FINAL HYDRAULIC STUDY

SALEM STREET BRIDGE AT LITTLE CHICO CREEK

Bridge Number 12C0336

City of Chico, CALIFORNIA

AVILA & ASSOCIATES

~DRAFT~

Final Hydraulic Study

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City of Chico, CALIFORNIA

Bridge #12C0336

SEPTEMBER 21, 2020

PREPARED FOR:

MARK THOMAS AND CITY OF CHICO DEPARTMENT OF PUBLIC WORKS

Prepared by:

AVILA AND ASSOCIATES
CONSULTING ENGINEERS, INC.

Catherine M.C. Avila, P.E

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EXECUTIVE SUMMARY

The Salem Street Bridge (bridge) at Little Chico Creek in Chico, California is proposed for replacement by The City of Chico. The proposed bridge is a single span cast-in-place post-tensioned concrete voided slab bridge. The bridge will be 48.3 feet wide and will accommodate two 12-ft travel lanes with 5-ft shoulders and 6.2 ft sidewalks as shown in the attached General Plan (See Appendix A). The superstructure will be supported by assumed 24-inch cast-in-drilled-hole type piles.

Little Chico Creek flows southwesterly through the western part of Butte County (County) draining an approximate 48.3-square mile basin at the bridge site. The discharges used for the bridge hydraulic analysis are shown in Table 1.

Table 1. Estimated discharges and water surface elevations for bridge design

	CVFPB	Design	Base
Frequency (years)	Not available	50	100
Discharge (cubic feet per second)	3,000	2,800	2,800
Water Surface (elevation in feet at upstream face of Bridge)	192.7	192.1	192.1
Freeboard (feet)	0.3	0.9	0.9

This study used hydraulic modeling based on a HEC-RAS[1] model version 5.0.7 to estimate the water surface elevation (WSE) for the existing and proposed bridge. Results indicate that after construction of the new bridge, the water surface elevation will be lowered upstream from the bridge and slightly increased (less than 0.4 feet) just downstream of the bridge due to the new draw down curve. With a proposed minimum soffit elevation of 193 feet, there will be approximately 0.9 feet of freeboard over the 50-yr and 100-yr WSE of 192.1 feet. The proposed bridge will improve the hydraulics because it will be a single span bridge instead of a three-span bridge. The removal of the existing piers will improve the hydraulics through the bridge reach.

This report follows the California Department of Transportation (Caltrans) Final Hydraulic Report Format and has been prepared in accordance with the Caltrans Local Assistance Program Guidelines (Caltrans 2018) and Memos to Designers 16-1 [2].

[1] US Army Corps of Engineers Hydraulic Engineering Center River Analysis System which backwater hydraulic model designed to perform one-dimensional hydraulic calculations for a full network of natural and constructed channels.
[2] Caltrans Memo to Designers 16-1 December 2017 (http://www.dot.ca.gov/des/techpubs/manuals/bridge-memo-to-designer/page/section-16/MTD_16-1-attach1.pdf)

GENERAL

This design hydraulic study has been prepared for the sole purpose of meeting the requirements of the Caltrans "Local Assistance Program Guidelines." Although potentially useful for other purposes, this analysis has not been prepared for any other purpose. Reuse of information contained in this report for purposes other than for which Avila and Associates Consulting Engineers, Inc. (Avila and Associates) intended and without their written authorization is not endorsed or encouraged and is at the sole risk of the entity reusing the information.

Avila and Associates was retained to complete the bridge hydrology, hydraulics, and scour analysis for the replacement of the existing Salem Street Bridge over Little Chico Creek in The City of Chico. The location of this project is shown in Figure 1. The following scope of work has been completed to develop this report:

1. Obtain backup information and field review.
2. Estimate hydrology.
3. Create HEC-RAS model.
4. Estimate scour, channel bed degradation and bank protection parameters.
5. Prepare draft report for comment.
6. Prepare final report.
7. Complete location hydraulic study.

The existing bridge is located approximately in the City of Chico as shown in Figure 1. The existing bridge was constructed in 1930. It is a continuous reinforced concrete T-Girder (7) on reinforced concrete pier walls and reinforced concrete abutments, all supported by spread foundations. It has a sufficiency rating as of 75.4 as of 2014 and is functionally obsolete. The City of Chico Public Works proposes to replace the existing bridge using Highway Bridge Program (HBP) funds.

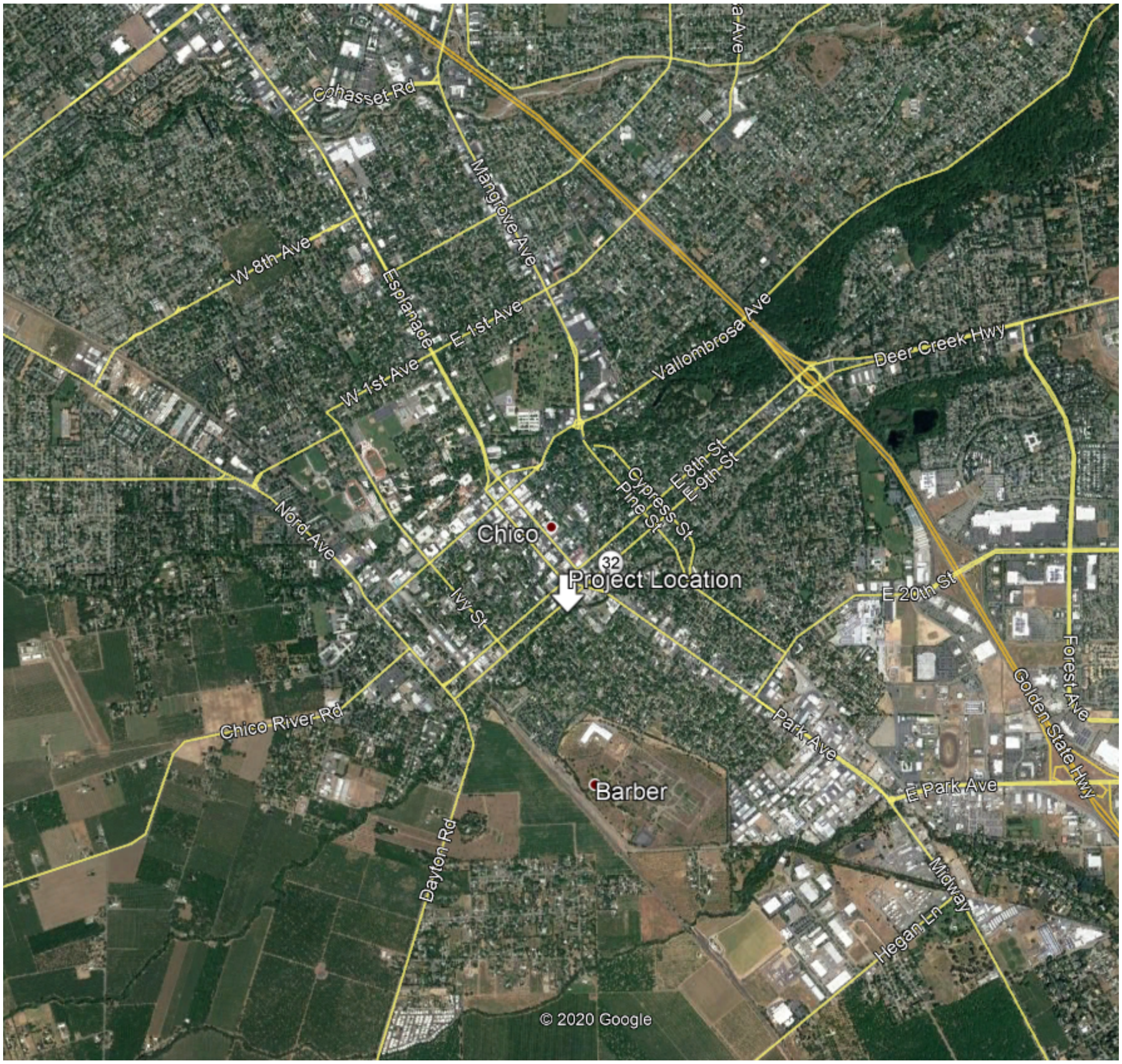


Figure 1. Bridge location map

The datum elevation used for this study is the same as the project topographic survey which is based on the City of Chico's own datum. According to the project surveyor, the conversion from the City datum to NAVD-88 is +3.07 ft[3]. The proposed bridge will be located on the same alignment as the existing bridge. As shown in Figure 2, the proposed bridge is a single span cast-in-place post-tensioned concrete voided slab bridge. The bridge will be 48.3 feet wide and will accommodate two 12-ft travel lanes with 5-ft shoulders and 6.2 ft sidewalks as shown in the attached General Plan (See Appendix A). The superstructure will be supported by assumed 24-inch cast-in-drilled-hole type piles.

[3] Electronic mail from Julie Passalacqua, Structures Division Manager, Mark Thomas to Cathy Avila, Project Manager, Avila and Associates dated September 7, 2017.

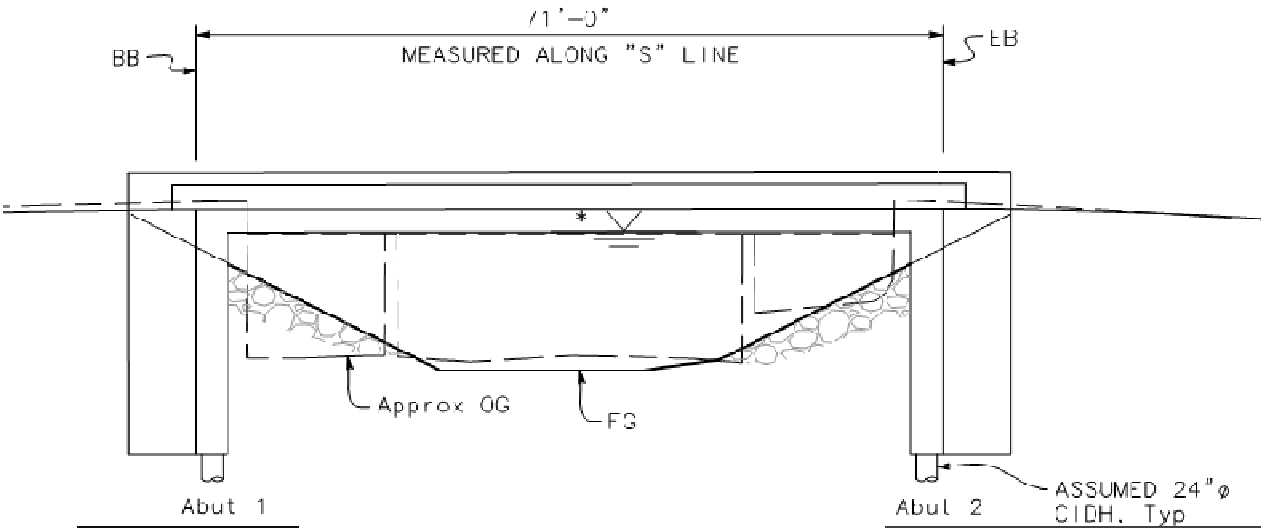


Figure 2. Proposed bridge profile view

BRIDGE HISTORY

Avila and Associates reviewed the pertinent bridge maintenance records for the existing bridge to review the typical impacts to bridges along this reach. Details of the bridge and a summary of the maintenance records are shown in Table 2.

Table 2. Bridge details and summary of maintenance records

	Chestnut Street at Little Chico Creek	Salem Street at Little Chico Creek	Broadway Street over Little Chico Creek
Bridge Number	12C0335	12C0336	12C00337
Bridge Length (ft)	78	30.8	49.9
Span Lengths (ft)	1 @ 22.6, 1 @ 29.9, 1 @ 22.6	1 @ 15.1, 1 @ 30.8, 1 @ 15.1	1 @ 48
Bridge Type	Continuous RC slab on RC column/pile extension (7) bents and RC end diaphragm abutments. Abutments founded on driven RC piles and bents founded on continuous spread footings	Continuous RC T-girder (7) on RC pier walls and RC abutments. All founded on spread footings	Original: Simply supported RC t-girders (6) with RC diaphragm abutments with monolithic wingwalls. Foundations unknown. Left widening: simply supported RC T-girders (6) with left cantilevered RC sidewalk, on original abutments.
Debris Challenges	None noted	1985[4], 2002[5], 2004[6]	
Cross Sections Available for	1992, 2001, 2010	2002, 2010	2002, 2010
NBIS Item 113 (scour) code	8	5	U
ELI Flag 361 Condition State[7]	n/a	2	2
ELI 210/6000 (Pier Wall – RC/ Scour)[8]	n/a	2	2
Pier Type	RC column/ pile extension	RC Pier walls	n/a
Year Built	1980	1930	1920
Year Widened	n/a	n/a	1930
Scour	2010[9]	1989[10], 1992[11],1997[12],	1992[22], 2007[23], 2008[24],

[4] Debris accumulated on upstream side of P3
[5] Debris build up on the nose of Pier 3, approximately 1 cubic meter
[6] Debris build up on the upstream nose of Piers 2 and 3
[7] In 2012 before change in inspection methodology
[8] In 2014 after change in inspection methodology

Challenges		1998[13], 2000[14], 2002[15], 2004[16], 2007[17], 2008[18], 2010[19], 2013[20], 2014[21]	2010[25], 2012[26], 2014[27], 2016[28]

[9] A comparison of the channel section from 2001 indicates the channel is approximately 2 feet lower at P2
[10] Undermining of right wingwall and sidewalk at A4. The sidewalk is being undermined at the A1 right wingwall.
[11] Undermining of riprap and right wingwall at A4 approximately 2 feet back and around the end of the wingwall.
[12] Erosion at A4 has undermined the sidewalk
[22] There is a scour holes 6" deep, 6' wide to 0' at 8' along footing with 6" of footing exposed at the right Abutment 1.
[23] The top of the abutment footings are exposed along the middle section, however no undermining was observed.
[24] Top of footings are exposed at both abutments with no undermining
[13] The sidewalk is being undermined at the right wingwall of A1. There is undermining of the right wingwall and sidewalk at A4.
[14] Same as 1998
[15] Same as 2000
[16] Same as 2002
[17] Significant erosion behind the right wingwall at A4 extending under the adjacent approach sidewalk. The sidewalk is completely unsupported and cantilevered over the now vertical embankment. In addition, there is a 50 mm offset between the bridge sidewalk and approach sidewalk.
[18] Same as 2007.
[19] Same as 2008. Channel cross section indicates channel has lowered 0.8 m at the Span 2 midspan since 2009
[20] Local scour hole at the upstream side of P3, approximately 50 feet by 20 feet by 10 feet deep. The hole contributed to the exposure of the nose of P3 but did not expose sections of the foundation. The height from the channel elevation to the bottom of the RC stiffener beam at the nose of P3 was measured at 14 feet 8 inches. Embankment at A4 right side appeared to be eroding due to roadway runoff and flow in the channel. Due to the erosion, a 4 ft long section of the wingwall was undermined to a maximum of 10 inches deep and 6 inches vertically.
[21] Same as 2013. Scour hole is now 8 feet deep.
[25] Top of footing is exposed along a 3 m middle section of A2. The channel section indicates flow has shifted toward A2 with 2 feet degradation near the abutment and 2 feet aggradation in the midspan.
[26] A1 and A2 foundation was exposed along a 15' section about the centerline of the structure. The top and side of the foundations were exposed up to 8" (A1) and 3" (A2). Channel section indicates channel degraded 1 ft at the midspan and 2.5 feet at A2. Aggradation shown at A1 is attributed to placement of RSP.
[27] Same as 2012 with foundation at A2 exposed 8"
[28] Same as 2014.

BASIN AND DISCHARGE

The watershed draining to the bridge is 48.3 square miles as shown in Figure 3. The average annual rainfall for the watershed is approximately 42 inches per year[29]. Little Chico Creek carries flow southwesterly to the bridge site.

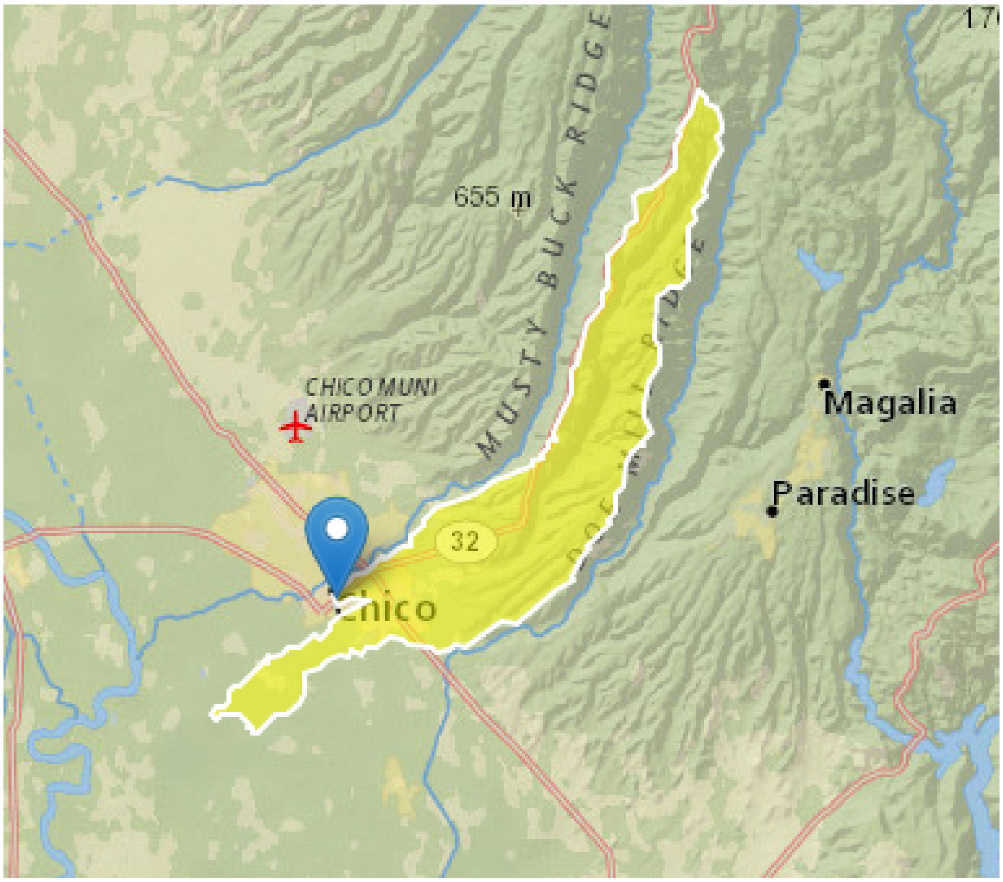


Figure 3. Basin contributing to the bridge (USGS streamstats)

As shown in Figure 4, approximately 4 miles upstream from the project, the Little Chico – Butte Creek Diversion Structure diverts high flows from Little Chico Creek to Butte Creek and regulates the flow in Little Chico Creek. Therefore, a Flood of Record for the project was not determined as it is not applicable.

[29] **www.streamstatsags.cr.usgs.gov** (U.S.G.S.)

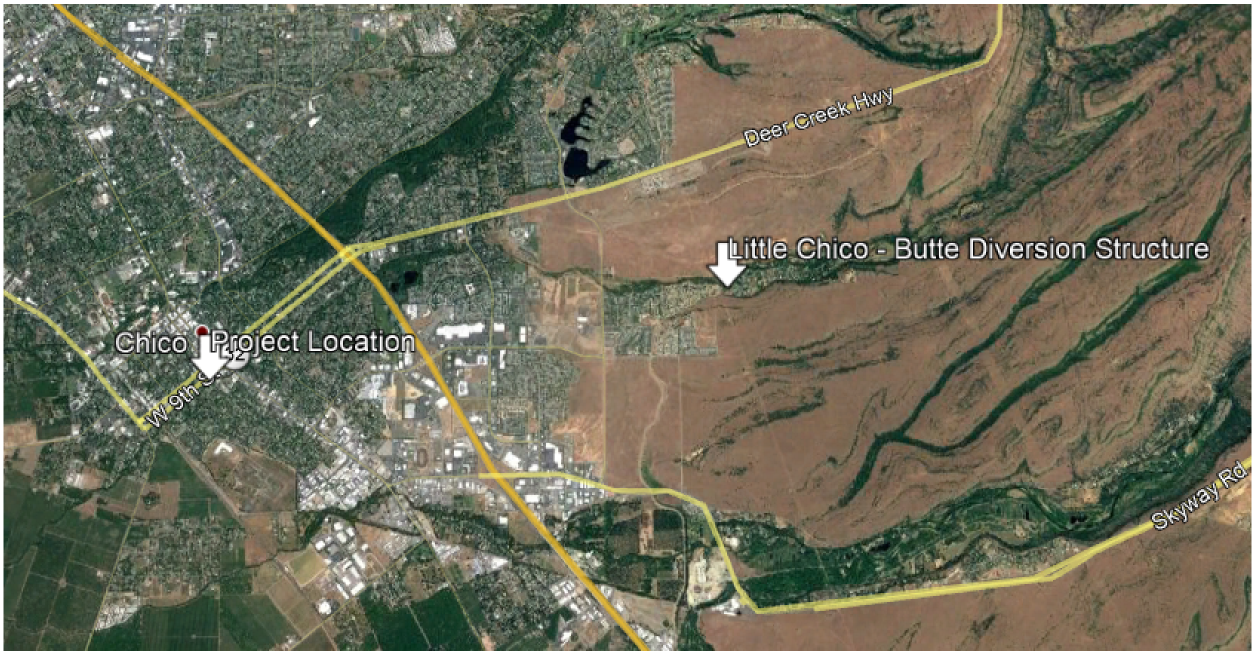


Figure 4. Project location and Little Chico - Butte Creek Diversion Structure location

Little Chico Creek was included in a FEMA Flood Insurance Study (FIS). According to the FIS, the 50-yr and 100-yr discharges are the same and are 2,800 cfs. Additionally, Little Chico Creek is in the jurisdiction of the Central Valley Flood Protection Board (CVFPB). The CVFPB discharge in Little Chico Creek of 3,000 cfs was obtained from the Sacramento River Flood Control Project Operations and Maintenance Manual[30]. The discharges used for this analysis are shown in Table 3.

Table 3. Discharges used for analysis (cfs)

	CVFPB	Design	Base
Frequency (years)	Not available	50	100
Discharge (cubic feet per second)	3,000	2,800	2,800

HEC-RAS ANALYSIS

Hydraulic parameters (water surface elevations and velocity) were obtained from the U.S. Army Corps of Engineers HEC-RAS (Hydraulic Engineering Center River Analysis System) version 5.0.7 model based on: 1) survey information provided by Mark Thomas, and 2) field investigation by Avila and Associates on July 27, 2017. Cross sections surveyed for the HEC-RAS model are shown in Figure 5.

[30] Received from Sungho Lee, CVFPB via electronic mail to Cathy Avila, Project Manager, Avila and Associates on September 21, 2017.

Figure 5. Plan view of HEC-RAS cross section

Existing Conditions

The Manning "n" values of 0.04 for the channel and 0.06 for the overbanks were used in the model. These are consistent with the USGS estimates (HH Barnes, 1967) and field reviews by Avila and Associates as shown in Figure 6.

Figure 6. Looking downstream at the channel. The overbank areas are heavily vegetated with relatively high manning "n" values.

The existing bridge was input into the model as a two-span span bridge with a minimum soffit elevation of 193 feet, as illustrated in Figure 7.

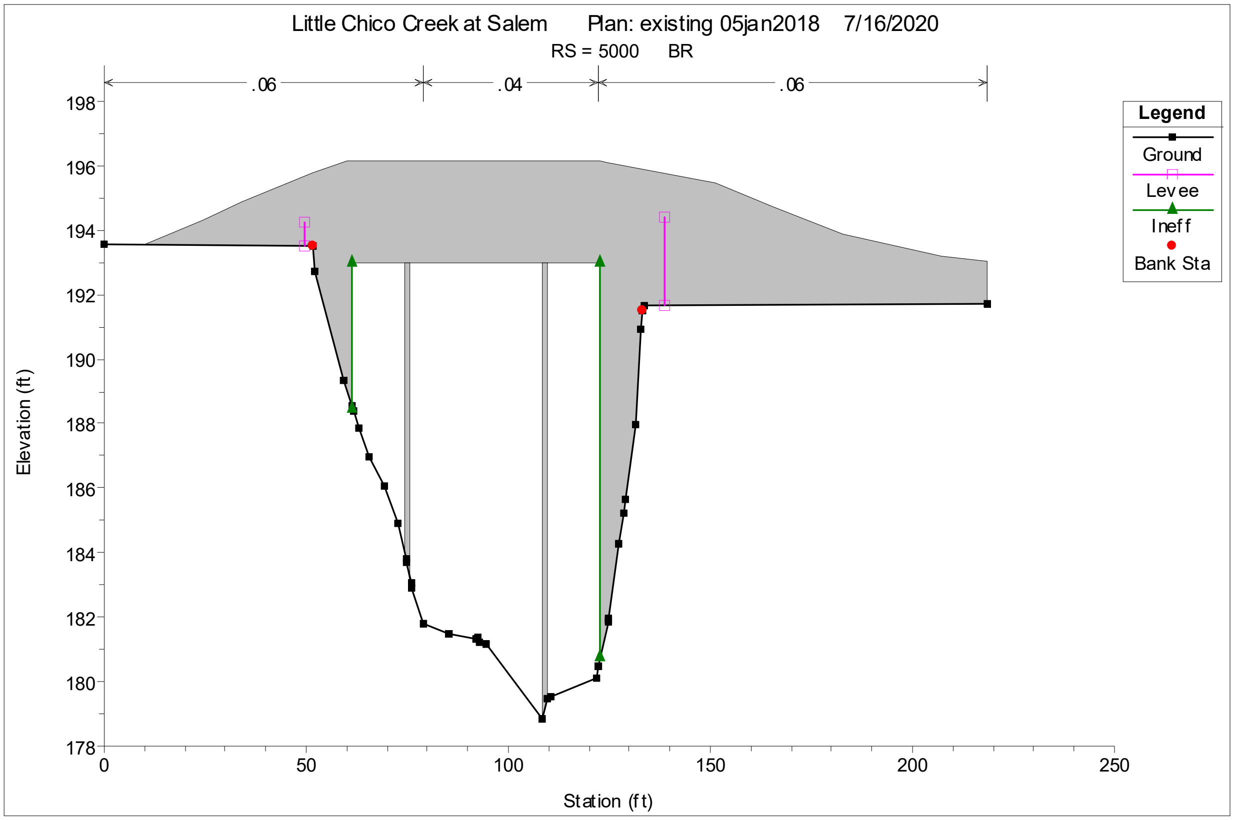


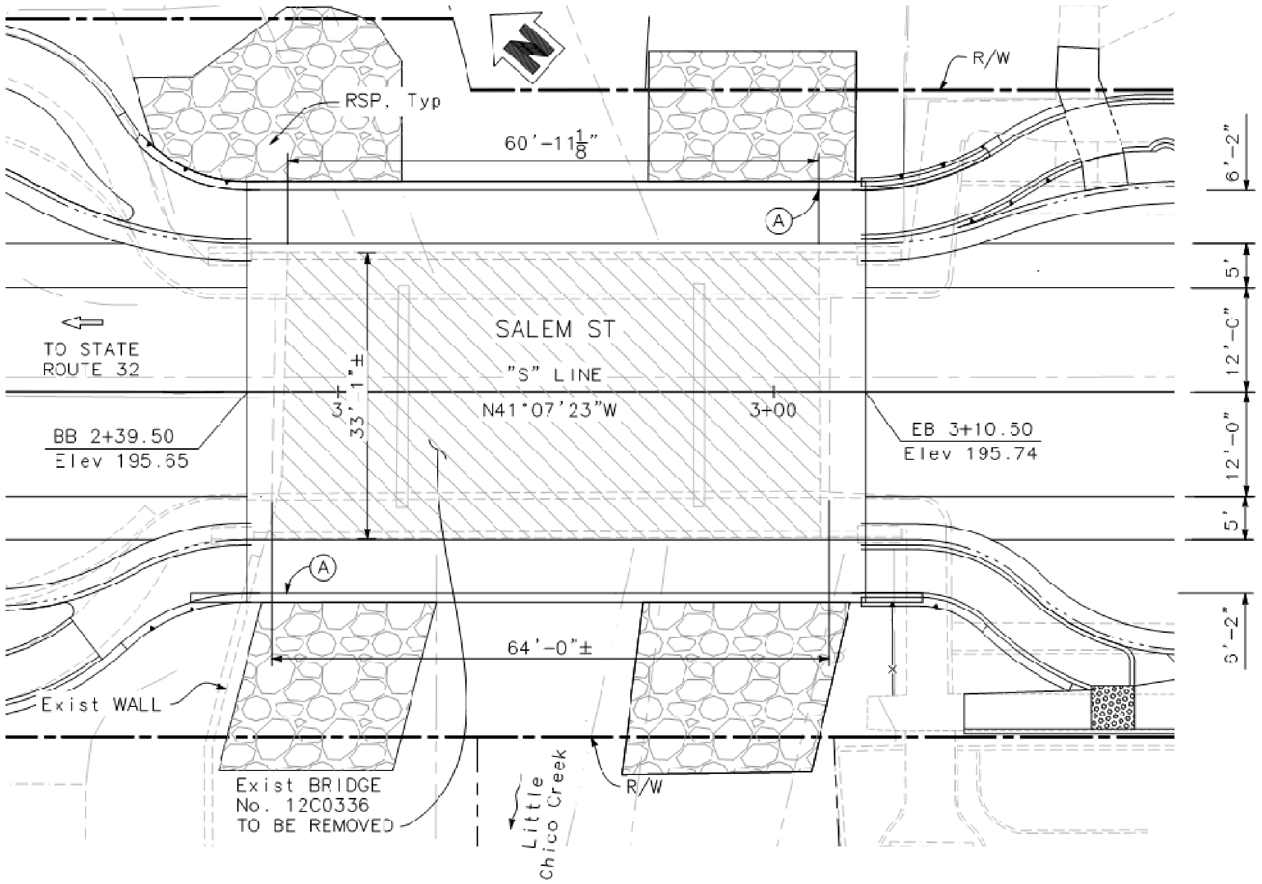
Figure 7. HEC-RAS cross section for the upstream existing conditions

Starting Water Surface Elevation

The starting water surface elevation used for the 50-yr and 100-yr discharge was taken from the water surface profile of Little Chico Creek in the FIS at the approximate location of the most downstream surveyed cross section. Adjusted for the difference in datum, the FIS water surface elevation is approximately 189.13 and was used as the starting water surface elevation for the 50-yr and 100-yr discharge. The slope of the energy grade at this location was calculated to be 0.002 ft/ft and was used as the slope for the normal depth boundary condition for the CVFPB discharge.

Proposed Bridge Model

The HEC-RAS model was re-run for the proposed bridge alternative. The only change to the model was that the existing bridge was replaced with the proposed bridge. The proposed bridge in the same location as the proposed bridge and is a single span bridge approximately 6.3 feet longer than existing. It will have a minimum soffit elevation of 193 ft on the upstream side and will be approximately 15 feet wider than existing as shown in



R/W
RSP, Typ
60'-11 1/8"
A
TO STATE
ROUTE 32
SALEM ST
"S" LINE
N41°07'23"W
3+00
33'-1"±
BB 2+39.50
Elev 195.65
EB 3+10.50
Elev 195.74
6'-2"
5'
12'-0"
12'-0"
5'
6'-2"
A
64'-0"±
Exist WALL
Exist BRIDGE
No. 12C0336
TO BE REMOVED
Little
Chico Creek
R/W

Figure 8.

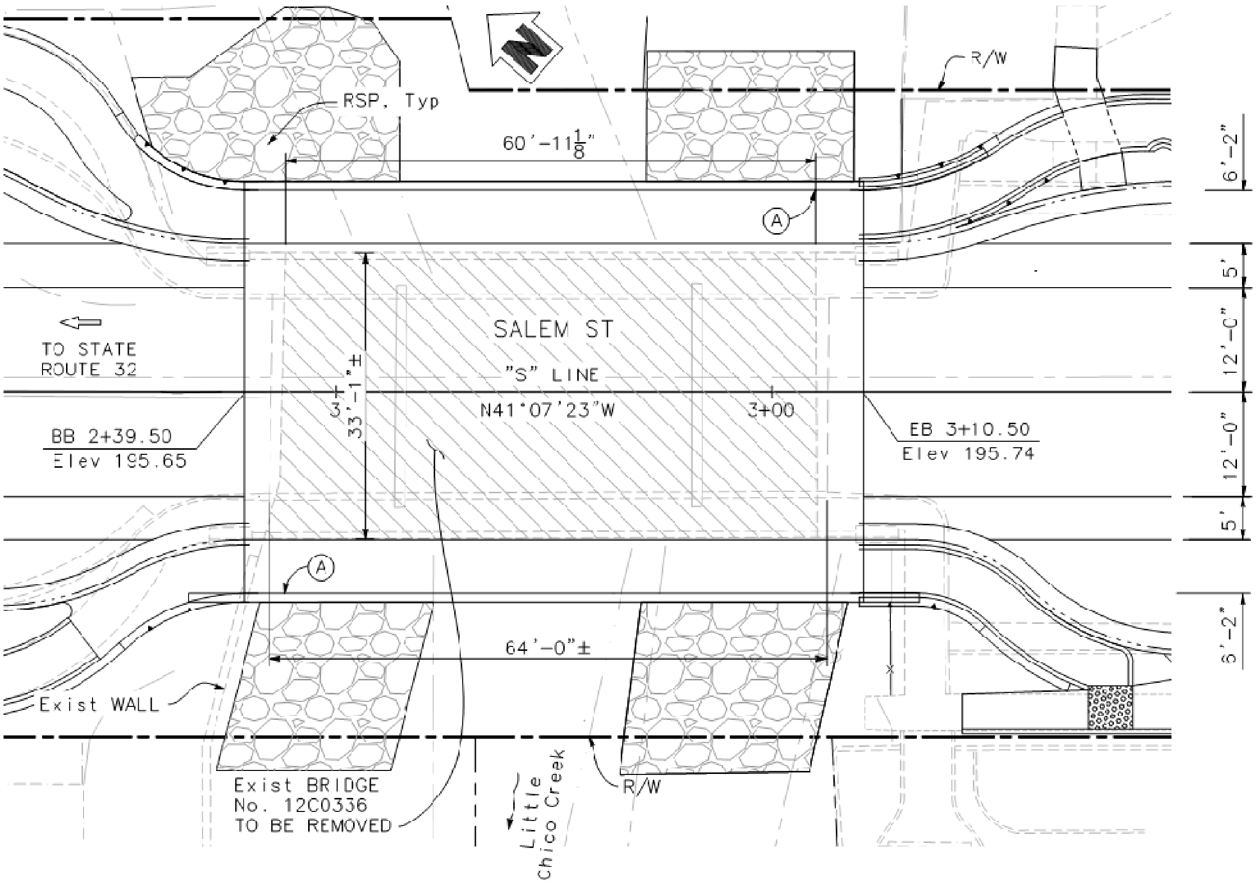


Figure 8. Existing and proposed bridges shown in plan view

Figure 9, Figure 10, and Table 4 shows a comparison of the existing to the proposed water surface elevation (WSE) profiles for the 100-yr and CVFPB discharges (50-yr is the same as 100-yr). As can be seen, the WSE is lowered upstream from the bridge and slightly increased (less than 0.04 ft) downstream due to the change in draw down curve through the bridge with the removal of the existing piers.

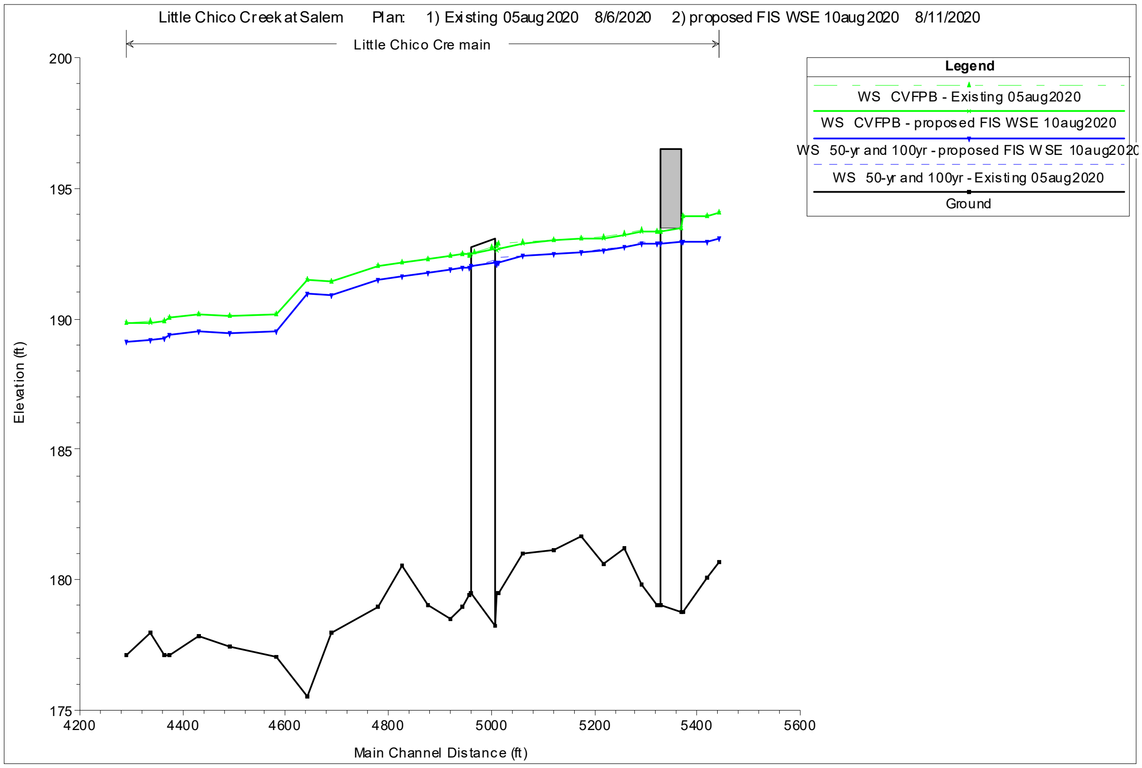


Figure 9. Water surface elevation profile comparison of existing to proposed for the 100-yr and CVFPB discharges

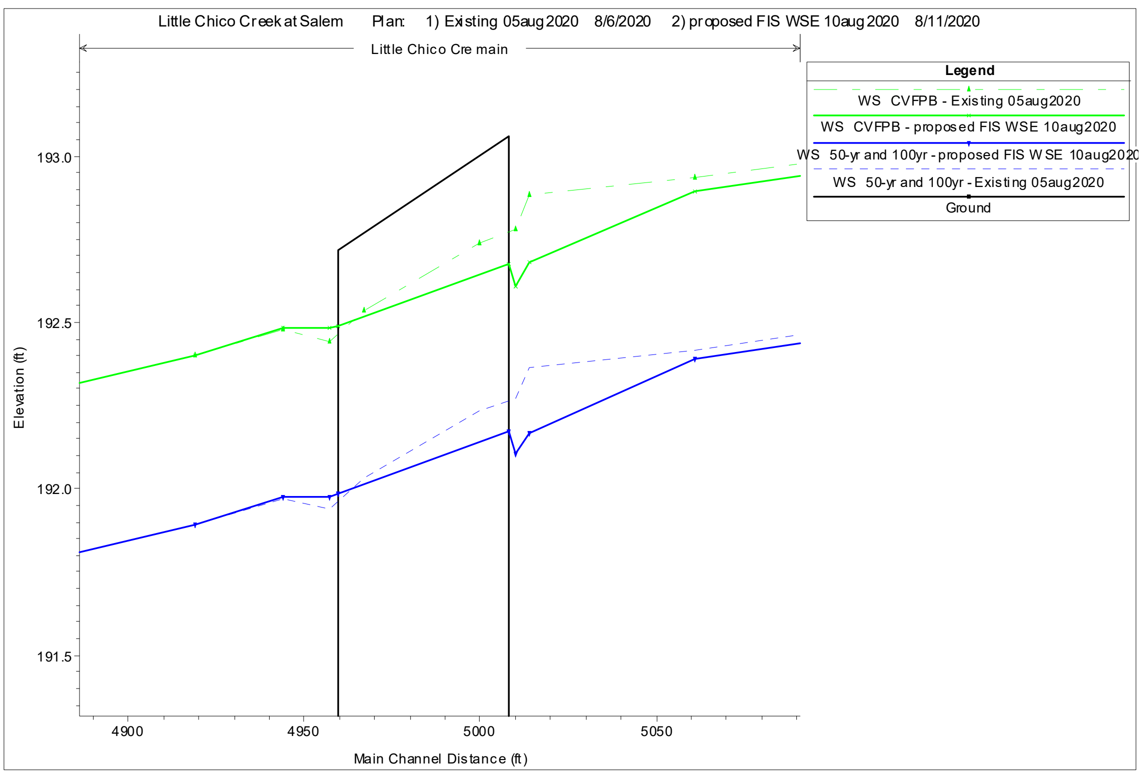


Figure 10. Close up of Figure 9

Table 4. Water Surface Elevation (WSE) comparison existing to proposed condition 100-yr and CVFPB discharges

River Station	**100-yr** (and 50-yr)			**CVFPB**		
	Existing	**Proposed**	**Difference**	**Existing**	**Proposed**	**Difference**
	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)
5323	192.88	192.86	-0.02	193.35	193.32	-0.03
5291	192.91	192.89	-0.02	193.39	193.36	-0.03
5260	192.76	192.74	-0.02	193.24	193.21	-0.03
5217	192.65	192.62	-0.03	193.14	193.1	-0.04
5173	192.58	192.55	-0.03	193.08	193.04	-0.04
5122	192.51	192.48	-0.03	193.02	192.98	-0.04
5061	192.42	192.39	-0.03	192.93	192.9	-0.03
5014	192.37	192.17	-0.2	192.88	192.68	-0.2
5010	192.27	192.1	-0.17	192.78	192.61	-0.17
Upstream Face of Bridge						
4957	191.94	191.98	0.04	192.44	192.48	0.04
4944	191.97	191.97	0	192.48	192.48	0
4919	191.89	191.89	0	192.4	192.4	0
4875	191.78	191.78	0	192.29	192.29	0

See Appendix D for detailed HEC-RAS output and Appendix E for overtopping and Flood of Record output.

HYDRAULIC CRITERIA

Chapter 820 of the Caltrans Highway Design Manual (HDM) delineates the hydraulic design criteria for bridges (Caltrans, 2017). The basic HDM rule for hydraulic design is that bridges should be designed to pass the Q_{50} with sufficient freeboard and convey the Q_{100} without freeboard. Exceptions may be granted if the bridge designer can provide sufficient evidence that less freeboard is needed. The HDM notes that 2 feet of freeboard is often assumed to be appropriate for preliminary bridge designs but leaves the recommendation for freeboard to the judgment of the hydraulic engineer based primarily upon the debris anticipated at the bridge.

Since the minimum soffit elevation under proposed conditions is 193 feet on the upstream side, a minimum of 0.9 feet of freeboard will be provided above the 50-yr and 100-yr WSE of 192.1. This does not meet the HDM freeboard requirements.

The Central Valley Flood Protection Board (CVFPB) regulations as provided in Title 23, Section 128, Part 10(a) require that the proposed bridge soffit be at least 2 feet (for minor streams) above the channel for their design discharge. Since Little Chico Creek has a CVFPB discharge less than 8,000 cfs, it is considered a minor stream[31]. With a minimum soffit elevation of 193 feet on the upstream side, 0.3 feet freeboard will be provided above the CVFPB WSE of 192.7 feet, and a variance will be required.

The City of Chico requires 3 feet of freeboard above the 200-yr WSE. According to the FIS, the 500-yr discharge is the same as the 100-yr discharge. It is assumed that the 200-yr WSE is the same as the 100-yr WSE and the resultant freeboards in the discussion of the HDM requirements are the same for the 200-yr WSE. This does not meet the City's freeboard requirement and a variance will be required.

DRIFT

Avila and Associates researched the available Bridge Maintenance Reports for the existing bridge to determine if floating debris catches on the bridge. Three instances instances of debris being caught on the bridge piers were noted.

The proposed bridge will improve the hydraulics; however, due to the removal of the two existing piers.

[31] Electronic mail from Sungho Lee, Central Valley Flood Protection Board/DWR to Catherine Avila, Avila and Associates on September 21, 2017.

SCOUR

Avila and Associates reviewed the available channel cross-sections to compare the oldest recorded condition in 1930 with the most recent cross sections taken from the 2017 topo information. During this 87-year span of time, the channel degraded approximately 2 feet, as shown in Figure 11. A conservative estimate of future degradation using straight-line extrapolation is that the channel could degrade an additional 2 -ft during the anticipated 75-year life of the proposed bridge.

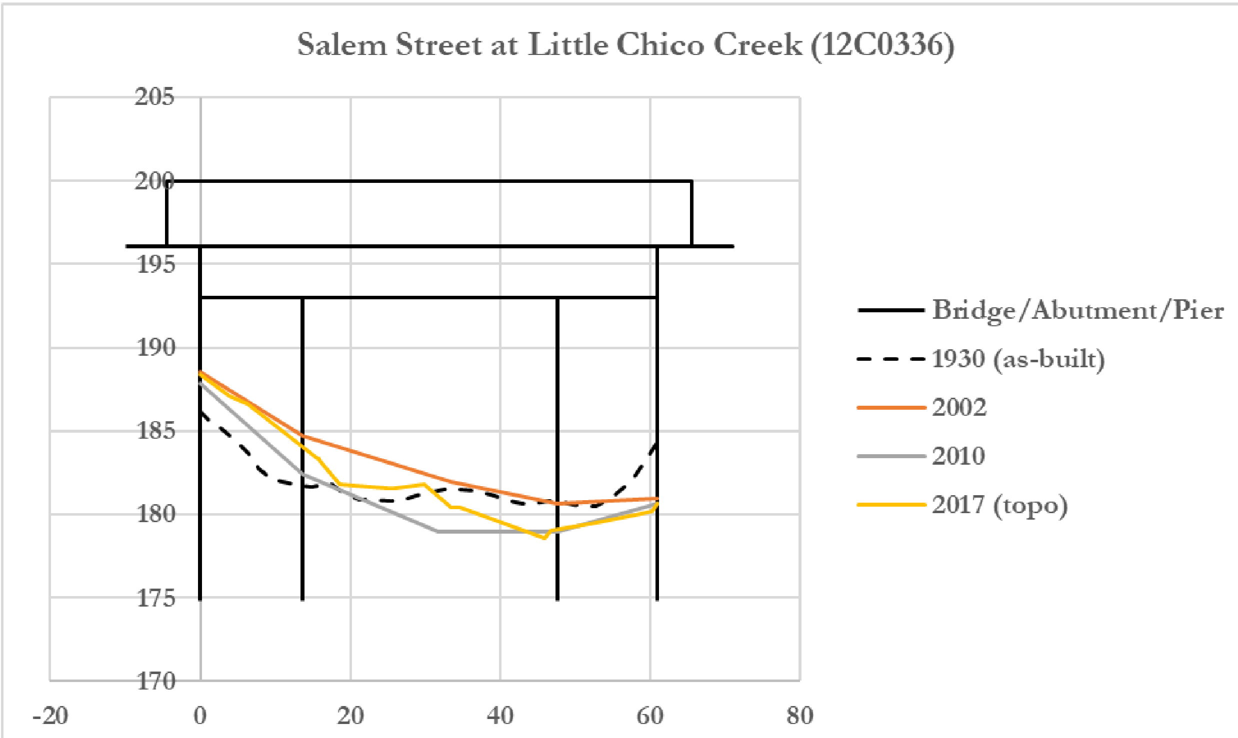


Figure 11. Cross sections taken at the bridge over time (from Caltrans Maintenance Reports)

All scour calculations were completed following the methodology outlined in HEC-18 (Arneson, 2012).

Contraction Scour

The proposed bridge constricts the channel from approximately 84 feet upstream to approximately 65 feet through the bridge reach. This does not result in appreciable calculated contraction scour.

Abutment Scour

Abutment scour was calculated using the equations from NCHRP 24-20 resulting in 5 feet of estimated scour. Abutment scour depths are determined by multiplying the contraction scour by an amplification factor. In this case, contraction scour is low, but the amplification factor is high due to turbulence caused by the abutments. The amplification factor was determined using Condition A, where the abutments are near the main channel. Without additional geotechnical information, it is assumed the channel thalweg can migrate laterally to the abutments. Therefore, the reference elevation for scour is the thalweg elevation of 179 ft.

Total Scour

According to the Preliminary Foundation Memorandum, there is no scour or erosion resistant material at the project site (Crawford, 2019). Therefore, the theoretical scour depths will not be limited by geotechnical considerations. The total scour depths, elevations, and elevations of scour resistant material at the Salem Street Bridge over Little Chico Creek are provided in Table 5, assuming a channel thalweg of 179 ft. The scour summary table is provided in Table 6.

Table 5. Total scour depths and elevations assuming a thalweg elevation of 179 ft.

Support	**A1**	**A4**
Degradation Depth (ft)	2	2
Contraction Scour Depth (ft)	n/a*	n/a*
Abutment Scour Depth (ft)	5	5
Total Scour Depth (ft)	7	7
Elevation of Scour Resistant Material (ft)	none	none
Total Scour Elevation (ft)	172	172

*Abutment scour is inclusive of contraction scour.

Table 6. Scour Summary Table

Long Term & Short-Term Scour Depths			
Support No.	Degradation Scour Depth (ft)	Contraction Scour Depth (ft)	Short Term (Local) Scour Depth (ft)
A1	2	n/a*	5
A2	2	n/a*	5

*Abutment scour is inclusive of contraction scour.

See Appendix D for detailed scour calculations.

ROCK SLOPE PROTECTION

Riprap size was calculated using the FHWA Hydraulic Engineering Circular No. 23 (HEC 23) guidelines for RSP (Lagasse, 2009). The riprap revetment design guidelines outlined in HEC 23 are based on flume studies performed by Stephen Maynord in 1989 and 1990 and were published in the U.S. Army Corp of Engineers (USACE) Engineering Manual (EM) 1601 in 1991. The rock slope protection was designed using the HEC-RAS results for the 100-year discharge and assumes a side slope of 1.5:1.

As shown in Table 7 below, the necessary RSP size is Class I, which is 20-lb rock with a D_{50} of 6 inches. The RSP should be 12 inches thick (the greater of 1.5 times the D_{50} or the D_{100}).

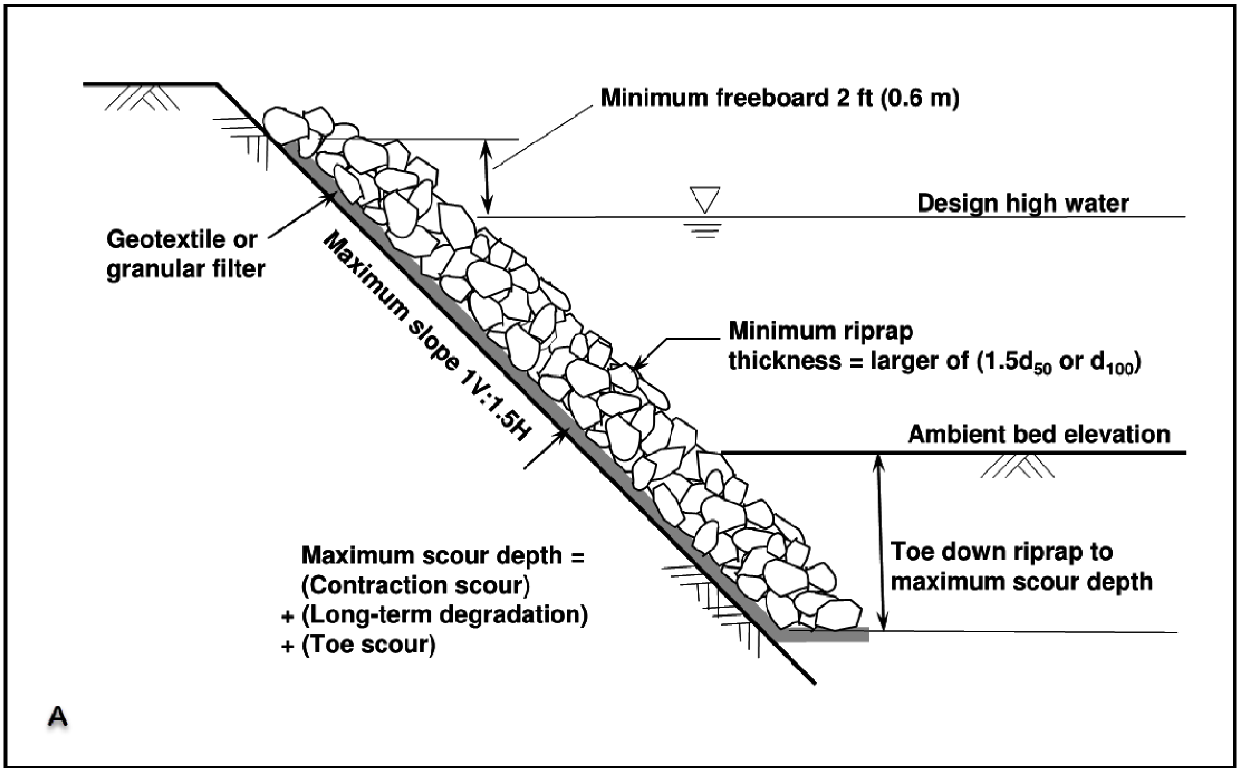
Table 7. Rock slope protection sizing for cross sections near the bridge.

Cross-Section	5061	5014	5010	5000 BR U	5000 BR D	4957	4944	4919
Width (ft)	95.8	79.7	77.9	65.0	57.4	60.4	62.6	59.7
Average Velocity (ft/s)	4.2	4.0	4.4	4.5	5.4	5.4	4.9	5.1
Hydraulic Depth (ft)	6.9	8.9	9.7	9.7	9.1	9.0	9.1	9.3
Calculated D50 (in)	1.4	1.0	1.3	1.2	1.9	2.0	1.5	1.6
Class (based on size)	I	I	I	I	I	I	I	I
D50 (in)	6	6	6	6	6	6	6	6
Weight (lbs)	20	20	20	20	20	20	20	20
Thickness (in)	12	12	12	12	12	12	12	12

The California Bank and Shore Protection manual recommended that if smaller rocks are likely to be relocated by recreational or others who frequent the area under the structure, a minimum rock size of "light" (200-lb) rock should be considered. Photos from the bridge inspection reports (Figure 12) show graffiti beneath the existing bridge and the bridge is surrounded by a residential area. Thus, it is likely smaller rocks would be relocated by people under the bridge and the larger rock size is necessary. With the new gradations, consideration should be given to the next size larger than 200-lb rock or Class IV (300-lb) rock to minimize rock relocation.

Figure 12. Graffiti beneath the bridge indicates the presence of recreational users (City of Chico, 2017).

The rock slope protection should extend up the banks to the design water surface elevation of 192.7 plus 2 feet of freeboard or elevation 194.7 ft. The RSP should be keyed into the channel the total scour depth or depth to erosion resistant material or utilize a mounded toe as shown in Figure 13.



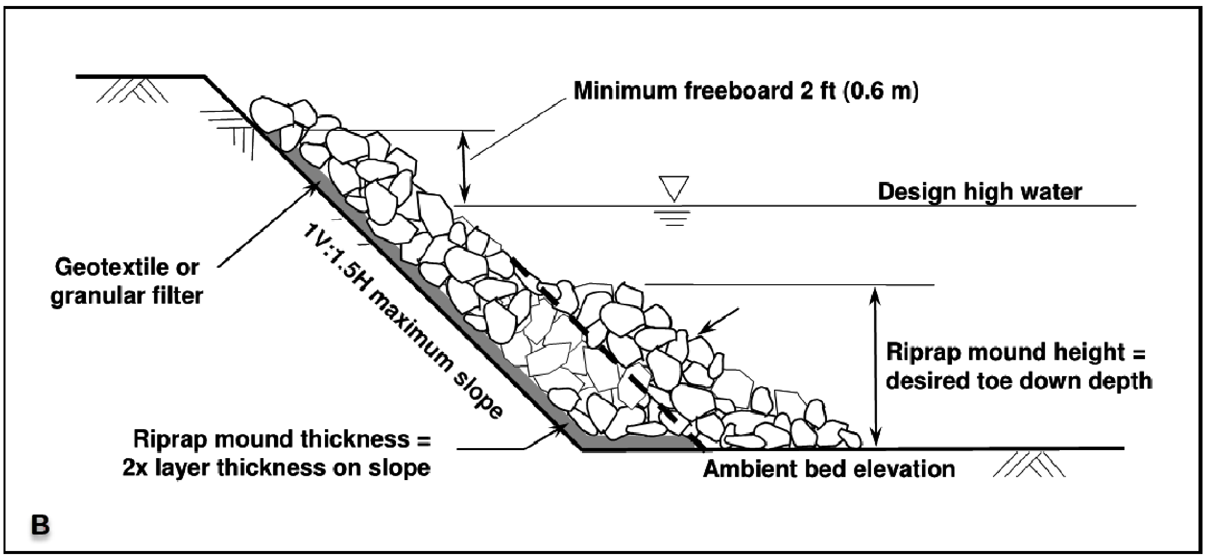


Figure 13. Bank RSP freeboard and termination options: A) key down to the scour depth and B) Mounded Toe

SUMMARY TABLES

The following Hydrologic Summary Table is provided for your use for placement on the Foundation Plan:

Drainage Area: 48.3 Square miles

<table>
<tr><th></th><th>CVFPB</th><th>Design</th><th>Base</th><th>Flood of Record</th></tr>
<tr><td>Frequency (Years)</td><td>Not available</td><td>50</td><td>100</td><td rowspan="3">n/a*</td></tr>
<tr><td>Discharge (Cubic feet per second)</td><td>3,000</td><td>2,800</td><td>2,800</td></tr>
<tr><td>Water Surface (Elevation at u/s face of Bridge)</td><td>192.68</td><td>192.1</td><td>192.1</td></tr>
<tr><td colspan="5">Flood plain data are based upon information available when the plans were prepared and are shown to meet Federal requirements. The accuracy of said information is not warranted by the County and interested or affected parties should make their own investigation.

*High flows in Little Chico Creek are diverted to Butte Creek approximately 4 miles upstream of the project</td></tr>
</table>

The following Scour Data Table is provided for placement on the Foundation Plan, assuming a thalweg elevation of 179 ft:

<table>
<tr><th>Support No.</th><th>Long Term (Degradation and Contraction) Scour Elevation (ft)</th><th>Short Term (Local) Scour Depth (ft)</th></tr>
<tr><td>A1</td><td>n/a*</td><td>5</td></tr>
<tr><td>A2</td><td>n/a*</td><td>5</td></tr>
<tr><td colspan="3">*Abutment scour is inclusive of contraction scour.</td></tr>
</table>

The Floodplain Evaluation Report as outlined in 23 CFR 650 Subpart A, Section 650.111(b)(c)(d) is included in Appendices G and H.

REFERENCES

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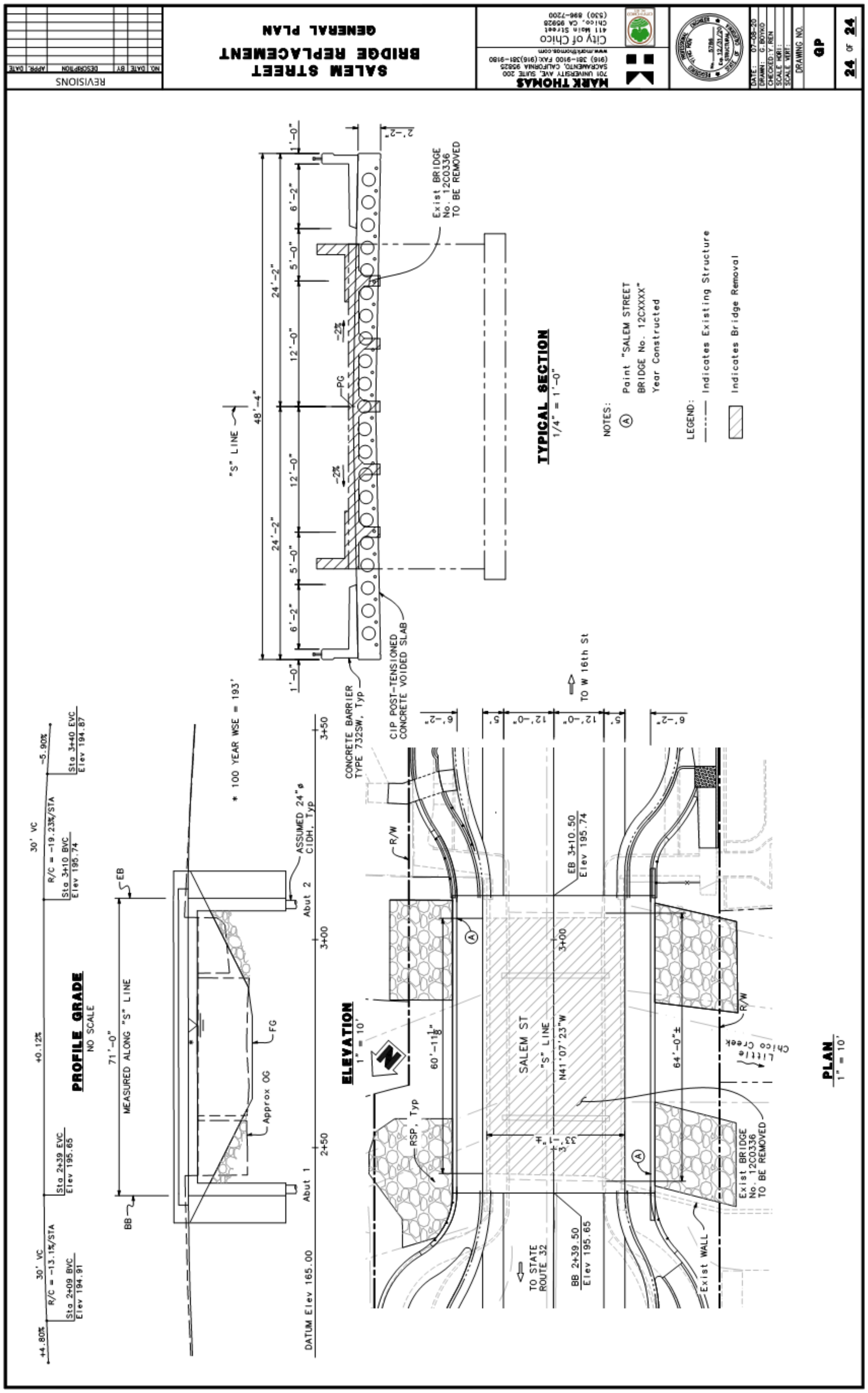
APPENDICES

APPENDIX A – GENERAL PLAN



APPENDIX B – DISCHARGES

From FIS

Table 3 – Summary of Discharges, continued

Flooding Source and Location	Drainage Area (sq mi)	Peak Discharges (cfs) 10-Percent-Annual-Chance	2-Percent-Annual-Chance	1-Percent-Annual-Chance	0.2-Percent-Annual-Chance
LITTLE CHICO CREEK					
Below Diversion Structure	*	2,300	4,400	5,600	7,800
At Forest Avenue	*	1,500	2,000	2,200	2,500
At State Highway 99	*	2,100	3,400	3,700	*
Approximately 100 feet above Bruce Street	*	2,100	3,400	3,500	3,700
At Bruce Street	*	2,200	3,100	3,100	3,100
At Mills Street	*	2,200	2,800	2,800	2,800
At Crouch Road	*	2,200	2,500	2,500	2,500
Approximately 3,000 feet below Alberton	*	2,300	2,600	2,600	2,600
Sacramento River Floodplain	*	2,300	2,700	2,700	2,700
MUD CREEK					
Downstream of Confluence with Sycamore Circle	44.89[2]	*	*	10,410	*
At Nord Highway	45.44[2]	*	*	10,700	*
PALERMO TRIBUTARY					
At Baldwin Avenue	1.0	255	355	390	470
Approximately 100 feet downstream of Palermo Road	1.7	500	690	760	920
Approximately 550 feet downstream of South Villa Avenue[1]	1.7	126	126	126	126
At confluence with Wyman Ravine Tributary 1	2.1	500	690	760	920
RUDDY CREEK					
Just upstream of confluence with Ruddy Creek Tributary	0.7	255	350	380	460
Approximately 350 feet upstream of Feather River	1.9	580	790	870	1,050
Entire Reach	0.5	165	220	250	300

[1] *See Section 3.2 for an explanation of the reduction in flow.*

[2] *Includes Big Chico Creek Diversion Channel and Sycamore Creek drainage area.*

**Data not available*

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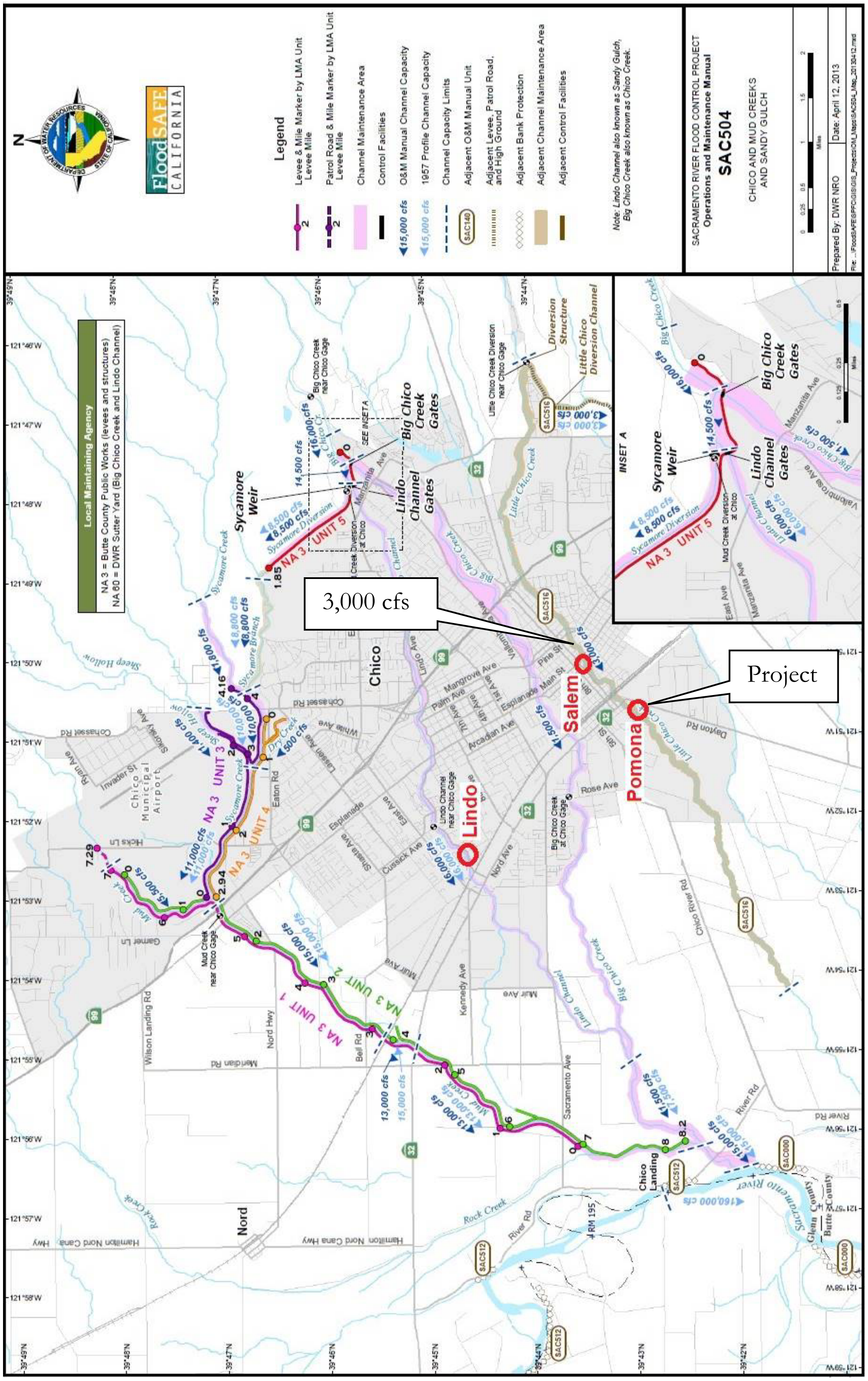
APPENDIX C – CVFPB DISCHARGE



Existing Conditions

HEC-RAS Plan: Existing 05aug2020 River: Little Chico Cre Reach: main Profile: 50-yr and 100yr

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)	
main	5443	50-yr and 100yr	2800.00	180.69	193.09		193.67	0.003441	6.10	458.97	51.36	0.36
main	5419	50-yr and 100yr	2800.00	180.06	192.96		193.58	0.003966	6.31	443.69	49.72	0.37
main	5372	50-yr and 100yr	2800.00	178.79	192.94	186.19	193.43	0.001468	5.60	500.00	49.68	0.29
main	5369		Bridge									
main	5323	50-yr and 100yr	2800.00	179.02	192.88	185.95	193.34	0.000923	5.45	514.13	68.66	0.28
main	5291	50-yr and 100yr	2800.00	179.84	192.91		193.23	0.001918	4.53	618.15	72.38	0.27
main	5260	50-yr and 100yr	2800.00	181.18	192.76		193.15	0.002545	5.02	560.42	76.64	0.31
main	5217	50-yr and 100yr	2800.00	180.59	192.65		193.04	0.002834	5.02	558.31	74.51	0.32
main	5173	50-yr and 100yr	2800.00	181.69	192.58		192.90	0.002506	4.54	616.91	88.59	0.30
main	5122	50-yr and 100yr	2800.00	181.16	192.51		192.78	0.001727	4.13	678.57	92.60	0.27
main	5061	50-yr and 100yr	2800.00	181.01	192.42		192.67	0.001658	4.03	694.58	98.78	0.27
main	5014	50-yr and 100yr	2800.00	177.39	192.37		192.59	0.001271	3.83	730.69	83.08	0.22
main	5010	50-yr and 100yr	2800.00	177.69	192.27	185.15	192.58	0.001285	4.47	625.88	79.58	0.25
main	5000		Bridge									
main	4957	50-yr and 100yr	2800.00	179.26	191.94	186.42	192.40	0.001795	5.46	512.37	61.20	0.32
main	4944	50-yr and 100yr	2800.00	178.97	191.97		192.32	0.001987	4.76	589.08	66.34	0.27
main	4919	50-yr and 100yr	2800.00	178.47	191.89		192.27	0.002155	4.90	571.02	60.13	0.28
main	4875	50-yr and 100yr	2800.00	179.00	191.78		192.17	0.002236	5.01	558.76	62.11	0.29
main	4825	50-yr and 100yr	2800.00	180.53	191.65		192.05	0.002328	5.08	551.57	65.05	0.31
main	4778	50-yr and 100yr	2800.00	178.98	191.51		191.94	0.002460	5.26	532.21	60.98	0.31
main	4690	50-yr and 100yr	2800.00	177.94	190.91	186.13	191.62	0.004831	6.72	416.39	49.46	0.41
main	4641	50-yr and 100yr	2800.00	175.50	190.95		191.37	0.002438	5.15	543.34	60.85	0.30
main	4582	50-yr and 100yr	2800.00	177.04	189.52		190.98	0.013974	9.66	290.01	46.77	0.68
main	4491	50-yr and 100yr	2800.00	177.44	189.47		190.12	0.003972	6.49	431.33	49.93	0.39
main	4431	50-yr and 100yr	2800.00	177.81	189.53		189.86	0.001919	4.60	608.61	69.41	0.27
main	4373	50-yr and 100yr	2800.00	177.14	189.38	184.01	189.74	0.002222	4.86	589.09	78.25	0.30
main	4364	50-yr and 100yr	2800.00	177.14	189.23	184.13	189.71	0.002923	5.54	505.71	61.41	0.34
main	4337	50-yr and 100yr	2800.00	178.00	189.18	183.90	189.62	0.002595	5.33	524.94	62.88	0.33
main	4292	50-yr and 100yr	2800.00	177.12	189.13	183.65	189.49	0.002259	4.79	584.59	70.94	0.29

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HEC-RAS Plan: Existing 05aug2020 River: Little Chico Cre Reach: main Profile: CVFPB

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)	
main	5443	CVFPB	3000.00	180.69	194.06		194.60	0.002924	5.89	510.91	54.92	0.33
main	5419	CVFPB	3000.00	180.06	193.94		194.52	0.003388	6.09	492.95	50.62	0.34
main	5372	CVFPB	3000.00	178.79	193.93	186.45	194.36	0.001807	5.30	566.56	52.50	0.28
main	5369		Bridge									
main	5323	CVFPB	3000.00	179.02	193.35	186.20	193.84	0.000933	5.62	534.06	70.18	0.28
main	5291	CVFPB	3000.00	179.84	193.39		193.71	0.001880	4.60	652.83	73.06	0.27
main	5260	CVFPB	3000.00	181.18	193.24		193.64	0.002415	5.06	597.42	76.64	0.31
main	5217	CVFPB	3000.00	180.59	193.14		193.53	0.002701	5.04	595.27	76.15	0.32
main	5173	CVFPB	3000.00	181.69	193.08		193.40	0.002318	4.54	661.21	88.59	0.29
main	5122	CVFPB	3000.00	181.16	193.02		193.28	0.001612	4.14	725.48	92.60	0.26
main	5061	CVFPB	3000.00	181.01	192.93		193.18	0.001520	4.03	747.36	106.01	0.26
main	5014	CVFPB	3000.00	177.39	192.88		193.11	0.001235	3.88	774.90	87.51	0.22
main	5010	CVFPB	3000.00	177.69	192.78	185.44	193.10	0.001255	4.57	657.01	85.51	0.25
main	5000		Bridge									
main	4957	CVFPB	3000.00	179.26	192.44	186.64	192.92	0.001770	5.55	540.54	63.69	0.32
main	4944	CVFPB	3000.00	178.97	192.48		192.84	0.001941	4.83	625.07	75.57	0.27
main	4919	CVFPB	3000.00	178.47	192.40		192.79	0.002118	4.99	601.90	61.54	0.28
main	4875	CVFPB	3000.00	179.00	192.29		192.69	0.002196	5.08	590.58	62.81	0.29
main	4825	CVFPB	3000.00	180.53	192.17		192.58	0.002260	5.13	585.28	65.83	0.30
main	4778	CVFPB	3000.00	178.98	192.02		192.46	0.002399	5.32	563.89	61.52	0.31
main	4690	CVFPB	3000.00	177.94	191.43	186.42	192.15	0.004711	6.78	442.41	50.40	0.40
main	4641	CVFPB	3000.00	175.50	191.48		191.90	0.002365	5.21	575.49	61.01	0.30
main	4582	CVFPB	3000.00	177.04	190.18		191.54	0.011944	9.37	321.68	50.04	0.63
main	4491	CVFPB	3000.00	177.44	190.12		190.77	0.003730	6.46	464.32	50.95	0.38
main	4431	CVFPB	3000.00	177.81	190.19		190.52	0.001798	4.58	654.90	70.78	0.27
main	4373	CVFPB	3000.00	177.14	190.06	184.26	190.41	0.001966	4.79	642.50	78.49	0.29
main	4364	CVFPB	3000.00	177.14	189.93	184.38	190.38	0.002615	5.42	568.61	77.98	0.32
main	4337	CVFPB	3000.00	178.00	189.87	184.14	190.30	0.002379	5.27	569.11	64.28	0.31
main	4292	CVFPB	3000.00	177.12	189.83	183.88	190.18	0.002002	4.73	635.66	72.44	0.28

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Proposed Conditions

HEC-RAS Plan: proposed FIS WSE 10aug2020 River: Little Chico Cre Reach: main Profile: 50-yr and 100yr

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)	
main	5443	50-yr and 100yr	2800.00	180.69	193.07		193.65	0.003462	6.11	457.90	51.30	0.36
main	5419	50-yr and 100yr	2800.00	180.06	192.94		193.56	0.003994	6.33	442.61	49.70	0.37
main	5372	50-yr and 100yr	2800.00	178.79	192.92	186.19	193.41	0.001478	5.61	499.07	49.62	0.29
main	5369		Bridge									
main	5323	50-yr and 100yr	2800.00	179.02	192.86	185.95	193.32	0.000929	5.46	513.18	68.58	0.28
main	5291	50-yr and 100yr	2800.00	179.84	192.89		193.21	0.001932	4.54	616.54	72.34	0.27
main	5260	50-yr and 100yr	2800.00	181.18	192.74		193.13	0.002569	5.04	558.60	76.64	0.32
main	5217	50-yr and 100yr	2800.00	180.59	192.62		193.01	0.002860	5.03	556.45	74.43	0.32
main	5173	50-yr and 100yr	2800.00	181.69	192.55		192.87	0.002535	4.56	614.60	88.59	0.30
main	5122	50-yr and 100yr	2800.00	181.16	192.48		192.75	0.001746	4.14	676.07	92.60	0.27
main	5061	50-yr and 100yr	2800.00	181.01	192.39		192.64	0.001678	4.05	691.80	98.59	0.27
main	5014	50-yr and 100yr	2800.00	179.50	192.17		192.53	0.002613	4.88	574.91	82.30	0.32
main	5010	50-yr and 100yr	2800.00	179.50	192.10	187.14	192.52	0.002194	5.17	541.21	79.14	0.32
main	5000		Bridge									
main	4957	50-yr and 100yr	2800.00	179.42	191.98	186.31	192.36	0.001515	5.01	571.52	71.82	0.29
main	4944	50-yr and 100yr	2800.00	178.97	191.97		192.32	0.001887	4.72	594.12	67.10	0.27
main	4919	50-yr and 100yr	2800.00	178.47	191.89		192.27	0.002155	4.90	571.02	60.13	0.28
main	4875	50-yr and 100yr	2800.00	179.00	191.78		192.17	0.002236	5.01	558.76	62.11	0.29
main	4825	50-yr and 100yr	2800.00	180.53	191.65		192.05	0.002328	5.08	551.57	65.05	0.31
main	4778	50-yr and 100yr	2800.00	178.98	191.51		191.94	0.002460	5.26	532.21	60.98	0.31
main	4690	50-yr and 100yr	2800.00	177.94	190.91	186.13	191.62	0.004831	6.72	416.39	49.46	0.41
main	4641	50-yr and 100yr	2800.00	175.50	190.95		191.37	0.002438	5.15	543.34	60.85	0.30
main	4582	50-yr and 100yr	2800.00	177.04	189.52		190.98	0.013974	9.66	290.01	46.77	0.68
main	4491	50-yr and 100yr	2800.00	177.44	189.47		190.12	0.003972	6.49	431.33	49.93	0.39
main	4431	50-yr and 100yr	2800.00	177.81	189.53		189.86	0.001919	4.60	608.61	69.41	0.27
main	4373	50-yr and 100yr	2800.00	177.14	189.38	184.01	189.74	0.002222	4.86	589.09	78.25	0.30
main	4364	50-yr and 100yr	2800.00	177.14	189.23	184.13	189.71	0.002923	5.54	505.71	61.41	0.34
main	4337	50-yr and 100yr	2800.00	178.00	189.18	183.90	189.62	0.002595	5.33	524.94	62.88	0.33
main	4292	50-yr and 100yr	2800.00	177.12	189.13	183.65	189.49	0.002259	4.79	584.59	70.94	0.29

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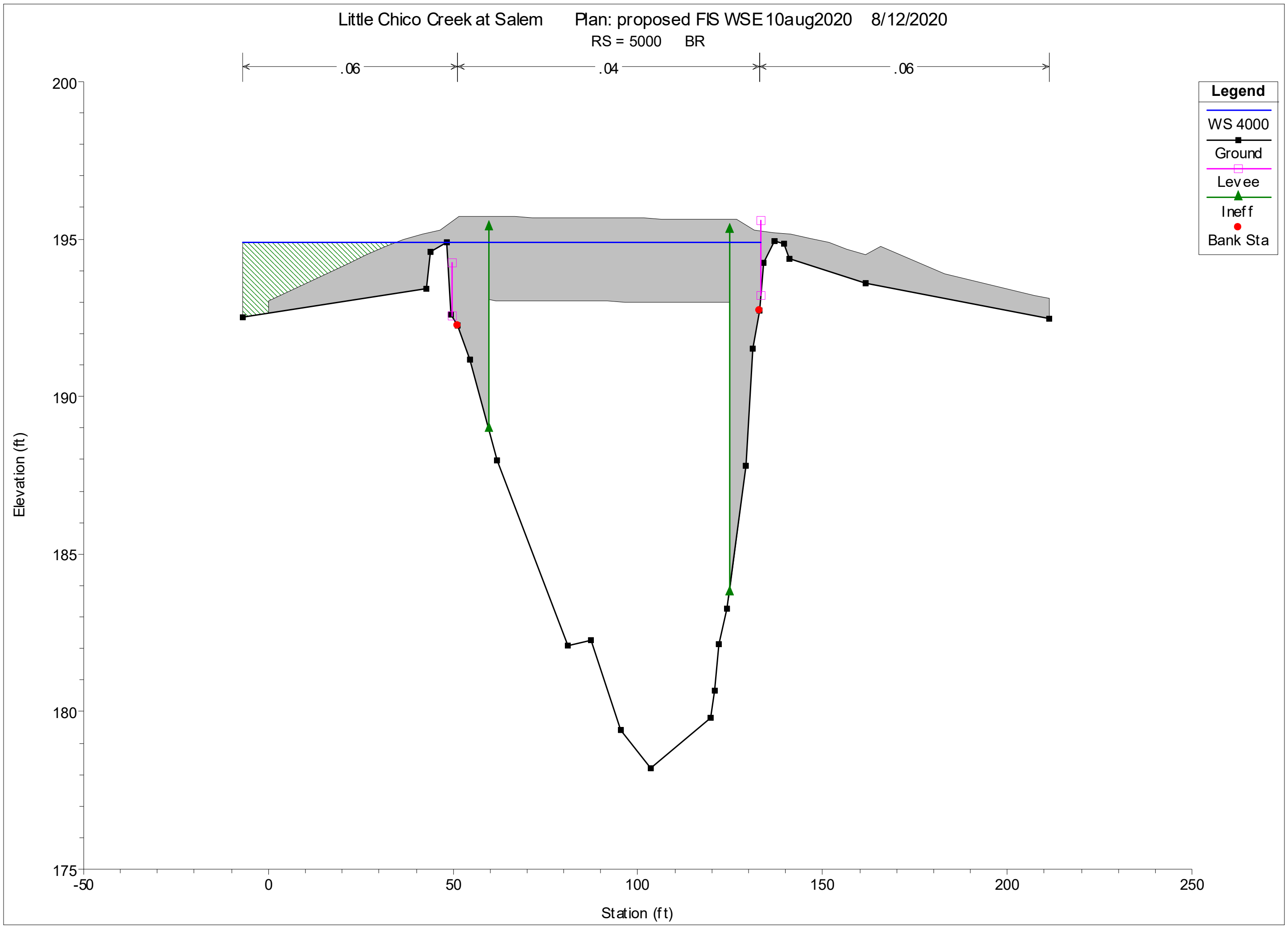
HEC-RAS Plan: proposed FIS WSE 10aug2020 River: Little Chico Cre Reach: main Profile: CVFPB

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)	
main	5443	CVFPB	3000.00	180.69	194.06		194.60	0.002924	5.89	510.88	54.92	0.33
main	5419	CVFPB	3000.00	180.06	193.94		194.52	0.003388	6.09	492.93	50.62	0.34
main	5372	CVFPB	3000.00	178.79	193.92	186.45	194.36	0.001807	5.30	566.54	52.50	0.28
main	5369		Bridge									
main	5323	CVFPB	3000.00	179.02	193.32	186.20	193.81	0.000941	5.63	532.80	70.08	0.28
main	5291	CVFPB	3000.00	179.84	193.36		193.69	0.001898	4.61	650.66	73.02	0.27
main	5260	CVFPB	3000.00	181.18	193.21		193.61	0.002444	5.08	595.01	76.64	0.31
main	5217	CVFPB	3000.00	180.59	193.10		193.50	0.002737	5.06	592.75	76.15	0.32
main	5173	CVFPB	3000.00	181.69	193.04		193.37	0.002351	4.56	658.17	88.59	0.29
main	5122	CVFPB	3000.00	181.16	192.98		193.25	0.001634	4.15	722.20	92.60	0.26
main	5061	CVFPB	3000.00	181.01	192.90		193.15	0.001545	4.05	743.48	105.20	0.26
main	5014	CVFPB	3000.00	179.50	192.68		193.05	0.002417	4.87	618.25	86.48	0.31
main	5010	CVFPB	3000.00	179.50	192.61	187.37	193.03	0.002069	5.23	574.07	80.83	0.31
main	5000		Bridge									
main	4957	CVFPB	3000.00	179.42	192.48	186.56	192.88	0.001451	5.07	606.14	74.38	0.29
main	4944	CVFPB	3000.00	178.97	192.48		192.84	0.001847	4.79	630.57	76.62	0.27
main	4919	CVFPB	3000.00	178.47	192.40		192.79	0.002118	4.99	601.90	61.54	0.28
main	4875	CVFPB	3000.00	179.00	192.29		192.69	0.002196	5.08	590.58	62.81	0.29
main	4825	CVFPB	3000.00	180.53	192.17		192.58	0.002260	5.13	585.28	65.83	0.30
main	4778	CVFPB	3000.00	178.98	192.02		192.46	0.002399	5.32	563.89	61.52	0.31
main	4690	CVFPB	3000.00	177.94	191.43	186.42	192.15	0.004711	6.78	442.41	50.40	0.40
main	4641	CVFPB	3000.00	175.50	191.48		191.90	0.002365	5.21	575.49	61.01	0.30
main	4582	CVFPB	3000.00	177.04	190.18		191.54	0.011944	9.37	321.68	50.04	0.63
main	4491	CVFPB	3000.00	177.44	190.12		190.77	0.003730	6.46	464.32	50.95	0.38
main	4431	CVFPB	3000.00	177.81	190.19		190.52	0.001798	4.58	654.90	70.78	0.27
main	4373	CVFPB	3000.00	177.14	190.06	184.26	190.41	0.001966	4.79	642.50	78.49	0.29
main	4364	CVFPB	3000.00	177.14	189.93	184.38	190.38	0.002615	5.42	568.61	77.98	0.32
main	4337	CVFPB	3000.00	178.00	189.87	184.14	190.30	0.002379	5.27	569.11	64.28	0.31
main	4292	CVFPB	3000.00	177.12	189.83	183.88	190.18	0.002002	4.73	635.66	72.44	0.28

APPENDIX E – OVERTOPPING

The model was re-run with various discharges to determine the discharge at which overtopping of the bridge or approach roadway first occurs. This discharge was 4,000 cfs which results in a water surface elevation of 194.9 feet at the upstream face of the bridge.



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RIVER FOCUS WATER RESOURCE CONSULTANTS

HEC-18 5th Edition - Scour Calculation Spreadsheet (1D)

Critical Velocity Calculation (Clear vs. Live Bed Determination)

***Critical Velocity** (V_c): The velocity above which the bed material of size D, D_{50}, etc. and smaller will be transported. Critical velocity is used as an indicator for clear-water or live-bed scour.*

→ If the mean velocity (V) of the upstream reach is equal to or less than the critical velocity (V_c) of the median diameter (D_{50}) of the bed material, then contraction and local scour will be clear-water.

→ If the mean velocity (V) of the upstream reach is greater than the critical velocity (V_c) of the median diameter (D_{50}) of the bed material, then contraction and local scour will be live-bed.

Parameter	Metric		US	
Median Diameter of Bed Material (D_{50}):	3.60	(mm)	3.6	(mm)
Average Upstream Depth (y):	2.17	(m)	7.11	(ft)
Critical Velocity Parameter (K_u):	6.19	($m^{1/2}/s$)	11.17	($ft^{1/2}/s$)
Average Upstream Velocity (V):	1.487	(m/s)	4.88	(ft/s)
Critical Velocity (V_c):	1.079	(m/s)	**3.5**	(ft/s)

$$V_c = K_u \, y^{1/6} \, D^{1/3}$$

*Note: To determine Live Bed Scour vs Clear Scour, D in the equation above is set equal to D_{50}

Upstream V ≤ V_c: Clear Water Contraction Scour

Upstream V > V_c: Live Bed Contraction Scour

Proceed to Live Bed Contraction Scour Tab

RIVER FOCUS WATER RESOURCE CONSULTANTS

HEC-18 5th Edition - Scour Calculation Spreadsheet (1D)

Live Bed Contraction Scour

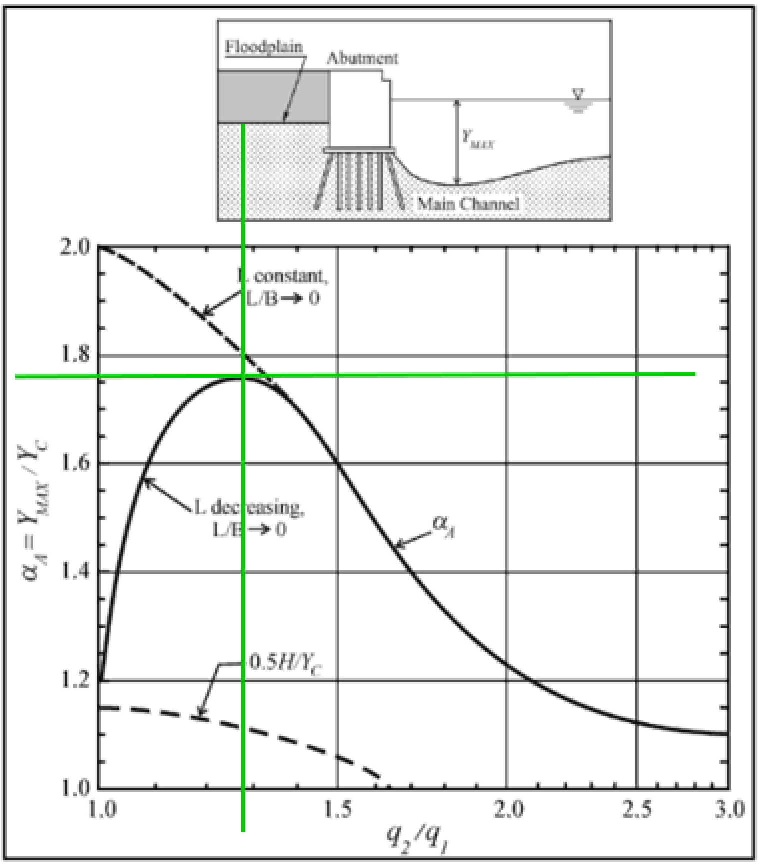
***Live Bed Contraction Scour**: Scour at a contraction when the bed material in the channel upstream of the bridge is moving at the flow causing bridge scour.*

Modified Laursen's Equation (1): $\frac{y_2}{y_1} = \left(\frac{Q_2}{Q_1}\right)^{6/7} \left(\frac{W_1}{W_2}\right)^{k_1}$

Average Contraction Scour Depth: $y_s = y_2 - y_o$

Parameter	Description	Metric Units		US Units		Notes
y_o	Existing Depth in the Contracted Section Before Scour	3.15	(m)	10.32	(ft)	*Flow area of bridge / W_2*
y_1	Average Depth in the Upstream Channel	2.17	(m)	7.11	(ft)	*Data from Chosen Upstream XS*
y_2	Average Depth in the Contraction Section	2.56	(m)	8.39	(ft)	*Modified Laursen's Equation*
Q_1	Flow in the Upstream Channel Transporting Sediment	79.27	(m^3/s)	2799.52	(cfs)	*Flow in the main channel upstream of the bridge, not including overbank flow.*
Q_2	Flow in the Contracted Channel	79.29	(m^3/s)	2800.00	(cfs)	*Flow at the bridge section (through the bridge opening)*
W_1	Bottom Width of the Upstream Main Channel that is Transporting Bed Material	25.63	(m)	84.09	(ft)	*Can be estimated by Upstream Channel Top Width. Data from Chosen Upstream XS*
W_2	Bottom width of the Contracted Section Minus Pier and Debris Width	19.81	(m)	65.00	(ft)	*Effective Bridge Width Calculated Given Bridge, Pier, and Debris Width*
S_1	Slope of EGL of Upstream Channel	0.00	(m/m)	0.00	(ft/ft)	*Data from Chosen Upstream XS*
V^*	Shear Velocity in the Upstream Main Channel	0.24	(m/s)	0.77	(ft/s)	*Calculated from data from Chosen Upstream XS(s). [$V^* = (gy_1S_1)^{0.5}$]*
ω	Fall Velocity of Bed Material based on D50	0.19	(m/s)	0.63	(ft/s)	*See Fall Velocity Tab*
V^*/ω	Ratio of Shear Velocity to Fall Velocity	1.236	-	1.236	-	*Determines Mode of Bed Transport and k_1*
k_1	Modified Laursen's Equation Exponent	0.64	-	0.64	-	*See Table 2 to the right.*

Average Live Bed Contraction Scour Depth (y_s)	**0.0**	**(ft)**
	0.0	(m)



2a) Scour occurring when the abutment is in or close to the main channel (Live Bed)

$$y_c = y_1 \left(\frac{q_{2c}}{q_1} \right)^{6/7} \qquad y_{max} = \alpha_A \, y_c \qquad y_s = y_{max} - y_0$$

Parameter	Description	Metric Units		US Units		Notes
y_1	Upstream flow depth	2.17	(m)	7.11	(ft)	*Flow area of bridge / W_2*
y_0	Flow depth prior to scour	3.15	(m)	10.32	(ft)	*Data from chosen upstream XS*
α_a	Amplification factor for live-bed conditions	1.71	-	1.71	-	*For spill through abutments: Use Figure 8.9 For wingwall abutments: Use Figure 8.10*
W_1	Width of the upstream channel	25.63	(m)	84.09	(ft)	*Width of Flow upstream of the bridge section*
Q_1	Flow in the upstream channel	79.27	(m^3/s)	2799.5	(ft^3/s)	*Flow upstream of the bridge section*
q_{2c}	Unit discharge in the constricted opening accounting for non-uniform flow distribution	4.00	(m^2/s)	43.08	(ft^2/s)	*Estimated as the total discharge in the bridge opening divided by the width of the bridge opening: Q_2 / W_2*
q_1	Upstream unit discharge	3.09	(m^2/s)	33.29	(ft^2/s)	*Q_1 / W_1*
q_2/q_1	Ratio of unit discharge	1.29	(m)	1.29	(ft)	*Value used in Figure 8.9 and Figure 8.10 to determine amplification factor*
y_c	Flow depth including live-bed contraction scour	2.70	(m)	8.87	(ft)	*Equation Above*
y_{max}	Max flow depth resulting from abutment scou	4.62	(m)	15.16	(ft)	*Equation Above*

Live Bed Abutment Scour Depth (y_s)	**4.8**	**(ft)**
	1.5	(m)

APPENDIX G – ROCK SLOPE PROTECTION ESTIMATES

Caltrans HDM Methodology for RSP Size

USER DATA REQUIRED IN YELLOW

Salem Street

Stone Size (d30)		**5061**	**5014**	**5010**	**5000 BR U**	**5000 BR D**	**4957**	**4944**	**4919**	Units
Constants and Coefficients										
Safety Factor (typically 1.1)	Sf	1.10	1.1	1.1	1.1	1.1	1.1	1.1	1.1	
Stability Coefficient	Cs	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	
Velocity distribution coefficient	Cv	1.03	1.02	1.02	1.00	1.00	1.00	1.00	1.00	
Blanket thickness coefficient	CT	1	1	1	1	1	1	1	1	
Specific Gravity of stone (2.5 min)	Sg	2.65	2.65	2.65	2.65	2.65	2.65	2.65	2.65	
Acceleration due to gravity	g	32.2	32.2	32.2	32.2	32.2	32.2	32.2	32.2	ft/s2
Inputs from HEC-RAS										
Width of WS u/s channel bend	W	96.74	80.81	79.14	65	61.54	63.2	63.4	60.13	
Average Velocity	Vavg	4.05	4.88	5.17	4.17	4.95	5.01	4.72	4.9	ft/s
Hydraulic Depth	y	7.15	7.11	8.33	10.32	9.2	9.34	9.36	9.5	feet
Other Inputs										
Slope	fraction	1/1.5	1/1.5	1/1.5	1/1.5	1/1.5	1/1.5	1/1.5	1/1.5	
Slope	decimal	0.666666667	0.66666667	0.666666667	0.666666667	0.66666667	0.66666667	0.666666667	0.66666667	
Bank Angle	theta	33.69	33.69	33.69	33.69	33.69	33.69	33.69	33.69	
Radius of curvature of bend	Rc	1700	1700	1700	1700	1700	1700	1700	1700	feet
Calculations										
$K_1 = \sqrt{1 - \left[\frac{\sin(\theta - 14^\circ)}{\sin 32^\circ}\right]^{1.6}}$	Rc/W	17.57	21.04	21.48	26.15	27.62	26.90	26.81	28.27	
	K1	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	
Characteristic velocity	Vdes	4.43	5.13	5.41	4.17	4.95	5.01	4.72	4.90	ft/s
	d30	0.09	0.13	0.14	0.07	0.11	0.11	0.10	0.11	feet
$d_{30} = y(S_f C_s C_v C_T)\left[\frac{V_{des}}{\sqrt{K_1(S_g - 1)gy}}\right]^{2.5}$	**d50**	0.11	0.16	0.17	0.08	0.13	0.13	0.12	0.13	feet
	d50	1.31	1.87	2.05	0.99	1.57	1.61	1.39	1.52	inches
Stone Weight (W)										
	Yw	62.4	62.4	62.4	62.4	62.4	62.4	62.4	62.4	lb/ft3
$W = 0.85(\gamma_s d^3)$	Sg	2.65	2.65	2.65	2.65	2.65	2.65	2.65	2.65	
	Ys	165.36	165.36	165.36	165.36	165.36	165.36	165.36	165.36	lb/ft3
	d	0.1	0.2	0.2	0.1	0.1	0.1	0.1	0.1	feet
	W	0.18	0.53	0.70	0.08	0.31	0.34	0.22	0.28	pounds
RSP Class by Size	Class	I	I	I	I	I	I	I	I	
	Size	6	6	6	6	6	6	6	6	inches
	1.5*d50	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	inches
	d100	12	12	12	12	12	12	12	12	inches
	Thickness	12	12	12	12	12	12	12	12	inches
	Method	B	B	B	B	B	B	B	B	
RSP Class by Weight	Class	I	I	I	I	I	I	I	I	
	Weight	20	20	20	20	20	20	20	20	pounds
	W100	140	140	140	140	140	140	140	140	pounds
	Method	B	B	B	B	B	B	B	B	

Table 4.1. Minimum and Maximum Allowable Particle Size in Inches.								
Nominal Riprap Class by Median Particle Diameter		d_{15}		d_{50}		d_{85}		d_{100}
Class	Size	Min	Max	Min	Max	Min	Max	Max
I	6 in	3.7	5.2	5.7	6.9	7.8	9.2	12.0
II	9 in	5.5	7.8	8.5	10.5	11.5	14.0	18.0
III	12 in	7.3	10.5	11.5	14.0	15.5	18.5	24.0
IV	15 in	9.2	13.0	14.5	17.5	19.5	23.0	30.0
V	18 in	11.0	15.5	17.0	20.5	23.5	27.5	36.0
VI	21 in	13.0	18.5	20.0	24.0	27.5	32.5	42.0
VII	24 in	14.5	21.0	23.0	27.5	31.0	37.0	48.0
VIII	30 in	18.5	26.0	28.5	34.5	39.0	46.0	60.0
IX	36 in	22.0	31.5	34.0	41.5	47.0	55.5	72.0
X	42 in	25.5	36.5	40.0	48.5	54.5	64.5	84.0
Note: Particle size d corresponds to the intermediate ("B") axis of the particle.								

Table 4.2. Minimum and Maximum Allowable Particle Weight in Pounds.								
Nominal Riprap Class by Median Particle Weight		W_{15}		W_{50}		W_{85}		W_{100}
Class	Weight	Min	Max	Min	Max	Min	Max	Max
I	20 lb	4	12	15	27	39	64	140
II	60 lb	13	39	51	90	130	220	470
III	150 lb	32	93	120	210	310	510	1100
IV	300 lb	62	180	240	420	600	1,000	2,200
V	1/4 ton	110	310	410	720	1,050	1,750	3,800
VI	3/8 ton	170	500	650	1,150	1,650	2,800	6,000
VII	1/2 ton	260	740	950	1,700	2,500	4,100	9,000
VIII	1 ton	500	1,450	1,900	3,300	4,800	8,000	1,7600
IX	2 ton	860	2,500	3,300	5,800	8,300	13,900	30,400
X	3 ton	1,350	4,000	5,200	9,200	13,200	22,000	48,200
Note: Weight limits for each class are estimated from particle size by: $W = 0.85(\gamma_s d^3)$ where d corresponds to the intermediate ("B") axis of the particle, and particle specific gravity is taken as 2.65.								

APPENDIX H – LOCATION HYDRAULIC STUDY FORM

LOCATION HYDRAULIC STUDY FORM

Dist. 3 Co. Butte Rte. Salem Street Project ID: Bridge # 12C0336
Federal-Aid Project Number :BRLO-5037(022)

Floodplain Description:

Little Chico Creek flows southwesterly through the project site through the central part of Chico, CA in Butte County (County). It drains an approximate 48.3 square miles at the project site. The area surrounding the project is residential. The channel top width (top of bank to top of bank) varies from approximately 75 feet upstream of the bridge to approximately 45 feet downstream of the bridge. The channel bottom is clear of vegetation and the banks and overbanks are heavily vegetated. The project channel is within a FEMA Floodplain Zone AE (an area inundated by the 100-year event for which base flood elevations have been determined), the left (looking downstream) overbanks are Zone AO, an area inundated by shallow flow (1 to 3 feet) during the 100-year event and the right overbanks are Zone X, an area of minimal flood hazard.

1. Description of Proposal *(include any physical barriers i.e. concrete barriers, sound walls, etc. and design elements to minimize floodplain impacts)*

The City of Chico is proposing to remove the existing 64-foot-long and 34-foot-wide three-span bridge (Bridge No. 12C0336) on Salem Street over Little Chico Creek and replace it with a 70-foot-long and 54-foot-wide single-span bridge. The purpose of the proposed project is to provide a safe, reliable crossing of Little Chico Creek that meets current standards.

2. ADT: Current 5200 (2000) Projected 6141 (2036)

3. Hydraulic Data: Base Flood Q100= 2,800 CFS

WSE100= 192.1 ft (City of Chico's datum[1])

The flood of record, if greater than Q100:

Q= n/a CFS WSE= n/a

Overtopping flood Q= ~4,000 CFS

WSE= ~ 194.9 ft (City of Chico's datum[1])

Are NFIP maps and studies available? NO ____ YES X

The project channel is within a FEMA designated Floodplain Zone AE the left (looking downstream) overbanks are Zone AO, an area inundated by shallow flow (1 to 3 feet) during the 100-year event and the right overbanks are Zone X, an area of minimal flood hazard, as shown on Figure 1. Note, the elevations shown in the FIRMette are NAVD-88 while the project datum is the City of Chico's datum (conversion from City Datum to NAVD-88 is +3.07 ft[1])

[1] Conversion to NAVD-88 is +3.07 ft per electronic mail from Julie Passalacqua, Structures Division Manager, Mark Thomas to Cathy Avila, Project Manager, Avila and Associates dated September 7, 2017.

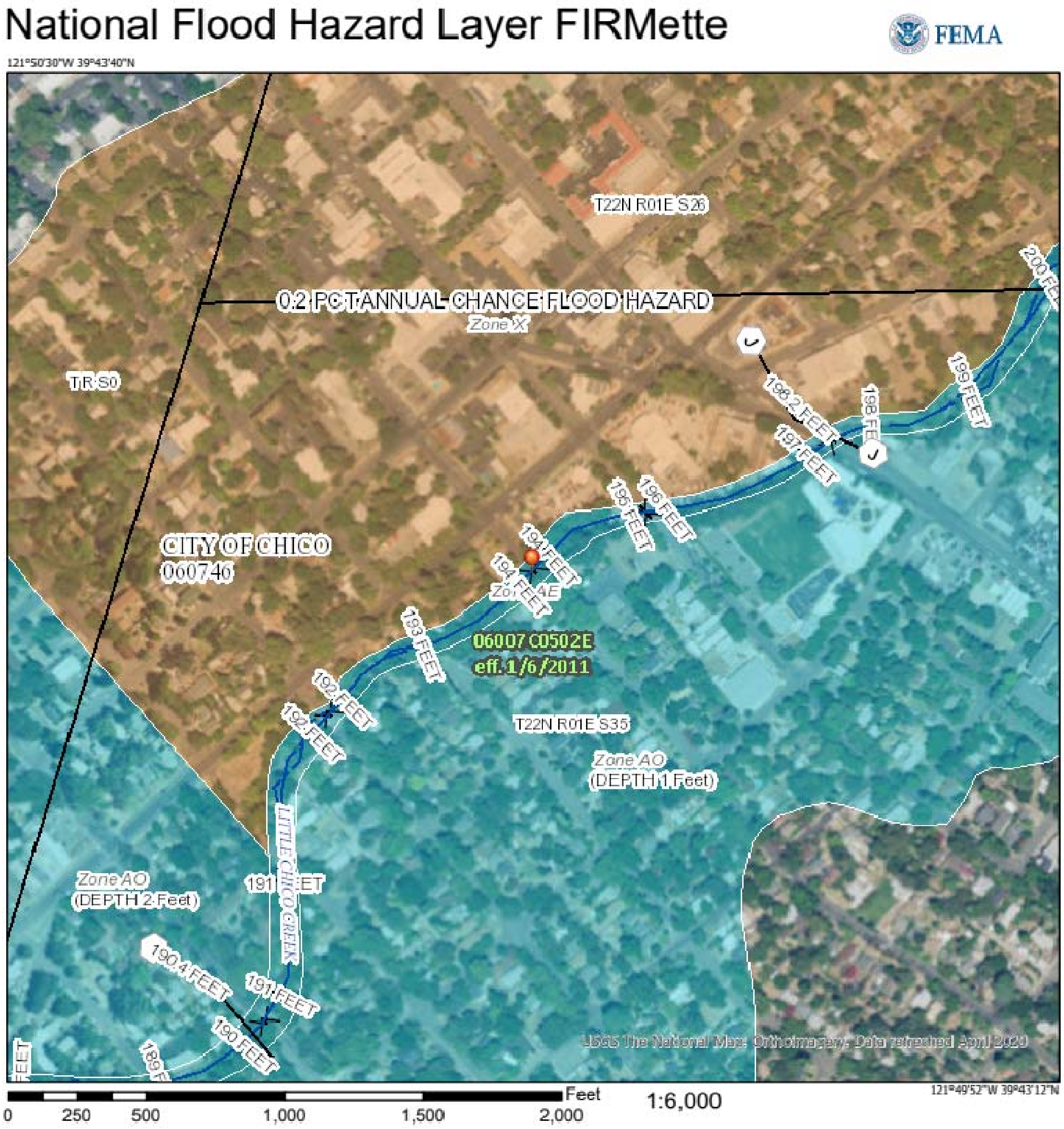


Figure 1. FEMA FIRMette of Map Number 06007C0502E dated January 6, 2011

4. Is the highway location alternative within a regulatory floodway?

NO ___X_____YES_________

5. Attach map with flood limits outlined showing all buildings or other improvements within the base floodplain.

As shown in Figure 2, Figure 3 and Figure 4 the water surface elevation is lowered upstream and slightly increased (less than 0.4 ft) downstream as a result of the proposed bridge. The water extents will be slightly increased downstream as a result of the proposed abutment grading for the wider bridge. This will have no adverse impact on the floodplain or surrounding insurable properties.

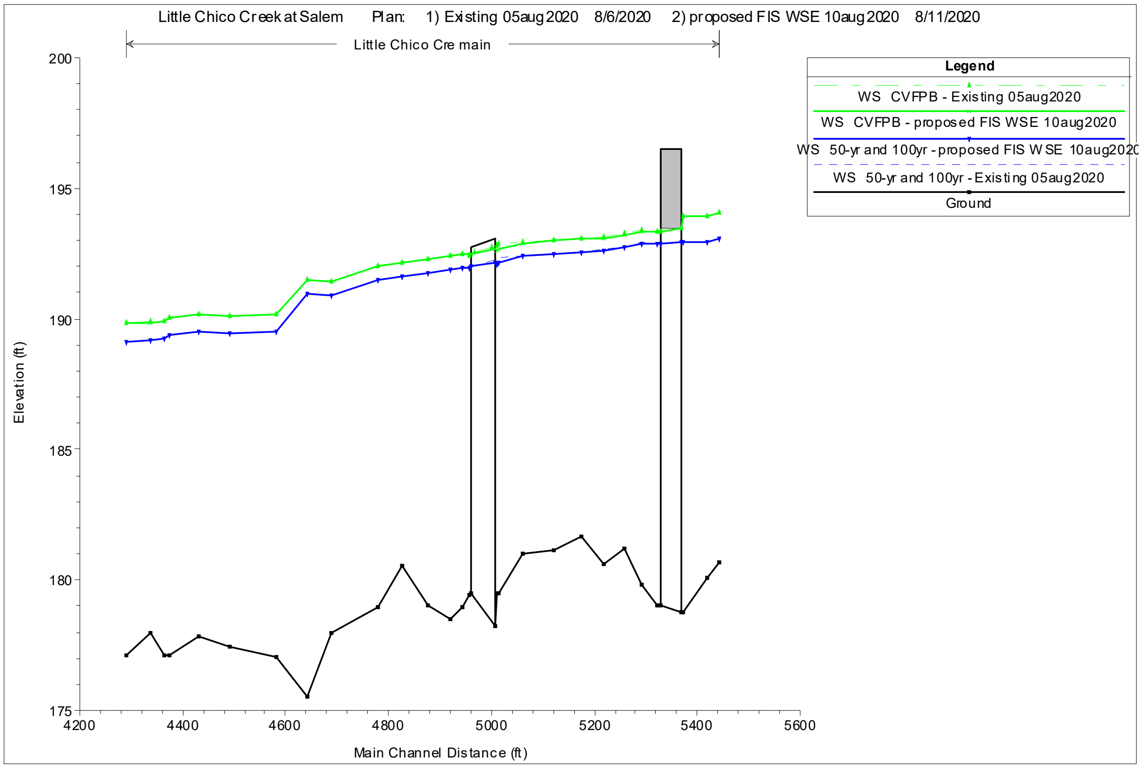


Figure 2. WSE comparison between existing (dashed) and proposed (solid) conditions for the 100-yr discharge.

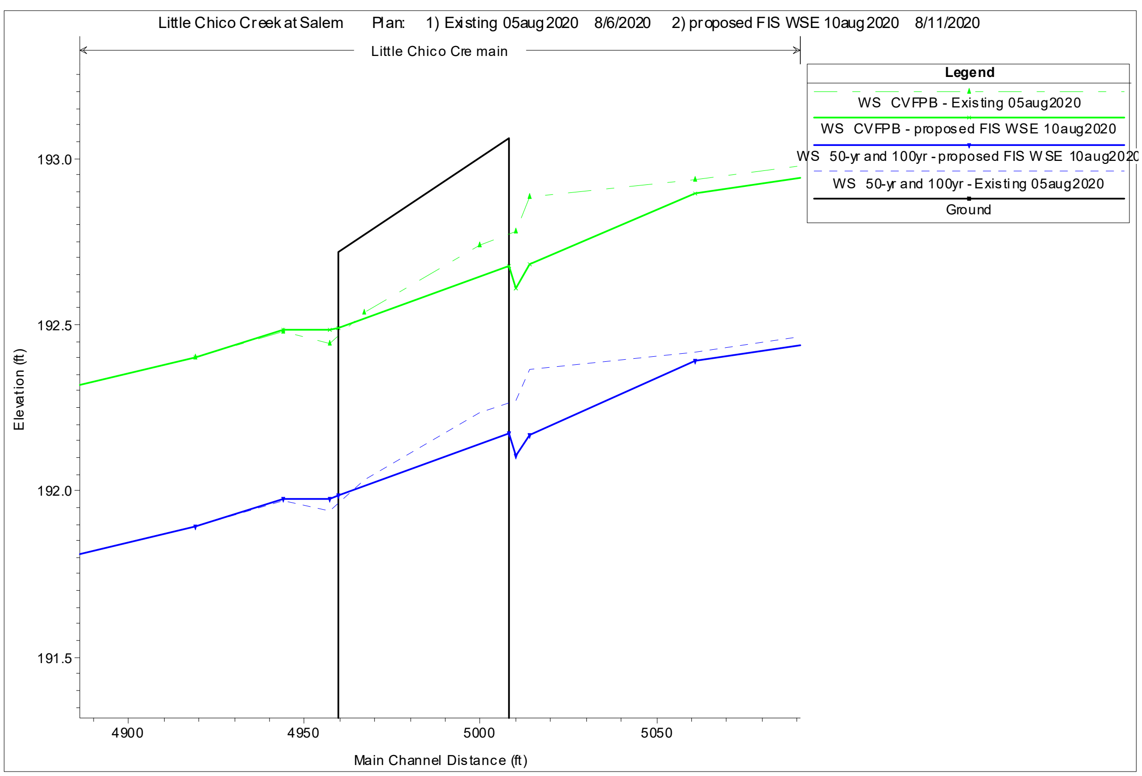


Figure 3. Zoomed in Figure 2.

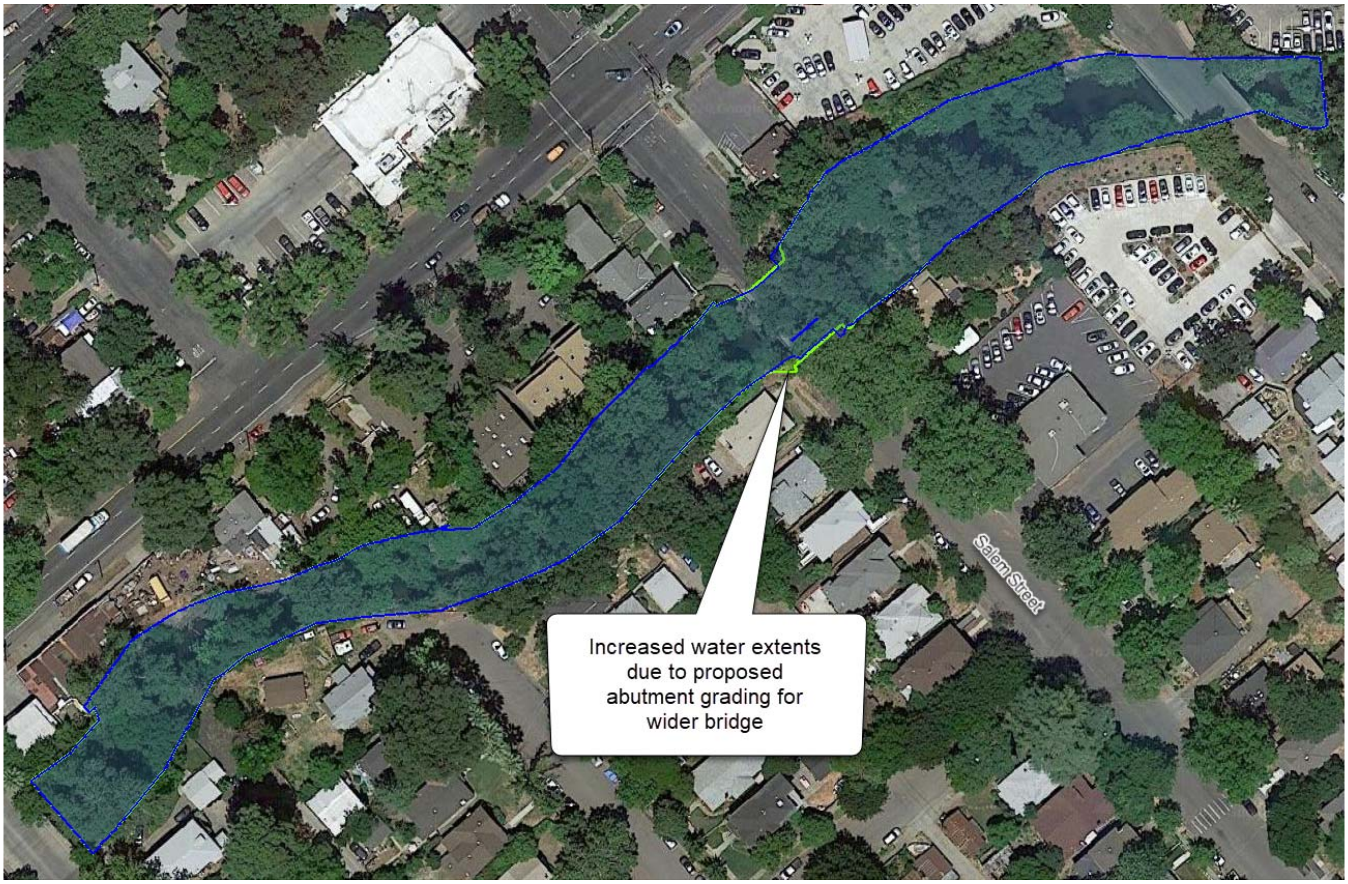


Figure 4. Water surface extents comparison between existing (green dashed) and proposed (blue solid) conditions for the 100-yr discharge.

Potential Q100 backwater damages:

A. Residences? NO____X_____YES_________

The water surface elevation is lowered upstream of the bridge, and only slightly increased less than 0.4 feet downstream of the project, and will not adversely impact the water surface elevation at the adjacent residences.

B. Other Bldgs? NO____X_____YES_________

The water surface elevation is lowered upstream of the bridge, , and only slightly increased less than 0.4 feet downstream of the project, and will not adversely impact the water surface elevation at the adjacent buildings.

C. Crops? NO____X_____YES_________

The are no crops surrounding the project.

D. Natural and beneficial Floodplain values? NO____X_____YES_________

"Natural and beneficial flood-plain values" shall include but are not limited to fish, wildlife, plants, open space, natural beauty, scientific study, outdoor recreation, agriculture, aquaculture, forestry, natural moderation of floods, water quality maintenance, and groundwater recharge.

The water surface elevation is lowered upstream, and only slightly increased less than 0.4 feet downstream as a result of the proposed bridge and will not adversely impact the natural and beneficial floodplain values.

6. Type of Traffic:

A. Emergency supply or evacuation route? NO__________YES___X_____

B. Emergency vehicle access? NO__________YES___X_____

C. Practicable detour available? NO__________YES___X_____

D. School bus or mail route? NO__________YES ___X_____

7. Estimated duration of traffic interruption for 100-year event hours:____n/a___

8. Estimated value of Q100 flood damages (if any) – moderate risk level.

A.	Roadway	$______n/a_____
B	Property	$______n/a_____
	Total	$______n/a_____

9. Assessment of Level of Risk

Low___X______

Moderate______

High_________

For High Risk projects, during design phase, additional Design Study Risk Analysis may be necessary to determine design alternative.

LOCATION HYDRAULIC STUDY FORM cont.

Dist.___3__Co. Butte__Rte.___Salem St P.M.__ Federal-Aid Project Number :BRLO-5037(022)
Project ID_______________________________________Bridge No.______12C0336______________

PREPARED BY:

Signature:
I certify that I have conducted a Location Hydraulic Study consistent with 23 CFR 650 and that the information summarized in items numbers 3, 4, 5, 7, and 9 of this form is accurate.

____ *Date* ___________________
District Hydraulic Engineer *(capital and 'on' system projects)*

Cashew MC Smith_______________________________ *Date* September 16, 2020_________
Local Agency/Consulting Hydraulic Engineer *(local assistance projects)*

Is there any longitudinal encroachment, significant encroachment, or any support of incompatible Floodplain development? NO___X_____YES_________

If yes, provide evaluation and discussion of practicability of alternatives in accordance with 23 CFR 650.113

Information developed to comply with the Federal requirement for the Location Hydraulic Study shall be retained in the project files.

I certify that item numbers 1, 2, 6 and 8 of this Location Hydraulic Study Form are accurate and will ensure that Final PS&E reflects the information and recommendations of said report:

____ *Date* ___________________
District Project Engineer *(capital and 'on' system projects)*

____ *Date* 17 SEP 2020___________
Local Agency Project Engineer *(local assistance projects)*

CONCURRED BY:
I have reviewed the quality and adequacy of the floodplain submittal consistent with the attached checklist, and concur that the submittal is adequate to meet the mandates of 23 CFR 650.

____ *Date* ___________________
District Project Manager *(capital and 'on' system projects)*

____ *Date* 17 SEP 2020___________
Local Agency Project Manager *(Local Assistance projects)*

____ *Date* 9/18/2020___________
District Local Assistance Engineer *(or District Hydraulic Branch for very complex projects or when required expertise is unavailable. Note: District Hydraulic Branch review of local assistance projects shall be based on reasonableness and concurrence with the information provided).*

I concur that the natural and beneficial floodplain values are consistent with the results of other studies prepared pursuant to 23 CFR 771, and that the NEPA document or determination includes environmental mitigation consistent with the Floodplain analysis.

Laura Loeffler_________________________________ *Date* 09/21/20___________
District Senior Environmental Planner *(or Designee)*

Note: If a significant floodplain encroachment is identified as a result of floodplains studies, FHWA will need to approve the encroachment and concur in the Only Practicable Alternative Finding.

APPENDIX I – SUMMARY FLOODPLAIN ENCROACHMENT REPORT

SUMMARY FLOODPLAIN ENCROACHMENT REPORT

Dist. ____3______Co. ___Butte___ Rte._ Salem Street _ __ K.P. ____________

Federal-Aid Project Number :BRLO-5037(022)

Project No.: __________________________ Bridge No. _____12C0336_________________

Limits:

The City of Chico is proposing to remove the existing 64-foot-long and 34-foot-wide three-span bridge (Bridge No. 12C0336) on Salem Street over Little Chico Creek and replace it with a 70-foot-long and 48.33-foot-wide single-span bridge. The purpose of the proposed project is to provide a safe, reliable crossing of Little Chico Creek that meets current standards

Floodplain Description:

Little Chico Creek flows southwesterly through the project site through the central part of Chico, CA in Butte County (County). It drains an approximate 48.3 square miles at the project site. The area surrounding the project is residential. The channel top width (top of bank to top of bank) varies from approximately 75 feet upstream of the bridge to approximately 45 feet downstream of the bridge. The channel bottom is clear of vegetation and the banks and overbanks are heavily vegetated. The project channel is within a FEMA Floodplain Zone AE (an area inundated by the 100-year event for which base flood elevations have been determined), the left (looking downstream) overbanks are Zone AO, an area inundated by shallow flow (1 to 3 feet) during the 100-year event and the right overbanks are Zone X, an area of minimal flood hazard.

		No	Yes
1.	Is the proposed action a longitudinal encroachment of the base floodplain? *The proposed bridge is not a longitudinal encroachment.*	_x_	___
2.	Are the risks associated with the implementation of the proposed action significant? *The level of risk to the floodplain of the project site is low because the action is to replace the existing bridge with a bridge with 2 fewer piers, thus improving the hydraulics through the structure and slightly lowering the water surface elevation upstream.*	_x_	___
3.	Will the proposed action support probable incompatible floodplain development? *The proposed bridge replacement will remove the 2 existing bridge piers and will lower the water surface elevation upstream of the project while only slightly increasing the water surface elevation downstream due a new drawdown curve through the bridge. The project will not support incompatible floodplain development.*	_x_	___

4. Are there any significant impacts on natural and beneficial floodplain values? _x_ ___
The proposed construction will have only minor temporary impact to the existing riparian habitat in the creek at the bridge site

5. Routine construction procedures are required to minimize impacts on the floodplain. Are there any special mitigation measures necessary to minimize impacts or restore and preserve natural and beneficial floodplain values? If yes, explain. _x_ ___
Best management practices for erosion control measures should be used for proposed construction to minimize temporary impacts to the floodplain during construction.

6. Does the proposed action constitute a significant floodplain encroachment as defined in 23 CFR, Section 650.105(q). _x_ ___

7. Are Location Hydraulic Studies that document the above answers on file? If not explain. ___ _x_

PREPARED BY:

________________________________ *Date* ________________
District Project Engineer *(capital and 'on' system projects)*

________________________________ *Date* 17 SEP 2020
Local Agency Project Engineer *(local assistance projects)*

CONCURRED BY:

________________________________ *Date* ________________
District Project Manager *(capital and 'on' system projects)*

________________________________ *Date* 9/18/2020
District Local Assistance Engineer *(Local Assistance projects)*

I concur that impacts to natural and beneficial floodplain values are consistent with the results of other studies prepared pursuant to 23 CFR 771, and that the NEPA document or determination includes environmental mitigation consistent with the Floodplain analysis.

Laura Loeffler *Date* 09/21/20
District Senior Environmental Planner *(or Designee)*

Note: If a significant floodplain encroachment is identified as a result of floodplains studies, FHWA will need to approve the encroachment and concur in the Only Practicable Alternative Finding.