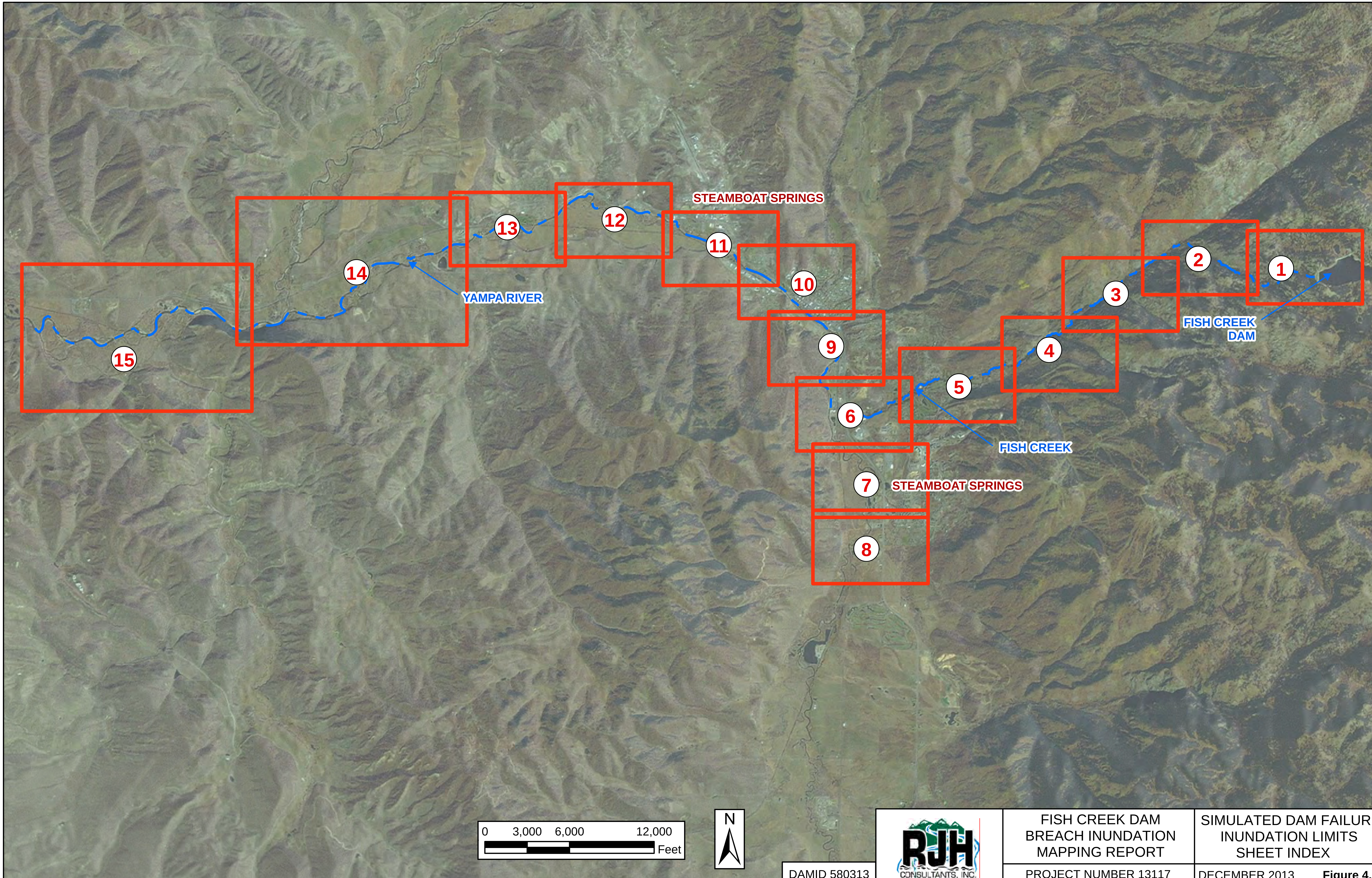
Cross Section (Stream Miles Below Dam)	Peak Flood Wave Discharge (cfs)	Peak Flood Wave Velocity(1) (ft/s)	Maximum Water Surface Elevation(2) (ft)	Peak Flood Wave Arrival Time (HR:MIN)	Notes:
-0.037	72,100	18.00	9833.15	0:00	Downstream of dam
-0.305	72,100	39.05	9690.02	0:01	
-0.562	72,100	26.89	9519.99	0:01	
-0.857	72,100	36.99	9345.47	0:02	
-1.194	72,100	34.40	9141.62	0:02	
-1.474	72,100	36.99	8934.72	0:03	
-1.755	72,100	31.80	8714.38	0:03	
-1.972	72,100	48.26	8502.38	0:03	
-2.151	71,651	33.95	8325.87	0:04	
-2.445	71,651	25.33	8214.94	0:04	
-2.710	71,651	30.52	8117.93	0:05	
-3.095	71,651	24.97	8029.65	0:05	

Cross Section (Stream Miles Below Dam)	Peak Flood Wave Discharge (cfs)	Peak Flood Wave Velocity(1) (ft/s)	Maximum Water Surface Elevation(2) (ft)	Peak Flood Wave Arrival Time (HR:MIN)	Notes:
-3.321	71,651	25.99	7976.18	0:05	
-3.599	71,651	43.87	7832.87	0:06	
-3.856	71,651	32.05	7738.11	0:06	
-4.128	71,651	43.33	7609.5	0:07	
-4.325	71,651	45.38	7469.59	0:07	Confluence of Fish Creek/North Fork Fish Creek
-4.573	71,651	31.37	7368.35	0:07	
-4.819	71,651	26.96	7309.59	0:08	
-5.013	71,472	25.62	7273.1	0:08	
-5.215	71,472	33.06	7202.38	0:09	Upstream limits of Steamboat Springs
-5.413	71,472	8.57	7170.71	0:09	
-5.467	71,472	9.99	7167.21	0:09	Steamboat Blvd. bridge
-5.480	71,472	12.37	7158.19	0:09	
-5.516	71,472	9.11	7154.96	0:09	Pedestrian bridge
-5.520	71,472	9.79	7153.21	0:09	
-5.568	71,472	16.49	7144.26	0:09	
-5.721	71,472	17.57	7126.3	0:10	
-5.952	71,472	26.45	7084.78	0:10	
-6.339	71,472	19.35	7017.23	0:11	
-6.660	71,472	29.16	6943.99	0:12	
-6.834	71,472	21.72	6905.68	0:13	
-7.066	71,472	19.68	6866.26	0:13	
-7.250	71,472	17.42	6836.64	0:14	
-7.491	71,472	13.31	6807.05	0:15	
-7.596	71,472	7.20	6798.75	0:15	Rollingstone Dr. bridge
-7.610	71,472	13.01	6793.75	0:15	
-7.689	71,472	10.87	6785.44	0:15	
-7.756	71,472	8.99	6780.22	0:15	
-7.805	71,472	6.86	6776.98	0:15	Highway 40 bridge
-7.841	71,472	77.85	6768.59	0:15	
-7.926	71,472	6.37	6761.02	0:16	Railroad bridge
-7.939	71,472	3.98	6760.76	0:16	
-8.056	70,598	8.74	6756.52	0:16	Confluence of Yampa River/Fish Creek

Cross Section (Stream Miles Below Dam)	Peak Flood Wave Discharge (cfs)	Peak Flood Wave Velocity(1) (ft/s)	Maximum Water Surface Elevation(2) (ft)	Peak Flood Wave Arrival Time (HR:MIN)	Notes:
-8.188	70,598	15.63	6746.38	0:17	
-8.597	70,598	7.54	6738.12	0:19	
-8.819	70,598	10.72	6731.73	0:21	
-8.907	70,598	6.83	6731.70	0:21	Railroad bridge
-8.927	70,598	9.33	6728.58	0:21	
-9.011	70,598	6.51	6726.14	0:22	
-9.232	70,598	7.61	6722.51	0:23	
-9.410	70,598	9.21	6718.91	0:24	5th St. bridge
-9.428	70,598	9.68	6717.91	0:24	
-9.539	70,598	6.50	6716.52	0:25	
-9.719	70,598	7.26	6714.2	0:26	
-9.962	70,598	7.03	6712.22	0:27	
-10.051	70,598	10.26	6710.10	0:28	13th St. bridge
-10.064	70,598	12.73	6705.99	0:28	
-10.113	70,598	17.42	6700.48	0:28	
-10.255	70,598	16.31	6692.06	0:29	
-10.466	70,598	5.19	6691.49	0:30	
-10.517	70,598	9.14	6688.94	0:31	Yampa Core Trail pedestrian bridge
-10.525	70,598	11.57	6686.36	0:31	
-10.641	70,598	12.34	6679.79	0:32	
-10.841	70,598	5.32	6678.98	0:33	
-11.055	70,598	4.71	6678.00	0:34	
-11.093	70,598	6.91	6676.91	0:34	Shield Dr. bridge
-11.111	70,598	17.05	6669.16	0:34	
-11.142	70,598	9.55	6669.84	0:35	
-11.390	37,573	11.10	6656.25	0:36	
-11.657	37,573	4.95	6651.02	0:39	
-12.165	37,573	8.93	6636.33	0:44	
-12.398	37,573	4.51	6631.59	0:47	Steamboat Campground bridge
-12.406	37,573	3.86	6631.52	0:47	
-12.615	37,573	8.58	6625.88	0:49	
-12.938	37,573	5.02	6619.62	0:53	Downstream limits of Steamboat Springs
-13.457	37,573	4.75	6613.19	0:59	

Cross Section (Stream Miles Below Dam)	Peak Flood Wave Discharge (cfs)	Peak Flood Wave Velocity[(1)] (ft/s)	Maximum Water Surface Elevation[(2)] (ft)	Peak Flood Wave Arrival Time (HR:MIN)	Notes:
-13.772	37,573	4.64	6609.79	1:02	
-14.090	37,573	7.59	6603.15	1:06	
-14.196	37,573	7.02	6600.15	1:07	Railroad bridge
-14.208	37,573	8.39	6598.58	1:07	
-14.317	22,163	4.13	6597.18	1:08	
-14.665	22,163	8.42	6587.98	1:15	
-15.023	22,163	3.31	6582.84	1:22	
-15.426	22,163	5.91	6578.18	1:30	
-16.032	22,163	4.82	6564.21	1:41	
-16.610	22,163	2.75	6556.04	1:53	
-16.707	22,163	3.64	6554.54	1:54	County Road 33A bridge
-16.715	22,163	7.29	6552.31	1:55	
-16.786	22,163	3.67	6551.63	1:56	
-17.20	15,127	2.60	6547.09	2:04	
-17.665	15,127	4.78	6541.04	2:13	
-18.094	15,127	2.68	6535.86	2:21	
-18.509	15,127	5.80	6532.00	2:29	
-19.137	15,127	4.35	6525.07	2:40	Confluence of Elk River/Yampa River
-19.650	15,127	4.35	6518.76	2:50	
-20.143	15,127	7.51	6511.31	2:59	
-20.502	15,127	1.78	6510.30	3:06	
-20.594	15,127	10.69	6507.67	3:08	Railroad bridge
-20.601	15,127	17.47	6504.41	3:08	
-20.695	15,127	3.92	6503.82	3:10	
-21.099	15,127	1.54	6502.22	3:17	
-21.206	15,127	8.85	6500.23	3:19	County Road 179 bridge
-21.220	15,127	8.51	6498.73	3:20	
-21.278	15,127	3.86	6497.03	3:21	
-21.595	15127	1.75	6493.43	3:27	

Notes:
1. Average velocity from total cross section.
2. NAVD 1988.



FISH CREEK DAM BREACH INUNDATION MAPPING REPORT

SIMULATED DAM FAILURE INUNDATION LIMITS SHEET INDEX

DAMID 580313

RJH CONSULTANTS, INC.

PROJECT NUMBER 13117

DECEMBER 2013

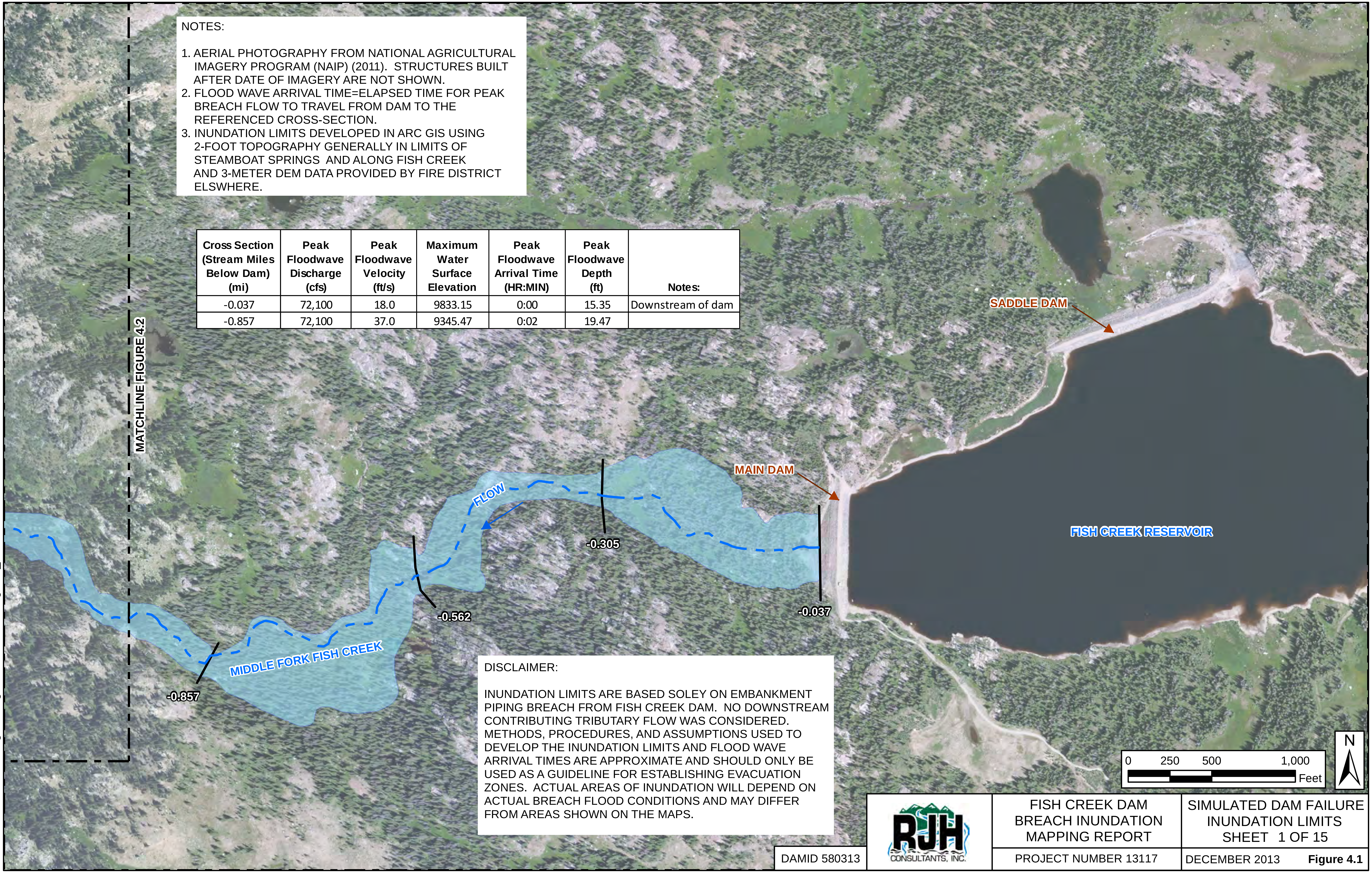
Figure 4.0

P:\13117 - Steamboat\Engineering\GIS\Fish Creek\Index Map.mxd

NOTES:

1. AERIAL PHOTOGRAPHY FROM NATIONAL AGRICULTURAL IMAGERY PROGRAM (NAIP) (2011). STRUCTURES BUILT AFTER DATE OF IMAGERY ARE NOT SHOWN.
2. FLOOD WAVE ARRIVAL TIME=ELAPSED TIME FOR PEAK BREACH FLOW TO TRAVEL FROM DAM TO THE REFERENCED CROSS-SECTION.
3. INUNDATION LIMITS DEVELOPED IN ARC GIS USING 2-FOOT TOPOGRAPHY GENERALLY IN LIMITS OF STEAMBOAT SPRINGS AND ALONG FISH CREEK AND 3-METER DEM DATA PROVIDED BY FIRE DISTRICT ELSWHERE.

Cross Section (Stream Miles Below Dam) (mi)	Peak Floodwave Discharge (cfs)	Peak Floodwave Velocity (ft/s)	Maximum Water Surface Elevation	Peak Floodwave Arrival Time (HR:MIN)	Peak Floodwave Depth (ft)	Notes:
-0.037	72,100	18.0	9833.15	0:00	15.35	Downstream of dam
-0.857	72,100	37.0	9345.47	0:02	19.47	



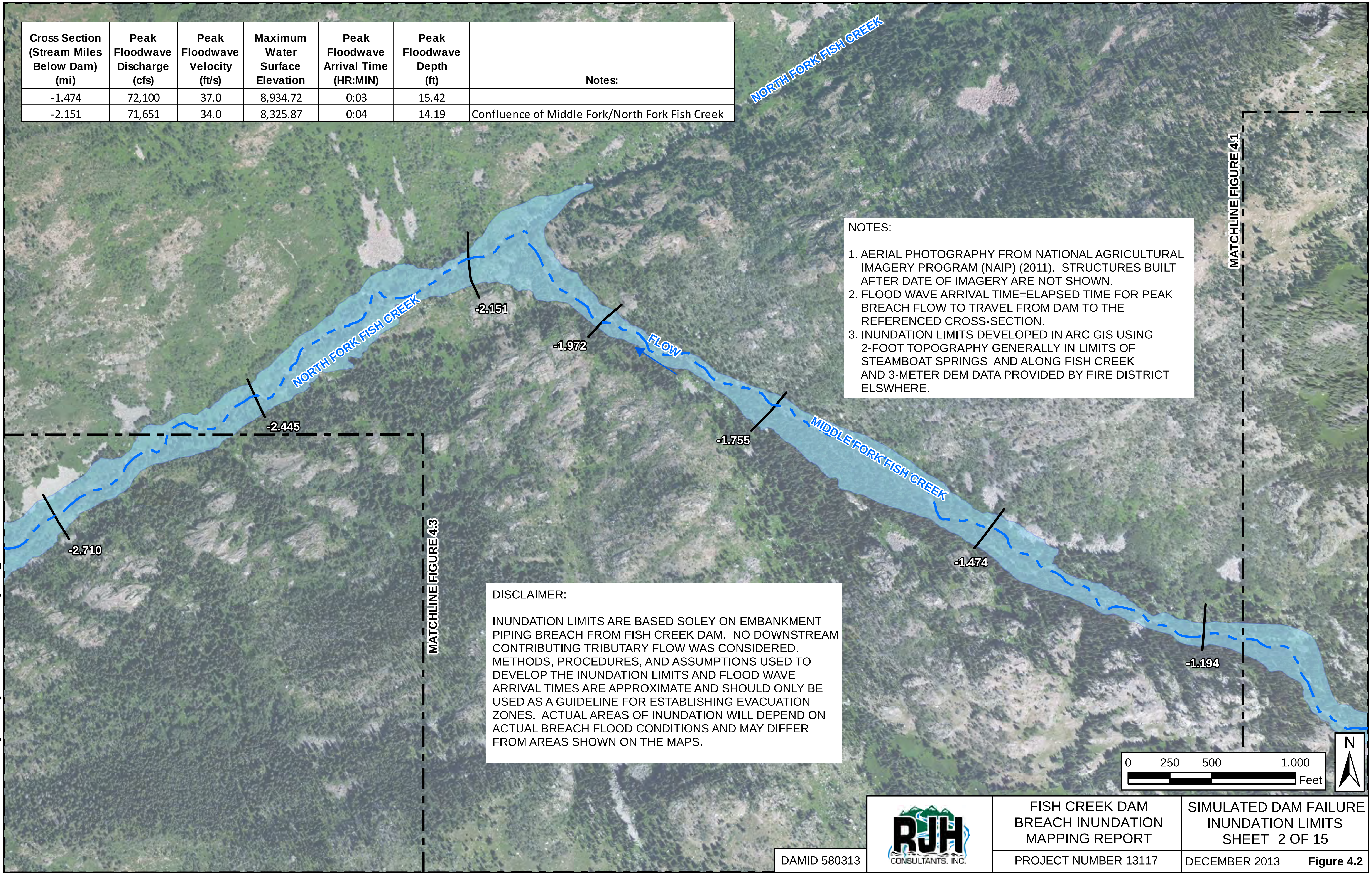
DISCLAIMER:

INUNDATION LIMITS ARE BASED SOLEY ON EMBANKMENT PIPING BREACH FROM FISH CREEK DAM. NO DOWNSTREAM CONTRIBUTING TRIBUTARY FLOW WAS CONSIDERED. METHODS, PROCEDURES, AND ASSUMPTIONS USED TO DEVELOP THE INUNDATION LIMITS AND FLOOD WAVE ARRIVAL TIMES ARE APPROXIMATE AND SHOULD ONLY BE USED AS A GUIDELINE FOR ESTABLISHING EVACUATION ZONES. ACTUAL AREAS OF INUNDATION WILL DEPEND ON ACTUAL BREACH FLOOD CONDITIONS AND MAY DIFFER FROM AREAS SHOWN ON THE MAPS.

	RJH CONSULTANTS, INC.	FISH CREEK DAM BREACH INUNDATION MAPPING REPORT	SIMULATED DAM FAILURE INUNDATION LIMITS SHEET 1 OF 15
DAMID 580313		PROJECT NUMBER 13117	DECEMBER 2013 Figure 4.1

P:\13117 - Steamboat\Engineering\GIS\Fish Creek\Figures_1-13.mxd

Cross Section (Stream Miles Below Dam) (mi)	Peak Floodwave Discharge (cfs)	Peak Floodwave Velocity (ft/s)	Maximum Water Surface Elevation	Peak Floodwave Arrival Time (HR:MIN)	Peak Floodwave Depth (ft)	Notes:
-1.474	72,100	37.0	8,934.72	0:03	15.42	
-2.151	71,651	34.0	8,325.87	0:04	14.19	Confluence of Middle Fork/North Fork Fish Creek



NOTES:

1. AERIAL PHOTOGRAPHY FROM NATIONAL AGRICULTURAL IMAGERY PROGRAM (NAIP) (2011). STRUCTURES BUILT AFTER DATE OF IMAGERY ARE NOT SHOWN.
2. FLOOD WAVE ARRIVAL TIME=ELAPSED TIME FOR PEAK BREACH FLOW TO TRAVEL FROM DAM TO THE REFERENCED CROSS-SECTION.
3. INUNDATION LIMITS DEVELOPED IN ARC GIS USING 2-FOOT TOPOGRAPHY GENERALLY IN LIMITS OF STEAMBOAT SPRINGS AND ALONG FISH CREEK AND 3-METER DEM DATA PROVIDED BY FIRE DISTRICT ELSWHERE.

DISCLAIMER:

INUNDATION LIMITS ARE BASED SOLEY ON EMBANKMENT PIPING BREACH FROM FISH CREEK DAM. NO DOWNSTREAM CONTRIBUTING TRIBUTARY FLOW WAS CONSIDERED. METHODS, PROCEDURES, AND ASSUMPTIONS USED TO DEVELOP THE INUNDATION LIMITS AND FLOOD WAVE ARRIVAL TIMES ARE APPROXIMATE AND SHOULD ONLY BE USED AS A GUIDELINE FOR ESTABLISHING EVACUATION ZONES. ACTUAL AREAS OF INUNDATION WILL DEPEND ON ACTUAL BREACH FLOOD CONDITIONS AND MAY DIFFER FROM AREAS SHOWN ON THE MAPS.

DAMID 580313

RJH CONSULTANTS, INC.

FISH CREEK DAM BREACH INUNDATION MAPPING REPORT

PROJECT NUMBER 13117

SIMULATED DAM FAILURE INUNDATION LIMITS SHEET 2 OF 15

DECEMBER 2013

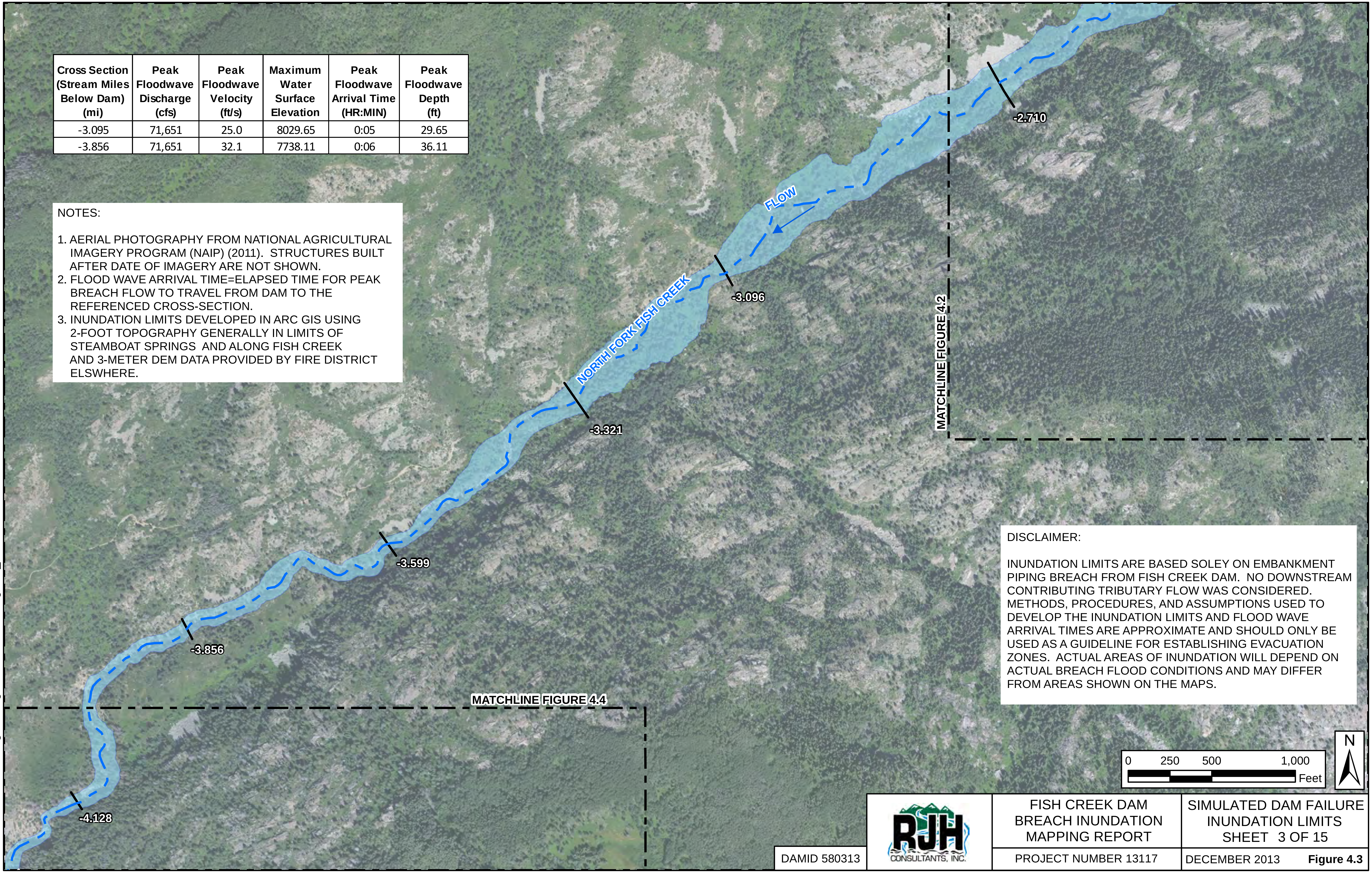
Figure 4.2

P:\13117 - Steamboat\Engineering\GIS\Fish Creek\Figures_1-13.mxd

Cross Section (Stream Miles Below Dam) (mi)	Peak Floodwave Discharge (cfs)	Peak Floodwave Velocity (ft/s)	Maximum Water Surface Elevation	Peak Floodwave Arrival Time (HR:MIN)	Peak Floodwave Depth (ft)
-3.095	71,651	25.0	8029.65	0:05	29.65
-3.856	71,651	32.1	7738.11	0:06	36.11

NOTES:

1. AERIAL PHOTOGRAPHY FROM NATIONAL AGRICULTURAL IMAGERY PROGRAM (NAIP) (2011). STRUCTURES BUILT AFTER DATE OF IMAGERY ARE NOT SHOWN.
2. FLOOD WAVE ARRIVAL TIME=ELAPSED TIME FOR PEAK BREACH FLOW TO TRAVEL FROM DAM TO THE REFERENCED CROSS-SECTION.
3. INUNDATION LIMITS DEVELOPED IN ARC GIS USING 2-FOOT TOPOGRAPHY GENERALLY IN LIMITS OF STEAMBOAT SPRINGS AND ALONG FISH CREEK AND 3-METER DEM DATA PROVIDED BY FIRE DISTRICT ELSWHERE.



DISCLAIMER:

INUNDATION LIMITS ARE BASED SOLEY ON EMBANKMENT PIPING BREACH FROM FISH CREEK DAM. NO DOWNSTREAM CONTRIBUTING TRIBUTARY FLOW WAS CONSIDERED. METHODS, PROCEDURES, AND ASSUMPTIONS USED TO DEVELOP THE INUNDATION LIMITS AND FLOOD WAVE ARRIVAL TIMES ARE APPROXIMATE AND SHOULD ONLY BE USED AS A GUIDELINE FOR ESTABLISHING EVACUATION ZONES. ACTUAL AREAS OF INUNDATION WILL DEPEND ON ACTUAL BREACH FLOOD CONDITIONS AND MAY DIFFER FROM AREAS SHOWN ON THE MAPS.

DAMID 580313

RJH CONSULTANTS, INC.

FISH CREEK DAM BREACH INUNDATION MAPPING REPORT

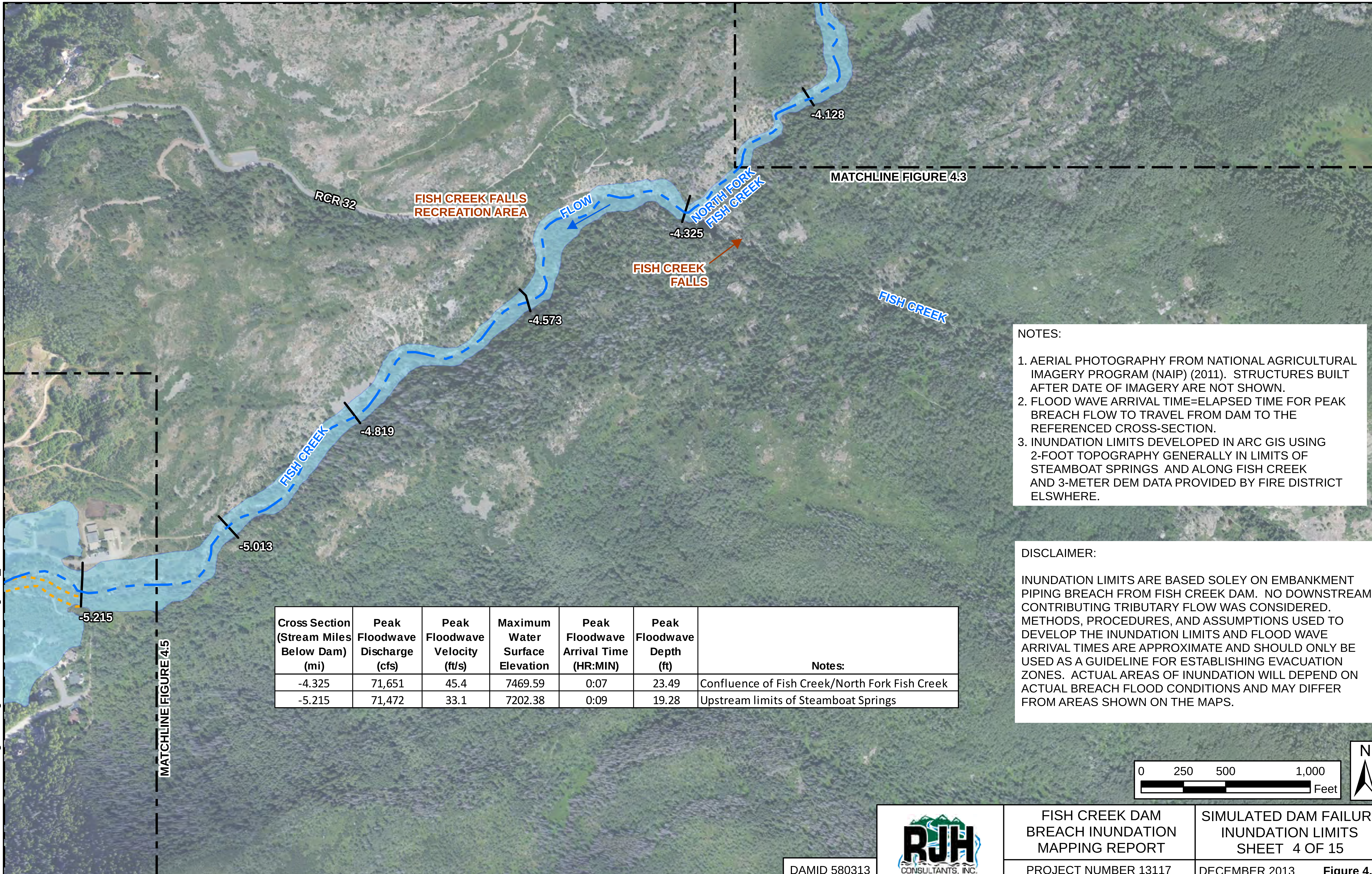
PROJECT NUMBER 13117

SIMULATED DAM FAILURE INUNDATION LIMITS SHEET 3 OF 15

DECEMBER 2013

Figure 4.3

P:\13117 - SteamboatEngineering\GIS\Fish Creek\Figures_1-13.mxd



Cross Section (Stream Miles Below Dam) (mi)	Peak Floodwave Discharge (cfs)	Peak Floodwave Velocity (ft/s)	Maximum Water Surface Elevation	Peak Floodwave Arrival Time (HR:MIN)	Peak Floodwave Depth (ft)	Notes:
-4.325	71,651	45.4	7469.59	0:07	23.49	Confluence of Fish Creek/North Fork Fish Creek
-5.215	71,472	33.1	7202.38	0:09	19.28	Upstream limits of Steamboat Springs

NOTES:

1. AERIAL PHOTOGRAPHY FROM NATIONAL AGRICULTURAL IMAGERY PROGRAM (NAIP) (2011). STRUCTURES BUILT AFTER DATE OF IMAGERY ARE NOT SHOWN.
2. FLOOD WAVE ARRIVAL TIME=ELAPSED TIME FOR PEAK BREACH FLOW TO TRAVEL FROM DAM TO THE REFERENCED CROSS-SECTION.
3. INUNDATION LIMITS DEVELOPED IN ARC GIS USING 2-FOOT TOPOGRAPHY GENERALLY IN LIMITS OF STEAMBOAT SPRINGS AND ALONG FISH CREEK AND 3-METER DEM DATA PROVIDED BY FIRE DISTRICT ELSWHERE.

DISCLAIMER:

INUNDATION LIMITS ARE BASED SOLEY ON EMBANKMENT PIPING BREACH FROM FISH CREEK DAM. NO DOWNSTREAM CONTRIBUTING TRIBUTARY FLOW WAS CONSIDERED. METHODS, PROCEDURES, AND ASSUMPTIONS USED TO DEVELOP THE INUNDATION LIMITS AND FLOOD WAVE ARRIVAL TIMES ARE APPROXIMATE AND SHOULD ONLY BE USED AS A GUIDELINE FOR ESTABLISHING EVACUATION ZONES. ACTUAL AREAS OF INUNDATION WILL DEPEND ON ACTUAL BREACH FLOOD CONDITIONS AND MAY DIFFER FROM AREAS SHOWN ON THE MAPS.

DAMID 580313

RJH CONSULTANTS, INC.

FISH CREEK DAM BREACH INUNDATION MAPPING REPORT

PROJECT NUMBER 13117

SIMULATED DAM FAILURE INUNDATION LIMITS SHEET 4 OF 15

DECEMBER 2013

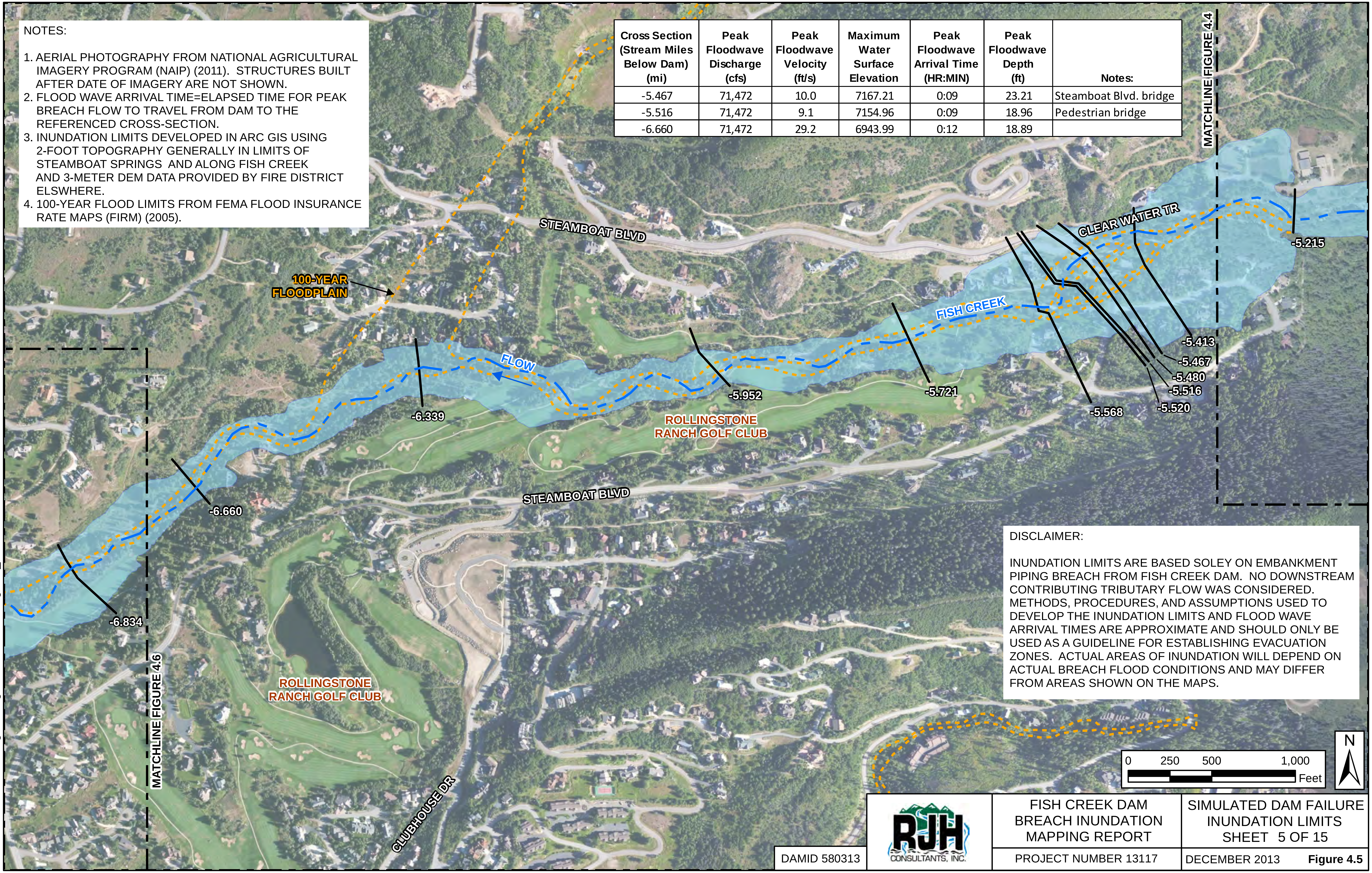
Figure 4.4

P:\13117 - Steamboat\Engineering\GIS\Fish Creek\Figures_1-13.mxd

NOTES:

1. AERIAL PHOTOGRAPHY FROM NATIONAL AGRICULTURAL IMAGERY PROGRAM (NAIP) (2011). STRUCTURES BUILT AFTER DATE OF IMAGERY ARE NOT SHOWN.
2. FLOOD WAVE ARRIVAL TIME=ELAPSED TIME FOR PEAK BREACH FLOW TO TRAVEL FROM DAM TO THE REFERENCED CROSS-SECTION.
3. INUNDATION LIMITS DEVELOPED IN ARC GIS USING 2-FOOT TOPOGRAPHY GENERALLY IN LIMITS OF STEAMBOAT SPRINGS AND ALONG FISH CREEK AND 3-METER DEM DATA PROVIDED BY FIRE DISTRICT ELSWHERE.
4. 100-YEAR FLOOD LIMITS FROM FEMA FLOOD INSURANCE RATE MAPS (FIRM) (2005).

Cross Section (Stream Miles Below Dam) (mi)	Peak Floodwave Discharge (cfs)	Peak Floodwave Velocity (ft/s)	Maximum Water Surface Elevation	Peak Floodwave Arrival Time (HR:MIN)	Peak Floodwave Depth (ft)	Notes:
-5.467	71,472	10.0	7167.21	0:09	23.21	Steamboat Blvd. bridge
-5.516	71,472	9.1	7154.96	0:09	18.96	Pedestrian bridge
-6.660	71,472	29.2	6943.99	0:12	18.89	



DISCLAIMER:

INUNDATION LIMITS ARE BASED SOLEY ON EMBANKMENT PIPING BREACH FROM FISH CREEK DAM. NO DOWNSTREAM CONTRIBUTING TRIBUTARY FLOW WAS CONSIDERED. METHODS, PROCEDURES, AND ASSUMPTIONS USED TO DEVELOP THE INUNDATION LIMITS AND FLOOD WAVE ARRIVAL TIMES ARE APPROXIMATE AND SHOULD ONLY BE USED AS A GUIDELINE FOR ESTABLISHING EVACUATION ZONES. ACTUAL AREAS OF INUNDATION WILL DEPEND ON ACTUAL BREACH FLOOD CONDITIONS AND MAY DIFFER FROM AREAS SHOWN ON THE MAPS.

P:\13117 - SteamboatEngineering\GIS\Fish Creek\Figures_1-13.mxd

DAMID 580313

RJH CONSULTANTS, INC.

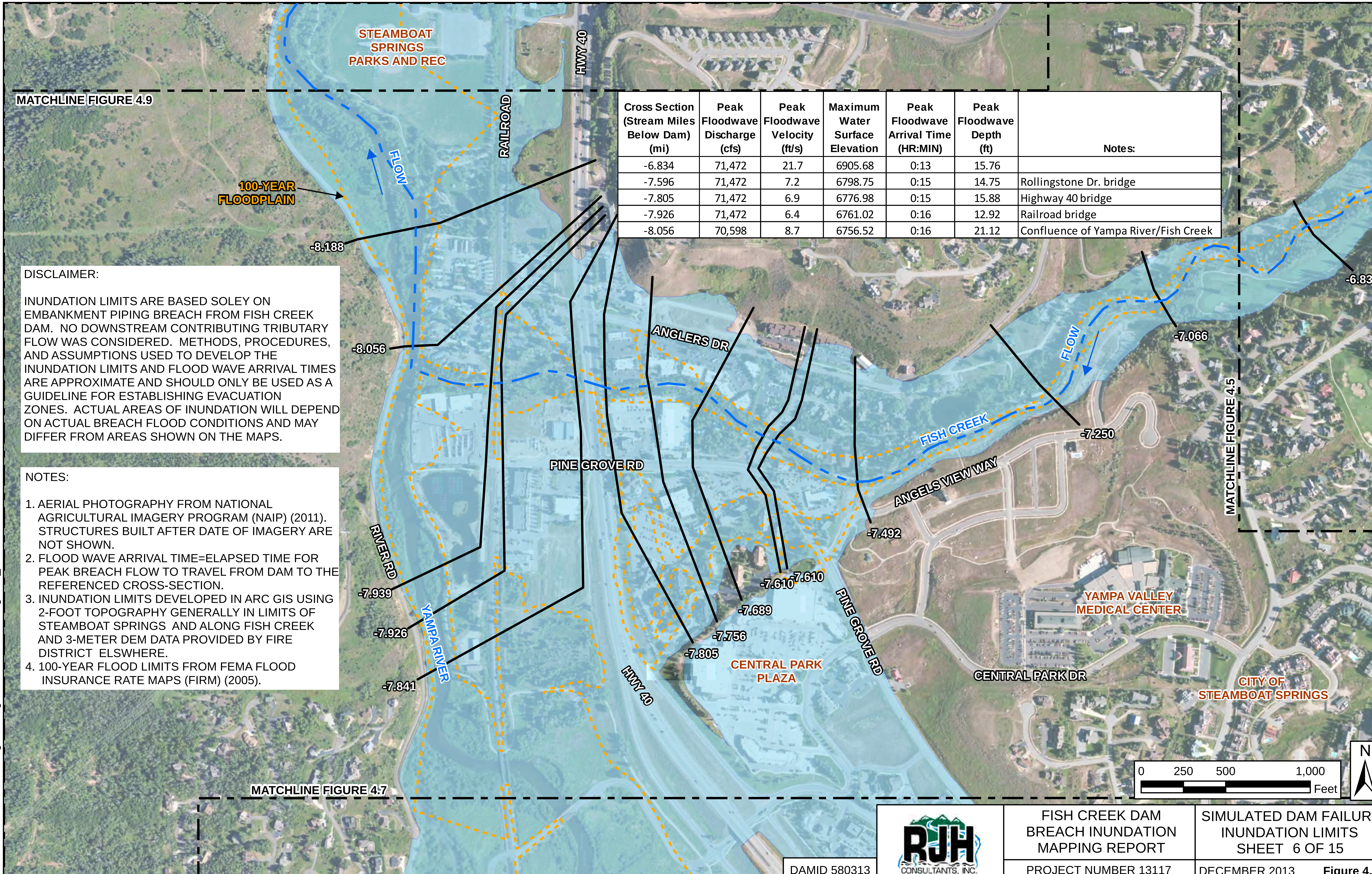
FISH CREEK DAM BREACH INUNDATION MAPPING REPORT

PROJECT NUMBER 13117

SIMULATED DAM FAILURE INUNDATION LIMITS SHEET 5 OF 15

DECEMBER 2013

Figure 4.5



Cross Section (Stream Miles Below Dam) (mi)	Peak Floodwave Discharge (cfs)	Peak Floodwave Velocity (ft/s)	Maximum Water Surface Elevation	Peak Floodwave Arrival Time (HR:MIN)	Peak Floodwave Depth (ft)	Notes:
-6.834	71,472	21.7	6905.68	0:13	15.76	
-7.596	71,472	7.2	6798.75	0:15	14.75	Rollingstone Dr. bridge
-7.805	71,472	6.9	6776.98	0:15	15.88	Highway 40 bridge
-7.926	71,472	6.4	6761.02	0:16	12.92	Railroad bridge
-8.056	70,598	8.7	6756.52	0:16	21.12	Confluence of Yampa River/Fish Creek

DISCLAIMER:

INUNDATION LIMITS ARE BASED SOLEY ON EMBANKMENT PIPING BREACH FROM FISH CREEK DAM. NO DOWNSTREAM CONTRIBUTING TRIBUTARY FLOW WAS CONSIDERED. METHODS, PROCEDURES, AND ASSUMPTIONS USED TO DEVELOP THE INUNDATION LIMITS AND FLOOD WAVE ARRIVAL TIMES ARE APPROXIMATE AND SHOULD ONLY BE USED AS A GUIDELINE FOR ESTABLISHING EVACUATION ZONES. ACTUAL AREAS OF INUNDATION WILL DEPEND ON ACTUAL BREACH FLOOD CONDITIONS AND MAY DIFFER FROM AREAS SHOWN ON THE MAPS.

NOTES:

1. AERIAL PHOTOGRAPHY FROM NATIONAL AGRICULTURAL IMAGERY PROGRAM (NAIP) (2011). STRUCTURES BUILT AFTER DATE OF IMAGERY ARE NOT SHOWN.
2. FLOOD WAVE ARRIVAL TIME=ELAPSED TIME FOR PEAK BREACH FLOW TO TRAVEL FROM DAM TO THE REFERENCED CROSS-SECTION.
3. INUNDATION LIMITS DEVELOPED IN ARC GIS USING 2-FOOT TOPOGRAPHY GENERALLY IN LIMITS OF STEAMBOAT SPRINGS AND ALONG FISH CREEK AND 3-METER DEM DATA PROVIDED BY FIRE DISTRICT ELSWHERE.
4. 100-YEAR FLOOD LIMITS FROM FEMA FLOOD INSURANCE RATE MAPS (FIRM) (2005).

P:\13117 - Steamboat\Engineering\GIS\Fish Creek\Figures_1-13.mxd

DAMID 580313

RJH CONSULTANTS, INC.

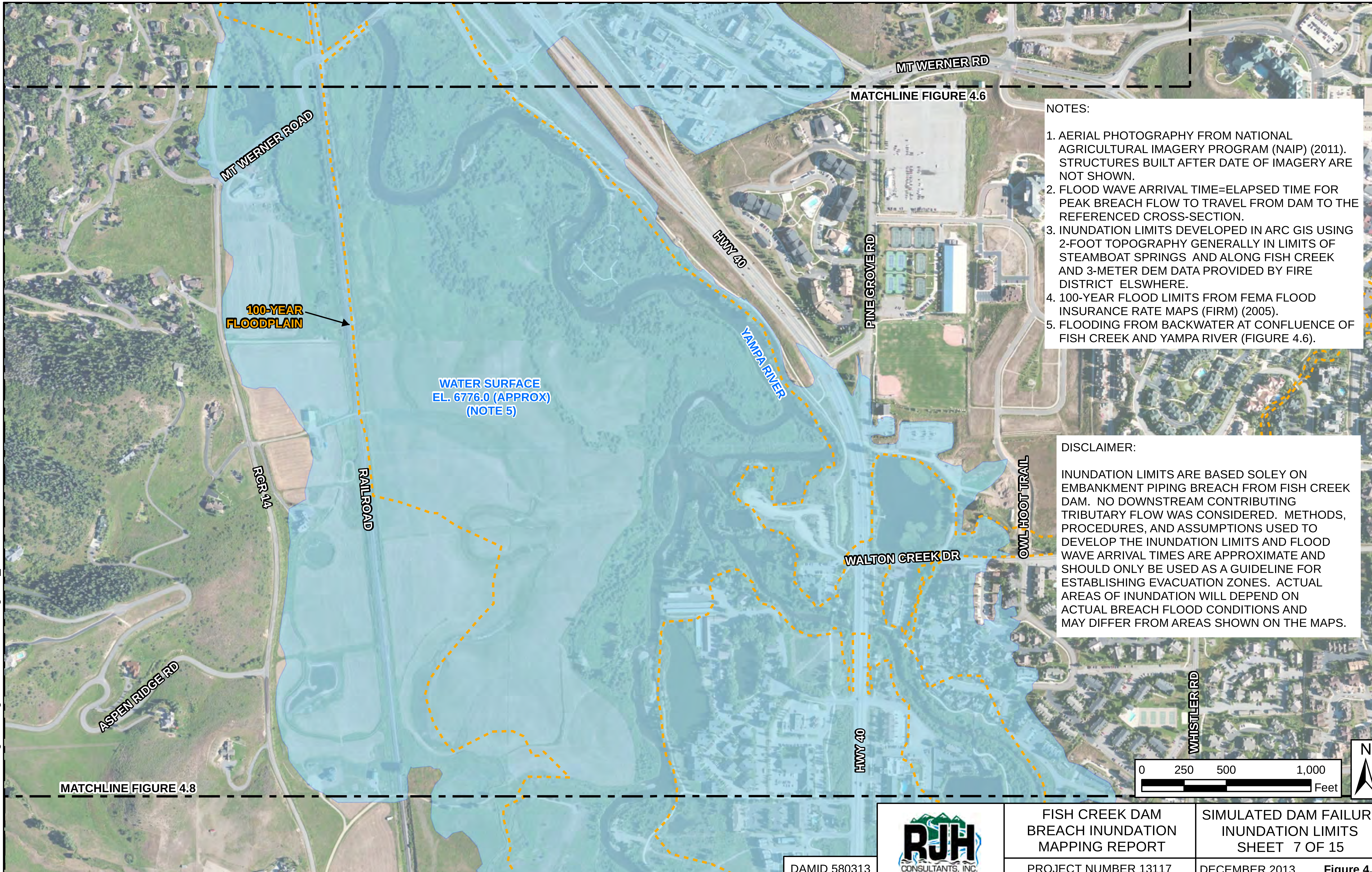
FISH CREEK DAM BREACH INUNDATION MAPPING REPORT

PROJECT NUMBER 13117

SIMULATED DAM FAILURE INUNDATION LIMITS SHEET 6 OF 15

DECEMBER 2013

Figure 4.6



NOTES:

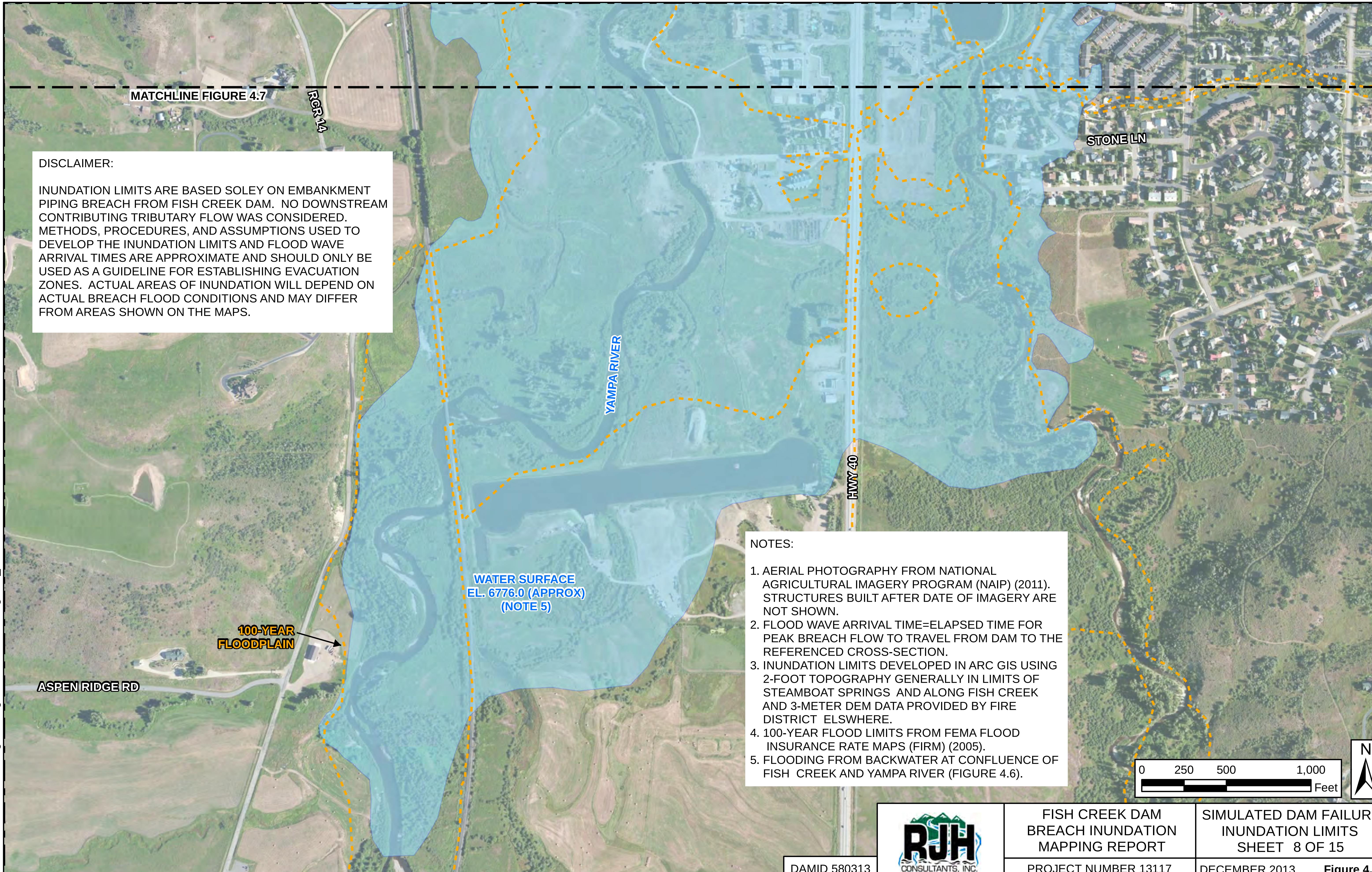
1. AERIAL PHOTOGRAPHY FROM NATIONAL AGRICULTURAL IMAGERY PROGRAM (NAIP) (2011). STRUCTURES BUILT AFTER DATE OF IMAGERY ARE NOT SHOWN.
2. FLOOD WAVE ARRIVAL TIME=ELAPSED TIME FOR PEAK BREACH FLOW TO TRAVEL FROM DAM TO THE REFERENCED CROSS-SECTION.
3. INUNDATION LIMITS DEVELOPED IN ARC GIS USING 2-FOOT TOPOGRAPHY GENERALLY IN LIMITS OF STEAMBOAT SPRINGS AND ALONG FISH CREEK AND 3-METER DEM DATA PROVIDED BY FIRE DISTRICT ELSWHERE.
4. 100-YEAR FLOOD LIMITS FROM FEMA FLOOD INSURANCE RATE MAPS (FIRM) (2005).
5. FLOODING FROM BACKWATER AT CONFLUENCE OF FISH CREEK AND YAMPA RIVER (FIGURE 4.6).

DISCLAIMER:

INUNDATION LIMITS ARE BASED SOLEY ON EMBANKMENT PIPING BREACH FROM FISH CREEK DAM. NO DOWNSTREAM CONTRIBUTING TRIBUTARY FLOW WAS CONSIDERED. METHODS, PROCEDURES, AND ASSUMPTIONS USED TO DEVELOP THE INUNDATION LIMITS AND FLOOD WAVE ARRIVAL TIMES ARE APPROXIMATE AND SHOULD ONLY BE USED AS A GUIDELINE FOR ESTABLISHING EVACUATION ZONES. ACTUAL AREAS OF INUNDATION WILL DEPEND ON ACTUAL BREACH FLOOD CONDITIONS AND MAY DIFFER FROM AREAS SHOWN ON THE MAPS.

DAMID 580313	RJH CONSULTANTS, INC.	FISH CREEK DAM BREACH INUNDATION MAPPING REPORT	SIMULATED DAM FAILURE INUNDATION LIMITS SHEET 7 OF 15
		PROJECT NUMBER 13117	DECEMBER 2013 Figure 4.7

P:\13117 - Steamboat\Engineering\GIS\Fish Creek\Figures_1-13.mxd



DISCLAIMER:

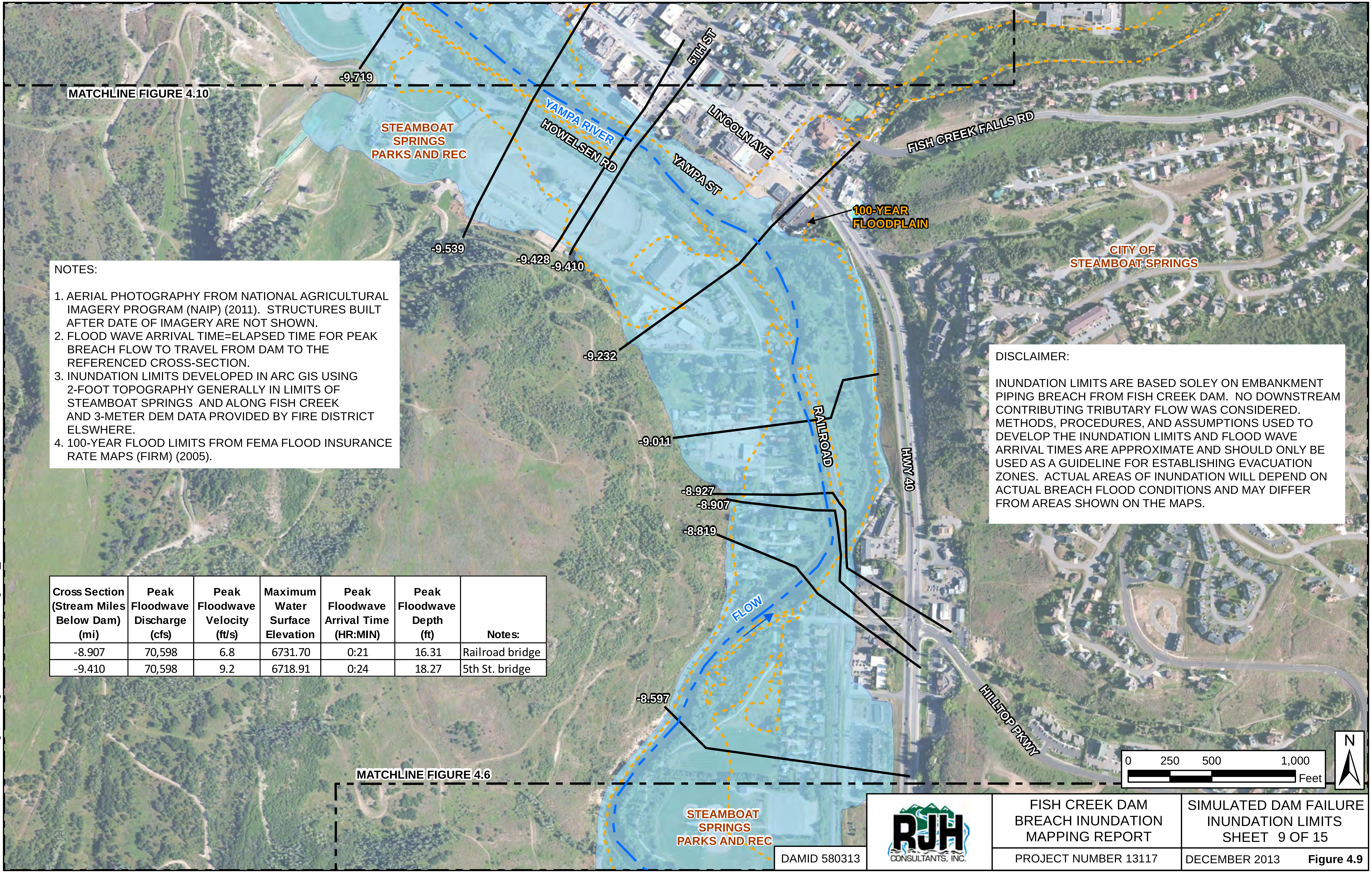
INUNDATION LIMITS ARE BASED SOLEY ON EMBANKMENT PIPING BREACH FROM FISH CREEK DAM. NO DOWNSTREAM CONTRIBUTING TRIBUTARY FLOW WAS CONSIDERED. METHODS, PROCEDURES, AND ASSUMPTIONS USED TO DEVELOP THE INUNDATION LIMITS AND FLOOD WAVE ARRIVAL TIMES ARE APPROXIMATE AND SHOULD ONLY BE USED AS A GUIDELINE FOR ESTABLISHING EVACUATION ZONES. ACTUAL AREAS OF INUNDATION WILL DEPEND ON ACTUAL BREACH FLOOD CONDITIONS AND MAY DIFFER FROM AREAS SHOWN ON THE MAPS.

NOTES:

1. AERIAL PHOTOGRAPHY FROM NATIONAL AGRICULTURAL IMAGERY PROGRAM (NAIP) (2011). STRUCTURES BUILT AFTER DATE OF IMAGERY ARE NOT SHOWN.
2. FLOOD WAVE ARRIVAL TIME=ELAPSED TIME FOR PEAK BREACH FLOW TO TRAVEL FROM DAM TO THE REFERENCED CROSS-SECTION.
3. INUNDATION LIMITS DEVELOPED IN ARC GIS USING 2-FOOT TOPOGRAPHY GENERALLY IN LIMITS OF STEAMBOAT SPRINGS AND ALONG FISH CREEK AND 3-METER DEM DATA PROVIDED BY FIRE DISTRICT ELSWHERE.
4. 100-YEAR FLOOD LIMITS FROM FEMA FLOOD INSURANCE RATE MAPS (FIRM) (2005).
5. FLOODING FROM BACKWATER AT CONFLUENCE OF FISH CREEK AND YAMPA RIVER (FIGURE 4.6).

DAMID 580313	RJH CONSULTANTS, INC.	FISH CREEK DAM BREACH INUNDATION MAPPING REPORT	SIMULATED DAM FAILURE INUNDATION LIMITS SHEET 8 OF 15
		PROJECT NUMBER 13117	DECEMBER 2013 Figure 4.8

P:\13117 - Steamboat\Engineering\GIS\Fish Creek\Figures_1-13.mxd



NOTES:

1. AERIAL PHOTOGRAPHY FROM NATIONAL AGRICULTURAL IMAGERY PROGRAM (NAIP) (2011). STRUCTURES BUILT AFTER DATE OF IMAGERY ARE NOT SHOWN.
2. FLOOD WAVE ARRIVAL TIME=ELAPSED TIME FOR PEAK BREACH FLOW TO TRAVEL FROM DAM TO THE REFERENCED CROSS-SECTION.
3. INUNDATION LIMITS DEVELOPED IN ARC GIS USING 2-FOOT TOPOGRAPHY GENERALLY IN LIMITS OF STEAMBOAT SPRINGS AND ALONG FISH CREEK AND 3-METER DEM DATA PROVIDED BY FIRE DISTRICT ELSWHERE.
4. 100-YEAR FLOOD LIMITS FROM FEMA FLOOD INSURANCE RATE MAPS (FIRM) (2005).

DISCLAIMER:

INUNDATION LIMITS ARE BASED SOLEY ON EMBANKMENT PIPING BREACH FROM FISH CREEK DAM. NO DOWNSTREAM CONTRIBUTING TRIBUTARY FLOW WAS CONSIDERED. METHODS, PROCEDURES, AND ASSUMPTIONS USED TO DEVELOP THE INUNDATION LIMITS AND FLOOD WAVE ARRIVAL TIMES ARE APPROXIMATE AND SHOULD ONLY BE USED AS A GUIDELINE FOR ESTABLISHING EVACUATION ZONES. ACTUAL AREAS OF INUNDATION WILL DEPEND ON ACTUAL BREACH FLOOD CONDITIONS AND MAY DIFFER FROM AREAS SHOWN ON THE MAPS.

Cross Section (Stream Miles Below Dam) (mi)	Peak Floodwave Discharge (cfs)	Peak Floodwave Velocity (ft/s)	Maximum Water Surface Elevation	Peak Floodwave Arrival Time (HR:MIN)	Peak Floodwave Depth (ft)	Notes:
-8.907	70,598	6.8	6731.70	0:21	16.31	Railroad bridge
-9.410	70,598	9.2	6718.91	0:24	18.27	5th St. bridge

RJH CONSULTANTS, INC.

FISH CREEK DAM BREACH INUNDATION MAPPING REPORT

SIMULATED DAM FAILURE INUNDATION LIMITS SHEET 9 OF 15

DAMID 580313

PROJECT NUMBER 13117

DECEMBER 2013

Figure 4.9

P:\13117 - SteamboatEngineering\GIS\Fish Creek\Figures_1-13.mxd

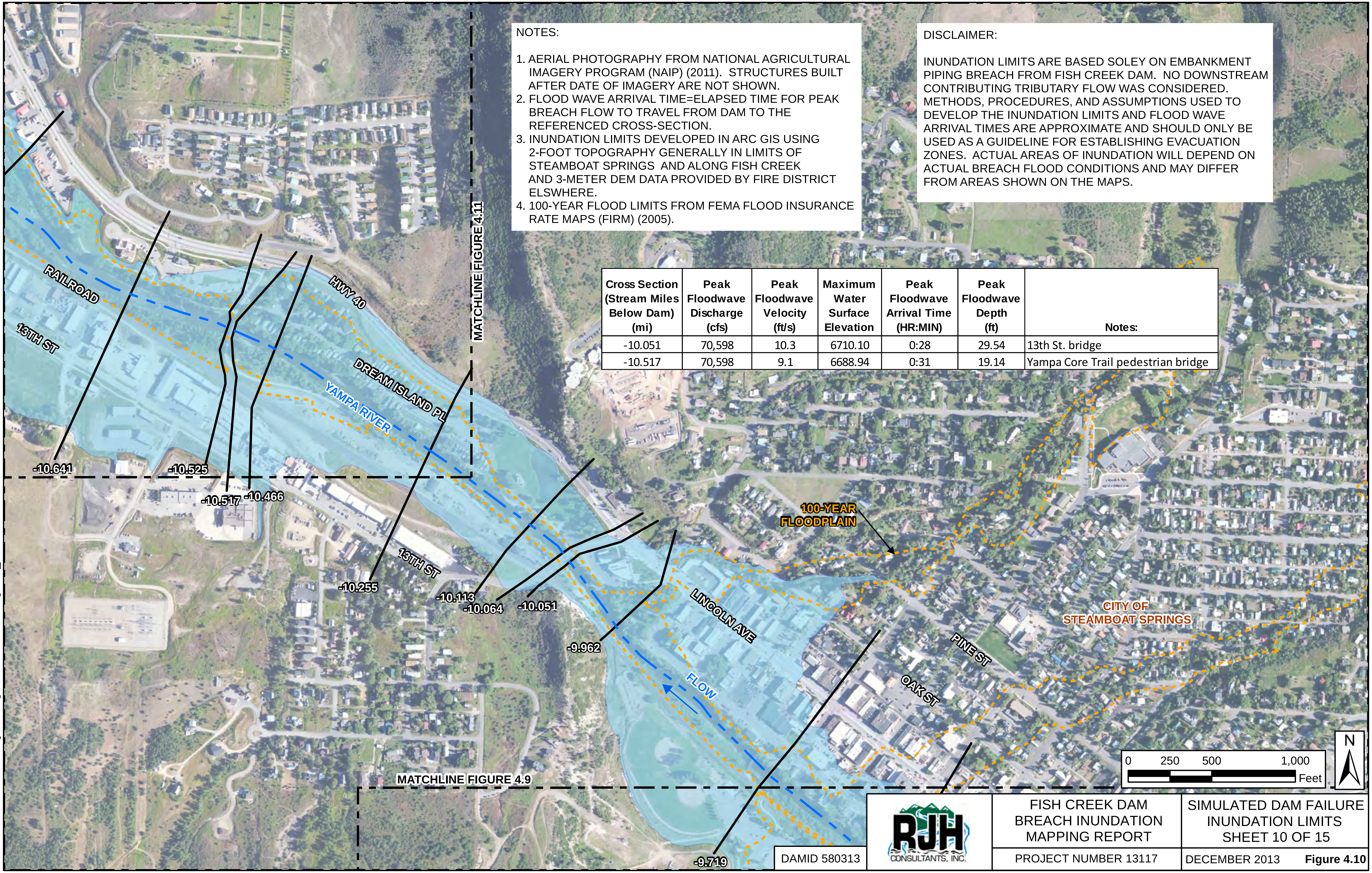
NOTES:

1. AERIAL PHOTOGRAPHY FROM NATIONAL AGRICULTURAL IMAGERY PROGRAM (NAIP) (2011). STRUCTURES BUILT AFTER DATE OF IMAGERY ARE NOT SHOWN.
2. FLOOD WAVE ARRIVAL TIME=ELAPSED TIME FOR PEAK BREACH FLOW TO TRAVEL FROM DAM TO THE REFERENCED CROSS-SECTION.
3. INUNDATION LIMITS DEVELOPED IN ARC GIS USING 2-FOOT TOPOGRAPHY GENERALLY IN LIMITS OF STEAMBOAT SPRINGS AND ALONG FISH CREEK AND 3-METER DEM DATA PROVIDED BY FIRE DISTRICT ELSWHERE.
4. 100-YEAR FLOOD LIMITS FROM FEMA FLOOD INSURANCE RATE MAPS (FIRM) (2005).

DISCLAIMER:

INUNDATION LIMITS ARE BASED SOLEY ON EMBANKMENT PIPING BREACH FROM FISH CREEK DAM. NO DOWNSTREAM CONTRIBUTING TRIBUTARY FLOW WAS CONSIDERED. METHODS, PROCEDURES, AND ASSUMPTIONS USED TO DEVELOP THE INUNDATION LIMITS AND FLOOD WAVE ARRIVAL TIMES ARE APPROXIMATE AND SHOULD ONLY BE USED AS A GUIDELINE FOR ESTABLISHING EVACUATION ZONES. ACTUAL AREAS OF INUNDATION WILL DEPEND ON ACTUAL BREACH FLOOD CONDITIONS AND MAY DIFFER FROM AREAS SHOWN ON THE MAPS.

Cross Section (Stream Miles Below Dam) (mi)	Peak Floodwave Discharge (cfs)	Peak Floodwave Velocity (ft/s)	Maximum Water Surface Elevation	Peak Floodwave Arrival Time (HR:MIN)	Peak Floodwave Depth (ft)	Notes:
-10.051	70,598	10.3	6710.10	0:28	29.54	13th St. bridge
-10.517	70,598	9.1	6688.94	0:31	19.14	Yampa Core Trail pedestrian bridge



DAMID 580313

RJH CONSULTANTS, INC.

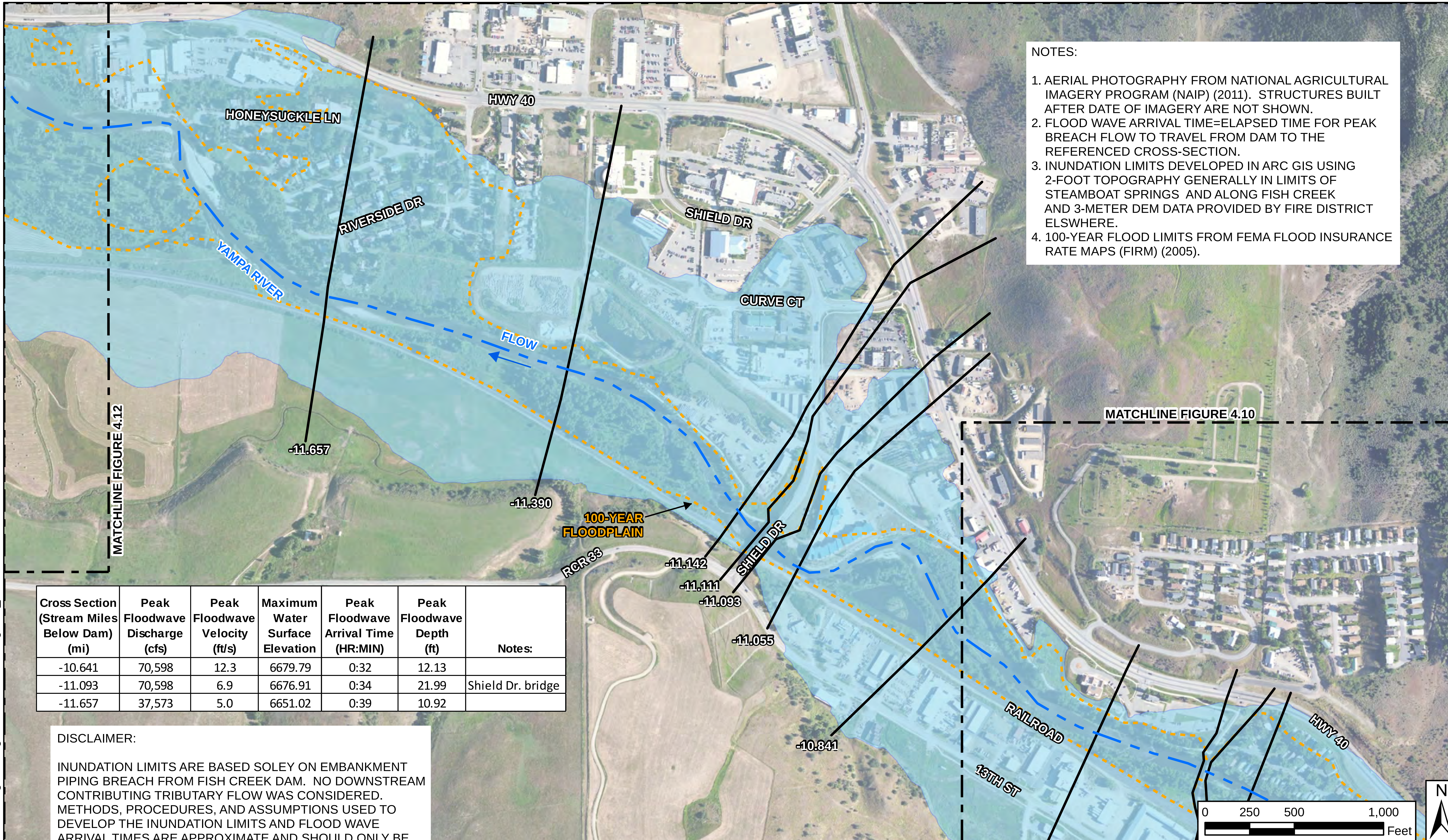
FISH CREEK DAM BREACH INUNDATION MAPPING REPORT

PROJECT NUMBER 13117

SIMULATED DAM FAILURE INUNDATION LIMITS SHEET 10 OF 15

DECEMBER 2013 **Figure 4.10**

P:\13117 - Steamboat\Engineering\GIS\Fish Creek\Figures_1-13.mxd



NOTES:

1. AERIAL PHOTOGRAPHY FROM NATIONAL AGRICULTURAL IMAGERY PROGRAM (NAIP) (2011). STRUCTURES BUILT AFTER DATE OF IMAGERY ARE NOT SHOWN.
2. FLOOD WAVE ARRIVAL TIME=ELAPSED TIME FOR PEAK BREACH FLOW TO TRAVEL FROM DAM TO THE REFERENCED CROSS-SECTION.
3. INUNDATION LIMITS DEVELOPED IN ARC GIS USING 2-FOOT TOPOGRAPHY GENERALLY IN LIMITS OF STEAMBOAT SPRINGS AND ALONG FISH CREEK AND 3-METER DEM DATA PROVIDED BY FIRE DISTRICT ELSWHERE.
4. 100-YEAR FLOOD LIMITS FROM FEMA FLOOD INSURANCE RATE MAPS (FIRM) (2005).

Cross Section (Stream Miles Below Dam) (mi)	Peak Floodwave Discharge (cfs)	Peak Floodwave Velocity (ft/s)	Maximum Water Surface Elevation	Peak Floodwave Arrival Time (HR:MIN)	Peak Floodwave Depth (ft)	Notes:
-10.641	70,598	12.3	6679.79	0:32	12.13	
-11.093	70,598	6.9	6676.91	0:34	21.99	Shield Dr. bridge
-11.657	37,573	5.0	6651.02	0:39	10.92	

DISCLAIMER:

INUNDATION LIMITS ARE BASED SOLEY ON EMBANKMENT PIPING BREACH FROM FISH CREEK DAM. NO DOWNSTREAM CONTRIBUTING TRIBUTARY FLOW WAS CONSIDERED. METHODS, PROCEDURES, AND ASSUMPTIONS USED TO DEVELOP THE INUNDATION LIMITS AND FLOOD WAVE ARRIVAL TIMES ARE APPROXIMATE AND SHOULD ONLY BE USED AS A GUIDELINE FOR ESTABLISHING EVACUATION ZONES. ACTUAL AREAS OF INUNDATION WILL DEPEND ON ACTUAL BREACH FLOOD CONDITIONS AND MAY DIFFER FROM AREAS SHOWN ON THE MAPS.

DAMID 580313

RJH CONSULTANTS, INC.

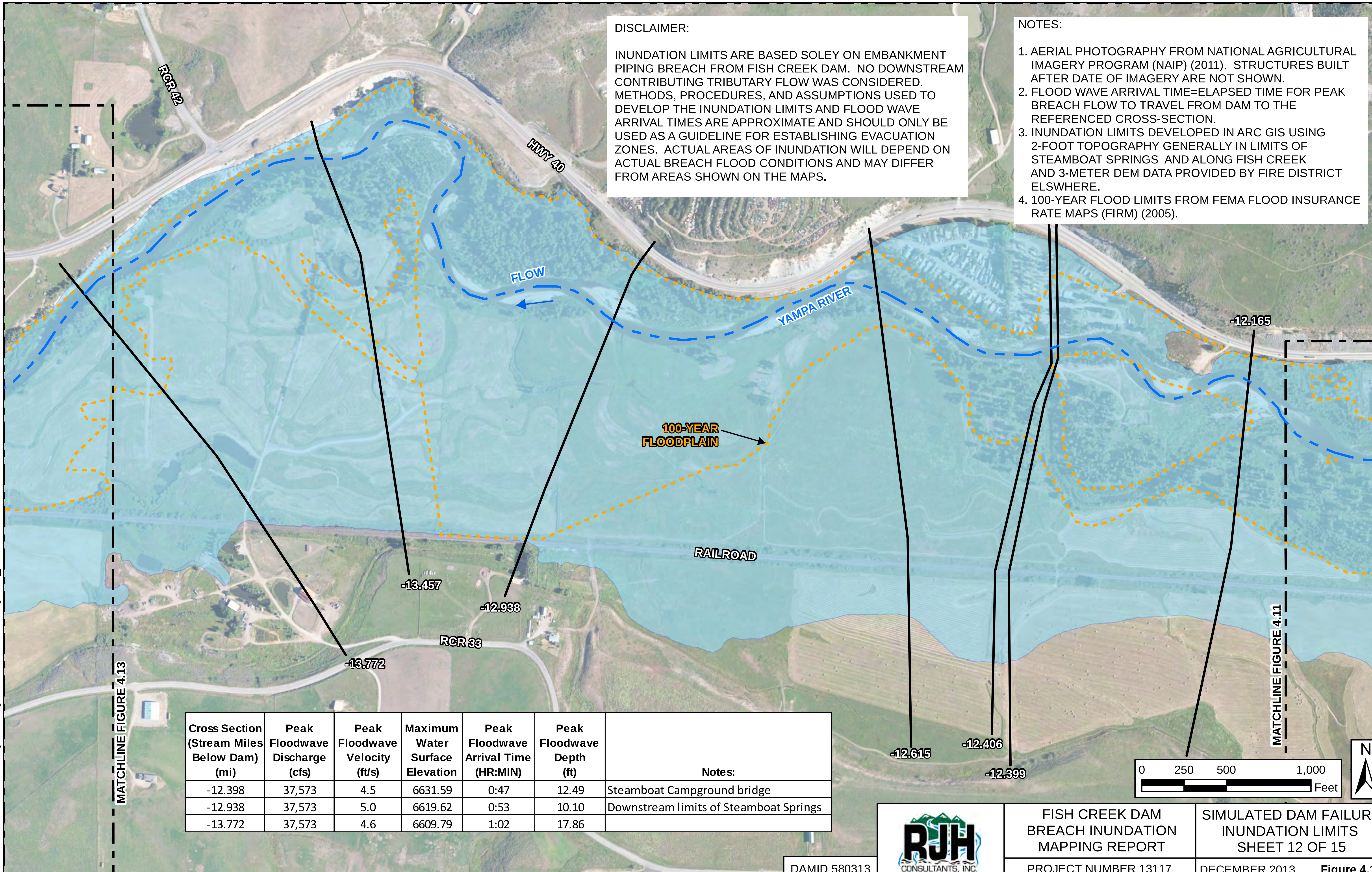
FISH CREEK DAM BREACH INUNDATION MAPPING REPORT

PROJECT NUMBER 13117

SIMULATED DAM FAILURE INUNDATION LIMITS SHEET 11 OF 15

DECEMBER 2013 **Figure 4.11**

P:\13117 - Steamboat\Engineering\GIS\Fish Creek\Figures_1-13.mxd



DISCLAIMER:

INUNDATION LIMITS ARE BASED SOLEY ON EMBANKMENT PIPING BREACH FROM FISH CREEK DAM. NO DOWNSTREAM CONTRIBUTING TRIBUTARY FLOW WAS CONSIDERED. METHODS, PROCEDURES, AND ASSUMPTIONS USED TO DEVELOP THE INUNDATION LIMITS AND FLOOD WAVE ARRIVAL TIMES ARE APPROXIMATE AND SHOULD ONLY BE USED AS A GUIDELINE FOR ESTABLISHING EVACUATION ZONES. ACTUAL AREAS OF INUNDATION WILL DEPEND ON ACTUAL BREACH FLOOD CONDITIONS AND MAY DIFFER FROM AREAS SHOWN ON THE MAPS.

NOTES:

1. AERIAL PHOTOGRAPHY FROM NATIONAL AGRICULTURAL IMAGERY PROGRAM (NAIP) (2011). STRUCTURES BUILT AFTER DATE OF IMAGERY ARE NOT SHOWN.
2. FLOOD WAVE ARRIVAL TIME=ELAPSED TIME FOR PEAK BREACH FLOW TO TRAVEL FROM DAM TO THE REFERENCED CROSS-SECTION.
3. INUNDATION LIMITS DEVELOPED IN ARC GIS USING 2-FOOT TOPOGRAPHY GENERALLY IN LIMITS OF STEAMBOAT SPRINGS AND ALONG FISH CREEK AND 3-METER DEM DATA PROVIDED BY FIRE DISTRICT ELSWHERE.
4. 100-YEAR FLOOD LIMITS FROM FEMA FLOOD INSURANCE RATE MAPS (FIRM) (2005).

Cross Section (Stream Miles Below Dam) (mi)	Peak Floodwave Discharge (cfs)	Peak Floodwave Velocity (ft/s)	Maximum Water Surface Elevation	Peak Floodwave Arrival Time (HR:MIN)	Peak Floodwave Depth (ft)	Notes:
-12.398	37,573	4.5	6631.59	0:47	12.49	Steamboat Campground bridge
-12.938	37,573	5.0	6619.62	0:53	10.10	Downstream limits of Steamboat Springs
-13.772	37,573	4.6	6609.79	1:02	17.86	

DAMID 580313

RJH CONSULTANTS, INC.

FISH CREEK DAM BREACH INUNDATION MAPPING REPORT

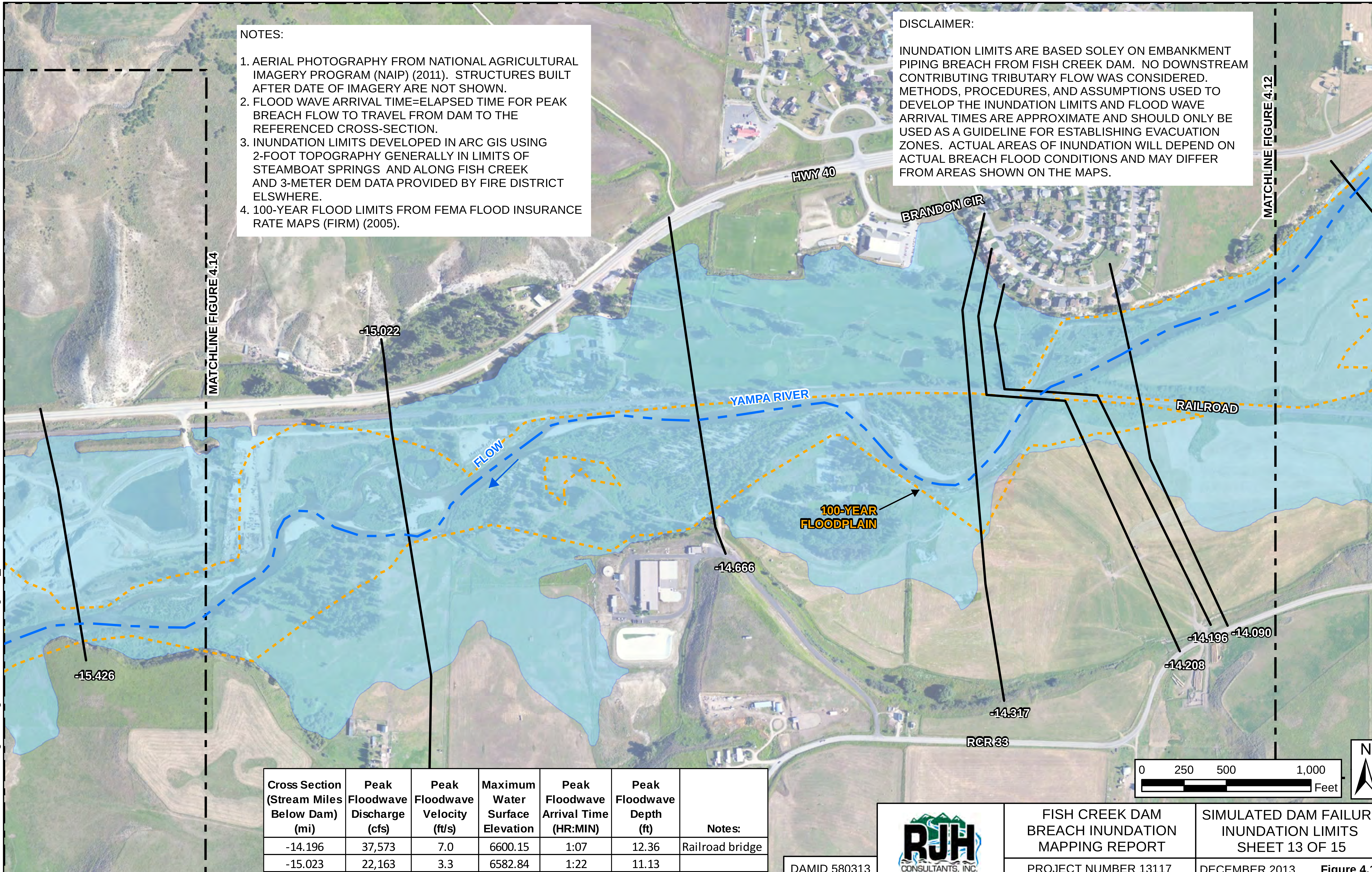
PROJECT NUMBER 13117

SIMULATED DAM FAILURE INUNDATION LIMITS SHEET 12 OF 15

DECEMBER 2013

Figure 4.12

P:\13117 - Steamboat\Engineering\GIS\Fish Creek\Figures_1-13.mxd



NOTES:

1. AERIAL PHOTOGRAPHY FROM NATIONAL AGRICULTURAL IMAGERY PROGRAM (NAIP) (2011). STRUCTURES BUILT AFTER DATE OF IMAGERY ARE NOT SHOWN.
2. FLOOD WAVE ARRIVAL TIME=ELAPSED TIME FOR PEAK BREACH FLOW TO TRAVEL FROM DAM TO THE REFERENCED CROSS-SECTION.
3. INUNDATION LIMITS DEVELOPED IN ARC GIS USING 2-FOOT TOPOGRAPHY GENERALLY IN LIMITS OF STEAMBOAT SPRINGS AND ALONG FISH CREEK AND 3-METER DEM DATA PROVIDED BY FIRE DISTRICT ELSWHERE.
4. 100-YEAR FLOOD LIMITS FROM FEMA FLOOD INSURANCE RATE MAPS (FIRM) (2005).

DISCLAIMER:

INUNDATION LIMITS ARE BASED SOLEY ON EMBANKMENT PIPING BREACH FROM FISH CREEK DAM. NO DOWNSTREAM CONTRIBUTING TRIBUTARY FLOW WAS CONSIDERED. METHODS, PROCEDURES, AND ASSUMPTIONS USED TO DEVELOP THE INUNDATION LIMITS AND FLOOD WAVE ARRIVAL TIMES ARE APPROXIMATE AND SHOULD ONLY BE USED AS A GUIDELINE FOR ESTABLISHING EVACUATION ZONES. ACTUAL AREAS OF INUNDATION WILL DEPEND ON ACTUAL BREACH FLOOD CONDITIONS AND MAY DIFFER FROM AREAS SHOWN ON THE MAPS.

Cross Section (Stream Miles Below Dam) (mi)	Peak Floodwave Discharge (cfs)	Peak Floodwave Velocity (ft/s)	Maximum Water Surface Elevation	Peak Floodwave Arrival Time (HR:MIN)	Peak Floodwave Depth (ft)	Notes:
-14.196	37,573	7.0	6600.15	1:07	12.36	Railroad bridge
-15.023	22,163	3.3	6582.84	1:22	11.13	

DAMID 580313

RJH CONSULTANTS, INC.

FISH CREEK DAM BREACH INUNDATION MAPPING REPORT

PROJECT NUMBER 13117

SIMULATED DAM FAILURE INUNDATION LIMITS SHEET 13 OF 15

DECEMBER 2013

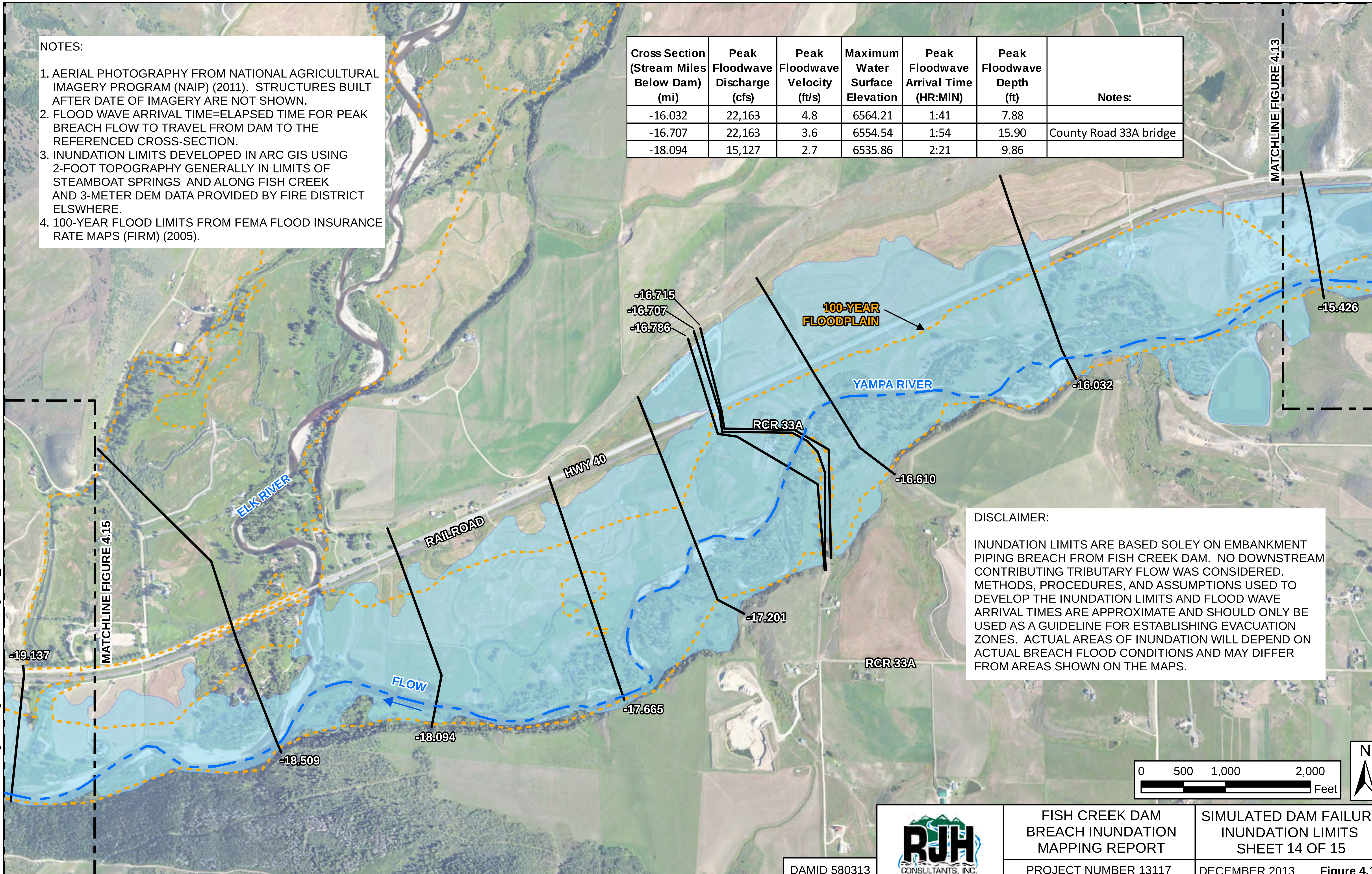
Figure 4.13

P:\13117 - Steamboat\Engineering\GIS\Fish Creek\Figures_1-13.mxd

NOTES:

1. AERIAL PHOTOGRAPHY FROM NATIONAL AGRICULTURAL IMAGERY PROGRAM (NAIP) (2011). STRUCTURES BUILT AFTER DATE OF IMAGERY ARE NOT SHOWN.
2. FLOOD WAVE ARRIVAL TIME=ELAPSED TIME FOR PEAK BREACH FLOW TO TRAVEL FROM DAM TO THE REFERENCED CROSS-SECTION.
3. INUNDATION LIMITS DEVELOPED IN ARC GIS USING 2-FOOT TOPOGRAPHY GENERALLY IN LIMITS OF STEAMBOAT SPRINGS AND ALONG FISH CREEK AND 3-METER DEM DATA PROVIDED BY FIRE DISTRICT ELSWHERE.
4. 100-YEAR FLOOD LIMITS FROM FEMA FLOOD INSURANCE RATE MAPS (FIRM) (2005).

Cross Section (Stream Miles Below Dam) (mi)	Peak Floodwave Discharge (cfs)	Peak Floodwave Velocity (ft/s)	Maximum Water Surface Elevation	Peak Floodwave Arrival Time (HR:MIN)	Peak Floodwave Depth (ft)	Notes:
-16.032	22,163	4.8	6564.21	1:41	7.88	
-16.707	22,163	3.6	6554.54	1:54	15.90	County Road 33A bridge
-18.094	15,127	2.7	6535.86	2:21	9.86	



DISCLAIMER:

INUNDATION LIMITS ARE BASED SOLEY ON EMBANKMENT PIPING BREACH FROM FISH CREEK DAM. NO DOWNSTREAM CONTRIBUTING TRIBUTARY FLOW WAS CONSIDERED. METHODS, PROCEDURES, AND ASSUMPTIONS USED TO DEVELOP THE INUNDATION LIMITS AND FLOOD WAVE ARRIVAL TIMES ARE APPROXIMATE AND SHOULD ONLY BE USED AS A GUIDELINE FOR ESTABLISHING EVACUATION ZONES. ACTUAL AREAS OF INUNDATION WILL DEPEND ON ACTUAL BREACH FLOOD CONDITIONS AND MAY DIFFER FROM AREAS SHOWN ON THE MAPS.

DAMID 580313

RJH CONSULTANTS, INC.

FISH CREEK DAM BREACH INUNDATION MAPPING REPORT

PROJECT NUMBER 13117

SIMULATED DAM FAILURE INUNDATION LIMITS SHEET 14 OF 15

DECEMBER 2013

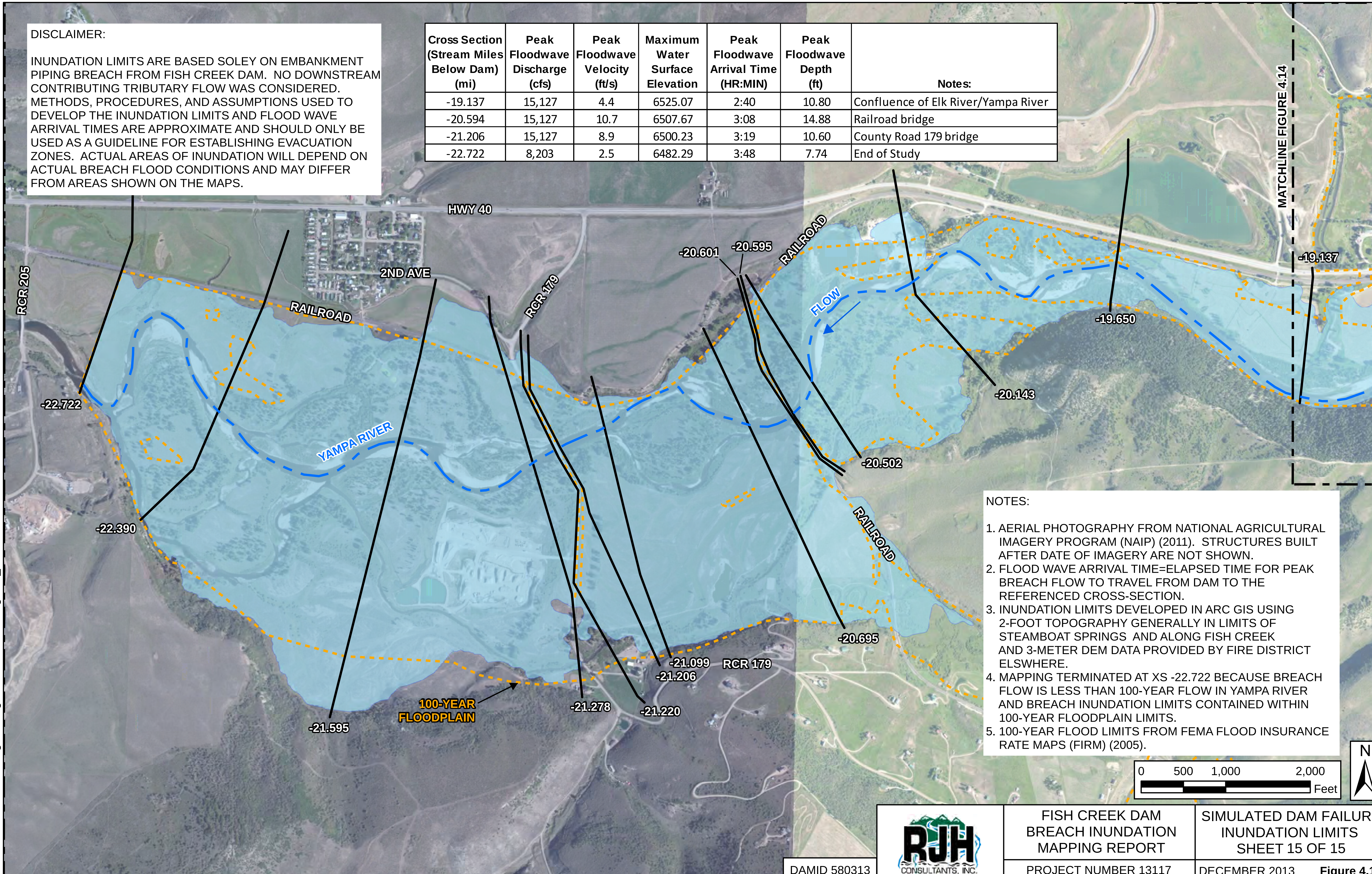
Figure 4.14

P:\13117 - SteamboatEngineering\GIS\Fish Creek\Figures_14-15.mxd

DISCLAIMER:

INUNDATION LIMITS ARE BASED SOLEY ON EMBANKMENT PIPING BREACH FROM FISH CREEK DAM. NO DOWNSTREAM CONTRIBUTING TRIBUTARY FLOW WAS CONSIDERED. METHODS, PROCEDURES, AND ASSUMPTIONS USED TO DEVELOP THE INUNDATION LIMITS AND FLOOD WAVE ARRIVAL TIMES ARE APPROXIMATE AND SHOULD ONLY BE USED AS A GUIDELINE FOR ESTABLISHING EVACUATION ZONES. ACTUAL AREAS OF INUNDATION WILL DEPEND ON ACTUAL BREACH FLOOD CONDITIONS AND MAY DIFFER FROM AREAS SHOWN ON THE MAPS.

Cross Section (Stream Miles Below Dam) (mi)	Peak Floodwave Discharge (cfs)	Peak Floodwave Velocity (ft/s)	Maximum Water Surface Elevation	Peak Floodwave Arrival Time (HR:MIN)	Peak Floodwave Depth (ft)	Notes:
-19.137	15,127	4.4	6525.07	2:40	10.80	Confluence of Elk River/Yampa River
-20.594	15,127	10.7	6507.67	3:08	14.88	Railroad bridge
-21.206	15,127	8.9	6500.23	3:19	10.60	County Road 179 bridge
-22.722	8,203	2.5	6482.29	3:48	7.74	End of Study



NOTES:

1. AERIAL PHOTOGRAPHY FROM NATIONAL AGRICULTURAL IMAGERY PROGRAM (NAIP) (2011). STRUCTURES BUILT AFTER DATE OF IMAGERY ARE NOT SHOWN.
2. FLOOD WAVE ARRIVAL TIME=ELAPSED TIME FOR PEAK BREACH FLOW TO TRAVEL FROM DAM TO THE REFERENCED CROSS-SECTION.
3. INUNDATION LIMITS DEVELOPED IN ARC GIS USING 2-FOOT TOPOGRAPHY GENERALLY IN LIMITS OF STEAMBOAT SPRINGS AND ALONG FISH CREEK AND 3-METER DEM DATA PROVIDED BY FIRE DISTRICT ELSWHERE.
4. MAPPING TERMINATED AT XS -22.722 BECAUSE BREACH FLOW IS LESS THAN 100-YEAR FLOW IN YAMPA RIVER AND BREACH INUNDATION LIMITS CONTAINED WITHIN 100-YEAR FLOODPLAIN LIMITS.
5. 100-YEAR FLOOD LIMITS FROM FEMA FLOOD INSURANCE RATE MAPS (FIRM) (2005).

DAMID 580313	RJH CONSULTANTS, INC.	FISH CREEK DAM BREACH INUNDATION MAPPING REPORT	SIMULATED DAM FAILURE INUNDATION LIMITS SHEET 15 OF 15
		PROJECT NUMBER 13117	DECEMBER 2013 Figure 4.15

P:\13117 - SteamboatEngineering\GIS\Fish Creek\Figures_14-15.mxd

SECTION 5 - CONCLUSIONS

Based on the results of this evaluation, RJH offers the following conclusions:

1. Dam breach parameters for a simulated failure of Fish Creek Dam are as follows:

Average Breach Width, B_f	140 feet
Bottom Breach Width, B_b	90 feet
Breach Formation Time, t_f	1.0 hour
Breach Side Slopes, z (zH:1V)	0.7

2. The dam breach hydrograph peak flow is 72,100 cfs and the total breach volume is 4,120 ac-ft. Attenuation of the breach hydrograph is as follows:

Distance Downstream from Dam (miles)	Sunny-Day Failure	
	Flow (cfs)	Volume (ac-ft)
Fish Creek Dam	72,100	4120.2
2.151	71,651	4126.4
5.013	71,472	4124.8
8.056	70,597	4138.1
11.390	37,573	4138.1
14.317	22,163	4138.1
17.200	15,127	4138.1
22.722	8,203	4132.6

3. Simulated floodwave velocities in the downstream channel ranged from about 2 to 78 feet per second (fps) and peak depths ranged from about 5 to 36 feet.

4. Peak floodwave arrival times at key locations are as follows:

Location	Time (Hr:Min)
Upstream limits of Steamboat Springs (XS -5.215)	0:09
Steamboat Boulevard bridge (XS -5.518)	0:09
Pedestrian bridge (XS -7.60)	0:09
Rollingstone Dr. bridge (XS -7.81)	0:15
Highway 40 bridge (XS -7.93)	0:16
Confluence of Yampa River/Fish Creek (XS -8.056)	0:16
Railroad bridge (XS -8.91)	0:21
5^{th} Street bridge (XS -9.42)	0:24

Location	Time (Hr:Min)
13th Street bridge (XS -10.06)	0:28
Yampa Core Trail pedestrian bridge (XS -10.52)	0:31
Shield Drive bridge (XS -11.1)	0:34
Steamboat Campground bridge (XS -12.4)	0:47
Railroad bridge (XS -14.2)	1:07
County Road 33B bridge (XS -16.72)	1:55
Railroad bridge (XS -20.6)	3:08
County Road 179 bridge (XS -21.21)	3:19

5. The breach inundation mapping was terminated just upstream of County Road 205. The peak breach flow at this location is about 8,200 cfs, which is less than the estimated 100-year flow of 14,520 cfs in the Yampa River at this location.

SECTION 6 - LIMITATIONS

The information presented in this Report is suitable for use in evaluating simulated breach scenarios at Fish Creek Dam and corresponding floodwave inundation mapping in the drainage channel downstream of the dam. Future modifications to the Report analyses and inundation mapping will be required in accordance with periodic updates of EAP documents, and will need to consider development and current conditions within the downstream floodplain. The information presented in this Report is based on RJH's understanding of the dam project features, drainage basin characteristics, available information, and current computer model capabilities. The analyses and inundation mapping presented in the Report are based, in part, upon the level of detail of the available topographic information. Variations in the conditions of the drainage channel and impacted structures are possible and future modifications may be necessary if more detailed input data becomes available.

RJH has endeavored to conduct our professional services for this Project in a manner consistent with a level of care and skill ordinarily exercised by members of the engineering profession currently practicing in Colorado under similar conditions as this Project. RJH makes no other warranty, expressed or implied.

This work has been prepared for the exclusive use of the City of Steamboat Springs and the SEO for specific application to Fish Creek Dam in Routt County, Colorado.

SECTION 7 - REFERENCES

Colorado Office of the State Engineer (SEO) (2007). *Rules and Regulations for Dam Safety and Dam Construction*.

Colorado Office of the State Engineer (SEO) (2010). *Guidelines for Dam Breach Analysis*.

Federal Emergency Management Agency (FEMA) (2005). *Flood Insurance Study Routt County Colorado and Unincorporated Areas*.

U.S. Army Corps of Engineers (USACE) (2009). *HEC-HMS User's Manual*.

APPENDIX A

DAM BREACH PARAMETERS

RJH CONSULTANTS, INC.

Client: Steamboat Springs
Subject: Fish Creek Dam

Project: 13117 Page: 1/10
Date: 9/18/13 By: EMH
Checked: 10/16/13 By: TEO
Approved: 11/1/13 By: GGS

REQUIRED - Develop dam breach parameters for Fish Creek Dam

ASSUMPTIONS -
1) Use Colorado SEO "Guidelines for Dam Breach Analysis" (Feb 2010) (SEO) ✓
2) Use elevation-capacity information from RJH dated 9/18/13 ✓
3) Use record drawings from Fish Creek Reservoir Enlargement (Woodward Clyde Consultants 1994) ✓
4) Use the simple-level analysis methodology per scope of work from owner and SEO ✓
5) Sunny-day, piping failure ✓

Summary -

- Avg. Breach Width, $B_{avg} = 140'$ ✓
- Breach Bottom Width, $B_b = 90'$ ✓
- Breach side slopes, $z = 0.7$ ✓
- Breach Bottom Elev. = 9821.0 ✓
- Breach Piping Elev. = 9857.5 ✓
- Piping Coefficient = 0.6 ✓
- Time to Failure, $T_f = 1.0$ hours ✓

ANALYSIS –

- SEO guidelines specify the use of emperical equations to estimate dam breach parameters for a simple-level analysis. Use the Froelich equation supplemented with MacDonald and Langride-Monopolis method or Washington State method: (see p. 7)

1) Height of water above breach, H_w

   - assume sunny-day failure at maximum normal pool (i.e. El. 9886.0)

   - assume average bottom elevation of breach is average of downstream toe (~El. 9816.0) and upstream toe (~El. 9826.0) (see pg. 10)
     = El. 9821.0

   $H_w = 9886.0 - 9821.0$

   $H_w = \underline{\underline{65'}}$

2) Volume of water at time of failure, V_w

   $V_w = \underline{4,150 \text{ ac-ft}}$ (see RJH 9/18/13)

3) Reservoir surface area at H_w

   $A_w = \underline{139 \text{ ac}}$ (see RJH 9/18/13)

4) Height of breach, H_b

   - dam crest = El. 9894.0

   $H_b = 9894.0 - 9821.0$

   $H_b = \underline{\underline{73'}}$

ANALYSIS -

5) $K_o = 1.0$ ✓✓ for piping (see p. 9) ✓

6) $z = 0.7$ ✓✓ for piping (see p. 9) ✓

- Use SEO spreadsheet to compute dam breach parameters ✓ (see p. 5) using Froelich method. Results are summarized as follows

  - $B_{avg} = 140.7'$ say 140' ✓✓
  - $B_b = 89.6'$ say 90' ✓✓
  - $T_f = 0.57$ hours ✓✓

- Other required breach parameters include

  - Breach bottom elev = 9821.0 ✓✓
  - Piping Coefficient = 0.6 ✓ ok (conservative) (typical orifice coefficient) ✓
    ↳ used in HEC-HMS. SEO spreadsheet use $C_p = 0.68$
  - Piping elev = set at mid-point of final breach ✓ height (see p.)

$$= \frac{9894.0 + 9821.0}{2} \checkmark$$

$$= 9857.5 \checkmark\checkmark$$

- In RJH's opinion, the time to failure calculated using the Froehlich method is unrealistically short given the volume of the embankment and geometry. ✓ ✓

  ↳ Use the Washington State method (for cohesionless soils) ✓ ✓ to calculate T_f because it accounts for embankment geometry and volume eroded

    ↳ the embankment may contain some cohesive materials but ✓ material properties for the existing embankment are unknown, so RJH conservatively assumed a cohesionless material. ✓

ANALYSIS –

- The Washington State method requires the following input parameters:

1) $H_w = 65'$ (see p. 2) ✓✓
2) $V_w = 4,150$ ac-ft (see p. 2) ✓✓
3) $A_w = 139$ ac (see p. 2) ✓✓
4) Crest width, $C = 20'$ ✓✓ (see pg. 10)
5) $H_b = 73'$ ✓✓ (see pg. 2)
6) Upstream slope, $Z_u = 3H:1V$ ✓✓ (p. 10) ✓
7) Downstream slope, $Z_d = 2H:1V$ ✓✓ (p. 10) ✓
8) Breach side slope ratio, $Z_b = 1.0$ ✓✓ (SEO recommends using 2H:1V but this results in a negative bottom breach width → independent of time to failure) (see pg. 9) ✓

- Use the SEO spreadsheet to compute T_f (see p. 6). ✓

↳ $T_f =$ __1.0 hours__ ✓✓

RJH Consultants, Inc.
Fish Creek and Long's Lake Dam Breach Mapping
Project No. 13117
Prepared by: E. Hahn 9/18/2013
Checked by: TEO 10/16/13
Approved by: GGS 11/1/13

ESTIMATION OF DAM BREACH PARAMETERS USING THE FROEHLICH 2008 METHOD

PROJECT: Fish Creek and Long's Lake Dams

BREACH INPUT PARAMETERS:

Select Failure Mode From Drop-Down Menu:	PIPING	
Height of water over base elevation of breach (H_w) =	65.0	Feet
Volume of water in the reservoir at the time of failure (V_w) =	4,150.0	Acre-Feet
Reservoir Surface Area at Hw (A_s) =	139.0	Acres
Height of breach (H_b) =	73.0	Feet
Failure Mode Factor (K_o) =	1	
Breach Side-Slope Ratio (Z_b) =	0.7	Z(H):1(V)
Dam Size Class:	Large ok	Assumes Full Reservoir At Time of Breach.

CALCULATED BREACH CHARACTERISTICS:

Average Breach Width (B_{avg}) =	140.7	Feet
Bottom Width of Breach (B_b) =	89.6	Feet
Breach Formation Time (T_f) =	0.57	Hours
Storage Intensity (SI) =	63.8	Acre Feet/Foot
Predicted Peak Flow (Q_p) =	132681	Cubic Feet per Second

RESULTS CHECK:

Average Breach Width Divided by Height of Breach (B_{avg}/H_b) =	1.93	If (B_{avg}/H_b) > 0.6, Full Breach Devlopment is Anticipated
Erosion Rate (ER), Calculated as (B_{avg}/T_f) =	246.9	
Erosion Rate Divided by Height of Water Over Base of Breach (ER/H_w) =	3.8	If 1.6 < (ER/H_w) < 21, Erosion Rate is Assumed Reasonable

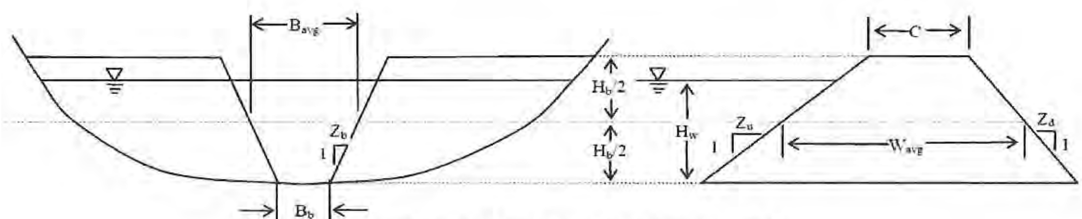


Figure 1- Breach Variable Definition Sketch

RJH Consultants, Inc.
Fish Creek and Long's Lake Dam Breach Mapping, Project No. 13117
Prepared by: E. Hahn 9/18/2013
Checked by: T. Owen 10/16/13
Approved by: GGS 11/1/13

ESTIMATION OF DAM BREACH PARAMETERS USING THE MACDONALD & LANGRIDGE-MONOPOLIS OR WASHINGTON STATE METHODS WITH ALL FAILURE TIMES ESTIMATED BY WASHINGTON STATE METHOD

PROJECT: Fish Creek Dam

BREACH INPUT PARAMETERS:

Select Embankment Type From Drop-Down Menu:	EARTHEN (NON-COHESIVE)	
Height of water over base elevation of breach (H_w) =	65.0	Feet
Volume of water stored in reservoir at time of failure (V_w) =	4150.0	Acre-Feet
Reservoir Surface Area at H_w (A_s) =	139.0	Acres
Crest width of dam (C) =	20.0	Feet
Height of breach from dam crest to base elevation of breach (H_b) =	73.0	Feet
Slope of upstream dam face (Z_u) =	3.0	Z(H):1(V)
Slope of downstream dam face (Z_d) =	2.0	Z(H):1(V)
Breach side-slope ratio (Z_b) =	1.0	Z(H):1(V)
Piping Orifice Coefficient (C_p) =	0.68	Used To Calculate Peak Discharge Through Piping Hole
Dam Size Class:	Large	Assumes Full Reservoir At Time of Breach

CALCULATED BREACH CHARACTERISTICS:

Breach Formation Factor (BFF) =	269750	
Embankment Volume Eroded (V_{er}) =	56999.6	Cubic Yards
Average Dam Width (W_{avg}) =	202.5	Feet (In Direction of Flow)
Average Breach Width (B_{avg}) =	104.1	Feet
Bottom Width of Breach (B_b) =	31.1	Feet
Breach Formation Time (T_f) =	1.03	Hours
Storage Intensity (SI) =	63.8	Acre Feet/Foot
Peak Breach Discharge (Q_p) =	83355	Cubic Feet per Second

RESULTS CHECK:

Average Breach Width Divided by Height of Breach (Bavg/Hb) =	1.43	If (Bavg/Hb) > 0.6, Full Breach Development is Anticipated
Erosion Rate (ER), Calculated as (Bavg/Tf) =	101.0	
Erosion Rate Divided by Height of Water Over Base of Breach (ER/Hw) =	1.6	If 1.6 < (ER/Hw) < 21, Erosion Rate is Assumed Reasonable

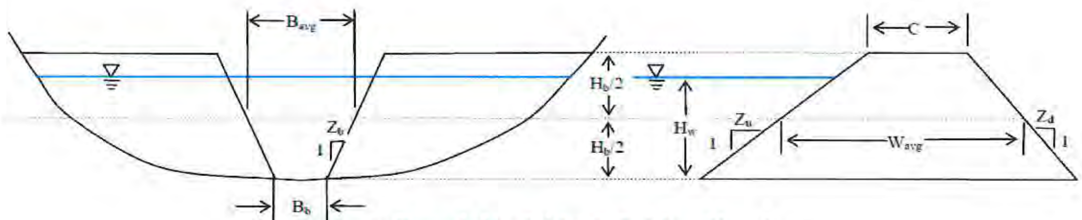


Figure 1- Breach Variable Definition Sketch

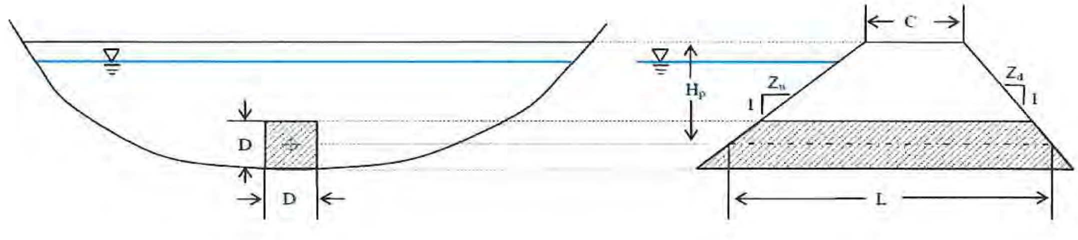


Figure 2 – Piping Hole Variable Definition Sketch

✓TEO 10/16/13 7/10
✓ GGS 11/1/13

Erosion rate (ER) guidelines of $1 < ER/H_w < 21$, where $ER=B_{avg}/T_f$, can be used as check of the methods and the parameters adjusted accordingly. Table 3 summarizes the generally appropriate empirical methods for varying dam sizes and storage intensities. This is only a guide and engineering judgment is needed on a case-by-case basis considering the ER/H_w and B_{avg}/H_b guidelines mentioned above.

Table 3 - Guide of Appropriate Empirical Methods for Various Dam Sizes and Storage-Intensities

Dam Size	Storage Intensity $(SI) = V_w/H_w$		
	Low ($SI < 5$)	**Medium** ($5 < SI < 20$)	**High** ($SI > 20$)
Minor	*MacDonald & Langridge-Monopolis with Washington State failure time. Froehlich for Overtopping.	*MacDonald & Langridge-Monopolis with Washington State failure time. Froehlich for Overtopping.	*MacDonald & Langridge-Monopolis with Washington State failure time. Froehlich for Overtopping.
Small	*MacDonald & Langridge-Monopolis with Washington State failure time and possibly Froehlich (case-by-case). Froehlich for Overtopping.	Froehlich and possibly *MacDonald & Langridge-Monopolis with Washington State failure time (case-by-case).	Froehlich for geometry and failure time.
Large	Froehlich. The side slopes may need to be adjusted to yield a reasonable bottom width.	Froehlich and possibly *MacDonald & Langridge-Monopolis with Washington State failure time (case-by-case).	Froehlich and possibly *MacDonald & Langridge-Monopolis with Washington State failure time (case-by-case). ✓
Comments	Parameters likely need to be adjusted with judgment on a case-by-case basis – may need to be modeled as piping hole for Small and Minor dams.	Both Froehlich and *MacDonald & Langridge-Monopolis seem to work for Small and Large dams in the middle range of SI. Engineering judgment is needed on a case-by-case basis.	It is important to look at valley and dam constraints as the computed parameters may exceed the valley width and/or dam length.
References	Froehlich (2008) MacDonald & Langridge-Monopolis (1984) Washington State (2007)		

* Where the MacDonald & Langridge-Monopolis Method is referenced as a recommendation, this only applies for embankments constructed of cohesive materials. The Washington State Method is preferred for cohesionless earthen embankments.

7.1.1.1 Piping Failure Considerations with Empirical Methods

For Small and Minor dams with low storage intensities (SI less than 5) that are built with cohesive soils, it is possible that a piping failure could occur and drain the reservoir without fully breaching the dam (i.e. collapsing the crest). This situation is evident when the MacDonald & Langridge-Monopolis and Washington State empirical method for establishing the breach parameters shows that the volume eroded (V_{er}) results in a corresponding B_{avg}/H_b of less than about 0.5. This phenomenon is common for Small dams with a volume less than 100 AF and SI less than about 2.5, and Minor dams when SI is less than about 1.5. When this occurs, it is possible to calculate the maximum piping-hole size (assumed to be square) from the volume of embankment eroded. This piping-only failure mode does not apply to dams

$SI = \frac{V_w}{H_w} = \frac{4150\ AF}{65} \doteq 64 \quad (SI > 20)$

Table 1 - Tiered Dam Breach Analysis Structure

Level of Analysis	Breach Parameter Estimation (Size/Shape and Failure Time)	Breach Hydrograph Estimation	Breach Hydrograph Routing	Hydraulics at Critical Section(s)
Screening	Empirical Equations	Peak Breach Discharge from SMPDBK	Empirical Routing Equations or Nomographs	Normal Depth
Simple	Empirical Equations	Parametric Model (HEC-1 or HEC-HMS)	Hydrologic Model (HEC-1 or HEC-HMS)	Steady-State Hydraulics (HEC-RAS)
Intermediate	Empirical Equations	Parametric Model HEC-1 or HEC-HMS	Unsteady Hydraulic Model (HEC-RAS)	Peak Water Surface Profile (Unsteady HEC-RAS)
Advanced	Empirical Equations	Parametric Model (HEC-RAS or DAMBRK)	Unsteady Hydraulic Model (HEC-RAS)	Peak Water Surface Profile (Unsteady HEC-RAS)

The hydraulic conditions at critical locations downstream of the dam can usually be determined with normal depth calculations as long as steady, uniform flow is a valid assumption (i.e. no significant backwater effects in the vicinity of the section).

Because the screening level of analysis is very conservative, it can be used to determine if further analysis is required. It is expected that, if the hydraulics calculated at critical locations indicate a specific hazard classification with a screening-level analysis, then more sophisticated analyses would not likely result in a higher hazard classification. So if a screening analysis indicates a Low Hazard, no further analysis is required. If the screening analysis indicates High or Significant Hazard, a more accurate, less conservative approach may show a lower hazard classification and additional analysis may be warranted to demonstrate this depending on the situation.

Note that the screening level of analysis does not lead to inundation maps which are required for Significant and High Hazard dams. The minimum level of analysis required to develop inundations maps is the next level: Simple.

6.2 Simple

The Simple level of analysis is slightly more sophisticated than the screening analysis. Results of the Simple level of analysis may provide the necessary conclusion, or may indicate that the intermediate or advanced approach is warranted. This analysis uses the recommended empirical methods to determine the breach parameters and then uses a hydrologic parametric model (HEC-HMS or HEC-1) to compute a breach hydrograph. The hydrologic tool can then be used to route the flood downstream to critical locations. At that point, a steady-state hydraulic model can be used to calculate the hydraulic conditions where required.

✓TEO 10/16/13 9/10
✓GGS 11/1/13

Table 2 – Summary of Recommended Empirical Equations (English Units)

Breach Parameters	MacDonald & Langridge-Monopolis (1984)	Washington (2007)	Froehlich (2008) ✓
Volume Eroded V_{er} (yd³)	$V_{er} = 3.264BFF^{0.77}$ (best fit all data)	$V_{er} = 3.75BFF^{0.77}$ (cohesionless dams)	
	$V_{er} = 0.714BFF^{0.852}$ (rockfill)	$V_{er} = 2.5BFF^{0.77}$ (cohesive dams)	
Average Breach Width B_{avg} (ft)	$B_{avg} = \frac{V_{er}}{(H_b \times W_{avg})}$		$B_{avg} = 8.239K_oV_w^{0.32}H_b^{0.04}$ K_o=1.0 for piping ✓ K_o=1.3 for overtopping
Breach Side slopes Z_b (H:V)	2.0:1 ✓ Used 1:1 b/c 2:1 resulted in negative bottom width		0.7:1 - piping ✓ 1.0:1 - overtopping
Breach Development Time T_f (hr)	$T_f = 0.016V_{er}^{0.364}$	$T_f = 0.02V_{er}^{0.36}$ (cohesionless) ← USED FOR T_f	$T_f = 3.664\sqrt{\frac{V_w}{gH_b^2}}$
		$T_f = 0.036V_{er}^{0.36}$ (cohesive)	

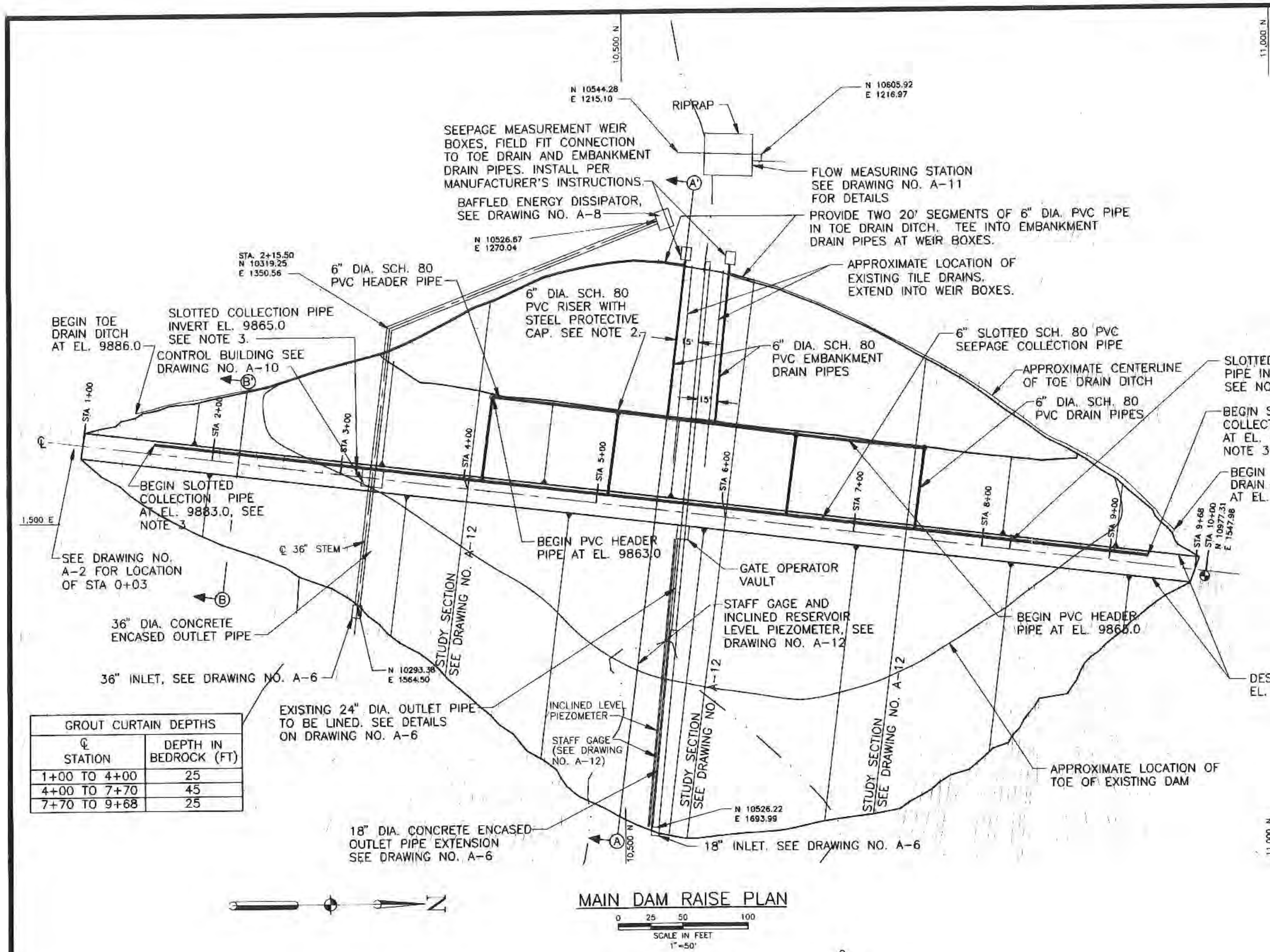
Suggested Methods to Validate the Parameters Calculated using Empirical Methods:

On a case by case basis, judgment is needed with the predicted parameters calculated using the recommended methods presented here. There are a few general tools used to validate the predicted parameters:

1. An estimate of linear erosion rate can be used to check the validity of the failure time. Linear erosion rate (ER) is defined as the B_{avg}/T_f. Von Thun and Gillette (1990) suggests the minimum allowable erosion rate related to the height of the water above the breach bottom, can be empirically defined as $4H_w$ and the maximum erosion rate related to the water depth is $200 + 4H_w$. However, the data set used to develop the empirical parameters suggest a minimum ER of $1.6H_w$. **If the T_f, B_{avg}, and H_w computed by the empirical methods listed above produces an ER/H_w much less than 1.6, then either the T_f is too long or B_{avg} is too small** and adjustments are needed or a different method selected. Likewise, the maximum ER/H_w in the data set was only 21, which is considerably less than upper limit defined by Von Thun and Gillette (1990) (greater than 200). The average ER/H_w computed from the database was 6.7. **Therefore, if the ER/H_w ratio is greater than 21, then the parameters are considered suspect.**

2. Von Thun and Gillette (1990) suggests that B_{avg}/H_w cannot be less than 2.5. However, the data set, especially for piping, shows B_{avg}/H_w less than 2.5 in many instances. In fact, it is near 1.0 in several cases and less than 1.0 in a few instances. The minimum B_{avg}/H_w for the data set was 0.6 and the minimum B_{avg}/H_b was 0.5. This ratio is highly dependent on storage-intensity ($SI = V_w/H_w$) and with a relatively small reservoir volume relative to the dam height (low storage intensity), the reservoir evacuates quickly and does not allow for the breach to widen. Piping failure of a dam with a very low storage-intensity may evacuate the reservoir through the piping hole without a full rectangular or trapezoidal breach forming. Paquir, et.al, (post 1995) suggested that the piping hole width has to reach 2/3 of the dam height above the bottom of the pipe before the roof of the piping hole collapses

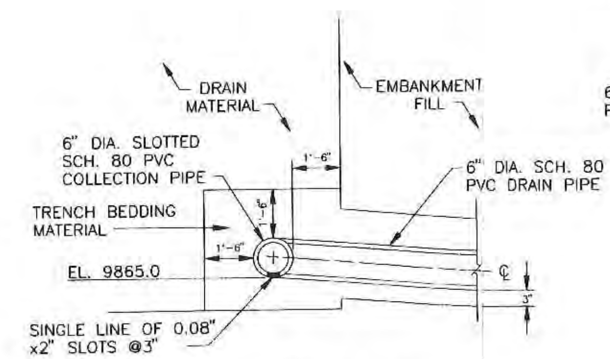
10/10
✓TEO 10/16/13
✓GGS 11/1/13



GROUT CURTAIN DEPTHS	
℄ STATION	DEPTH IN BEDROCK (FT)
1+00 TO 4+00	25
4+00 TO 7+70	45
7+70 TO 9+68	25

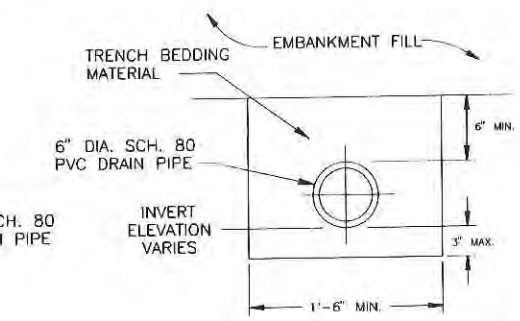
MAIN DAM RAISE PLAN

SCALE IN FEET 1"=50'



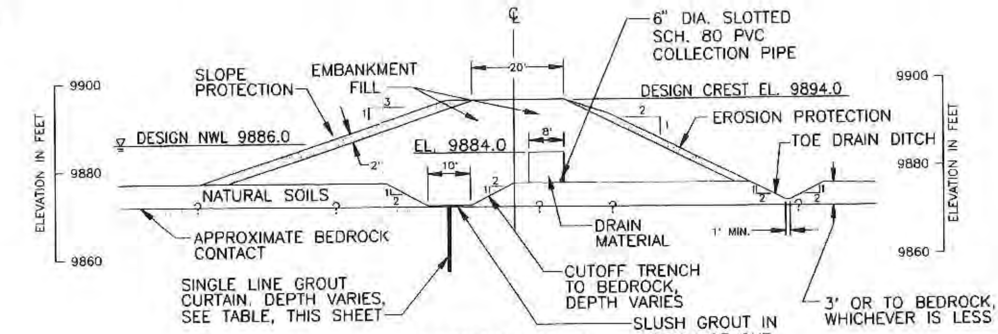
SEEPAGE COLLECTION SYSTEM DETAIL

NOT TO SCALE



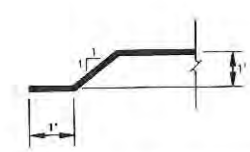
DRAIN PIPE TRENCH DETAIL (TYPICAL)

NOT TO SCALE



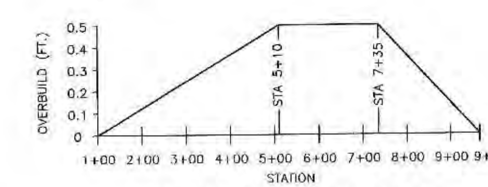
SECTION B-B'

SCALE IN FEET 1"=20'

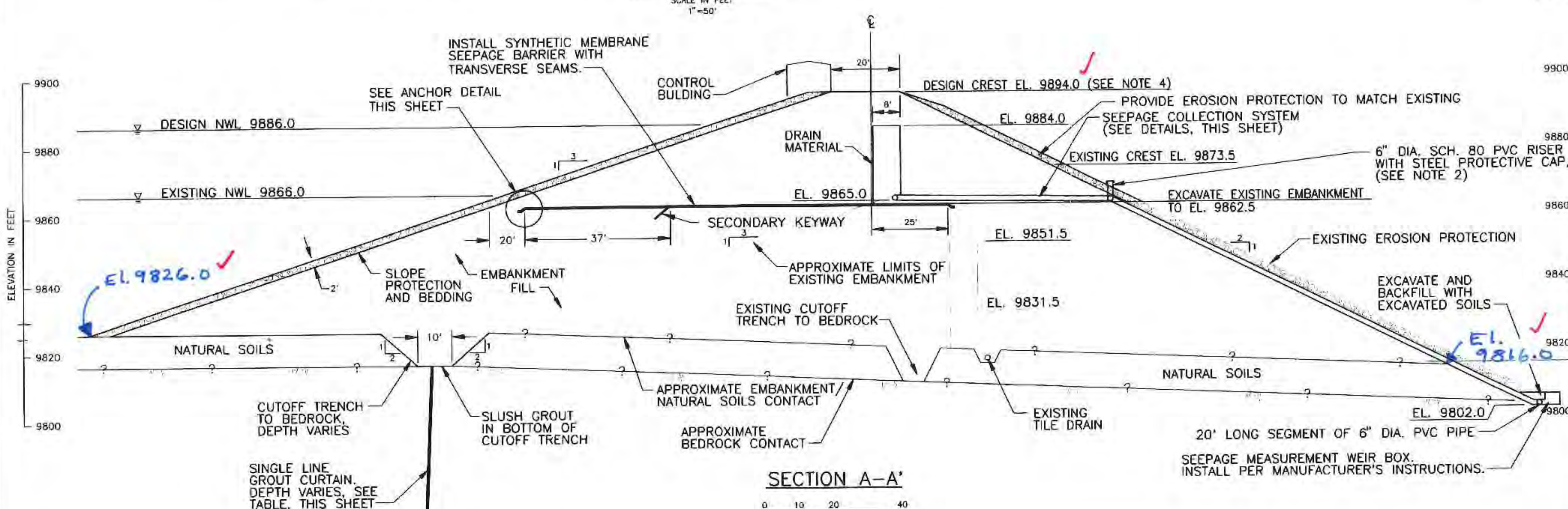


TYPICAL MEMBRANE ANCHOR DETAIL (RIGHT SIDE SIMILAR)

NOT TO SCALE



PVC DRAIN PIPE MAIN DAM CAMBER DETAIL



SECTION A-A'

SCALE IN FEET 1"=20'

NOTES:

1. ENDS OF SLOTTED PVC COLLECTION PIPE TO BE CAPPED.
2. PVC RISERS AT JUNCTIONS OF FOUR DRAIN PIPES WITH HEADER PIPE TO BE PROTECTED WITH STEEL CASING AS SHOWN ON PIEZOMETER DETAIL, DRAWING NO. A-12.
3. ABOVE ELEVATION 9865.0, SLOTTED PVC COLLECTOR PIPE TO APPROXIMATELY FOLLOW GROUND SURFACE TO ELEVATION 9883.0.
4. DAM CREST TO BE AT MINIMUM ELEVATION 9894.0, NOT INCLUDING CAMBER.
5. EXISTING MAIN DAM SECTION BASED ON PLANS FOR ENLARGEMENT OF FISH CREEK RESERVOIR DAM NO. 1 AND CONSTRUCTION OF FISH CREEK RESERVOIR NO. 2, DATED 8/31/72, AVAILABLE AT STATE OF COLORADO DIVISION OF WATER RESOURCES.

DRAWN BY: G.O.J. DATE 1/27/93 — CHECKED BY: J.G.S. DATE 3/11/94

AS CONSTRUCTED - CORRECTIONS COMPLETE BY G.O.J. DATE 3/31/97

REVISIONS			
NO.	DESCRIPTION	DATE	BY

MAIN DAM RAISE, PLAN, SECTION, AND DETAILS

Woodward-Clyde Consultants
Consulting Engineers — Denver, Colorado

FISH CREEK RESERVOIR ENLARGEMENT PROJECT NO. 23100-116

DRAWING NO. A-3 OF A-14

3171-3R

RJH CONSULTANTS, INC.

Project	13117	Page	1/4
Date	9/18/13	By	EMH
Checked	10/16/13	By	TEO
Approved	11-13-13	By	GGS

Client: Steamboat Springs

Subject: Fish Creek Dam

REQUIRED - Identify elevation-capacity data for Fish Creek Dam

ASSUMPTIONS - 1) Use record drawings from the Fish Creek Reservoir Enlargement Project (Woodward Clyde Consultants 1994) ✓

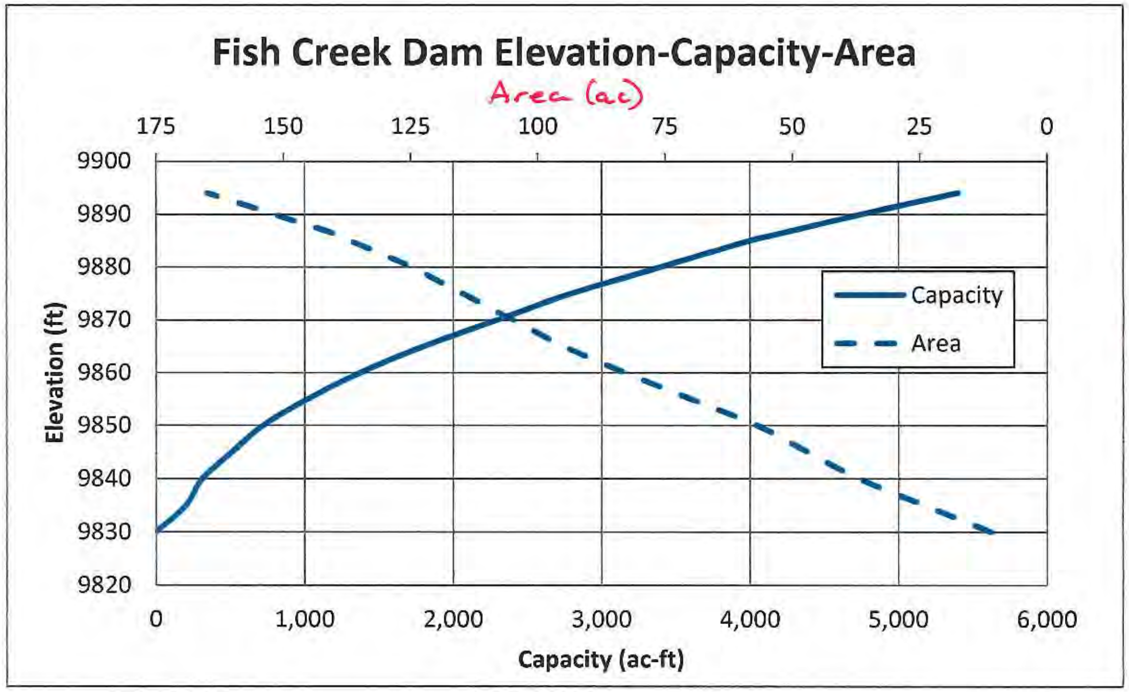
ANALYSIS -

- Elevation-capacity-area information obtained from graph on record drawings (see p. 4) ✓✓
  - ↳ Graph brought into AutoCAD and a grid was digitized ✓ (see p. 3)
- See results on p. 2 ✓
  - ↳ @ Max NWL = 9886.0 ✓
    - Area = 139 ac ✓✓
    - Capacity = 4,150 ac-ft ✓✓

Fish Creek and Long's Lake Dams
Breach Inundation Study
Project No. 13117

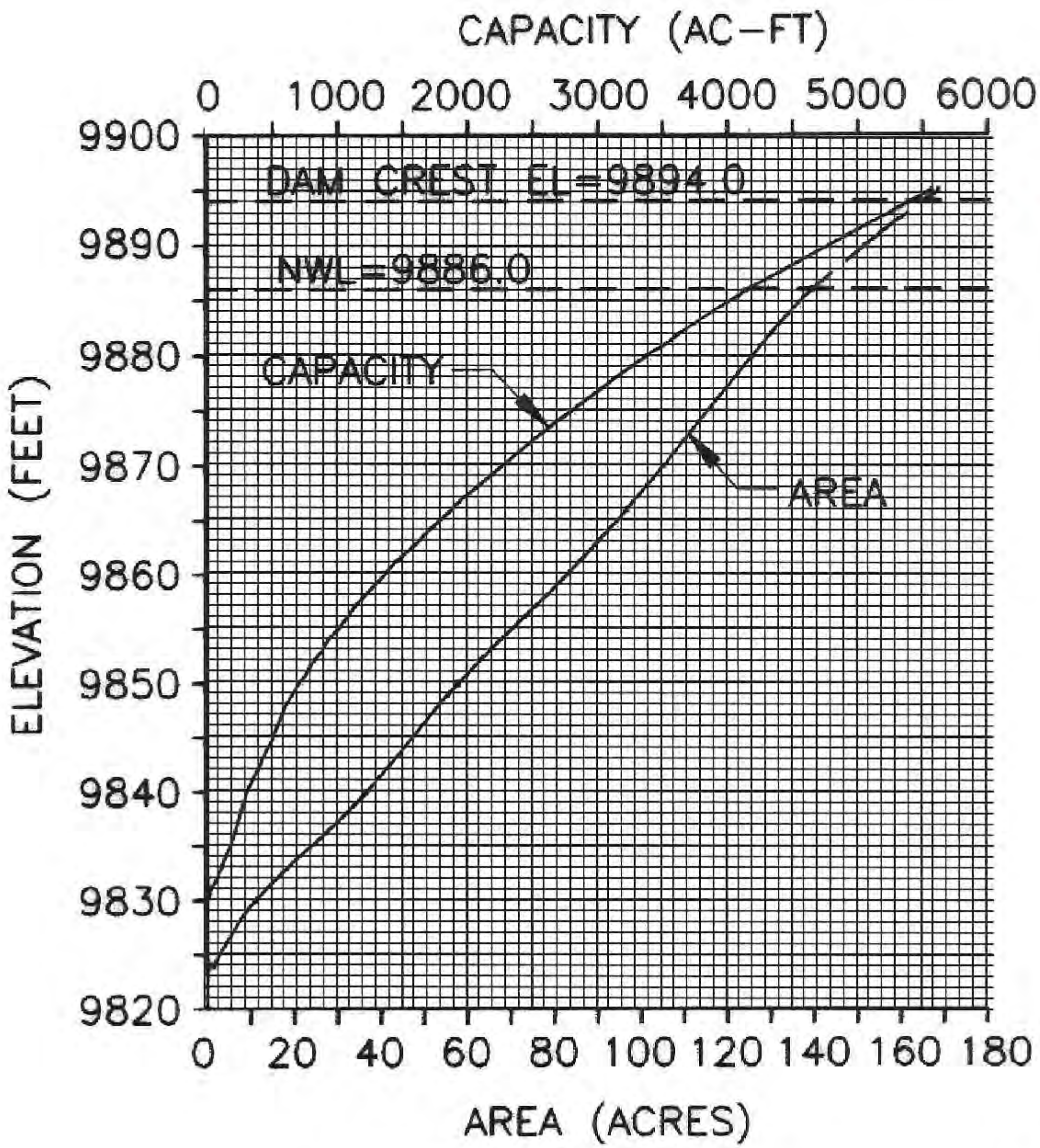
FISH CREEK DAM ELEVATION-CAPACITY

Elev (ft)	Area (ac)	Capacity (ac-ft)
9830	11	0
9835	24	200
9840	37	310
9845	47	510
9850	57	720
9855	70	1,020
9860	83	1,375
9865	95	1,800
9870	105	2,300
9875	115	2,800
9880	125	3,400
9885	137	4,000
9886	139	4,150
9890	152	4,750
9894	165	5,400



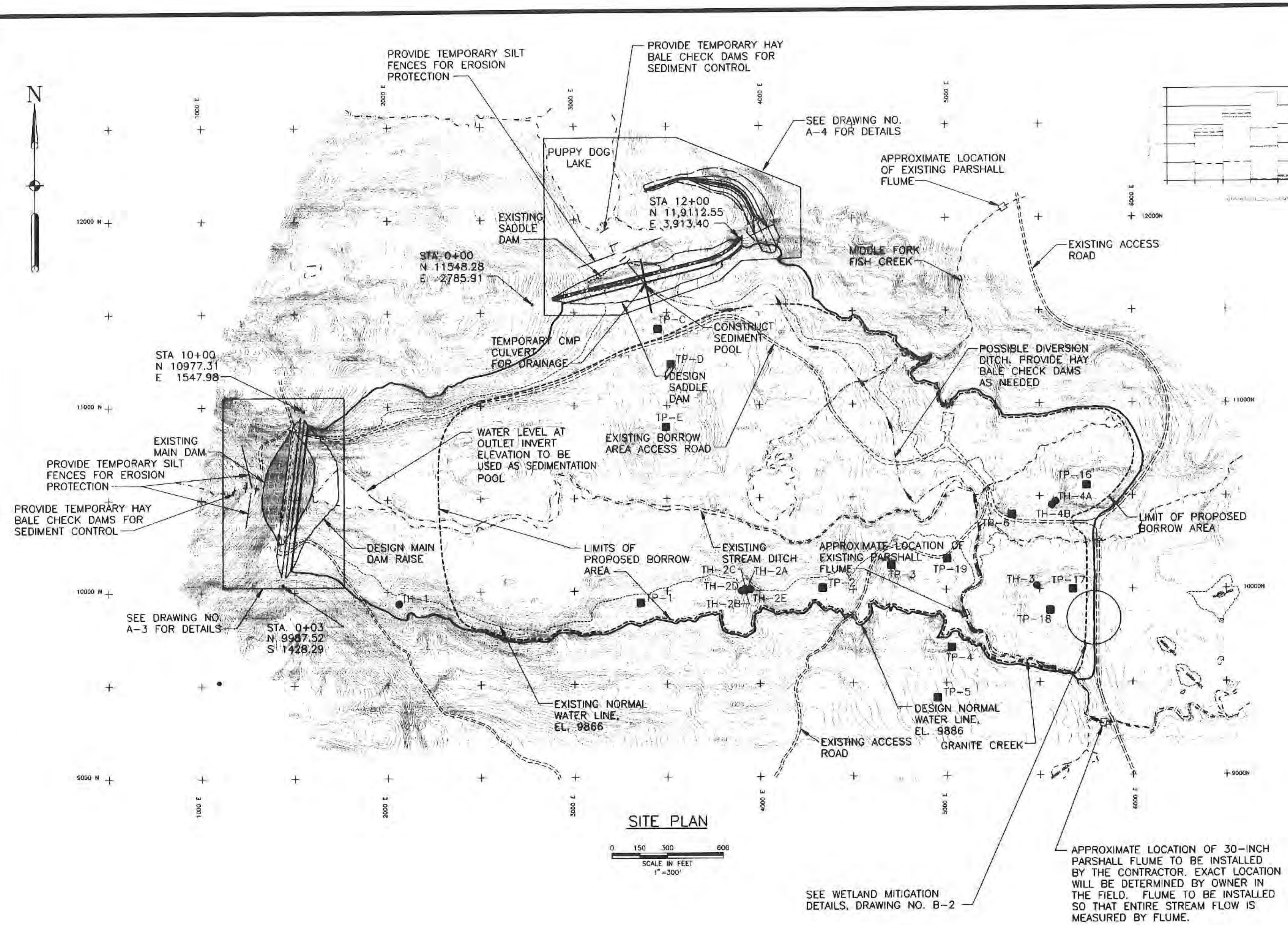
√TEO 10/16/13
GGS 11/13/13

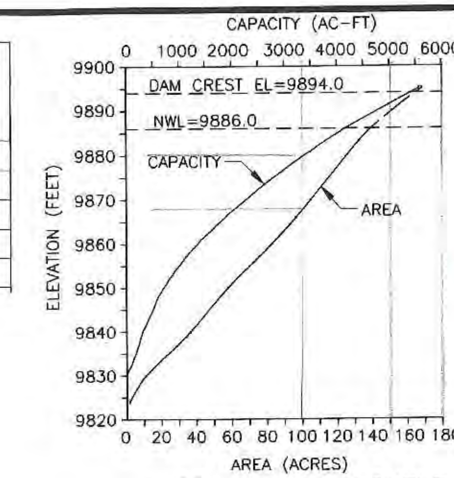
44



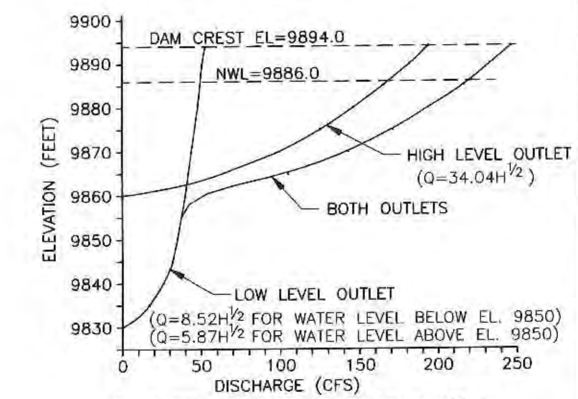
RJH CONSULTANTS, INC.	FISH CREEK DAM AND LONG'S LAKE DAM BREACH INUNDATION STUDY	FISH CREEK DAM ELEVATION-CAPACITY-AREA
	PROJECT NO. 10113	September 2013

P:\13117 - STEAMBOAT\ENGINEERING\DATA COLLECTION\13117 ELEV-CAPACITY-AREA.DWG 9/18/2013

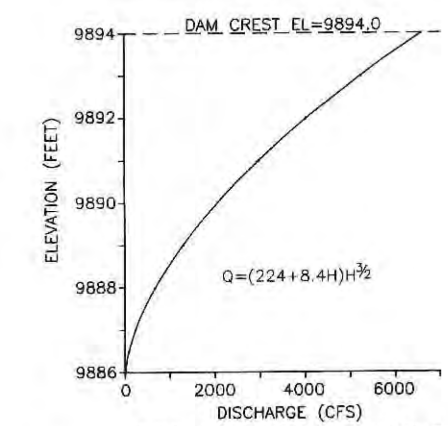




AREA–CAPACITY CURVE



OUTLET WORKS RATING CURVE



SPILLWAY RATING CURVE

LEGEND

- ● BORROW AREA INVESTIGATION TEST HOLE LOCATION
- ■ BORROW AREA INVESTIGATION TEST PIT LOCATION

NOTES:

1. BASE TOPO MAP WAS PROVIDED BY D & D INC. THE TOPO MAP WAS GENERATED FROM AERIAL PHOTOGRAPHY TAKEN ON 10/17/92. THE RESERVOIR WAS LOWERED TO THE OUTLET INVERT LEVEL SHOWN AT THE TIME THE PHOTOGRAPHY WAS TAKEN.
2. SEE DRAWING NO. A-5C FOR LOGS OF BORROW AREA INVESTIGATION TEST HOLES AND TEST PITS.

POSSIBLE DIVERSION SCHEME

1ST CONSTRUCTION SEASON (SUMMER AND FALL)

- DRAIN THE RESERVOIR.
- CONSTRUCT DIVERSION DITCH AND REMOVE SADDLE DAM.
- RUN WATER THROUGH DIVERSION DITCH AND BYPASS TO THE SEDIMENTATION POOL UNTIL THE WATER CLEARS.
- WHEN WATER IS CLEAR CONNECT DIVERSION DITCH TO TEMPORARY CULVERT.
- CONSTRUCT LOW LEVEL OUTLET PIPE AND BEGIN MAIN DAM RAISE.
- REMOVE TEMPORARY CULVERT AND ABANDON DIVERSION DITCH AND REDIRECT INFLOWS TO LOW LEVEL OUTLET PIPE USING THE EXISTING STREAM DITCH.
- CONSTRUCT NEW SADDLE DAM TO ELEVATION 9872 (CURRENT ELEVATION) AS A MINIMUM.
- AT ALL TIMES PROVIDE ALL NECESSARY EROSION CONTROL MEASURES TO MAINTAIN THE QUALITY AT WATER DOWNSTREAM.
- THROUGHOUT THE DIVERSION SCHEME MAINTAIN A 25 YEAR FLOOD HANDLING CAPACITY.

2ND CONSTRUCTION SEASON

- COMPLETE MAIN DAM RAISE CONSTRUCTION.
- COMPLETE NEW SADDLE DAM CONSTRUCTION.
- CONSTRUCT NEW SPILLWAY
- PROVIDE A MINIMUM OF 700 ACRE-FEET OF STORAGE CAPACITY.

DRAWN BY: G.O.J.	DATE 1/27/93	CHECKED BY: J.G.S.	DATE 3/11/94
AS CONSTRUCTED – CORRECTIONS COMPLETE			
BY G.O.J.		DATE 3/31/97	

REVISIONS

NO.	DESCRIPTION	DATE	BY

SITE PLAN, BORROW AREAS, DIVERSION AND EROSION CONTROL

Woodward-Clyde Consultants
Consulting Engineers — Denver, Colorado

FISH CREEK RESERVOIR ENLARGEMENT
PROJECT NO. 23100-116

DRAWING NO.	OF
A-2	A-14

4/4 ✓TEO 10/16/13 GGS 11/13/13 ✓✓

3171-29

APPENDIX B

HEC-HMS HYDROLOGIC MODEL RESULTS

RJH CONSULTANTS, INC.

Project 13117 Page 1/
Date 9/23/13 By EMH
Client Steamboat Springs
Checked 10/18/13 By TEO
Subject Fish Creek Dam
Approved 11-13-13 By GGS

REQUIRED - Determine Muskingum-Cunge channel routing parameters for the dam breach inundation modeling for Fish Creek Dam

ASSUMPTIONS -
1) Use channel cross-section geometry from the RJH Dam Breach HEC-RAS model. Geometry from this model was obtained using 2-ft topography within the City of Steamboat Springs ✓✓

2) Use RJH Manning's n analysis dated 10/30/13.

3) Use 8-point method to define cross-sections ✓✓

4) Channel routing in the Yampa River will be performed using Modified Puls method ok ✓

ANALYSIS -

- Divide the downstream channel into generally homogeneous hydrologic river reaches ✓

- Three reaches were defined as follows

Reach	HEC-RAS XS Range
R-FC1	-0.037 to -2.151 ✓
R-FC2	-2.151 to -5.013 ✓
R-FC3	-5.013 to -8.056 ✓

RJH CONSULTANTS, INC.

Client: Steamboat Springs
Subject: Fish Creek Dam

Project: 13117 Page: 21
Date: 9/23/13 By: EMH
Checked: 10/18/13 By: TEO
Approved: 11/11/13 By: GGS

ANALYSIS -

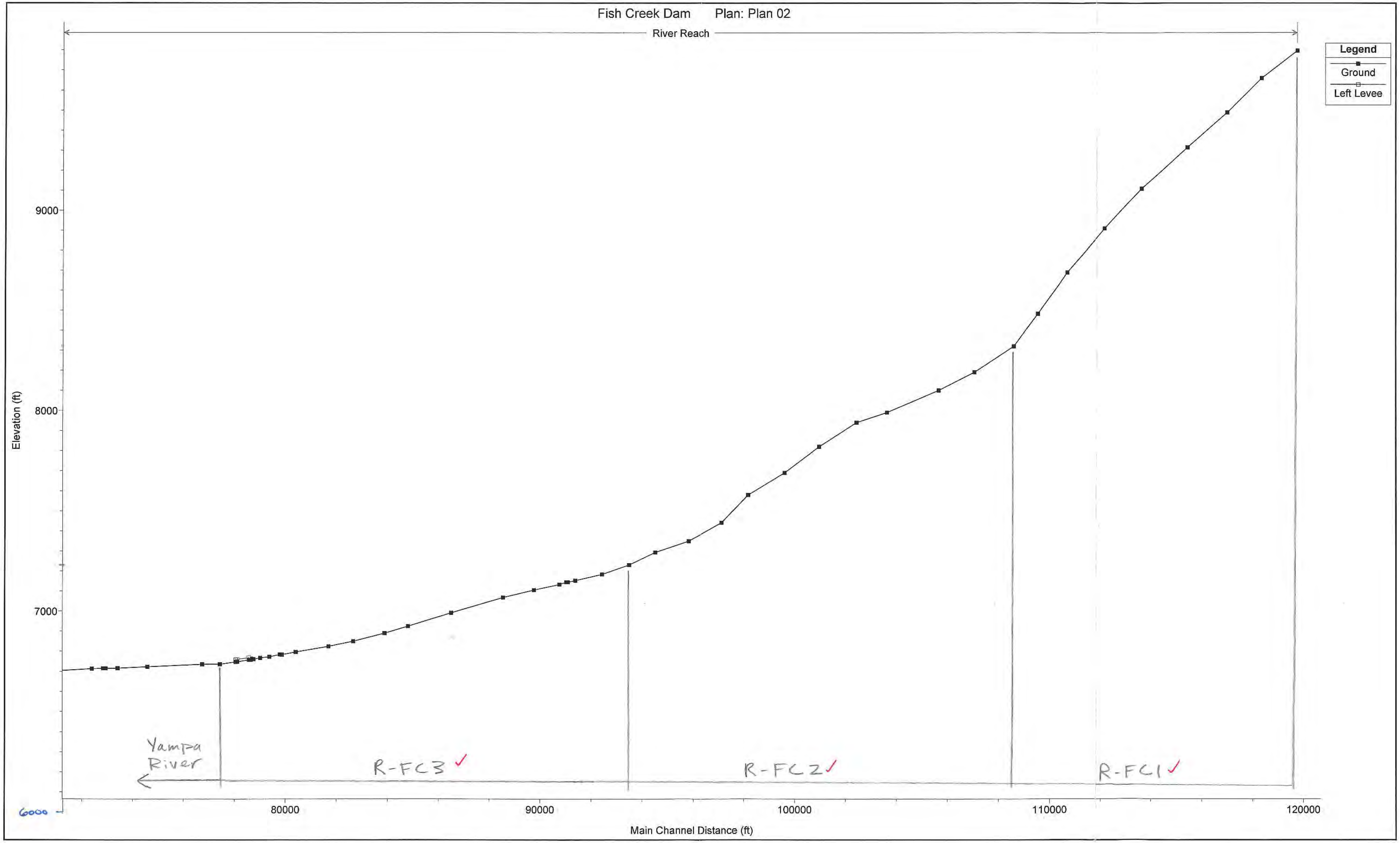
- The Muskingum-Cunge method requires the following input parameters:

  - Length and Slope - Determined using 2' topo provided by Steamboat Springs ✓✓
  - Manning's n Values - Determined from RJH 10/30/13 and assuming main channel n will have minimal impact and using floodplain/overbank n values ✓
  - Channel Geometry - The 8-point method was used with cross-sections from HEC-RAS. See p. 4-6. ✓✓

Reach	Rep. HEC-RAS XS
R-FC1	-0.86 ✓
R-FC2	-3.32 ✓
R-FC3	-6.83 ✓

Reach	Manning's n	Length (ft)	D/S Elev.	U/S Elev.	Slope (ft/ft)
R-FC1	0.08	11,157 ✓	8311.68 ✓✓	9817.80 ✓	0.135 ✓
R-FC2	0.08	15,116 ✓✓	7240.0 ✓✓	8311.68 ✓✓	0.071 ✓✓
R-FC3	0.06	16,064 ✓✓	6735.0 ok	7240.0 ✓✓	0.031 ✓✓

VTEO 10/18/13
GGS 11/13/13



✓ TEO 10/18/13
GOS 11/13/13

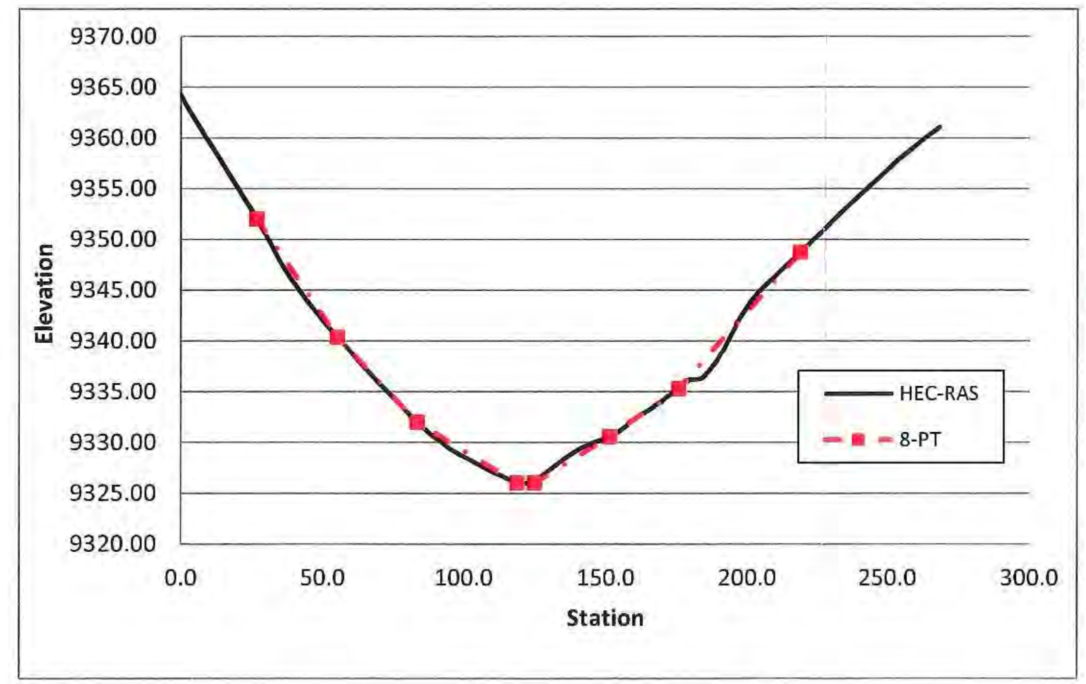
Fish Creek Breach Inundation Study
Project No. 13117

HEC-RAS XS -0.86 ✓

Station	Elevation	Station	Elevation	Station	Elevation	Station	Elevation
0.0	9364.27	92.1	9330.00	158.0	9331.76	229.9	9351.72
0.5	9364.00	95.2	9329.32	158.4	9331.85	230.8	9352.00
1.6	9363.45	96.7	9329.12	159.0	9332.00	236.9	9353.58
4.5	9362.00	98.1	9328.84	161.4	9332.49	238.5	9354.00
6.1	9361.29	100.8	9328.48	161.7	9332.56	244.3	9355.45
9.0	9360.00	101.7	9328.34	162.6	9332.71	246.6	9356.00
9.6	9359.73	104.0	9328.00	166.4	9333.38	247.1	9356.12
13.5	9358.00	105.1	9327.83	167.6	9333.68	254.4	9358.00
16.0	9356.90	105.3	9327.81	167.9	9333.72	255.3	9358.19
18.0	9356.00	108.5	9327.31	168.1	9333.73	263.0	9360.00
21.2	9354.60	109.9	9327.09	169.6	9334.00	268.0	9361.04
22.5	9354.00	111.6	9326.90	171.4	9334.40		
23.9	9353.37	113.4	9326.67	172.4	9334.63		
26.9	9352.00	114.7	9326.49	173.4	9334.80		
30.2	9350.30	116.0	9326.36	176.0	9335.27		
30.8	9350.00	117.8	9326.15	178.5	9336.00		
31.6	9349.56	118.8	9326.00	179.8	9336.20		
34.6	9348.00	119.4	9326.00	182.5	9336.19		
36.5	9347.08	119.7	9326.00	182.9	9336.22		
38.9	9346.00	121.2	9326.00	184.0	9336.31		
42.8	9344.53	121.8	9326.00	186.7	9337.12		
44.2	9344.00	124.2	9326.00	189.1	9338.00		
49.1	9342.33	124.9	9326.00	189.2	9338.00		
50.1	9342.00	125.3	9326.12	190.5	9338.71		
55.4	9340.33	128.1	9326.84	191.6	9339.06		
55.9	9340.18	130.1	9327.28	193.2	9340.00		
56.5	9340.00	133.4	9328.00	196.0	9341.56		
57.6	9339.65	133.5	9328.00	196.7	9342.00		
62.8	9338.00	134.8	9328.30	196.7	9342.00		
65.5	9337.19	136.4	9328.60	197.1	9342.19		
69.4	9336.00	140.7	9329.38	201.3	9344.00		
74.4	9334.59	144.2	9329.84	204.0	9344.86		
76.4	9334.00	144.4	9329.89	205.2	9345.22		
80.7	9332.77	145.8	9330.00	208.3	9346.00		
82.0	9332.41	147.9	9330.19	210.0	9346.45		
83.5	9332.00	148.3	9330.27	211.1	9346.79		
85.1	9331.55	151.5	9330.55	216.0	9348.00		
85.3	9331.49	151.9	9330.52	218.8	9348.70		
87.0	9331.10	152.1	9330.55	220.1	9349.12		
88.9	9330.62	152.7	9330.71	223.3	9350.00		
90.7	9330.28	153.4	9330.83	227.3	9350.96		
91.3	9330.16	155.4	9331.15	229.2	9351.55		

R-FC1
8-POINT XS ✓

Station	Elevation
26.9	9352.0
55.4	9340.3
83.5	9332.0
118.8	9326.0
124.9	9326.0
151.5	9330.6
176.0	9335.3
218.8	9348.7



✓✓

Length: 11,157 ft ✓
U/S Invert: 9817.80 ft ✓
D/S Invert: 8311.68 ft ✓
Slope: 0.135 ft/ft ✓

✓TEO 10/18/13 5/6
GGS 11/13/13

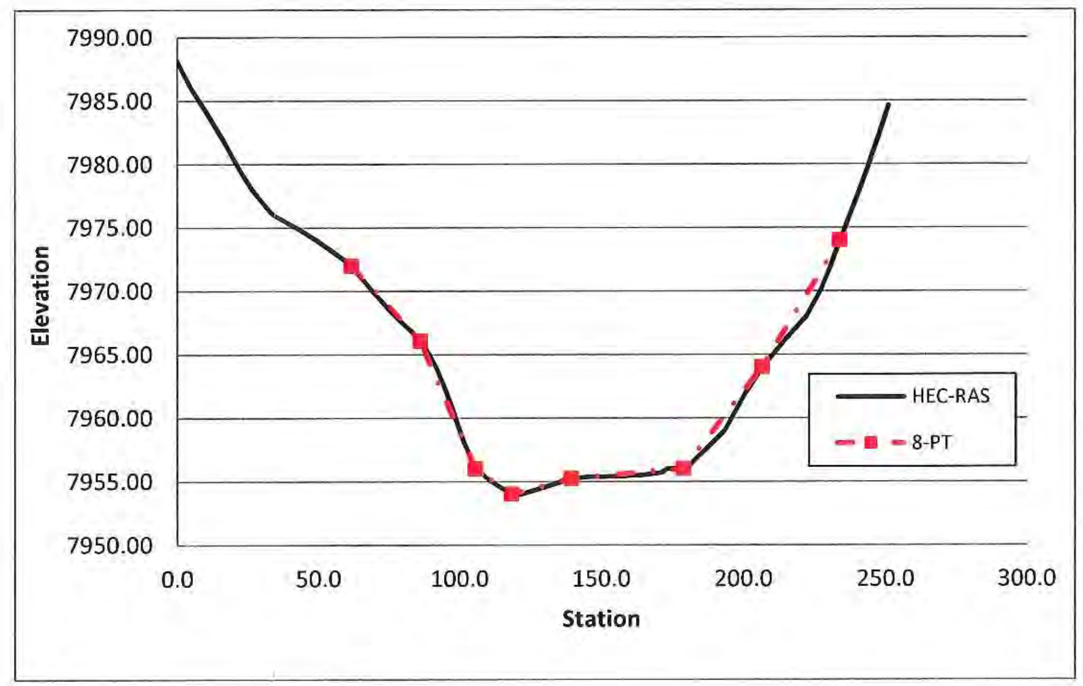
Fish Creek Breach Inundation Study
Project No. 13117

HEC-RAS XS -3.32 ✓

Station	Elevation	Station	Elevation	Station	Elevation
0.0	7988.15	114.6	7954.53	193.3	7959.01
0.3	7988.00	115.8	7954.34	195.8	7960.00
2.0	7987.25	116.6	7954.24	200.3	7961.82
3.6	7986.56	118.5	7954.00	200.7	7962.00
4.9	7986.00	118.7	7954.00	201.3	7962.18
8.0	7984.90	121.0	7954.00	206.6	7964.00
10.5	7984.00	121.0	7954.00	213.2	7965.79
13.3	7982.96	121.1	7954.00	214.0	7966.00
15.8	7982.00	121.5	7954.00	214.5	7966.12
17.7	7981.25	121.5	7954.00	214.7	7966.17
20.7	7980.00	121.7	7954.00	216.2	7966.56
22.3	7979.38	132.2	7954.72	220.2	7967.55
26.2	7978.00	139.5	7955.22	222.0	7968.00
30.4	7976.83	140.1	7955.23	223.1	7968.47
31.9	7976.46	141.2	7955.27	226.8	7970.00
34.0	7976.00	142.6	7955.30	230.3	7971.86
40.9	7975.15	143.6	7955.33	230.5	7972.00
44.1	7974.74	143.9	7955.33	230.9	7972.23
49.4	7974.00	144.7	7955.35	231.9	7972.89
51.4	7973.68	145.3	7955.36	233.9	7974.00
52.5	7973.51	145.8	7955.38	235.6	7975.06
61.8	7972.00	158.0	7955.41	237.3	7976.00
63.1	7971.62	159.0	7955.46	239.7	7977.39
69.0	7970.00	164.4	7955.50	240.7	7978.00
74.0	7968.73	168.0	7955.60	243.5	7979.70
77.1	7968.00	168.3	7955.59	243.9	7980.00
83.5	7966.68	171.2	7955.70	244.9	7980.62
86.1	7966.06	171.4	7955.70	247.0	7982.00
86.4	7966.00	173.2	7956.00	247.7	7982.47
87.8	7965.50	174.8	7956.00	249.9	7984.00
91.7	7964.00	176.1	7956.00	250.6	7984.48
93.0	7963.28	176.8	7956.00	250.9	7984.63
95.3	7962.00	179.1	7956.00		
98.4	7960.05	181.2	7956.30		
98.4	7960.00	182.5	7956.52		
98.6	7959.88	185.1	7956.93		
98.9	7959.71	185.4	7956.98		
101.5	7958.00	188.0	7957.50		
102.5	7957.53	189.7	7957.97		
105.6	7956.00	189.8	7957.98		
109.1	7955.37	189.8	7958.00		
111.0	7955.03	189.8	7958.00		

R-FC2 ✓
8-POINT XS

Station	Elevation
61.8	7972.0
86.1	7966.1
105.6	7956.0
118.5	7954.0
139.5	7955.2
179.1	7956.0
206.6	7964.0
233.9	7974.0



✓ ✓

Length:	15,116	ft ✓
U/S Invert:	8311.68	ft ✓
D/S Invert:	7240	ft ✓
Slope:	0.071	ft/ft ✓

✓TEO 10/18/13 6/6
GGS 11/13/13

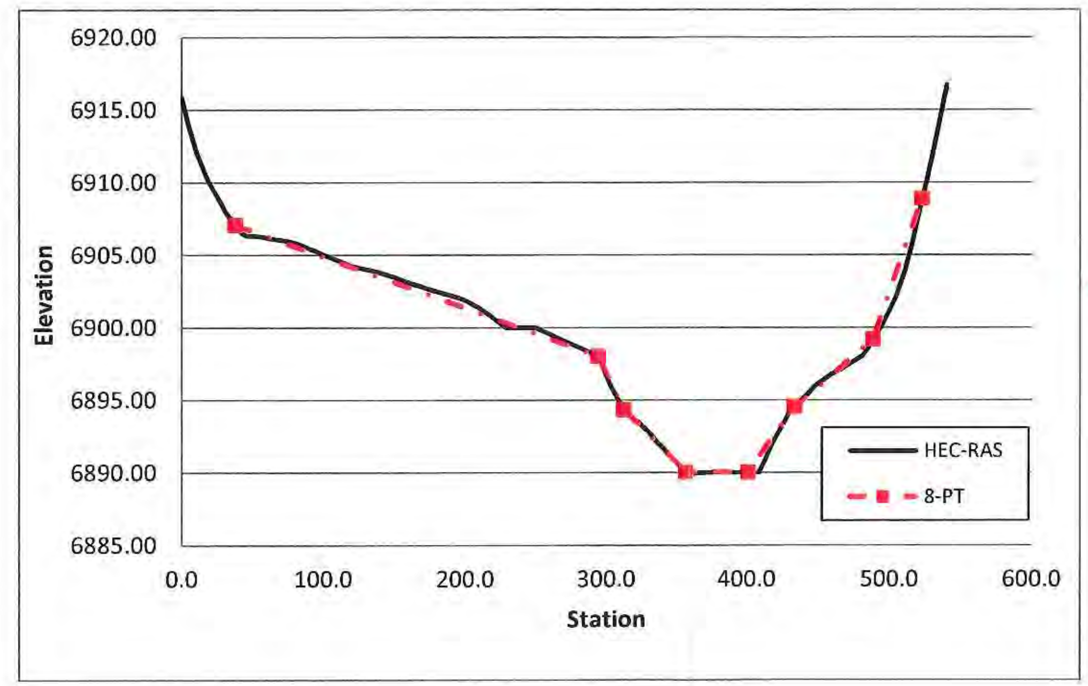
Fish Creek Breach Inundation Study
Project No. 13117

HEC-RAS XS -6.83 ✓

Station	Elevation	Station	Elevation	Station	Elevation	Station	Elevation	Station	Elevation
0.0	6915.88	94.4	6905.29	161.6	6903.04	300.9	6896.41	475.6	6897.71
4.9	6914.00	94.8	6905.27	163.7	6902.97	302.5	6896.00	480.2	6898.00
11.0	6912.00	97.3	6905.15	164.5	6902.94	307.0	6895.24	480.4	6898.00
14.3	6911.23	99.1	6905.08	165.6	6902.92	312.7	6894.33	482.3	6898.23
17.5	6910.45	101.5	6904.97	167.4	6902.86	315.0	6894.00	482.9	6898.33
19.5	6910.00	103.3	6904.90	169.7	6902.80	316.0	6894.00	485.2	6898.63
27.5	6908.60	104.0	6904.88	170.6	6902.76	322.7	6893.45	486.6	6898.86
30.9	6908.00	105.2	6904.83	172.6	6902.70	325.5	6893.15	488.7	6899.18
32.9	6907.71	106.9	6904.76	173.0	6902.68	328.5	6892.91	491.1	6899.58
34.3	6907.56	108.1	6904.72	176.3	6902.58	330.4	6892.69	493.0	6899.91
37.9	6907.08	110.3	6904.63	176.8	6902.57	331.2	6892.62	498.3	6900.84
39.3	6906.90	111.4	6904.59	178.5	6902.51	333.6	6892.34	502.9	6901.80
39.3	6906.89	113.7	6904.48	179.4	6902.49	336.0	6892.03	503.2	6901.86
40.6	6906.73	114.6	6904.45	181.6	6902.43	336.4	6892.00	503.9	6902.00
40.8	6906.72	116.7	6904.36	182.6	6902.40	340.5	6891.58	505.6	6902.48
42.4	6906.53	118.4	6904.30	183.0	6902.38	343.8	6891.24	511.1	6904.00
45.2	6906.34	118.9	6904.27	185.5	6902.32	345.4	6891.10	512.8	6904.61
45.6	6906.33	120.7	6904.22	185.6	6902.31	345.4	6891.09	516.6	6906.00
46.9	6906.34	122.6	6904.16	187.5	6902.27	348.1	6890.83	518.6	6906.90
47.2	6906.33	123.8	6904.13	189.5	6902.22	356.3	6890.03	523.4	6908.89
49.3	6906.33	125.5	6904.10	193.2	6902.11	356.8	6890.00	523.9	6909.08
50.1	6906.32	126.9	6904.07	193.3	6902.10	358.4	6889.92	525.2	6909.61
55.3	6906.28	129.1	6904.03	194.9	6902.06	371.0	6890.00	526.2	6910.00
56.9	6906.25	131.4	6904.00	197.5	6901.97	401.4	6890.00	528.7	6911.12
58.0	6906.22	134.3	6903.93	197.6	6901.96	408.7	6890.00	530.7	6912.00
58.9	6906.21	134.4	6903.93	201.8	6901.78	411.6	6890.62	531.2	6912.23
60.2	6906.18	138.0	6903.83	203.6	6901.69	412.5	6890.80	531.6	6912.40
61.3	6906.16	139.0	6903.81	204.4	6901.64	417.9	6892.00	534.9	6914.00
64.6	6906.11	139.1	6903.80	209.2	6901.40	418.0	6892.00	538.0	6915.43
68.6	6906.06	140.8	6903.75	213.4	6901.10	427.1	6893.65	539.2	6916.00
69.2	6906.05	143.0	6903.68	214.5	6901.03	429.1	6894.00	539.5	6916.12
72.8	6906.00	143.3	6903.68	217.0	6900.88	431.5	6894.29	540.8	6916.72
75.6	6905.94	144.6	6903.63	219.4	6900.70	433.7	6894.52		
76.1	6905.94	145.1	6903.62	227.2	6900.09	440.1	6895.22		
77.2	6905.90	147.3	6903.54	227.6	6900.07	442.3	6895.44		
80.2	6905.83	148.3	6903.53	228.5	6900.00	447.5	6896.00		
81.7	6905.78	150.6	6903.45	249.5	6900.00	448.0	6896.04		
84.5	6905.68	151.0	6903.43	250.1	6899.98	458.9	6896.79		
87.6	6905.55	153.6	6903.34	252.4	6899.86	459.5	6896.81		
88.3	6905.53	156.4	6903.22	253.3	6899.84	463.4	6896.99		
90.8	6905.41	158.4	6903.16	294.5	6898.00	464.9	6897.06		
92.5	6905.36	160.7	6903.06	295.1	6898.00	474.8	6897.67		

R-FC3
8-POINT XS ✓

Station	Elevation
37.92	6907.08
294.47	6898
312.65	6894.33
356.3	6890.03
401.42	6890
433.71	6894.52
488.65	6899.18
523.38	6908.89



✓✓

Length:	16,064	ft ✓
U/S Invert:	7240	ft ✓
D/S Invert:	6735	ft ok
Slope:	0.031	ft/ft ✓

REQUIRED - Determine Modified Puls storage-discharge relationships for channel reaches on the Yampa River

ASSUMPTIONS -

1) Determine storage-discharge relationships using water surface profiles developed in HEC-RAS for a range of discharges ✓✓
2) Use RJH HEC-RAS model for Fish Creek Dam Breach dated 10/31/13. ✓✓
3) Use the average end method to determine floodplain storage between cross-sections ✓✓
4) Use USACE HEC-HMS Technical Reference Manual (2000) ✓✓

ANALYSIS -

- The USACE HEC-HMS Technical Reference Manual provides 3 methods for determining storage-discharge data for the Modified Puls method: ✓

  1) Water surface profiles from hydraulic model ✓
  2) Historical observations of stage and flow ✓
  3) Observed inflow/outflow hydrographs ✓

- RJH used the water surface profile method because a lack of historical/observed data ✓✓

- The model was run for the following flow rates:

  - 1,000 cfs
  - 5,000 cfs
  - 10,000 cfs ✓
  - 20,000 cfs
  - 35,000 cfs
  - 50,000 cfs
  - 75,000 cfs

ANALYSIS -

- For each flow rate, the average end method was used to determine ✓ storage between cross-sections. Distances between cross-sections was assumed to be the reach length of the main channel from ✓✓ the HEC-RAS model.

- See p. 3-6 for a summary of storage calculations and final ✓✓ storage-discharge relationships for each reach.

- HEC-RAS output is shown on p. 7-14 ✓

- The Modified Puls routing was developed for the following reaches: ✓

Reach	XS Range
YR-1	-8.056 to -11.39 ✓
YR-2	-11.39 to -14.317 ✓
YR-3	-14.317 to -17.20 ✓
YR-4	-17.20 to -22.72 ✓

3/17

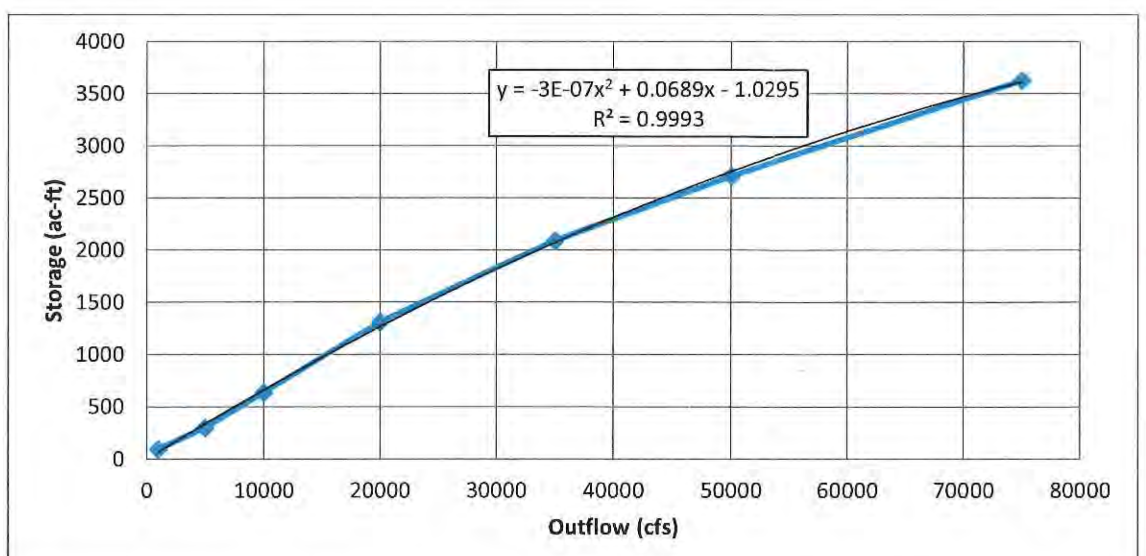
✓TEO 11/6/13
GGS 11/14/13

Fish Creek Dam Breach Study
Project No. 13117

REACH YR-1

XS	Distance (ft)	75,000 cfs Flow Area (ft^2)	75,000 cfs Volume (ac-ft)	50,000 cfs Flow Area (ft^2)	50,000 cfs Volume (ac-ft)	35,000 cfs Flow Area (ft^2)	35,000 cfs Volume (ac-ft)	20,000 cfs Flow Area (ft^2)	20,000 cfs Volume (ac-ft)	10,000 cfs Flow Area (ft^2)	10,000 cfs Volume (ac-ft)	5,000 cfs Flow Area (ft^2)	5,000 cfs Volume (ac-ft)	1,000 cfs Flow Area (ft^2)	1,000 cfs Volume (ac-ft)
-8.056	698.4	8380.5		4908.6		4017.87		2117.2		789.2		311.9		173.3	
-8.188	2159.1	4776.8	105.5	3885.7	70.5	2672.02	53.6	2439.6	36.5	1506.6	18.4	827.7	9.1	314.6	3.9
-8.597	1169.7	9825.6	361.9	7394.3	279.6	5596.87	204.9	3472.4	146.5	1642.9	78.1	829.9	41.1	193.6	12.6
-8.819	468.6	6965.5	225.4	4621.8	161.3	3326.59	119.8	2353.8	78.2	1444.6	41.5	576.9	18.9	278.9	6.3
-8.907	105.4	10888.1	96.0	7376.9	64.5	5438.41	47.1	3708.4	32.6	2236.5	19.8	1324.1	10.2	317.2	3.2
-8.927	444.3	7904.2	22.7	5945.8	16.1	4764.89	12.3	3339.6	8.5	2231.7	5.4	1425.1	3.3	361.9	0.8
-9.011	1164.5	11296.1	97.9	8565.8	74.0	6764.07	58.8	4599.3	40.5	2230.3	22.8	808.9	11.4	227.2	3.0
-9.232	941.8	9702.3	280.7	7081.9	209.2	5282.98	161.0	3068.3	102.5	1519.5	50.1	816.5	21.7	206.3	5.8
-9.41	95.5	7959.6	190.9	6236.5	144.0	5145.07	112.7	3771.3	73.9	2175.0	39.9	651.8	15.9	271.4	5.2
-9.428	584.6	7653.8	17.1	5420.4	12.8	4075.46	10.1	2745.0	7.1	1376.0	3.9	566.7	1.3	223.4	0.5
-9.539	949.2	11483.2	128.4	7715.0	88.1	5526.86	64.4	3841.0	44.2	1810.8	21.4	762.5	8.9	215.3	2.9
-9.719	1283.9	10167.8	235.9	7329.2	163.9	5382.31	118.9	2014.5	63.8	951.4	30.1	673.9	15.6	234.6	4.9
-9.962	471.6	10349.6	302.4	8137.8	227.9	6589.32	176.4	4119.4	90.4	1489.2	36.0	553.8	18.1	154.8	5.7
-10.051	68.7	7113.3	94.5	5666.6	74.7	4674.46	61.0	2492.3	35.8	841.8	12.6	544.0	5.9	220.7	2.0
-10.064	258.4	4752.3	9.4	3433.3	7.2	2090.48	5.3	1233.4	2.9	852.7	1.3	571.4	0.9	243.1	0.4
-10.113	746.5	4088.5	26.2	2823.5	18.6	1711.7	11.3	1344.0	7.6	933.8	5.3	606.4	3.5	194.1	1.3
-10.255	1114.8	4627.9	74.7	2773.1	48.0	2759.7	38.3	1943.8	28.2	1148.9	17.8	589.8	10.2	216.9	3.5
-10.466	269.4	13995.5	238.3	11542.3	183.2	9782.73	160.5	7991.6	127.1	2460.8	46.2	685.8	16.3	216.4	5.5
-10.517	42.8	8035.8	68.1	6107.8	54.6	5407.99	47.0	4508.1	38.6	1142.2	11.1	725.8	4.4	263.0	1.5
-10.525	612.2	6356.1	7.1	4587.9	5.2	3085.67	4.2	2471.1	3.4	980.4	1.0	634.3	0.7	225.2	0.2
-10.641	1055.3	6092.0	87.5	4379.8	63.0	3381.29	45.4	1514.4	28.0	1020.5	14.1	693.6	9.3	309.0	3.8
-10.841	1133.3	13556.5	238.0	10901.9	185.1	8551.84	144.5	5745.1	87.9	3173.9	50.8	1124.8	22.0	130.2	5.3
-11.055	199.5	15195.3	374.0	12246.3	301.1	9201.23	230.9	2983.9	113.6	1029.3	54.7	612.3	22.6	258.3	5.1
-11.093	93.8	10187.9	58.1	7993.1	46.3	5590.9	33.9	2436.4	12.4	1475.2	5.7	726.2	3.1	241.6	1.1
-11.111	163.2	4291.0	15.6	3027.8	11.9	3589.12	9.9	3015.2	5.9	1763.2	3.5	831.0	1.7	340.7	0.6
-11.142	1312.2	7742.8	22.5	6020.3	16.9	4773.29	15.7	2451.8	10.2	1008.2	5.2	609.1	2.7	224.5	1.1
-11.39		8638.7	246.7	6218.1	184.3	4779.97	143.9	3337.9	87.2	1549.3	38.5	755.8	20.6	209.6	6.5
		Total	**3625.6**		**2712.1**		**2092.0**		**1313.8**		**635.2**		**299.5**		**92.9**

Storage (ac-ft)	Outflow (cfs)
93	1000
300	5000
635	10000
1314	20000
2092	35000
2712	50000
3626	75000



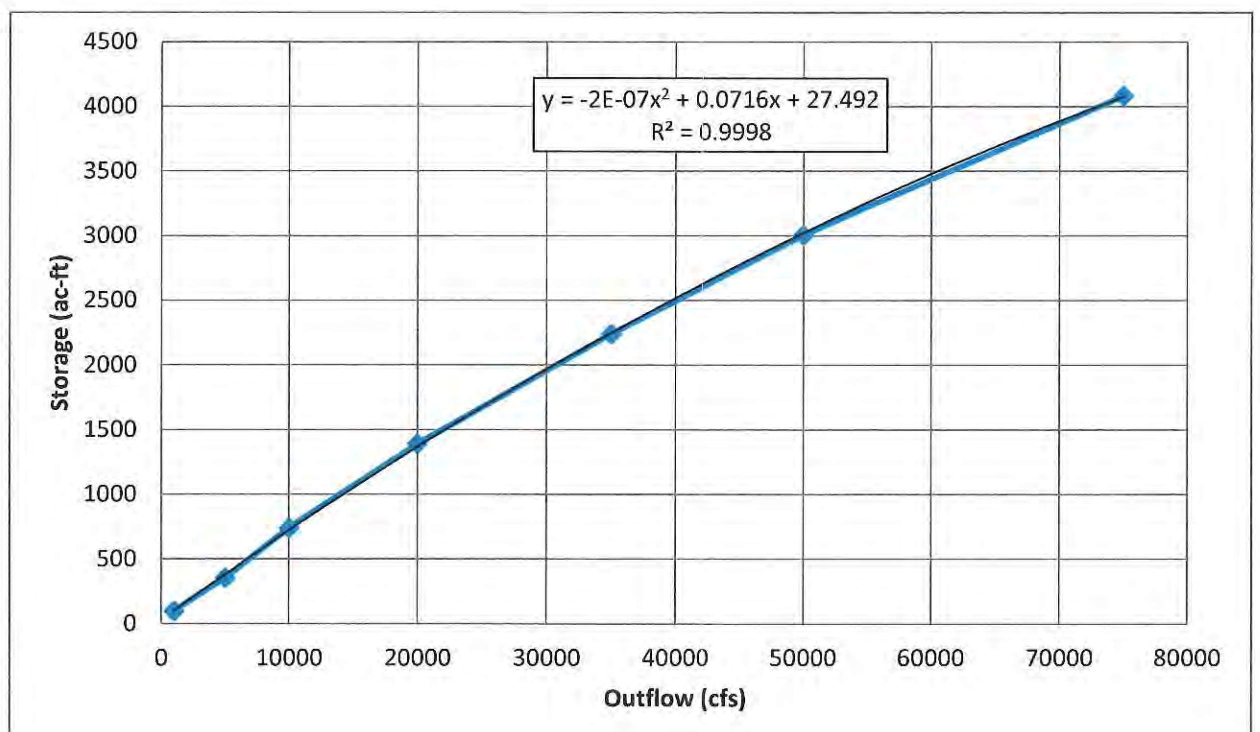
√TEO 11/6/13
GGS 11/14/13

Fish Creek Dam Breach Study
Project No. 13117

REACH YR-2

XS	Distance (ft)	75,000 cfs		50,000 cfs		35,000 cfs		20,000 cfs		10,000 cfs		5,000 cfs		1,000 cfs	
		Flow Area (ft^2)	Volume (ac-ft)	Flow Area (ft^2)	Volume (ac-ft)	Flow Area (ft^2)	Volume (ac-ft)	Flow Area (ft^2)	Volume (ac-ft)	Flow Area (ft^2)	Volume (ac-ft)	Flow Area (ft^2)	Volume (ac-ft)	Flow Area (ft^2)	Volume (ac-ft)
-11.39	1408.4	8638.7		6218.1		4779.97		3337.9		1549.3		755.8		209.6	
-11.657	2681.6	12015.9	333.9	9389.3	252.3	7183.08	193.4	4364.6	124.5	2730.4	69.2	1408.0	35.0	285.5	8.0
-12.165	1231.3	7708.4	607.1	5189.1	448.7	4019.36	344.8	2944.7	225.0	1499.1	130.2	861.7	69.9	173.5	14.1
-12.398	40.5	14210.3	309.8	10649.4	223.9	7782.9	166.8	3745.8	94.6	2045.1	50.1	894.3	24.8	319.0	7.0
-12.406	1104.8	15284.3	13.7	11899.3	10.5	9179.04	7.9	4680.0	3.9	1569.8	1.7	531.0	0.7	185.8	0.2
-12.615	1707.1	10127.5	322.2	6691.9	235.8	4034.25	167.6	2466.3	90.6	1451.9	38.3	1011.2	19.6	352.5	6.8
-12.938	2738.4	10690.3	407.9	8526.1	298.2	7242.94	221.0	5057.1	147.4	2878.2	84.8	1126.7	41.9	402.1	14.8
-13.457	1662.2	15120.4	811.3	10683.6	603.8	7349.08	458.7	3910.7	281.9	1791.2	146.8	916.1	64.2	156.5	17.6
-13.772	1679.9	14463.1	564.4	10584.7	405.8	7684.1	286.8	4942.5	168.9	2600.6	83.8	1052.6	37.6	395.3	10.5
-14.09	560.7	8886.7	450.2	6269.9	325.0	4663.66	238.1	2917.1	151.6	1396.9	77.1	557.7	31.1	155.0	10.6
-14.196	63.3	7966.5	108.5	6363.7	81.3	5120.03	63.0	3515.6	41.4	2186.1	23.1	1279.5	11.8	351.2	3.3
-14.208	573.3	8923.0	12.3	6807.1	9.6	5383.65	7.6	3686.7	5.2	2300.8	3.3	1369.2	1.9	322.9	0.5
-14.317	1841.3	12379.8	140.2	9697.4	108.6	7320.98	83.6	4825.8	56.0	2507.7	31.6	1001.2	15.6	255.5	3.8
		Total	**4081.6**		**3003.4**		**2239.2**		**1391.0**		**739.9**		**353.9**		**97.2**

Storage (ac-ft)	Outflow (cfs)
97	1000
354	5000
740	10000
1391	20000
2239	35000
3003	50000
4082	75000



5/17

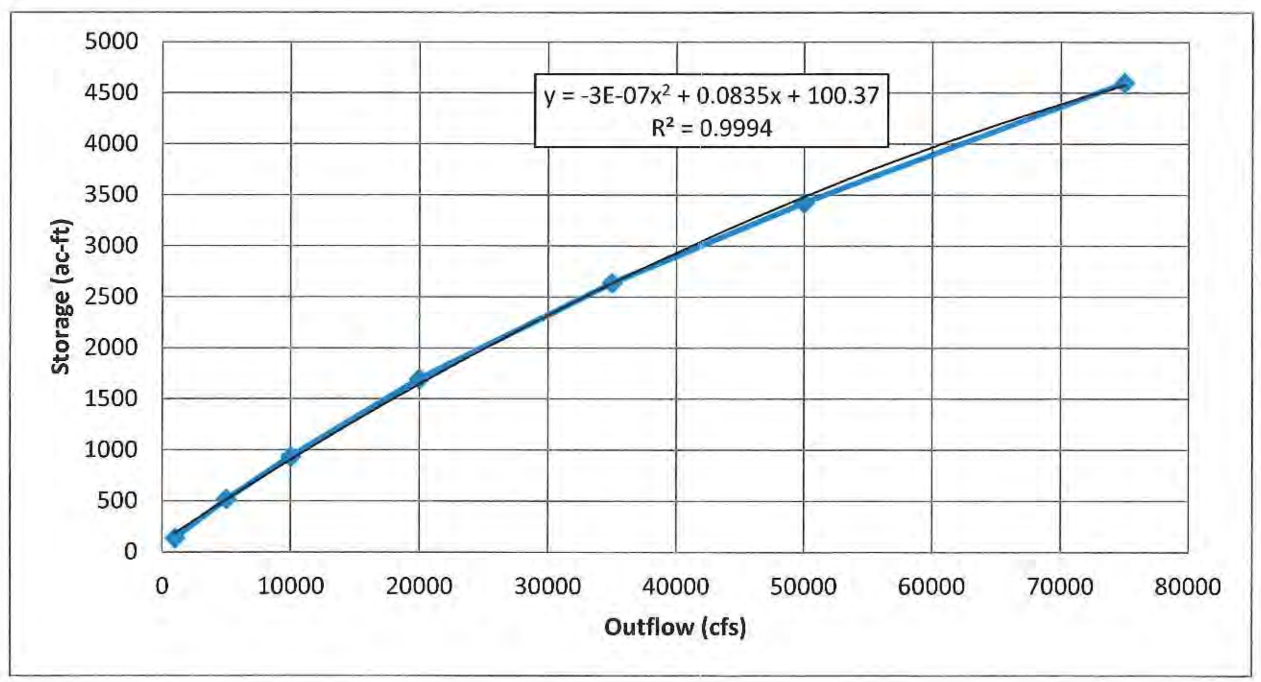
TEO 11/6/13
GGS 11/14/13

Fish Creek Dam Breach Study
Project No. 13117

REACH YR-3

XS	Distance (ft)	75,000 cfs Flow Area (ft^2)	75,000 cfs Volume (ac-ft)	50,000 cfs Flow Area (ft^2)	50,000 cfs Volume (ac-ft)	35,000 cfs Flow Area (ft^2)	35,000 cfs Volume (ac-ft)	20,000 cfs Flow Area (ft^2)	20,000 cfs Volume (ac-ft)	10,000 cfs Flow Area (ft^2)	10,000 cfs Volume (ac-ft)	5,000 cfs Flow Area (ft^2)	5,000 cfs Volume (ac-ft)	1,000 cfs Flow Area (ft^2)	1,000 cfs Volume (ac-ft)
-14.317	1841.3	12379.8		9697.4		7320.98		4825.8		2507.7		1001.2		255.5	
-14.665	1885.3	9774.5	468.2	6415.6	340.6	4821.23	256.6	2567.9	156.3	1590.2	86.6	696.2	35.9	249.2	10.7
-15.023	2128.3	17988.1	600.8	12670.0	413.0	9549.95	311.0	6109.6	187.8	2995.7	99.2	1584.9	49.4	325.4	12.4
-15.426	3201.4	9135.5	662.6	7121.2	483.5	5445.66	366.3	3526.8	235.4	1382.1	106.9	894.8	60.6	278.6	14.8
-16.032	3050.4	11805.5	769.5	8557.4	576.1	6416.13	435.9	3932.2	274.1	2503.1	142.8	1791.9	98.7	737.7	37.3
-16.61	515.5	16374.7	986.7	13077.2	757.5	10616.53	596.4	7464.2	399.0	4351.3	240.0	2091.2	136.0	155.5	31.3
-16.707	40.1	12929.4	173.4	9998.5	136.5	8404.48	112.5	5515.6	76.8	2182.0	38.7	1212.4	19.5	365.5	3.1
-16.715	374.7	11726.9	11.4	8225.0	8.4	4531.12	6.0	2925.1	3.9	2134.8	2.0	1109.1	1.1	393.1	0.3
-16.786	2189.0	16633.3	122.0	12322.7	88.4	9175.56	59.0	5859.2	37.8	3489.5	24.2	1794.1	12.5	334.8	3.1
-17.2	2450.8	15359.1	803.8	12162.1	615.2	10341.88	490.4	7044.2	324.2	4147.5	191.9	2271.5	102.2	476.0	20.4
		Total	**4598.4**		**3419.2**		**2634.1**		**1695.3**		**932.3**		**515.8**		**133.4**

Storage (ac-ft)	Outflow (cfs)
133	1000
516	5000
932	10000
1695	20000
2634	35000
3419	50000
4598	75000



6/17

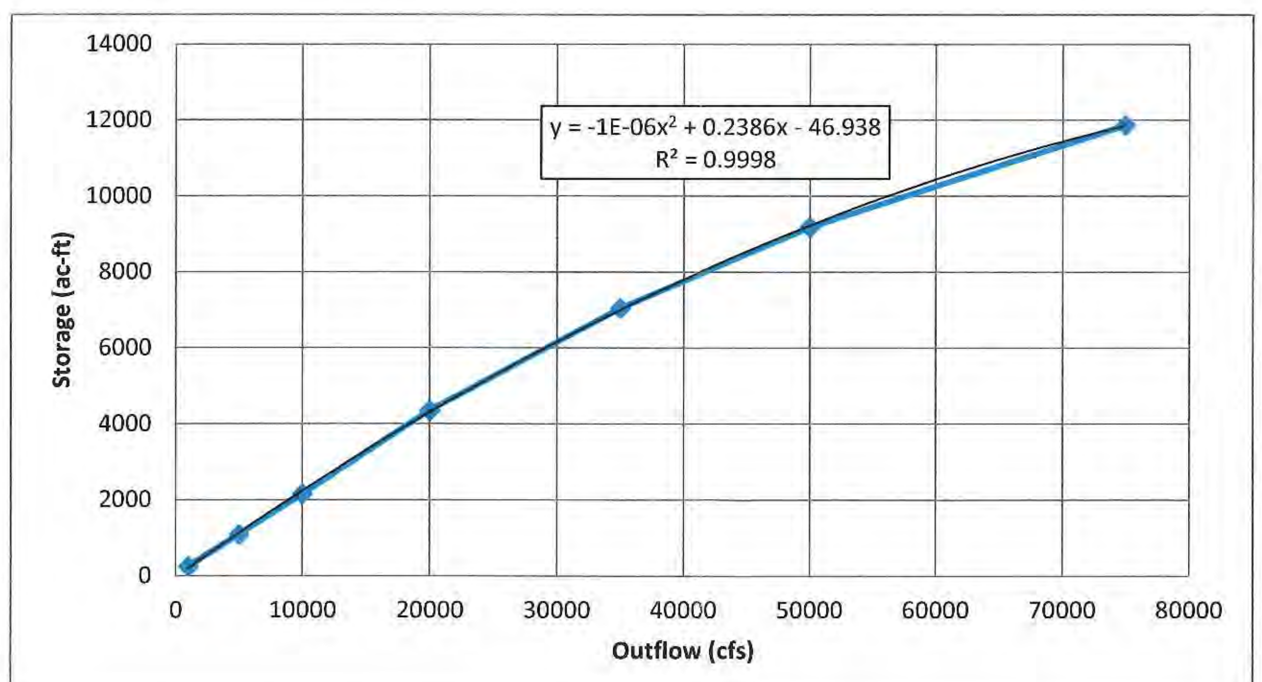
✓TEO 11/6/13
GGS 11/14/13

Fish Creek Dam Breach Study
Project No. 13117

REACH YR-4

		75,000 cfs		50,000 cfs		35,000 cfs		20,000 cfs		10,000 cfs		5,000 cfs		1,000 cfs	
XS	Distance (ft)	Flow Area (ft^2)	Volume (ac-ft)	Flow Area (ft^2)	Volume (ac-ft)	Flow Area (ft^2)	Volume (ac-ft)	Flow Area (ft^2)	Volume (ac-ft)	Flow Area (ft^2)	Volume (ac-ft)	Flow Area (ft^2)	Volume (ac-ft)	Flow Area (ft^2)	Volume (ac-ft)
-17.2	2450.8	15359.1		12162.1		10341.88		7044.2		4147.5		2271.5		476.0	
-17.665	2265.5	13859.0	821.9	9602.3	612.3	6360.81	469.9	3686.6	301.9	2802.5	195.5	1588.9	108.6	324.3	22.5
-18.094	2191.8	19363.7	863.9	16020.6	666.3	12652.72	494.4	7689.9	295.8	3285.1	158.3	1271.6	74.4	251.2	15.0
-18.509	3317.7	15931.4	888.0	9692.3	646.9	4836.74	440.0	3033.8	269.8	2018.4	133.4	1216.0	62.6	353.7	15.2
-19.137	2705.7	11851.1	1058.0	9471.8	729.8	7786.41	480.7	4810.3	298.7	2476.4	171.2	1353.1	97.8	442.7	30.3
-19.65	2604.8	10439.7	692.3	7148.9	516.2	4398.32	378.4	3574.2	260.4	1916.2	136.4	1019.7	73.7	131.1	17.8
-20.143	1896.5	21594.6	957.8	18603.9	770.0	14635.69	569.1	4592.9	244.2	2224.1	123.8	1394.4	72.2	639.3	23.0
-20.502	487.5	32088.6	1168.6	29640.3	1050.2	25900.95	882.4	12893.6	380.7	3948.1	134.4	1553.7	64.2	209.5	18.5
-20.594	33.0	11217.2	242.3	6312.6	201.2	6197.49	179.6	2145.0	84.2	938.6	27.3	695.7	12.6	398.3	3.4
-20.601	499.3	8072.1	7.3	5483.8	4.5	1993.4	3.1	1083.4	1.2	661.5	0.6	680.7	0.5	411.6	0.3
-20.695	2131.0	23068.1	178.5	17958.9	134.4	14198.99	92.8	9739.0	62.0	4727.3	30.9	2255.4	16.8	458.6	5.0
-21.099	567.3	23015.2	1127.2	19672.7	920.5	17232.25	768.8	14873.4	602.0	5109.2	240.6	1645.3	95.4	424.9	21.6
-21.206	70.6	12330.4	230.1	9684.6	191.1	7101.99	158.4	8516.8	152.3	1284.6	41.6	956.3	16.9	503.1	6.0
-21.22	309.2	7754.4	16.3	5616.3	12.4	3739.53	8.8	3064.5	9.4	1151.9	2.0	939.0	1.5	488.9	0.8
-21.278	1673.3	15284.3	81.8	11803.1	61.8	9265.32	46.2	5774.3	31.4	3263.1	15.7	1569.5	8.9	295.1	2.8
-21.595	4198.1	23503.9	745.0	17558.9	563.9	13724.76	441.6	9184.8	287.3	5650.1	171.2	2995.2	87.7	454.6	14.4
-22.39	1749.1	19981.6	2095.4	14947.1	1566.4	11684.39	1224.4	7611.8	809.4	3605.0	446.0	1802.4	231.2	261.3	34.5
-22.722	145.2	14472.5	691.7	11019.2	521.3	8588.73	407.0	5486.0	263.0	2623.3	125.0	1228.1	60.8	402.7	13.3
		Total	**11866.3**		**9169.2**		**7045.7**		**4353.6**		**2153.9**		**1085.9**		**244.5**

Storage (ac-ft)	Outflow (cfs)
245	1000
1086	5000
2154	10000
4354	20000
7046	35000
9169	50000
11866	75000



R-YR1 ✓

HEC-RAS Plan: Mod Puls River: River Reach: Reach

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	-8.056	PF 1	1000.00	6735.40	6740.66	6739.63	6741.18	0.005890	5.77	173.27	58.81	0.59
Reach	-8.056	PF 2	5000.00	6735.40	6742.76	6743.78	6746.75	0.027134	16.03	311.86	71.15	1.35
Reach	-8.056	PF 3	10000.00	6735.40	6746.64	6747.85	6750.33	0.013274	15.69	789.15	368.42	1.02
Reach	-8.056	PF 4	20000.00	6735.40	6749.65	6750.41	6752.61	0.008943	16.19	2117.22	540.05	0.89
Reach	-8.056	PF 5	35000.00	6735.40	6752.60	6752.61	6755.06	0.006633	16.48	4017.87	740.60	0.80
Reach	-8.056	PF 6	50000.00	6735.40	6753.75	6753.75	6757.03	0.008501	19.71	4908.64	818.39	0.91
Reach	-8.056	PF 7	75000.00	6735.40	6756.77	6756.77	6759.45	0.006470	19.51	8380.49	1202.17	0.82
Reach	-8.188	PF 1	1000.00	6735.54	6737.98	6736.92	6738.15	0.003184	2.58	314.61	146.04	0.35
Reach	-8.188	PF 2	5000.00	6735.54	6740.54	6739.33	6741.11	0.006159	6.29	827.70	304.99	0.56
Reach	-8.188	PF 3	10000.00	6735.54	6742.42	6741.05	6743.17	0.005839	7.62	1506.56	539.22	0.58
Reach	-8.188	PF 4	20000.00	6735.54	6743.90	6743.25	6745.28	0.008546	10.85	2439.56	720.79	0.73
Reach	-8.188	PF 5	35000.00	6735.54	6744.21	6745.26	6747.82	0.021604	17.77	2672.02	784.16	1.17
Reach	-8.188	PF 6	50000.00	6735.54	6745.67	6746.56	6749.26	0.018711	18.72	3885.70	866.41	1.13
Reach	-8.188	PF 7	75000.00	6735.54	6746.66	6748.22	6752.02	0.025334	23.42	4776.76	928.33	1.33
Reach	-8.597	PF 1	1000.00	6723.30	6725.71	6725.33	6726.12	0.012345	5.16	193.64	115.43	0.70
Reach	-8.597	PF 2	5000.00	6723.30	6729.90		6730.51	0.004123	6.38	829.88	197.86	0.49
Reach	-8.597	PF 3	10000.00	6723.30	6731.68	6729.75	6732.49	0.004555	7.98	1642.92	699.75	0.54
Reach	-8.597	PF 4	20000.00	6723.30	6733.55		6734.28	0.003768	8.53	3472.42	1066.36	0.51
Reach	-8.597	PF 5	35000.00	6723.30	6735.42	6734.11	6736.17	0.003197	8.94	5596.87	1194.65	0.48
Reach	-8.597	PF 6	50000.00	6723.30	6736.76	6734.98	6737.63	0.003284	9.81	7394.31	1443.47	0.50
Reach	-8.597	PF 7	75000.00	6723.30	6738.44	6735.91	6739.49	0.003249	10.65	9825.55	1452.96	0.51
Reach	-8.819	PF 1	1000.00	6716.27	6720.31		6720.51	0.002484	3.59	278.90	102.72	0.38
Reach	-8.819	PF 2	5000.00	6716.27	6722.84	6721.87	6724.02	0.007770	8.68	576.90	157.29	0.73
Reach	-8.819	PF 3	10000.00	6716.27	6724.88	6724.88	6726.08	0.006860	9.55	1444.63	601.61	0.72
Reach	-8.819	PF 4	20000.00	6716.27	6726.35	6726.35	6727.98	0.008699	11.97	2353.84	636.40	0.83
Reach	-8.819	PF 5	35000.00	6716.27	6727.84	6727.84	6730.16	0.010040	14.71	3326.59	671.21	0.92
Reach	-8.819	PF 6	50000.00	6716.27	6729.48	6729.23	6731.90	0.008508	15.35	4621.75	824.77	0.87
Reach	-8.819	PF 7	75000.00	6716.27	6732.14		6734.51	0.006218	15.45	6965.54	950.02	0.78
Reach	-8.907	PF 1	1000.00	6715.39	6719.12	6718.45	6719.30	0.003270	3.82	317.17	205.20	0.43
Reach	-8.907	PF 2	5000.00	6715.39	6721.91	6720.46	6722.21	0.002423	5.12	1324.06	637.51	0.41
Reach	-8.907	PF 3	10000.00	6715.39	6723.14	6721.88	6723.59	0.002945	6.57	2236.54	756.86	0.47
Reach	-8.907	PF 4	20000.00	6715.39	6725.05	6723.47	6725.64	0.002838	7.76	3708.40	836.09	0.49
Reach	-8.907	PF 5	35000.00	6715.39	6727.21	6724.85	6727.98	0.002763	9.00	5438.41	892.61	0.50
Reach	-8.907	PF 6	50000.00	6715.39	6729.16	6725.96	6729.97	0.002517	9.66	7376.88	1139.72	0.49
Reach	-8.907	PF 7	75000.00	6715.39	6732.16	6727.48	6732.97	0.001996	9.99	10888.14	1190.29	0.45
Reach	-8.91		Bridge									
Reach	-8.927	PF 1	1000.00	6715.39	6718.90		6719.02	0.002227	3.12	361.85	186.32	0.35
Reach	-8.927	PF 2	5000.00	6715.39	6721.65		6721.92	0.002345	4.86	1425.13	743.64	0.40
Reach	-8.927	PF 3	10000.00	6715.39	6722.75		6723.18	0.003274	6.47	2231.69	859.39	0.49
Reach	-8.927	PF 4	20000.00	6715.39	6724.16		6724.87	0.004189	8.36	3339.64	893.55	0.57
Reach	-8.927	PF 5	35000.00	6715.39	6725.82		6726.79	0.005121	10.65	4764.89	932.11	0.65
Reach	-8.927	PF 6	50000.00	6715.39	6727.07		6728.31	0.005302	11.90	5945.75	973.92	0.68
Reach	-8.927	PF 7	75000.00	6715.39	6728.88		6730.41	0.005299	13.35	7904.16	1138.32	0.70
Reach	-9.011	PF 1	1000.00	6714.00	6715.20		6715.53	0.006460	3.23	227.22	134.53	0.53
Reach	-9.011	PF 2	5000.00	6714.00	6717.91	6717.23	6718.51	0.005943	6.33	808.93	327.11	0.61
Reach	-9.011	PF 3	10000.00	6714.00	6719.65	6718.74	6720.06	0.003700	6.57	2230.32	977.32	0.51
Reach	-9.011	PF 4	20000.00	6714.00	6721.56		6721.94	0.002663	6.89	4599.26	1310.90	0.46
Reach	-9.011	PF 5	35000.00	6714.00	6723.17		6723.66	0.002759	8.06	6764.07	1360.16	0.48
Reach	-9.011	PF 6	50000.00	6714.00	6724.49		6725.09	0.002738	8.83	8565.79	1368.76	0.49
Reach	-9.011	PF 7	75000.00	6714.00	6726.47		6727.22	0.002592	9.70	11296.08	1380.04	0.50
Reach	-9.232	PF 1	1000.00	6704.23	6708.10		6708.47	0.005564	4.85	206.30	88.49	0.56
Reach	-9.232	PF 2	5000.00	6704.23	6712.63		6713.31	0.003430	6.78	816.50	229.78	0.51
Reach	-9.232	PF 3	10000.00	6704.23	6714.67	6713.13	6715.70	0.003773	8.76	1519.48	607.61	0.56
Reach	-9.232	PF 4	20000.00	6704.23	6716.72	6715.98	6718.08	0.004411	11.10	3068.25	957.78	0.63
Reach	-9.232	PF 5	35000.00	6704.23	6718.88		6720.11	0.003765	11.73	5282.98	1070.48	0.60
Reach	-9.232	PF 6	50000.00	6704.23	6720.54		6721.77	0.003404	12.17	7081.88	1095.65	0.58
Reach	-9.232	PF 7	75000.00	6704.23	6722.89		6724.19	0.003061	12.85	9702.31	1131.85	0.57
Reach	-9.410	PF 1	1000.00	6700.64	6705.04	6703.43	6705.25	0.002260	3.68	271.38	89.07	0.37
Reach	-9.410	PF 2	5000.00	6700.64	6708.87	6706.65	6709.78	0.004078	7.67	651.80	109.70	0.55
Reach	-9.410	PF 3	10000.00	6700.64	6712.14	6710.86	6712.77	0.002496	7.26	2175.01	783.05	0.45
Reach	-9.410	PF 4	20000.00	6700.64	6714.16	6712.90	6714.86	0.002576	8.43	3771.29	792.73	0.48
Reach	-9.410	PF 5	35000.00	6700.64	6715.89	6714.31	6716.91	0.003225	10.52	5145.07	801.33	0.55
Reach	-9.410	PF 6	50000.00	6700.64	6717.23	6715.43	6718.57	0.003713	12.15	6236.49	825.16	0.60
Reach	-9.410	PF 7	75000.00	6700.64	6719.25	6717.02	6721.01	0.004059	14.01	7959.56	881.95	0.64
Reach	-9.42		Bridge									
Reach	-9.428	PF 1	1000.00	6701.17	6704.61		6704.92	0.004506	4.48	223.37	92.22	0.51
Reach	-9.428	PF 2	5000.00	6701.17	6707.96		6709.17	0.006625	8.82	566.73	111.92	0.69
Reach	-9.428	PF 3	10000.00	6701.17	6710.54	6710.54	6711.96	0.005715	10.15	1375.98	608.10	0.67
Reach	-9.428	PF 4	20000.00	6701.17	6712.46	6712.46	6713.97	0.005978	11.79	2745.02	787.48	0.71
Reach	-9.428	PF 5	35000.00	6701.17	6714.14		6715.90	0.006472	13.57	4075.46	799.51	0.76
Reach	-9.428	PF 6	50000.00	6701.17	6715.77		6717.62	0.005820	14.24	5420.43	845.73	0.74
Reach	-9.428	PF 7	75000.00	6701.17	6718.31		6720.25	0.004820	14.79	7653.75	905.94	0.69
Reach	-9.539	PF 1	1000.00	6698.89	6701.41		6701.74	0.006648	4.64	215.32	112.90	0.59
Reach	-9.539	PF 2	5000.00	6698.89	6705.03		6705.78	0.004498	7.08	762.51	193.51	0.57
Reach	-9.539	PF 3	10000.00	6698.89	6707.79	6705.71	6708.53	0.003231	7.54	1810.78	554.51	0.51
Reach	-9.539	PF 4	20000.00	6698.89	6710.23	6708.75	6710.97	0.002704	8.41	3840.97	960.90	0.49
Reach	-9.539	PF 5	35000.00	6698.89	6711.92		6712.95	0.003301	10.40	5526.86	1030.21	0.56
Reach	-9.539	PF 6	50000.00	6698.89	6713.95		6714.96	0.002793	10.73	7714.96	1123.04	0.53
Reach	-9.539	PF 7	75000.00	6698.89	6717.00		6717.97	0.002193	10.94	11483.24	1304.82	0.48

JTEO 11/6/13
GGS 11/14/13
7/17

HEC-RAS Plan: Mod Puls River: River Reach: Reach (Continued)

Reach	River Sta	Profile	Q Total (cfs)	Min Ch El (ft)	W.S. Elev (ft)	Crit W.S. (ft)	E.G. Elev (ft)	E.G. Slope (ft/ft)	Vel Chnl (ft/s)	Flow Area (sq ft)	Top Width (ft)	Froude # Chl
Reach	-9.719	PF 1	1000.00	6693.20	6696.58		6696.87	0.004069	4.26	234.60	96.52	0.48
Reach	-9.719	PF 2	5000.00	6693.20	6700.24		6701.09	0.005393	7.42	673.93	148.58	0.61
Reach	-9.719	PF 3	10000.00	6693.20	6701.92		6703.64	0.008850	10.51	951.37	180.52	0.81
Reach	-9.719	PF 4	20000.00	6693.20	6704.56	6703.98	6706.78	0.007413	12.56	2014.46	510.19	0.79
Reach	-9.719	PF 5	35000.00	6693.20	6709.11		6710.17	0.002505	9.90	5382.31	809.16	0.50
Reach	-9.719	PF 6	50000.00	6693.20	6711.47		6712.56	0.002182	10.38	7329.23	840.29	0.48
Reach	-9.719	PF 7	75000.00	6693.20	6714.67		6715.90	0.001994	11.31	10167.77	923.47	0.47
Reach	-9.962	PF 1	1000.00	6684.37	6687.85		6688.50	0.011907	6.46	154.82	76.46	0.80
Reach	-9.962	PF 2	5000.00	6684.37	6692.38		6693.69	0.006100	9.18	553.79	132.92	0.67
Reach	-9.962	PF 3	10000.00	6684.37	6696.00		6697.08	0.003178	9.16	1489.19	327.52	0.53
Reach	-9.962	PF 4	20000.00	6684.37	6703.12		6703.66	0.000944	7.27	4119.37	459.04	0.32
Reach	-9.962	PF 5	35000.00	6684.37	6707.36		6708.09	0.001050	8.93	6589.32	683.23	0.35
Reach	-9.962	PF 6	50000.00	6684.37	6709.57		6710.48	0.001206	10.24	8137.76	710.97	0.38
Reach	-9.962	PF 7	75000.00	6684.37	6712.64		6713.80	0.001355	11.79	10349.64	729.43	0.41
Reach	-10.051	PF 1	1000.00	6680.56	6685.47	6683.97	6685.79	0.003197	4.53	220.69	68.46	0.44
Reach	-10.051	PF 2	5000.00	6680.56	6689.61	6687.83	6690.92	0.005651	9.19	543.97	88.20	0.65
Reach	-10.051	PF 3	10000.00	6680.56	6692.72	6690.92	6694.91	0.006571	11.88	841.82	103.24	0.73
Reach	-10.051	PF 4	20000.00	6680.56	6701.66	6695.32	6702.97	0.001991	9.49	2492.27	403.95	0.44
Reach	-10.051	PF 5	35000.00	6680.56	6706.26	6701.93	6707.47	0.001507	9.94	4674.46	528.32	0.40
Reach	-10.051	PF 6	50000.00	6680.56	6708.08	6704.46	6709.73	0.001898	11.86	5666.60	564.22	0.46
Reach	-10.051	PF 7	75000.00	6680.56	6710.45	6707.14	6712.86	0.002511	14.67	7113.32	685.36	0.54
Reach	-10.06		Bridge									
Reach	-10.064	PF 1	1000.00	6680.45	6685.27		6685.53	0.002657	4.11	243.07	76.00	0.41
Reach	-10.064	PF 2	5000.00	6680.45	6689.15		6690.34	0.005266	8.75	571.39	94.87	0.63
Reach	-10.064	PF 3	10000.00	6680.45	6691.92		6694.06	0.006541	11.73	852.65	106.30	0.73
Reach	-10.064	PF 4	20000.00	6680.45	6695.29	6694.42	6699.37	0.009164	16.22	1233.36	120.92	0.89
Reach	-10.064	PF 5	35000.00	6680.45	6700.12	6701.66	6705.27	0.007984	18.37	2090.48	436.66	0.88
Reach	-10.064	PF 6	50000.00	6680.45	6702.68	6704.10	6707.66	0.006943	19.22	3433.32	585.50	0.84
Reach	-10.064	PF 7	75000.00	6680.45	6704.78	6706.32	6710.69	0.007787	22.07	4752.28	652.55	0.91
Reach	-10.113	PF 1	1000.00	6681.15	6683.98		6684.40	0.007807	5.15	194.06	98.10	0.65
Reach	-10.113	PF 2	5000.00	6681.15	6687.81		6688.86	0.005653	8.25	606.35	117.53	0.64
Reach	-10.113	PF 3	10000.00	6681.15	6690.42		6692.21	0.006449	10.71	933.83	134.43	0.72
Reach	-10.113	PF 4	20000.00	6681.15	6693.23	6692.49	6696.69	0.009150	14.92	1343.99	164.19	0.89
Reach	-10.113	PF 5	35000.00	6681.15	6695.20	6697.25	6702.03	0.014649	21.08	1711.70	213.61	1.15
Reach	-10.113	PF 6	50000.00	6681.15	6698.46	6700.61	6704.98	0.010566	21.27	2823.54	567.82	1.02
Reach	-10.113	PF 7	75000.00	6681.15	6700.53	6702.76	6707.85	0.010963	23.84	4088.52	652.09	1.06
Reach	-10.255	PF 1	1000.00	6676.44	6679.69		6680.02	0.004515	4.61	216.85	85.52	0.51
Reach	-10.255	PF 2	5000.00	6676.44	6683.51		6684.63	0.005691	8.48	589.75	109.97	0.65
Reach	-10.255	PF 3	10000.00	6676.44	6685.39	6685.39	6687.11	0.007131	11.06	1148.94	368.30	0.75
Reach	-10.255	PF 4	20000.00	6676.44	6687.50	6687.50	6689.80	0.008231	13.73	1943.76	384.88	0.83
Reach	-10.255	PF 5	35000.00	6676.44	6689.43	6689.43	6692.80	0.009930	17.16	2759.70	473.96	0.95
Reach	-10.255	PF 6	50000.00	6676.44	6689.45	6689.45	6696.26	0.020010	24.40	2773.14	475.43	1.34
Reach	-10.255	PF 7	75000.00	6676.44	6692.49	6694.19	6698.24	0.013413	23.76	4627.94	697.74	1.15
Reach	-10.466	PF 1	1000.00	6671.31	6674.03		6674.36	0.005741	4.62	216.38	102.00	0.56
Reach	-10.466	PF 2	5000.00	6671.31	6677.89		6678.72	0.004808	7.29	685.76	141.76	0.58
Reach	-10.466	PF 3	10000.00	6671.31	6681.50	6679.38	6681.86	0.001890	5.36	2460.84	684.76	0.38
Reach	-10.466	PF 4	20000.00	6671.31	6687.13	6681.26	6687.26	0.000364	3.63	7991.56	1164.48	0.19
Reach	-10.466	PF 5	35000.00	6671.31	6688.60	6682.98	6688.88	0.000659	5.29	9782.73	1287.72	0.26
Reach	-10.466	PF 6	50000.00	6671.31	6689.96	6684.14	6690.35	0.000843	6.39	11542.29	1302.57	0.29
Reach	-10.466	PF 7	75000.00	6671.31	6691.78	6685.57	6692.37	0.001149	8.06	13995.53	1397.42	0.35
Reach	-10.517	PF 1	1000.00	6669.80	6672.94	6671.89	6673.17	0.003357	3.80	263.04	110.90	0.44
Reach	-10.517	PF 2	5000.00	6669.80	6676.85	6674.56	6677.59	0.003502	6.89	725.82	127.41	0.51
Reach	-10.517	PF 3	10000.00	6669.80	6679.90	6676.90	6681.09	0.003840	8.76	1142.16	557.69	0.56
Reach	-10.517	PF 4	20000.00	6669.80	6686.45	6680.96	6687.07	0.001160	7.08	4508.11	1260.32	0.34
Reach	-10.517	PF 5	35000.00	6669.80	6687.16	6685.36	6688.49	0.002520	10.80	5407.99	1278.48	0.50
Reach	-10.517	PF 6	50000.00	6669.80	6687.70	6687.70	6689.80	0.003969	13.90	6107.81	1287.68	0.64
Reach	-10.517	PF 7	75000.00	6669.80	6689.18	6689.18	6691.69	0.004691	16.09	8035.75	1330.84	0.70
Reach	-10.52		Bridge									
Reach	-10.525	PF 1	1000.00	6669.68	6672.67		6672.97	0.004823	4.44	225.19	99.09	0.52
Reach	-10.525	PF 2	5000.00	6669.68	6676.37		6677.34	0.005034	7.88	634.25	120.73	0.61
Reach	-10.525	PF 3	10000.00	6669.68	6679.08	6677.14	6680.70	0.005555	10.20	980.44	321.62	0.67
Reach	-10.525	PF 4	20000.00	6669.68	6682.97	6682.97	6684.83	0.004346	11.57	2471.10	988.54	0.63
Reach	-10.525	PF 5	35000.00	6669.68	6683.67	6685.03	6687.55	0.008965	17.36	3085.67	1037.02	0.91
Reach	-10.525	PF 6	50000.00	6669.68	6685.07	6686.29	6688.81	0.008579	18.37	4587.92	1135.33	0.91
Reach	-10.525	PF 7	75000.00	6669.68	6686.56	6687.69	6690.61	0.009130	20.41	6356.13	1225.59	0.96
Reach	-10.641	PF 1	1000.00	6667.66	6670.73		6670.89	0.002432	3.24	309.00	131.11	0.37
Reach	-10.641	PF 2	5000.00	6667.66	6673.40		6674.22	0.005007	7.26	693.59	168.71	0.60
Reach	-10.641	PF 3	10000.00	6667.66	6674.61	6674.61	6676.47	0.008667	11.14	1020.48	397.66	0.81
Reach	-10.641	PF 4	20000.00	6667.66	6675.62	6677.22	6679.84	0.017116	17.42	1514.35	620.40	1.17
Reach	-10.641	PF 5	35000.00	6667.66	6677.59	6678.57	6680.85	0.012189	17.41	3381.29	1033.96	1.03
Reach	-10.641	PF 6	50000.00	6667.66	6678.54	6679.42	6682.15	0.013000	19.25	4379.81	1060.84	1.09
Reach	-10.641	PF 7	75000.00	6667.66	6680.12	6680.98	6683.85	0.012063	20.50	6091.98	1139.85	1.07
Reach	-10.841	PF 1	1000.00	6661.20	6664.32	6664.32	6665.24	0.019253	7.68	130.23	71.25	1.00
Reach	-10.841	PF 2	5000.00	6661.20	6668.31	6667.76	6668.88	0.004953	7.12	1124.80	804.58	0.59
Reach	-10.841	PF 3	10000.00	6661.20	6670.33	6669.02	6670.58	0.001890	5.62	3173.89	1131.87	0.39
Reach	-10.841	PF 4	20000.00	6661.20	6672.58	6670.22	6672.82	0.001295	5.66	5745.09	1150.01	0.34
Reach	-10.841	PF 5	35000.00	6661.20	6675.01	6671.23	6675.31	0.001132	6.23	8551.84	1158.75	0.33
Reach	-10.841	PF 6	50000.00	6661.20	6677.02	6672.05	6677.39	0.001094	6.83	10901.87	1197.64	0.33

✓TEO 11/6/13
GGS 11/14/13

8/17

HEC-RAS Plan: Mod Puls River: River Reach: Reach (Continued)

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	-10.841	PF 7	75000.00	6661.20	6679.21	6673.21	6679.73	0.001246	8.07	13556.50	1227.55	0.36
Reach	-11.055	PF 1	1000.00	6652.72	6658.78	6656.87	6659.01	0.002334	3.87	258.28	79.82	0.38
Reach	-11.055	PF 2	5000.00	6652.72	6662.88		6663.92	0.004097	8.17	612.31	94.25	0.56
Reach	-11.055	PF 3	10000.00	6652.72	6665.45	6663.40	6667.30	0.005445	11.17	1029.34	238.77	0.67
Reach	-11.055	PF 4	20000.00	6652.72	6669.02	6669.02	6670.62	0.003871	11.76	2983.93	1049.02	0.60
Reach	-11.055	PF 5	35000.00	6652.72	6673.91		6674.31	0.000965	7.38	9201.23	1389.34	0.32
Reach	-11.055	PF 6	50000.00	6652.72	6676.08		6676.47	0.000860	7.55	12246.27	1419.43	0.30
Reach	-11.055	PF 7	75000.00	6652.72	6678.13		6678.66	0.001046	8.91	15195.25	1488.59	0.34
Reach	-11.093	PF 1	1000.00	6654.92	6658.16	6657.07	6658.43	0.003764	4.14	241.55	97.88	0.46
Reach	-11.093	PF 2	5000.00	6654.92	6662.23	6660.06	6662.96	0.004626	6.88	726.24	159.52	0.57
Reach	-11.093	PF 3	10000.00	6654.92	6665.37	6662.74	6666.15	0.003296	7.20	1475.18	496.16	0.51
Reach	-11.093	PF 4	20000.00	6654.92	6668.41	6665.66	6669.63	0.003163	9.18	2436.38	901.51	0.53
Reach	-11.093	PF 5	35000.00	6654.92	6672.94	6667.90	6674.00	0.001880	9.21	5590.90	1249.31	0.44
Reach	-11.093	PF 6	50000.00	6654.92	6675.08	6668.97	6676.18	0.001800	9.92	7993.08	1465.92	0.44
Reach	-11.093	PF 7	75000.00	6654.92	6676.89	6674.64	6678.31	0.002195	11.76	10187.88	1491.78	0.49
Reach	-11.1		Bridge									
Reach	-11.111	PF 1	1000.00	6653.74	6657.93		6658.07	0.001384	2.94	340.68	108.86	0.29
Reach	-11.111	PF 2	5000.00	6653.74	6661.81		6662.37	0.002854	6.02	831.03	154.87	0.46
Reach	-11.111	PF 3	10000.00	6653.74	6664.92		6665.49	0.002642	6.09	1763.22	515.15	0.45
Reach	-11.111	PF 4	20000.00	6653.74	6667.47		6668.29	0.002609	7.62	3015.15	980.35	0.47
Reach	-11.111	PF 5	35000.00	6653.74	6668.42	6667.16	6670.44	0.005581	12.00	3589.12	1009.41	0.70
Reach	-11.111	PF 6	50000.00	6653.74	6667.50	6667.91	6672.59	0.016114	18.99	3027.79	980.60	1.17
Reach	-11.111	PF 7	75000.00	6653.74	6669.36	6671.56	6675.92	0.016559	22.07	4290.96	1022.40	1.23
Reach	-11.142	PF 1	1000.00	6654.51	6657.30		6657.61	0.005684	4.45	224.47	110.99	0.55
Reach	-11.142	PF 2	5000.00	6654.51	6660.45		6661.55	0.006285	8.46	609.11	147.96	0.67
Reach	-11.142	PF 3	10000.00	6654.51	6662.57	6661.70	6664.44	0.007200	11.24	1008.23	312.68	0.75
Reach	-11.142	PF 4	20000.00	6654.51	6665.45	6665.45	6667.38	0.005729	12.65	2451.79	711.45	0.71
Reach	-11.142	PF 5	35000.00	6654.51	6667.76	6667.76	6669.51	0.004892	13.48	4773.29	1166.14	0.68
Reach	-11.142	PF 6	50000.00	6654.51	6668.79	6668.79	6670.87	0.005740	15.41	6020.29	1264.20	0.75
Reach	-11.142	PF 7	75000.00	6654.51	6670.10	6670.10	6672.67	0.006841	17.93	7742.78	1394.42	0.83
Reach	-11.390	PF 1	1000.00	6646.50	6649.35		6649.70	0.006399	4.77	209.62	102.15	0.59
Reach	-11.390	PF 2	5000.00	6646.50	6652.78		6653.60	0.005695	7.50	755.78	261.92	0.63
Reach	-11.390	PF 3	10000.00	6646.50	6654.51	6653.74	6655.63	0.005908	9.34	1549.28	867.30	0.67
Reach	-11.390	PF 4	20000.00	6646.50	6656.21	6655.98	6657.29	0.005529	10.43	3337.90	1247.22	0.67
Reach	-11.390	PF 5	35000.00	6646.50	6657.33	6657.25	6658.78	0.007023	12.89	4779.97	1349.59	0.78
Reach	-11.390	PF 6	50000.00	6646.50	6658.33	6658.26	6660.06	0.007720	14.55	6218.05	1527.12	0.83
Reach	-11.390	PF 7	75000.00	6646.50	6659.85	6659.56	6661.66	0.007302	15.60	8638.74	1660.12	0.83

√ TEO 11/6/13

GGS 11/14/13

9/17

R-YR2 ✓

JTEO 11/6/13
GGS 11/14/13

10/17

HEC-RAS Plan: Mod Puls River: River Reach: Reach

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	-11.390	PF 1	1000.00	6646.50	6649.35		6649.70	0.006399	4.77	209.62	102.15	0.59
Reach	-11.390	PF 2	5000.00	6646.50	6652.78		6653.60	0.005695	7.50	755.78	261.92	0.63
Reach	-11.390	PF 3	10000.00	6646.50	6654.51	6653.74	6655.63	0.005908	9.34	1549.28	867.30	0.67
Reach	-11.390	PF 4	20000.00	6646.50	6656.21	6655.98	6657.29	0.005529	10.43	3337.90	1247.22	0.67
Reach	-11.390	PF 5	35000.00	6646.50	6657.33	6657.25	6658.78	0.007023	12.89	4779.97	1349.59	0.78
Reach	-11.390	PF 6	50000.00	6646.50	6658.33	6658.26	6660.06	0.007720	14.55	6218.05	1527.12	0.83
Reach	-11.390	PF 7	75000.00	6646.50	6659.85	6659.56	6661.66	0.007302	15.60	8638.74	1660.12	0.83
Reach	-11.657	PF 1	1000.00	6640.10	6643.89		6644.08	0.002681	3.50	285.49	115.31	0.39
Reach	-11.657	PF 2	5000.00	6640.10	6646.93	6645.37	6647.36	0.003413	5.85	1408.04	1015.23	0.49
Reach	-11.657	PF 3	10000.00	6640.10	6648.08	6647.51	6648.57	0.004060	7.01	2730.42	1571.23	0.54
Reach	-11.657	PF 4	20000.00	6640.10	6649.11		6649.72	0.004951	8.61	4364.63	1610.87	0.62
Reach	-11.657	PF 5	35000.00	6640.10	6650.79		6651.35	0.003781	8.75	7183.08	1753.03	0.56
Reach	-11.657	PF 6	50000.00	6640.10	6652.02		6652.64	0.003481	9.28	9389.25	1832.58	0.55
Reach	-11.657	PF 7	75000.00	6640.10	6653.44		6654.23	0.003634	10.47	12015.90	1868.98	0.58
Reach	-12.165	PF 1	1000.00	6626.07	6628.79	6628.68	6629.30	0.017051	5.76	173.53	132.74	0.89
Reach	-12.165	PF 2	5000.00	6626.07	6631.99		6632.51	0.010781	5.80	861.74	461.94	0.75
Reach	-12.165	PF 3	10000.00	6626.07	6633.24		6633.94	0.008074	6.73	1499.07	552.50	0.70
Reach	-12.165	PF 4	20000.00	6626.07	6635.09		6635.98	0.005633	7.79	2944.69	950.50	0.63
Reach	-12.165	PF 5	35000.00	6626.07	6636.16	6635.73	6637.71	0.007800	10.49	4019.36	1138.40	0.77
Reach	-12.165	PF 6	50000.00	6626.07	6637.09	6636.98	6639.10	0.008713	12.22	5189.09	1387.02	0.83
Reach	-12.165	PF 7	75000.00	6626.07	6638.61	6638.61	6640.84	0.008078	13.45	7708.40	1843.05	0.83
Reach	-12.398	PF 1	1000.00	6619.10	6622.41	6621.29	6622.56	0.002609	3.13	319.04	149.58	0.38
Reach	-12.398	PF 2	5000.00	6619.10	6625.79	6623.56	6626.28	0.002911	5.63	894.32	203.94	0.45
Reach	-12.398	PF 3	10000.00	6619.10	6627.89	6625.46	6628.51	0.002757	6.71	2045.07	915.71	0.49
Reach	-12.398	PF 4	20000.00	6619.10	6629.34	6628.86	6630.27	0.003891	8.89	3745.81	1624.37	0.59
Reach	-12.398	PF 5	35000.00	6619.10	6631.37	6630.48	6631.99	0.002838	8.19	7782.90	2451.14	0.54
Reach	-12.398	PF 6	50000.00	6619.10	6632.49	6631.29	6633.09	0.002769	8.50	10649.38	2707.31	0.52
Reach	-12.398	PF 7	75000.00	6619.10	6633.77	6632.26	6634.45	0.002946	9.28	14210.31	2813.15	0.53
Reach	-12.4		Bridge									
Reach	-12.406	PF 1	1000.00	6619.10	6621.80		6622.25	0.010988	5.38	185.79	114.83	0.75
Reach	-12.406	PF 2	5000.00	6619.10	6624.40	6624.07	6625.77	0.012332	9.42	530.99	151.94	0.89
Reach	-12.406	PF 3	10000.00	6619.10	6627.14	6627.14	6628.20	0.006557	8.68	1569.78	882.78	0.78
Reach	-12.406	PF 4	20000.00	6619.10	6629.31		6629.87	0.003546	7.33	4680.01	1827.61	0.55
Reach	-12.406	PF 5	35000.00	6619.10	6631.30		6631.67	0.002189	6.67	9179.04	2505.17	0.43
Reach	-12.406	PF 6	50000.00	6619.10	6632.36		6632.78	0.002215	7.19	11899.34	2628.42	0.43
Reach	-12.406	PF 7	75000.00	6619.10	6633.62		6634.14	0.002480	8.20	15284.27	2782.66	0.46
Reach	-12.615	PF 1	1000.00	6613.22	6616.85		6616.98	0.002533	2.84	352.45	187.50	0.36
Reach	-12.615	PF 2	5000.00	6613.22	6620.21		6620.59	0.002123	4.94	1011.19	203.40	0.39
Reach	-12.615	PF 3	10000.00	6613.22	6622.08	6619.40	6622.83	0.003356	6.96	1451.89	447.35	0.51
Reach	-12.615	PF 4	20000.00	6613.22	6623.81	6622.71	6625.22	0.004825	9.91	2466.34	659.02	0.63
Reach	-12.615	PF 5	35000.00	6613.22	6625.58	6625.15	6627.66	0.005916	12.61	4034.25	1135.01	0.73
Reach	-12.615	PF 6	50000.00	6613.22	6627.24	6627.19	6629.11	0.004972	12.89	6691.89	1853.59	0.68
Reach	-12.615	PF 7	75000.00	6613.22	6628.82	6628.74	6630.54	0.004528	13.45	10127.47	2468.90	0.67
Reach	-12.938	PF 1	1000.00	6609.52	6613.62	6612.17	6613.72	0.001504	2.83	402.09	204.54	0.30
Reach	-12.938	PF 2	5000.00	6609.52	6615.69		6616.11	0.003442	6.07	1126.72	477.28	0.49
Reach	-12.938	PF 3	10000.00	6609.52	6617.03	6615.81	6617.43	0.002919	6.54	2878.24	1751.81	0.47
Reach	-12.938	PF 4	20000.00	6609.52	6618.26		6618.66	0.002842	7.28	5057.11	1787.68	0.47
Reach	-12.938	PF 5	35000.00	6609.52	6619.48		6619.99	0.003079	8.40	7242.94	1797.86	0.51
Reach	-12.938	PF 6	50000.00	6609.52	6620.18		6620.92	0.004105	10.22	8526.05	1935.99	0.59
Reach	-12.938	PF 7	75000.00	6609.52	6621.30		6622.27	0.004629	11.70	10690.30	1945.25	0.64
Reach	-13.457	PF 1	1000.00	6601.11	6602.79	6602.79	6603.43	0.022302	6.39	156.50	125.42	1.01
Reach	-13.457	PF 2	5000.00	6601.11	6607.26		6607.73	0.002968	5.46	916.10	201.65	0.45
Reach	-13.457	PF 3	10000.00	6601.11	6609.19	6606.93	6609.92	0.003187	7.08	1791.15	700.25	0.49
Reach	-13.457	PF 4	20000.00	6601.11	6611.20	6609.90	6612.03	0.003159	8.46	3910.69	1354.80	0.52
Reach	-13.457	PF 5	35000.00	6601.11	6612.95	6611.79	6613.78	0.003018	9.38	7349.08	2397.72	0.52
Reach	-13.457	PF 6	50000.00	6601.11	6614.34		6614.99	0.002367	9.05	10683.60	2408.44	0.47
Reach	-13.457	PF 7	75000.00	6601.11	6616.17		6616.78	0.002010	9.21	15120.42	2481.50	0.44
Reach	-13.772	PF 1	1000.00	6591.93	6599.04	6596.04	6599.14	0.000831	2.53	395.25	103.80	0.23
Reach	-13.772	PF 2	5000.00	6591.93	6603.90		6604.31	0.001498	5.19	1052.58	318.08	0.34
Reach	-13.772	PF 3	10000.00	6591.93	6605.71		6606.17	0.001671	6.27	2600.64	895.87	0.37
Reach	-13.772	PF 4	20000.00	6591.93	6607.64		6608.15	0.001848	7.43	4942.46	1343.91	0.40
Reach	-13.772	PF 5	35000.00	6591.93	6609.52		6610.04	0.001847	8.18	7684.10	1564.76	0.40
Reach	-13.772	PF 6	50000.00	6591.93	6611.18		6611.74	0.001853	8.81	10584.71	1918.61	0.41
Reach	-13.772	PF 7	75000.00	6591.93	6613.02		6613.67	0.002049	9.99	14463.08	2250.70	0.44
Reach	-14.090	PF 1	1000.00	6592.77	6594.48	6594.48	6595.13	0.024385	6.48	155.00	122.45	1.05
Reach	-14.090	PF 2	5000.00	6592.77	6597.19	6597.05	6598.59	0.013115	10.02	557.71	215.13	0.92
Reach	-14.090	PF 3	10000.00	6592.77	6599.18	6599.14	6600.49	0.008784	10.62	1396.85	611.39	0.80
Reach	-14.090	PF 4	20000.00	6592.77	6601.15		6602.38	0.006872	11.41	2917.13	910.30	0.75
Reach	-14.090	PF 5	35000.00	6592.77	6602.89		6604.27	0.006522	12.82	4663.66	1098.22	0.75
Reach	-14.090	PF 6	50000.00	6592.77	6604.25		6605.85	0.006655	14.22	6269.93	1363.62	0.78
Reach	-14.090	PF 7	75000.00	6592.77	6606.09		6607.68	0.005707	14.69	8886.74	1458.46	0.74
Reach	-14.196	PF 1	1000.00	6587.79	6591.89	6590.34	6592.01	0.001641	2.85	351.23	134.46	0.31
Reach	-14.196	PF 2	5000.00	6587.79	6595.60	6592.79	6595.97	0.001884	5.08	1279.53	505.15	0.38
Reach	-14.196	PF 3	10000.00	6587.79	6596.90	6595.47	6597.52	0.002994	7.08	2186.14	821.83	0.49
Reach	-14.196	PF 4	20000.00	6587.79	6598.37	6597.65	6599.27	0.004419	9.21	3515.55	1153.13	0.60
Reach	-14.196	PF 5	35000.00	6587.79	6599.93	6599.12	6601.09	0.005313	10.95	5120.03	1360.76	0.67
Reach	-14.196	PF 6	50000.00	6587.79	6601.02	6600.15	6602.50	0.006119	12.61	6363.68	1512.69	0.73
Reach	-14.196	PF 7	75000.00	6587.79	6602.30	6601.63	6604.38	0.007655	15.25	7966.50	1698.21	0.84
Reach	-14.20		Bridge									

HEC-RAS Plan: Mod Puls River: River Reach: Reach (Continued)

Reach	River Sta	Profile	Q Total (cfs)	Min Ch El (ft)	W.S. Elev (ft)	Crit W.S. (ft)	E.G. Elev (ft)	E.G. Slope (ft/ft)	Vel Chnl (ft/s)	Flow Area (sq ft)	Top Width (ft)	Froude # Chl
Reach	-14.208	PF 1	1000.00	6587.54	6591.69		6591.84	0.002017	3.10	322.88	127.29	0.34
Reach	-14.208	PF 2	5000.00	6587.54	6595.38		6595.71	0.001939	4.94	1369.19	602.00	0.38
Reach	-14.208	PF 3	10000.00	6587.54	6596.57		6597.10	0.002927	6.74	2300.79	961.10	0.48
Reach	-14.208	PF 4	20000.00	6587.54	6597.90		6598.66	0.003930	8.70	3686.70	1249.65	0.57 ✓
Reach	-14.208	PF 5	35000.00	6587.54	6599.32		6600.30	0.004575	10.32	5383.65	1453.07	0.63
Reach	-14.208	PF 6	50000.00	6587.54	6600.42		6601.62	0.004930	11.63	6807.08	1570.94	0.66
Reach	-14.208	PF 7	75000.00	6587.54	6601.76		6603.32	0.005688	13.64	8922.98	1689.25	0.73
Reach	-14.317	PF 1	1000.00	6586.18	6590.05		6590.29	0.003691	3.91	255.52	111.54	0.46
Reach	-14.317	PF 2	5000.00	6586.18	6593.82	6591.77	6594.39	0.003032	6.25	1001.23	432.65	0.47
Reach	-14.317	PF 3	10000.00	6586.18	6595.15	6594.86	6595.74	0.003268	7.33	2507.72	1262.41	0.51
Reach	-14.317	PF 4	20000.00	6586.18	6596.85	6595.86	6597.35	0.002746	7.74	4825.75	1619.56	0.48 ✓
Reach	-14.317	PF 5	35000.00	6586.18	6598.28	6596.98	6598.88	0.002972	8.98	7320.98	2001.90	0.52
Reach	-14.317	PF 6	50000.00	6586.18	6599.43	6597.75	6600.09	0.002940	9.65	9697.41	2161.98	0.52
Reach	-14.317	PF 7	75000.00	6586.18	6600.58		6601.47	0.003612	11.46	12379.79	2516.85	0.59

✓ TEO 11/6/13
GGS 11/14/13

11/17

R-YR3 ✓

HEC-RAS Plan: Mod Puls River: River Reach: Reach

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	-14.317	PF 1	1000.00	6586.18	6590.05		6590.29	0.003691	3.91	255.52	111.54	0.46
Reach	-14.317	PF 2	5000.00	6586.18	6593.82	6591.77	6594.39	0.003032	6.25	1001.23	432.65	0.47
Reach	-14.317	PF 3	10000.00	6586.18	6595.15	6594.86	6595.74	0.003268	7.33	2507.72	1262.41	0.51
Reach	-14.317	PF 4	20000.00	6586.18	6596.85	6595.86	6597.35	0.002746	7.74	4825.75	1619.56	0.48
Reach	-14.317	PF 5	35000.00	6586.18	6598.28	6596.98	6598.88	0.002972	8.98	7320.98	2001.90	0.52
Reach	-14.317	PF 6	50000.00	6586.18	6599.43	6597.75	6600.09	0.002940	9.65	9697.41	2161.98	0.52
Reach	-14.317	PF 7	75000.00	6586.18	6600.58		6601.47	0.003612	11.46	12379.79	2516.85	0.59
Reach	-14.665	PF 1	1000.00	6578.99	6582.39		6582.64	0.004708	4.01	249.19	124.75	0.50
Reach	-14.665	PF 2	5000.00	6578.99	6584.74	6584.50	6585.82	0.007945	8.59	696.22	367.40	0.73
Reach	-14.665	PF 3	10000.00	6578.99	6586.37	6586.37	6587.49	0.006557	9.69	1590.22	717.33	0.70
Reach	-14.665	PF 4	20000.00	6578.99	6587.70	6587.70	6589.26	0.008187	12.40	2567.94	756.45	0.81
Reach	-14.665	PF 5	35000.00	6578.99	6589.40	6589.40	6590.89	0.007019	13.22	4821.23	1601.91	0.78
Reach	-14.665	PF 6	50000.00	6578.99	6590.34	6590.34	6591.99	0.007406	14.51	6415.56	1757.46	0.82
Reach	-14.665	PF 7	75000.00	6578.99	6592.22		6593.58	0.005325	13.83	9774.50	1808.20	0.71
Reach	-15.023	PF 1	1000.00	6571.71	6574.86		6575.02	0.003516	3.52	325.39	200.74	0.43
Reach	-15.023	PF 2	5000.00	6571.71	6577.64		6577.84	0.002514	4.62	1584.94	608.30	0.41
Reach	-15.023	PF 3	10000.00	6571.71	6579.93	6577.28	6580.12	0.001382	4.44	2995.66	629.64	0.32
Reach	-15.023	PF 4	20000.00	6571.71	6582.45	6578.53	6582.68	0.001206	5.26	6109.56	1485.52	0.32
Reach	-15.023	PF 5	35000.00	6571.71	6584.55	6579.94	6584.83	0.001155	5.98	9549.95	1757.60	0.33
Reach	-15.023	PF 6	50000.00	6571.71	6586.23	6581.67	6586.56	0.001232	6.82	12669.95	2193.02	0.35
Reach	-15.023	PF 7	75000.00	6571.71	6588.52		6588.88	0.001307	7.88	17988.10	2626.42	0.37
Reach	-15.426	PF 1	1000.00	6564.55	6567.84		6568.04	0.003053	3.59	278.63	119.83	0.41
Reach	-15.426	PF 2	5000.00	6564.55	6572.50		6572.99	0.002038	5.59	894.83	144.51	0.40
Reach	-15.426	PF 3	10000.00	6564.55	6575.54		6576.38	0.002203	7.37	1382.14	189.23	0.44
Reach	-15.426	PF 4	20000.00	6564.55	6577.98	6574.83	6579.03	0.002478	9.19	3526.78	1076.26	0.48
Reach	-15.426	PF 5	35000.00	6564.55	6579.66	6578.88	6580.97	0.003057	11.19	5445.66	1175.01	0.55
Reach	-15.426	PF 6	50000.00	6564.55	6581.05	6580.08	6582.46	0.003210	12.27	7121.20	1219.42	0.57
Reach	-15.426	PF 7	75000.00	6564.55	6582.69	6581.48	6584.41	0.003659	14.08	9135.49	1234.23	0.62
Reach	-16.032	PF 1	1000.00	6556.33	6561.22	6559.60	6561.28	0.001443	2.79	737.71	626.82	0.29
Reach	-16.032	PF 2	5000.00	6556.33	6562.27	6561.79	6562.51	0.005001	6.19	1791.86	1315.57	0.56
Reach	-16.032	PF 3	10000.00	6556.33	6562.80		6563.21	0.008012	8.54	2503.12	1387.41	0.73
Reach	-16.032	PF 4	20000.00	6556.33	6563.79		6564.35	0.008678	10.20	3932.24	1494.77	0.78
Reach	-16.032	PF 5	35000.00	6556.33	6565.27		6565.85	0.006540	10.44	6416.13	1722.69	0.71
Reach	-16.032	PF 6	50000.00	6556.33	6566.40		6567.07	0.006334	11.39	8557.40	2218.33	0.71
Reach	-16.032	PF 7	75000.00	6556.33	6567.84		6568.60	0.005670	12.05	11805.48	2278.53	0.69
Reach	-16.610	PF 1	1000.00	6548.00	6549.59	6549.59	6550.24	0.021518	6.43	155.54	121.25	1.00
Reach	-16.610	PF 2	5000.00	6548.00	6553.00		6553.18	0.002159	4.18	2091.22	1542.30	0.38
Reach	-16.610	PF 3	10000.00	6548.00	6554.31		6554.44	0.001521	4.00	4351.34	1984.02	0.33
Reach	-16.610	PF 4	20000.00	6548.00	6555.78		6555.91	0.001391	4.14	7464.15	2263.57	0.32
Reach	-16.610	PF 5	35000.00	6548.00	6557.03		6557.23	0.001638	5.13	10616.53	2586.47	0.36
Reach	-16.610	PF 6	50000.00	6548.00	6557.98		6558.24	0.001729	5.78	13077.22	2616.66	0.38
Reach	-16.610	PF 7	75000.00	6548.00	6559.23		6559.59	0.001898	6.74	16374.70	2647.25	0.41
Reach	-16.707	PF 1	1000.00	6538.64	6548.80	6544.09	6548.91	0.000626	2.74	365.53	69.36	0.21
Reach	-16.707	PF 2	5000.00	6538.64	6551.15	6549.52	6551.68	0.003358	6.51	1212.39	1846.16	0.49
Reach	-16.707	PF 3	10000.00	6538.64	6552.42	6551.82	6553.01	0.003806	7.73	2181.96	2733.71	0.54
Reach	-16.707	PF 4	20000.00	6538.64	6554.32	6553.54	6554.70	0.002597	7.29	5515.59	3187.20	0.46
Reach	-16.707	PF 5	35000.00	6538.64	6555.42	6554.46	6555.85	0.002872	8.19	8404.48	3464.53	0.49
Reach	-16.707	PF 6	50000.00	6538.64	6555.99	6555.10	6556.60	0.004025	10.05	9998.48	3573.45	0.58
Reach	-16.707	PF 7	75000.00	6538.64	6557.00	6555.99	6557.77	0.004497	11.38	12929.40	3619.15	0.63
Reach	-16.71		Bridge									
Reach	-16.715	PF 1	1000.00	6539.98	6548.78		6548.88	0.000700	2.54	393.05	92.52	0.22
Reach	-16.715	PF 2	5000.00	6539.98	6550.88	6549.07	6551.51	0.003648	6.90	1109.14	1675.83	0.52
Reach	-16.715	PF 3	10000.00	6539.98	6551.71	6551.68	6552.55	0.005375	9.00	2134.84	2017.71	0.64
Reach	-16.715	PF 4	20000.00	6539.98	6552.24	6552.98	6554.02	0.012029	14.04	2925.08	2440.83	0.96
Reach	-16.715	PF 5	35000.00	6539.98	6553.00	6553.71	6555.16	0.015747	16.96	4531.12	2670.22	1.12
Reach	-16.715	PF 6	50000.00	6539.98	6554.43		6555.38	0.007114	12.46	8224.98	3250.37	0.77
Reach	-16.715	PF 7	75000.00	6539.98	6555.61		6556.52	0.005995	12.37	11726.85	3521.04	0.72
Reach	-16.786	PF 1	1000.00	6546.00	6548.17		6548.34	0.004112	3.37	334.78	412.64	0.46
Reach	-16.786	PF 2	5000.00	6546.00	6549.94	6549.23	6550.13	0.003479	4.21	1794.13	1316.76	0.45
Reach	-16.786	PF 3	10000.00	6546.00	6550.68	6549.95	6550.90	0.003747	5.12	3489.54	2524.64	0.49
Reach	-16.786	PF 4	20000.00	6546.00	6551.56	6550.82	6551.83	0.003835	6.04	5859.23	2783.42	0.52
Reach	-16.786	PF 5	35000.00	6546.00	6552.70	6551.49	6552.99	0.003186	6.45	9175.56	3054.74	0.49
Reach	-16.786	PF 6	50000.00	6546.00	6553.69		6554.00	0.002732	6.68	12322.70	3243.03	0.47
Reach	-16.786	PF 7	75000.00	6546.00	6555.00		6555.37	0.002401	7.09	16633.34	3317.54	0.45
Reach	-17.200	PF 1	1000.00	6538.11	6543.10		6543.17	0.001521	2.10	475.96	267.39	0.28
Reach	-17.200	PF 2	5000.00	6538.11	6545.17	6543.64	6545.28	0.001776	2.83	2271.50	1459.89	0.32
Reach	-17.200	PF 3	10000.00	6538.11	6546.30		6546.43	0.001550	3.40	4147.49	2079.87	0.32
Reach	-17.200	PF 4	20000.00	6538.11	6547.66		6547.82	0.001368	3.96	7044.15	2167.44	0.31
Reach	-17.200	PF 5	35000.00	6538.11	6548.97		6549.20	0.001466	4.79	10341.88	2665.79	0.34
Reach	-17.200	PF 6	50000.00	6538.11	6549.65		6549.98	0.001884	5.82	12162.07	2718.78	0.39
Reach	-17.200	PF 7	75000.00	6538.11	6550.78		6551.25	0.002247	7.03	15359.08	2853.62	0.44

✓ TEO 11/6/13
GGS 11/14/13

12/17

R-YR4 ✓

✓TEO 11/6/13
GGS 11/14/13

HEC-RAS Plan: Mod Puls River: River Reach: Reach

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	-17.200	PF 1	1000.00	6538.11	6543.10		6543.17	0.001521	2.10	475.96	267.39	0.28
Reach	-17.200	PF 2	5000.00	6538.11	6545.17	6543.64	6545.28	0.001776	2.83	2271.50	1459.89	0.32
Reach	-17.200	PF 3	10000.00	6538.11	6546.30		6546.43	0.001550	3.40	4147.49	2079.87	0.32
Reach	-17.200	PF 4	20000.00	6538.11	6547.66		6547.82	0.001368	3.96	7044.15	2167.44	0.31 ✓
Reach	-17.200	PF 5	35000.00	6538.11	6548.97		6549.20	0.001466	4.79	10341.88	2665.79	0.34
Reach	-17.200	PF 6	50000.00	6538.11	6549.65		6549.98	0.001884	5.82	12162.07	2718.78	0.39
Reach	-17.200	PF 7	75000.00	6538.11	6550.78		6551.25	0.002247	7.03	15359.08	2853.62	0.44
Reach	-17.665	PF 1	1000.00	6533.64	6537.89		6538.05	0.003050	3.16	324.31	164.80	0.34
Reach	-17.665	PF 2	5000.00	6533.64	6539.82		6540.04	0.003351	4.74	1588.88	917.42	0.39
Reach	-17.665	PF 3	10000.00	6533.64	6540.77		6541.09	0.004553	6.26	2802.51	1472.77	0.47
Reach	-17.665	PF 4	20000.00	6533.64	6541.35		6541.99	0.008582	9.18	3686.60	1646.01	0.65
Reach	-17.665	PF 5	35000.00	6533.64	6542.57	6541.92	6543.26	0.008636	10.38	6360.81	2559.81	0.67
Reach	-17.665	PF 6	50000.00	6533.64	6543.82		6544.33	0.004987	8.76	9602.34	2605.88	0.53
Reach	-17.665	PF 7	75000.00	6533.64	6545.44		6545.94	0.003506	8.24	13858.96	2647.57	0.45
Reach	-18.094	PF 1	1000.00	6526.00	6528.85		6529.09	0.005308	3.98	251.20	117.70	0.48
Reach	-18.094	PF 2	5000.00	6526.00	6532.18		6532.58	0.003389	5.56	1271.61	664.44	0.44
Reach	-18.094	PF 3	10000.00	6526.00	6534.42		6534.72	0.002014	5.50	3285.10	1526.64	0.36 ✓
Reach	-18.094	PF 4	20000.00	6526.00	6536.88		6537.04	0.000996	4.71	7689.89	2070.47	0.27
Reach	-18.094	PF 5	35000.00	6526.00	6539.20		6539.35	0.000724	4.64	12652.72	2195.72	0.24
Reach	-18.094	PF 6	50000.00	6526.00	6540.69		6540.87	0.000758	5.13	16020.64	2315.71	0.25
Reach	-18.094	PF 7	75000.00	6526.00	6542.13		6542.40	0.000935	6.10	19363.74	2327.31	0.28
Reach	-18.509	PF 1	1000.00	6518.28	6523.00		6523.13	0.001639	2.96	353.67	138.56	0.29
Reach	-18.509	PF 2	5000.00	6518.28	6527.38		6527.71	0.001553	5.05	1216.02	241.94	0.32
Reach	-18.509	PF 3	10000.00	6518.28	6530.32		6530.80	0.001590	6.34	2018.39	308.56	0.34
Reach	-18.509	PF 4	20000.00	6518.28	6532.84		6533.73	0.002421	9.01	3033.80	533.79	0.44
Reach	-18.509	PF 5	35000.00	6518.28	6535.04		6536.31	0.003271	11.61	4836.74	1265.48	0.52
Reach	-18.509	PF 6	50000.00	6518.28	6536.98	6535.23	6537.94	0.002760	11.54	9692.29	3552.96	0.49
Reach	-18.509	PF 7	75000.00	6518.28	6538.68		6539.36	0.002177	10.91	15931.43	3783.00	0.44
Reach	-19.137	PF 1	1000.00	6514.27	6518.77		6518.85	0.001032	2.26	442.67	140.56	0.22
Reach	-19.137	PF 2	5000.00	6514.27	6522.02		6522.30	0.001772	4.54	1353.12	393.60	0.33
Reach	-19.137	PF 3	10000.00	6514.27	6524.18		6524.69	0.002285	6.31	2476.40	1113.67	0.39
Reach	-19.137	PF 4	20000.00	6514.27	6526.23		6526.67	0.001973	6.80	4810.29	1166.35	0.37 ✓
Reach	-19.137	PF 5	35000.00	6514.27	6528.67		6529.10	0.001597	7.06	7786.41	1336.18	0.35
Reach	-19.137	PF 6	50000.00	6514.27	6529.90		6530.49	0.002030	8.46	9471.82	1407.33	0.40
Reach	-19.137	PF 7	75000.00	6514.27	6531.57		6532.35	0.002360	9.84	11851.10	1447.54	0.44
Reach	-19.650	PF 1	1000.00	6506.80	6510.16	6510.16	6511.07	0.024653	7.63	131.11	72.95	1.00
Reach	-19.650	PF 2	5000.00	6506.80	6514.54	6513.53	6515.06	0.004574	6.54	1019.67	374.66	0.51
Reach	-19.650	PF 3	10000.00	6506.80	6516.71	6515.01	6517.27	0.003463	7.20	1916.18	472.45	0.47
Reach	-19.650	PF 4	20000.00	6506.80	6518.83	6516.90	6519.60	0.003794	8.94	3574.21	1414.93	0.51
Reach	-19.650	PF 5	35000.00	6506.80	6519.40	6519.40	6521.02	0.007770	13.31	4398.32	1458.02	0.74
Reach	-19.650	PF 6	50000.00	6506.80	6521.20		6522.36	0.005161	12.11	7148.85	1617.44	0.62
Reach	-19.650	PF 7	75000.00	6506.80	6523.13		6524.22	0.004206	12.10	10439.65	1727.97	0.58
Reach	-20.143	PF 1	1000.00	6502.82	6505.91	6504.03	6505.95	0.000617	1.56	639.25	241.65	0.17
Reach	-20.143	PF 2	5000.00	6502.82	6508.53		6508.75	0.001538	3.80	1394.39	403.90	0.30
Reach	-20.143	PF 3	10000.00	6502.82	6510.19		6510.59	0.002141	5.29	2224.12	712.95	0.37
Reach	-20.143	PF 4	20000.00	6502.82	6512.84		6513.28	0.001873	6.05	4592.90	1324.76	0.36 ✓
Reach	-20.143	PF 5	35000.00	6502.82	6517.91	6511.85	6518.04	0.000404	3.81	14635.69	2451.61	0.18
Reach	-20.143	PF 6	50000.00	6502.82	6519.50		6519.65	0.000428	4.21	18603.86	2523.17	0.19
Reach	-20.143	PF 7	75000.00	6502.82	6520.67		6520.92	0.000625	5.34	21594.59	2543.95	0.23
Reach	-20.502	PF 1	1000.00	6500.78	6501.94	6501.94	6502.29	0.034288	4.77	209.51	303.59	1.01
Reach	-20.502	PF 2	5000.00	6500.78	6505.29		6505.48	0.001950	3.59	1553.67	602.01	0.32
Reach	-20.502	PF 3	10000.00	6500.78	6507.90		6508.03	0.000910	3.31	3948.12	1158.65	0.24
Reach	-20.502	PF 4	20000.00	6500.78	6512.27		6512.32	0.000206	2.26	12893.58	2284.54	0.12
Reach	-20.502	PF 5	35000.00	6500.78	6517.70		6517.74	0.000078	1.84	25900.95	2443.84	0.08
Reach	-20.502	PF 6	50000.00	6500.78	6519.23		6519.28	0.000105	2.26	29640.31	2459.11	0.10
Reach	-20.502	PF 7	75000.00	6500.78	6520.22		6520.32	0.000183	3.11	32088.59	2468.19	0.13
Reach	-20.594	PF 1	1000.00	6492.79	6500.52	6497.04	6500.62	0.000934	2.51	398.25	100.16	0.22
Reach	-20.594	PF 2	5000.00	6492.79	6503.23	6500.83	6504.03	0.004626	7.19	695.68	119.24	0.52
Reach	-20.594	PF 3	10000.00	6492.79	6505.13	6503.42	6506.91	0.007699	10.71	938.62	209.29	0.70 ✓
Reach	-20.594	PF 4	20000.00	6492.79	6510.22	6507.98	6511.90	0.004132	10.97	2144.99	1876.18	0.56
Reach	-20.594	PF 5	35000.00	6492.79	6516.15	6511.03	6517.50	0.002334	10.76	6197.49	2429.74	0.45
Reach	-20.594	PF 6	50000.00	6492.79	6516.20	6513.78	6518.87	0.004641	15.20	6312.59	2430.76	0.63
Reach	-20.594	PF 7	75000.00	6492.79	6518.19	6518.19	6519.94	0.003538	14.23	11217.20	2486.39	0.56
Reach	-20.6		Bridge									
Reach	-20.601	PF 1	1000.00	6492.80	6500.48		6500.57	0.000909	2.43	411.56	106.83	0.22
Reach	-20.601	PF 2	5000.00	6492.80	6502.87		6503.71	0.004909	7.35	680.69	118.17	0.54
Reach	-20.601	PF 3	10000.00	6492.80	6502.70	6503.16	6506.25	0.021402	15.12	661.48	117.41	1.12
Reach	-20.601	PF 4	20000.00	6492.80	6506.05	6507.16	6511.34	0.021605	18.47	1083.44	410.43	1.18
Reach	-20.601	PF 5	35000.00	6492.80	6509.86	6511.20	6515.67	0.014910	19.96	1993.40	1576.58	1.05
Reach	-20.601	PF 6	50000.00	6492.80	6513.59	6514.84	6517.15	0.007674	17.31	5483.78	2355.99	0.79
Reach	-20.601	PF 7	75000.00	6492.80	6514.68	6515.85	6518.24	0.008545	19.14	8072.14	2393.26	0.84
Reach	-20.695	PF 1	1000.00	6494.15	6499.78	6498.58	6499.88	0.002363	2.97	458.63	357.19	0.33
Reach	-20.695	PF 2	5000.00	6494.15	6501.89		6501.99	0.001753	3.45	2255.37	1157.76	0.30
Reach	-20.695	PF 3	10000.00	6494.15	6503.04	6501.38	6503.13	0.001566	3.85	4727.29	2524.13	0.30
Reach	-20.695	PF 4	20000.00	6494.15	6504.64	6502.55	6504.73	0.001116	3.90	9738.95	3746.29	0.27 ✓
Reach	-20.695	PF 5	35000.00	6494.15	6505.83	6503.27	6505.94	0.001063	4.24	14198.99	3756.03	0.27
Reach	-20.695	PF 6	50000.00	6494.15	6506.83	6503.75	6506.96	0.001025	4.51	17958.90	3763.73	0.27
Reach	-20.695	PF 7	75000.00	6494.15	6508.18	6504.71	6508.36	0.001027	4.96	23068.10	3774.61	0.27
Reach	-21.099	PF 1	1000.00	6491.28	6495.13		6495.21	0.002136	2.35	424.94	221.47	0.30

HEC-RAS Plan: Mod Puls River: River Reach: Reach (Continued)

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	-21.099	PF 2	5000.00	6491.28	6498.53		6498.71	0.001511	3.57	1645.33	775.77	0.29
Reach	-21.099	PF 3	10000.00	6491.28	6500.64		6500.77	0.000953	3.49	5109.23	2919.02	0.24
Reach	-21.099	PF 4	20000.00	6491.28	6503.87		6503.91	0.000218	2.07	14873.42	3079.39	0.12
Reach	-21.099	PF 5	35000.00	6491.28	6504.63		6504.71	0.000426	3.05	17232.25	3121.21	0.17
Reach	-21.099	PF 6	50000.00	6491.28	6505.41		6505.53	0.000570	3.72	19672.74	3126.46	0.20
Reach	-21.099	PF 7	75000.00	6491.28	6506.48		6506.66	0.000776	4.63	23015.24	3133.53	0.24
Reach	-21.206	PF 1	1000.00	6489.63	6494.45	6492.12	6494.52	0.000788	1.99	503.13	159.42	0.20
Reach	-21.206	PF 2	5000.00	6489.63	6497.13	6494.42	6497.55	0.002852	5.23	956.30	254.03	0.41
Reach	-21.206	PF 3	10000.00	6489.63	6498.71	6496.30	6499.67	0.004929	7.87	1284.64	2139.10	0.55
Reach	-21.206	PF 4	20000.00	6489.63	6503.46	6499.25	6503.68	0.000911	4.92	8516.83	4029.66	0.26
Reach	-21.206	PF 5	35000.00	6489.63	6503.08	6503.00	6504.10	0.003993	10.07	7101.99	4021.57	0.54
Reach	-21.206	PF 6	50000.00	6489.63	6503.77	6503.77	6504.78	0.004286	10.88	9684.55	4037.32	0.57
Reach	-21.206	PF 7	75000.00	6489.63	6504.48	6504.48	6505.69	0.005340	12.64	12330.37	4049.30	0.64
Reach	-21.21		Bridge									
Reach	-21.220	PF 1	1000.00	6489.87	6494.37		6494.44	0.000965	2.05	488.88	173.08	0.21
Reach	-21.220	PF 2	5000.00	6489.87	6496.83		6497.27	0.003189	5.32	939.02	546.56	0.43
Reach	-21.220	PF 3	10000.00	6489.87	6497.90		6499.07	0.007177	8.68	1151.85	895.08	0.65
Reach	-21.220	PF 4	20000.00	6489.87	6499.45	6499.80	6500.83	0.008500	10.52	3064.53	2882.81	0.73
Reach	-21.220	PF 5	35000.00	6489.87	6499.80	6500.87	6502.68	0.017951	15.83	3739.53	3100.66	1.07
Reach	-21.220	PF 6	50000.00	6489.87	6500.44	6501.36	6503.34	0.018748	17.17	5616.27	3747.44	1.11
Reach	-21.220	PF 7	75000.00	6489.87	6501.06	6502.06	6504.09	0.020430	18.92	7754.41	3843.50	1.17
Reach	-21.278	PF 1	1000.00	6491.73	6493.58		6493.76	0.007654	3.39	295.07	231.88	0.53
Reach	-21.278	PF 2	5000.00	6491.73	6495.91		6496.10	0.003695	3.89	1569.54	959.68	0.42
Reach	-21.278	PF 3	10000.00	6491.73	6496.77	6495.79	6497.01	0.003949	4.75	3263.12	2394.97	0.45
Reach	-21.278	PF 4	20000.00	6491.73	6497.69	6497.01	6497.97	0.003942	5.47	5774.34	2972.39	0.47
Reach	-21.278	PF 5	35000.00	6491.73	6498.68	6497.66	6498.99	0.003802	6.16	9265.32	3807.06	0.47
Reach	-21.278	PF 6	50000.00	6491.73	6499.33	6498.31	6499.70	0.003863	6.72	11803.08	3895.41	0.49
Reach	-21.278	PF 7	75000.00	6491.73	6500.23	6498.95	6500.67	0.003916	7.42	15284.34	3920.17	0.50
Reach	-21.595	PF 1	1000.00	6484.18	6489.54		6489.61	0.001197	2.20	454.60	169.53	0.24
Reach	-21.595	PF 2	5000.00	6484.18	6492.14	6490.51	6492.25	0.001544	3.20	2995.21	4332.31	0.29
Reach	-21.595	PF 3	10000.00	6484.18	6492.75	6491.46	6492.85	0.001602	3.59	5650.06	4385.74	0.30
Reach	-21.595	PF 4	20000.00	6484.18	6493.55		6493.66	0.001642	4.06	9184.81	4466.82	0.31
Reach	-21.595	PF 5	35000.00	6484.18	6494.50		6494.63	0.001656	4.55	13724.76	5009.43	0.32
Reach	-21.595	PF 6	50000.00	6484.18	6495.26		6495.42	0.001569	4.78	17558.94	5040.77	0.32
Reach	-21.595	PF 7	75000.00	6484.18	6496.44		6496.61	0.001404	5.01	23503.93	5104.25	0.31
Reach	-22.390	PF 1	1000.00	6477.41	6481.63	6480.31	6481.86	0.003191	3.83	261.32	105.51	0.43
Reach	-22.390	PF 2	5000.00	6477.41	6484.38	6483.44	6484.71	0.002717	5.64	1802.36	1071.23	0.44
Reach	-22.390	PF 3	10000.00	6477.41	6485.85		6486.15	0.002308	6.16	3604.99	1421.93	0.43
Reach	-22.390	PF 4	20000.00	6477.41	6487.31		6487.56	0.002042	6.64	7611.79	2929.68	0.42
Reach	-22.390	PF 5	35000.00	6477.41	6488.69		6488.94	0.001862	7.05	11684.39	2971.68	0.41
Reach	-22.390	PF 6	50000.00	6477.41	6489.78		6490.05	0.001803	7.47	14947.08	2997.53	0.41
Reach	-22.390	PF 7	75000.00	6477.41	6491.36		6491.67	0.001767	8.13	19981.56	3316.05	0.41
Reach	-22.722	PF 1	1000.00	6474.55	6477.37	6476.28	6477.46	0.002000	2.48	402.74	220.22	0.32
Reach	-22.722	PF 2	5000.00	6474.55	6480.30	6478.10	6480.58	0.002001	4.31	1228.13	632.38	0.37
Reach	-22.722	PF 3	10000.00	6474.55	6481.89	6479.49	6482.27	0.002003	5.29	2623.29	1222.18	0.39
Reach	-22.722	PF 4	20000.00	6474.55	6483.44	6481.94	6483.84	0.002001	6.21	5486.00	1983.55	0.41
Reach	-22.722	PF 5	35000.00	6474.55	6484.91	6483.46	6485.36	0.002001	7.02	8588.73	2183.94	0.42
Reach	-22.722	PF 6	50000.00	6474.55	6486.02	6484.11	6486.51	0.002000	7.61	11019.16	2201.54	0.43
Reach	-22.722	PF 7	75000.00	6474.55	6487.57	6485.18	6488.15	0.002001	8.39	14472.50	2341.93	0.44

√TEO 11/6/13
GGS 11/14/13

✓TEO 11/6/13
GLOS 11/14/13

Parameters, Initial Conditions, and Boundary Conditions

The basic information requirements for all routing models are:

- **A description of the channel.** All routing models that are included in HEC-HMS require a description of the channel. In some of the models, this description is implicit in parameters of the model. In others, the description is provided in more common terms: channel width, bed slope, cross-section shape, or the equivalent.
- **Energy-loss model parameters.** All routing models incorporate some type of energy-loss model. The physically-based routing models, such as the kinematic-wave model and the Muskingum-Cunge model use Manning's equation and Manning's roughness coefficients (*n* values). Other models represent the energy loss empirically.
- **Initial conditions.** All routing models require initial conditions: the flow (or stage) at the downstream cross section of a channel prior to the first time period. For example, the initial downstream flow could be estimated as the baseflow within the channel at the start of the simulation, as the initial inflow, or as downstream flow likely to occur during a hypothetical event.
- **Boundary conditions.** The boundary conditions for HEC-HMS routing models are the upstream inflow, lateral inflow, and tributary inflow hydrographs. These may be observed historical events, or they may be computed with the precipitation-runoff models of HEC-HMS.

Modified Puls Model ✓

Basic Concepts and Equations

The Modified Puls routing method, also known as storage routing or level-pool routing, is based upon a finite difference approximation of the continuity equation, coupled with an empirical representation of the momentum equation (Chow, 1964; Henderson, 1966). ✓

For the Modified Puls model, the continuity equation is written as

$$\frac{\partial Q}{\partial x} + \frac{\partial A}{\partial t} = 0 \qquad (8\text{-}6)$$

This simplification assumes that the lateral inflow is insignificant, and it allows width to change with respect to location. Rearranging this equation and incorporating a finite-difference approximation for the partial derivatives yields

$$\overline{I_t} - \overline{O_t} = \frac{\Delta S_t}{\Delta t} \qquad (8\text{-}7)$$

where $\overline{I_t}$ = average upstream flow (inflow to reach) during a period Δt; $\overline{O_t}$ = average downstream flow (outflow from reach) during the same period; and ΔS_t = change in storage in the reach during the period. Using a simple backward differencing scheme and rearranging the result to isolate the unknown values yields:

USACE

✓ TEO 11/6/13 16/17
COGS 11/14/13

$$\left(\frac{S_t}{\Delta t}+\frac{O_t}{2}\right)=\left(\frac{I_{t-1}+I_t}{2}\right)+\left(\frac{S_{t-1}}{\Delta t}-\frac{O_{t-1}}{2}\right) \quad (8\text{-}8)$$

in which I_{t-1} and I_t = inflow hydrograph ordinates at times t-1 and t, respectively; O_{t-1} and O_t = outflow hydrograph ordinates at times t-1 and t, respectively; and S_{t-1} and S_t = storage in reach at times t-1 and t, respectively. At time t, all terms on the right-hand side of this equation are known, and terms on the left-hand side are to be found. Thus, the equation has two unknowns at time t: S_t and O_t.

A functional relationship between storage and outflow is required to solve Equation 8-8. Once that function is established, it is substituted into Equation 8-8, reducing the equation to a nonlinear equation with a single unknown, O_t. This equation is solved recursively by HEC-HMS, using a trial-and-error procedure. [Note that at the first time t, the outflow at time t-1 must be specified to permit recursive solution of the equation; this outflow is the initial outflow condition for the storage routing model.]

Defining the Storage-outflow Relationship

The storage-outflow relationship required for the Modified Puls routing model can be determined with:

- **Water-surface profiles computed with a hydraulics model.** ✓ Steady-flow water surface profiles, computed for a range of discharges with programs like HEC-2 (USACE, 1990), HEC-RAS (USACE, 1998), or a similar model, define a relationship of storage to flow between two channel cross sections.

  Figure 8-1 illustrates this; it shows a set of water-surface profiles between cross section *A* and cross section *B* of a channel. These profiles were computed for a set of steady flows, Q_1, Q_2, Q_3, *and* Q_4.

  For each profile, the volume of water in the reach, S_i, can be computed, using solid geometry principles. In the simplest case, if the profile is approximately planar, the volume can be computed by multiplying the average cross-section area bounded by the water surface by the reach length. Otherwise, another numerical integration method can be used. If each computed volume is associated with the steady flow with which the profile is computed, the result ✓ is a set of points on the required storage-outflow relationship.

  This procedure can be used with existing or with proposed channel configurations. For example, to evaluate the impact of a proposed channel project, the channel cross sections can be modified, water surface profiles recalculated, and a revised storage-outflow relationship developed.

USACE

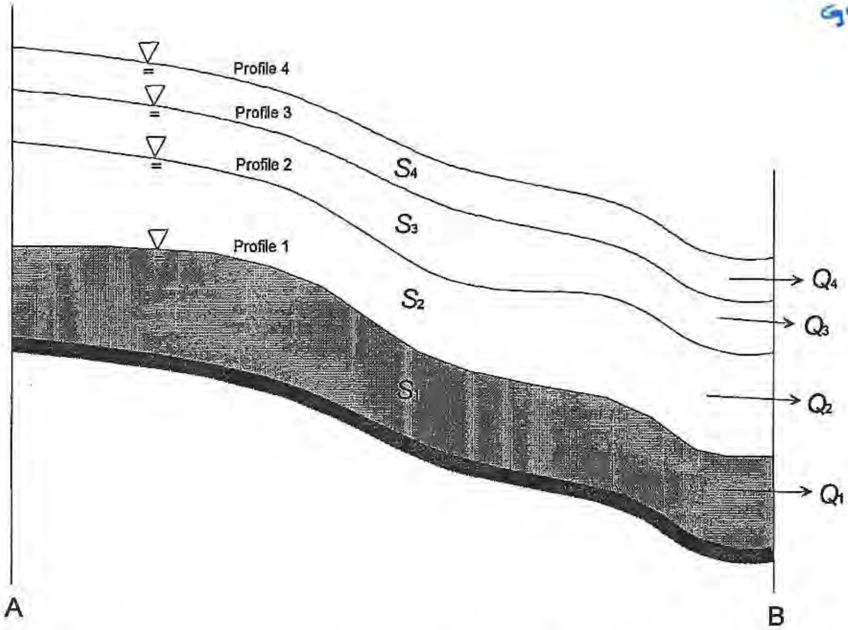


Figure 8-1. Steady-flow water-surface profiles and storage-outflow curve

- **Historical observations of flow and stage.** Observed water surface profiles, obtained from high water marks, can be used to define the required storage-outflow relationships, in much the same manner that computed water-surface profiles are used. Each observed discharge-elevation pair provides information for establishing a point of the relationship.

  Sufficient stage data over a range of floods is required to establish the storage-outflow relationship in this manner. If only a limited set of observations is available, these may best be used to calibrate a water-surface profile-model for the channel reach of interest. Then that calibrated model can be exercised to establish the storage-outflow relationship as described above.

- **Calibration, using observed inflow and outflow hydrographs for the reach of interest.** Observed inflow and outflow hydrographs can be used to compute channel storage by an inverse process of flood routing. When both inflow and outflow are known, the change in storage can be computed using Equation 8-7. Then, the storage-outflow function can be developed empirically. Note that tributary inflow, if any, must also be accounted for in this calculation.

  Inflow and outflow hydrographs also can be used to find the storage-outflow function by trial-and-error. In that case, a candidate function is defined and used to route the inflow hydrograph. The outflow hydrograph thus computed is compared with the observed hydrograph. If the match is not adequate, the function is adjusted, and the process is repeated. Chapter 9 provides more information regarding this process, which is referred to as calibration.

REQUIRED – Develop HEC-HMS hydrologic model to develop the dam breach hydrograph and evaluate attenuation of the hydrograph through the downstream channel

ASSUMPTIONS –

1) Use RJH Dam Breach Parameters analysis dated 9/18/13. ✓✓
2) Use RJH Muskingum-Cunge channel routing parameters analysis dated 9/23/13. ✓✓
3) Use RJH Modified Puls channel routing parameters analysis dated 10/30/13. ✓✓
4) Use USACE HEC-HMS Version 3.5 ✓
5) Use RJH Elevation-capacity analysis dated 9/18/13 ✓✓
6) Evaluate a sunny-day piping failure ✓✓

ANALYSIS –

- The HEC-HMS model consists of the reservoir and downstream channel reaches. ✓✓
- Model input is shown on p. 2-8 ✓
- Model output is shown on p. 8-10 ✓

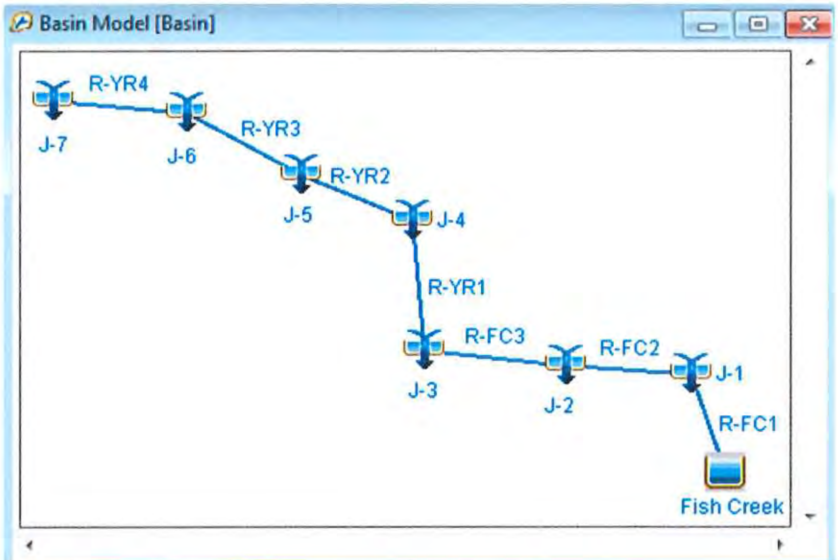
Summary –

- Dam Breach hydrograph shown on p. 10 ✓
- Peak Dam Breach outflow = 72,100 cfs ✓

✓TEO 11/12/13 2/10
GGS 11/14/13

Fish Creek Dam Breach Inundation Study
Project No. 13117

Schematic



Reservoir Parameters

Reservoir | Options

Basin Name:	**Basin**
Element Name:	**Fish Creek**
Description:	
Downstream:	R-FC1
Method:	Outflow Structures
Storage Method:	Elevation-Storage
*Elev-Stor Function:	Fish Creek El-Cap
Initial Condition:	Elevation
*Initial Elevation (FT)	9886.0
Main Tailwater:	Assume None
Auxiliary:	--None--
Time Step Method:	Automatic Adaption
Outlets:	0
Spillways:	0
Dam Tops:	0
Pumps:	0
Dam Break:	Yes
Dam Seepage:	No
Release:	No
Evaporation:	No

Breach Parameters

Reservoir | Dam Break | Options

Basin Name: Basin
Element Name: Fish Creek

Method:	Piping Breach ✓
Direction:	Main
*Top Elevation (FT)	9894 ✓✓
*Bottom Elevation (FT)	9821 ✓✓
*Bottom Width (FT)	90 ✓✓
*Left Slope (xH:1V)	0.7 ✓✓
*Right Slope (xH:1V)	0.7 ✓✓
*Piping Elevation (FT)	9857.5 ✓✓
*Piping Coefficient:	0.6 ✓✓ ok-conservative
*Development Time (HR)	1.0 ✓✓
Trigger Method:	Elevation ✓✓
*Trigger Elevation (FT)	9885.9 ✓✓
Progression Method:	Linear

✓

Elevation-Capacity

Paired Data | Table | Graph

Elevation (FT)	Storage (AC-FT)
9820.0	0.0
9830.0	0.1
9835.0	200.0 ✓
9840.0	310.0
9845.0	510.0
9850.0	720.0
9855.0	1020.0
9860.0	1375.0
9865.0	1800.0
9870.0	2300.0 ✓
9875.0	2800.0
9880.0	3400.0
9885.0	4000.0
9886.0	4150.0
9890.0	4750.0
9894.0	5400.0 ✓

✓

√TEO 11/12/13 4/10
GGS 11/14/13

Reach FC-1

Reach | Routing | Options

Basin Name: Basin
Element Name: R-FC1

Time Step Method:	Automatic Fixed Interval
*Length (FT)	11157
*Slope (FT/FT)	0.135
*Manning's n:	0.08
Invert (FT)	
Shape:	Eight Point
*Left Manning's n	0.08
*Right Manning's n	0.08
*Cross Section	R-FC1

Paired Data | Table | Graph

Station (FT)	Elevation (FT)
26.9	9352.0
55.4	9340.3
83.5	9332.0
118.8	9326.0
124.9	9326.0
151.5	9330.6
176.0	9335.3
218.8	9348.7

Reach FC-2

Reach | Routing | Options

Basin Name: Basin
Element Name: R-FC2

Time Step Method:	Automatic Fixed Interval
*Length (FT)	15116
*Slope (FT/FT)	0.071
*Manning's n:	0.08
Invert (FT)	
Shape:	Eight Point
*Left Manning's n	0.08
*Right Manning's n	0.08
*Cross Section	R-FC2

✓ TEO 11/12/13 5/10
GGS 11/14/13

Paired Data | Table | Graph

Station (FT)	Elevation (FT)
61.8	7972.0
86.1	7966.1
105.6	7956.0
118.5	7954.0
139.5	7955.2
179.1	7956.0
206.6	7964.0
233.9	7974.0

✓

Reach FC-3

Reach | Routing | Options

Basin Name: Basin
Element Name: R-FC3

Time Step Method: Automatic Fixed Interval
*Length (FT) 16064 ✓ ✓
*Slope (FT/FT) 0.031 ✓ ✓
*Manning's n: 0.06 ✓ ✓
Invert (FT)
Shape: Eight Point
*Left Manning's n 0.06 ✓ ✓
*Right Manning's n 0.06 ✓ ✓
*Cross Section R-FC3

✓

Paired Data | Table | Graph

Station (FT)	Elevation (FT)
37.92	6907.08
294.47	6898.00
312.65	6894.33
356.30	6890.03
401.42	6890.00
433.71	6894.52
488.65	6899.18
523.38	6908.89

✓

✓ TEO 11/12/13 6/10
GGS 11/14/13

Reach YR-1

Reach | **Routing** | Options

Basin Name: Basin
Element Name: R-YR1
*Stor-Dis Function: R-YR1
Subreaches: 1
Initial: Inflow = Outflow
Elev-Dis Function: --None--
Invert (FT)

Paired Data | **Table** | Graph

Storage (AC-FT)	Discharge (CFS)
93.0	1000.0
300.0	5000.0
635.0	10000.0
1314.0	20000.0
2092.0	35000.0
2712.0	50000.0
3626.0	75000.0

Reach YR-2

Reach | **Routing** | Options

Basin Name: Basin
Element Name: R-YR2
*Stor-Dis Function: R-YR2
Subreaches: 1
Initial: Inflow = Outflow
Elev-Dis Function: --None--
Invert (FT)

✓TEO 11/12/13 7/10
GGS 11/14/13

Paired Data | Table | Graph

Storage (AC-FT)	Discharge (CFS)
97.0	1000.0
354.0	5000.0
740.0	10000.0
1391.0	20000.0
2239.0	35000.0
3003.0	50000.0
4082.0	75000.0

Reach YR-3

Reach | Routing | Options

Basin Name: Basin
Element Name: R-YR3
*Stor-Dis Function: R-YR3
Subreaches: 1
Initial: Inflow = Outflow
Elev-Dis Function: --None--
Invert (FT)

Paired Data | Table | Graph

Storage (AC-FT)	Discharge (CFS)
133.0	1000.0
516.0	5000.0
932.0	10000.0
1695.0	20000.0
2634.0	35000.0
3419.0	50000.0
4598.0	75000.0

✓TEO 11/12/13
GGS 11/14/13

8/10

Reach YR-4

Reach | Routing | Options

Basin Name: Basin
Element Name: R-YR4

*Stor-Dis Function:	R-YR4
Subreaches:	1
Initial:	Inflow = Outflow
Elev-Dis Function:	--None--
Invert (FT)	

✓

Paired Data | Table | Graph

Storage (AC-FT)	Discharge (CFS)
245.0	1000.0
1086.0	5000.0
2154.0	10000.0
4354.0	20000.0
7046.0	35000.0
9169.0	50000.0
11866.0	75000.0

Results

Summary Results for Reservoir "Fish Creek"

Project: Fish Creek Dam
Simulation Run: Breach Reservoir: Fish Creek

Start of Run:	01Jan2000, 00:00	Basin Model:	Basin
End of Run:	02Jan2000, 00:00	Meteorologic Model:	Met
Compute Time:	31Oct2013, 09:24:48	Control Specifications:	Control

Volume Units: ○ IN ◉ AC-FT

✓

Computed Results

Peak Inflow :	0.0 (CFS)	Date/Time of Peak Inflow :	01Jan2000, 00:00
Peak Outflow :	72100.0 (CFS)	Date/Time of Peak Outflow :	01Jan2000, 00:56
Total Inflow :	0.0 (AC-FT)	Peak Storage :	4150.0 (AC-FT)
Total Outflow :	4120.2 (AC-FT)	Peak Elevation :	9886.0 (FT)

✓TEO 11/12/13
GGS 11/14/13

Global Summary Results for Run "Breach"

Project: Fish Creek Dam Simulation Run: Breach

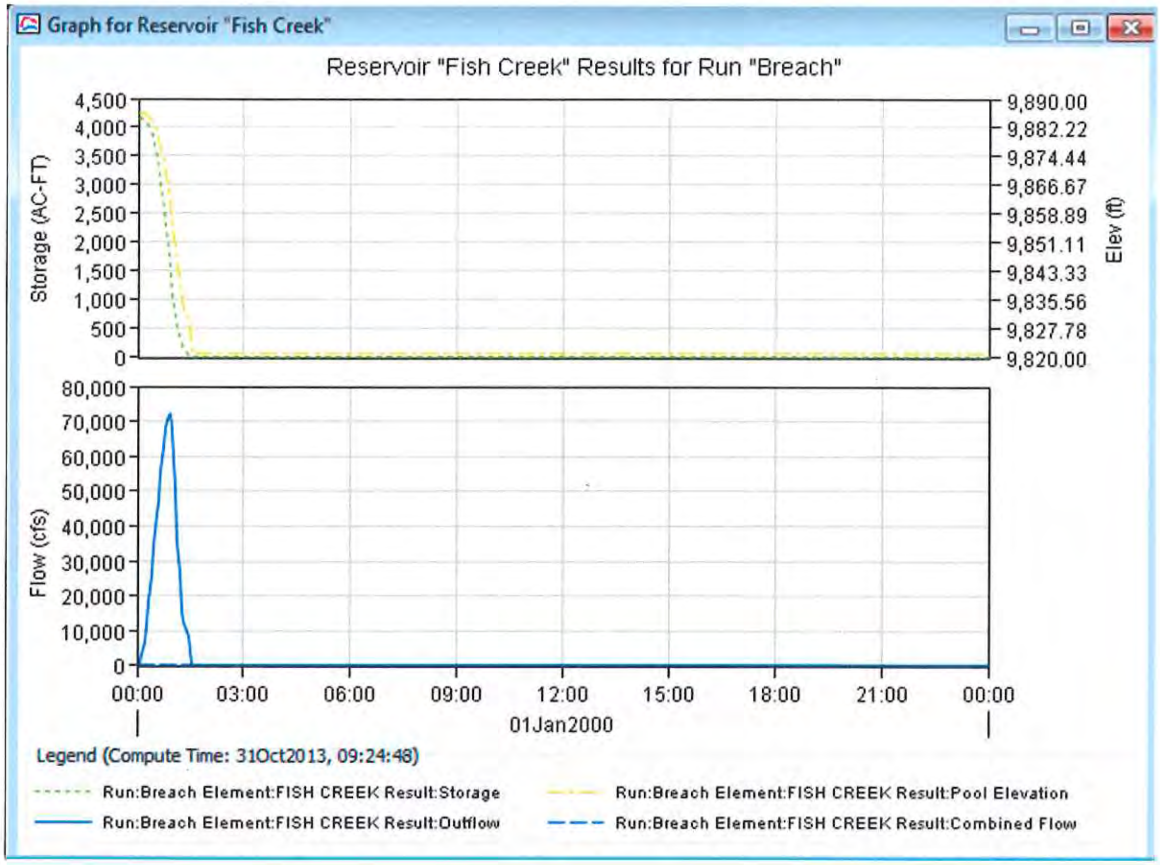
Start of Run: 01Jan2000, 00:00 Basin Model: Basin
End of Run: 02Jan2000, 00:00 Meteorologic Model: Met
Compute Time: 31Oct2013, 09:24:48 Control Specifications: Control

Show Elements: All Elements Volume Units: IN AC-FT Sorting: Hydrologic

Hydrologic Element	Drainage Area (MI2)	Peak Discharge (CFS)	Time of Peak	Volume (AC-FT)
Fish Creek	0	72100.0	01Jan2000, 00:56	4120.2
R-FC1	0	71650.9	01Jan2000, 00:56	4126.4
J-1	0	71650.9	01Jan2000, 00:56	4126.4
R-FC2	0	71472.1	01Jan2000, 01:04	4124.8
J-2	0	71472.1	01Jan2000, 01:04	4124.8
R-FC3	0	70597.5	01Jan2000, 01:12	4138.1
J-3	0	70597.5	01Jan2000, 01:12	4138.1
R-YR1	0	37573.4	01Jan2000, 01:32	4138.1
J-4	0	37573.4	01Jan2000, 01:32	4138.1
R-YR2	0	22162.5	01Jan2000, 02:04	4138.1
J-5	0	22162.5	01Jan2000, 02:04	4138.1
R-YR3	0	15127.3	01Jan2000, 03:00	4138.1
J-6	0	15127.3	01Jan2000, 03:00	4138.1
R-YR4	0	8203.0	01Jan2000, 04:44	4132.6
J-7	0	8203.0	01Jan2000, 04:44	4132.6

✓

Breach Hydrograph



APPENDIX C

MANNING'S N VALUES

RJH CONSULTANTS, INC.

Client: Steamboat Springs

Subject: Fish Creek Dam

Project: 13117 Page: 1/11

Date: 10/31/13 By: EMH

Checked: 11/1/13 By: TEO

Approved: 11/14/13 By: GGS

REQUIRED – Evaluate Manning's n values for the downstream drainage

ASSUMPTIONS –
1) Use FEMA Effective hydraulic models for the Yampa River and Fish Creek ✓✓
2) Use photographs from site visit October 2013 ✓✓
3) Use FEMA Flood Insurance Study Routt County Colorado and Unincorporated Areas (2005) ✓✓
4) Use USDA NAIP Aerial Imagery (2011) ✓✓
5) Use V.T. Chow Open Channel Hydraulics (1959) Table of Manning's n coefficients as shown in T.L. Sturm Open Channel Hydraulics (2001). ✓✓

ANALYSIS –

- RJH will generally use Manning's n values as presented in the FEMA Flood Insurance Study (FIS) and FEMA effective models ✓
  - ↳ The intent of this evaluation is to confirm that these Manning's n values are appropriate, and adjust where required ✓ ✓

- Middle Fork Fish Creek (Dam to XS-2.15), North Fork Fish Creek (XS-2.15 to -4.325) and Fish Creek (XS-4.325 to -5.013) ✓
  - Main channel consists of a steep mountain stream with large boulders and minimal vegetation (see p. 5) ✓
  - FEMA model used n=0.08 for upper reaches of Fish Creek main channel ✓
  - From Sturm:

	Min.	Avg.	Max
– Mountain stream w/ large boulders ✓	0.04	0.05	0.07 (see p. 11) ✓

ANALYSIS -

- increase Sturm values to account for significant presence of large boulders ✓
- use n = 0.08 ✓ for main channel → FEMA model confirmed ✓✓
- Overbanks consist of some areas of thick pine trees and brush with some areas of rock/gravel & native grasses interspersed (see p. 5) ✓
  - FEMA model used n = 0.10 for upper reaches of Fish Creek overbanks ✓
  - From Sturm:

	Min.	Avg.	Max.	
- Trees, heavy stand of timber	0.08	0.10	0.12	(see p. 10) ✓

  - use n = 0.08 ✓ to account for interspersed areas of short grass/bare areas (n = 0.10 used in a few select areas densely forested areas) ✓✓

- Fish Creek (XS -5.013 to -8.05)
  - Main channel consists of a steep mountain stream with gravel, cobbles, and some boulders (see p. 6) ✓
    - FEMA model used n = 0.06 for main channel ✓
    - From Sturm:

	Min.	Avg.	Max.
- Mountain stream w/ cobbles and large boulders ✓	0.04	0.05	0.07 ✓

    - use n = 0.06 ✓ for main channel → FEMA model confirmed ✓✓
  - Overbanks vary from areas with thick pine trees and brush to commercial/residential developed areas to a golf course ✓
    - Use n = 0.08 ✓ for areas with pine trees and brush (see above) ✓✓
    - Use n = 0.06 ✓ for developed areas (same as FEMA model) ✓✓

ANALYSIS

- For golf course areas/nativegrass areas:

  - From Sturm:

	Min.	Avg.	Max
- Pasture/grass ✓	0.03	0.035	0.05 ✓

  - use n=0.05 ✓ at higher end of range to account for some site features and scattered trees that would increase roughness ✓ ✓

- Yampa River (XS -8.05 to -22.72)

  - Manning's n values were generally unchanged from the FEMA model except in isolated places where land use may have changed ✓

  - Main channel consists of an intermountain valley stream that is generally clean (i.e. no significant boulders/vegetation) with some gentle meandering (see p. 7-9) ✓

    - FEMA model used n=0.04 to 0.045 ok

    - From Sturm:

	Min.	Avg.	Max.
- Clean, winding stream with some pools ✓	0.033	0.04	0.045 ✓

    - use n=0.04-0.045 ✓ → FEMA model confirmed ✓ ✓

  - Overbanks vary from pasture areas, native areas w/ grasses and some trees, native areas with dense trees and residential/commercial developed areas ✓

    - Pasture areas → FEMA used n=0.05 ok

      - From Sturm

	Min.	Avg.	Max.
- Pasture/grass ✓	0.03	0.035	0.05 ✓

    - use n=0.05 ✓ → FEMA model confirmed ✓ ✓

ANALYSIS –

- Native areas with some scattered trees
  - FEMA model used 0.06 ok
  - From Sturm:

	Min.	Avg.	Max.
– Pasture / high grass ✓	0.03	0.035	0.05 ✓
– Light brush / trees ✓	0.04	0.06	0.08 ✓

  - Use n = 0.06 ✓ → FEMA model confirmed ✓✓

- Dense trees
  - FEMA model used n = 0.10 ok
  - From Sturm:

	Min.	Avg.	Max.
– Heavy stand of timber ✓	0.08	0.10	0.12 ✓

  - use n = 0.10 ✓ → FEMA model confirmed ✓✓

- Resident / Commercial Developed Areas
  - FEMA model used n = 0.05 – 0.06 ok
  - Minimal research has been conducted for Manning's n values in developed areas ✓
  - Use FEMA model values ✓ → n = 0.05 – 0.06 ✓✓

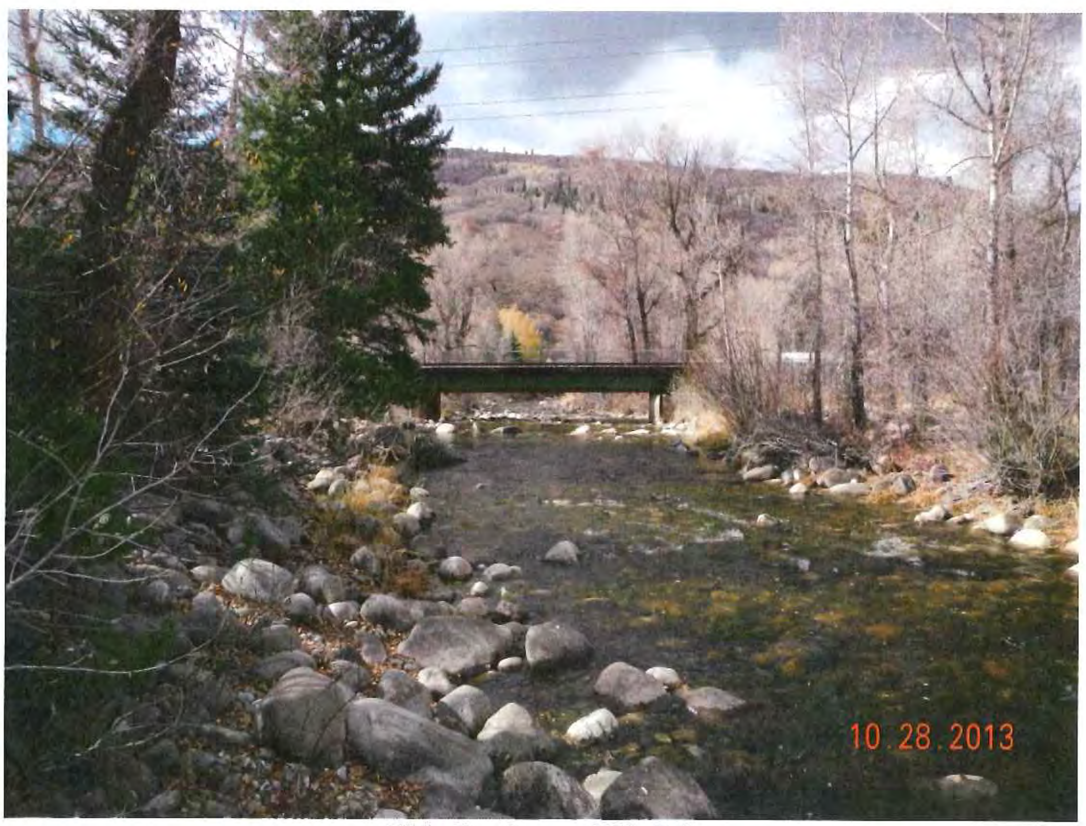
✓ TEO 11/1/13 5/11
GGS 11/14/13

Middle Fork Fish Creek – Aerial photograph near XS -3.6

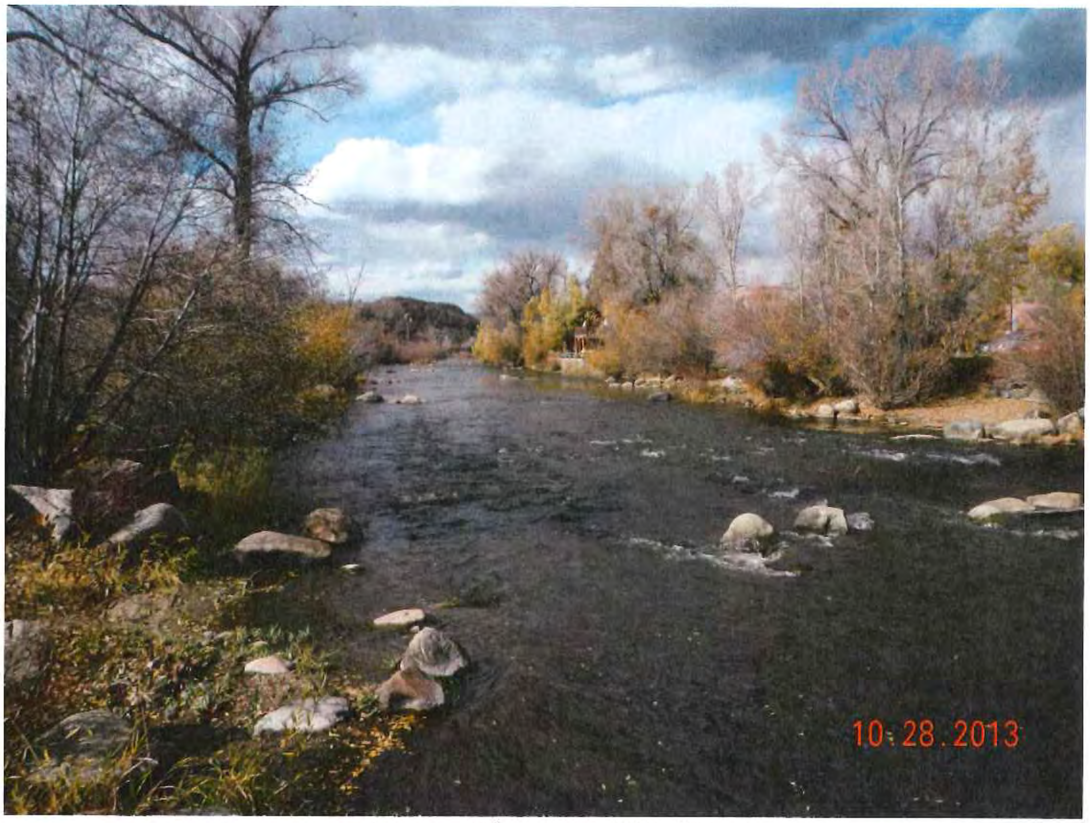
Fish Creek (representative of Middle Fork Fish Creek near confluence of Fish Creek and Middle Fork Creek near XS -5.9)

JTEO 11/1/13
GGS 11/14/13

Fish Creek near XS -7.5



Fish Creek near XS -7.9



✓

Yampa River near XS -9.5

✓

Yampa River near XS -11.0

JTEO 11/1/13 8
CGS 11/14/13

Yampa River near XS -12.4

Yampa River near XS -16.7

Yampa River near XS -21.2

JTEO 11/1/13 10/11
GGS 11/14/13

Type of Channel and Description	Minimum	Normal	Maximum
2. Clean, after weathering	0.018	0.022	0.025
3. Gravel, uniform section, clean	0.022	0.025	0.030
4. With short grass, few weeds	0.022	0.027	0.033
b. Earth, winding and sluggish			
1. No vegetation	0.023	0.025	0.030
2. Grass, some weeds	0.025	0.030	0.033
3. Dense weeds or aquatic plants in deep channels	0.030	0.035	0.040
4. Earth bottom and rubble sides	0.028	0.030	0.035
5. Stony bottom and weedy banks	0.025	0.035	0.040
6. Cobble bottom and clean sides	0.030	0.040	0.050
c. Dragline excavated or dredged			
1. No vegetation	0.025	0.028	0.033
2. Light brush on banks	0.035	0.050	0.060
d. Rock cuts			
1. Smooth and uniform	0.025	0.035	0.040
2. Jagged and irregular	0.035	0.040	0.050
e. Channels not maintained, weeds and brush uncut			
1. Dense weeds, high as flow depth	0.050	0.080	0.120
2. Clean bottom, brush on sides	0.040	0.050	0.080
3. Same, highest stage of flow	0.045	0.070	0.110
4. Dense brush, high stage	0.080	0.100	0.140
D. Natural Streams			
D–1. Minor streams (top width at flood stage < 100 ft)			
a. Streams on plain			
1. Clean, straight, full stage, no rifts or deep pools	0.025	0.030	0.033
2. Same as above, but more stones and weeds	0.030	0.035	0.040
3. Clean, winding, some pools and shoals	0.033	0.040	0.045
4. Same as above, but some weeds and stones	0.035	0.045	0.050
5. Same as above, lower stages, more ineffective slopes and sections	0.040	0.048	0.055
6. Same as 4, but more stones	0.045	0.050	0.060
7. Sluggish reaches, weedy, deep pools	0.050	0.070	0.080
8. Very weedy reaches, deep pools, or floodways with heavy stand of timber and underbrush	0.075	0.100	0.150
b. Mountain streams, no vegetation in channel, banks usually steep, trees and brush along banks submerged at high stages			
1. Bottom: gravels, cobbles, and few boulders	0.030	0.040	0.050
2. Bottom: cobbles with large boulders	0.040	0.050	0.070
D–2. Flood plains			
a. Pasture, no brush			
1. Short grass	0.025	0.030	0.035

(*continued*)

Sturm

√TEO 11/1/13 11/11
GGS 11/14/13

TABLE 4-1 (Continued)

Type of Channel and Description	Minimum	Normal	Maximum
→ 2. High grass	0.030	0.035	0.050 ✓
b. Cultivated areas			
1. No crop	0.020	0.030	0.040
2. Mature row crops	0.025	0.035	0.045
3. Mature field crops	0.030	0.040	0.050
c. Brush			
1. Scattered brush, heavy weeds	0.035	0.050	0.070
2. Light brush and trees, in winter	0.035	0.050	0.060
→ 3. Light brush and trees, in summer	0.040	0.060	0.080 ✓
4. Medium to dense brush, in winter	0.045	0.070	0.110
5. Medium to dense brush, in summer	0.070	0.100	0.160
d. Trees			
1. Dense willows, summer, straight	0.110	0.150	0.200
2. Cleared land with tree stumps, no sprouts	0.030	0.040	0.050
3. Same as above, but with heavy growth of sprouts	0.050	0.060	0.080
→ 4. Heavy stand of timber, a few down trees, little undergrowth, flood stage below branches	0.080	0.100	0.120 ✓
5. Same as above, but with flood stage reaching branches	0.100	0.120	0.160
D-3. Major streams (top width at flood stage > 100 ft). The *n* value is less than that for minor streams of similar description, because banks offer less effective resistance.			
a. Regular section with no boulders or brush	0.025	. . .	0.060
b. Irregular and rough section	0.035	. . .	0.100

Source: Chow 1959. Used with permission of Chow estate.

Chow (1959) presented methods by Horton, Einstein and Banks, and Lotter for obtaining a composite value of Manning's n for a single channel; that is, for the main channel only of a compound channel or a canal with laterally varying roughness. The Horton method is based on the assumption that the velocities in each wetted-perimeter subsection are equal to one another as well as equal to the mean velocity of the whole cross section. The resulting composite value of Manning's n, denoted n_c, is given by

$$n_c = \left[\frac{\sum_{i=1}^{N} P_i n_i^{3/2}}{P} \right]^{2/3} \qquad (4.27)$$

in which P_i, n_i = wetted perimeter and Manning's n of any section i; P = wetted perimeter of the entire cross section; and N = total number of sections into which

Sturm

APPENDIX D

HEC-RAS MODEL RESULTS

Project 13117 Page 1/4
Date 10/31/13 By EMH
Client Steamboat Springs
Checked 11/12/13 By TEO
Subject Fish Creek Dam
Approved 11/14/13 By GGS

REQUIRED - Develop a HEC-RAS model to route (map) the peak dam breach flow through the downstream drainage (Middle Fork Fish Creek, Fish Creek, Yampa River)

ASSUMPTIONS -
1) Use RJH Manning's n evaluation dated 10/31/13. ✓✓
2) Use attenuated peak flows from RJH HEC-HMS analysis dated 10/31/13. ✓
3) Develop HEC-RAS sections in ArcGIS using the HEC-GeoRAS extension & 2' topography provided by Steamboat Springs and 3-m DEM data provided by the Fire District and supplemented with channel topography from the FEMA effective hydraulic model, as appropriate. ✓✓
4) Use bridge data from FEMA effective hydraulic models, where available, and fieldwork measurements by RJH elsewhere. ✓✓
5) Assume the two upstream bridges are blocked with dam breach debris ✓✓

ANALYSIS -

- Cross-sections were developed for Middle Fork Fish Creek (dam to XS-2.151) North Fork Fish Creek (XS-2.151 to XS-4.325), Fish Creek (XS-4.325 to -8.058) and Yampa River (XS-8.058 to XS-22.722) ✓
- The following bridges were modeled:
  - Steamboat Blvd - based on field measurements by RJH (XS-5.47) (assumed blocked) ✓✓
  - Pedestrian bridge - based on field measurements by RJH (XS-5.518) (assumed blocked) ✓✓
  - Rollingstone Bridge - based on field measurements by RJH (XS-7.6) ✓✓
  - Hwy 40 - based on data from FEMA effective model (XS-7.81) ✓✓
  - Railroad Bridge - based on data from FEMA effective model (XS-7.93) ✓✓

ANALYSIS-

- Railroad Bridge - data from FEMA model (XS - 8.91) ✓✓
- 5th St. Bridge - data from FEMA model (XS - 9.42) ✓✓
- 13th St. Bridge - data from FEMA model (XS - 10.06) ✓✓
- Yampa Core Trail Pedestrian Bridge - data from FEMA model (XS - 10.52) ✓✓
- Shield Dr. bridge - data from FEMA model (XS - 11.1) ✓✓
- Steamboat Campground Bridge - data from FEMA model (XS - 12.4) ✓✓
- Railroad Bridge - data from FEMA model (XS - 14.20) ✓✓
- County Road 33B bridge - data from FEMA model (XS - 16.72) ✓✓
- Railroad Bridge - data from FEMA model (XS - 20.6) ✓✓
- County Road 179 - data from FEMA model (XS - 21.21) ✓✓

- Manning's n values were input from RJH 10/31/13 Manning's n evaluation ✓✓
- Flow data was input from the HEC-HMS model ✓

XS	Flow (cfs)
0.037	72,100 ✓✓
2.151	71,651 ✓✓
5.013	71,472 ✓
8.056	70,598 ✓
11.390	37,573 ✓✓
14.317	22,163 ✓
17.20	15,127 ✓✓
22.722	8,203 ✓✓

- Normal depth was used as the downstream boundary condition ✓✓ and critical depth as the upstream boundary condition

RJH CONSULTANTS, INC.

Project	13117
Page	3/4
Date	10/31/13
By	EMH
Client	Steamboat Springs
Checked	11/12/13
By	TEO
Subject	Fish Creek Dam
Approved	11/14/13
By	GGS

ANALYSIS

- See HEC-RAS results in Attachment 1 ✓
- QA/QC
  - Check in ArcGIS
    - Cross-section layout ✓
    - Reach Lengths ✓
  - Check in HEC-RAS
    - Reach Lengths ✓
    - Manning's n values ✓
    - Flow Data ✓
    - Cross-section topography ✓
    - Bridge data ✓
    - General model performance ✓

RJH CONSULTANTS, INC.

Client Steamboat Springs

Subject Fish Creek Dam

Project 13117 Page 4/4

Date 10/31/13 By EMH

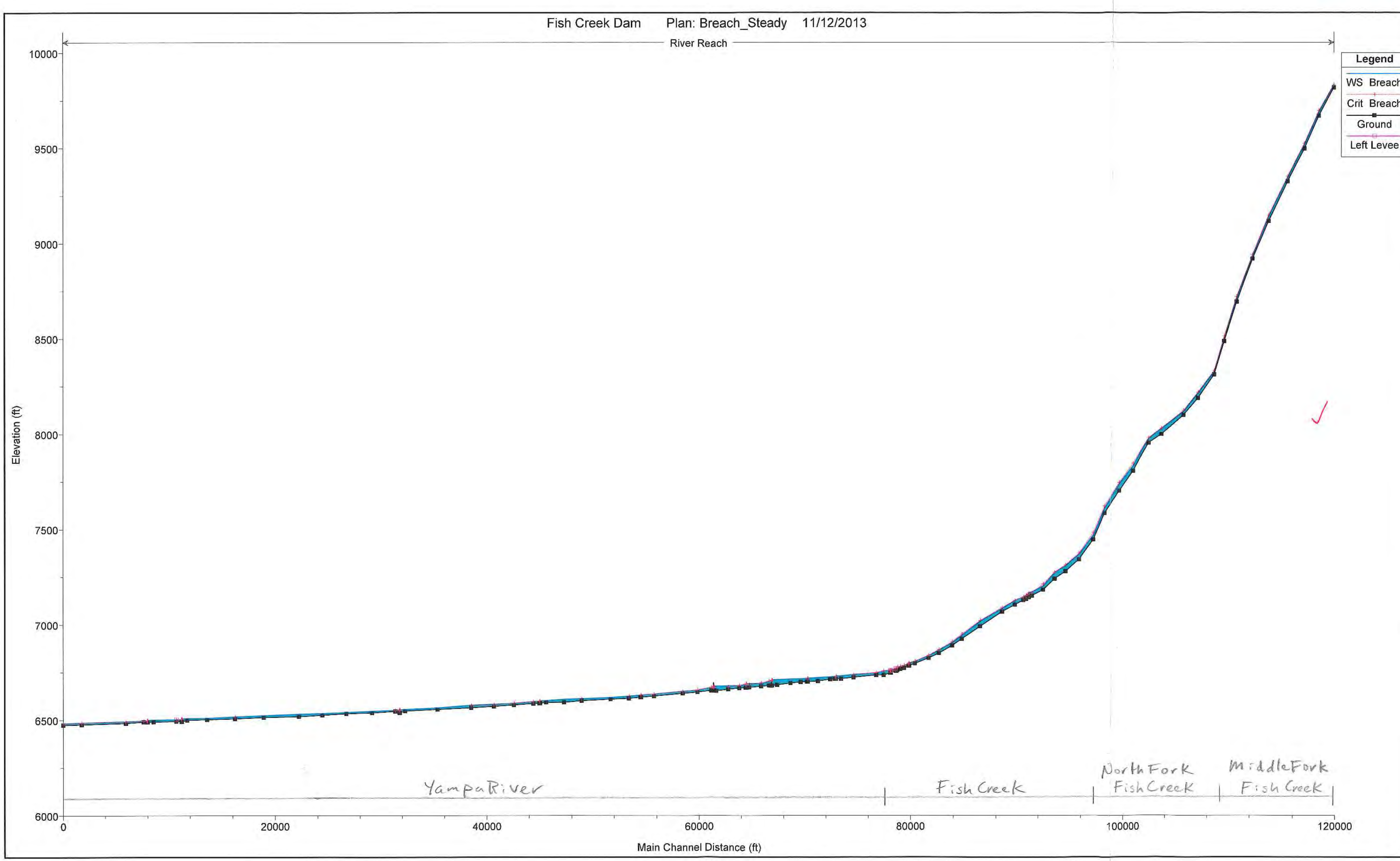
Checked 11/12/13 By TEO

Approved 11/14/13 By GGS

Attachment 1

HEC-RAS Results

√TEO 11/12/13
GGS 11/14/13



HEC-RAS Plan: Breach River: River Reach: Reach Profile: Breach

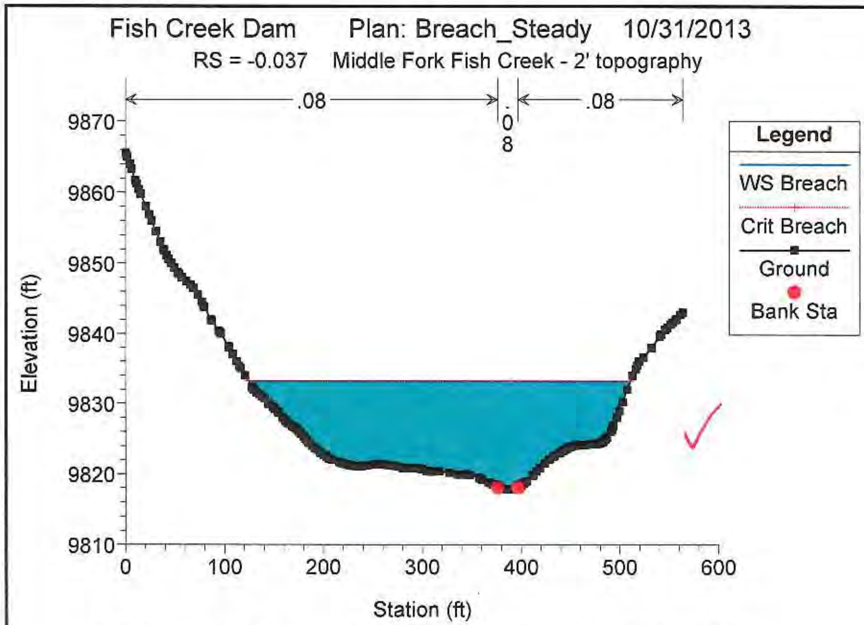
Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Reach	-0.037	Breach	72100.00	9817.80	9833.15	9833.15	9838.32	0.041244	23.23	4005.38	386.39	1.05
Reach	-0.305	Breach	72100.00	9670.00	9690.02	9697.68	9720.37	0.251159	64.56	1846.15	230.37	2.58
Reach	-0.562	Breach	72100.00	9497.95	9519.99	9524.69	9534.92	0.083210	39.68	2681.35	273.10	1.53
Reach	-0.857	Breach	72100.00	9326.00	9345.47	9352.87	9369.03	0.145402	50.06	1949.04	165.87	2.02
Reach	-1.194	Breach	72100.00	9117.54	9141.62	9148.14	9162.10	0.095680	47.00	2095.95	140.46	1.70
Reach	-1.474	Breach	72100.00	8919.30	8934.72	8941.28	8958.23	0.217209	52.45	1949.07	227.22	2.38
Reach	-1.755	Breach	72100.00	8693.62	8714.38	8720.68	8735.75	0.108966	44.70	2267.30	231.74	1.77
Reach	-1.972	Breach	72100.00	8487.21	8502.38	8512.55	8541.70	0.294394	58.11	1494.01	145.28	2.74
Reach	-2.151	Breach	71651.00	8311.68	8325.87	8331.90	8345.16	0.142524	39.29	2110.59	208.16	1.90
Reach	-2.445	Breach	71651.00	8188.57	8214.94	8218.15	8227.13	0.046086	34.63	2828.41	189.37	1.20
Reach	-2.710	Breach	71651.00	8100.00	8117.93	8123.27	8134.98	0.101192	38.32	2347.35	224.26	1.65
Reach	-3.095	Breach	71651.00	8000.00	8029.65	8029.65	8040.22	0.035119	30.35	2869.80	140.31	1.03
Reach	-3.321	Breach	71651.00	7954.00	7976.18	7979.35	7988.18	0.055248	33.78	2756.93	204.49	1.28
Reach	-3.599	Breach	71651.00	7806.00	7832.87	7844.67	7869.55	0.124191	56.91	1633.24	86.82	1.95
Reach	-3.856	Breach	71651.00	7702.00	7738.11	7743.68	7758.62	0.053685	45.13	2235.59	99.64	1.33
Reach	-4.128	Breach	71651.00	7584.00	7609.50	7620.73	7644.82	0.126291	56.13	1653.76	93.37	1.96
Reach	-4.325	Breach	71651.00	7446.10	7469.59	7481.15	7507.87	0.138786	55.35	1578.83	91.21	2.03
Reach	-4.573	Breach	71651.00	7342.00	7368.35	7373.39	7386.43	0.060787	39.69	2284.18	126.57	1.37
Reach	-4.819	Breach	71651.00	7280.00	7309.59	7311.45	7322.80	0.038945	34.21	2657.33	129.51	1.11
Reach	-5.013	Breach	71472.00	7240.00	7273.10	7273.42	7284.75	0.034548	34.67	2790.13	126.11	1.07
Reach	-5.215	Breach	71472.00	7183.10	7202.38	7211.26	7229.85	0.079125	49.56	2161.77	210.73	2.00
Reach	-5.413	Breach	71472.00	7152.16	7170.71	7166.80	7172.30	0.009759	16.70	8668.08	797.04	0.70
Reach	-5.467	Breach	71472.00	7144.00	7167.21	7165.07	7168.78	0.017269	13.89	7307.21	947.79	0.82
Reach	-5.47		Inl Struct									
Reach	-5.480	Breach	71472.00	7143.02	7158.19	7158.19	7161.46	0.038067	19.35	5200.15	780.72	1.19
Reach	-5.516	Breach	71472.00	7136.00	7154.96	7152.41	7156.65	0.007855	15.35	8277.38	820.84	0.63
Reach	-5.518		Inl Struct									
Reach	-5.520	Breach	71472.00	7134.28	7153.21	7151.88	7155.55	0.011366	18.13	7298.54	810.38	0.75
Reach	-5.568	Breach	71472.00	7128.00	7144.26	7144.26	7150.42	0.029863	26.71	4334.92	613.96	1.19
Reach	-5.721	Breach	71472.00	7104.58	7126.30	7126.48	7131.98	0.017155	24.30	4067.56	347.47	0.94
Reach	-5.952	Breach	71472.00	7068.10	7084.78	7088.52	7097.67	0.052373	35.85	2701.66	267.27	1.56
Reach	-6.339	Breach	71472.00	6991.10	7017.23	7020.23	7028.54	0.024596	31.51	3694.12	301.22	1.14
Reach	-6.660	Breach	71472.00	6925.10	6943.99	6950.08	6964.11	0.065094	42.67	2450.50	222.03	1.78
Reach	-6.834	Breach	71472.00	6889.92	6905.68	6908.81	6915.42	0.039763	30.39	3290.19	431.36	1.37
Reach	-7.066	Breach	71472.00	6850.10	6866.26	6867.77	6873.12	0.030990	27.06	3631.13	402.58	1.21
Reach	-7.250	Breach	71472.00	6824.10	6836.64	6837.59	6841.66	0.033521	22.53	4102.45	569.24	1.19
Reach	-7.491	Breach	71472.00	6796.10	6807.05	6807.05	6809.95	0.023836	16.86	5370.73	903.47	0.97
Reach	-7.596	Breach	71472.00	6784.00	6798.75	6795.94	6799.66	0.005223	9.78	9926.98	1414.28	0.48
Reach	-7.6		Bridge									
Reach	-7.610	Breach	71472.00	6784.00	6793.75	6794.35	6796.74	0.033260	18.05	5493.00	1291.03	1.11
Reach	-7.689	Breach	71472.00	6772.10	6785.44	6785.43	6787.58	0.021330	16.74	6573.66	1455.36	0.92
Reach	-7.756	Breach	71472.00	6767.10	6780.22	6779.93	6781.65	0.018935	13.82	7953.40	1958.06	0.84
Reach	-7.805	Breach	71472.00	6761.10	6776.98	6776.46	6777.97	0.009693	12.25	10413.72	2450.28	0.63
Reach	-7.81		Bridge									
Reach	-7.841	Breach	71472.00	6756.80	6768.59	6768.69	6910.48	0.759829	96.71	918.02	1234.44	5.49
Reach	-7.926	Breach	71472.00	6748.10	6761.02	6759.94	6761.72	0.007961	10.03	11227.07	2622.84	0.57
Reach	-7.93		Bridge									
Reach	-7.939	Breach	71472.00	6746.70	6760.76	6757.76	6761.02	0.001487	4.92	17936.30	2518.96	0.25
Reach	-8.056	Breach	70598.00	6735.40	6756.52	6756.52	6759.14	0.006341	19.13	8079.80	1198.76	0.81
Reach	-8.188	Breach	70598.00	6735.54	6746.38	6747.85	6751.72	0.025933	23.23	4516.31	920.68	1.34
Reach	-8.597	Breach	70598.00	6723.30	6738.12	6735.76	6739.15	0.003318	10.59	9366.09	1451.26	0.51
Reach	-8.819	Breach	70598.00	6716.27	6731.73		6734.06	0.006388	15.31	6584.52	903.93	0.78
Reach	-8.907	Breach	70598.00	6715.39	6731.70	6727.25	6732.50	0.002044	9.90	10338.96	1185.26	0.46
Reach	-8.91		Bridge									
Reach	-8.927	Breach	70598.00	6715.39	6728.58		6730.07	0.005327	13.15	7565.63	1127.30	0.70
Reach	-9.011	Breach	70598.00	6714.00	6726.14		6726.87	0.002618	9.57	10837.47	1378.35	0.50
Reach	-9.232	Breach	70598.00	6704.23	6722.51		6723.79	0.003106	12.74	9272.02	1127.72	0.57
Reach	-9.410	Breach	70598.00	6700.64	6718.91	6716.77	6720.60	0.004018	13.73	7663.87	872.57	0.64
Reach	-9.42		Bridge									
Reach	-9.428	Breach	70598.00	6701.17	6717.91		6719.82	0.004913	14.65	7296.08	898.43	0.70
Reach	-9.539	Breach	70598.00	6698.89	6716.52		6717.50	0.002285	10.95	10865.16	1297.09	0.49
Reach	-9.719	Breach	70598.00	6693.20	6714.20		6715.40	0.002003	11.13	9728.74	915.36	0.47
Reach	-9.962	Breach	70598.00	6684.37	6712.22		6713.32	0.001312	11.48	10038.58	726.69	0.40
Reach	-10.051	Breach	70598.00	6680.56	6710.10	6706.74	6712.40	0.002426	14.27	6878.24	682.35	0.53
Reach	-10.06		Bridge									
Reach	-10.064	Breach	70598.00	6680.45	6705.99	6705.99	6709.69	0.004720	17.93	5545.74	665.78	0.72
Reach	-10.113	Breach	70598.00	6681.15	6701.01	6702.66	6707.25	0.008985	22.02	4407.76	671.39	0.97
Reach	-10.255	Breach	70598.00	6676.44	6691.91	6693.88	6698.41	0.015622	24.89	4234.68	660.48	1.23
Reach	-10.466	Breach	70598.00	6671.31	6691.49	6685.40	6692.04	0.001101	7.80	13591.59	1382.86	0.34
Reach	-10.517	Breach	70598.00	6669.80	6688.94	6688.94	6691.39	0.004573	15.74	7727.46	1322.28	0.69
Reach	-10.52		Bridge									
Reach	-10.525	Breach	70598.00	6669.68	6686.36	6687.46	6690.31	0.008945	20.01	6103.97	1221.87	0.95
Reach	-10.641	Breach	70598.00	6667.66	6679.79	6680.77	6683.56	0.012536	20.49	5722.36	1091.23	1.09
Reach	-10.841	Breach	70598.00	6661.20	6678.98	6673.05	6679.46	0.001178	7.77	13280.43	1225.33	0.35
Reach	-11.055	Breach	70598.00	6652.72	6678.00		6678.47	0.000948	8.45	14993.38	1473.56	0.33
Reach	-11.093	Breach	70598.00	6654.92	6676.91	6673.68	6678.16	0.001931	11.04	10215.55	1492.19	0.46
Reach	-11.1		Bridge									
Reach	-11.111	Breach	70598.00	6653.74	6669.16	6671.12	6675.40	0.016048	21.44	4140.49	1019.53	1.20
Reach	-11.142	Breach	70598.00	6654.51	6669.84	6669.84	6672.38	0.006791	17.65	7390.76	1354.92	0.83
Reach	-11.390	Breach	37573.00	6646.50	6656.25	6657.43	6659.94	0.018883	19.33	3385.47	1250.84	1.24
Reach	-11.657	Breach	37573.00	6640.10	6651.02	6649.66	6651.59	0.003692	8.82	7595.48	1766.02	0.56
Reach	-12.165	Breach	37573.00	6626.07	6636.33	6635.96	6637.97	0.008052	10.85	4206.57	1175.55	0.78
Reach	-12.398	Breach	37573.00	6619.10	6631.59	6630.63	6632.20	0.002796	8.21	8334.34	2469.76	0.54
Reach	-12.4		Bridge									
Reach	-12.406	Breach	37573.00	6619.10	6631.52		6631.89	0.002158	6.72	9730.62	2515.15	0.42
Reach	-12.615	Breach	37573.00	6613.22	6625.88	6625.32	6627.95	0.005806	12.76	4380.53	1189.06	0.72
Reach	-12.938	Breach	37573.00	6609.52	6619.62		6620.16	0.003216	8.67	7484.43	1798.97	0.52
Reach	-13.457	Breach	37573.00	6601.11	6613.19	6611.92	6613.98	0.002920	9.37	7907.73	2399.45	0.51
Reach	-13.772	Breach	37573.00	6591.93	6609.79		6610.32	0.001849	8.28	8103.37	1580.74	0.40
Reach	-14.090	Breach	37573.00	6592.77	6603.15		6604.54	0.006445	12.98	4949.13	1123.45	0.75
Reach	-14.196	Breach	37573.00	6587.79	6600.15	6599.28	6601.36	0.005471	11.27	5353.98	1403.73	0.68

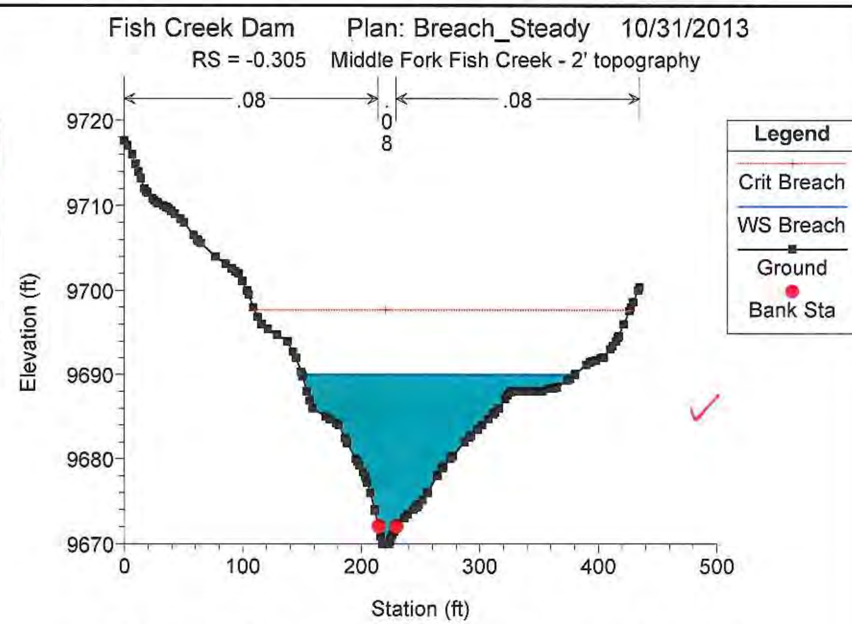
✓ TEO 11/12/13
GGS 11/14/13

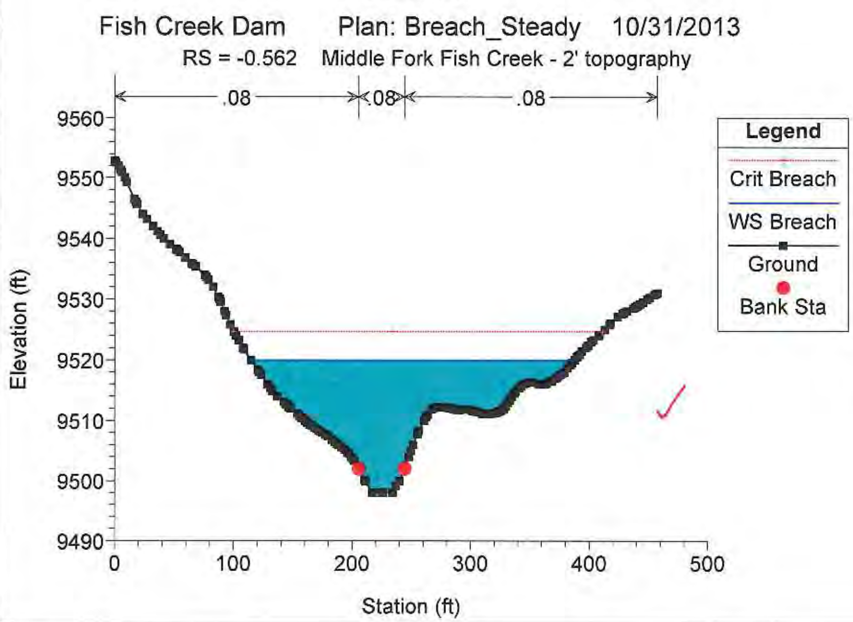
HEC-RAS Plan: Breach River: River Reach: Reach Profile: Breach (Continued)

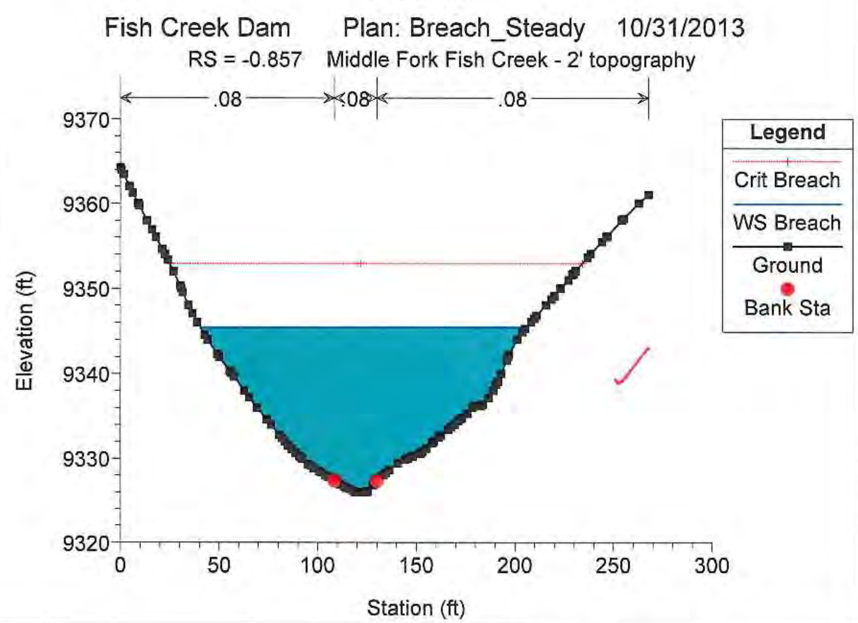
Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Reach	-14.20		Bridge									
Reach	-14.208	Breach	37573.00	6587.54	6598.58	6598.58	6600.28	0.008650	13.36	4475.74	1383.72	0.85
Reach	-14.317	Breach	22163.00	6586.18	6597.18	6595.96	6597.66	0.002593	7.73	5366.21	1662.20	0.47
Reach	-14.665	Breach	22163.00	6578.99	6587.98	6587.98	6589.71	0.008586	13.03	2630.72	681.45	0.84
Reach	-15.023	Breach	22163.00	6571.71	6582.88	6578.78	6583.11	0.001142	5.29	6757.51	1541.53	0.31
Reach	-15.426	Breach	22163.00	6564.55	6577.98	6575.52	6579.27	0.003030	10.16	3534.67	1076.53	0.53
Reach	-16.032	Breach	22163.00	6556.33	6564.21		6564.71	0.007162	9.75	4601.12	1692.43	0.72
Reach	-16.610	Breach	22163.00	6548.00	6556.04		6556.19	0.001540	4.44	8068.28	2532.02	0.34
Reach	-16.707	Breach	22163.00	6538.64	6554.54	6553.67	6554.91	0.002570	7.35	6085.32	3261.53	0.46
Reach	-16.71		Bridge									
Reach	-16.715	Breach	22163.00	6539.98	6552.31	6553.12	6554.29	0.013514	14.96	3039.27	2481.73	1.02
Reach	-16.786	Breach	22163.00	6546.00	6551.66	6551.02	6551.95	0.004159	6.38	6115.52	2800.30	0.54
Reach	-17.200	Breach	15127.00	6538.11	6547.02		6547.18	0.001470	3.74	5679.95	2132.18	0.32
Reach	-17.665	Breach	15127.00	6533.64	6540.98		6541.62	0.007268	9.00	3071.10	1429.77	0.66
Reach	-18.094	Breach	15127.00	6526.00	6535.86		6536.05	0.001249	4.89	5643.53	1766.61	0.29
Reach	-18.509	Breach	15127.00	6518.28	6532.00		6532.67	0.001900	7.64	2606.63	482.68	0.38
Reach	-19.137	Breach	15127.00	6514.27	6525.07		6525.63	0.002548	7.14	3475.98	1138.25	0.42
Reach	-19.650	Breach	15127.00	6506.80	6518.76	6515.96	6519.22	0.002276	6.89	3478.35	1409.86	0.40
Reach	-20.143	Breach	15127.00	6502.82	6511.31		6512.19	0.003604	7.51	2015.52	545.30	0.48
Reach	-20.502	Breach	15127.00	6500.78	6510.30		6510.37	0.000370	2.63	8506.08	2163.18	0.16
Reach	-20.594	Breach	15127.00	6492.79	6507.67	6505.49	6509.72	0.006378	11.64	1415.09	1008.11	0.66
Reach	-20.6		Bridge									
Reach	-20.601	Breach	15127.00	6492.80	6504.41	6505.29	6509.15	0.021333	17.47	865.93	139.01	1.16
Reach	-20.695	Breach	15127.00	6494.15	6503.82	6501.96	6504.11	0.003177	6.03	3856.79	1243.08	0.44
Reach	-21.099	Breach	15127.00	6491.28	6502.22		6502.28	0.000425	2.62	9825.11	3043.72	0.17
Reach	-21.206	Breach	15127.00	6489.63	6500.23	6498.00	6501.59	0.005302	9.43	1709.35	3473.48	0.59
Reach	-21.21		Bridge									
Reach	-21.220	Breach	15127.00	6489.87	6498.73	6497.80	6500.48	0.010360	10.84	1776.95	2596.51	0.79
Reach	-21.278	Breach	15127.00	6491.73	6497.03	6496.71	6497.41	0.006009	6.11	3917.52	2627.56	0.56
Reach	-21.595	Breach	15127.00	6484.18	6493.43	6491.73	6493.50	0.001120	3.30	8653.14	4458.17	0.26
Reach	-22.390	Breach	15127.00	6477.41	6486.14	6485.36	6486.71	0.004305	8.67	4227.56	2830.54	0.59
Reach	-22.722	Breach	8203.00	6474.55	6482.29	6479.03	6482.49	0.001001	3.91	3272.12	1810.12	0.28

√TEO 11/12/13
GGS 11/14/13

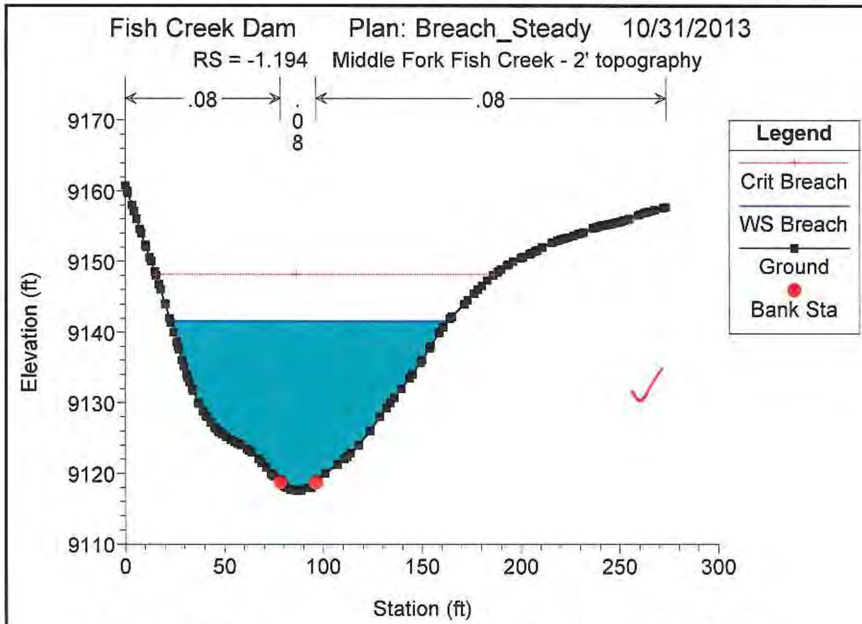


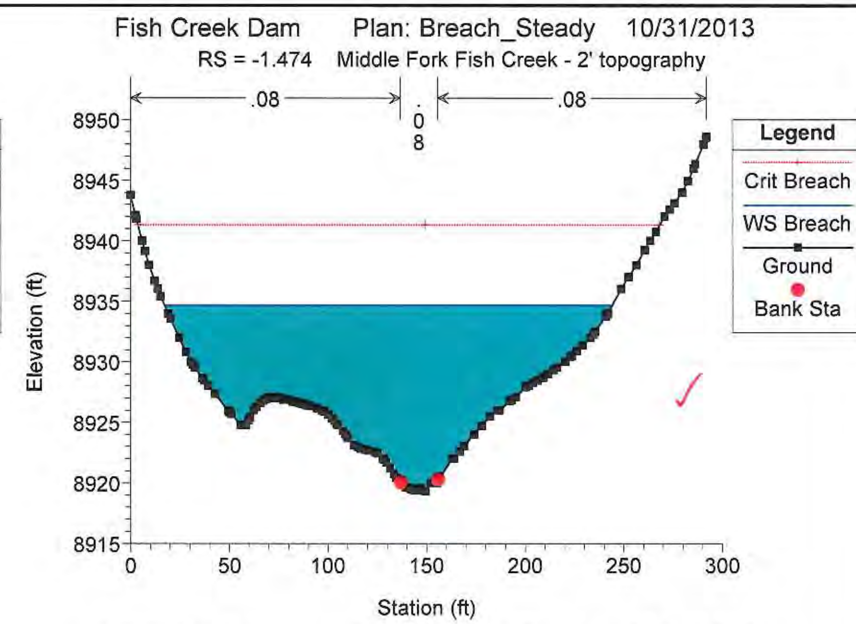


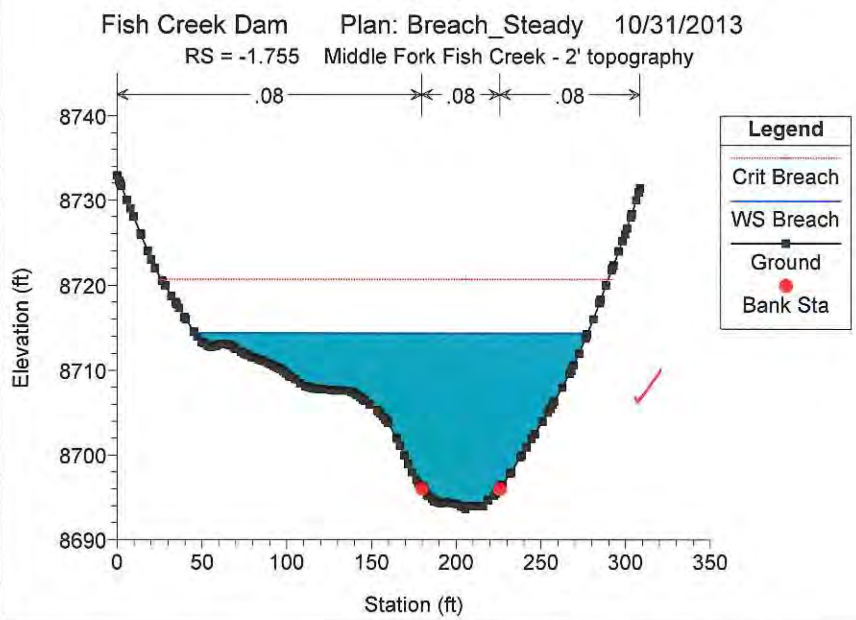


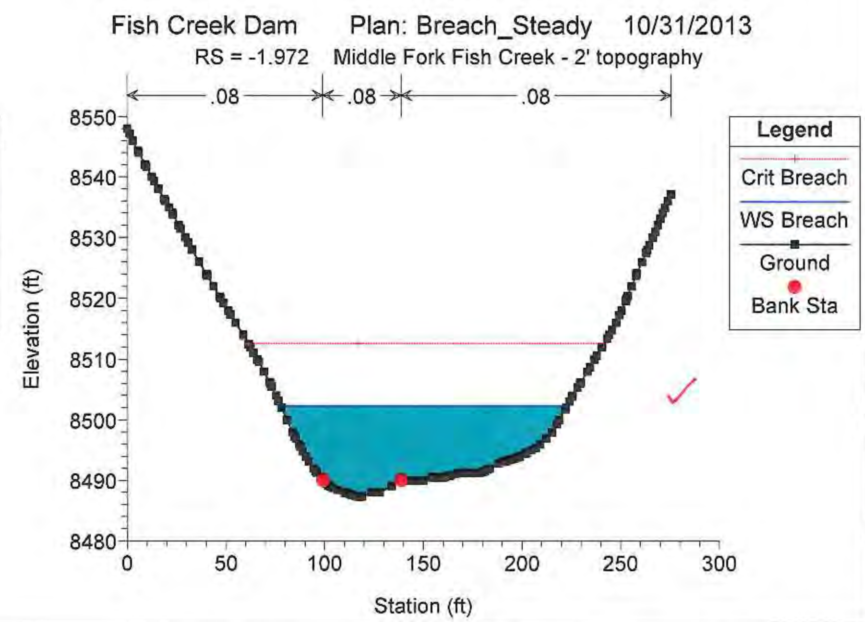


✓ TEO 11/12/13
GGS 11/14/13

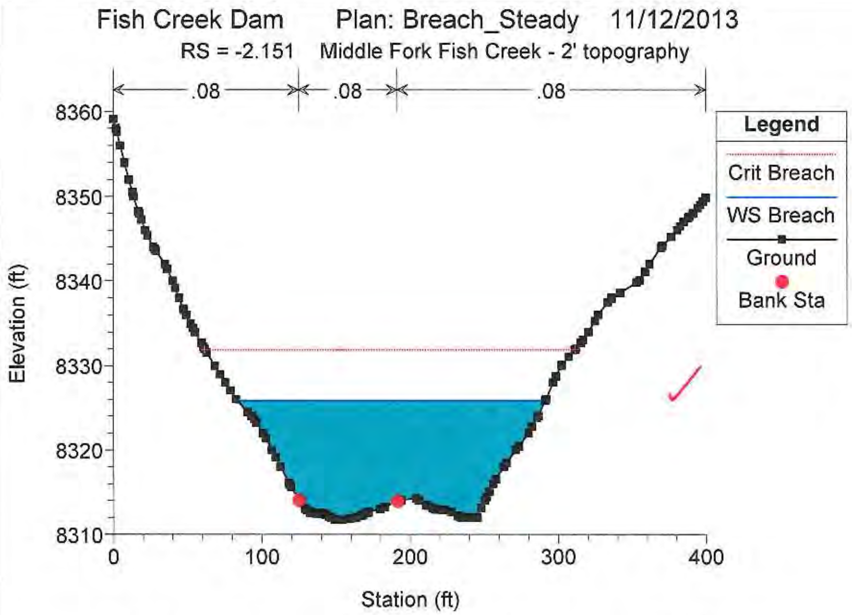


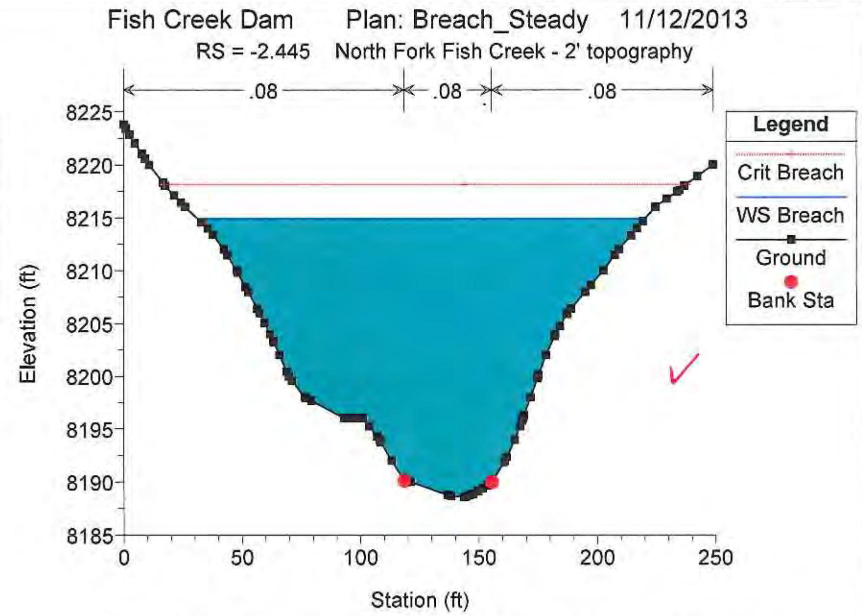


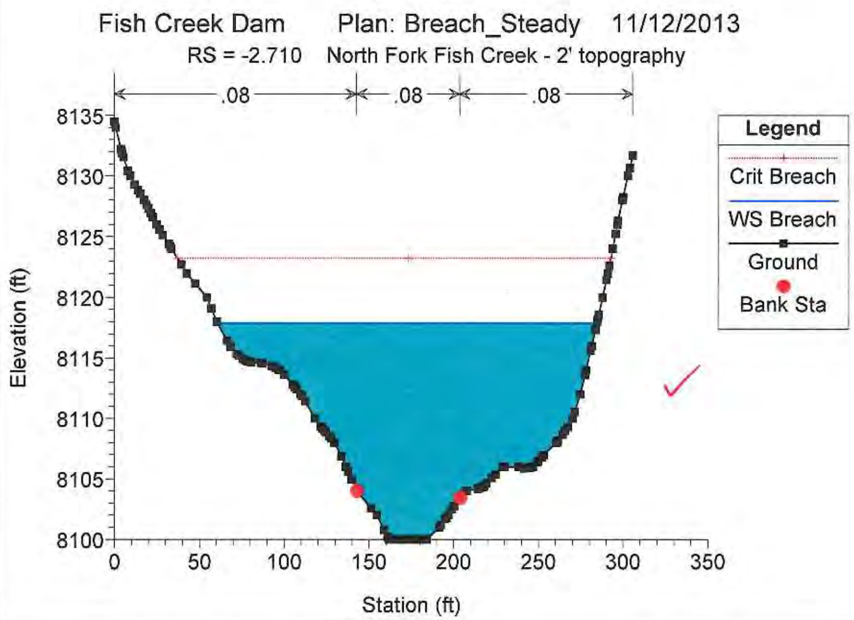


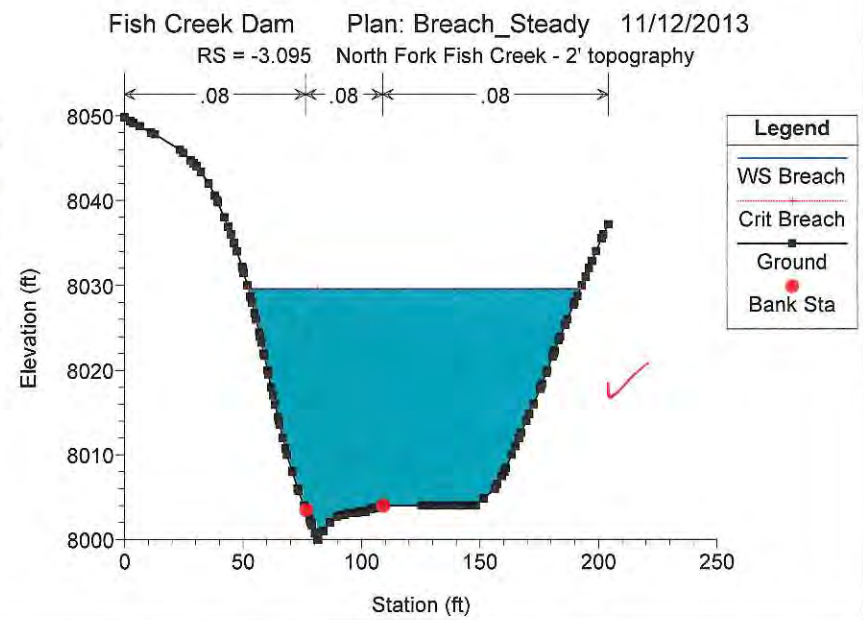


✓TEO 11/12/13
GOS 11/14/13

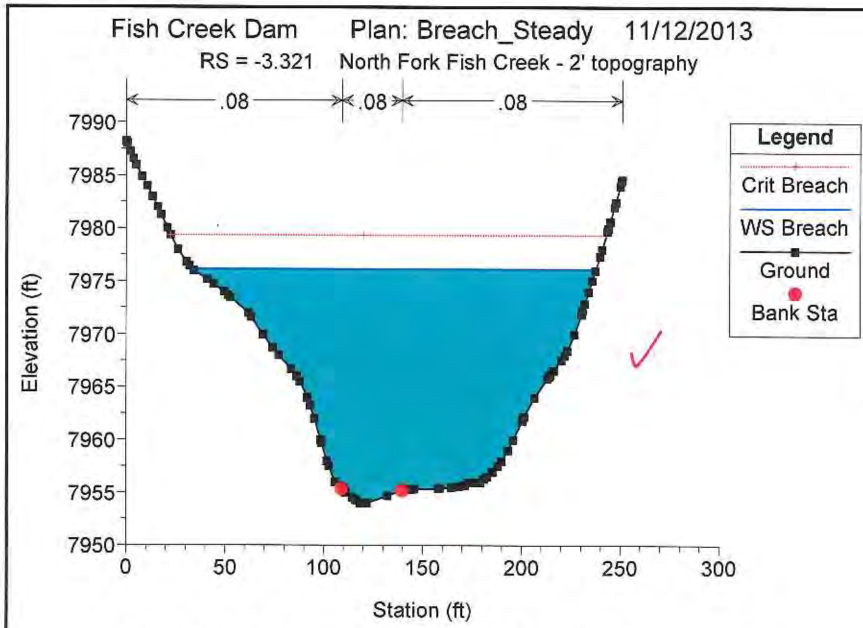


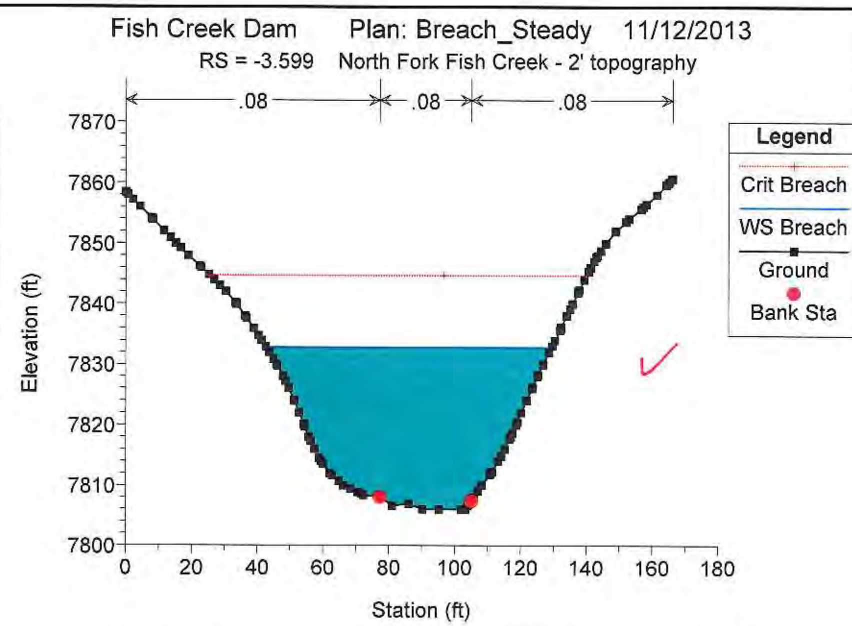


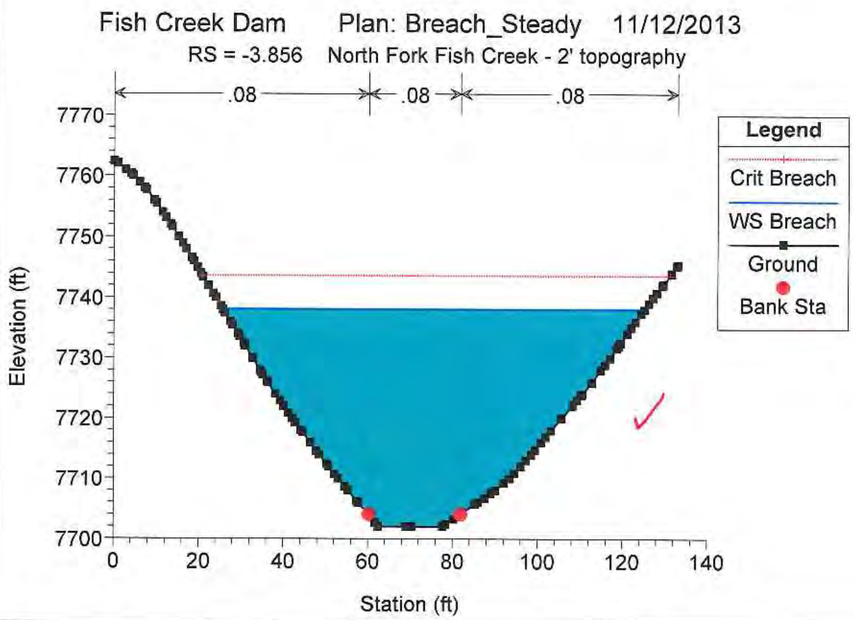


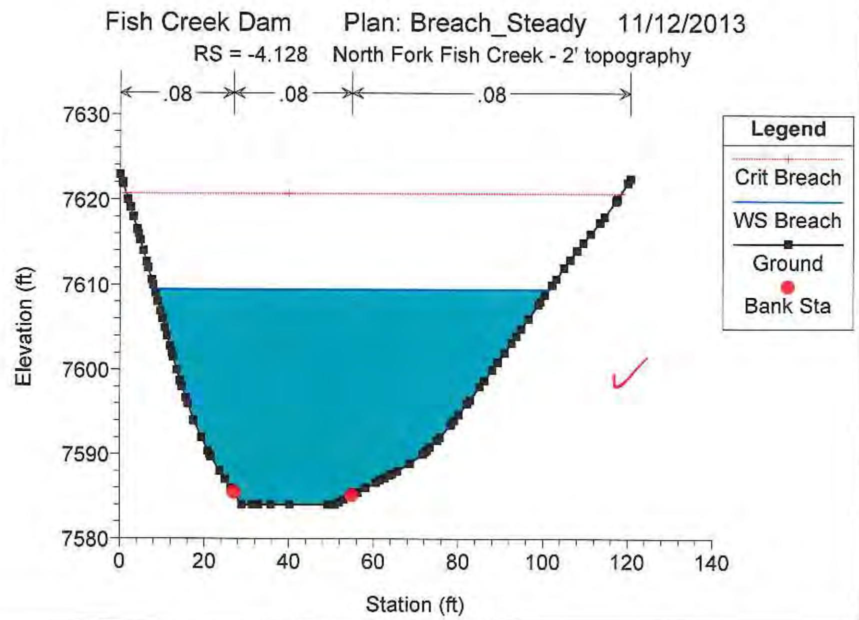


√ TEO 11/12/13
GGS 11/14/13



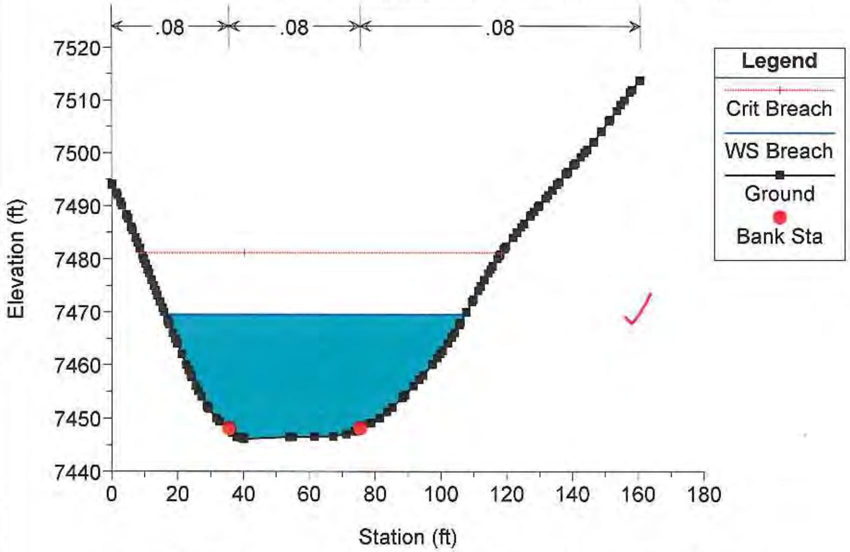




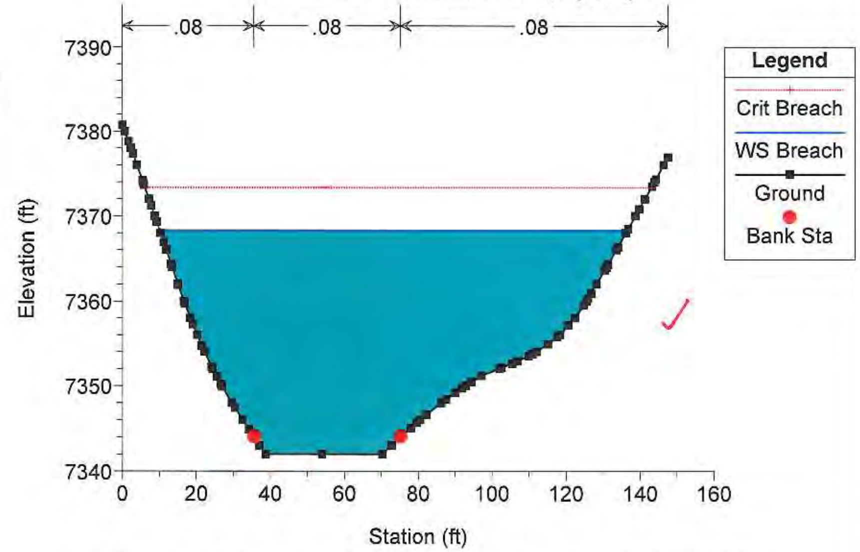


✓ TEO 11/12/13
COCS 11/14/13

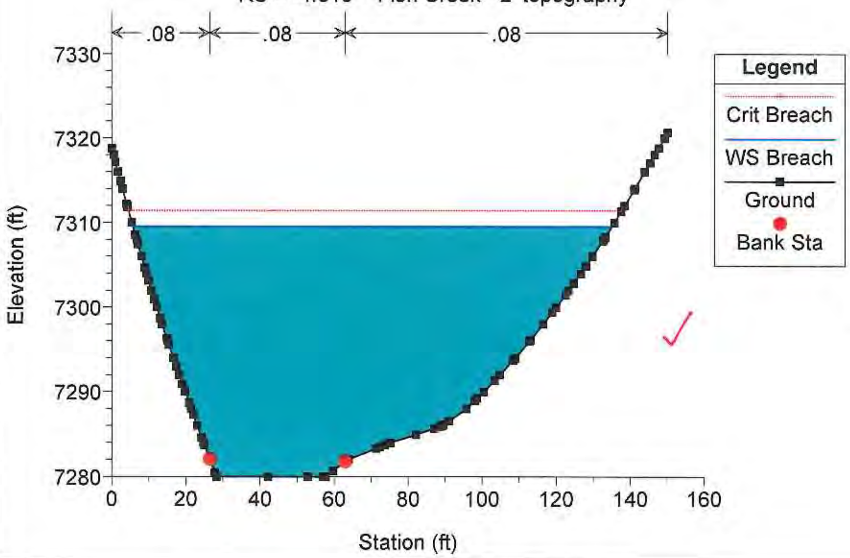
Fish Creek Dam Plan: Breach_Steady 10/31/2013
RS = -4.325 Fish Creek - 2' topography. Downstream of confluence of Fish Cr



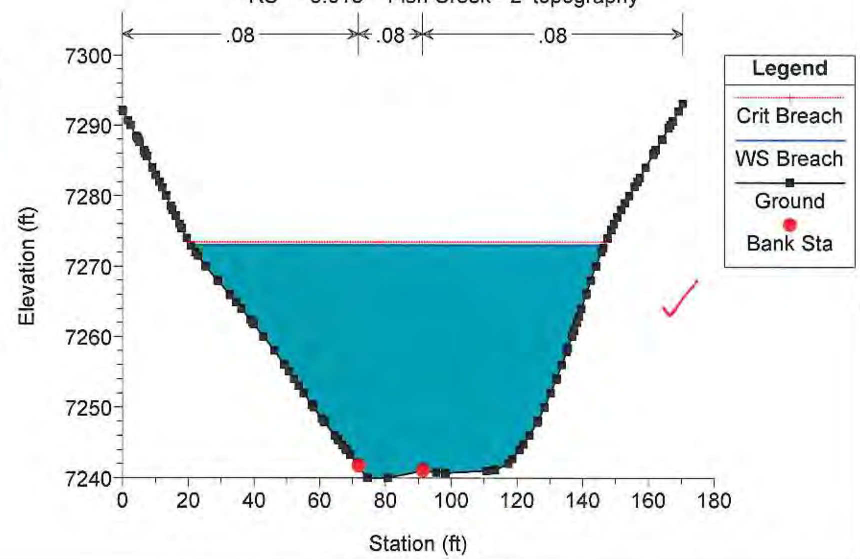
Fish Creek Dam Plan: Breach_Steady 10/31/2013
RS = -4.573 Fish Creek - 2' topography



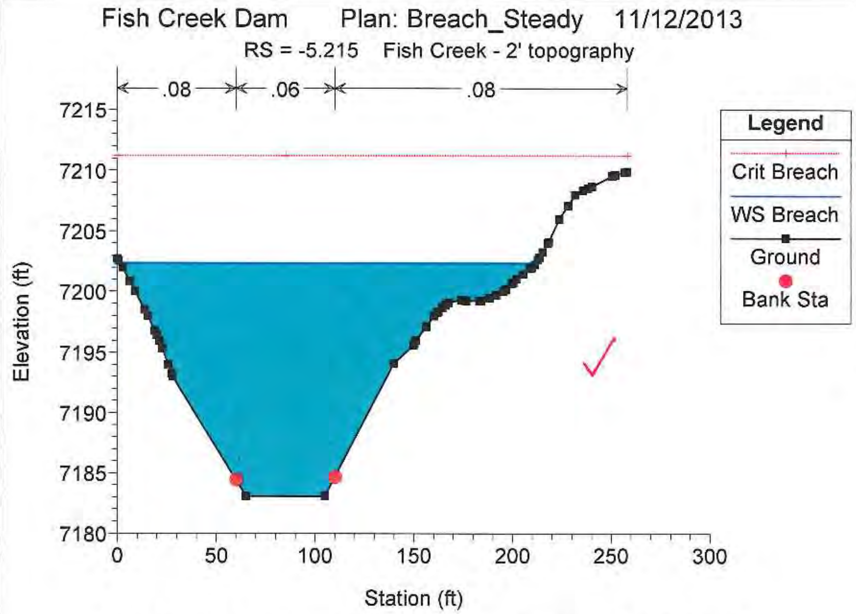
Fish Creek Dam Plan: Breach_Steady 10/31/2013
RS = -4.819 Fish Creek - 2' topography

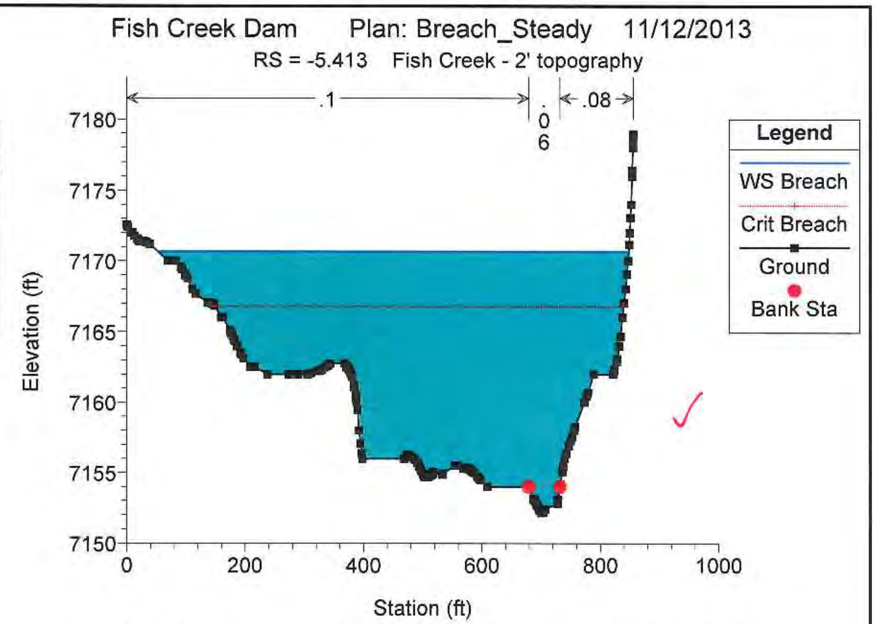


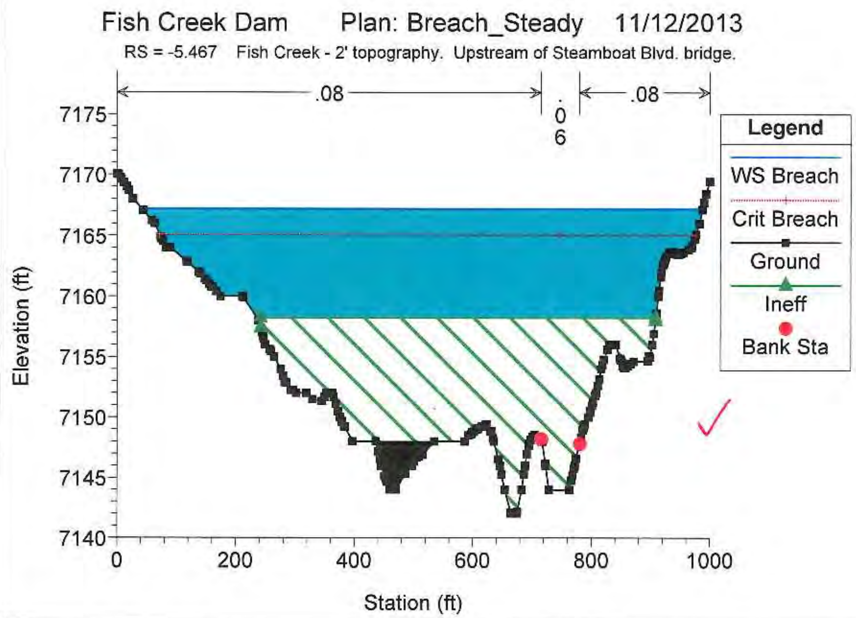
Fish Creek Dam Plan: Breach_Steady 10/31/2013
RS = -5.013 Fish Creek - 2' topography

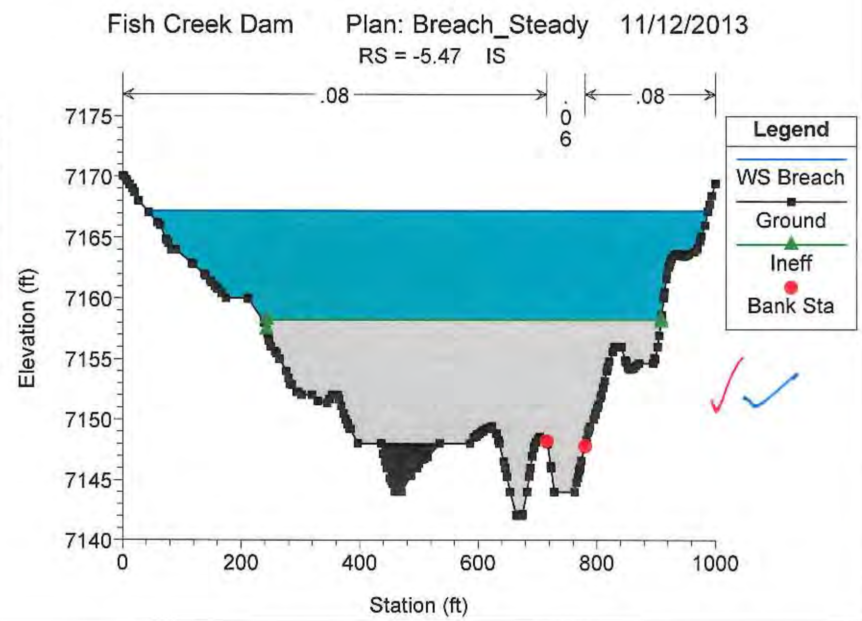


✓ TEO 11/12/13
GGS 11/14/13

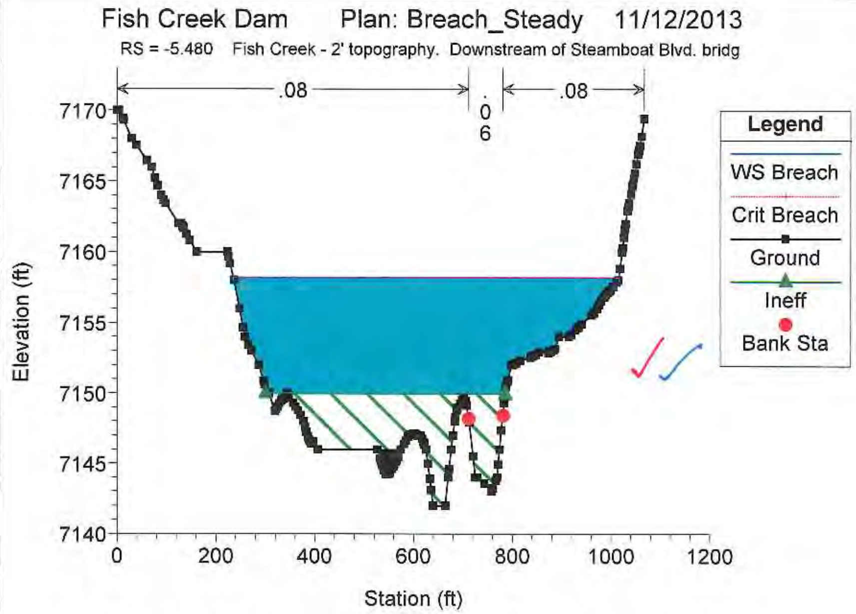


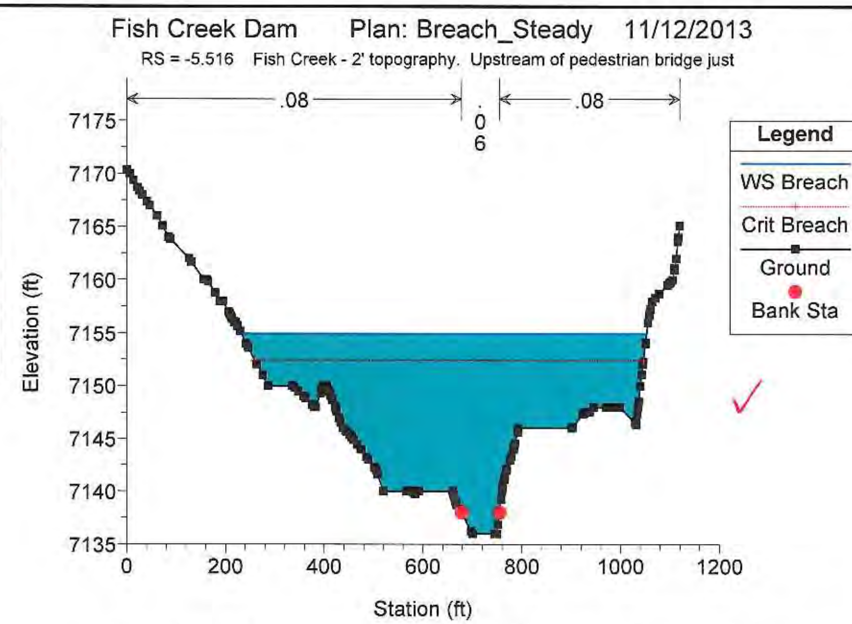


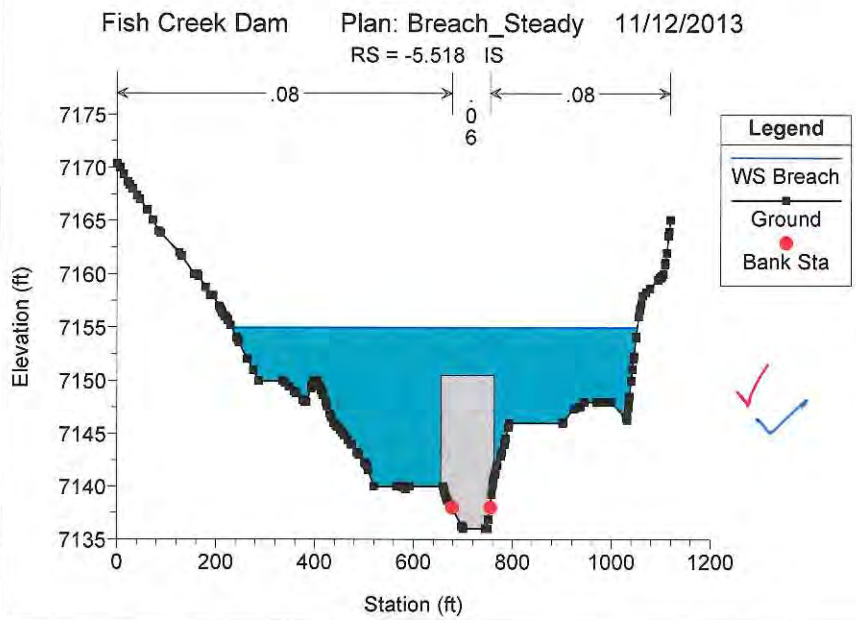


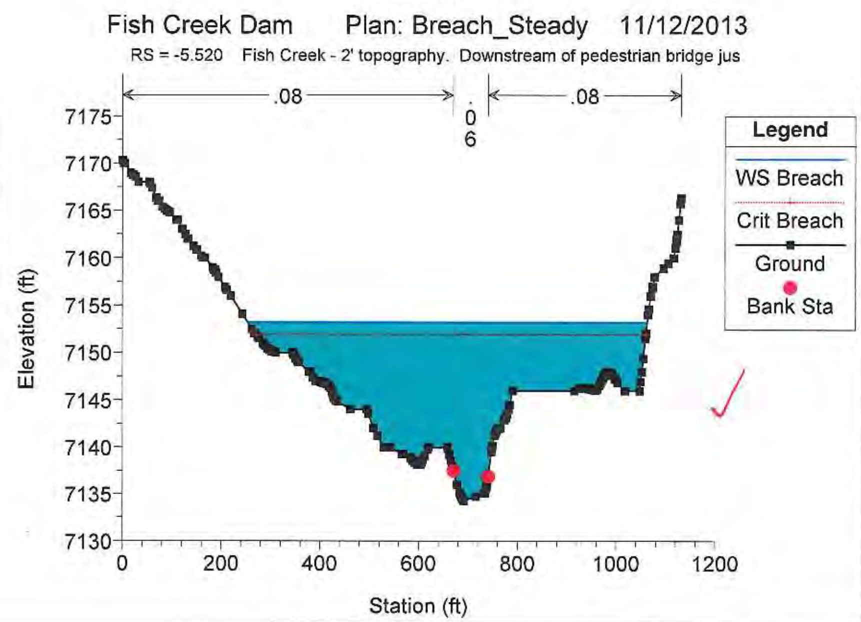


√TEO 11/12/13
GGS 11/14/13



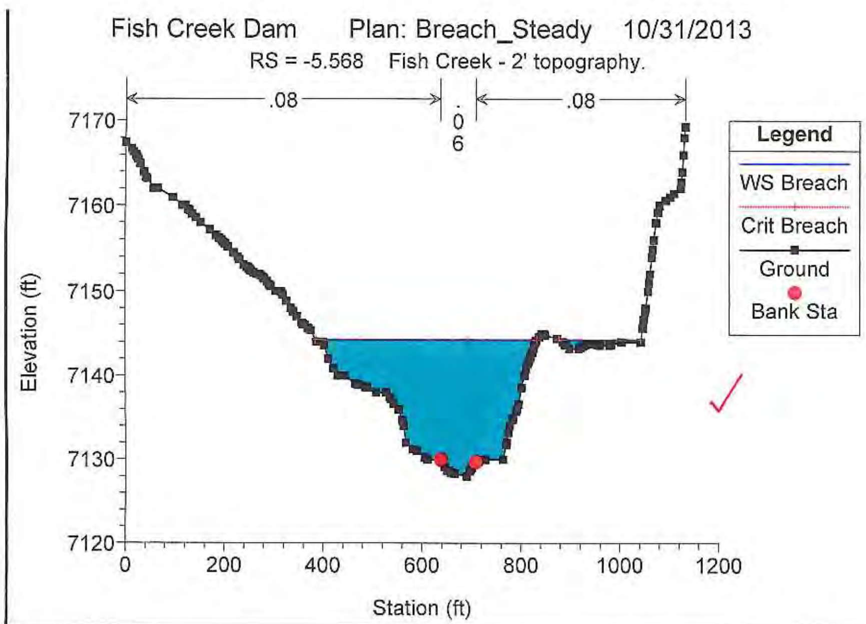


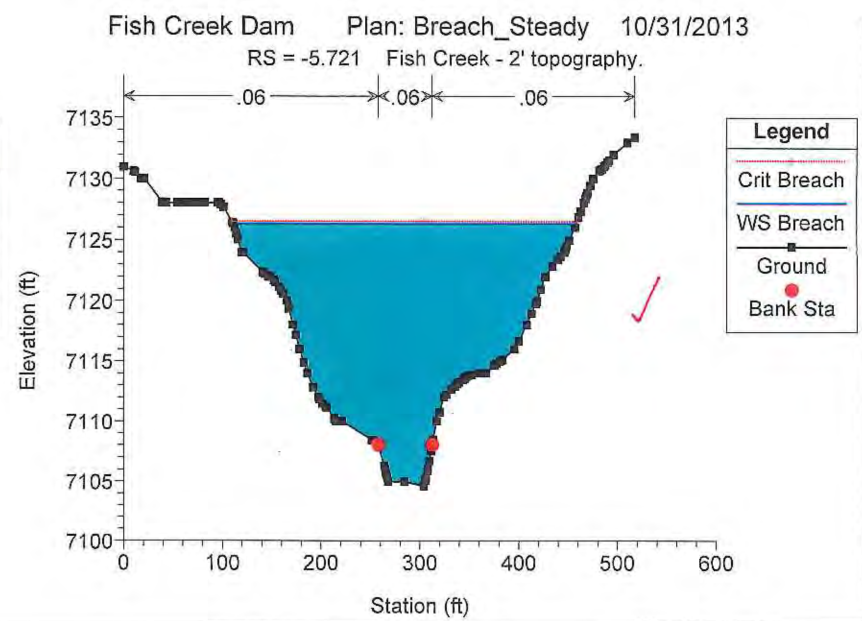




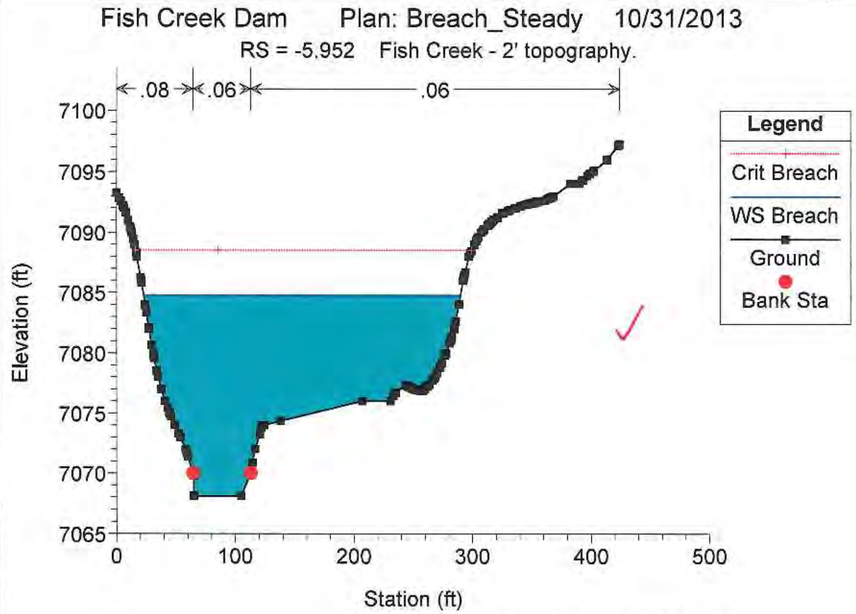
✓ TEO 11/12/13
GGS 11/14/13

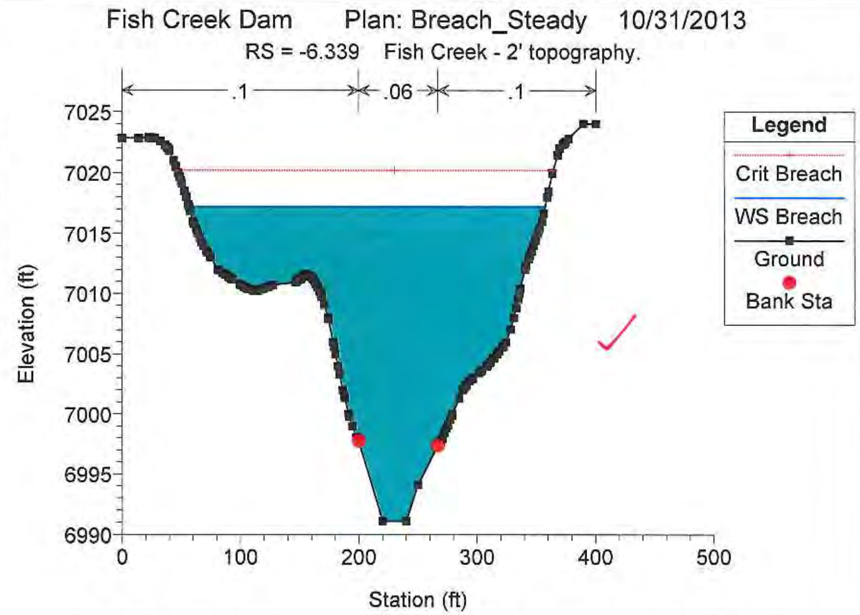
Intentionally Left Blank

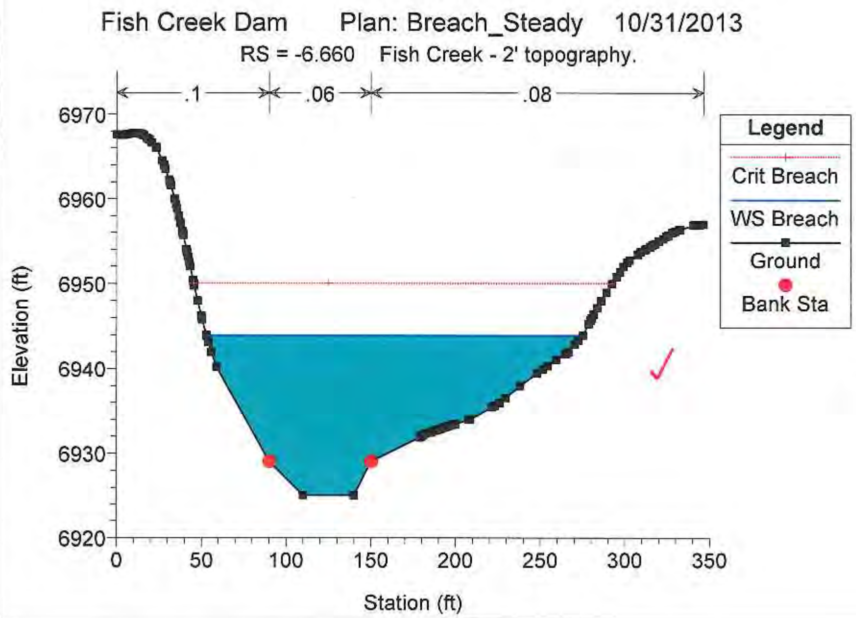


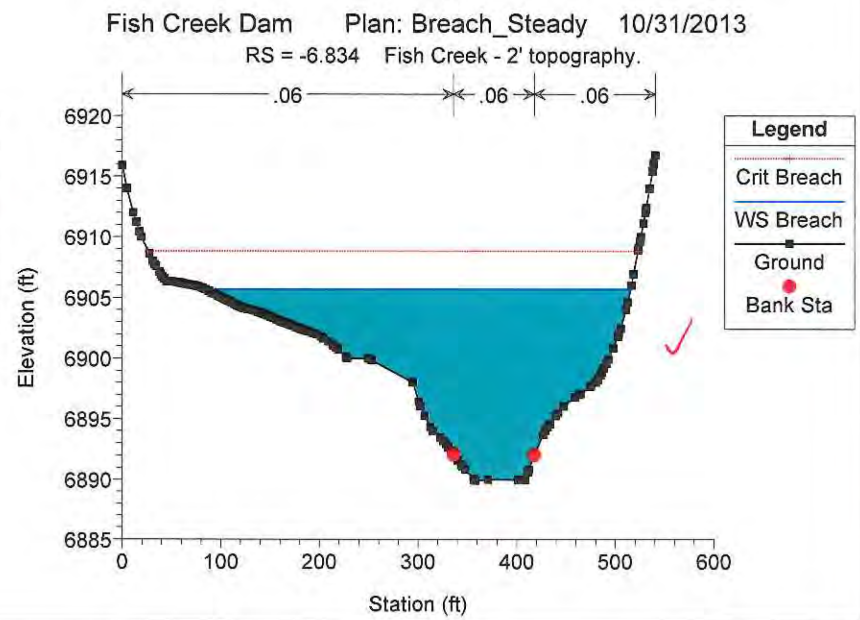


✓ TEO 11/12/13
GGS 11/14/13

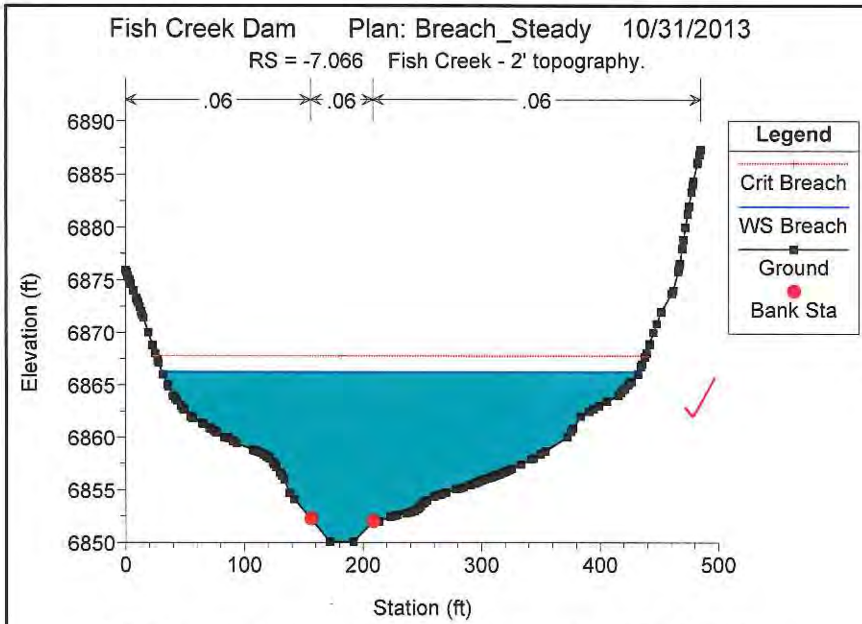


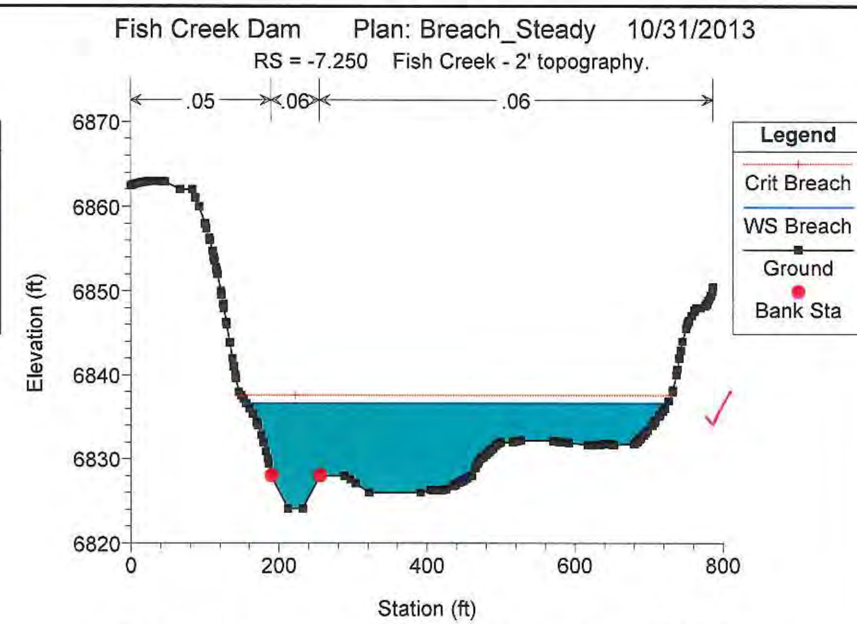


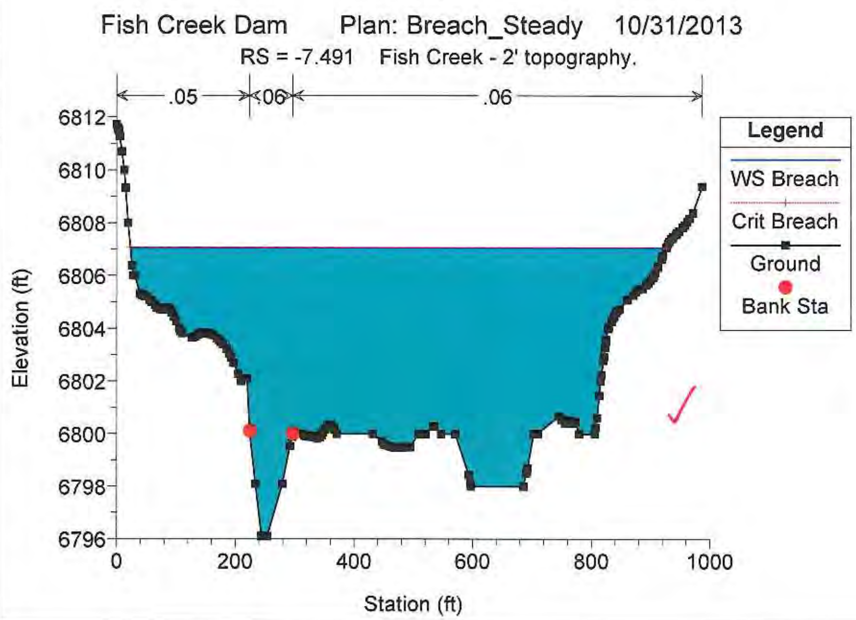


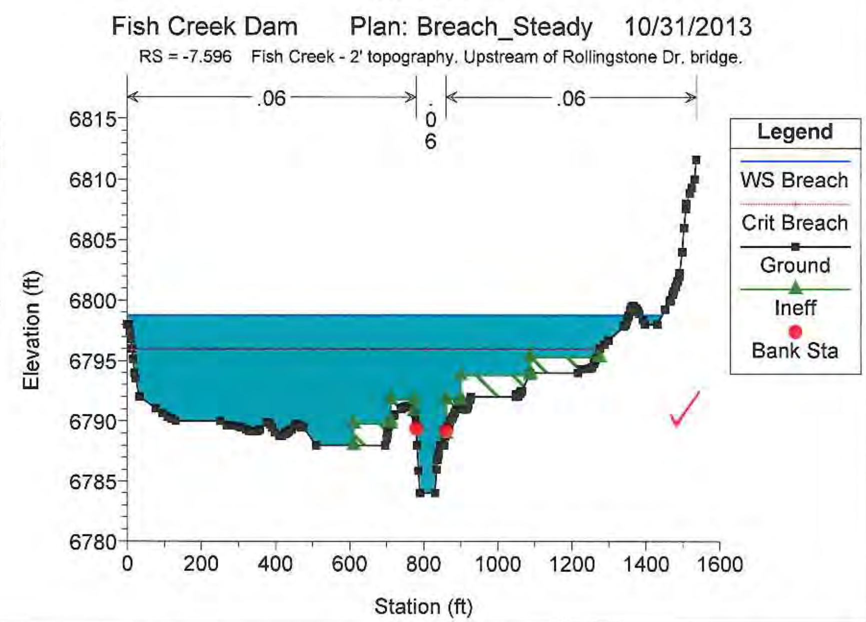


✓TEO 11/12/13
GGS 11/14/13

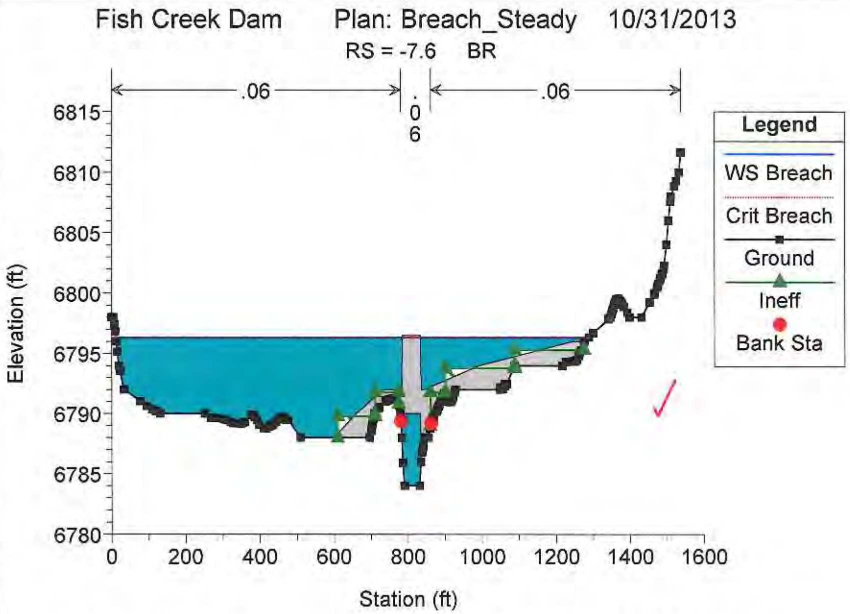


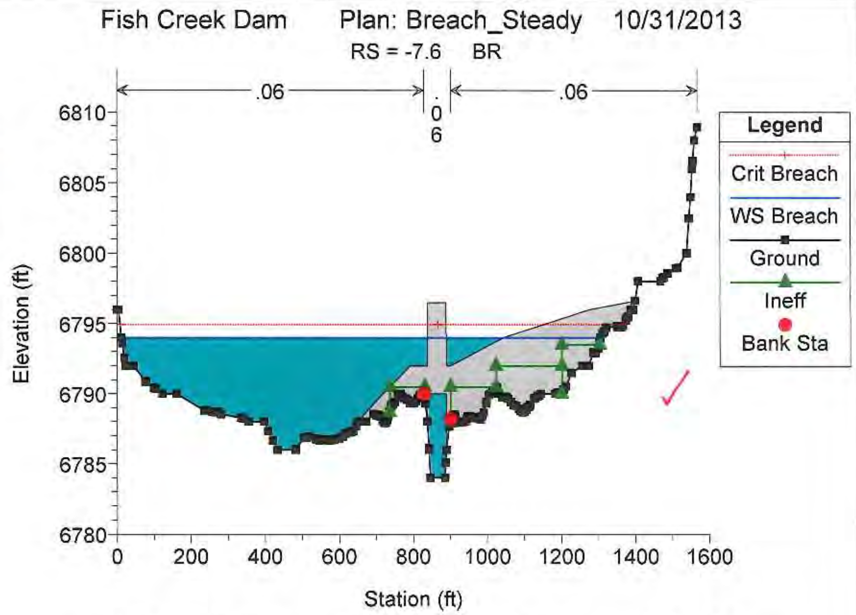


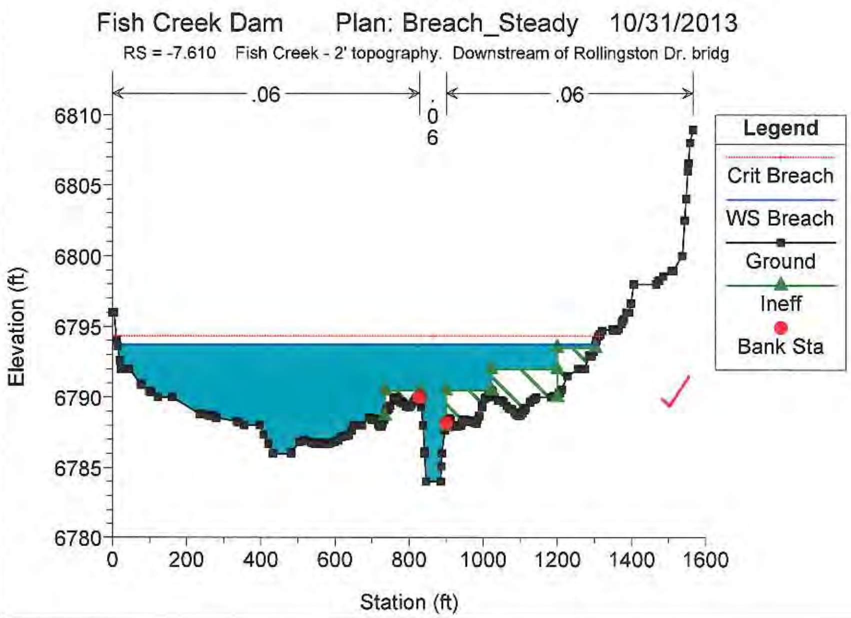


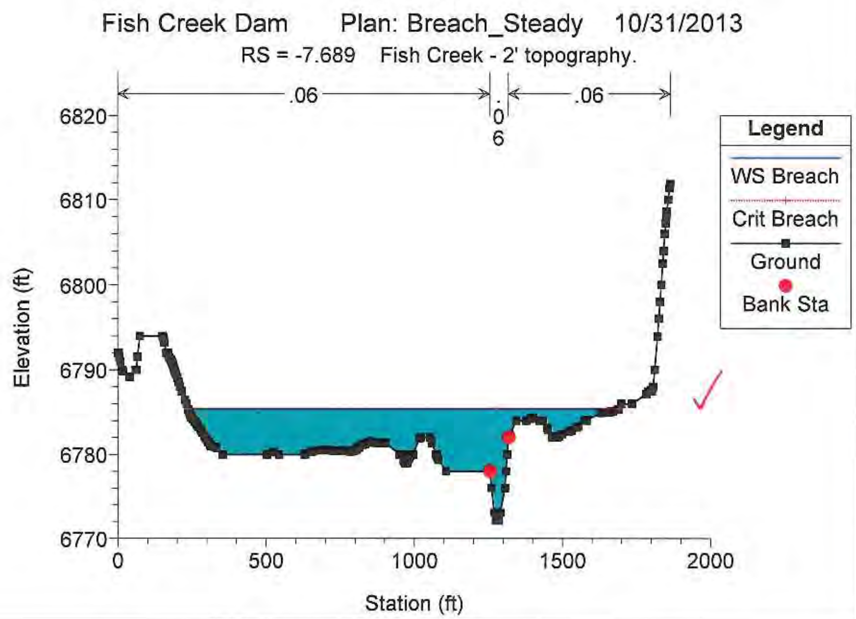


✓ TEO 11/12/13
GGS 11/14/13

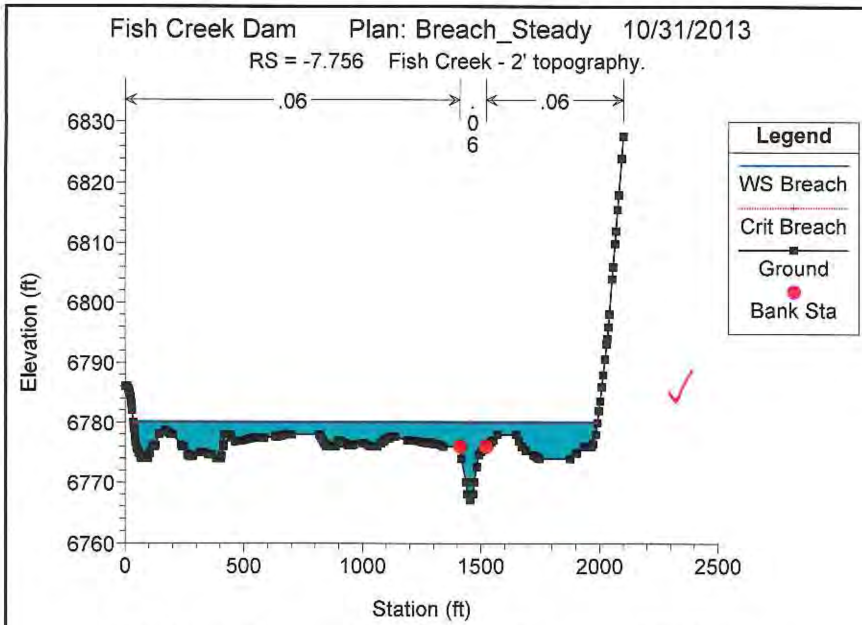


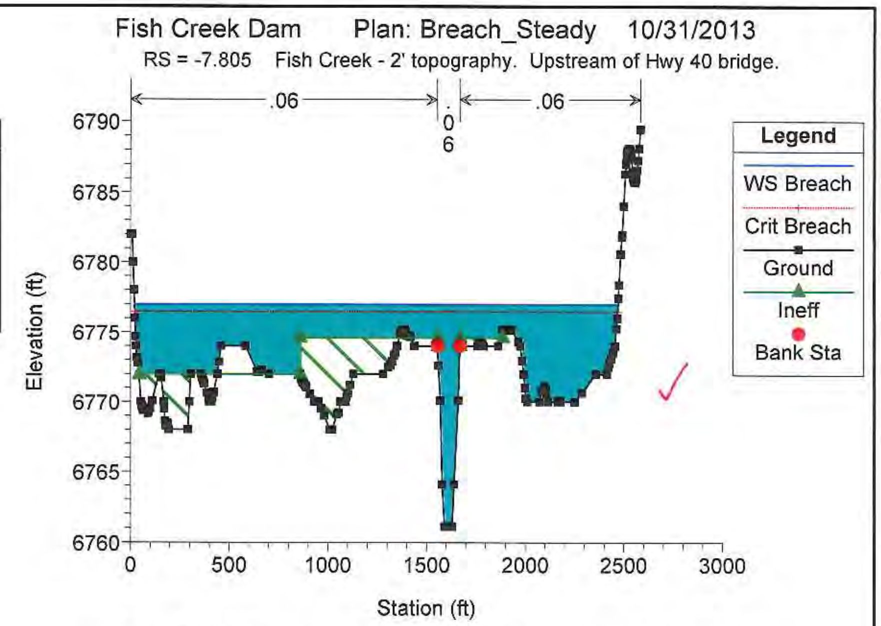


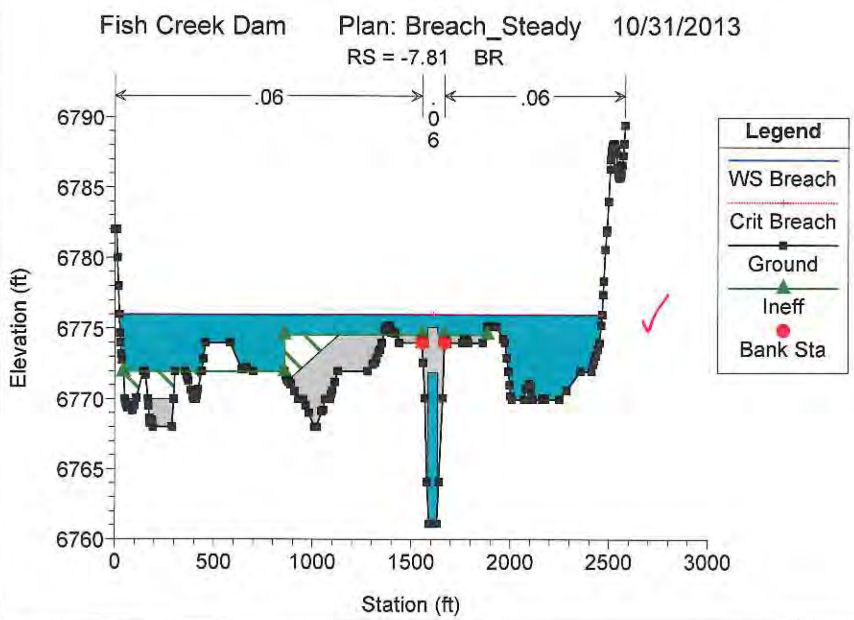


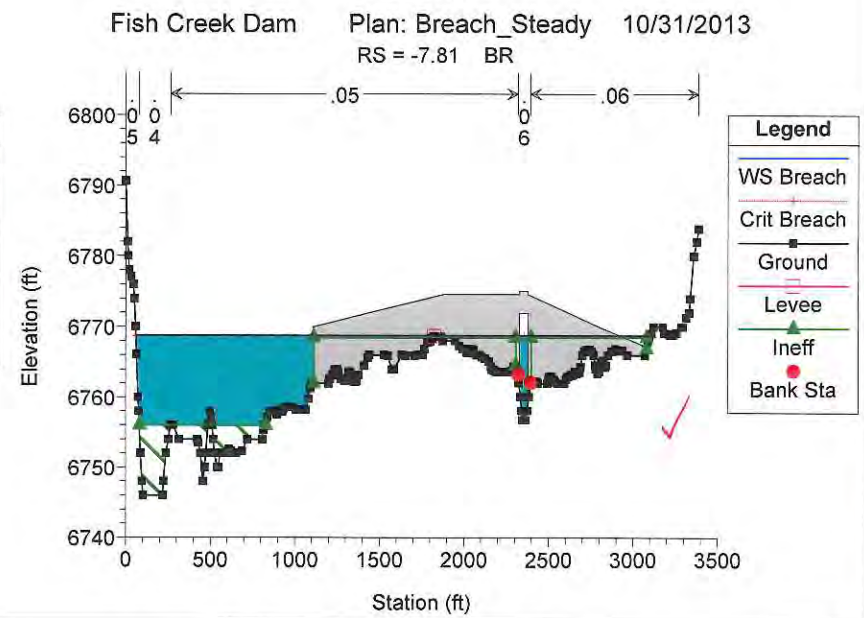


✓ TEO 11/12/13
GGS 11/14/13

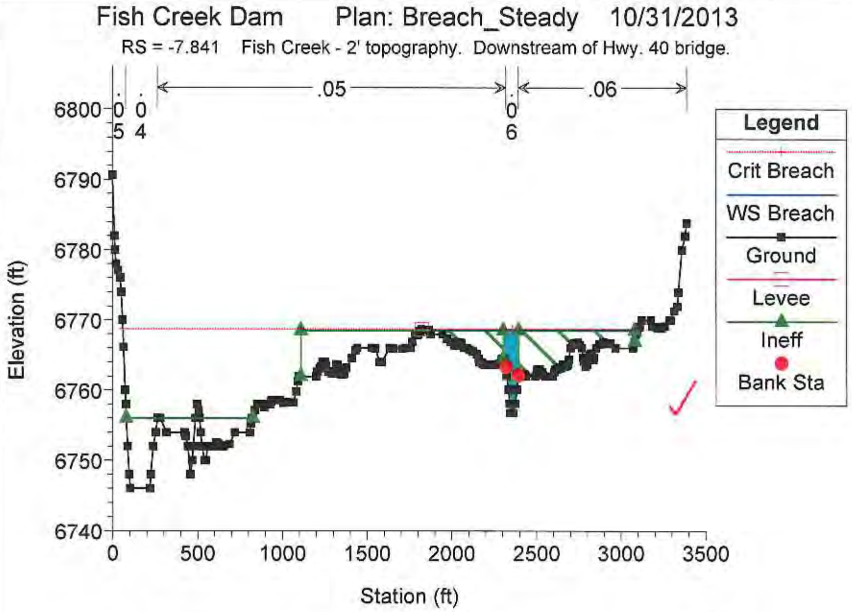


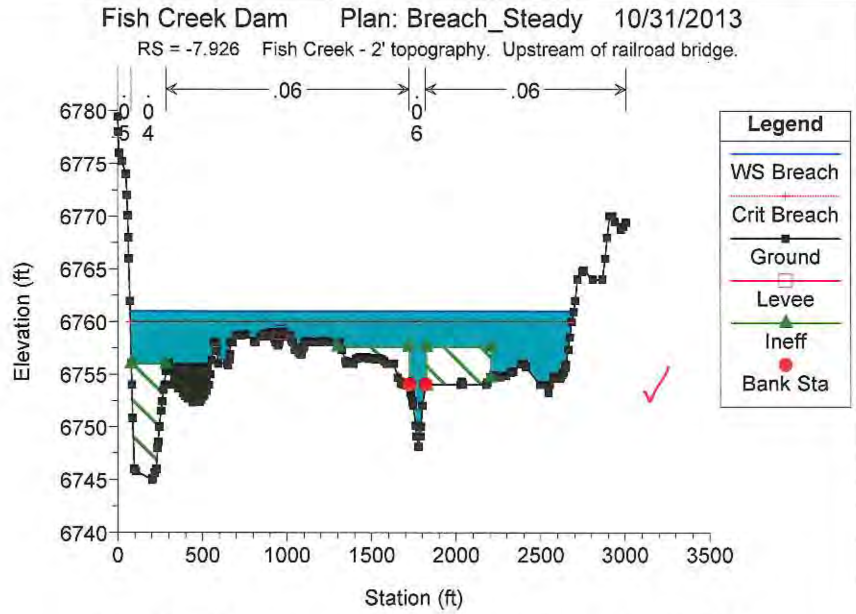


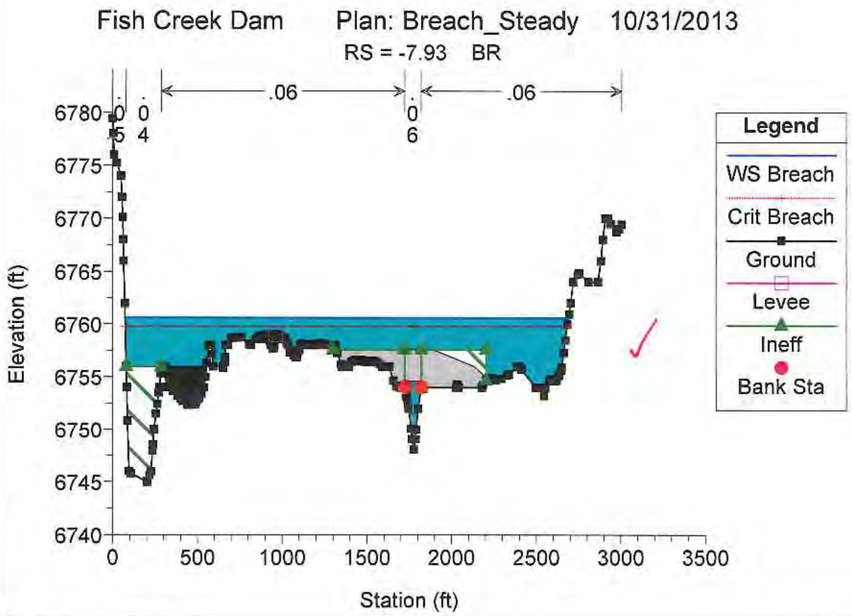


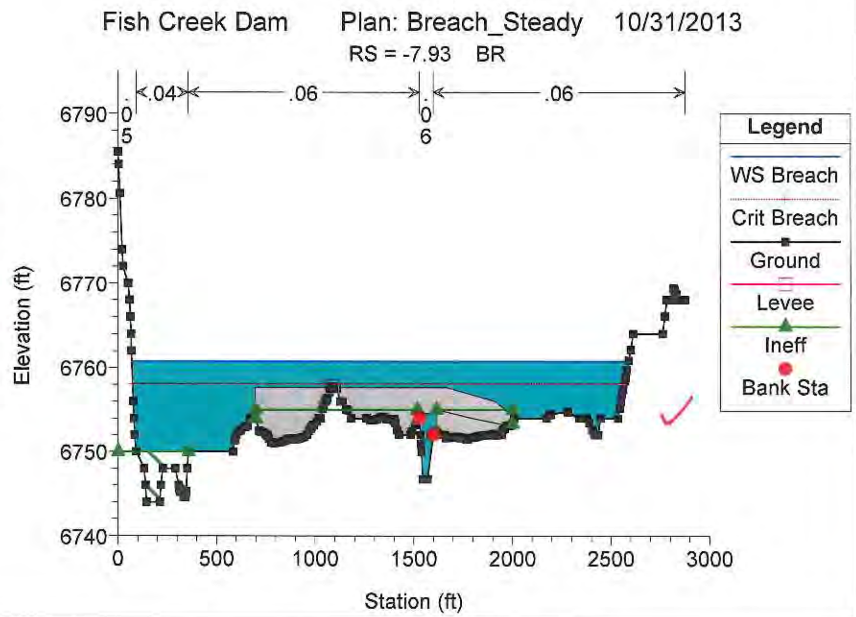


J TEO 11/12/13
GGS 11/14/13



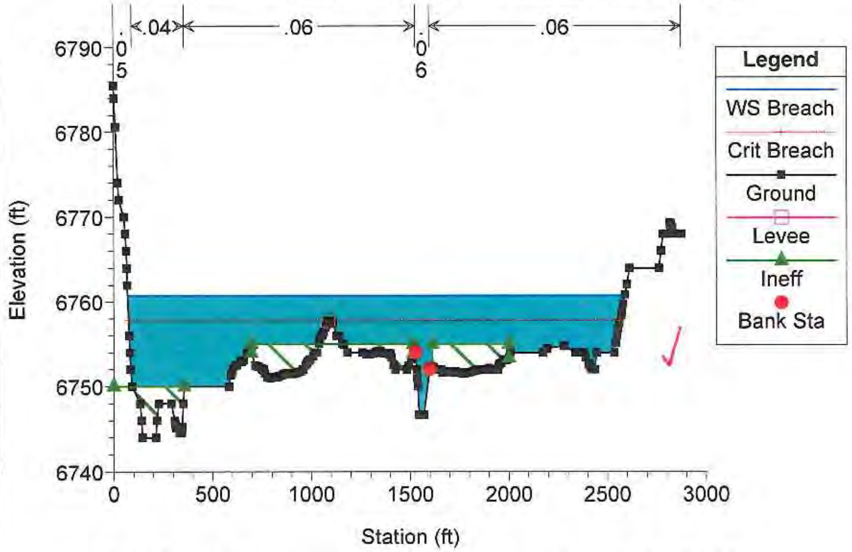




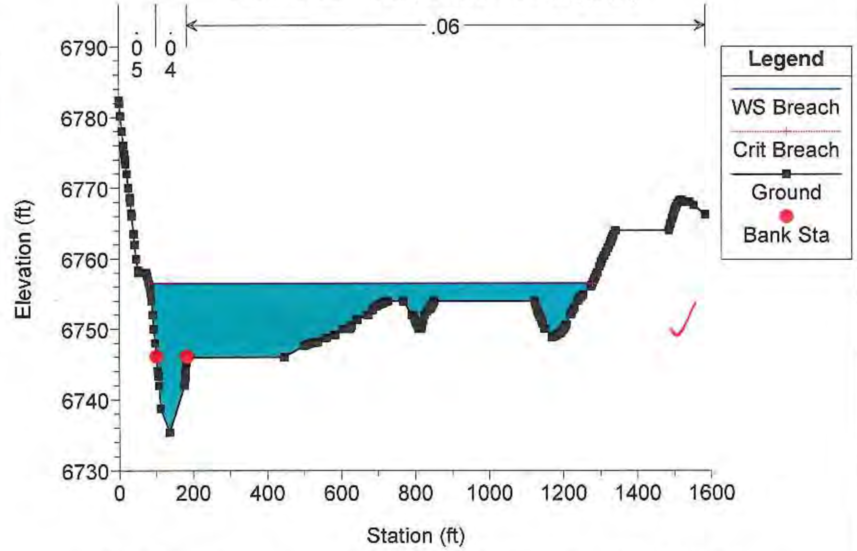


✓ TEO 11/12/13
GGS 11/14/13

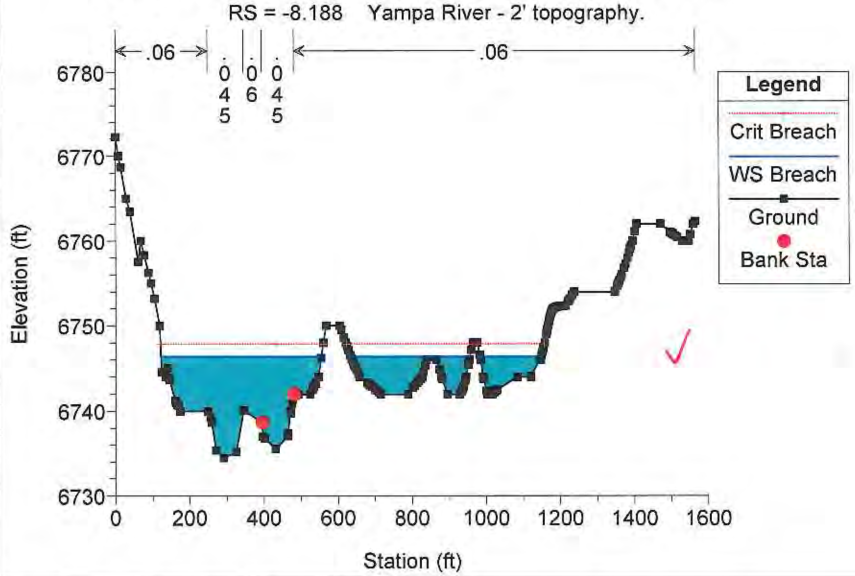
Fish Creek Dam Plan: Breach_Steady 10/31/2013
RS = -7.939 Fish Creek - 2' topography. Downstream of railroad bridge.



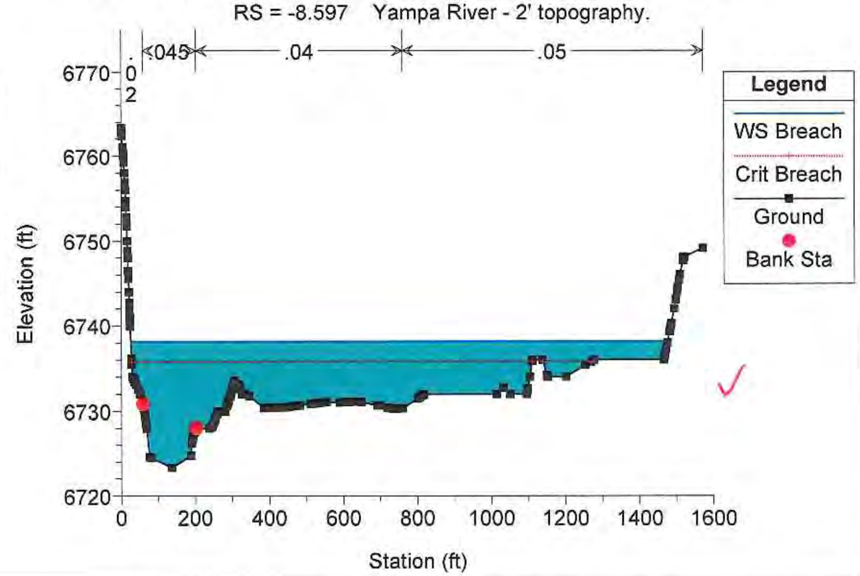
Fish Creek Dam Plan: Breach_Steady 10/31/2013
RS = -8.056 Yampa River - 2' topography.



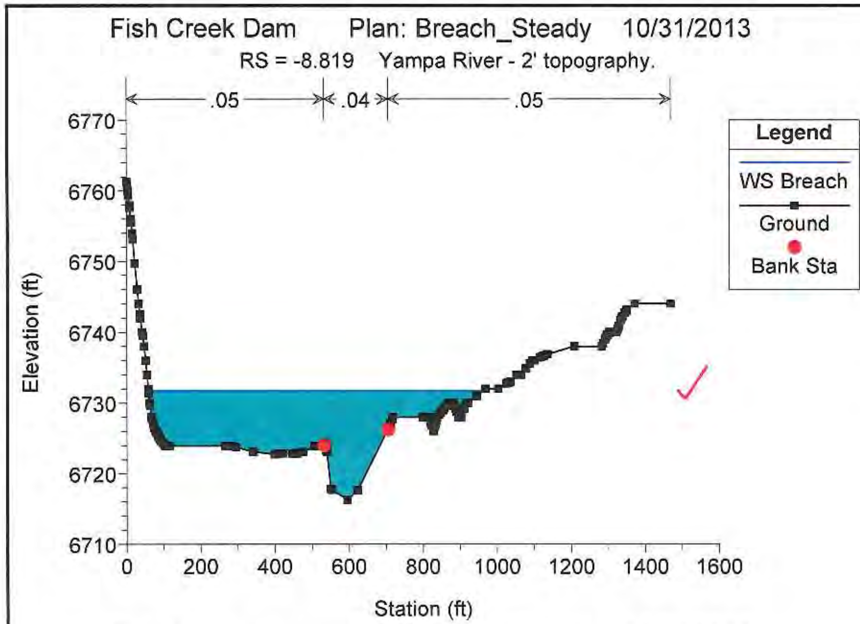
Fish Creek Dam Plan: Breach_Steady 10/31/2013
RS = -8.188 Yampa River - 2' topography.

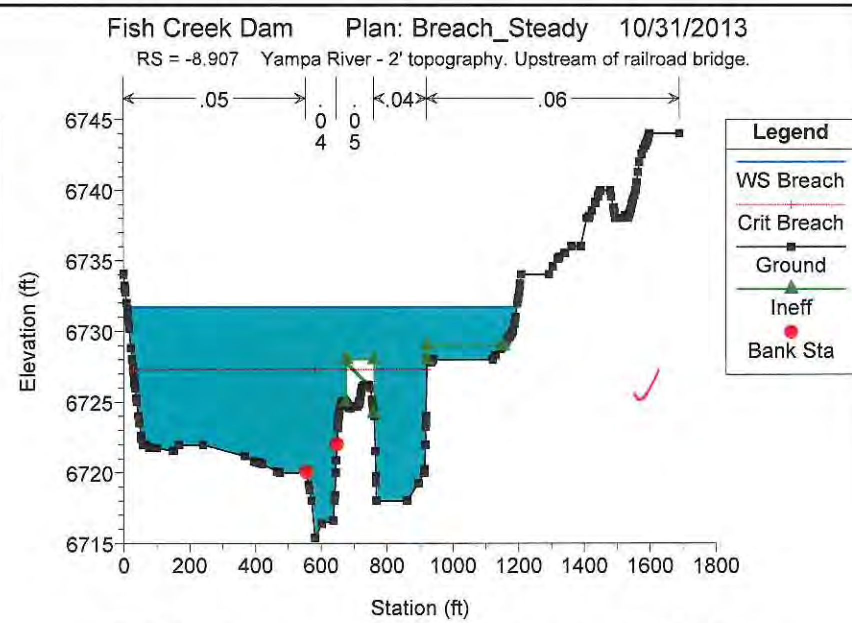


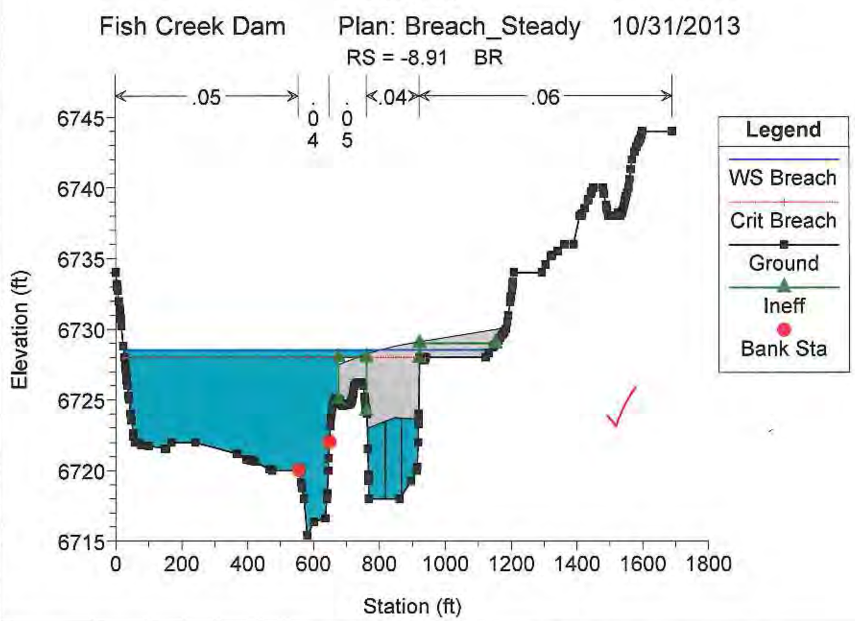
Fish Creek Dam Plan: Breach_Steady 10/31/2013
RS = -8.597 Yampa River - 2' topography.

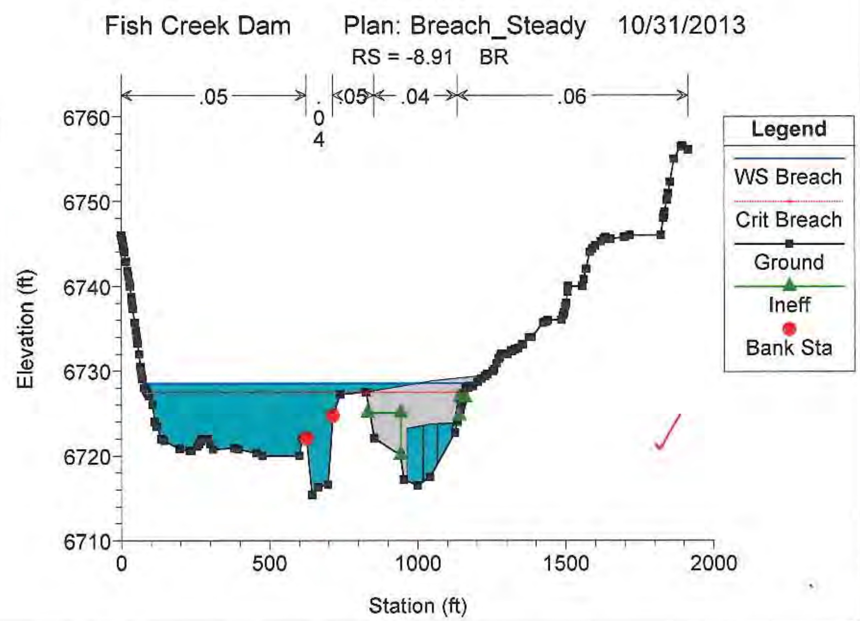


✓ TEO 11/12/13
GGS 11/14/13

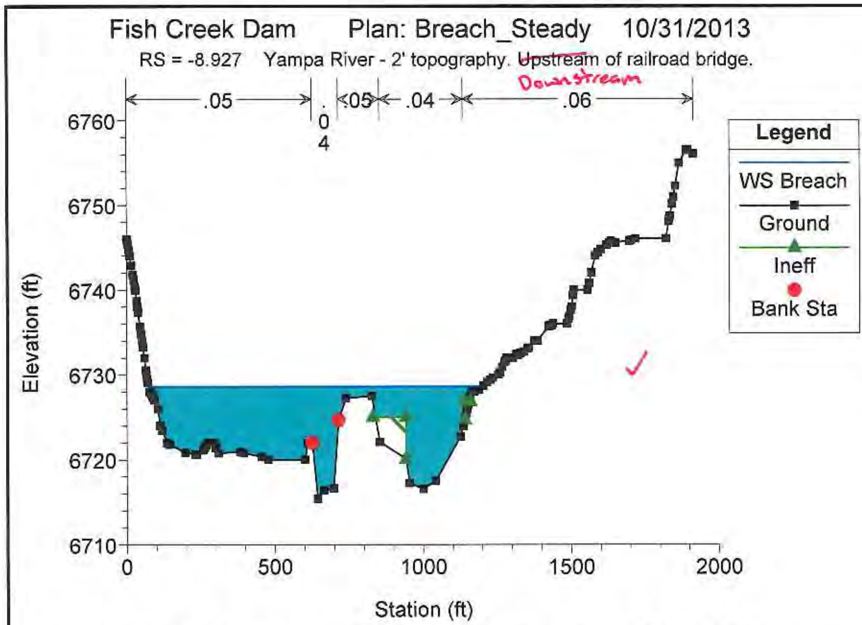


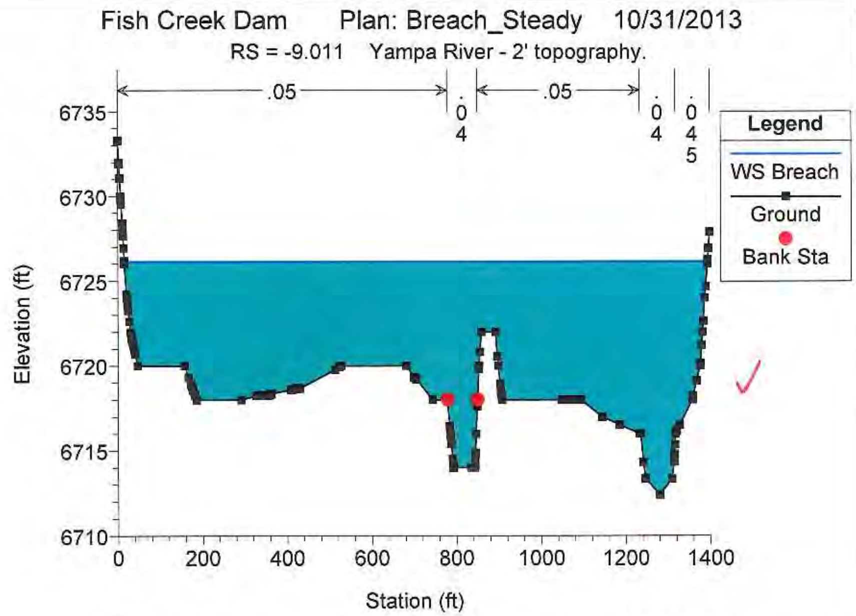


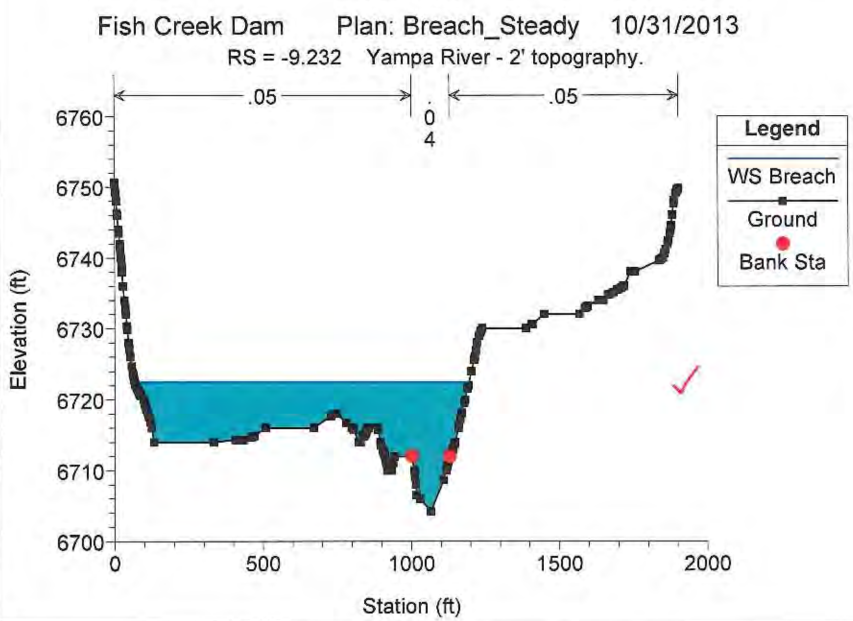


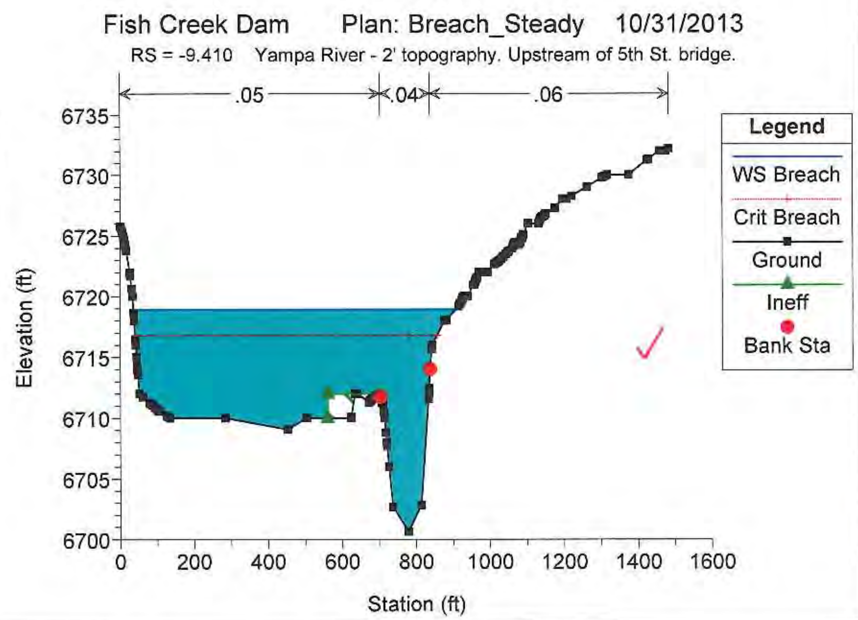


✓TEO 11/12/13
CGS 11/14/13

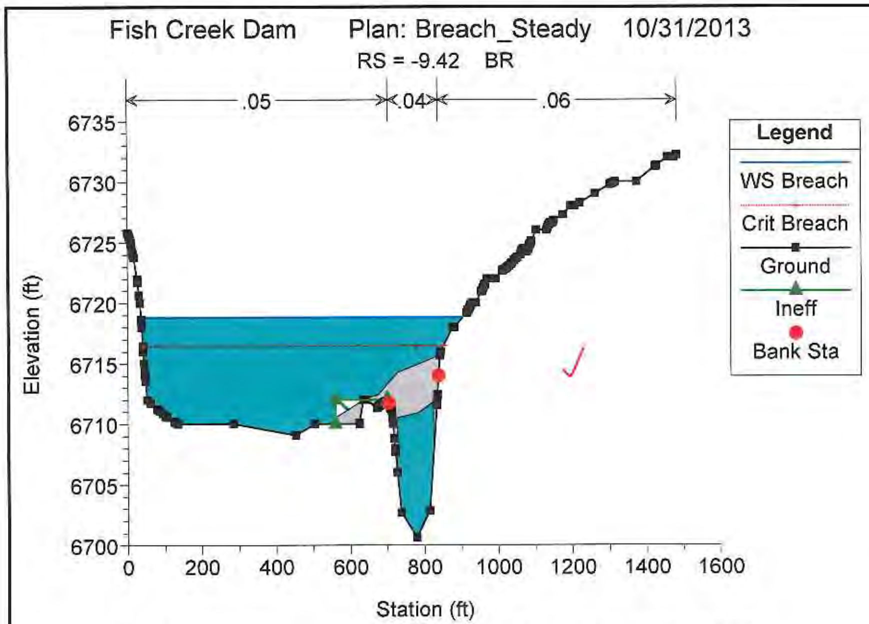


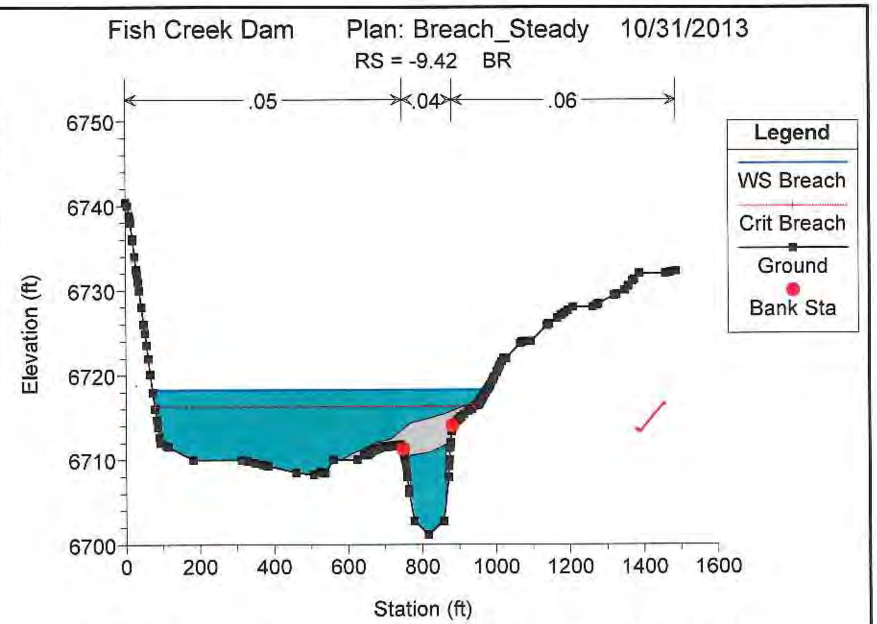


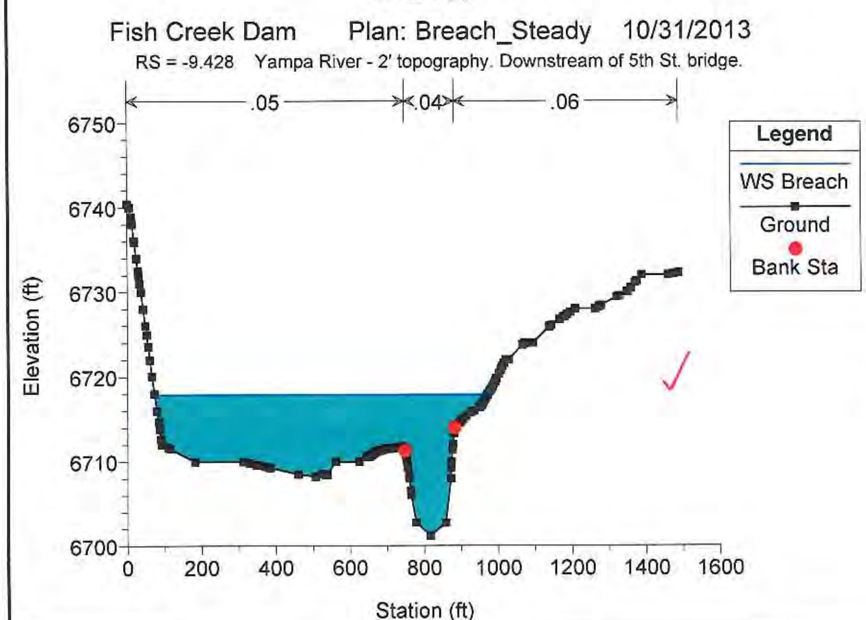


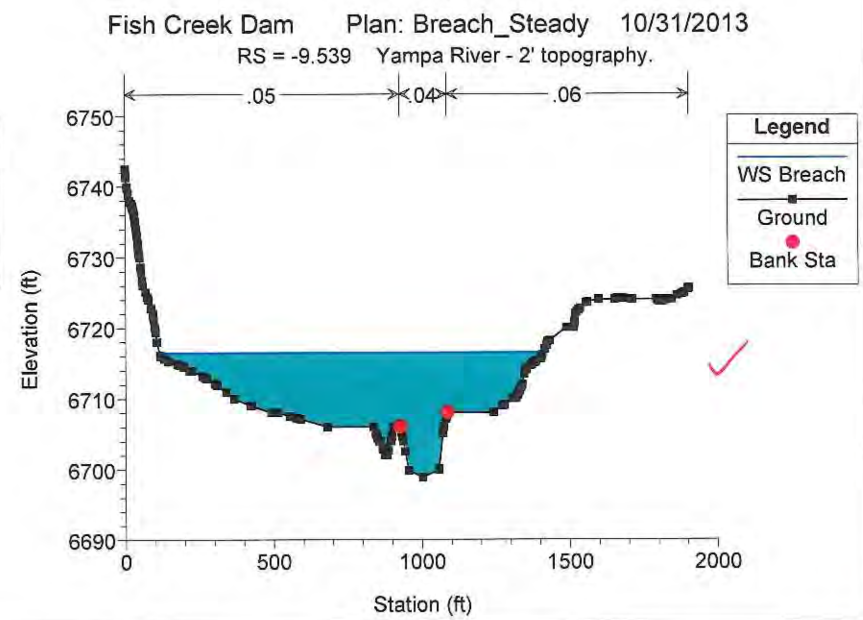


√ TEO 11/12/13
GGS 11/14/13



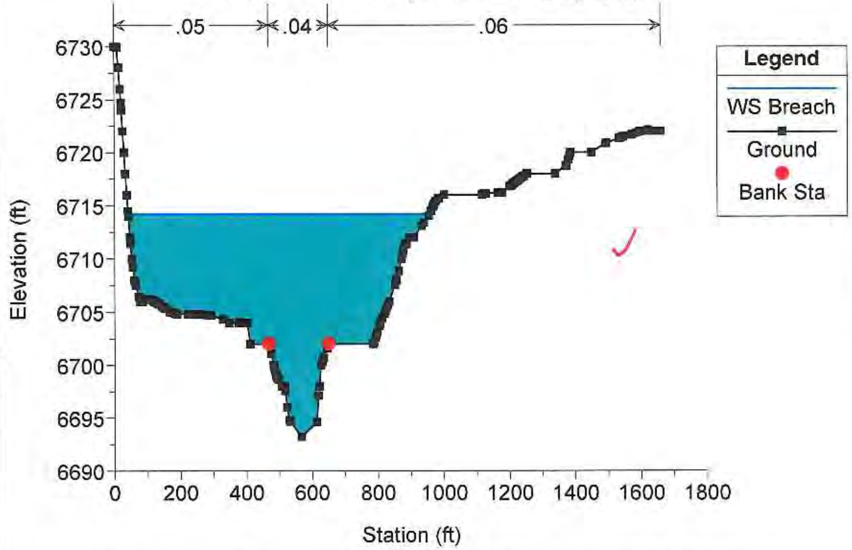




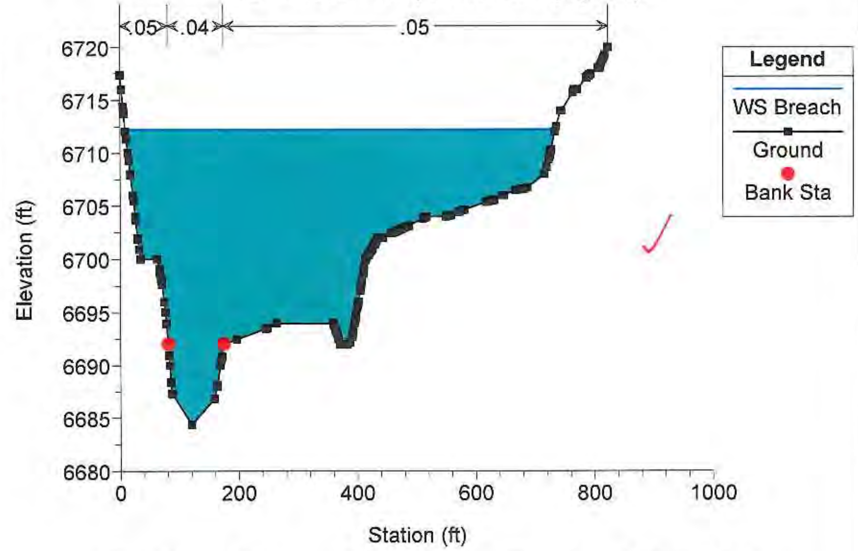


√ TEO 11/12/13
GGS 11/14/13

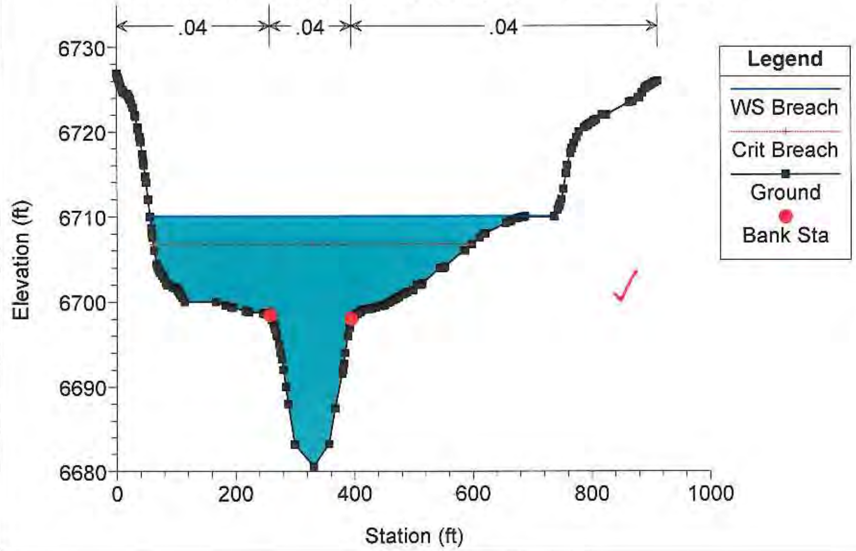
Fish Creek Dam Plan: Breach_Steady 10/31/2013
RS = -9.719 Yampa River - 2' topography.



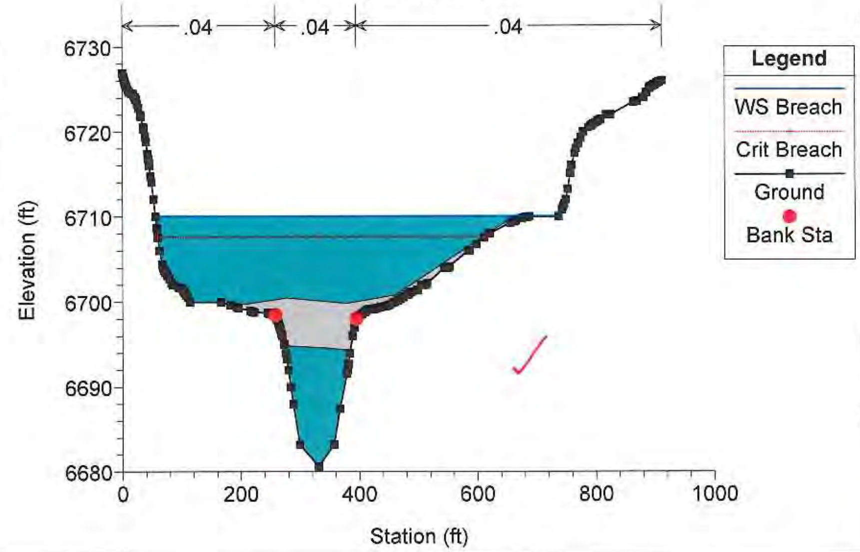
Fish Creek Dam Plan: Breach_Steady 10/31/2013
RS = -9.962 Yampa River - 2' topography.



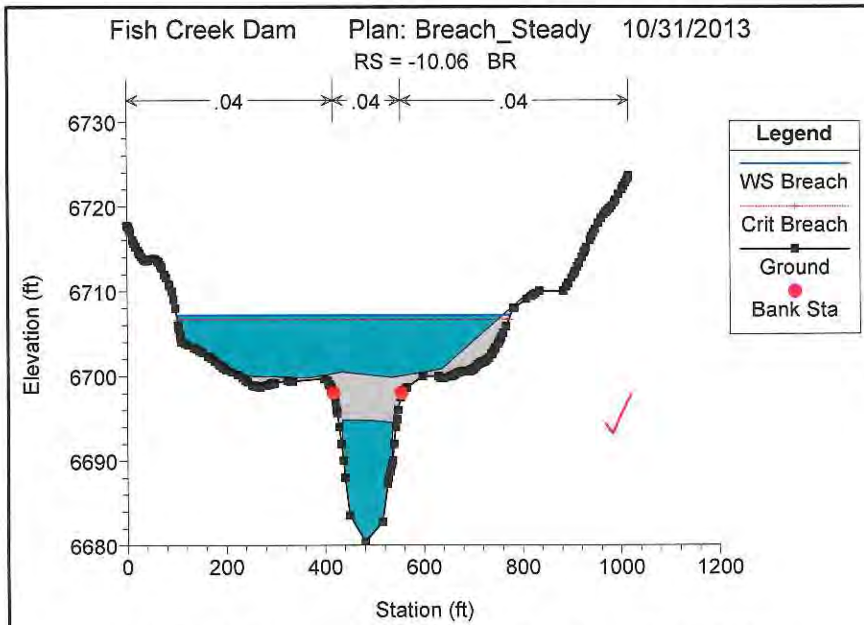
Fish Creek Dam Plan: Breach_Steady 10/31/2013
RS = -10.051 Yampa River - 2' topography. Upstream of 13th St. bridge.

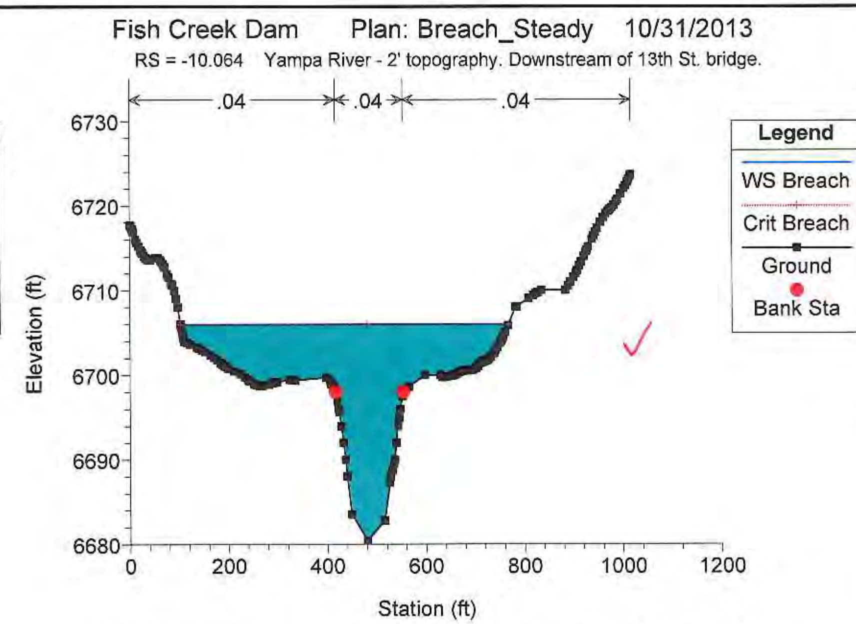


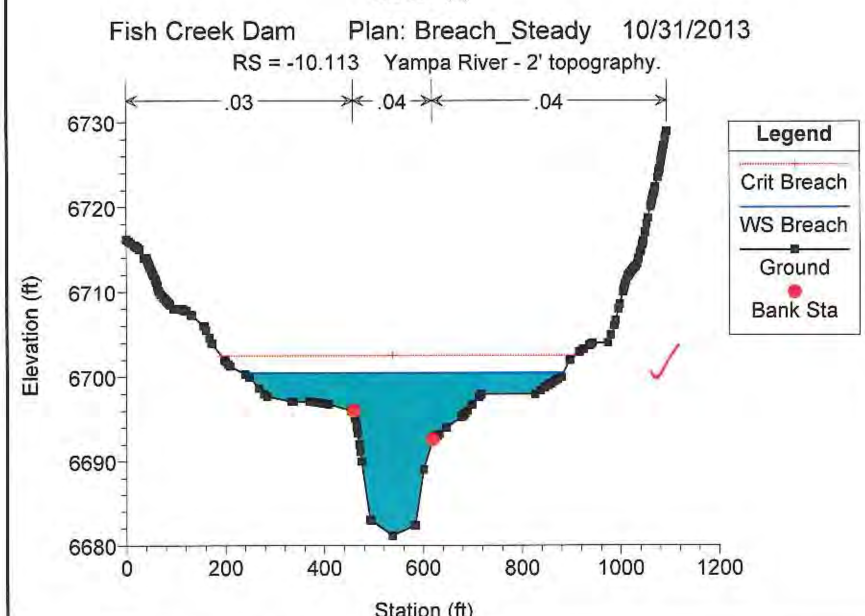
Fish Creek Dam Plan: Breach_Steady 10/31/2013
RS = -10.06 BR

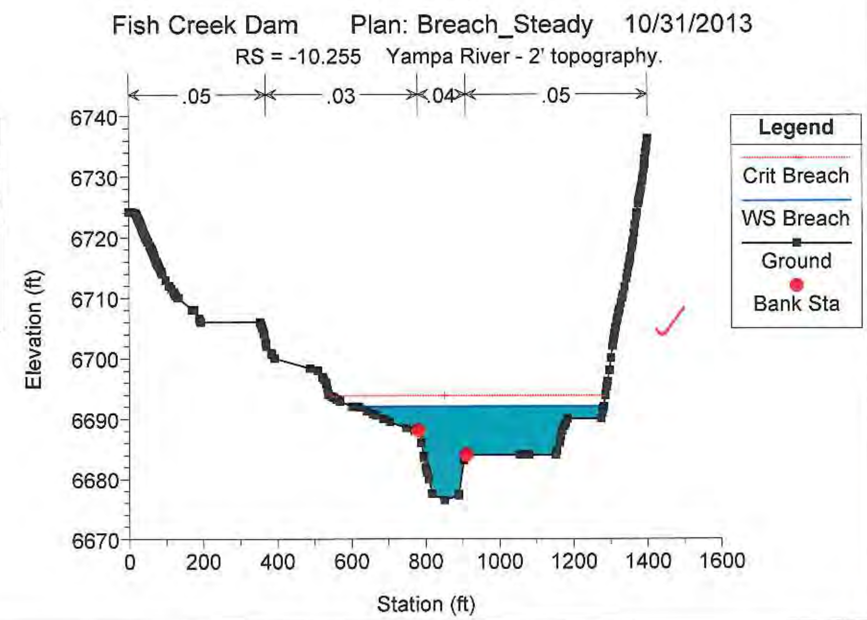


✓TEO 11/12/13
GGS 11/14/13

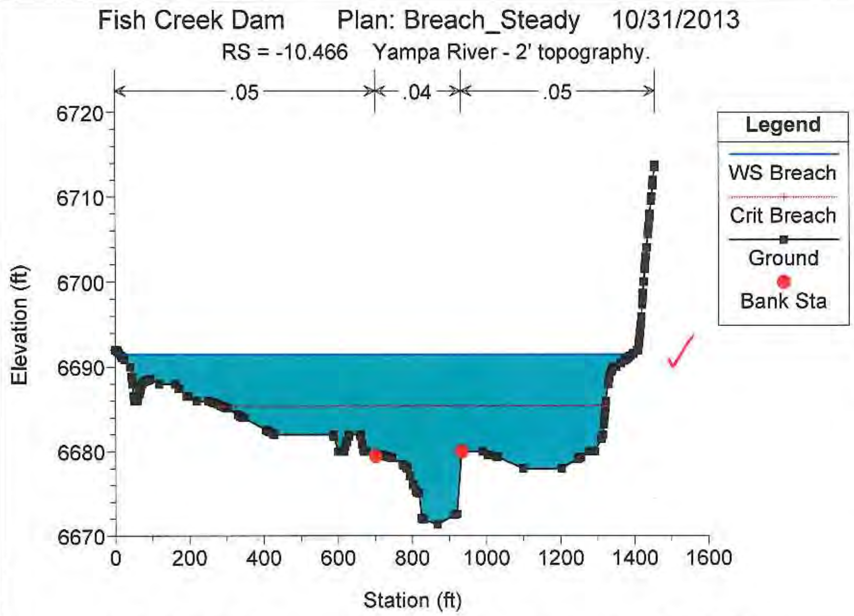


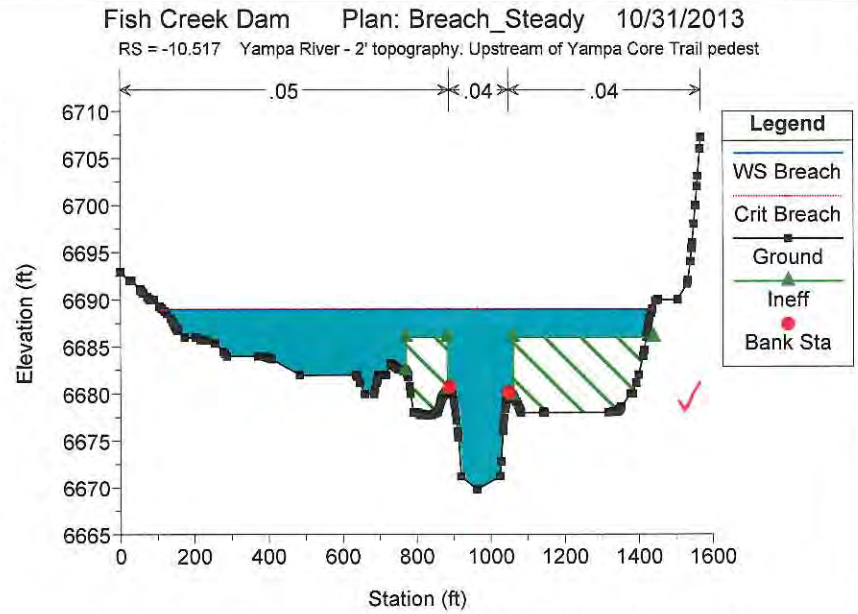


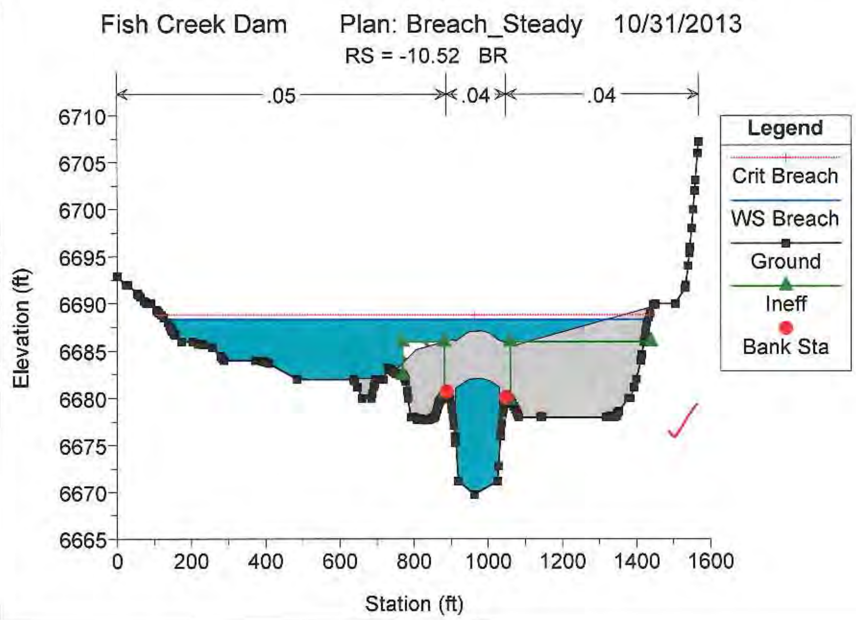


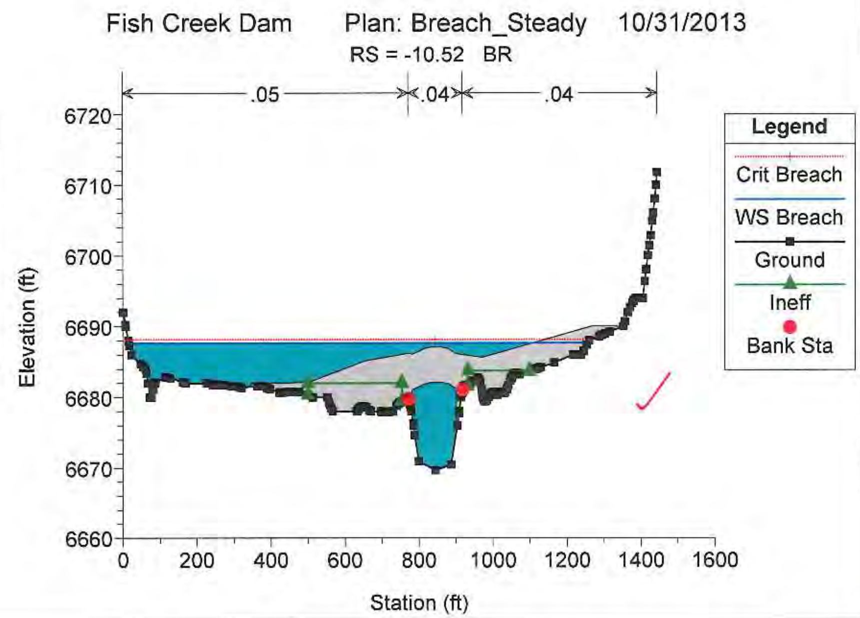


√ TEO 11/12/13
GGS 11/14/13

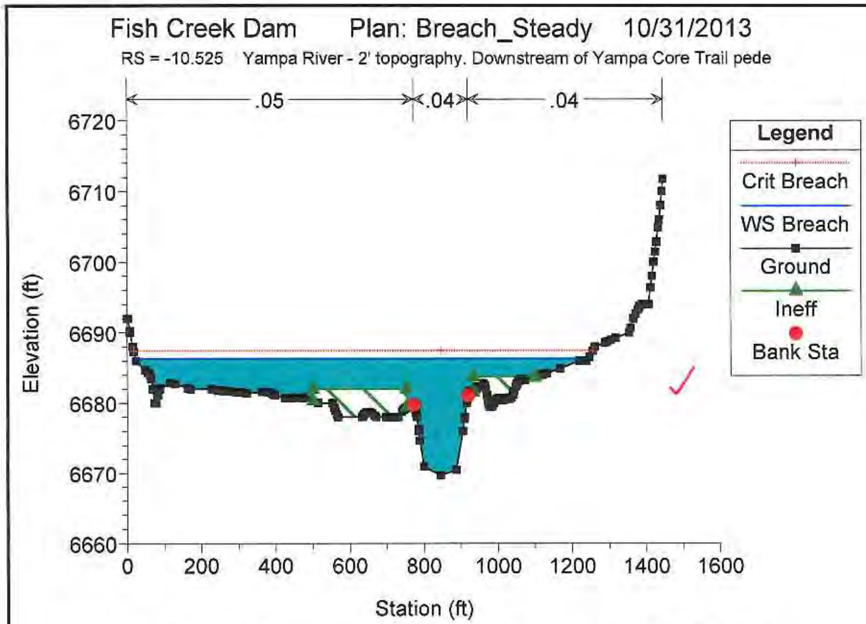


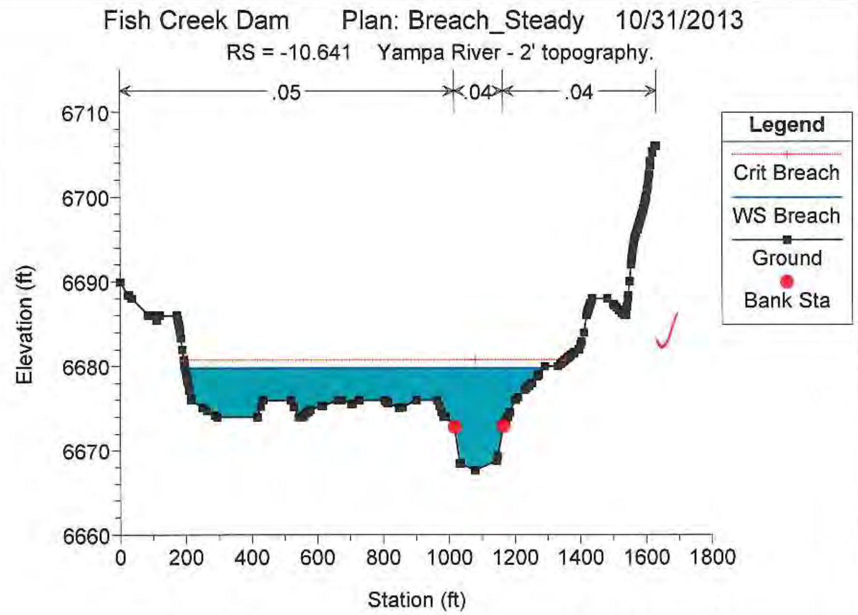


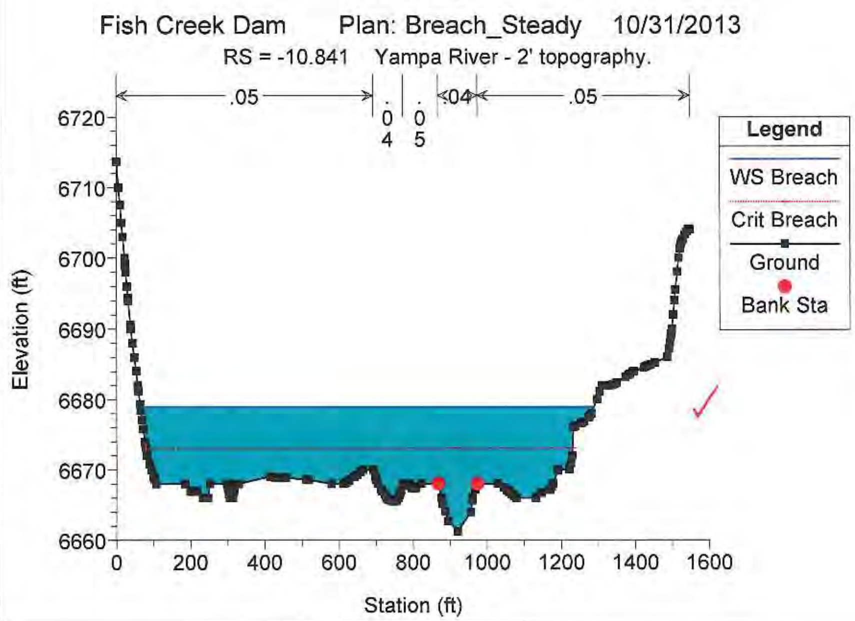


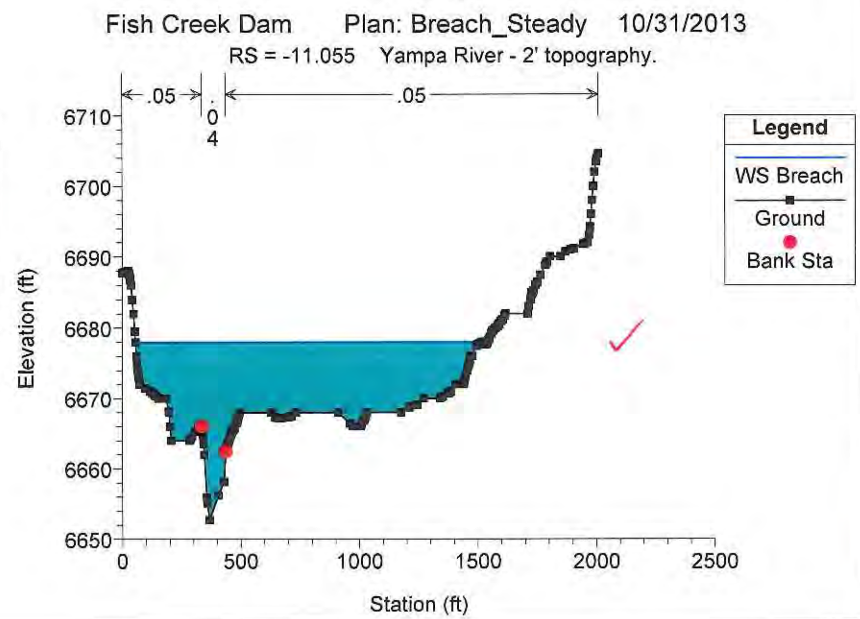


✓ TEO 11/12/13
GGS 11/14/13





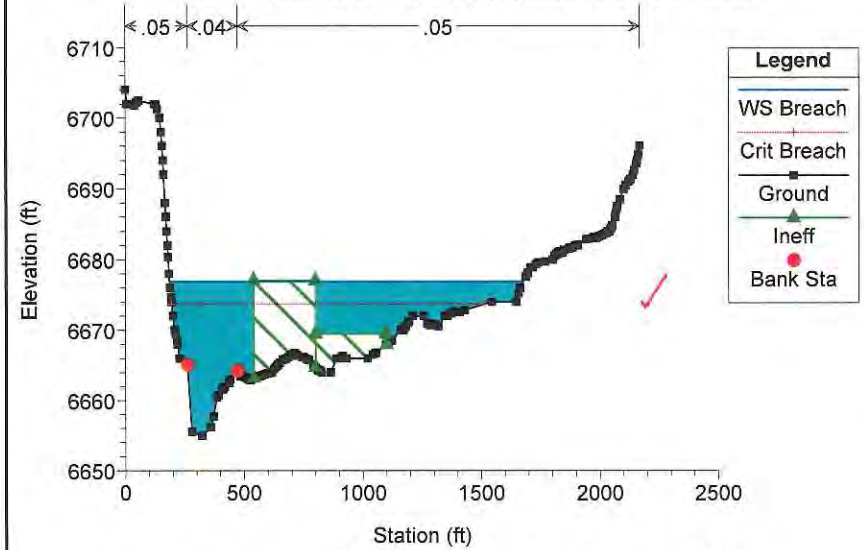




✓ TEO 11/12/13
GGS 11/14/13

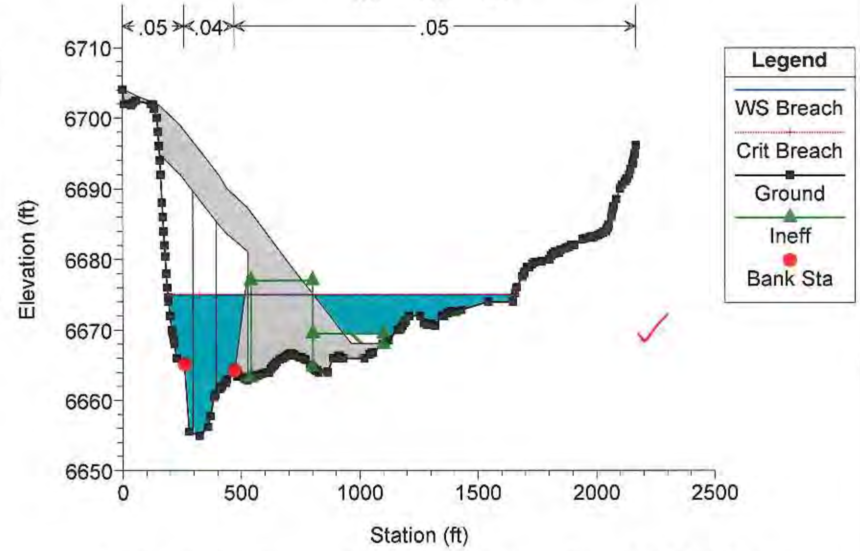
Fish Creek Dam Plan: Breach_Steady 10/31/2013

RS = -11.093 Yampa River - 2' topography. Upstream of Shield Dr. bridge.



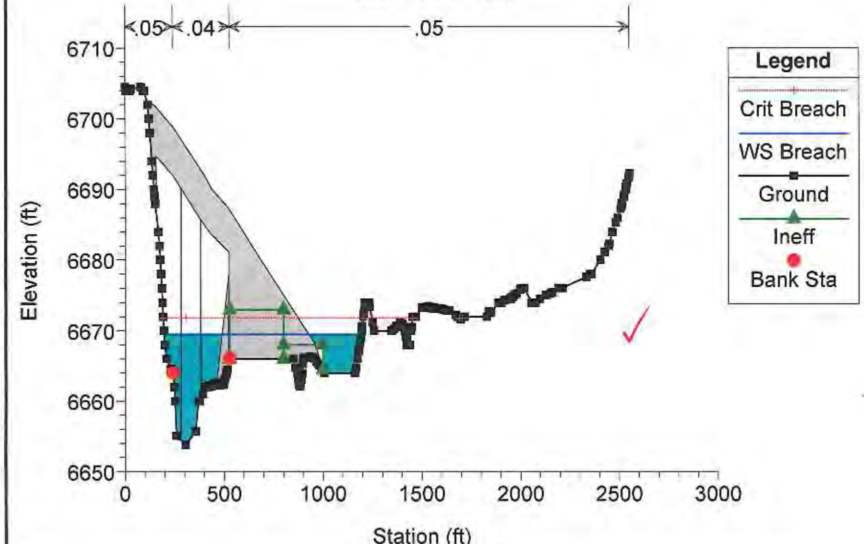
Fish Creek Dam Plan: Breach_Steady 10/31/2013

RS = -11.1 BR



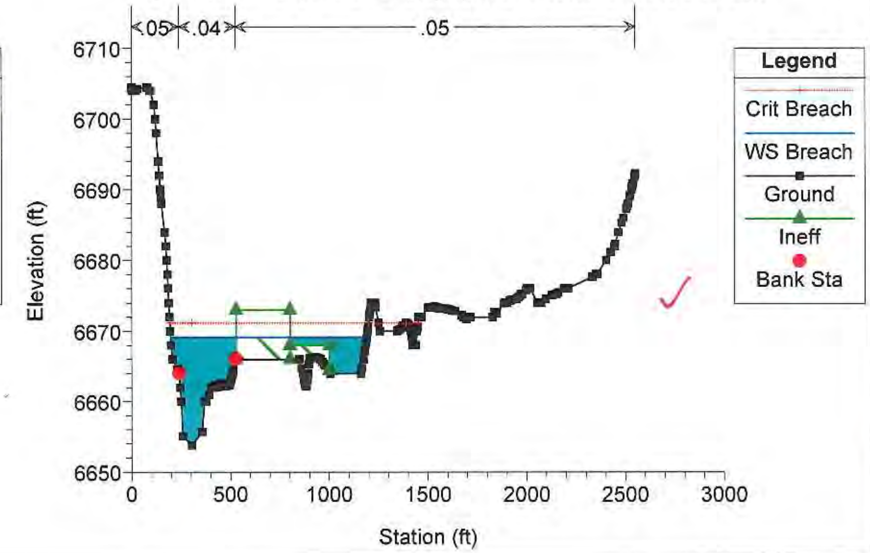
Fish Creek Dam Plan: Breach_Steady 10/31/2013

RS = -11.1 BR

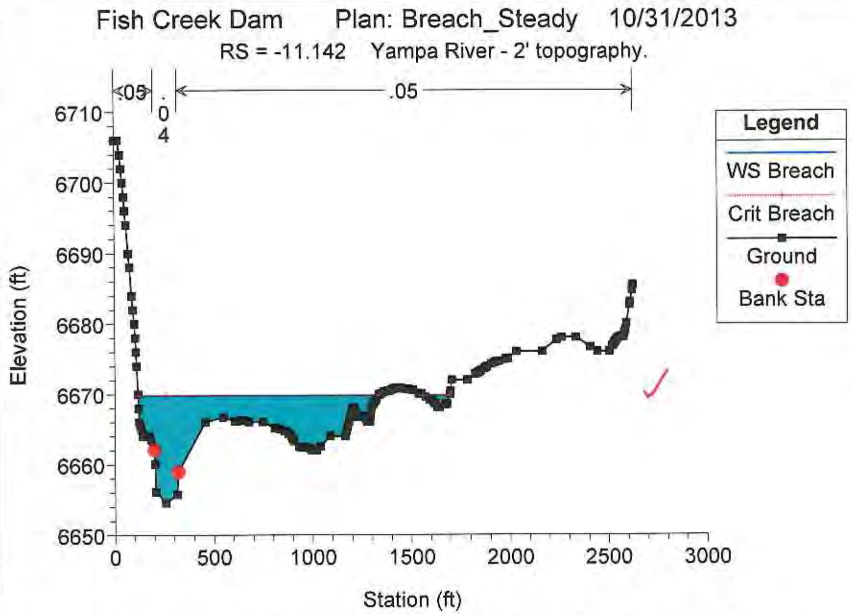


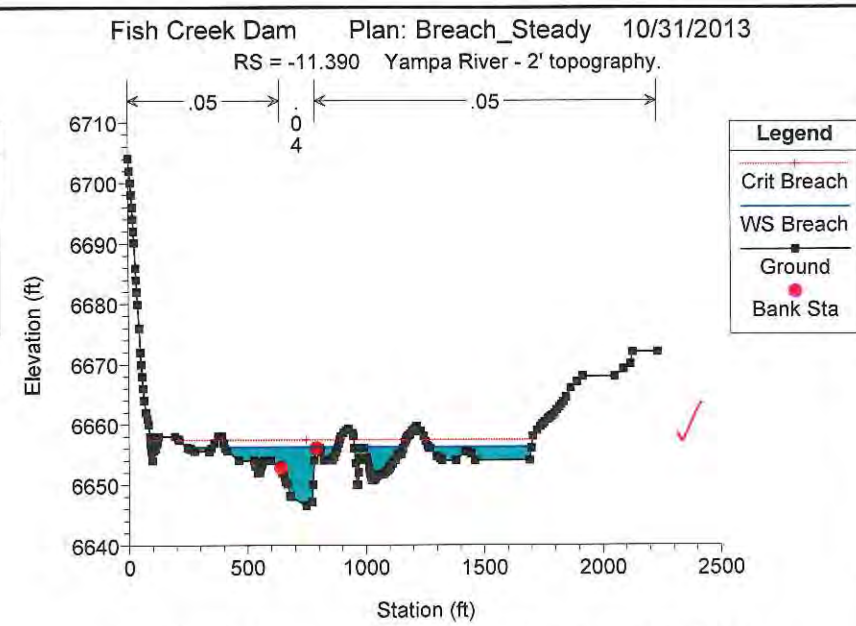
Fish Creek Dam Plan: Breach_Steady 10/31/2013

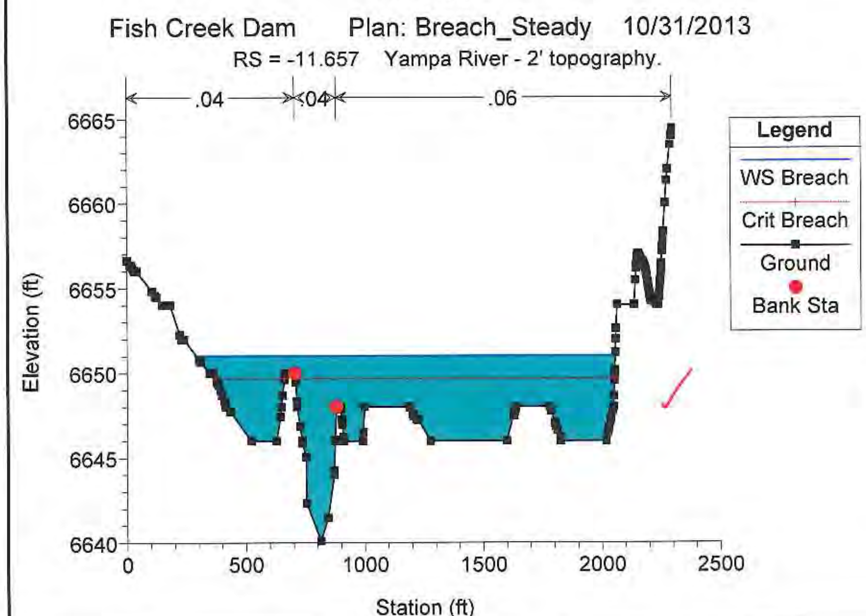
RS = -11.111 Yampa River - 2' topography. Downstream of Shield Dr. bridge.

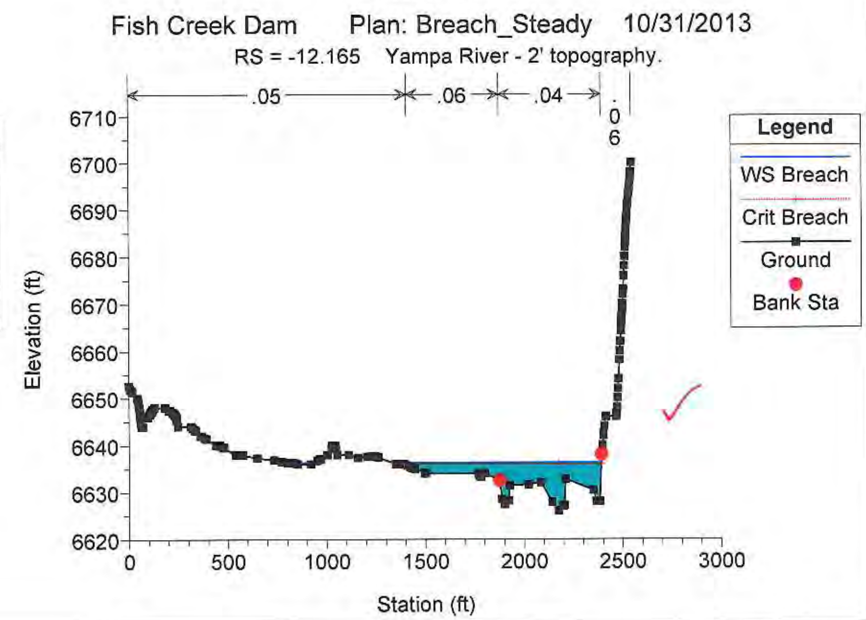


√ TEO 11/12/13
GGS 11/14/13

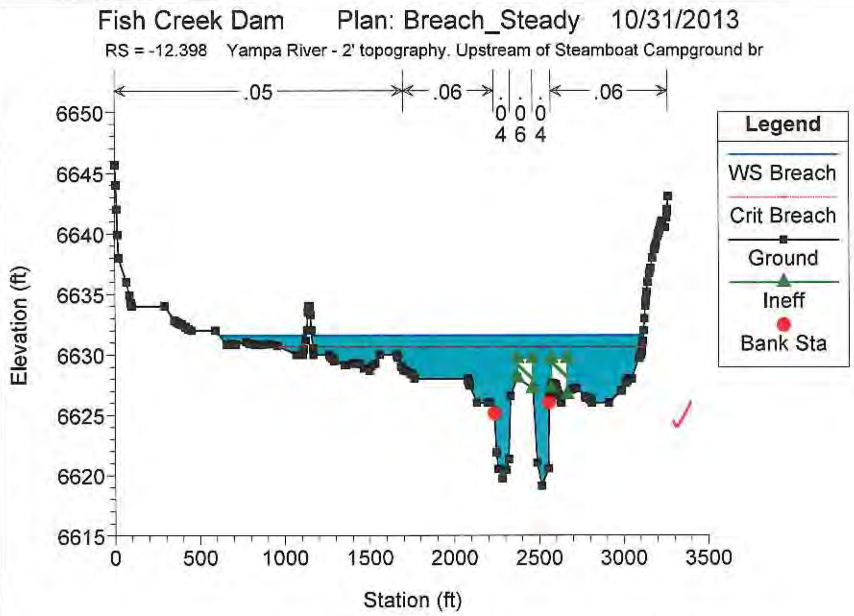


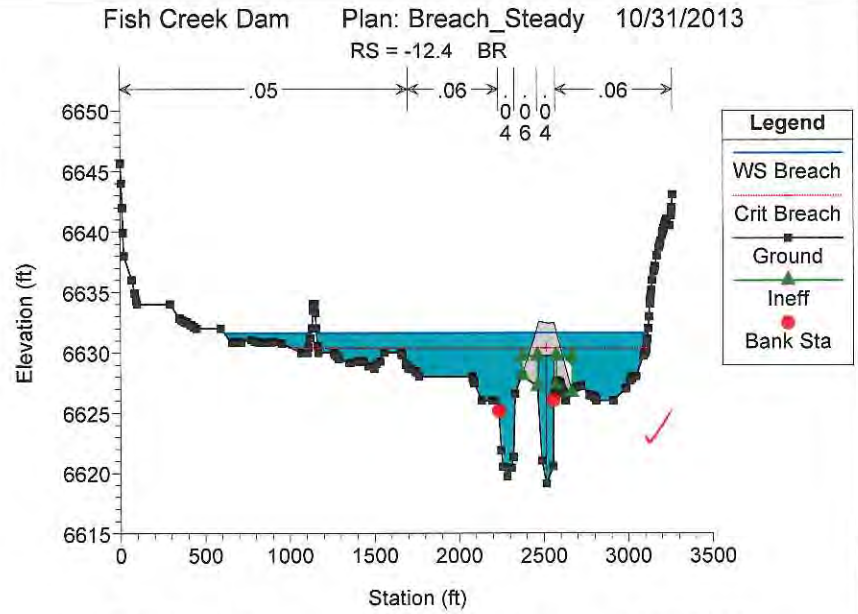


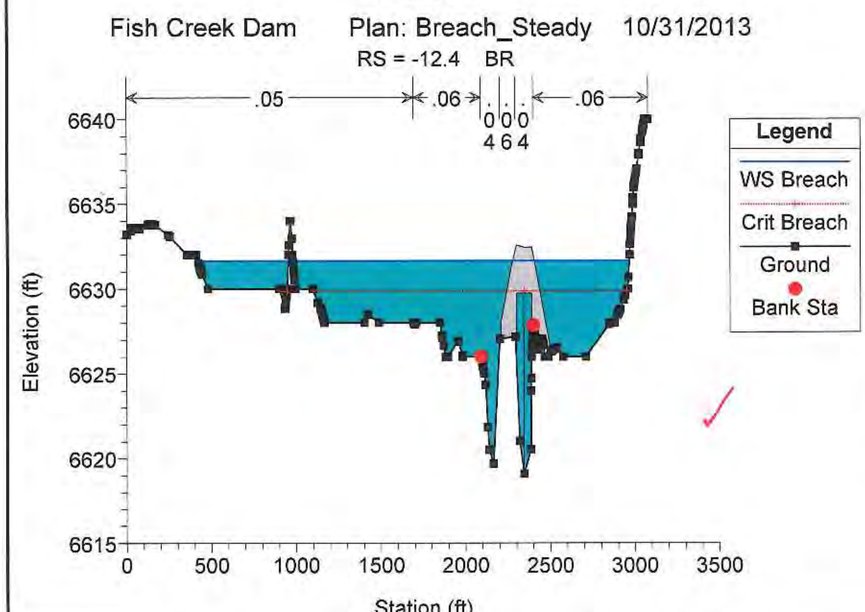


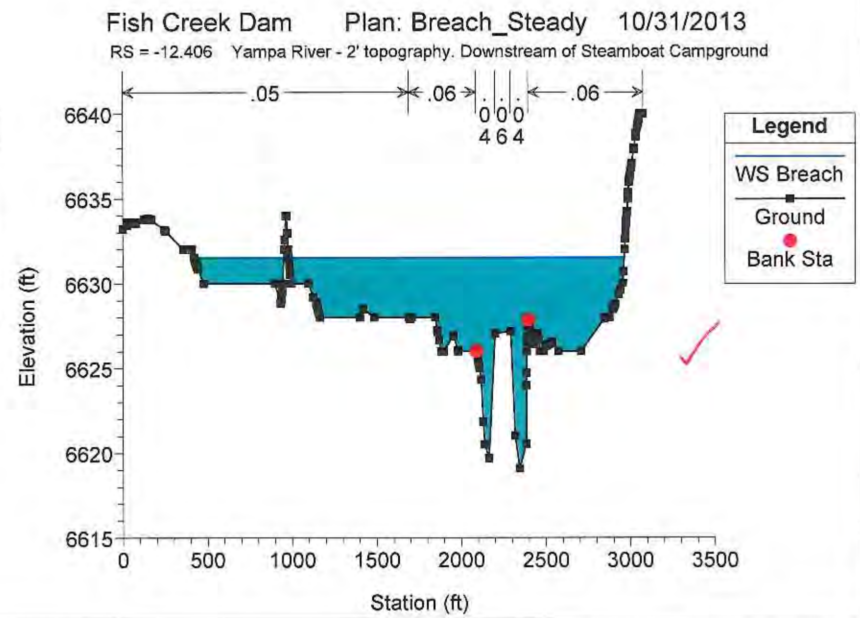


✓ TEO 11/12/13
GGS 11/14/13

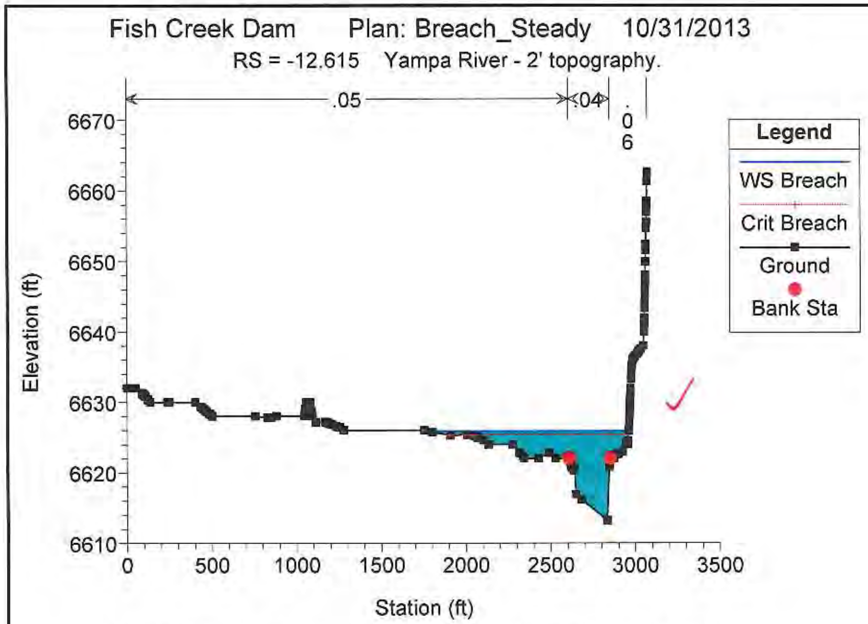


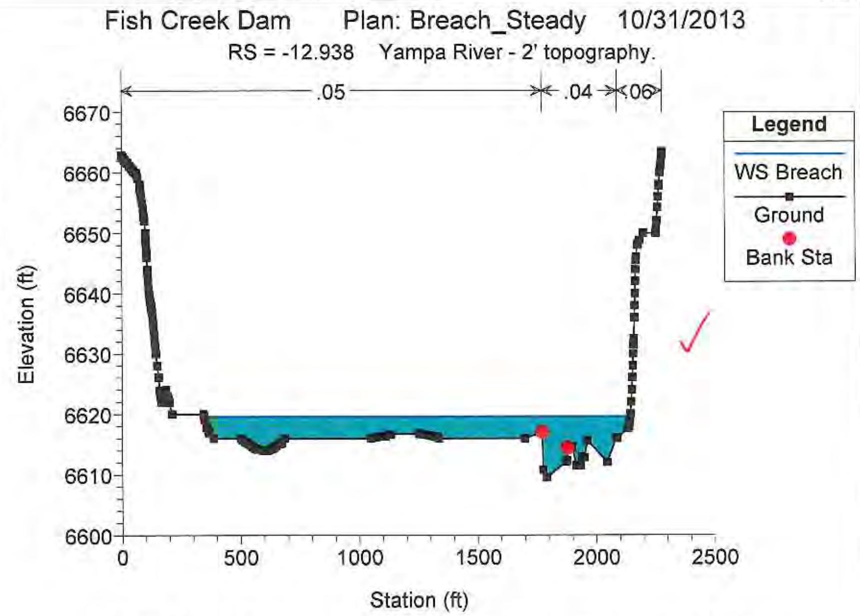


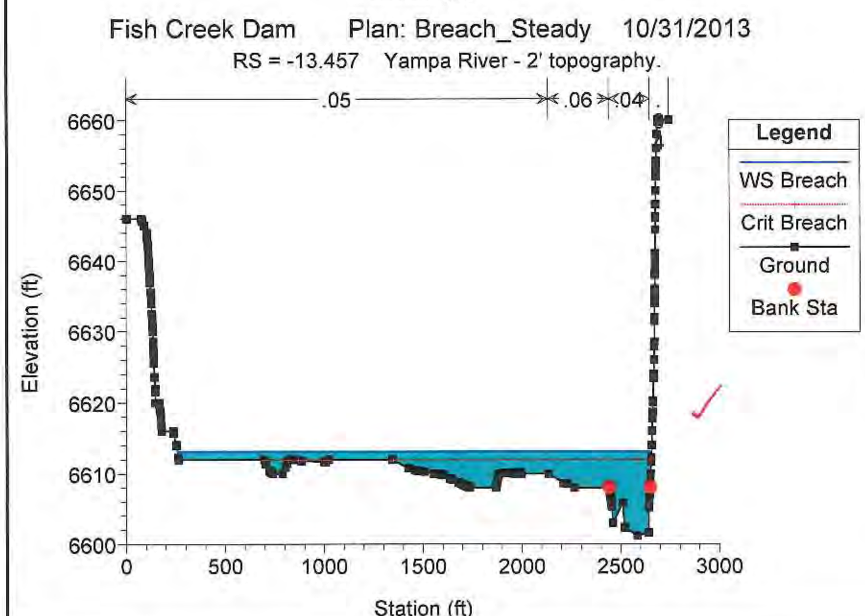


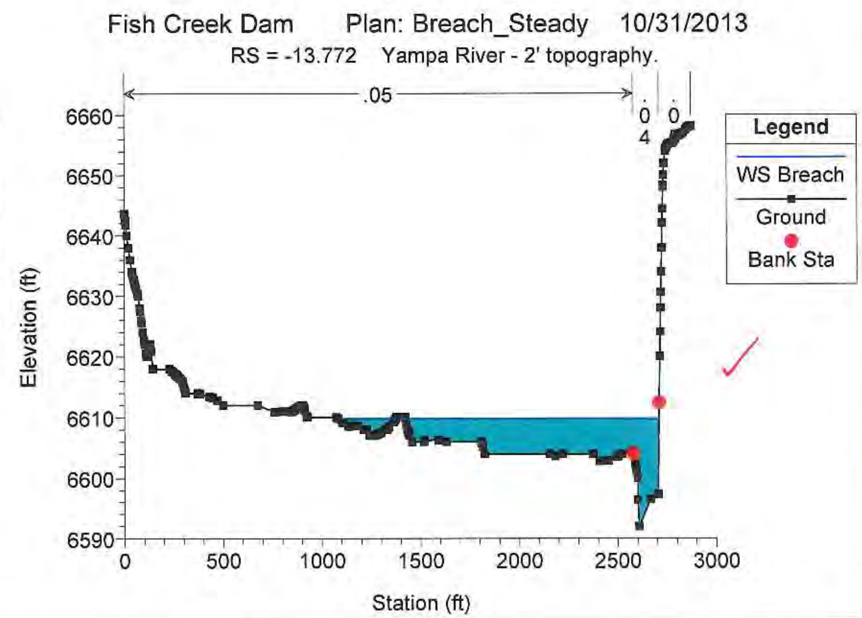


√TED 11/12/13
GGS 11/14/13

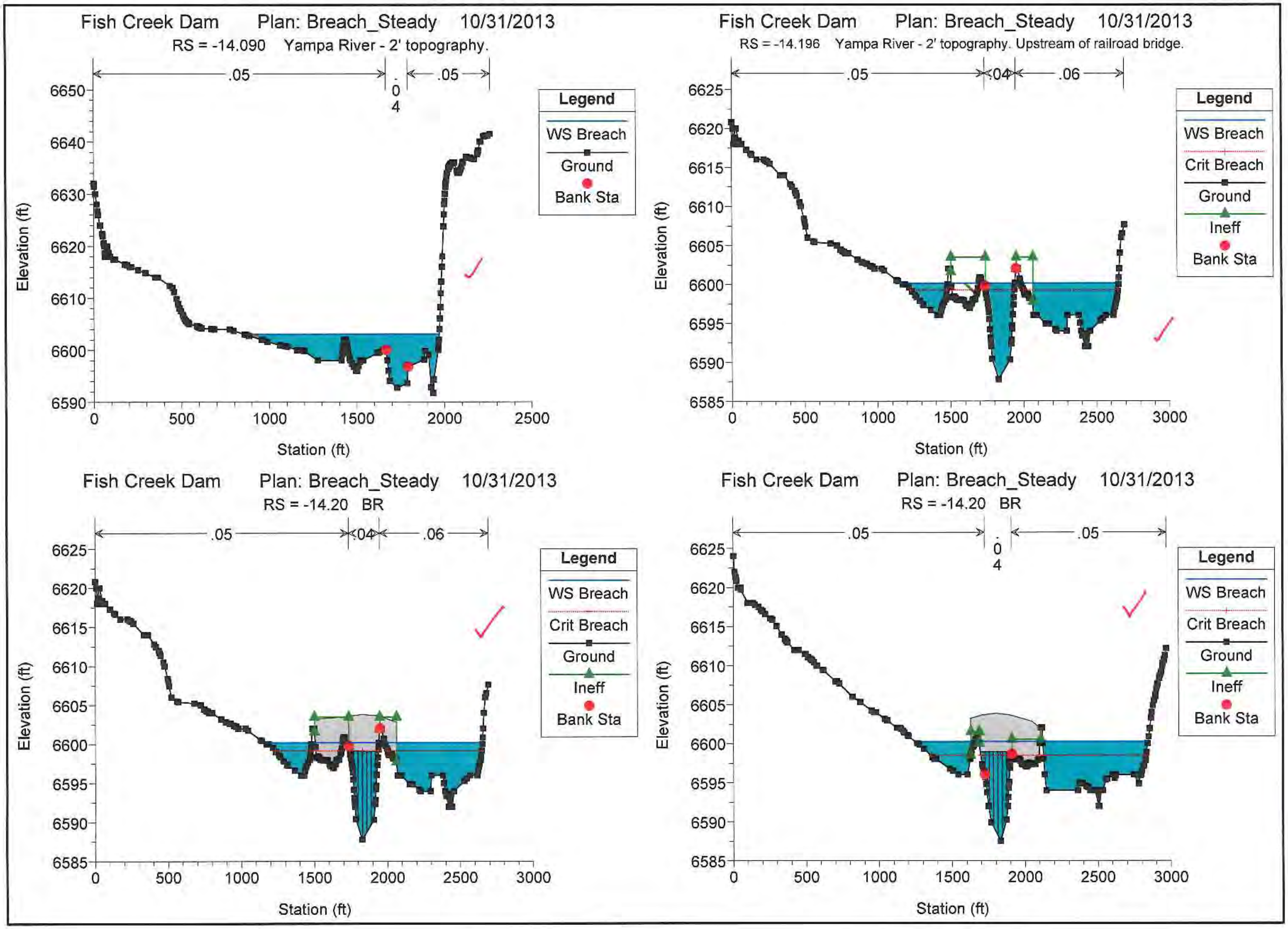




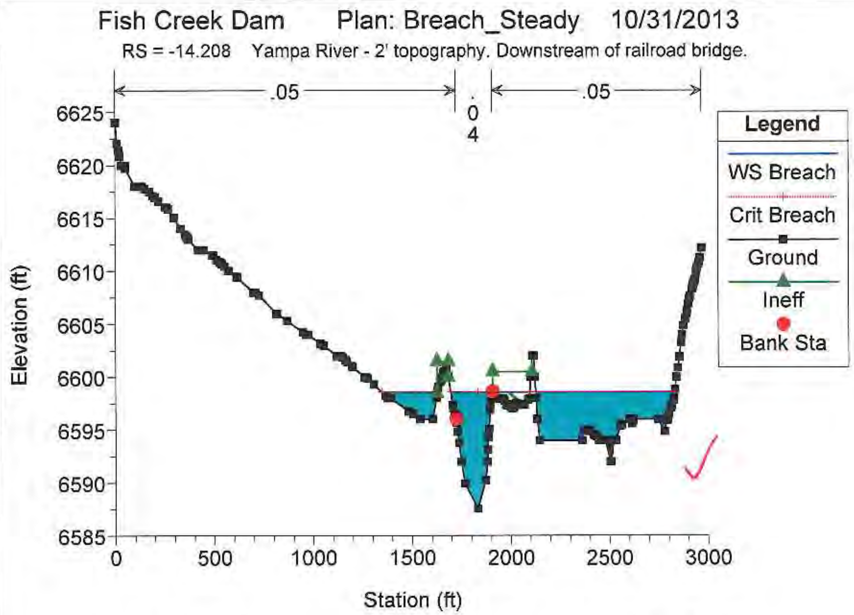


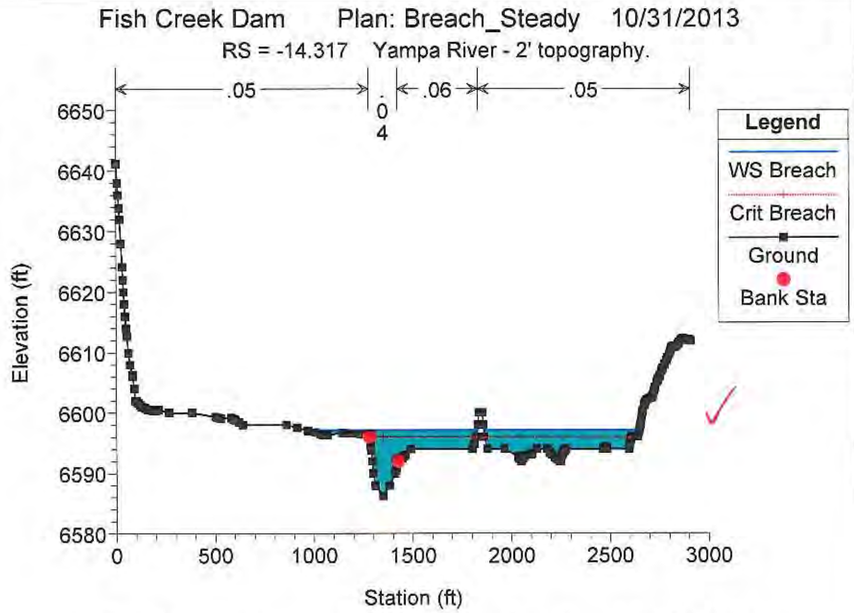


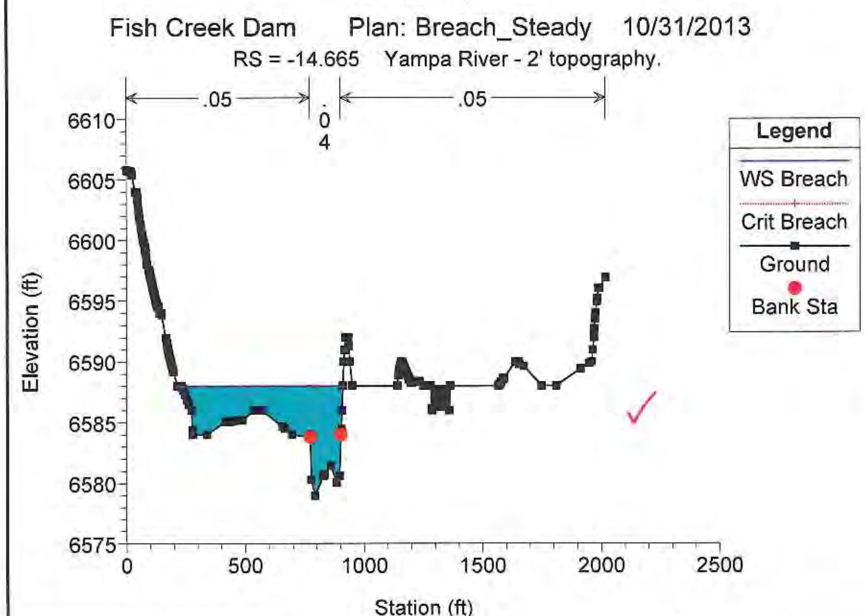
✓TEO 11/12/13
GGS 11/14/13

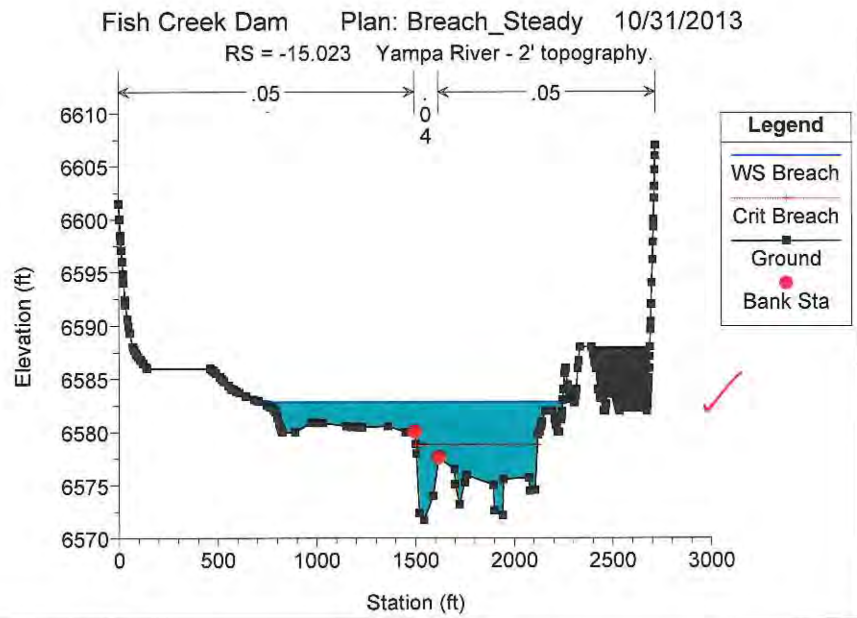


✓TEO 11/12/13
GGS 11/14/13

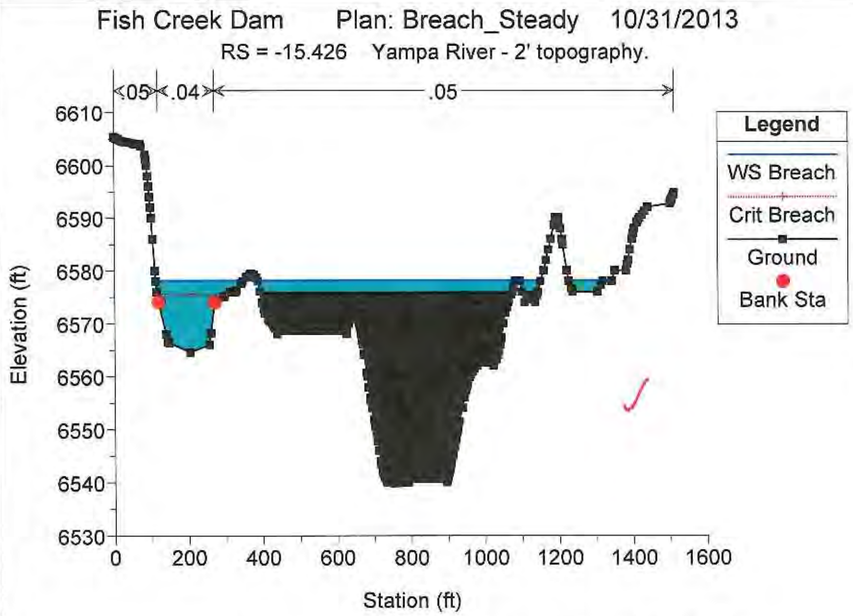


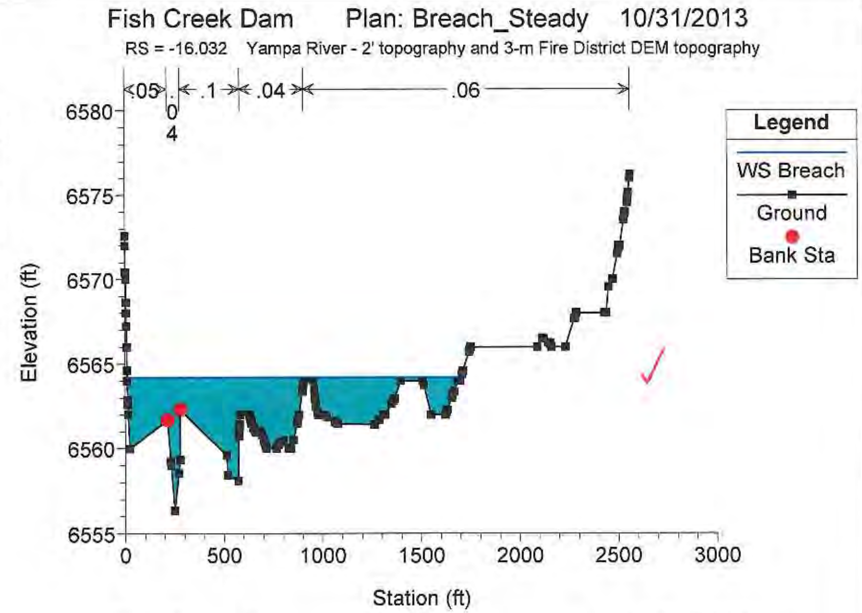


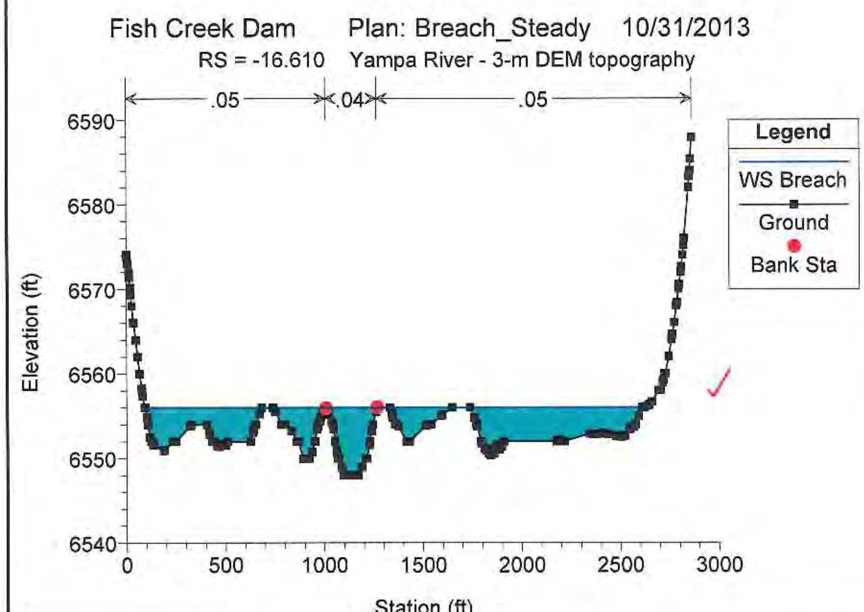


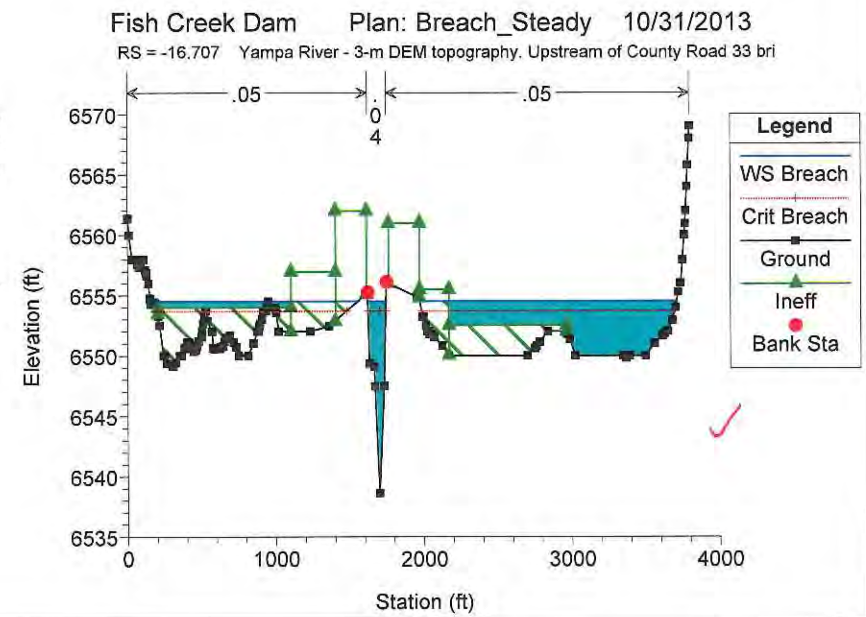


✓ TEO 11/12/13
GGS 11/14/13

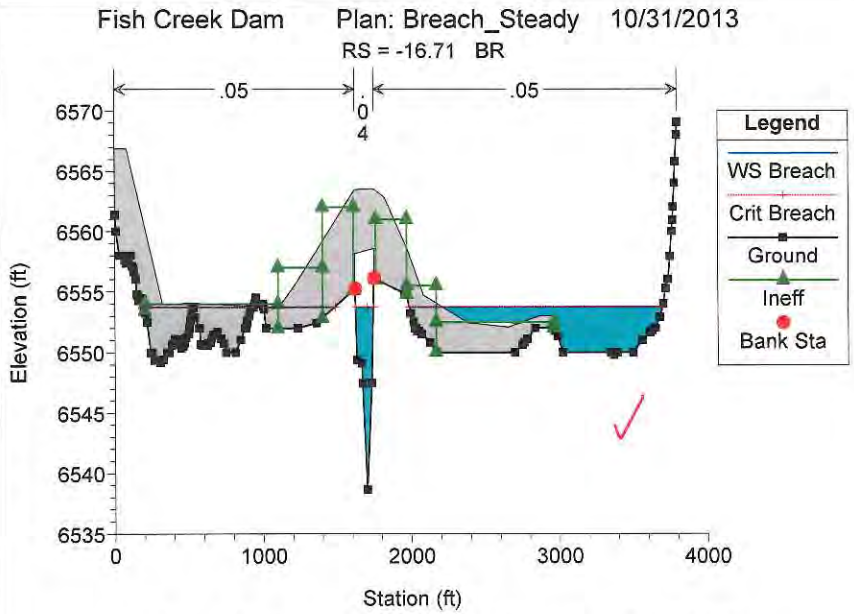


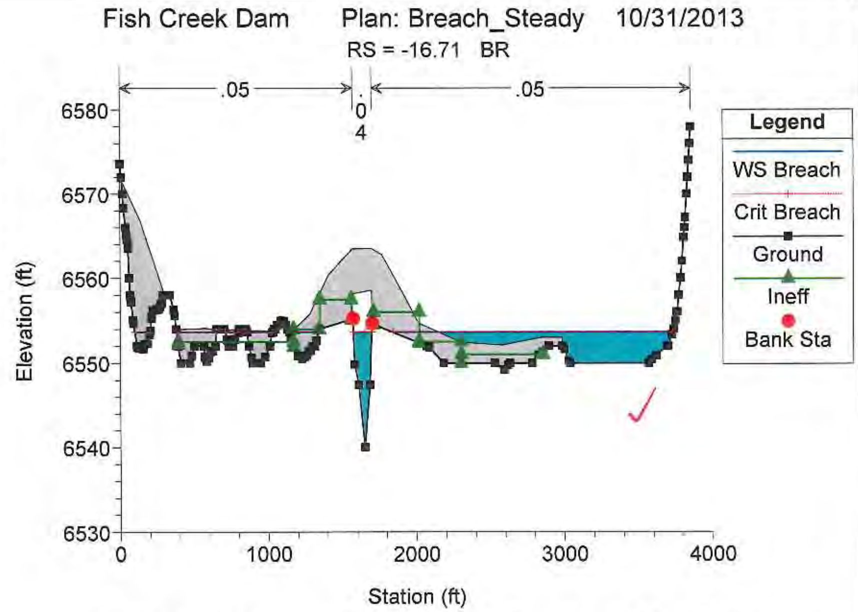


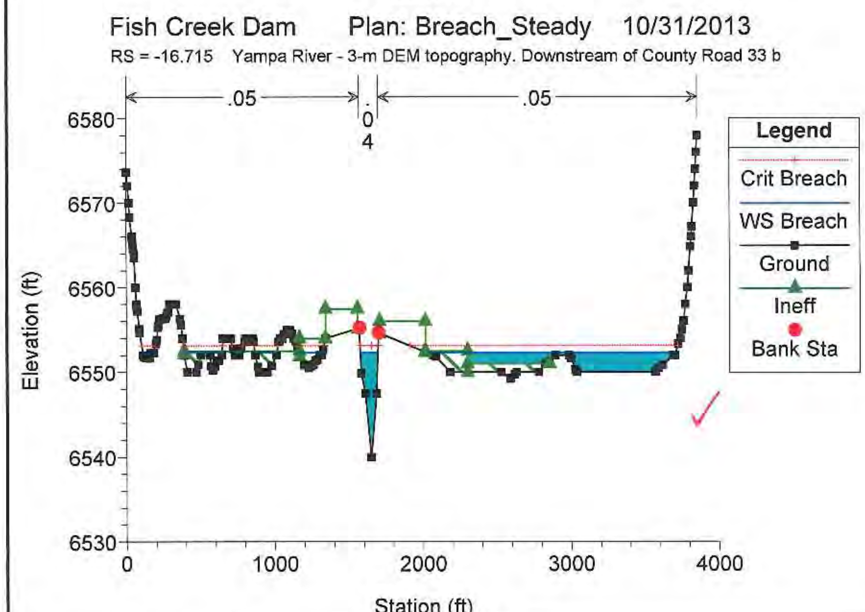


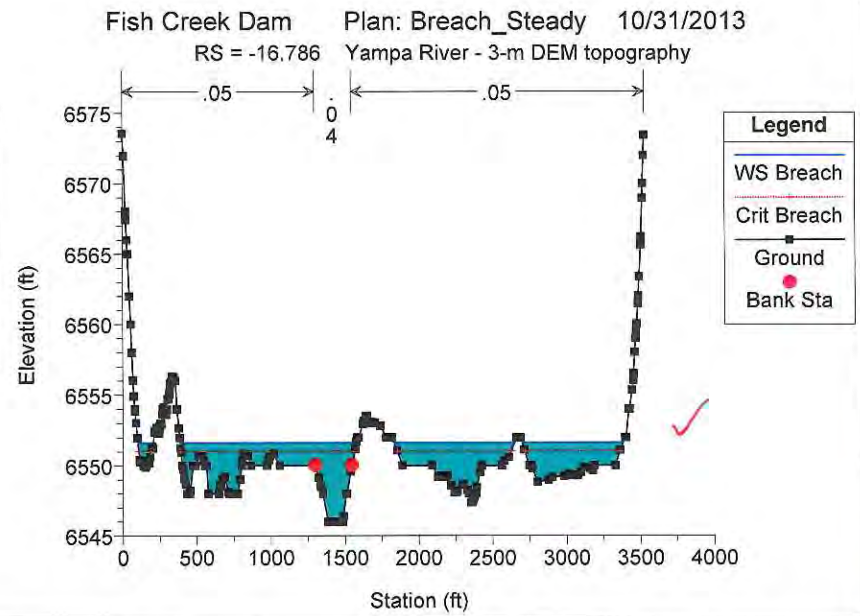


✓ TEO 11/12/13
GGS 11/14/13

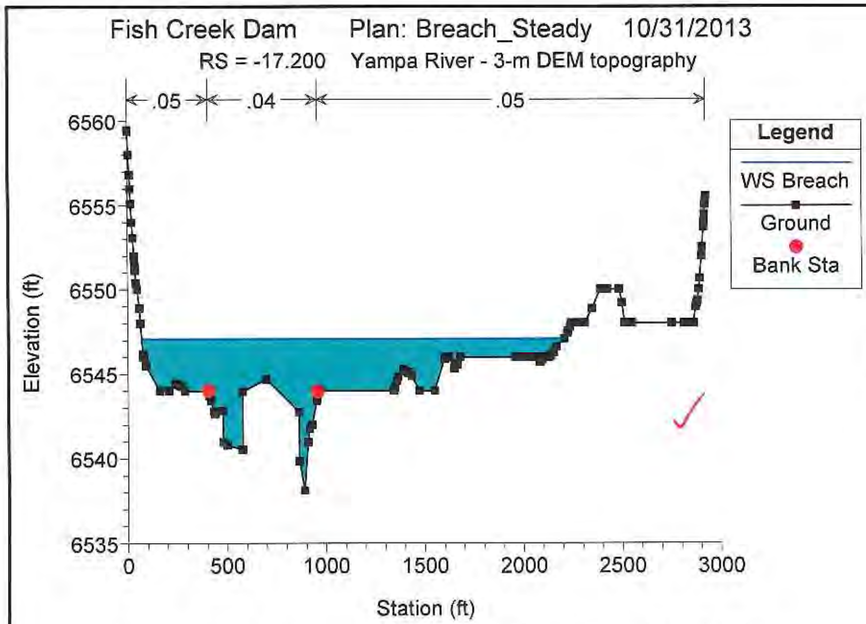


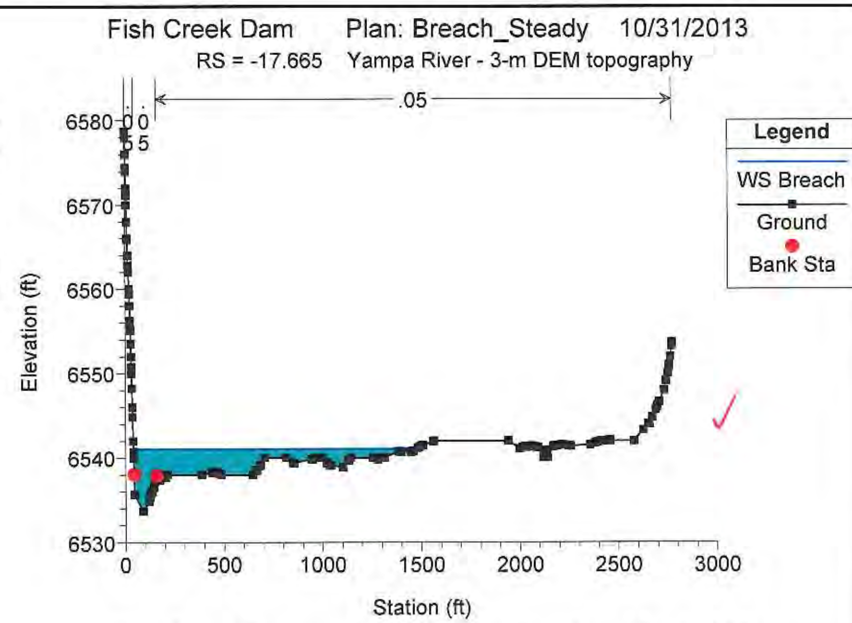


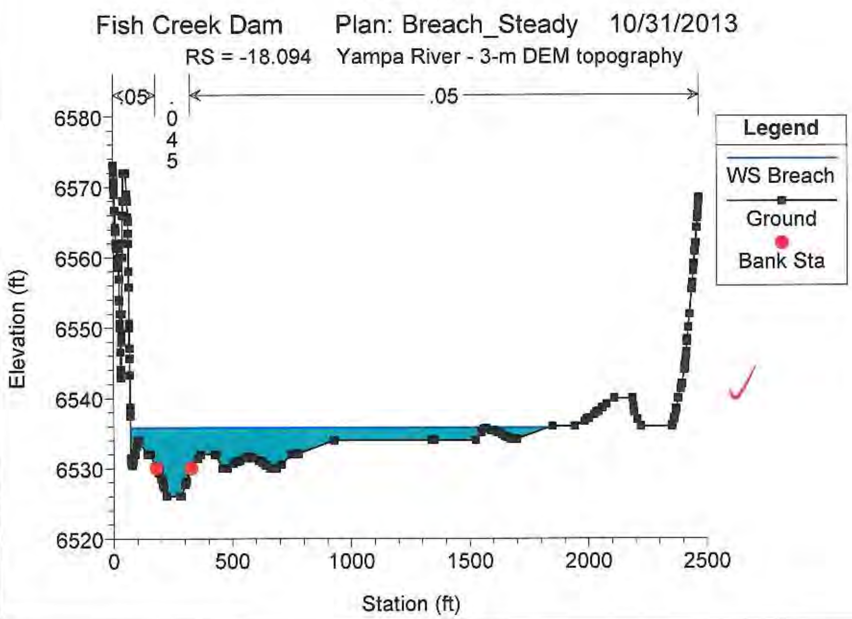


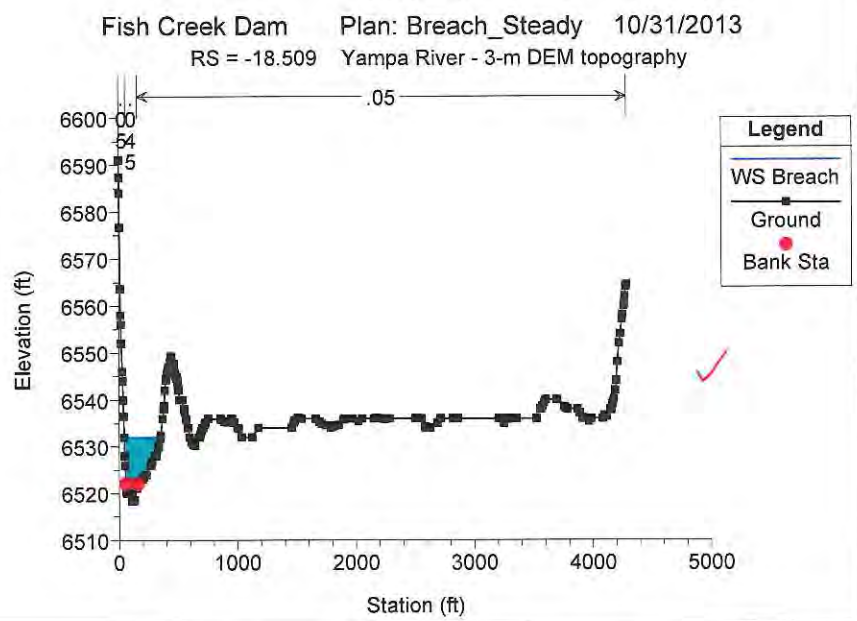


✓TEO 11/12/13
GGS 11/14/13

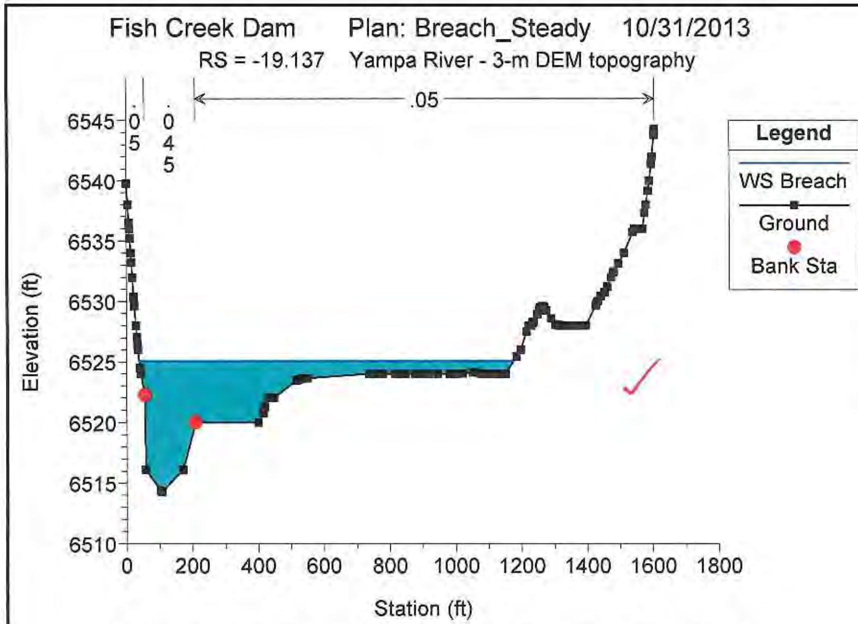


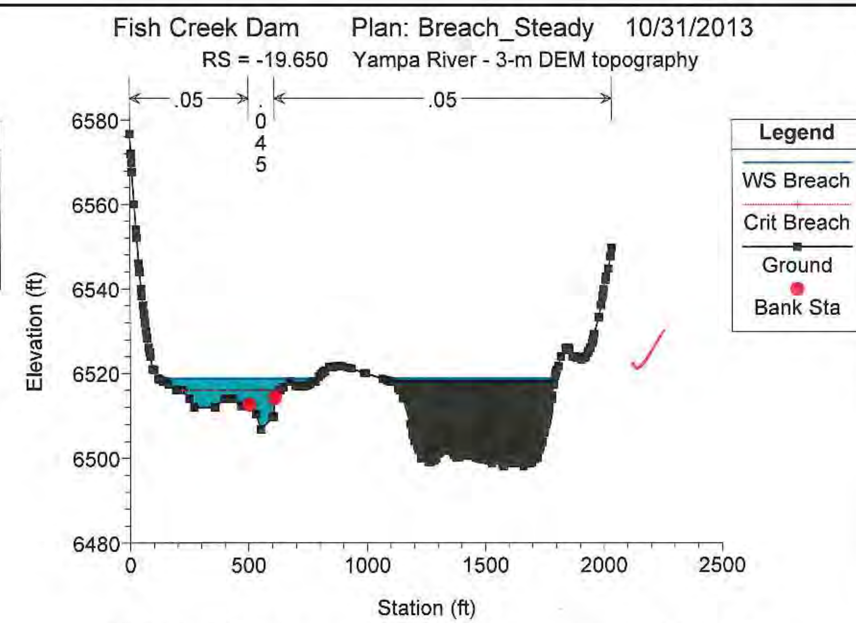


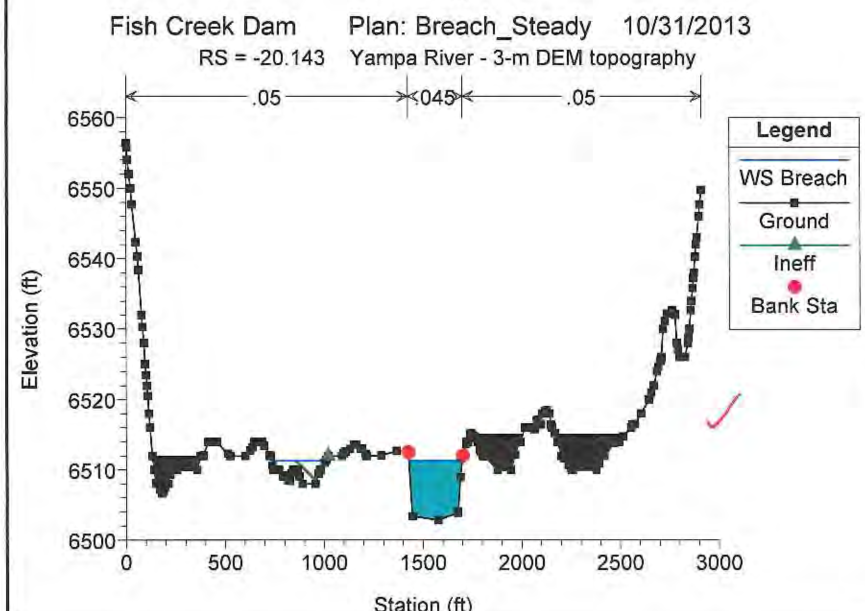


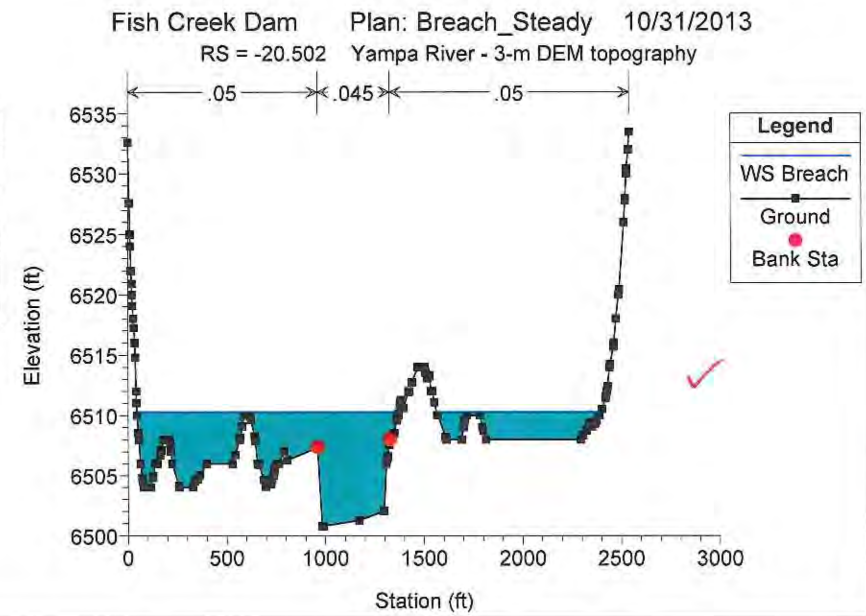


✓ TEO 11/12/13
GGOS 11/14/13





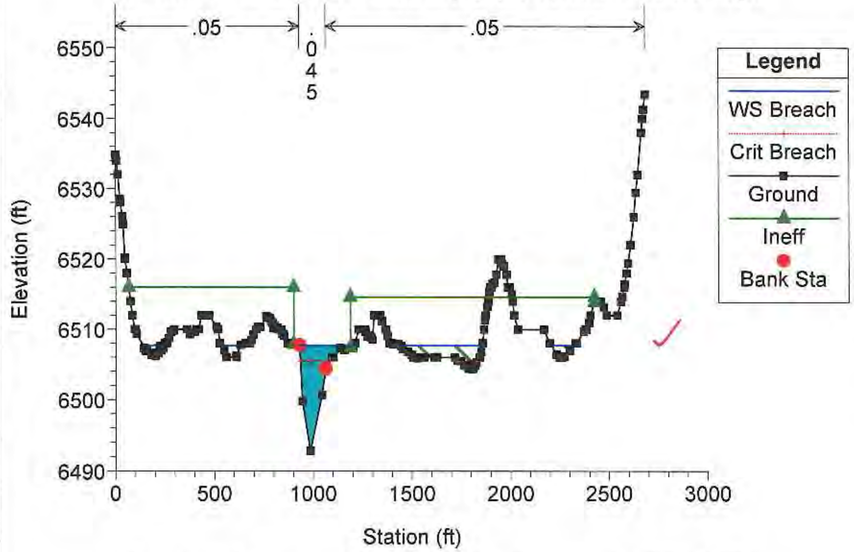




√ TEO 11/12/13
GGS 11/14/13

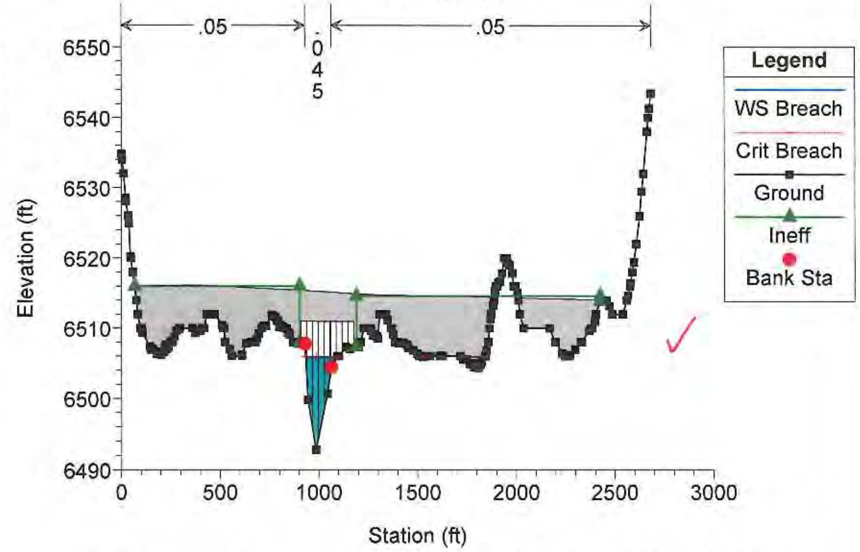
Fish Creek Dam Plan: Breach_Steady 10/31/2013

RS = -20.594 Yampa River - 3-m DEM topography. Upstream of railroad bridge.



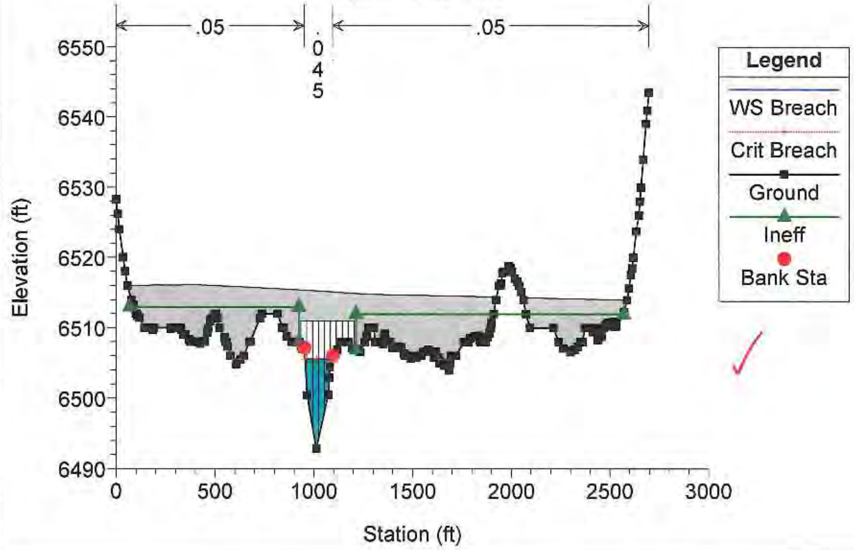
Fish Creek Dam Plan: Breach_Steady 10/31/2013

RS = -20.6 BR



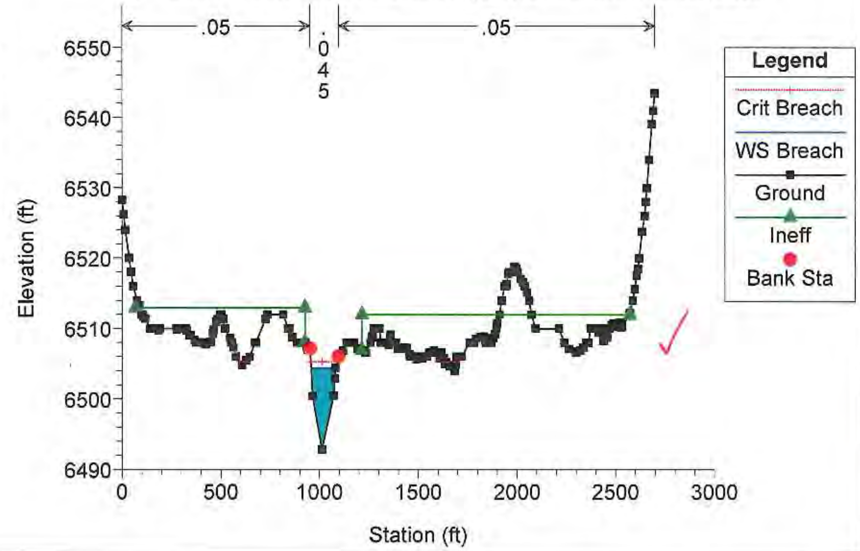
Fish Creek Dam Plan: Breach_Steady 10/31/2013

RS = -20.6 BR

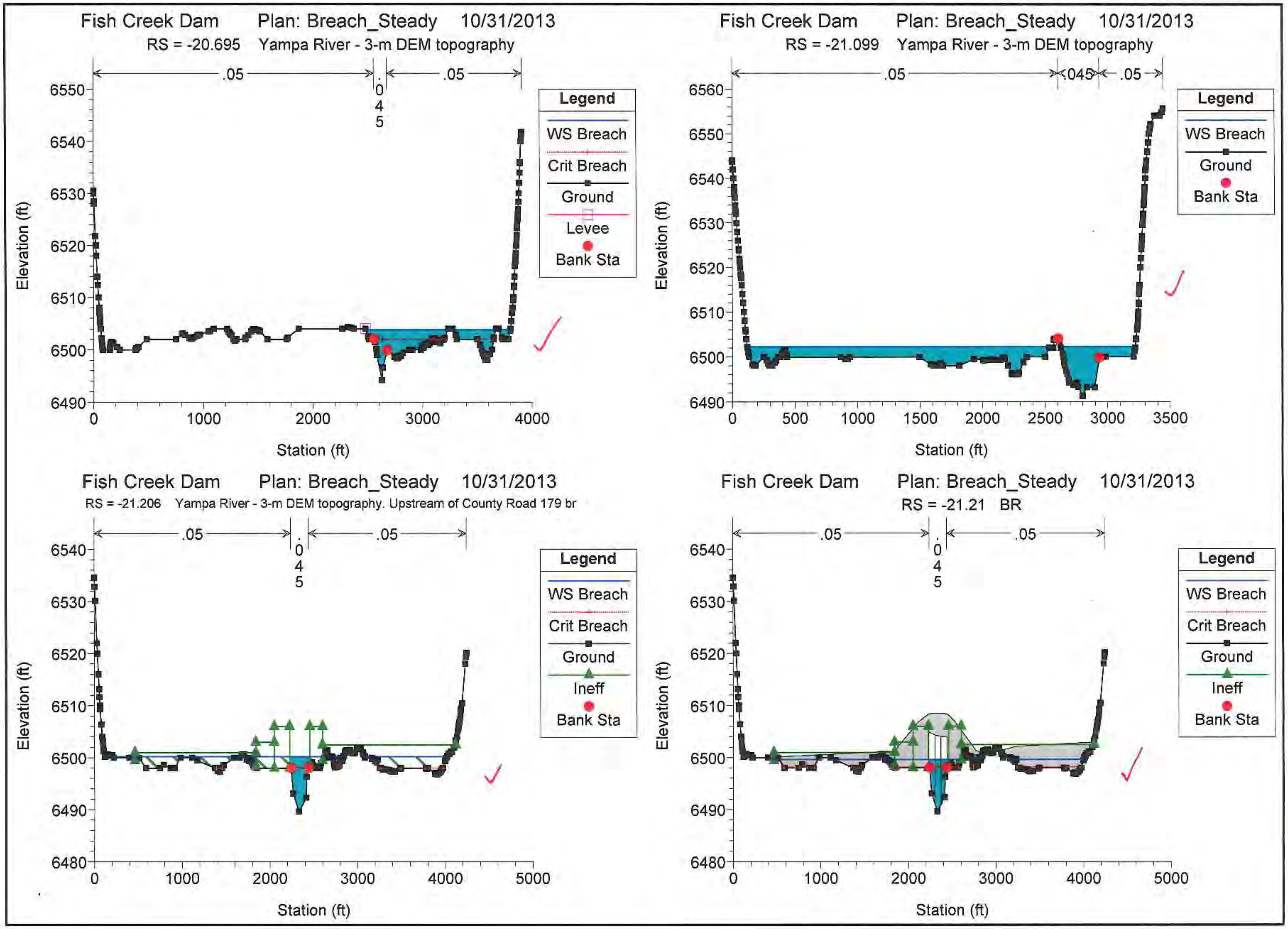


Fish Creek Dam Plan: Breach_Steady 10/31/2013

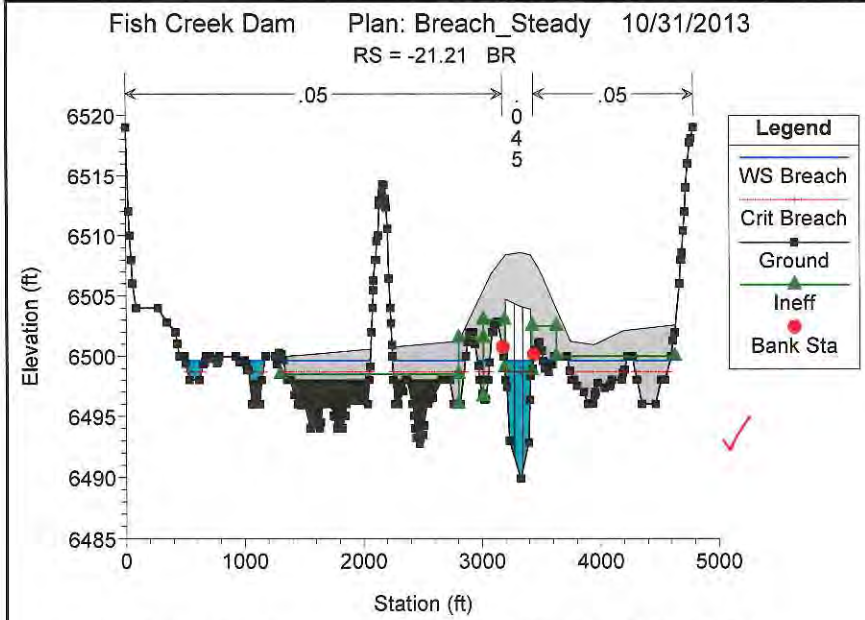
RS = -20.601 Yampa River - 3-m DEM topography. Downstream of railroad bridge.

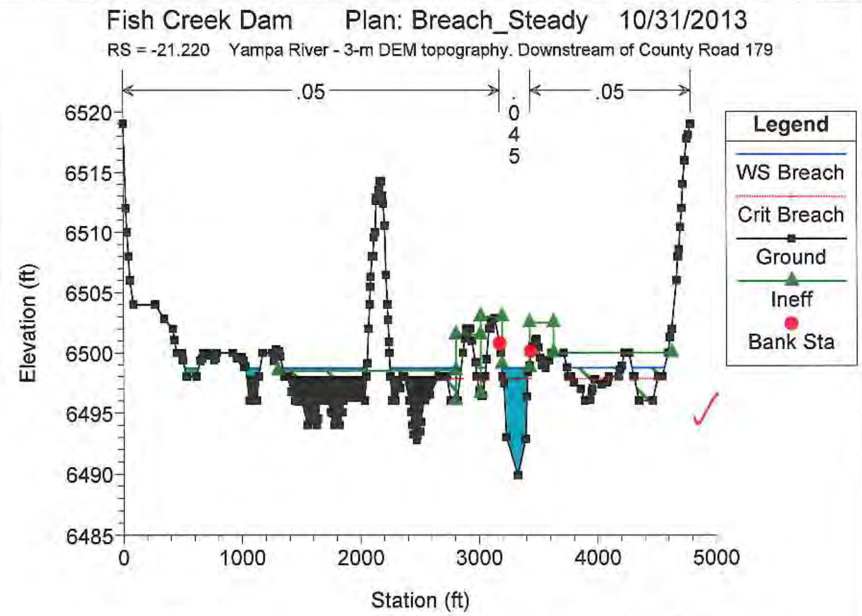


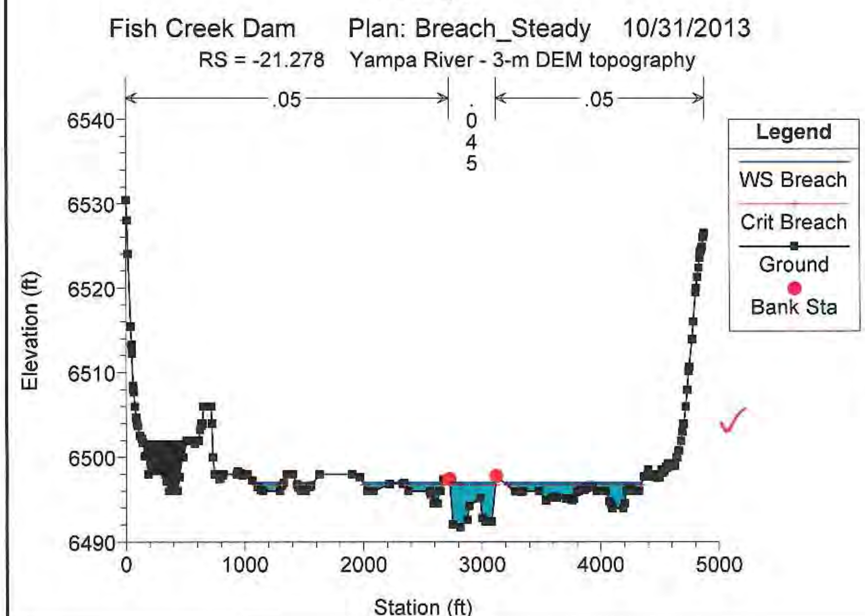
✓ TEO 11/12/13
GGS 11/14/13

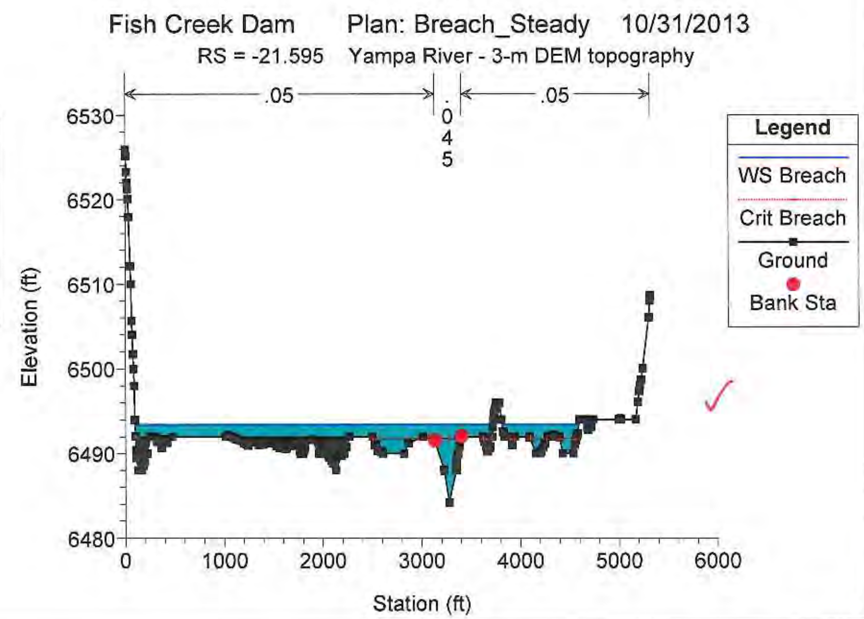


JTEO 11/12/13
GGS 11/14/13

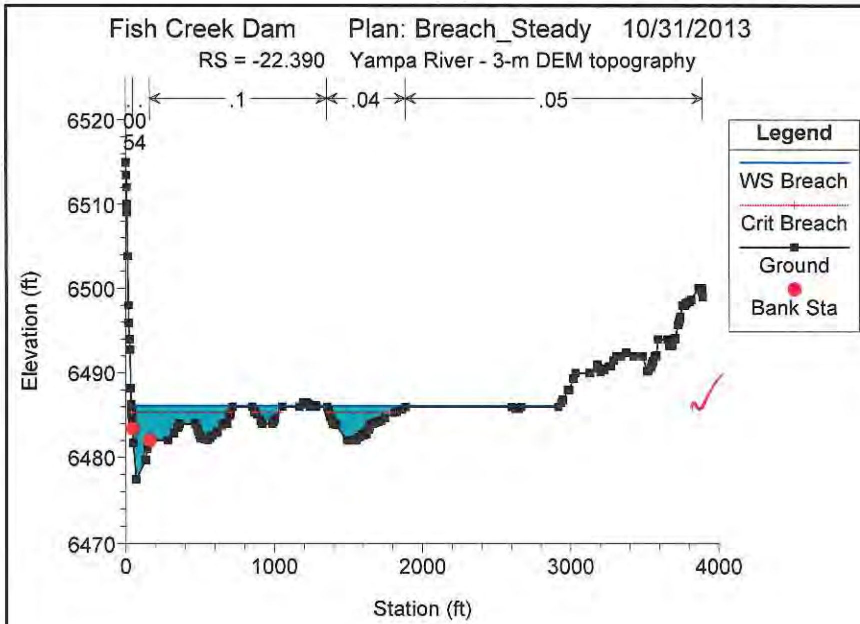


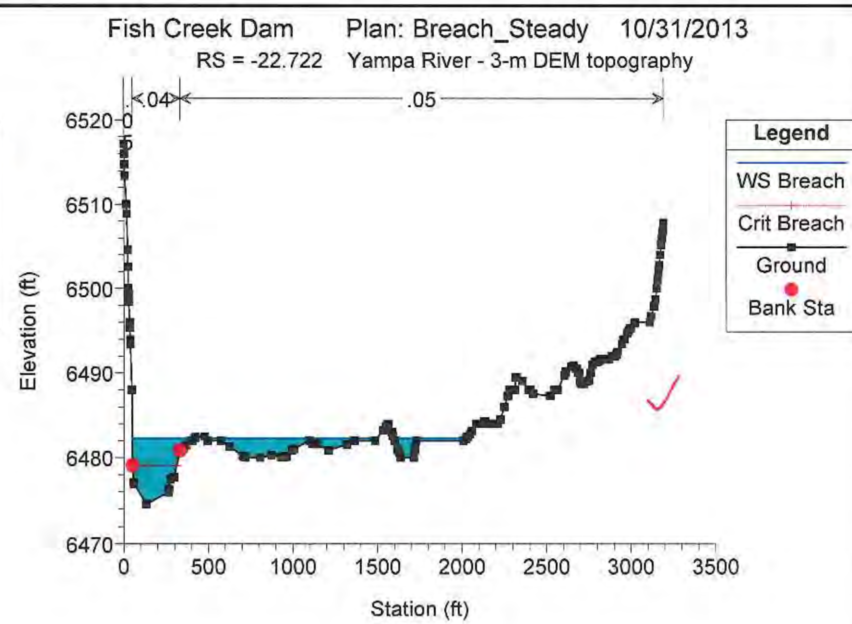






J TEO 11/12/13
GGS 11/14/13



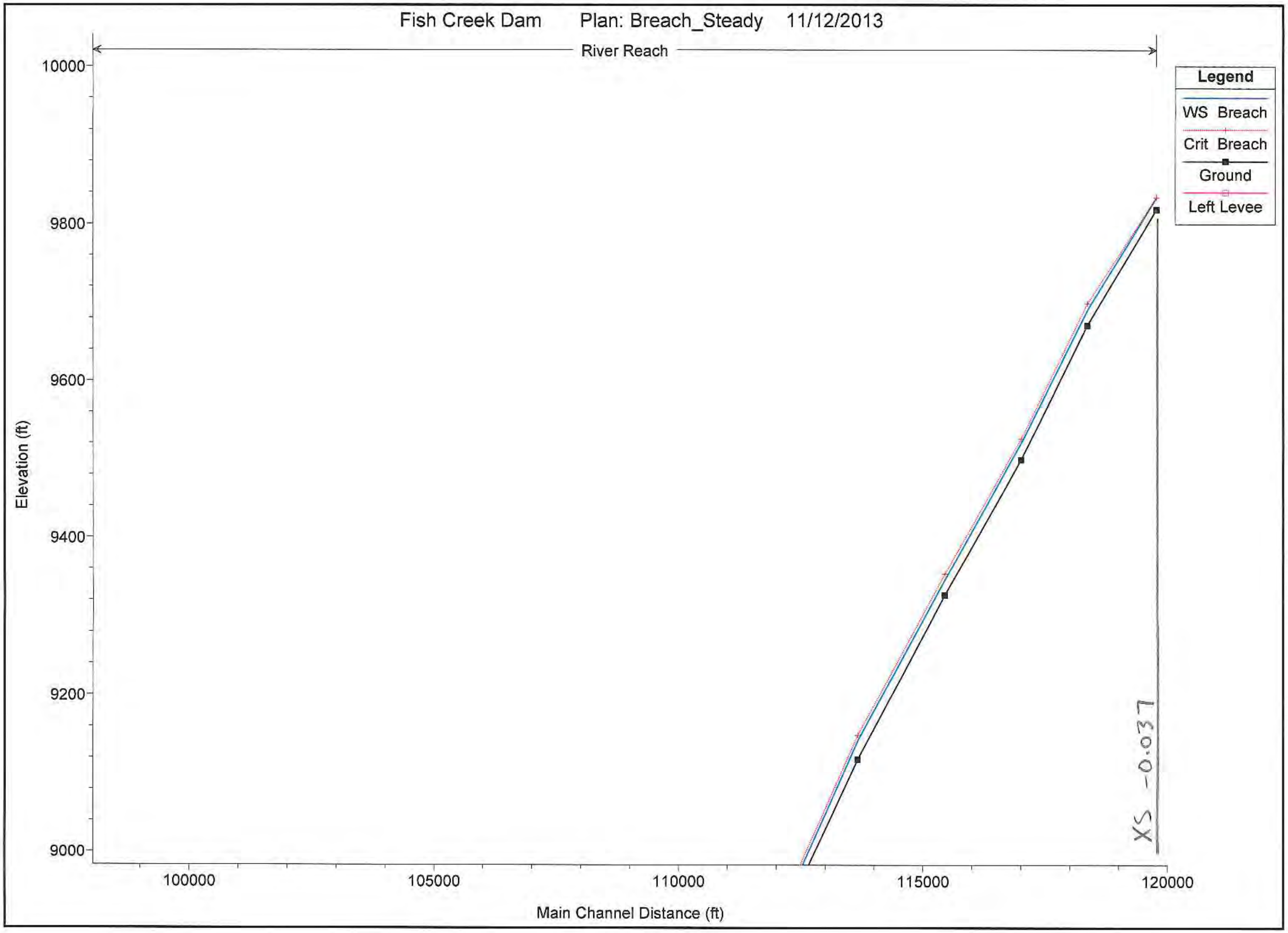


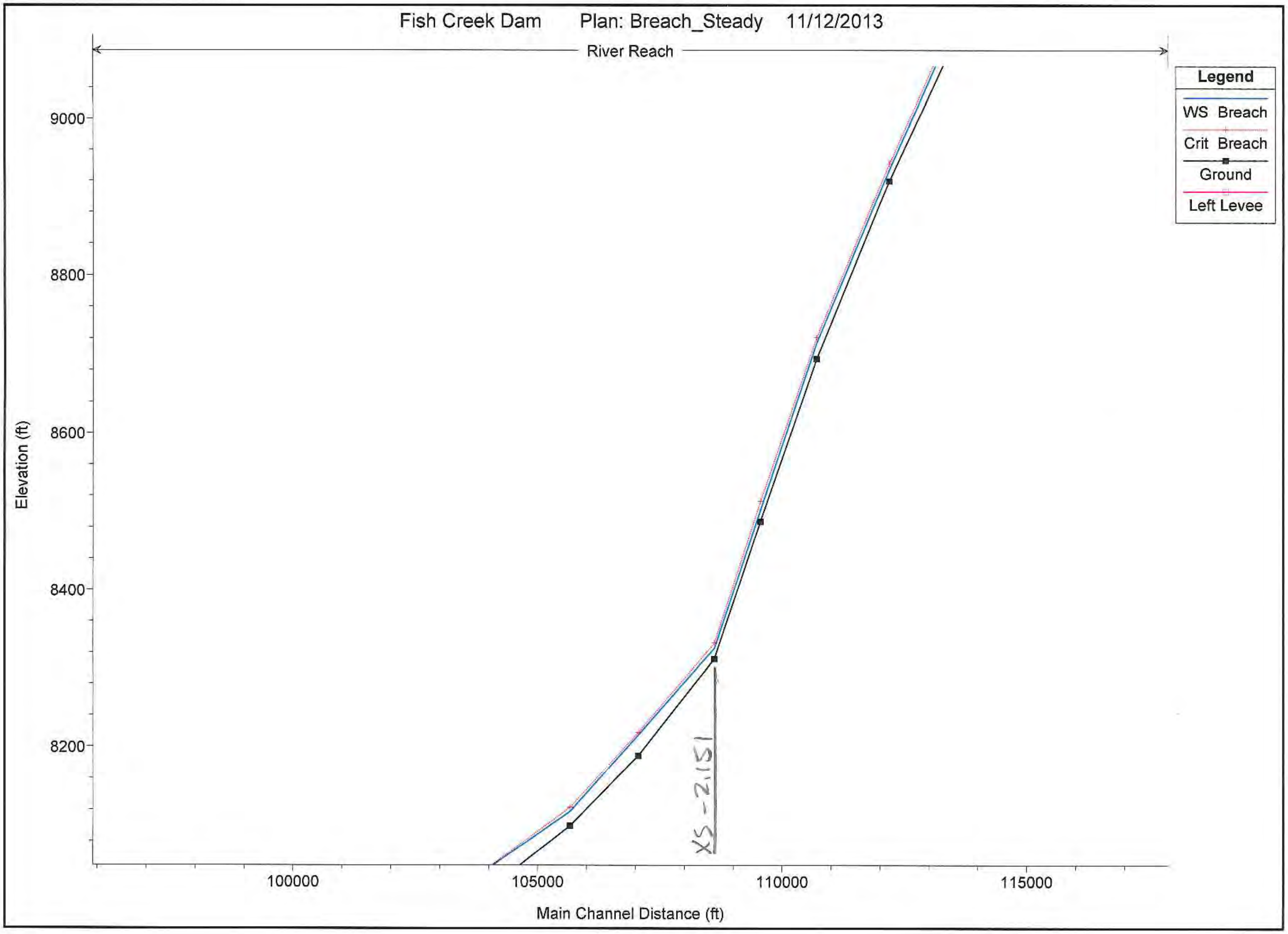
✓ TEO 11/12/13
GGS 11/14/13

Project 13133 Page —
Date — By —
Client Steamboat Springs
Subject Fish Creek Dam
Checked By
Approved By

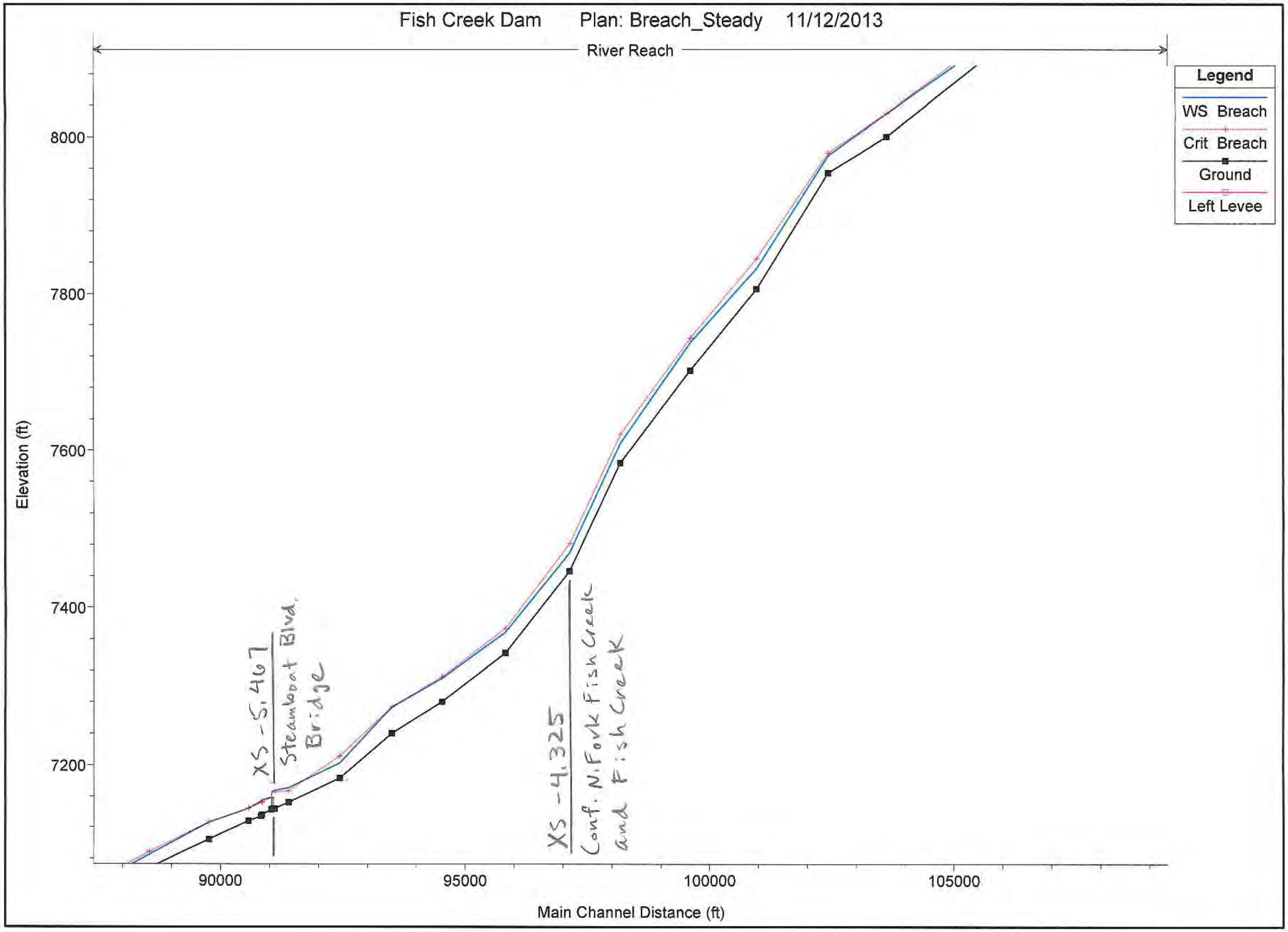
Attachment 1

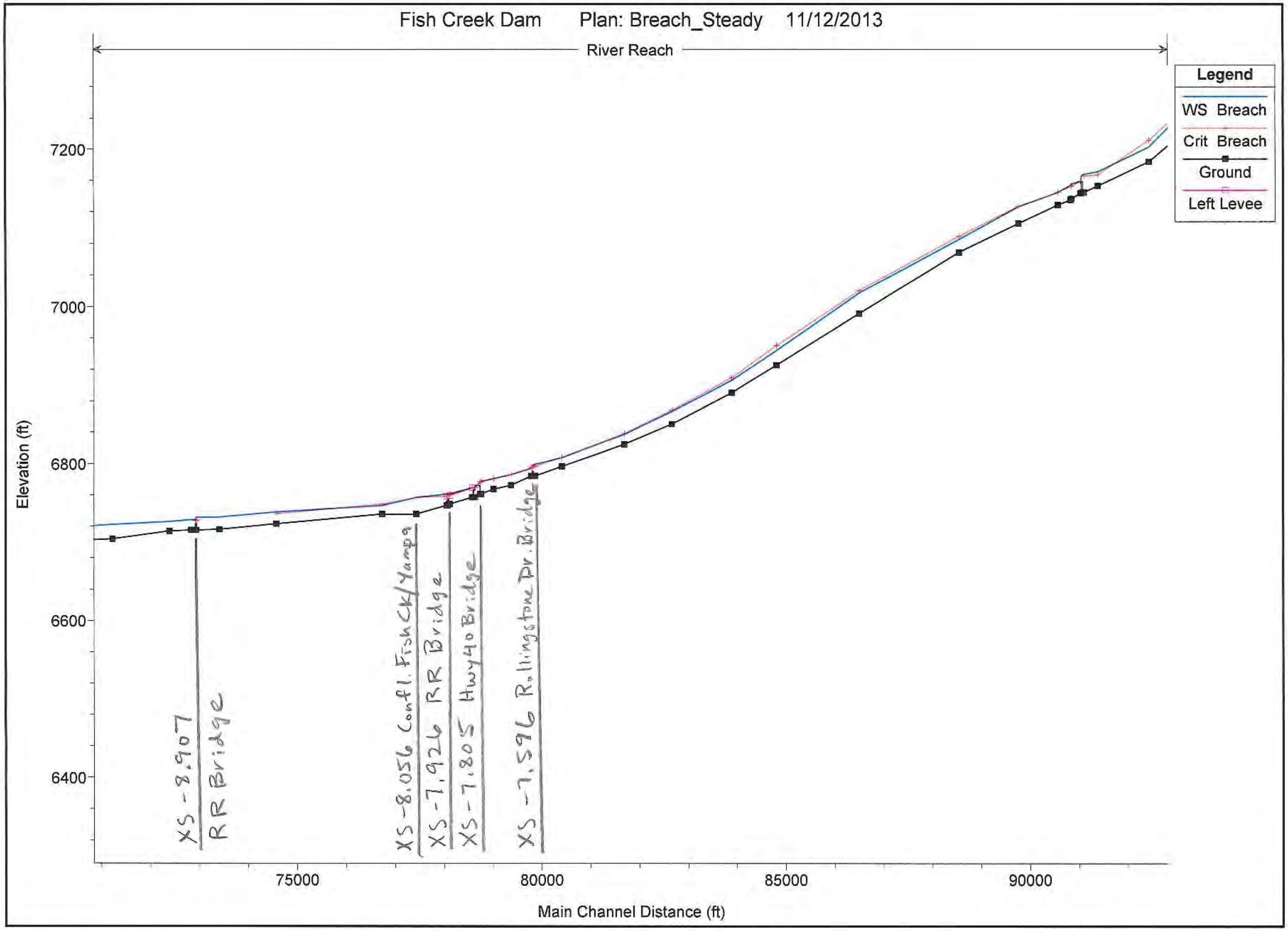
Detailed HEC-RAS Profile


Fish Creek Dam Plan: Breach_Steady 11/12/2013
River Reach
Legend
WS Breach
Crit Breach
Ground
Left Levee
Elevation (ft)
10000
9800
9600
9400
9200
9000
100000
105000
110000
115000
120000
Main Channel Distance (ft)
XS -0.037

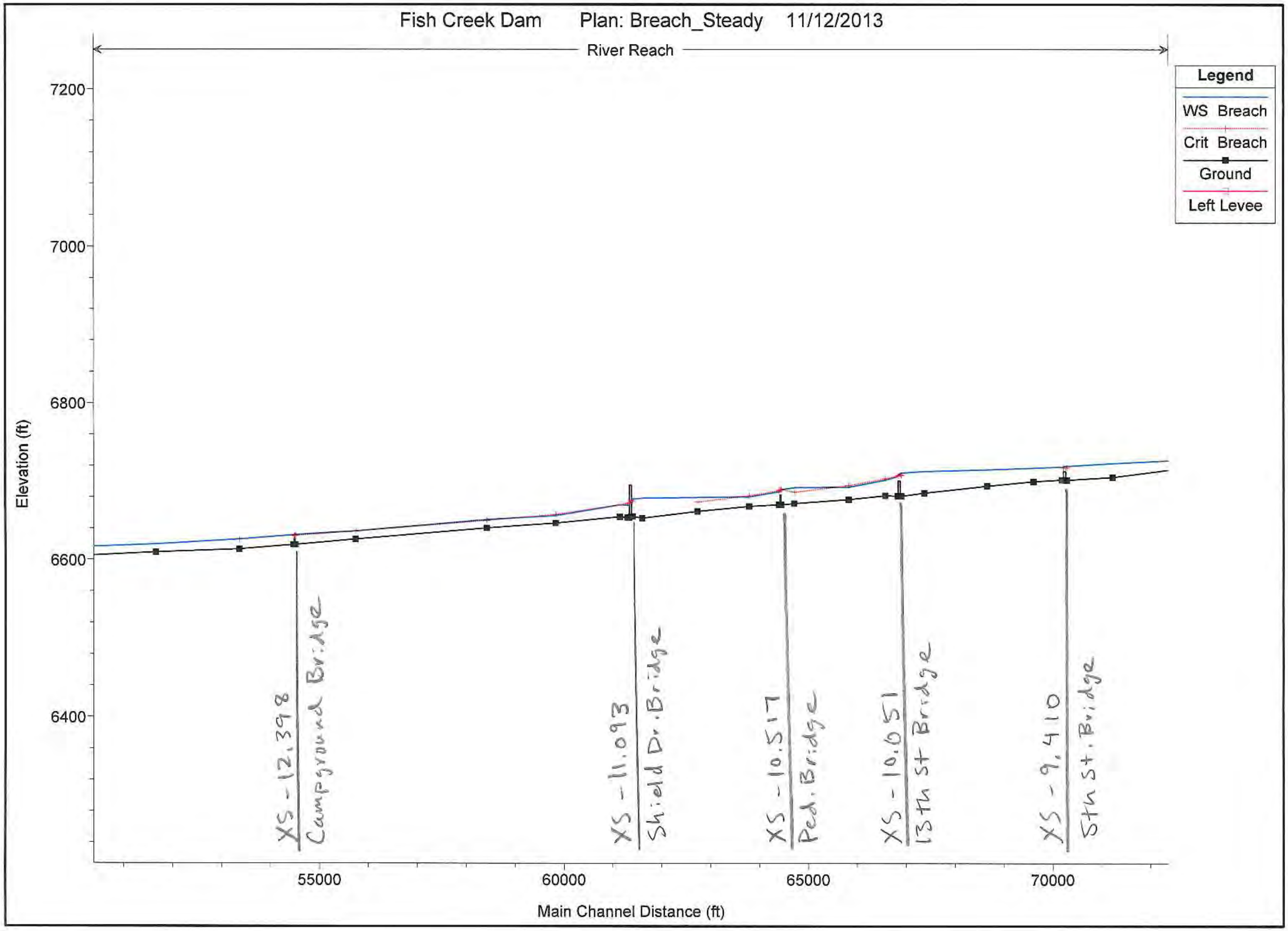


Fish Creek Dam Plan: Breach_Steady 11/12/2013
River Reach
Legend
WS Breach
Crit Breach
Ground
Left Levee
9000
8800
8600
8400
8200
Elevation (ft)
100000
105000
110000
115000
Main Channel Distance (ft)
XS - 2.151

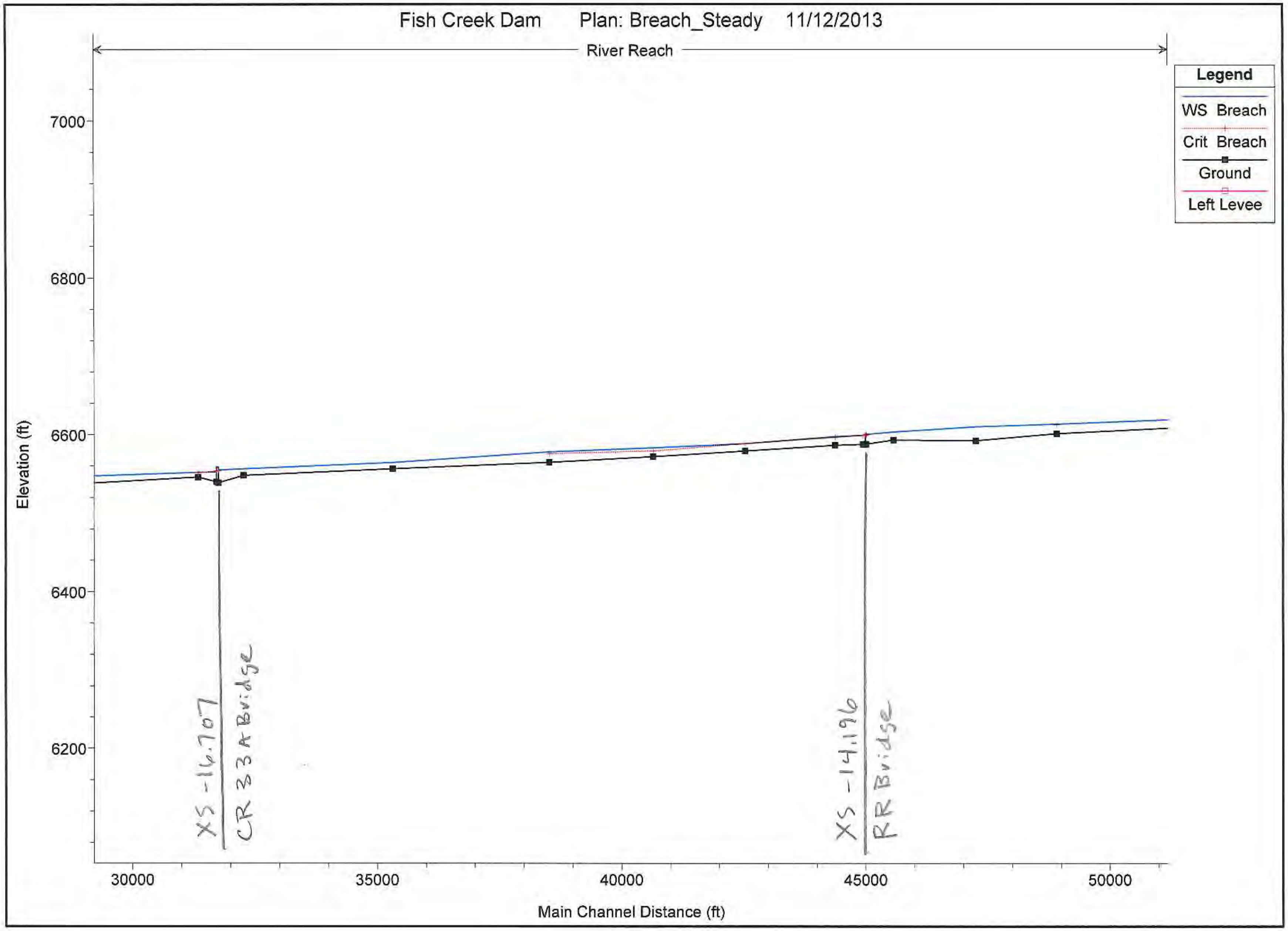

Fish Creek Dam Plan: Breach_Steady 11/12/2013
River Reach
Legend
WS Breach
Crit Breach
Ground
Left Levee
Elevation (ft)
8000
7800
7600
7400
7200
Main Channel Distance (ft)
90000
95000
100000
105000
XS -5.467
Steamboat Blvd. Bridge
XS -4.325
Conf. N. Fork Fish Creek and Fish Creek

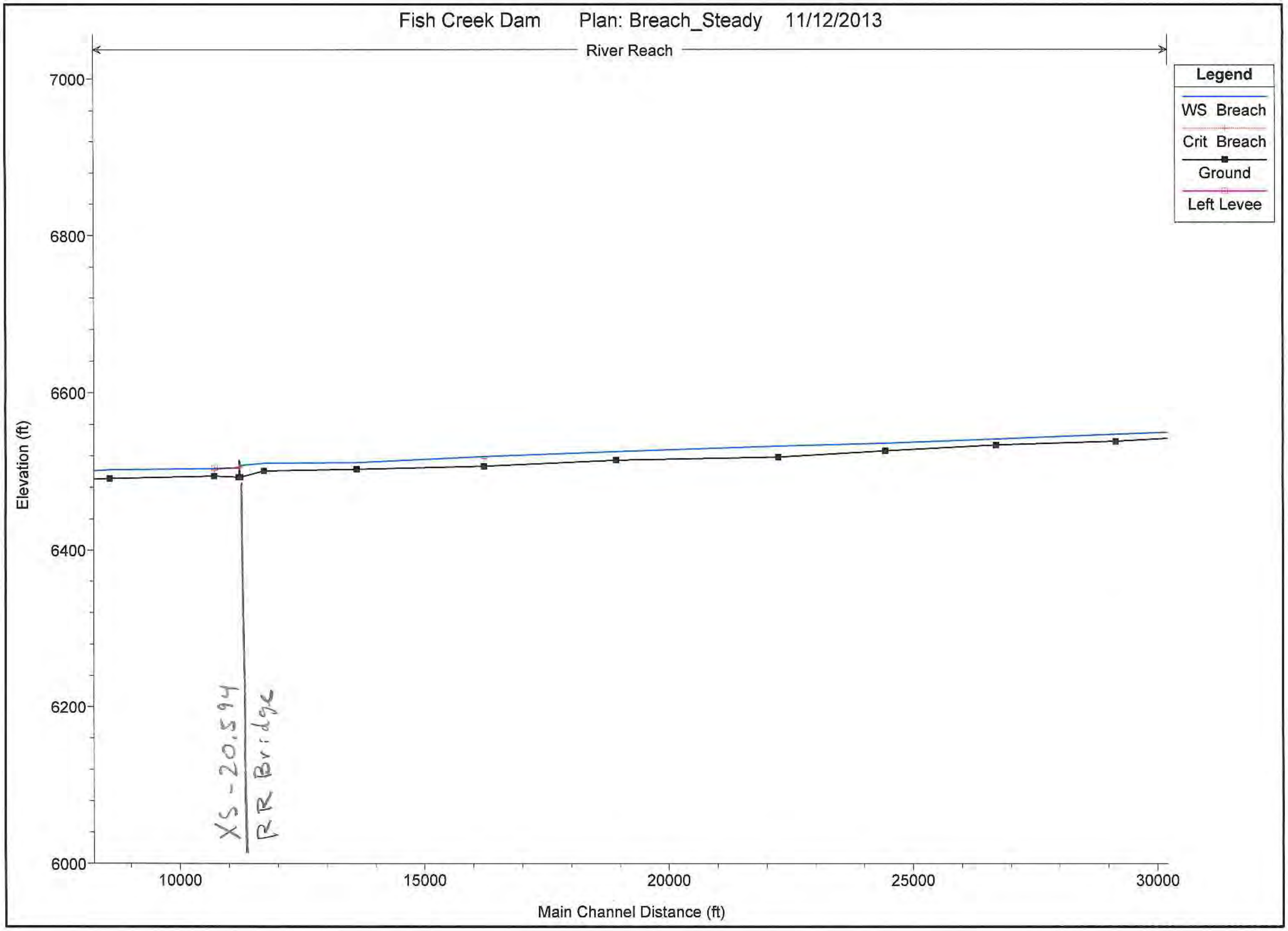


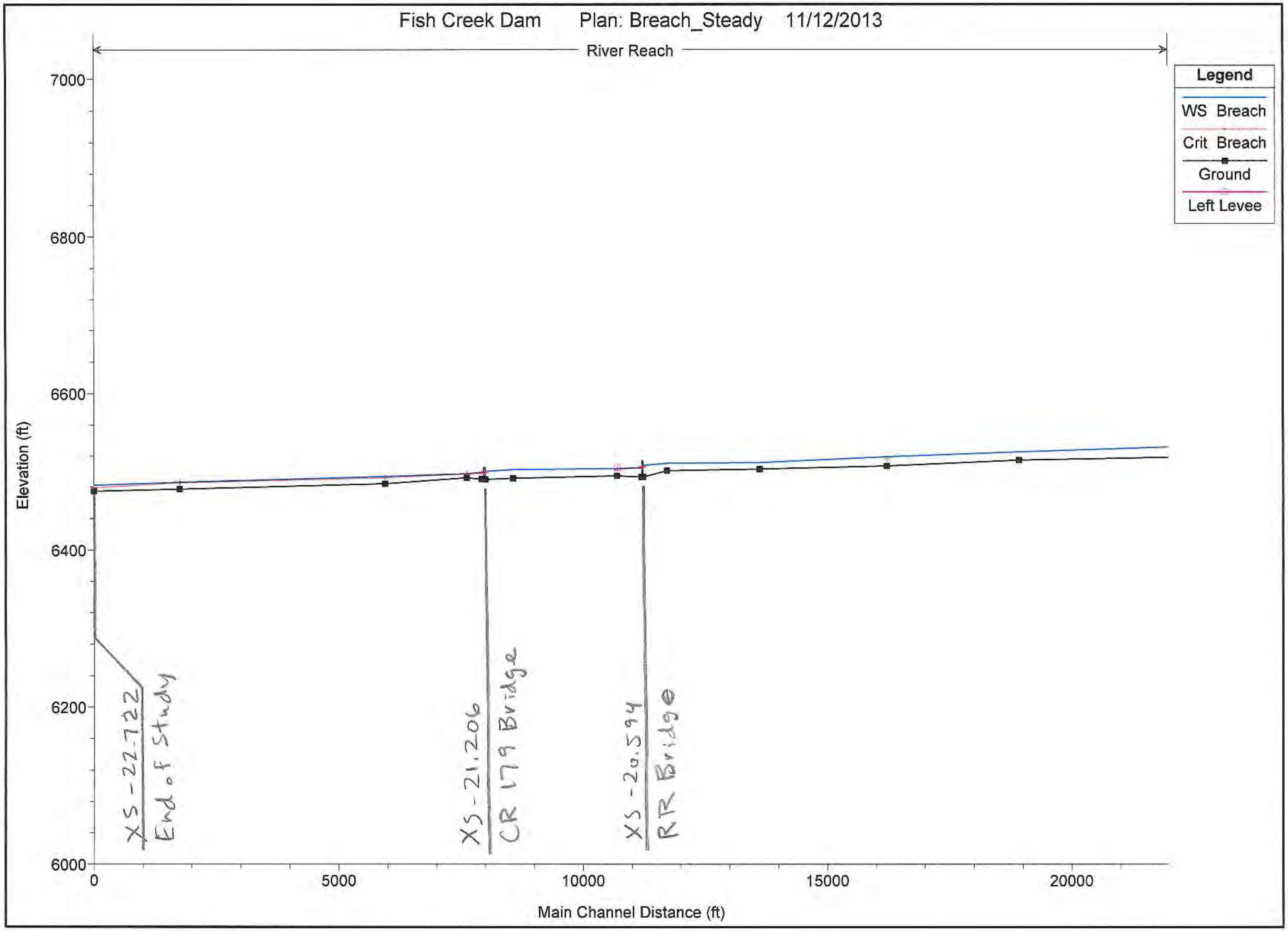
Fish Creek Dam Plan: Breach_Steady 11/12/2013
River Reach
Legend
WS Breach
Crit Breach
Ground
Left Levee
Elevation (ft)
7200
7000
6800
6600
6400
75000
80000
85000
90000
Main Channel Distance (ft)
XS - 8.907 RR Bridge
XS - 8.056 Confl. Fish Ck/Yampa
XS - 7.926 RR Bridge
XS - 7.805 Hwy 40 Bridge
XS - 7.596 Rollingstone Dr. Bridge



Fish Creek Dam Plan: Breach_Steady 11/12/2013
River Reach
Legend
WS Breach
Crit Breach
Ground
Left Levee
Elevation (ft)
7200
7000
6800
6600
6400
55000
60000
65000
70000
Main Channel Distance (ft)
XS - 12,398 Campground Bridge
XS - 11.093 Shield Dr. Bridge
XS - 10.517 Ped. Bridge
XS - 10.051 13th St Bridge
XS - 9,410 5th St. Bridge


Fish Creek Dam Plan: Breach_Steady 11/12/2013
River Reach
Legend
WS Breach
Crit Breach
Ground
Left Levee
Elevation (ft)
7000
6800
6600
6400
6200
30000
35000
40000
45000
50000
Main Channel Distance (ft)
XS -16.707
CR 33A Bridge
XS -14.196
RR Bridge


Fish Creek Dam Plan: Breach_Steady 11/12/2013
River Reach
Legend
WS Breach
Crit Breach
Ground
Left Levee
Elevation (ft)
7000
6800
6600
6400
6200
6000
10000
15000
20000
25000
30000
Main Channel Distance (ft)
XS - 20.594
RR Bridge


Fish Creek Dam Plan: Breach_Steady 11/12/2013
River Reach
Legend
WS Breach
Crit Breach
Ground
Left Levee
Elevation (ft)
7000
6800
6600
6400
6200
6000
0
5000
10000
15000
20000
Main Channel Distance (ft)
XS - 22.722
End of Study
XS - 21.206
CR 179 Bridge
XS - 20.594
RR Bridge