Appendix G

Hydraulic Impact Analysis

HYDRAULIC IMPACT ANALYSIS (HIA) FOR THE FREMONT WEIR ADULT FISH PASSAGE MODIFICATION PROJECT

DRAFT REPORT

DECEMBER 12, 2016

CONTENTS

TABLES

FIGURES

1. INTRODUCTION

The Department of Water Resources (DWR) and United States Bureau of Reclamation (Reclamation) propose to modify an existing fish passage structure at Fremont Weir to improve fish passage in the Yolo Bypass to satisfy requirements of the 2009 National Marine Fisheries Service's (NMFS's) *Biological Opinion and Conference Opinion on the Long-term Operations of the Central Valley Project and the State Water Project* (2009 NMFS BO). In addition, the California EcoRestore initiative identifies improving fish passage to known barriers along salmonid and sturgeon migration routes as a necessary near-term action to counteract declining populations of federally and State-listed fish species.

This Technical Memorandum (TM) documents the modeling approach and results of the hydraulic impact assessment (HIA) conducted to support the US Army Corps of Engineers (USACE) Section 408 permission, the Yolo County Flood Hazard Development Permit, and the Central Valley Flood Protection Board (CVFPB) Encroachment Permit for the proposed Fremont Weir Adult Fish Passage Modification Project (Project). The Project includes (i) modification of the weir by replacing the existing fish ladder, including earthwork to the existing channels that extend upstream and downstream of the existing fish ladder, and (ii) modification of agricultural road crossings along the Tule Canal, a small channel adjacent to the east Yolo Bypass levee, to meet fish passage criteria.

2. PURPOSE AND METHODOLOGY

The purpose of this HIA is to evaluate the potential impacts to water surface elevation (WSE) during the design flood due to construction of the Project. The methodology used to determine hydraulic effects was to configure and evaluate hydraulic model simulations of existing conditions and proposed Project conditions. The results of the Project conditions were then compared to that of existing conditions to evaluate hydraulic impacts.

4. HYDROLOGY

The Central Valley Hydrology Study (CVHS) was used in this study. The intent was to identify a CVHS flow dataset that would produce a flow at Fremont Weir that is similar to its design capacity of 343,000 cfs (CVFPP, 2016/ DWR, 2010a). The CVHS 1997 storm pattern scaled to 85% that produces WSEs close to the 1957 design profiles in Yolo Bypass, Sacramento River, and the streams in Delta (DWR DFM communication), was found to produce 353,660 cfs flow over Fremont Weir, which is slightly (~3%) higher than the design capacity. Therefore, CVHS 1997 storm pattern with 85% scaling was chosen as the hydrology for this study (Email correspondence with DWR Division of Flood Management dated 4/8/2016).

5. HYDRAULIC MODEL

The Central Valley Floodplain Evaluation and Delineation (CVFED) HEC-RAS model of the Sacramento River Flood Control Project was used for this HIA study. The CVFED HEC-RAS model and documentation are available from DWR's Library of Models as Model No. 14001, Combined Upper and Lower Sacramento River. This CVFED model was developed using HEC-RAS version 4.2 (Beta dated 2013.08.01). HEC-RAS is capable of simulating one-dimensional (1D) unsteady flow

calculations through a full network of open channels. A model schematic and extents are shown in Figure 1.

The CVFED HEC-RAS model and all of the results are referenced in the Universal Transverse Mercator Zone 10 coordinate horizontal system and the North American Vertical Datum of 1988 (NAVD88). All units are in U.S. survey feet. The geometry refinements to reflect Existing and Project conditions are described in the following sections.

5.1 HEC-RAS Model Geometry Changes to Reflect Existing Conditions

Under existing conditions, there are four agricultural road crossings in the Tule Canal (two of which are agricultural impoundments) which provide access for vehicles and farming equipment from the eastern Yolo Bypass levee road to the agricultural fields (Figure 2). The base geometry in the CVFED HEC-RAS model did not include the existing Fremont Weir fish ladder or the four agricultural road crossings in the Tule Canal. Therefore, modifications were made to the base geometry to include these features. A detailed description of all project components under existing conditions was obtained from the Project's Draft Initial Study/ Environmental Assessment (IS/EA) (DWR, 2016) as well as through personal communication with DWR staff who completed topography surveys of the existing components. All modifications made to create the existing conditions geometry are shown in Table 1. HEC-RAS schematics of these project components under existing conditions are shown in Figure 3 through Figure 7.

5.3 HEC-RAS Model Geometry Changes to Reflect Project Conditions

The Project includes (i) modification of the existing weir by widening the fish passage structure from 4 feet wide to 15 feet wide and lowering the invert of the structure by 4 feet (from an elevation of 26 feet to 22 feet), including earthwork to the existing channels that extend upstream and downstream of the existing fish ladder, and (ii) modification of agricultural road crossings along the Tule Canal to meet fish passage criteria. A detailed description of all project components and intended modifications is provided in the Project's Draft IS/EA (DWR, 2016). All modifications made to create the Project conditions geometry are shown in Table 2, except for Agricultural Road Crossing 3, which would be removed under Project conditions. Also note that no modification was made to Agricultural Road Crossings 1 and 4, as no construction is proposed for these locations. HEC-RAS schematics of these project components under Project conditions are shown in Figure 8 through Figure 11.

Table 1. List of CVFED model geometry changes made to reflect existing conditions

Project components	Fish passage structure at Fremont Weir	Agricultural Road Crossing 1	Agricultural Road Crossing 2	Agricultural Road Crossing 3	Agricultural Road Crossing 4
Physical description	A 4 feet wide and 6 feet deep Denil-type fish ladder with 26 feet invert.	A 21.5 feet high earthen berm.	A 17.5 feet high berm, which contains one 30" CMP culvert at an invert elevation of 12.1 feet.	A 15.6 feet high berm.	A 10 feet high berm which contains three culverts through it – two of which are 48 inches diameter CMP culverts placed at different inverts of 2.9 feet and 2.5 feet; the third one is a 72 inches diameter steel pipe culvert at 2 feet invert.
Model methodology	Inline weir with box culvert	Inline weir	Bridge with circular culverts	Inline weir	Bridge with circular culverts
Geometry changes	Add a box culvert with 4 feet span, 6 feet rise, and 26 feet invert to the existing inline weir	Add an inline weir with 21.5 feet elevation.	Add a bridge with one 30 inches diameter circular culvert with an invert elevation of 12.1 feet.	Add an inline weir with 15.6 feet elevation.	Add a bridge with 3 circular culverts, two of which are 48 inches diameters each placed at different inverts of 2.9 and 2.5 feet; the third one is a 72 inches diameter culvert at 2 feet invert.
Model Location	River Station YOL/R1/56.688	River Station YOL/R1/55.092	River Station YOL/R1/54.623	River Station YOL/R1/54.005	YOL/Sac Bypass-WSB/ 43.676

Other changes	Modify immediate upstream and downstream cross sections of Fremont Weir (Yol/R1/56.708, 56.707, and 56.649) to reflect design changes due to Fremont Weir modifications	– Rename LS Yol/R1/55.190 (LB) to 55.002 to start from the next cross section; – Delete LS Yol/R1/55.191 (RB) and add that length to the next upstream LS (Yol/R1/55.377)	– Adjust LS Yol/R1/54.818 (LB) and 54.817 (RB) in the original model		– Rename LS Yol/Sac Bypass-WSB/43.766 (LB) to 43.572 to start from the next cross section; – Adjust user defined stationing of LS Yol/Sac Bypass-WSB/43.951 (RB)
- *RB, LB, and LS stand for right bank, left bank, and lateral structure, respectively*					

Table 2. List of CVFED model geometry changes made to reflect Project conditions

Project components	Fish passage structure at Fremont Weir	Agricultural Road Crossing 1	Agricultural Road Crossing 2	Agricultural Road Crossing 4
Physical description	A 15 feet wide and 9 feet deep box culvert with invert at 22 feet.	Left unchanged from Existing conditions (Refer Table 1 for details).	A bridge with box culverts that spans channel toe-to-toe. The cross section here is 156 feet wide.	Left unchanged from Existing conditions (Refer Table 1 for details).
Model methodology	Inline weir with box culvert		Bridge with box culverts	
Geometry changes	Add a box culvert with 15 feet span, 8.8 feet rise (to match crest elevation of 31.8'), and 22 feet invert to the existing inline weir.		Add a new bridge with 6 box culverts, each with 24 feet span and 5.2 feet rise. The bridge has an invert elevation of 14 feet, bottom chord of 19.2' feet, and top of deck of 21.5 feet.	
Model Location	River station YOL/R1/56.688		River station YOL/R1/54.623	
Other changes	Modify immediate upstream and downstream cross sections of Fremont Weir (Yol/R1/56.708, 56.707, and 56.649) to reflect design changes due to Fremont Weir modifications.		– Adjust LS Yol/R1/54.818 (LB) and 54.817 (RB) in the original model.	

- *RB, LB, and LS stand for right bank, left bank, and lateral structure, respectively*

6 RESULTS

6.1 Impact on Flow

Comparisons of hydrographs between existing and Project conditions in key locations along the Sacramento River such as (i) upstream of the Fremont Weir, (ii) Verona Gage, (iii) I-Street Bridge, (iv) Freeport Bridge, (v) Walnut Grove Gage, and (vi) Rio Vista Gage are shown in Figure 12 through Figure 17. The near-identical nature of hydrographs between existing and Project conditions suggests that the Project would have a negligible impact on the overall flow pattern.

Comparisons of peak flows between existing and Project conditions in key locations along the Sacramento River and the Yolo Bypass are presented in Table 3 and Table 4, respectively. It is clear that, with the Project in place, additional water would be drawn into the Yolo Bypass. This is expected because the fish passage structure would be wider and deeper than the existing fish ladder. It should also be noted that the impact on peak flow would mainly be localized within the Project's footprint between Fremont Weir and Agricultural Road Crossing 3, beyond which there would be a minor impact on peak flow in both the Sacramento River (less than 0.06%) and the Yolo Bypass (less than 0.03%).

Table 3. Peak flow between existing and Project conditions along the Sacramento River at key locations

Locations along the Sacramento River	Existing Conditions Peak Flow (cfs)	Project Conditions Peak Flow (cfs)	Difference (cfs)
Upstream of Fremont Weir	32,052	32,028	-24
Natomas Cross Canal	99,760	99,444	-316
Verona gage	100,263	99,945	-318
Interstate 5	100,179	99,861	-318
Upstream of Sacramento Weir	100,071	99,751	-320
Interstate 80	53,433	53,342	-90
Bryte gage	53,444	53,351	-93
American River	112,696	112,641	-55
I Street Bridge	112,664	112,611	-53
Pioneer Memorial Bridge	112,639	112,584	-56
Freeport bridge	112,365	112,309	-55
Snodgrass Slough	112,281	112,222	-59
Sutter Slough	112,272	112,214	-58
Steamboat Slough	91,361	91,317	-44
Walnut Grove gage	66,053	66,023	-30
Cache Slough	46,931	46,906	-25
Rio Vista	552,877	552,923	45
3 Mile Slough	553,587	553,630	43
Collinsville gage	496,521	496,527	6

cfs = cubic feet per second

Table 4. Peak flow between existing and Project conditions along the Yolo Bypass at key locations

Locations along the Yolo Bypass	Existing Conditions Peak Flow (cfs)	Project Conditions Peak Flow (cfs)	Difference (cfs)
Fremont Weir	352,806	353,192	386
Agricultural crossing 1	352,711	353,090	379
Agricultural crossing 2	352,686	353,064	378
Knights Landing Ridge Cut	352,724	353,067	343
Interstate 5	361,813	362,157	344
Road 25 at West Levee	361,594	361,938	344
Sacramento Bypass	383,651	383,937	286
Agricultural crossing 4	464,515	464,602	87
Interstate 80	464,293	464,380	88
Putah Creek	463,354	463,445	91
Lisbon Gage	462,111	462,209	98
North end of Holland Tract	459,998	460,096	98
South end of Holland Tract	459,228	459,322	95
DWSC at Miner Slough	320,491	320,532	41

cfs = cubic feet per second

6.2 Impact on Maximum Water Surface Profile

Comparisons of maximum water surface profiles between existing and Project conditions in the Sacramento River and Yolo Bypass are presented in Figure 18 through Figure 22; numerical differences of maximum WSE at key locations along the Sacramento River and Yolo Bypass are presented in Table 5 and Table 6, respectively.

From these figures and tables, it is clear that the Project would have a negligible hydraulic impact on conveyance of peak flood flows. The Project would slightly lower the maximum WSE in both the Sacramento River and Yolo Bypass. In the Sacramento River, the maximum WSE change would be nominal (less than 0.1 feet). This change can be directly correlated with the minor reduction in peak flows in the Sacramento River as shown in Table 3. The WSE change in the Yolo Bypass would be more than that in the Sacramento River; however, the change would be localized. The zone of change would be confined within the Project's footprint between Fremont Weir and Agricultural Road Crossing 3 (refer to Figure 21).

It should be noted that although the Project would draw more water into the Yolo Bypass, there would be a drop in the maximum water surface profile. This result is expected because under Project conditions, Agricultural Road Crossing 3, which holds water up to an elevation of 15.6 feet under existing conditions, would be removed. In addition, the flow area of Agricultural Road Crossings 2 would increase, helping water to move freely without backing-up. There would be a negligible hydraulic impact on maximum water surface profile (less than 0.01 feet) downstream of Agricultural Road Crossing 3.

Table 5. Maximum Water Surface Elevation (WSE) between existing and Project conditions along the Sacramento River at key locations

Locations along the Sacramento River	Existing Conditions Maximum WSE (ft. NAVD88)	Project Conditions Maximum WSE (ft. NAVD88)	Difference (ft.)
Upstream of Fremont Weir	41.17	41.09	-0.08
Natomas Cross Canal	41.33	41.29	-0.04
Verona gage	41.24	41.2	-0.04
Interstate 5	37.87	37.84	-0.03
Upstream of Sacramento Weir	33.94	33.93	-0.01
Interstate 80	34.43	34.42	-0.01
Bryte gage	34.43	34.42	-0.01
American River	34.43	34.42	-0.01
I Street Bridge	33.91	33.9	-0.01
Pioneer Memorial Bridge	32.67	32.65	-0.02
Freeport bridge	27.76	27.75	-0.01
Snodgrass Slough	22.95	22.94	-0.01
Sutter Slough	21.38	21.37	-0.01
Steamboat Slough	20.49	20.49	0
Walnut Grove gage	17.45	17.45	0
Cache Slough	11.82	11.82	0
Rio Vista	11.54	11.54	0
3 Mile Slough	9.82	9.82	0
Collinsville gage	8.3	8.3	0

ft. = feet
NAVD88 = North American Vertical Datum of 1988

Table 6. Maximum Water Surface Elevation (WSE) between existing and Project conditions along the Yolo Bypass at key locations

Locations along the Yolo Bypass	Existing Condition Maximum WSE (ft. NAVD88)	Project Condition Maximum WSE (ft. NAVD88)	Difference (ft.)
Fremont Weir	40.32	40.25	-0.08
Agricultural crossing 1	37.62	37.46	-0.18
Agricultural crossing 2	37.26	37.10	-0.18
Knights Landing Ridge Cut	36.53	36.54	0.01
Interstate 5	33.50	33.51	0.01
Road 25 at West Levee	32.10	32.11	0.01
Sacramento Bypass	30.02	30.02	0.01
Agricultural crossing 4	29.87	29.87	0
Interstate 80	29.06	29.06	0
Putah Creek	27.59	27.59	0

Lisbon Gage	26.28	26.28	0
North end of Holland Tract	21.43	21.43	0
South end of Holland Tract	19.05	19.05	0
DWSC at Miner Slough	15.81	15.81	0

ft. = feet
NAVD88 = North American Vertical Datum of 1988

6.3 Impact of the Project on Local Hydraulics

Additional analyses were performed to determine whether there would be any change in local velocity at the time of overtopping due to implementation of the Project, as any significant change in local velocity may lead to local scour. In order to determine this, channel velocities in the cross sections immediately downstream of the Project components (Fremont Weir and three agricultural crossings) were compared between exiting and Project conditions (Table 7) at times when water surface elevations were close to the top of the structures (note that these elevations may be reached at different times). The results indicate that there would be a negligible impact on channel velocities due to implementation of the Project.

Table 7. Comparison of local channel velocities at the time of overtopping

Project Components	Immediate downstream cross section	Existing Conditions Channel Velocity (fps)	Existing Conditions Corresponding WSE (ft.)	Project Conditions Channel Velocity (fps)	Project Conditions Corresponding WSE (ft.)
Fremont Weir fish passage structure	Yolo/R1/56.649	1.93	31.37	1.93	31.36
Agricultural Road Crossing 1	Yolo/R1/55.006	0.31	21.05	0.3	21.06
Agricultural Road Crossing 2	Yolo/R1/54.447	0.3	21	0.3	21.01
Agricultural Road Crossing 4	Yolo/Sac Bypass-WSB/43.582	0.42	13.86	0.43	13.92

fps = feet per second
WSE =water surface elevation
ft. = feet

REFERENCES

California Department of Water Resources. 2016. Fremont Weir Adult Fish Passage Modification Project Initial Study/Environmental Assessment (Draft). Sacramento, CA. Last Revised: April 08, 2016.

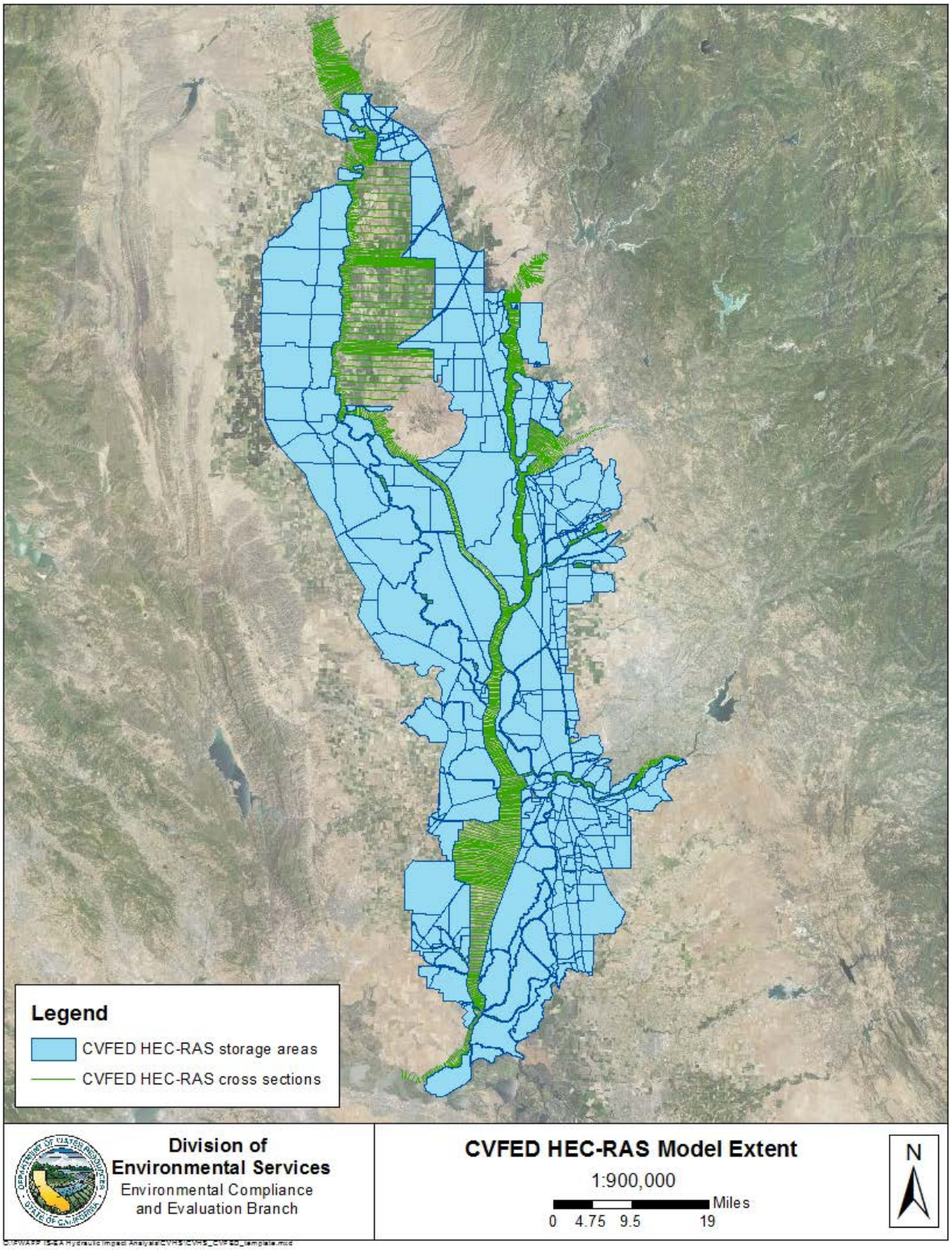

Figure 1. Schematic of CVFED HEC-RAS Model

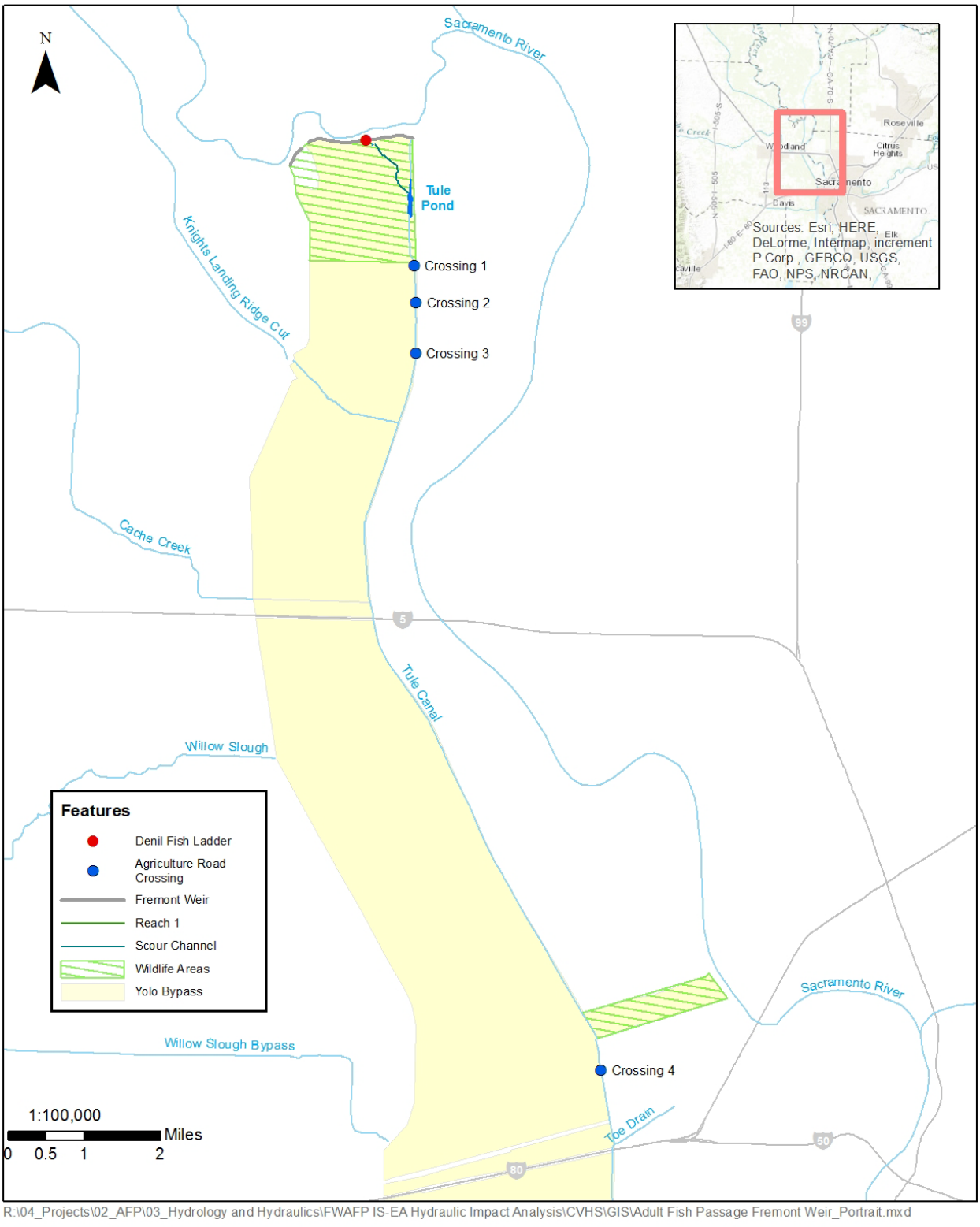

Figure 2. Overview Map

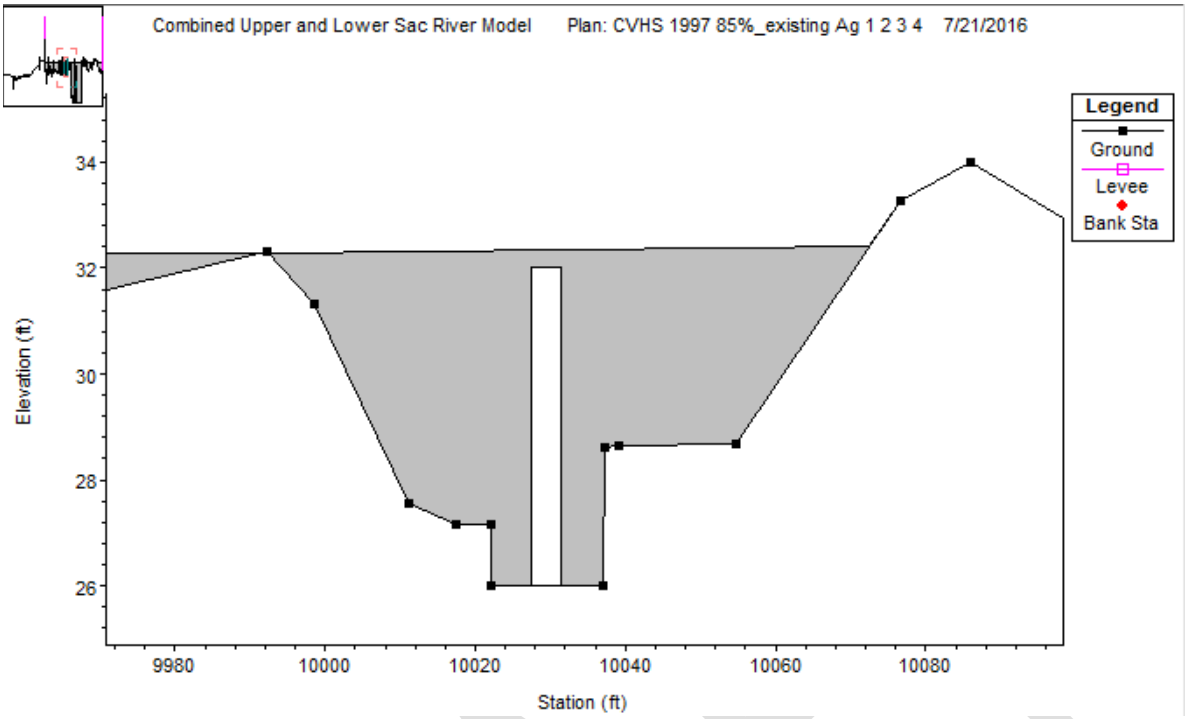

Figure 3. HEC-RAS Schematic of Fremont Weir under Existing Conditions

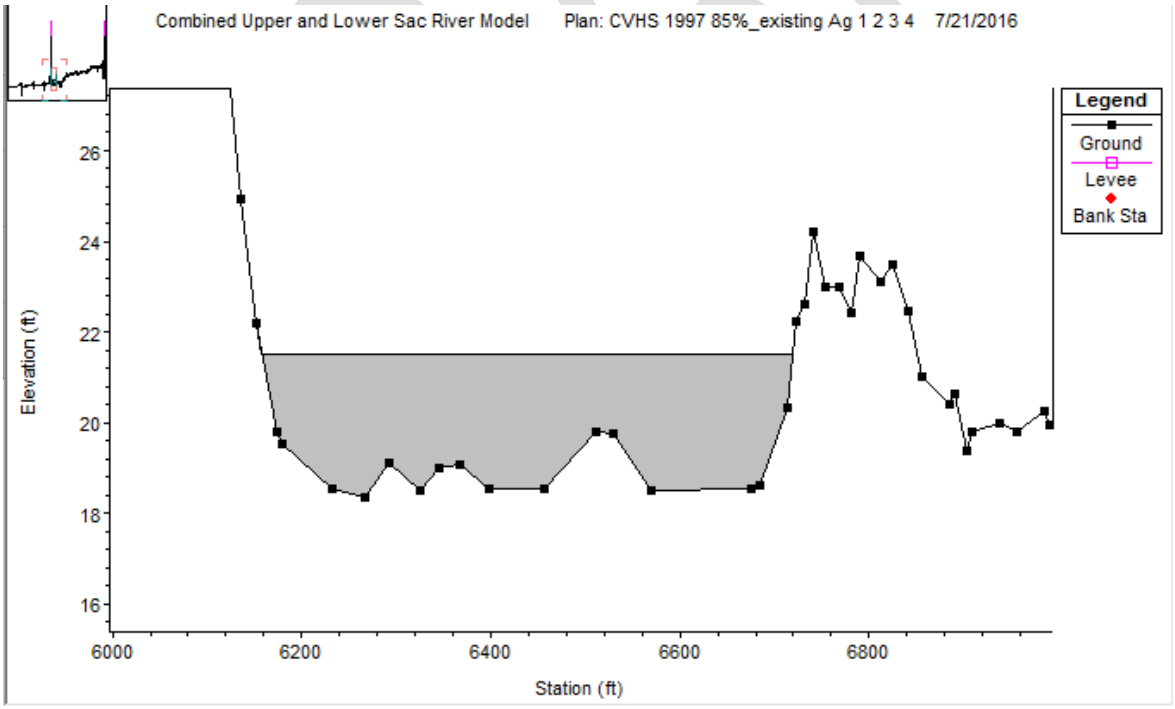

Figure 4. HEC-RAS Schematic of Agricultural Road Crossing 1 under Existing Conditions

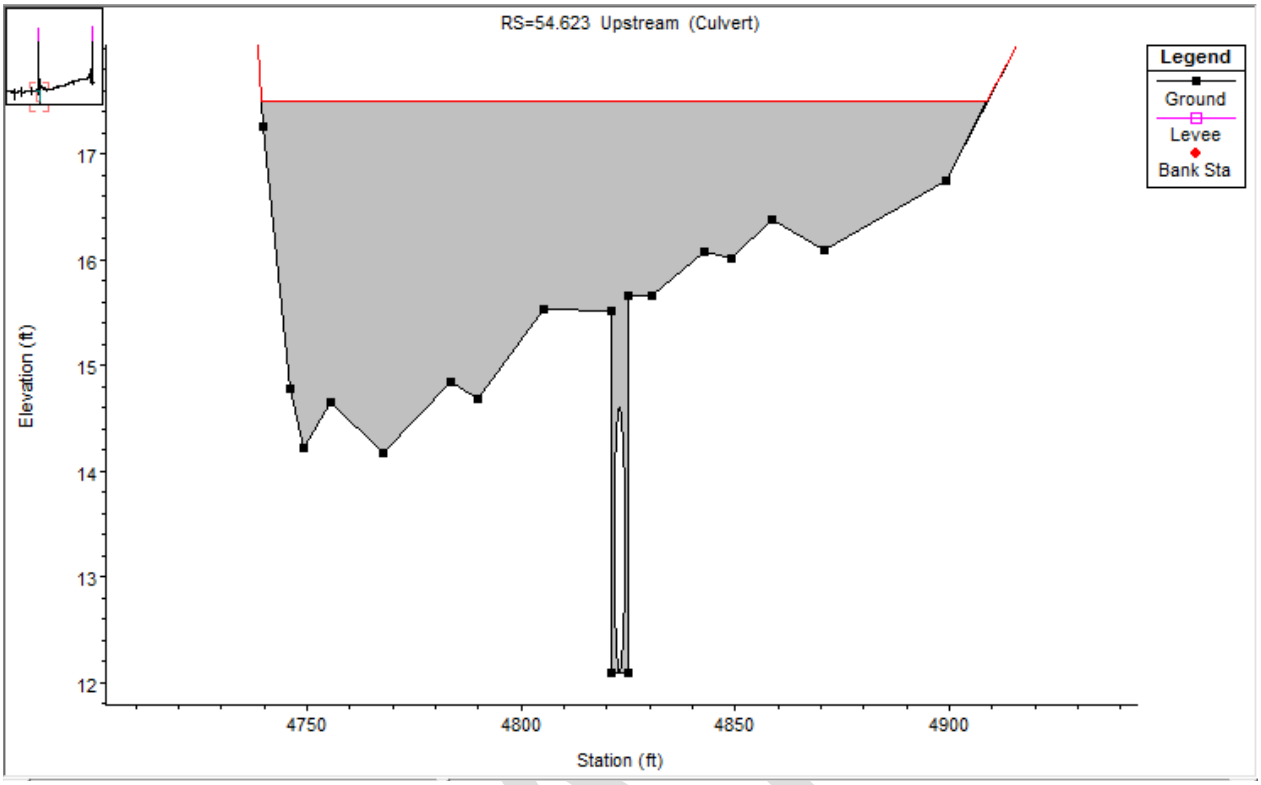

Figure 5. HEC-RAS Schematic of Agricultural Road Crossing 2 under Existing Conditions

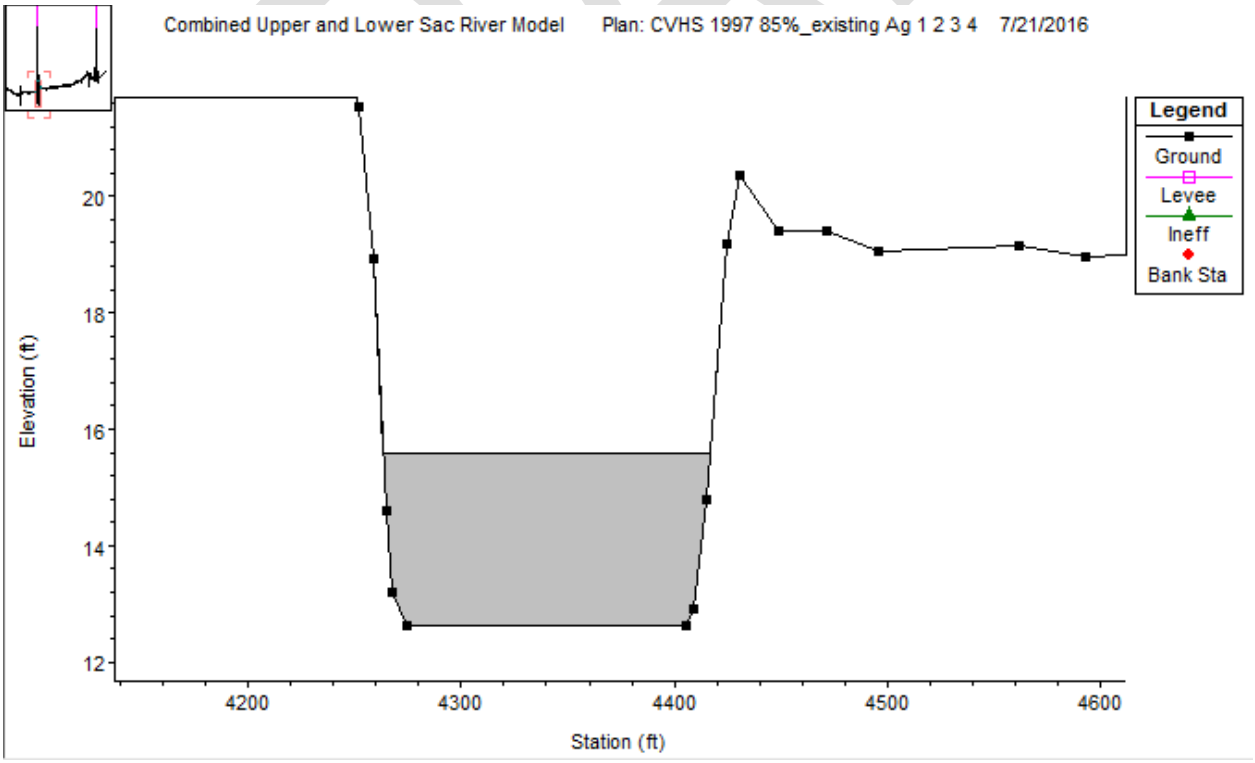

Figure 6. HEC-RAS Schematic of Agricultural Road Crossing 3 under Existing Conditions

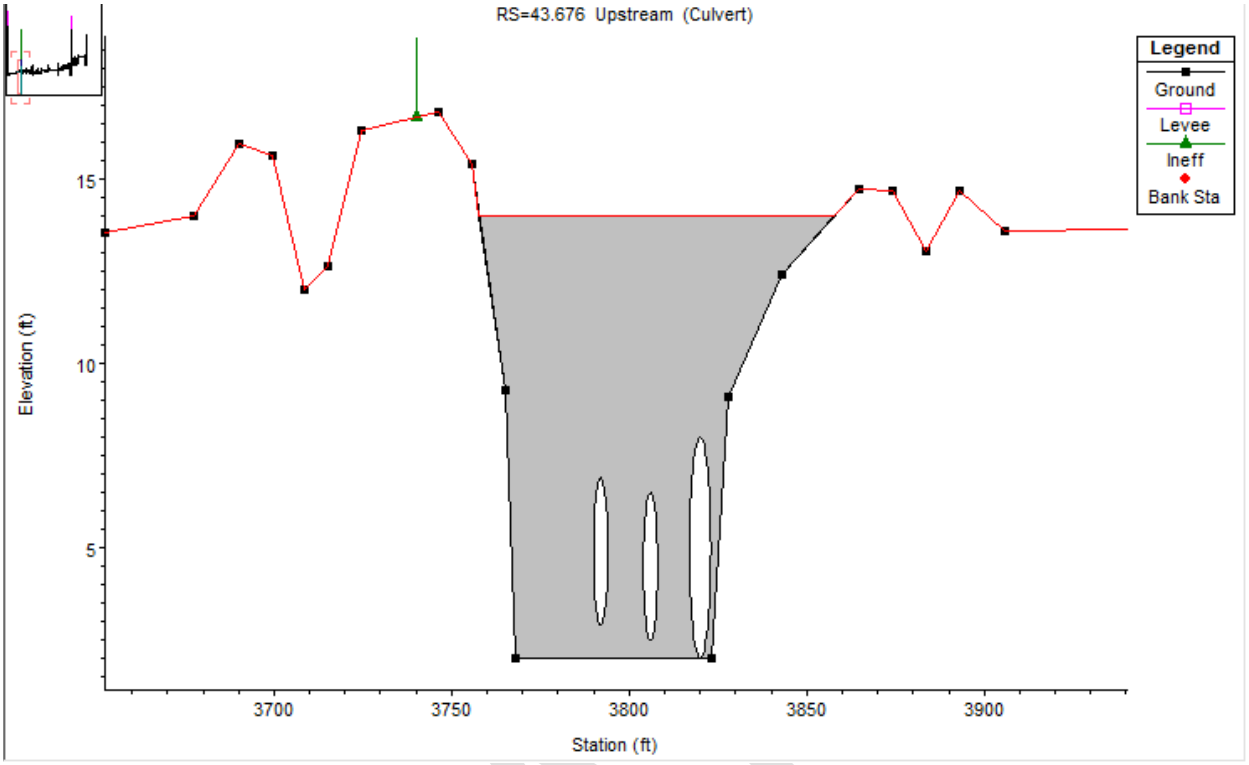

Figure 7. HEC-RAS Schematic of Agricultural Road Crossing 4 under Existing Conditions

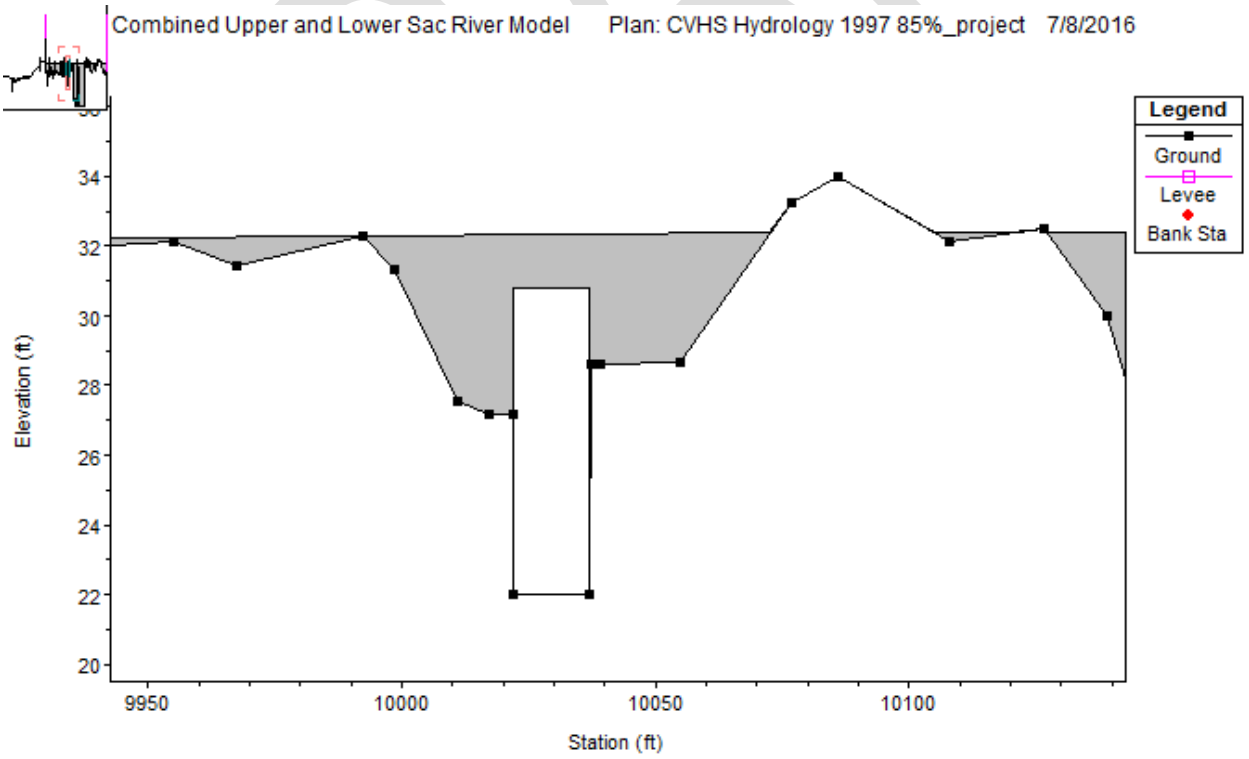

Figure 8. HEC-RAS Schematic of Fremont Weir under Project Conditions

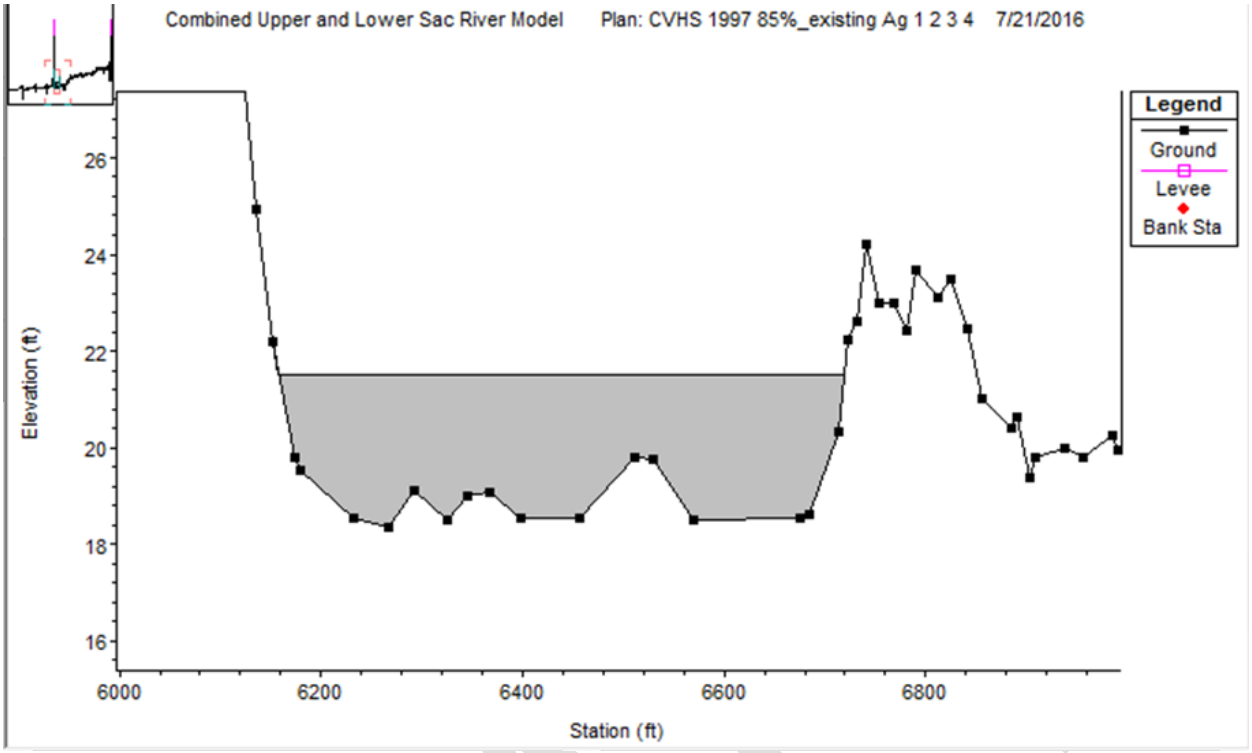

Figure 9. HEC-RAS Schematic of Agricultural Road Crossing 1 under Project Conditions (same as Existing Conditions)

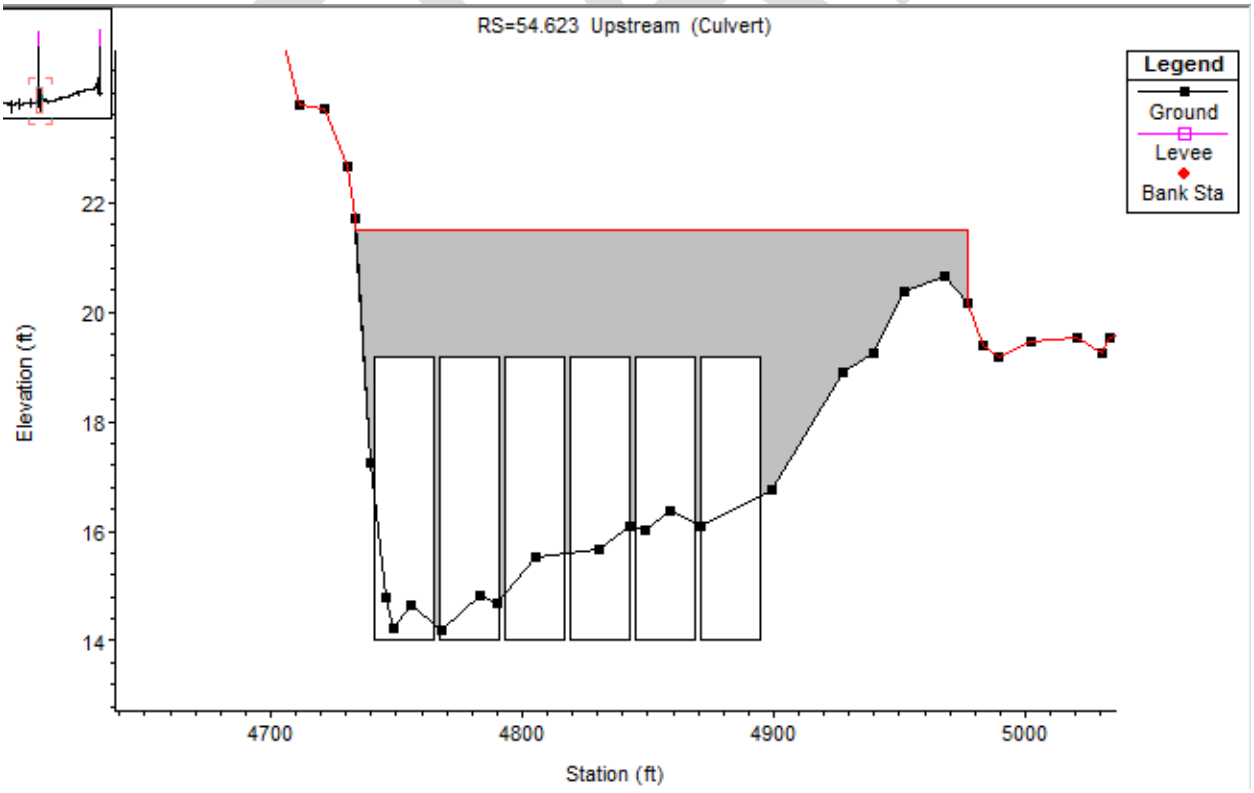

Figure 10. HEC-RAS Schematic of Agricultural Road Crossing 2 under Project Conditions

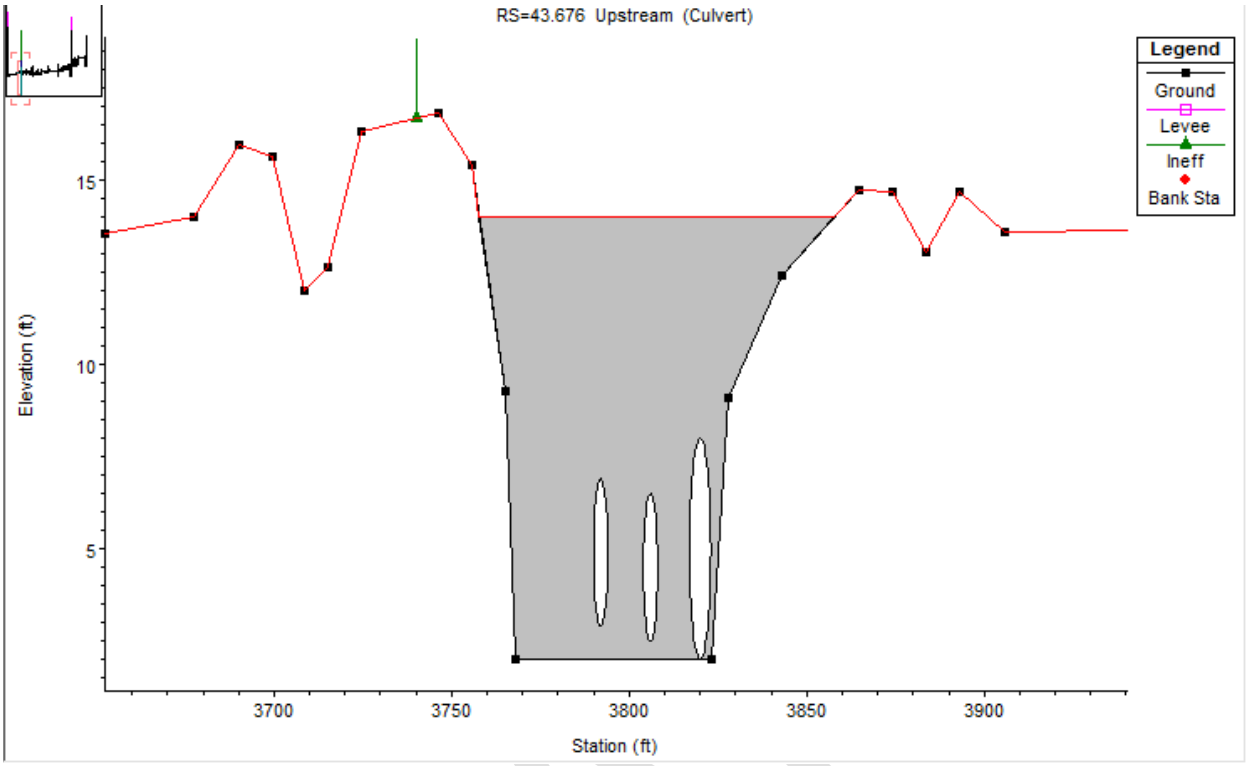

Figure 11. HEC-RAS Schematic of Agricultural Road Crossing 4 under Project Conditions (same as Existing Conditions)

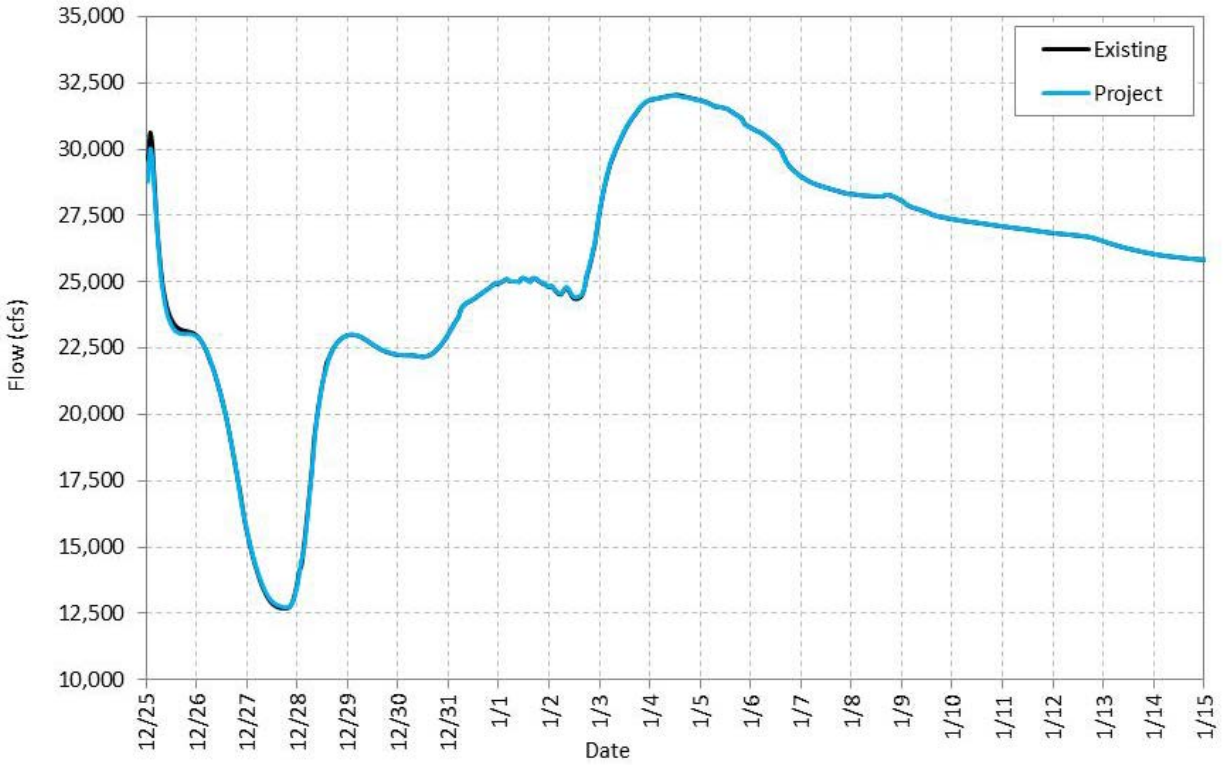

Figure 12. Comparison of Hydrographs between Existing and Project conditions upstream of the Fremont Weir

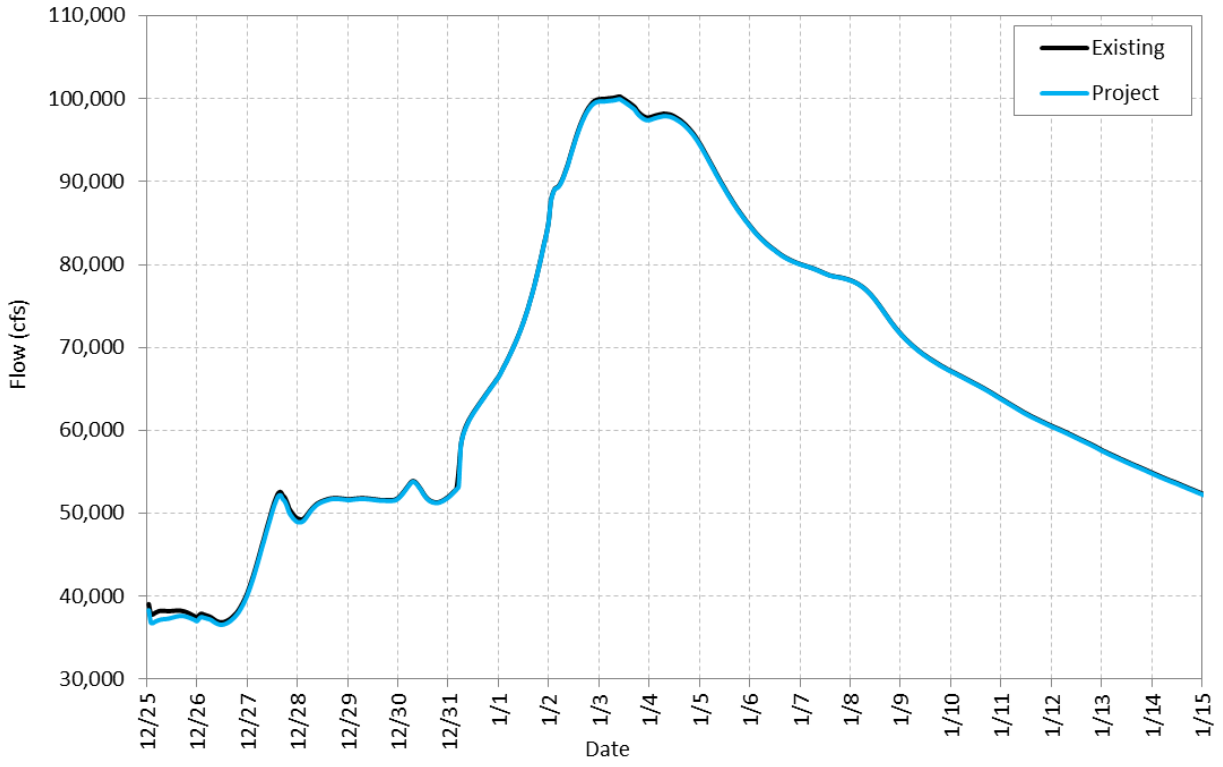

Figure 13. Comparison of Hydrographs between Existing and Project conditions at the Verona Gage

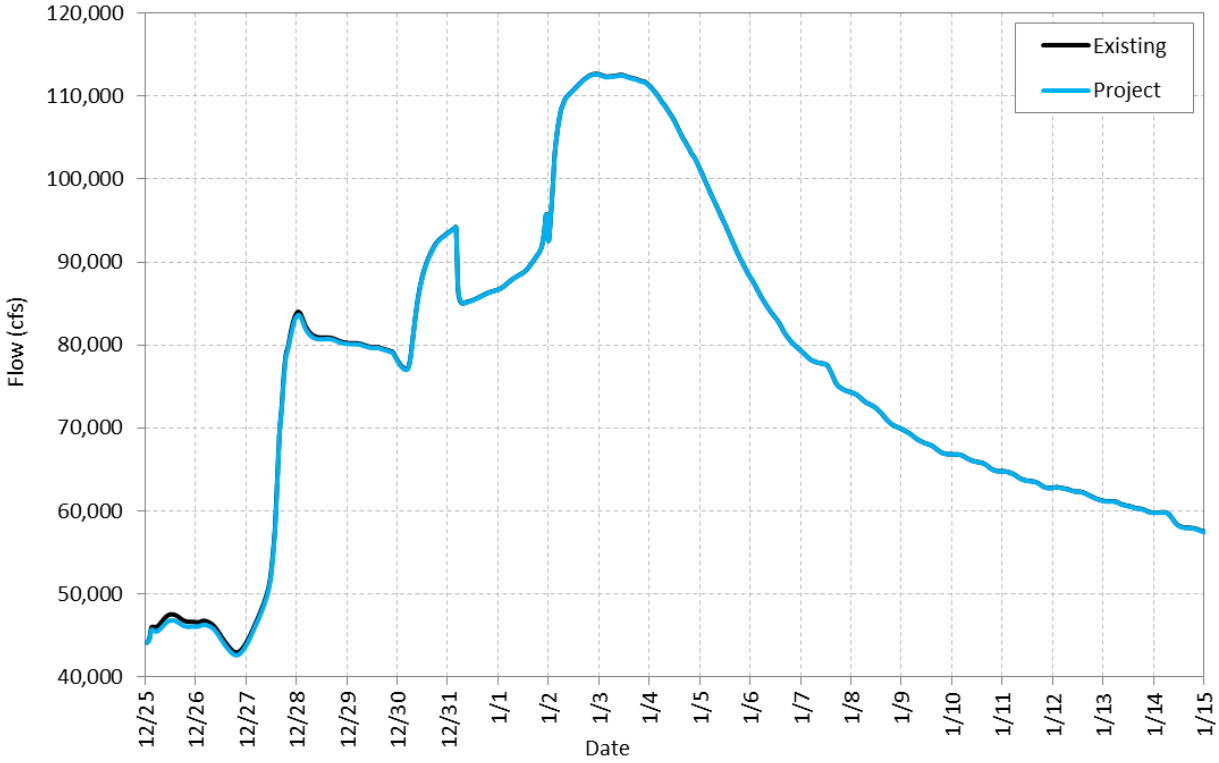

Figure 14. Comparison of Hydrographs between Existing and Project conditions at the I-Street Bridge

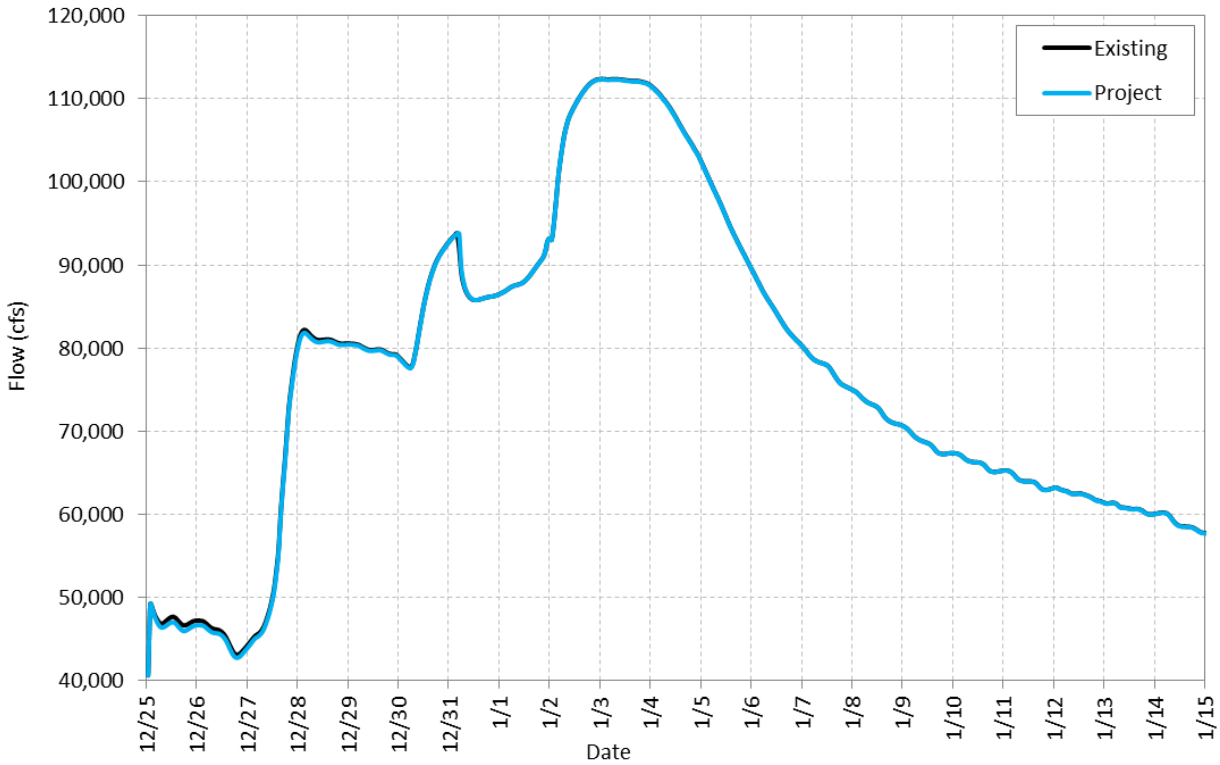

Figure 15. Comparison of Hydrographs between Existing and Project conditions at the Freeport Bridge

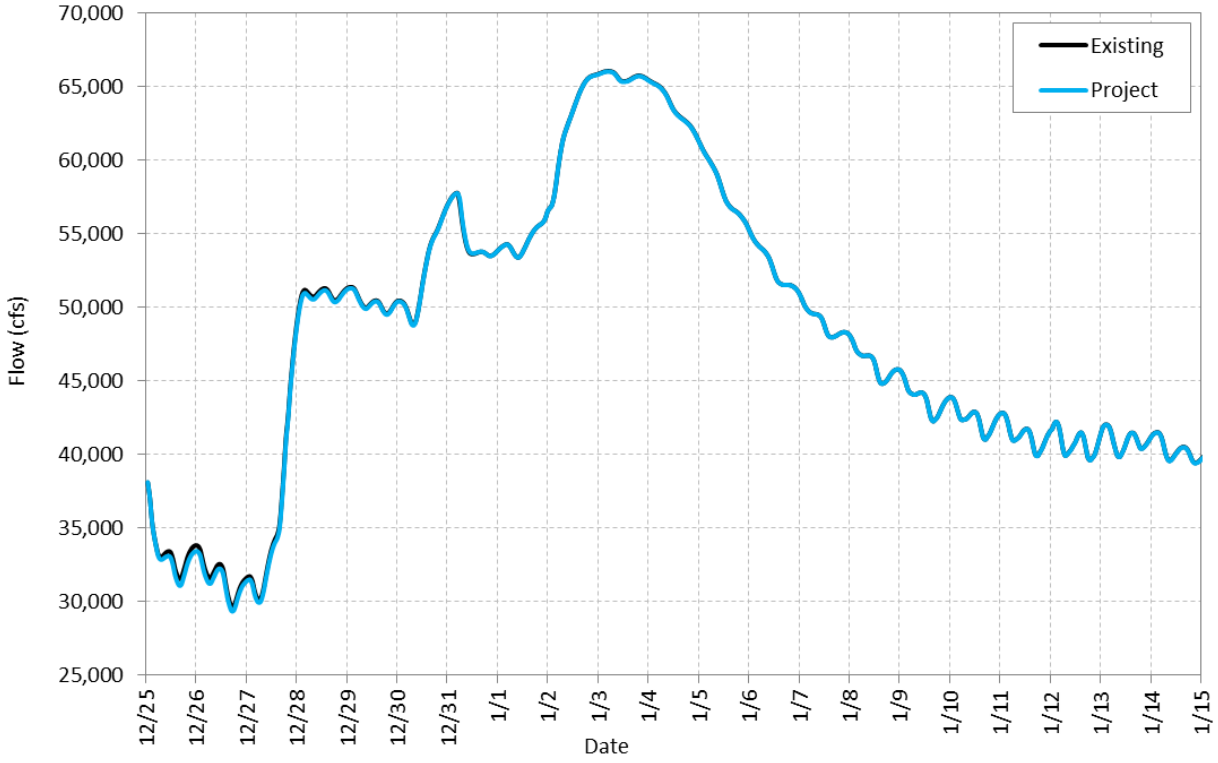

Figure 16. Comparison of Hydrographs between Existing and Project conditions at the Walnut Grove Gage

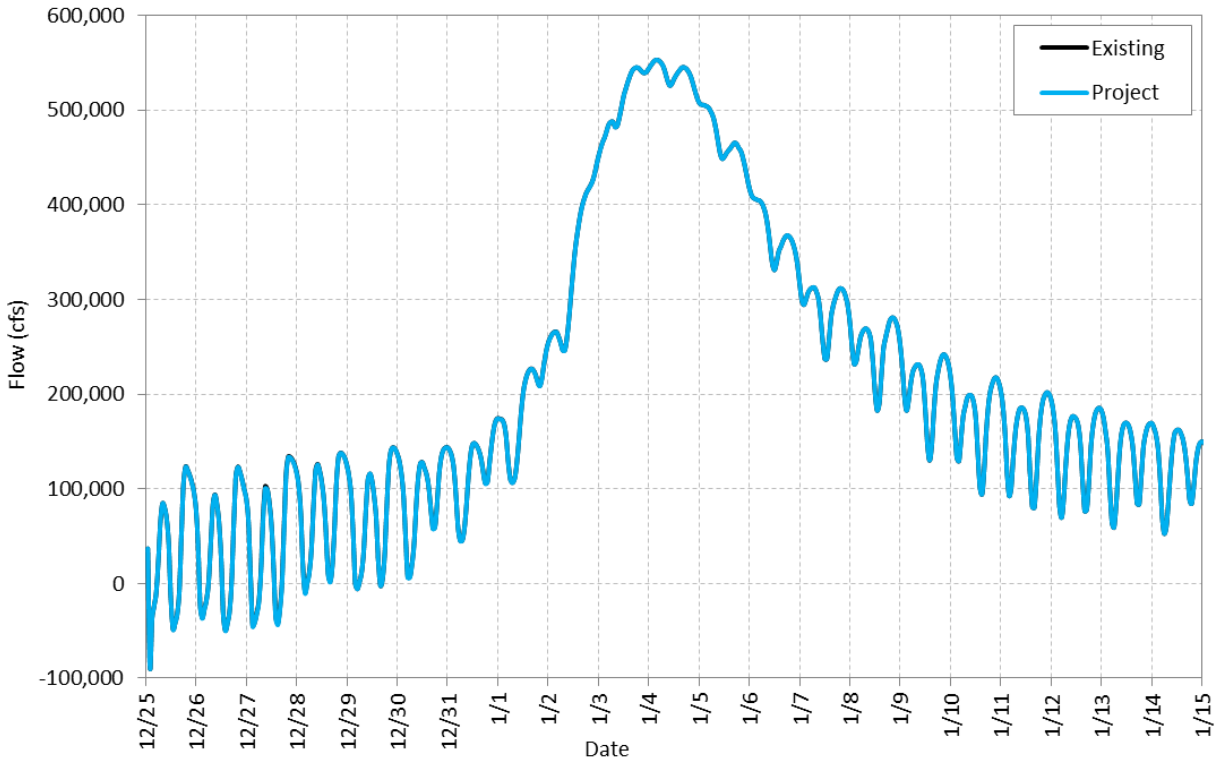

Figure 17. Comparison of Hydrographs between Existing and Project conditions at the Rio Vista Gage

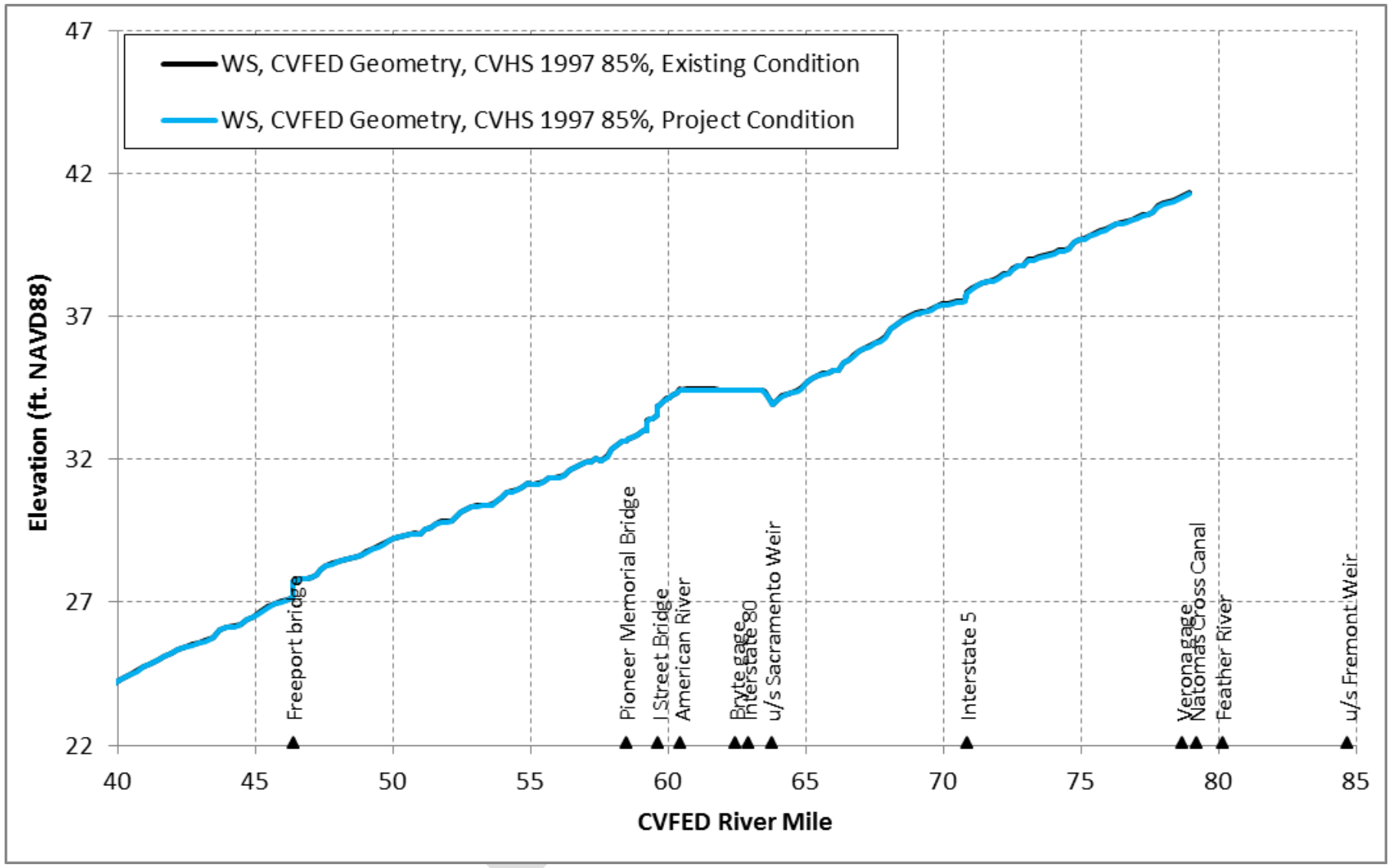

Figure 18. Maximum Water Surface Elevation (WSE) Profiles Comparison between Existing and Project Conditions in the Sacramento River between CVFED River Miles 40 to 85

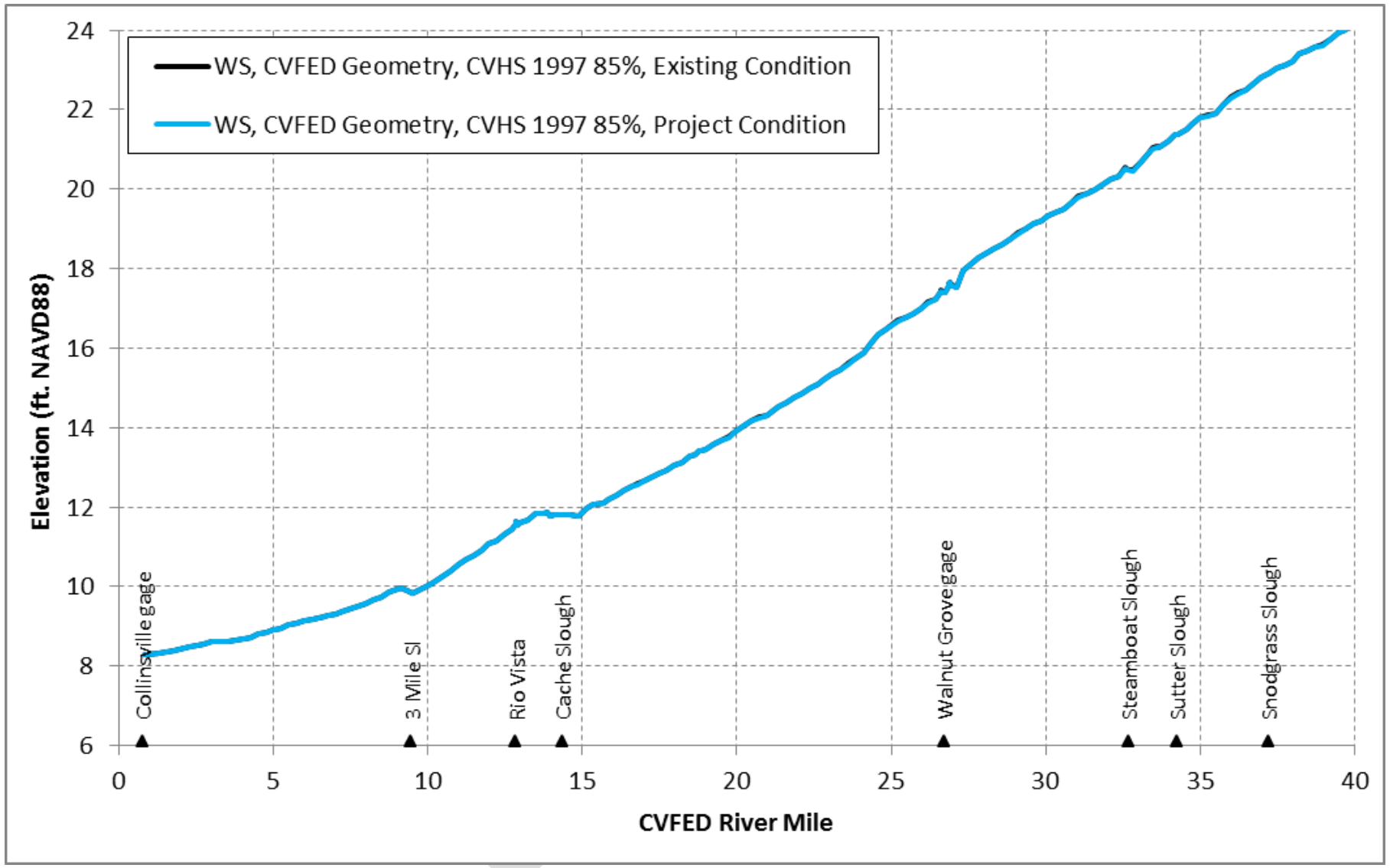

Figure 19. Maximum Water Surface Elevation (WSE) Profiles Comparison between Existing and Project Conditions in the Sacramento River between CVFED River Miles 0 to 40

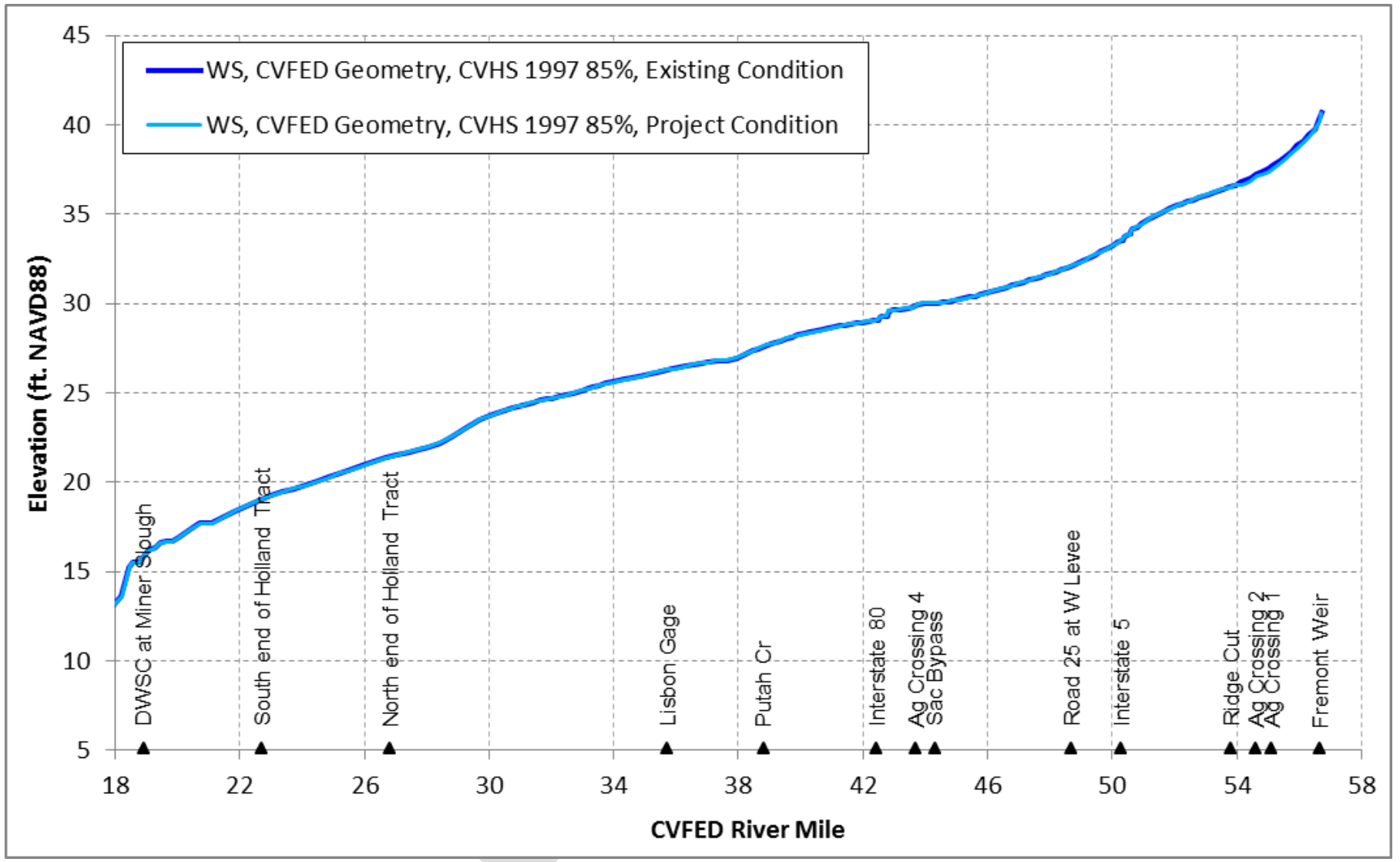

Figure 20. Maximum Water Surface Elevation (WSE) Profiles Comparison between Existing and Project Conditions in the Yolo Bypass

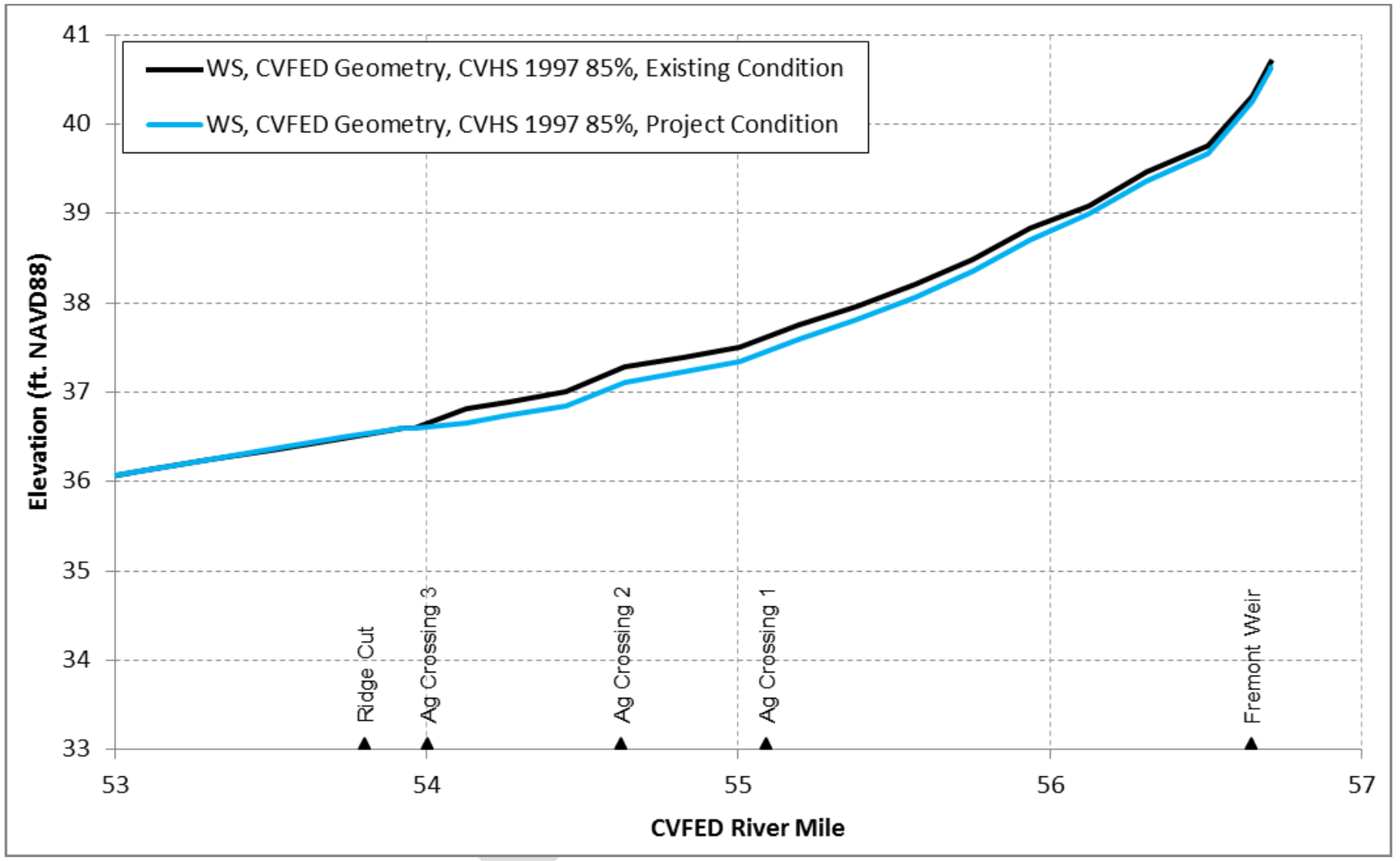

Figure 21. Maximum Water Surface Elevation (WSE) Profiles Comparison between Existing and Project Conditions in the Yolo Bypass in the Vicinity of Agricultural Road Crossings 1 and 2

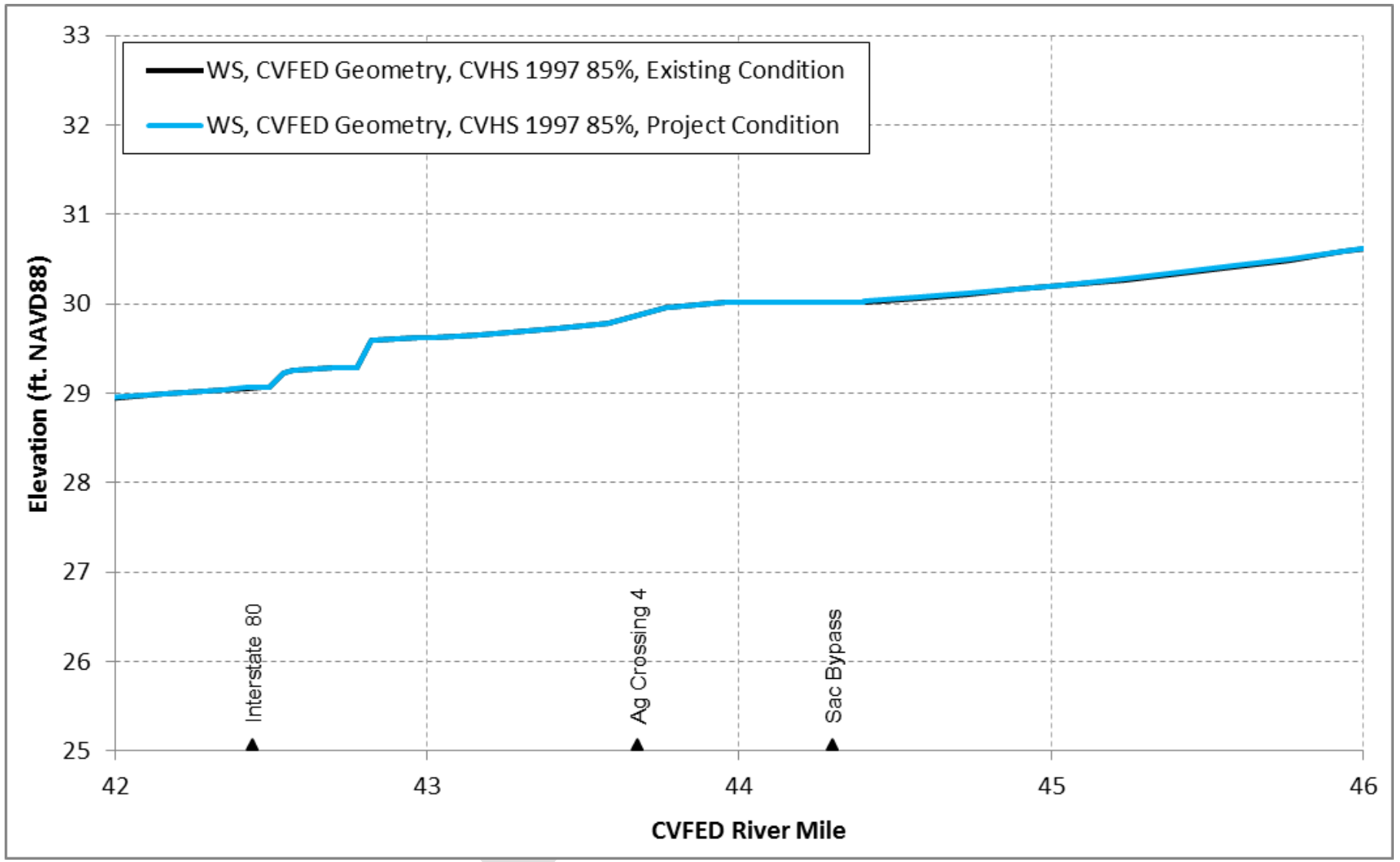

Figure 22. Maximum Water Surface Elevation (WSE) Profiles Comparison between Existing and Project Conditions in the Yolo Bypass in the Vicinity of Agricultural Road Crossing 4