

APPENDIX D
DESIGN HYDRAULIC STUDY



PRELIMINARY DESIGN

HYDRAULIC STUDY

COUNTY ROAD 305 BRIDGE AT
WATSON CREEK

Bridge Number 11C0091

GLENN COUNTY, CALIFORNIA



Preliminary Design Hydraulic Study
COUNTY ROAD 305 BRIDGE AT WATSON CREEK

GLENN COUNTY, CALIFORNIA

Bridge #11C0019

JANUARY 23, 2017

PREPARED FOR:
WILLDAN ENGINEERING
AND THE GLENN COUNTY PLANNING
AND PUBLIC WORKS AGENCY
ENGINEERING DIVISION

Prepared by:

AVILA AND ASSOCIATES
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Catherine M.C. Avila 1/23/17
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EXECUTIVE SUMMARY

The County Road 305 Bridge (bridge) at Watson Creek in Glenn County (County), California is proposed for replacement by the County in 2020. The proposed bridge will be a 2-span cast in place reinforced concrete slab deck bridge and will replace an existing 4-span reinforced concrete slab deck bridge. The bridge will be approximately 87.75 feet long and will accommodate 2 travel lanes with 4' wide shoulders as shown in the attached General Plan (Appendix A).

Watson Creek flows southeasterly through the project area and through the northwestern part of Glenn County draining an approximate 15.9 square miles at the bridge site. It is a tributary to Grindstone Creek that drains an approximate area of 156 square miles. The bridge is located approximately 400 feet upstream from the confluence with Grindstone Creek and the water surface elevation (WSE) is influenced by the flow condition in Grindstone Creek. Two flow conditions were analyzed to take into account the difference between the two drainage areas as follows:

- 1) 50-year and 100-year discharge in Watson Creek at time of 10-year peak discharge (and WSE) in Grindstone Creek
- 2) 10-year discharge in Grindstone Creek at time of 50-year and 100-year peak discharge in Watson Creek

Table 1 shows the estimated 50-yr and 100-yr discharges in Watson Creek and water surface elevations at the bridge for the two flow conditions.

Table 1: Estimated 50-yr and 100-yr discharges and water surface elevations for bridge design

	Peak in Grindstone Creek (Condition 1)		Peak in Watson Creek (Condition 2)	
	Design	Base	Design	Base
Recurrence Interval	50-yr	100-yr	50-yr	100-yr
Discharge (cubic feet per second)	2,417	2,850	3,705	4,425
Water Surface (elevation in feet at upstream face of Bridge)	643.9	644.0	643.0	643.7

The US Army Corps of Engineers HEC-RAS¹ model was used to estimate the water surface elevation (WSE) for the existing and proposed bridge. For both flow conditions at the bridge, the WSE was lowered upstream due to the proposed bridge.

This report follows the Caltrans Final Hydraulic Report Format and has been prepared in accordance with the Caltrans Local Assistance Program Guidelines (1) and Memos to Designers 1-23 (3).

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.

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 bridge. The following scope of work has been completed to develop this report.

1. Obtain backup information and field review
2. Estimate hydrology
3. Develop a HEC-RAS model using surveyed cross sections of Watson Creek and Grindstone Creek.
4. Estimate scour
5. Prepare Draft Report for comment
6. Prepare Final Report

The existing bridge is located approximately 20 miles northwest from the town of Willows as shown in Figure 1. The existing bridge was constructed in 1920. It is a 4-span reinforced concrete T-beam slab bridge supported by reinforced concrete abutments and concrete column bents. It has a sufficiency rating as of 2012 of 50.0 and is structurally deficient. The Glenn County Planning and Public Works Agency proposes to replace the existing bridge with a new bridge crossing Watson Creek using Highway Bridge Program (HBP) funds.

The datum elevation used for this study is NAVD-88². The proposed bridge will be a 2-span cast in place reinforced concrete slab deck bridge supported by concrete seat abutments and concrete pier wall. It will be approximately 87.75 feet long and will accommodate 2 travel lanes with 4' wide shoulders as shown in Figure 3 and in the attached General Plan (Appendix A).

² Electronic Mail from Gary Gordon, P.E., Project Manager, Willdan Engineering, to Todd Remington, Project Engineer, Avila and Associates, on April 22, 2016.

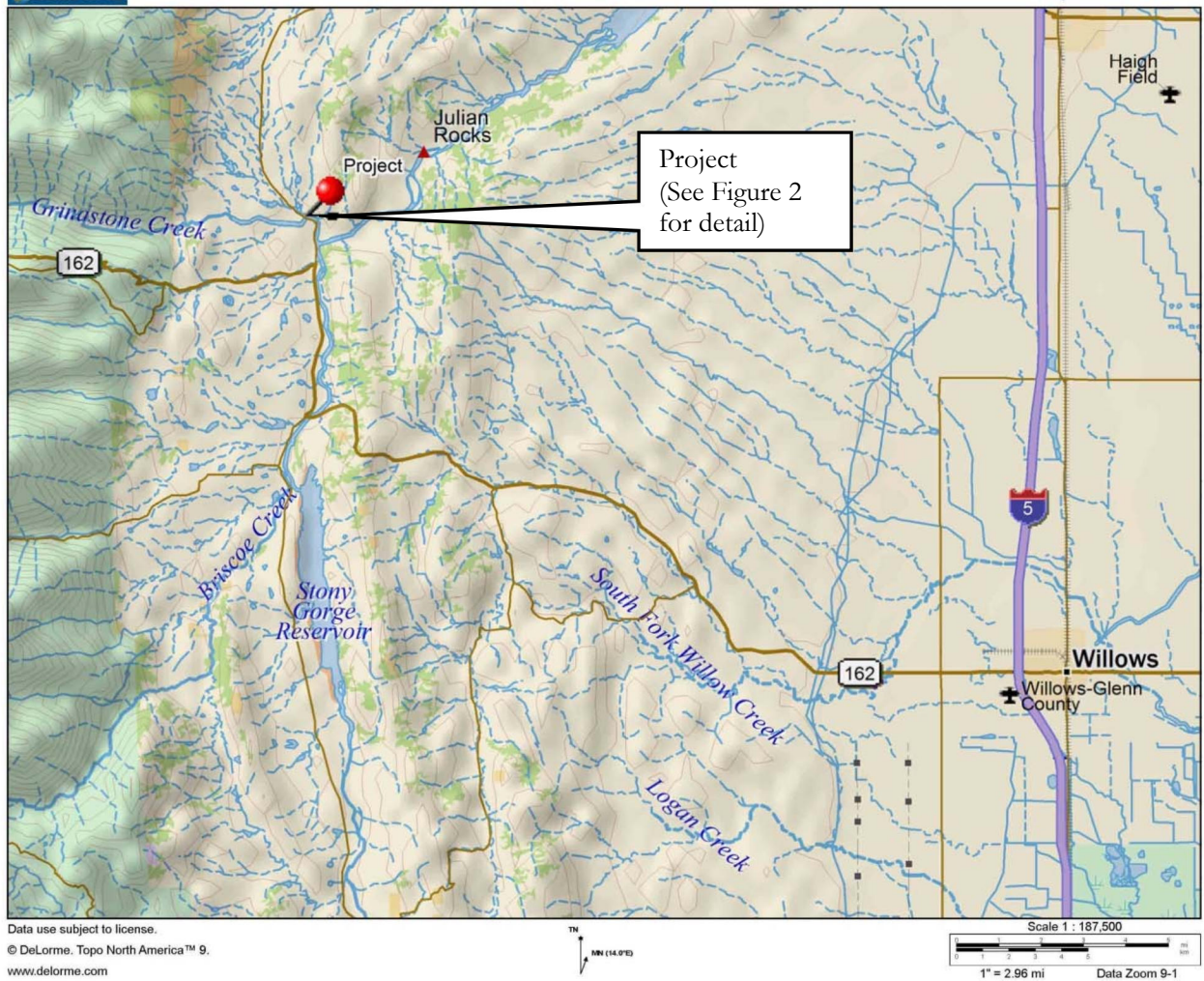


Figure 1. Location Map

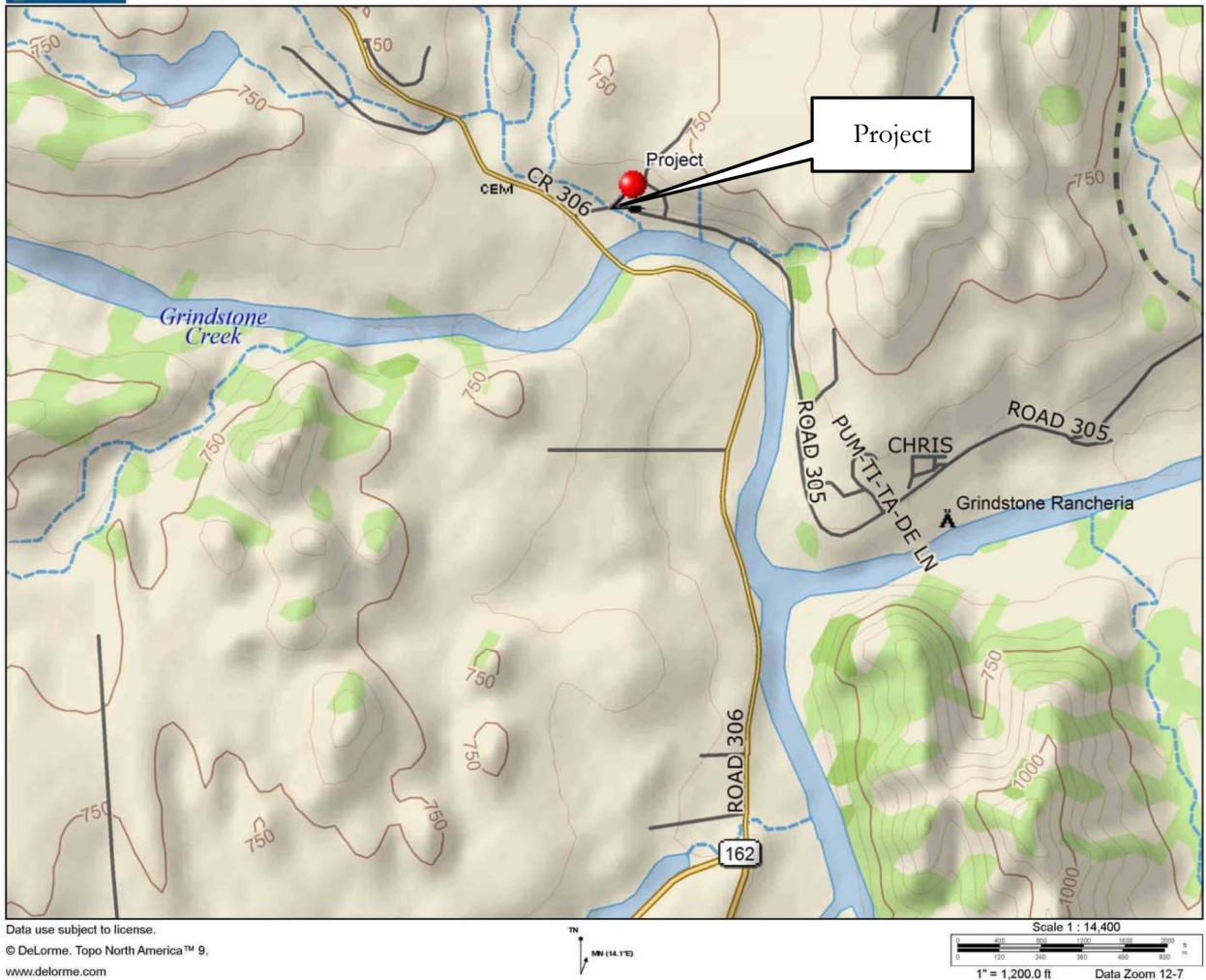


Figure 2: Detail of Bridge location

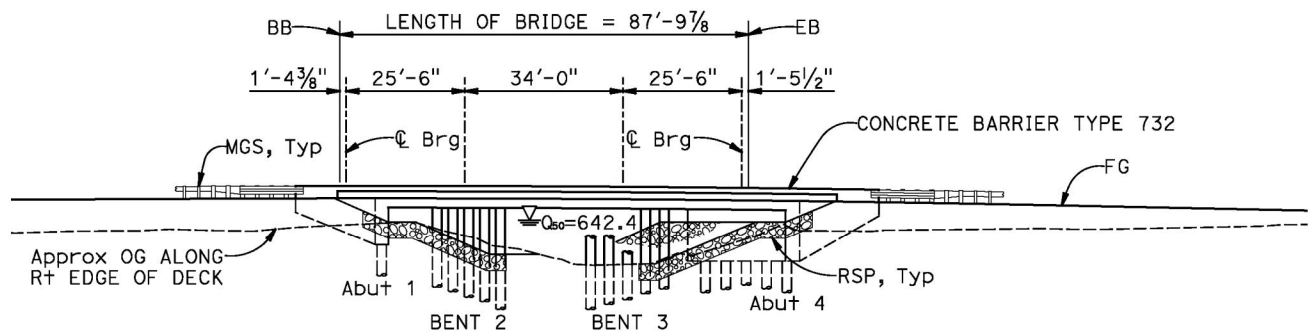


Figure 3: Proposed bridge profile view

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: Existing bridge information and summary of maintenance records

	Co. Rd. 305 at Watson Creek
Bridge Number	11C0091
Bridge Length (ft)	80
Span Lengths (ft)	4 @ 20
Bridge Type	Reinforced concrete T-beam slab on concrete wall abutments.
Debris Challenges	1948 ³ , 1977 ⁴ , 1983 ⁵ , 1987 ⁶ , 1996 ⁷ , 2000 ⁸ , 2002 ⁹ , 2004 ¹⁰ , 2006 ¹¹ , 2009 ¹² , 2011 ¹³ , 2012 ¹⁴
Cross Sections Available for	1993, 1996, 2000, 2011
NBIS Item 113 (scour) code	U
ELI Flag 361 Condition State	2
Pier Type	Concrete column bents on separate concrete pads.
Year Built	1920
Year Widened	N/A
Scour Challenges	1948 ¹⁵ , 1977 ¹⁶ , 1983 ¹⁷ , 1984 ¹⁸ , 1987 ¹⁹ , 1989 ²⁰ , 1993 ²¹ , 2000 ²² , 2002 ²³ , 2004 ²⁴ , 2006 ²⁵ , 2009 ²⁶ , 2011 ²⁷ , 2012 ²⁸

³ There is light drift at the bents.

⁴ Debris is accumulating at Bent 3.

⁵ Debris accumulated at the upstream columns at Bent 3 and Bent 4.

⁶ A large pile of drift has accumulated at Bent 4.

⁷ Drift and debris has accumulated against Bent 4.

⁸ Minor drifts are present at Bent 2 and Bent 4.

⁹ Same as 2000.

¹⁰ There are large amounts of drift present at Bent 2 and Bent 4.

¹¹ Same as 2004.

¹² Same as 2006.

¹³ Same as 2009.

¹⁴ Same as 2011.

¹⁵ There is minor scour at the bents.

¹⁶ The left footing of Bent 2 is becoming undermined.

¹⁷ Bent 4 downstream column footing appears to be undermined.

¹⁸ Bent 4 column 4 is undermined with 30%+/- of the bearing area removed by scour.

¹⁹ The column pedestals at Bent 3 and Bent 4 are exposed and have some undermining due to scour.

²⁰ The Bent 3 and Bent 4 column footing are exposed.

²¹ Footings at Bent 2 and Bent 3 are exposed with no undermining. Footings at Bent 4 are exposed with slight undermining of columns 3 and 4.

²² Same as 1993.

²³ Same as 2000. At Bent 3, the columns are undermined 0.1 m and the channel is 0.1 m below the column footing.

²⁴ Same as 2002.

²⁵ Same as 2004.

²⁶ Same as 2006.

²⁷ Same as 2009.

²⁸ Same as 2011.

BASIN AND DISCHARGE

The watershed draining to the bridge is approximately 15.9 square miles as shown in Figure 4. The average annual rainfall for the watershed is approximately 24.6 inches per year²⁹. Watson Creek carries flow southeasterly to the bridge site.

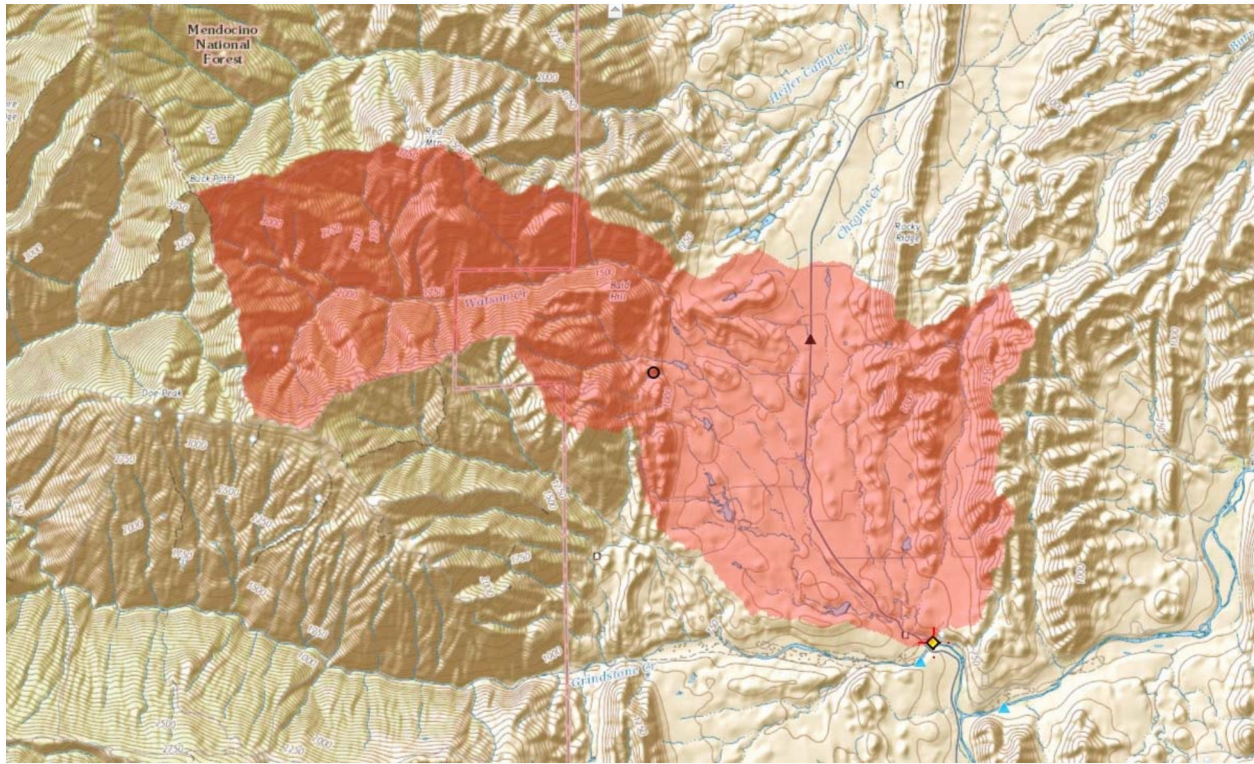


Figure 4: Basin contributing to the bridge (USGS streamstats)

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

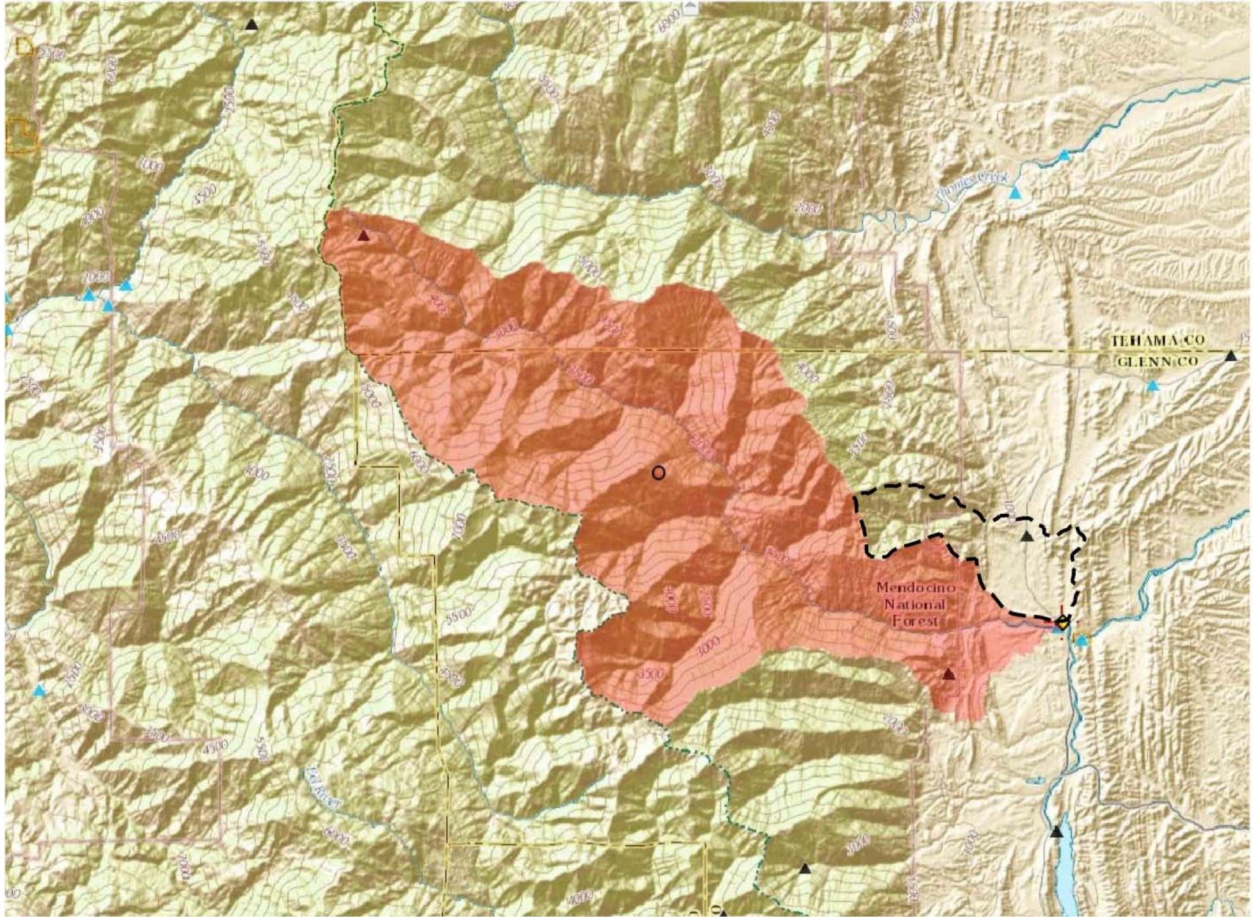


Figure 5: Grindstone Creek Watershed area (Watson Creek watershed shown in dashed line)

Watson Creek is a tributary to Grindstone Creek, which drains an area approximately 10 times larger than Watson Creek (156 sq. mi. vs. 15.9 sq. mi.) as shown in Figure 5. The mean annual rainfall within the Grindstone Creek watershed is approximately 35.1 inches/year. The flow characteristics through the bridge site are influenced by Grindstone Creek. For this analysis, the 50-yr and 100-yr discharges in Watson Creek were analyzed against the 10-yr discharge in Grindstone Creek. Two flow conditions were considered as follows:

1. **Peak in Grindstone Creek.** 50-year and 100-year discharges in Watson Creek at time of 10-year peak discharge (and WSE) in Grindstone Creek.
2. **Peak in Watson Creek.** 10-year discharge in Grindstone Creek at time of 50-year and 100-year peak discharges in Watson Creek

The 50-year and 100-yr discharges in Watson Creek at the bridge and the 10-yr discharge in Grindstone Creek were calculated using a regression analysis as outlined in *Methods for Determining Magnitude and Frequency of Floods in California, Based on Data through Water Year 2006* (USGS SIR 2012-5113) and a HEC-HMS analysis. The peak discharges determined by the two methods are shown in Table 3.

Table 3: Peak discharges from two methods

Method	Peak in Grindstone Creek	Peak in Watson Creek	
	10-yr	50-yr	100-yr
	(cfs)	(cfs)	(cfs)
Regression	15,000	2,660	3,160
HEC-HMS	18,990	3,705	4,425

Because the peak discharges from the HEC-HMS analysis are conservative compared to the regression and the discharges from different times during the storm event are needed for the two flow conditions, the HEC-HMS results will be used for design.

Graphically, the results of the HEC-HMS analysis are shown in Figure 6 (50-yr) and Figure 7 (100-yr). A complete summary of the hydrology analyses is included in Appendix B.

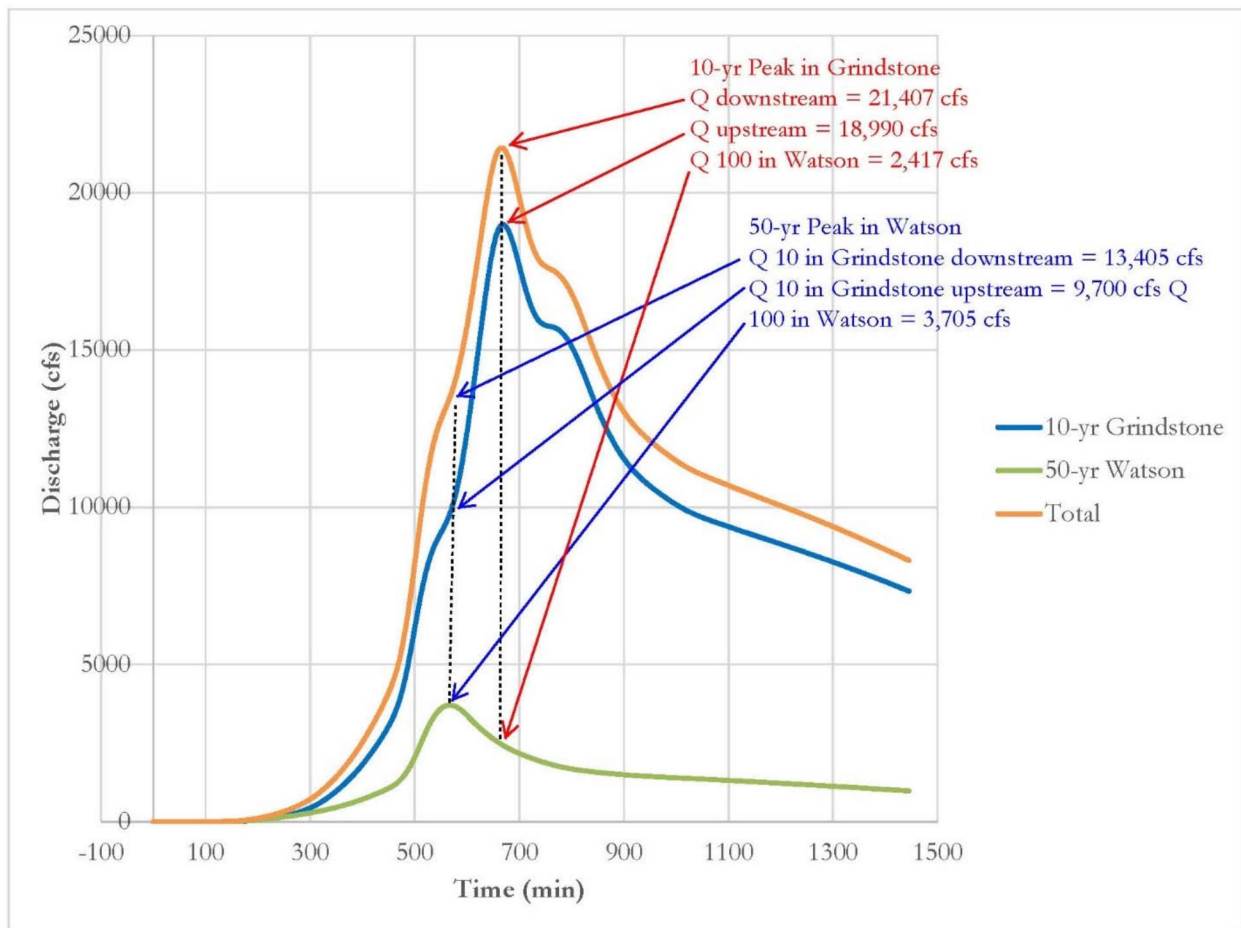


Figure 6: HEC-HMS results for 50-yr analysis

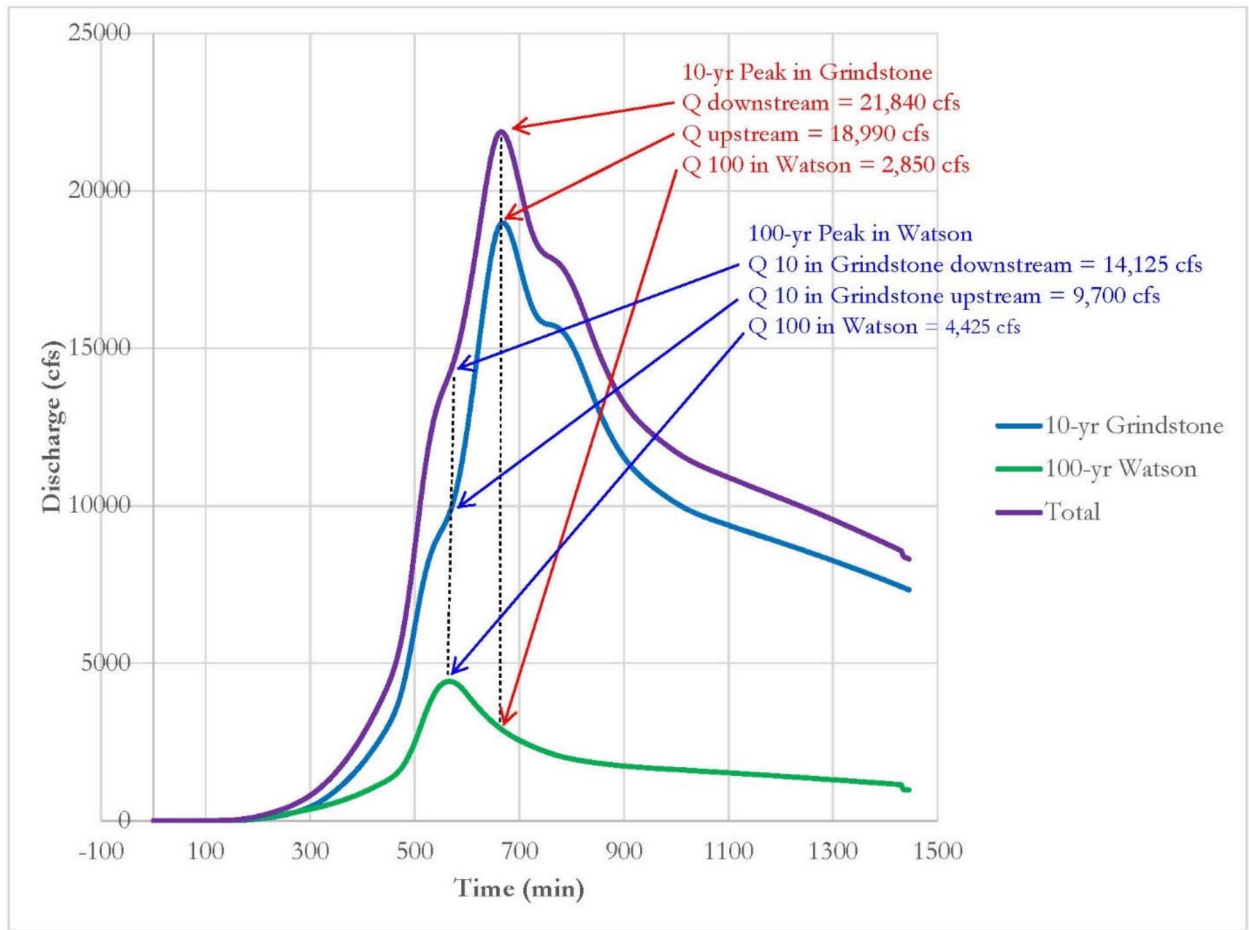


Figure 7: HEC-HMS results for 100-yr analysis

HEC-RAS ANALYSIS

Hydraulic parameters (water surface elevations and velocity) were obtained from the U.S. Army Corps of Engineers (USACOE) HEC-RAS (Hydraulic Engineering Center River Analysis System) version 5.0.1 model based on: 1) survey information supplied by Willdan Engineering and 2) a field investigation by Avila and Associates on August 5, 2015.

Grindstone Creek was modeled as two reaches, the lower reach downstream from the confluence with Watson Creek and the upper reach upstream from Watson Creek. A junction was modeled to represent the confluence. The distribution of discharges modeled in each reach for the two flow conditions is shown in Table 4 and graphically in Figure 6 and Figure 7.

Table 4: Discharge distribution modeled in HEC-RAS

	Flow Condition			
	Peak in Grindstone Creek (Condition 1)		Peak in Watson Creek (Condition 2)	
Recurrence Interval	50-yr	100-yr	50-yr	100-yr
Grindstone Creek				
<i>Upper Reach</i>	18,990	18,990	9,700	9,700
<i>Lower Reach</i>	21,407	21,840	13,405	14,125
Watson Creek	2,417	2,850	3,705	4,425

The bridge reach and cross sections for the HEC-RAS model are shown in Figure 8.

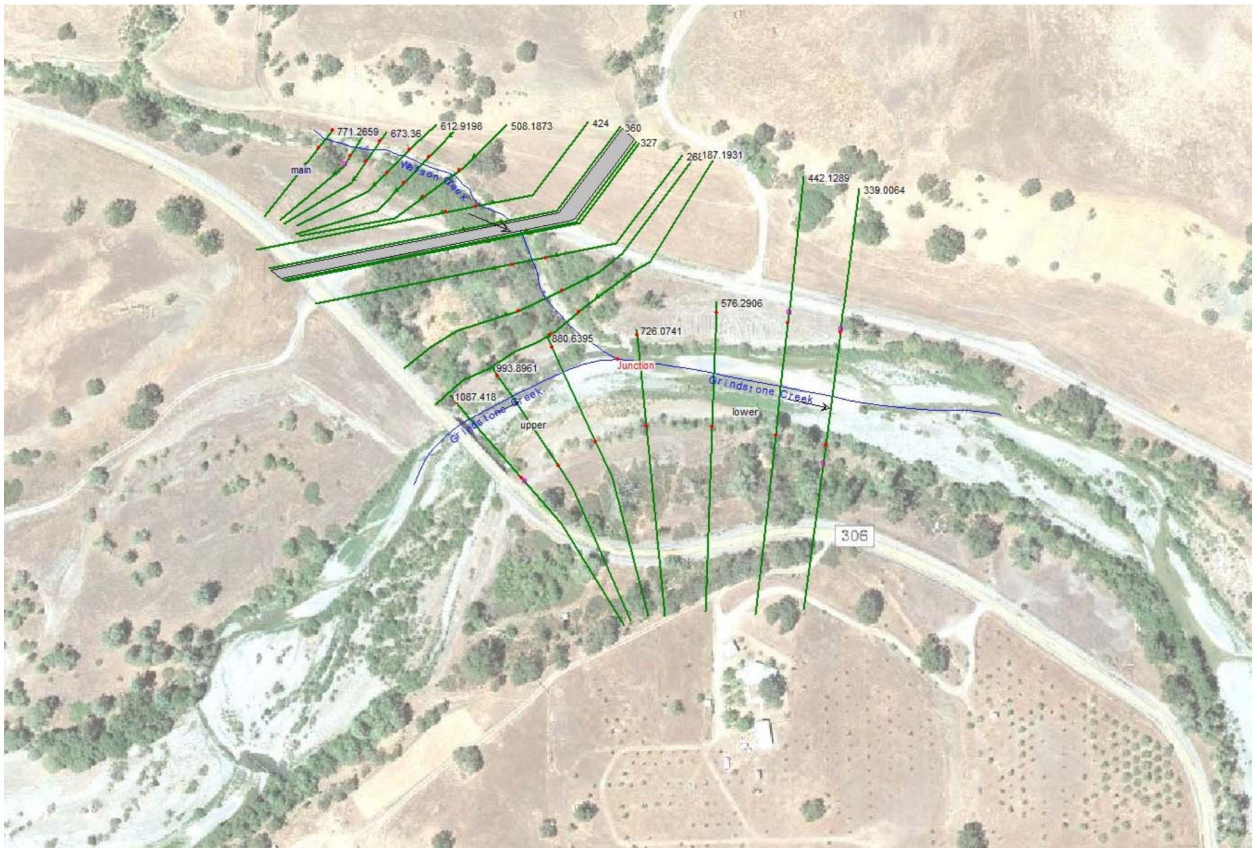


Figure 8. Plan view of HEC-RAS cross section (zoomed in to project area)

Existing Conditions

The Manning “n” values of 0.025 for the channel, 0.045 for the left overbank, and 0.050 for the right overbank were used in the model. These are consistent with the field review by Avila and Associates as shown in Figure 9.

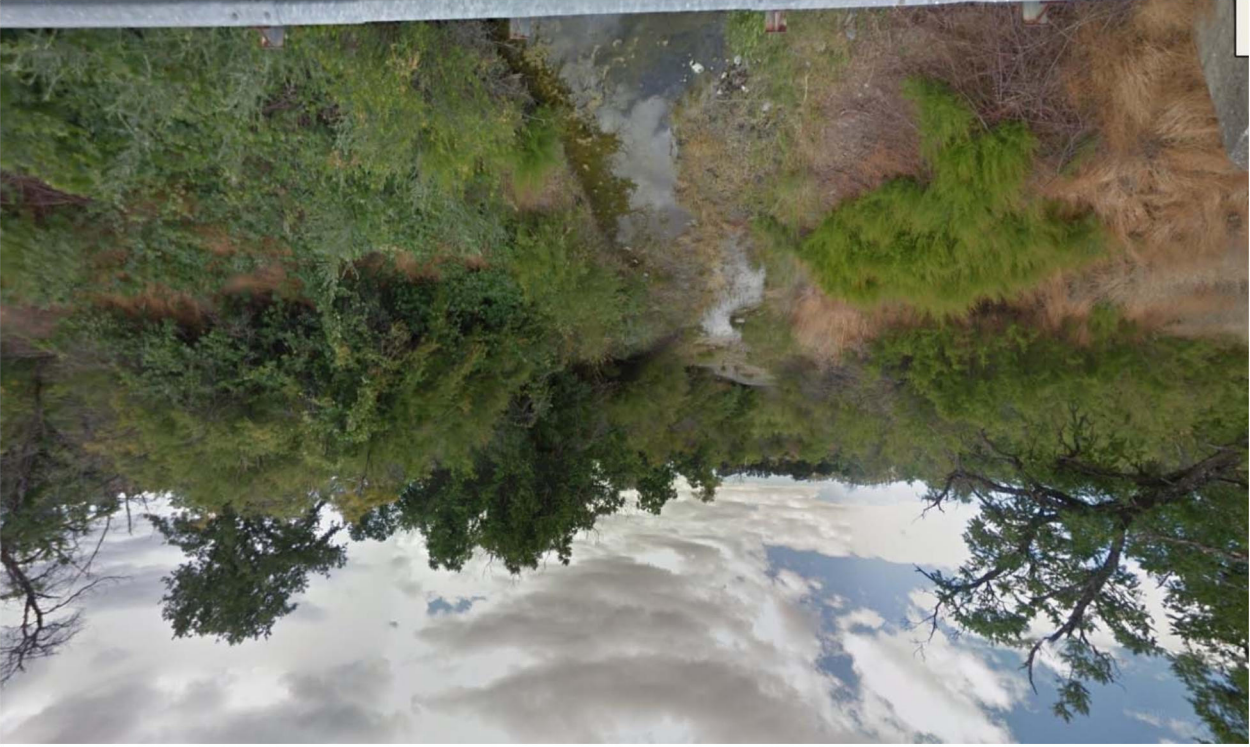


Figure 9: Looking downstream from the bridge. The overbank area on the right is more heavily vegetated, leading to a higher Manning's “n” value.

The existing bridge was input into the model as a 4-span bridge as shown in Figure 10.

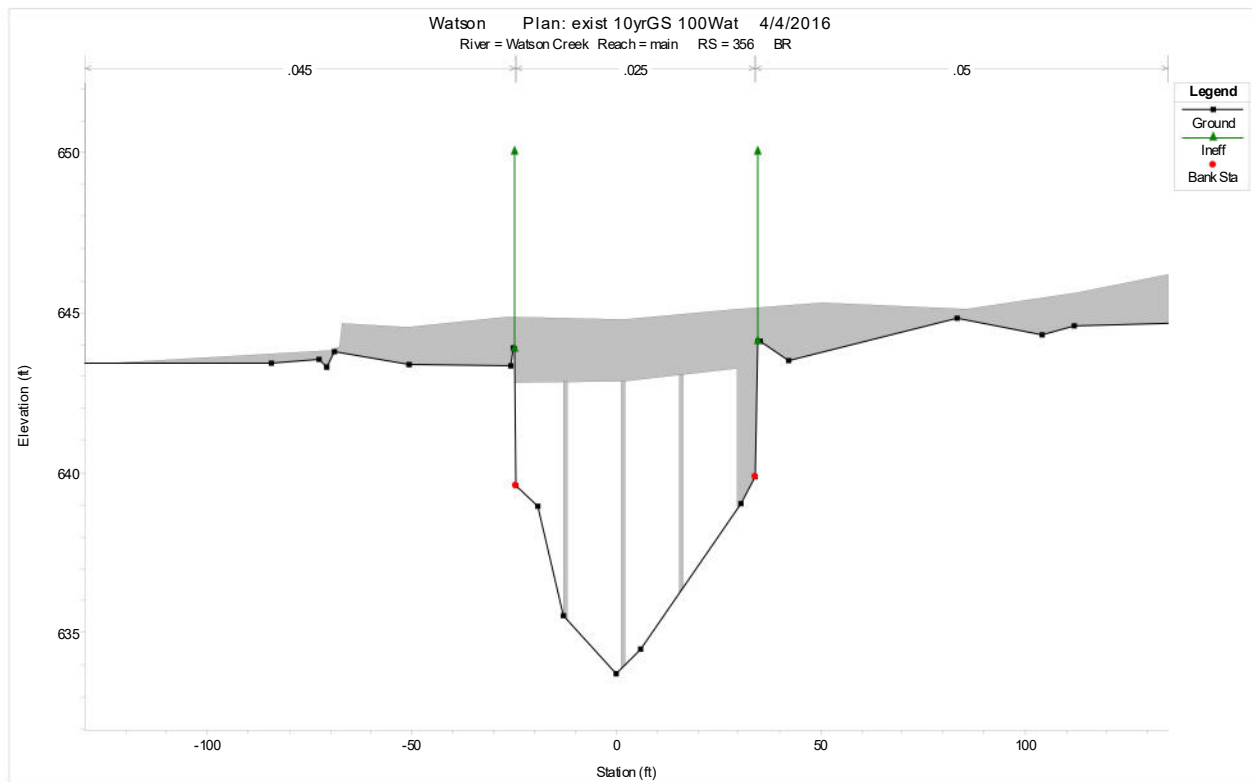


Figure 10: HEC-RAS cross section for the upstream existing condition

Starting Water Surface Elevation

Various starting water surface elevation conditions were analyzed for both flow conditions; 1) normal depth, 2) critical depth, and 3) elevation 639. All profiles converged at or before the confluence as shown in Figure 11.

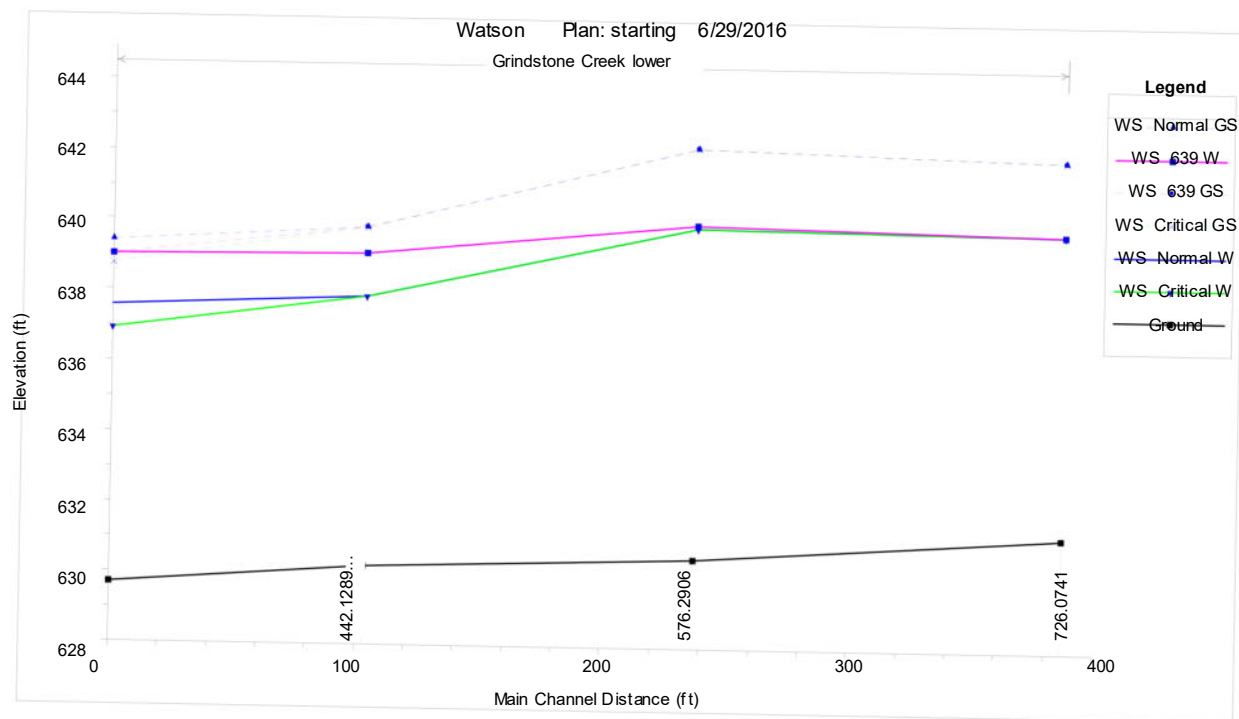


Figure 11: Starting WSE's for both flow conditions (GS = Peak in Grindstone, W = Peak in Watson)

Proposed Bridge Model

The HEC-RAS model was re-run with the proposed bridge. The only change to the proposed model was taking out the existing bridge and replacing it with the proposed bridge with new roadway profile. The proposed bridge will be a 2-span bridge and will have a minimum soffit elevation of 644.6-ft which is 1.8-ft higher than the minimum soffit elevation of the existing bridge at elevation 642.8-ft. A profile of the proposed bridge is shown in Figure 12.

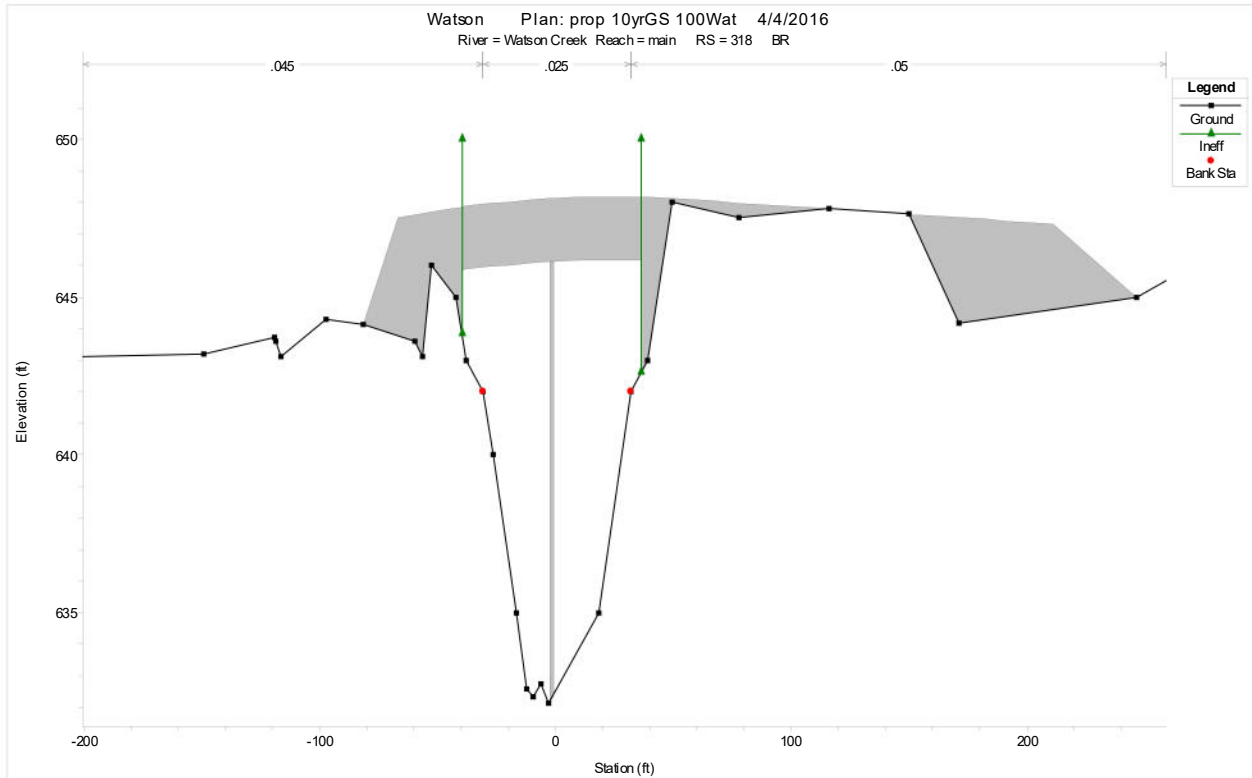


Figure 12: HEC-RAS cross section for the upstream proposed condition

The proposed bridge will be approximately 14.5-ft wider than the existing bridge and located approximately 12 feet downstream as shown in Figure 13.

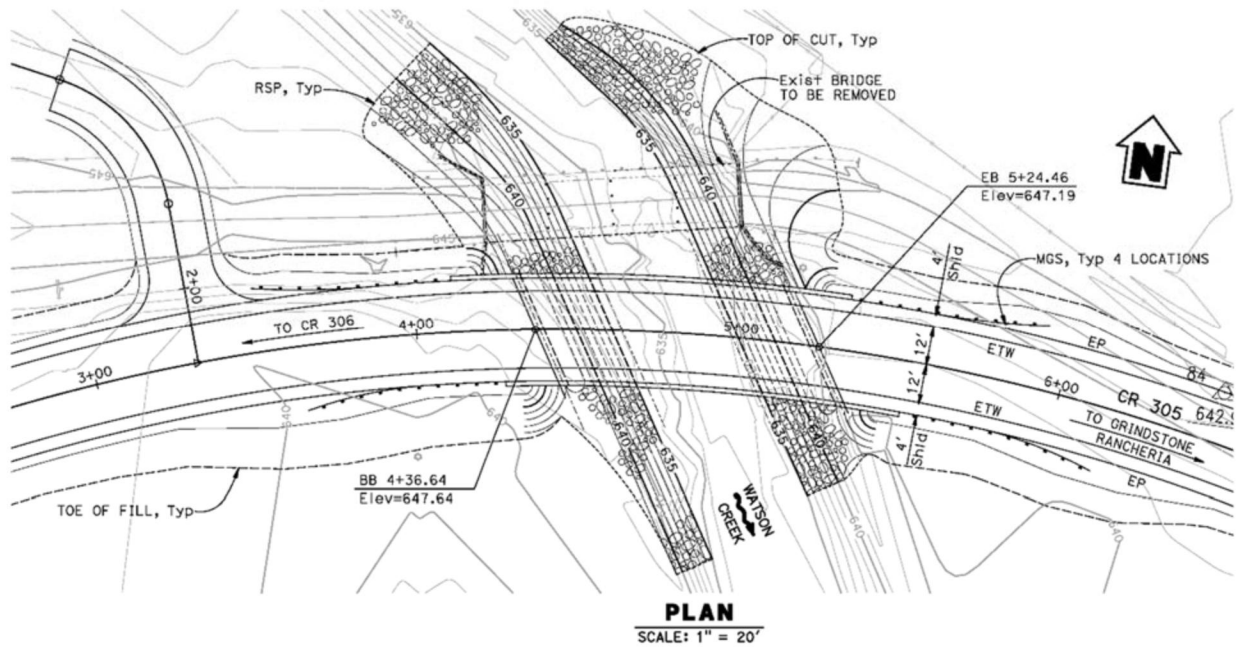


Figure 13: Existing and proposed bridge shown in plan view

Figure 14 through Figure 17 show the 50-yr and 100-yr WSE profile comparisons between existing and proposed for the Watson Creek reach for the two flow conditions. As shown in the figures, the water surface elevation is lowered upstream as a result of the proposed bridge for both flow conditions.

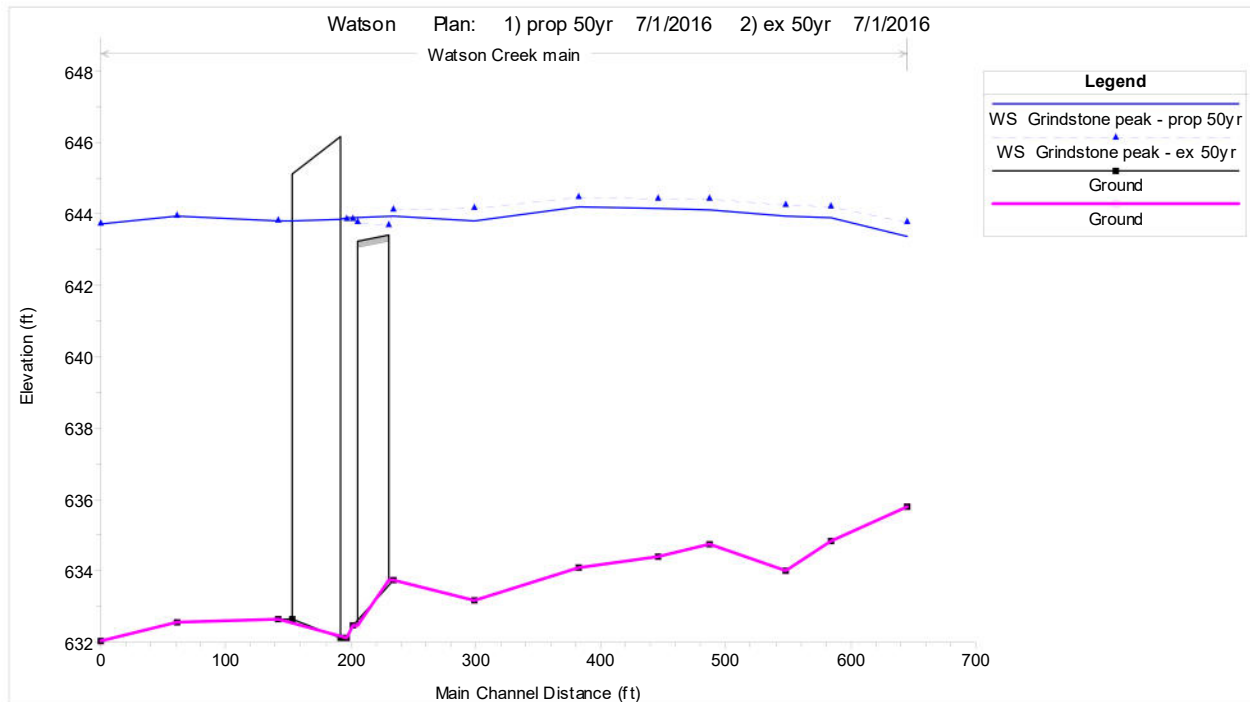


Figure 14: 50-yr WSE comparison existing vs. proposed for the Peak flow in Grindstone Creek condition

Figure 15: 100-yr WSE comparison existing vs. proposed for the Peak flow in Grindstone Creek condition

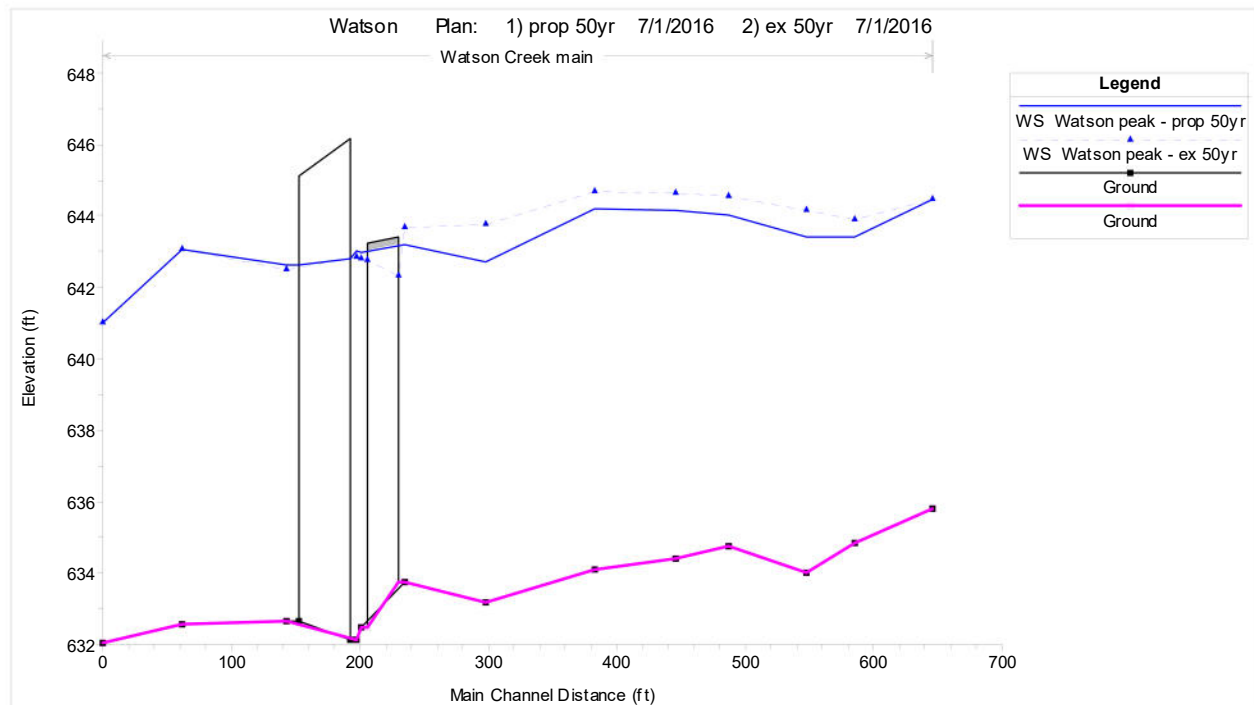


Figure 16: 50-yr WSE comparison existing vs. proposed for the Peak flow in Watson Creek condition

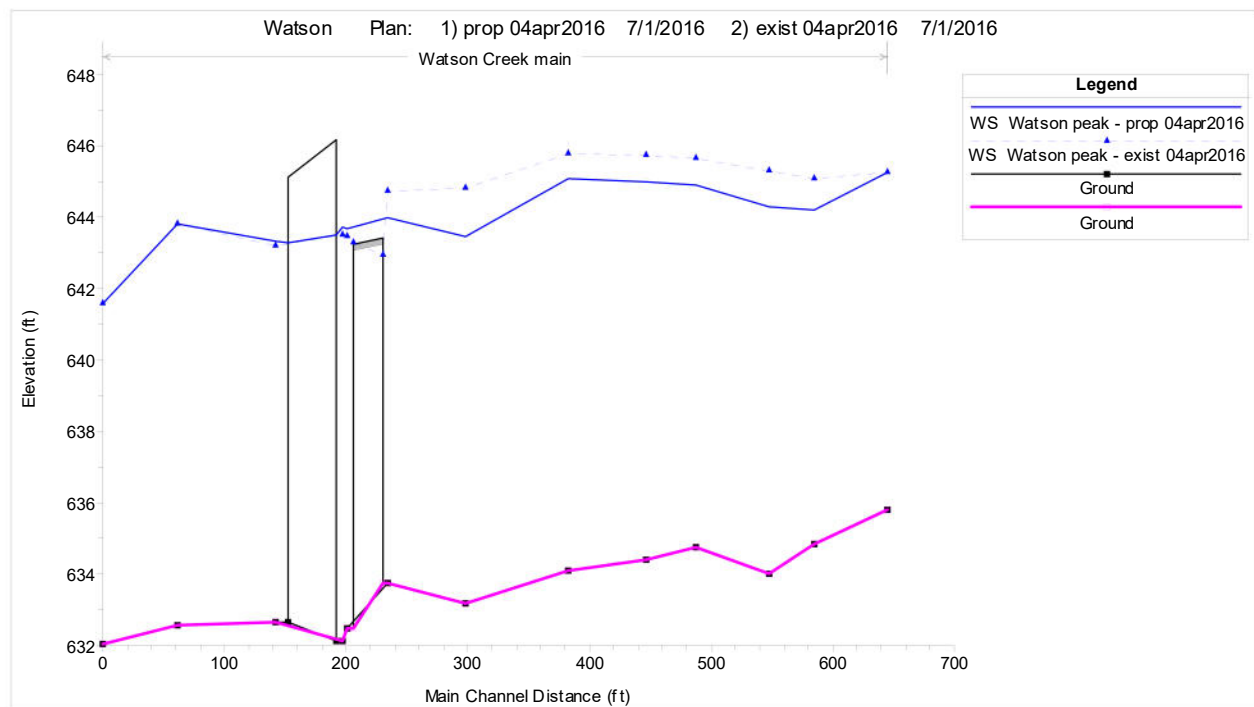


Figure 17: 100-yr WSE comparison existing vs. proposed for the Peak flow in Watson Creek condition

Table 5 shows the WSE comparison between existing and proposed for the 100-yr design discharges through the bridge for the two flow conditions.

Table 5: WSE comparison between existing and proposed for the two flow conditions

River Station (Watson Creek Reach)	Peak in Grindstone Creek (Condition 1)			Peak in Watson Creek (Condition 2)		
	Exist.	Prop.	Diff.	Exist.	Prop.	Diff.
187.2	644.0	644.0	0.0	643.8	643.8	0.0
268	643.8	643.9	0.1	643.2	643.3	0.1
Upstream face of bridge						
323	643.9	644.0	0.1	643.5	643.7	0.2
360	644.3	644.0	-0.3	644.7	644.0	-0.7
424	644.4	643.9	-0.5	644.8	643.4	-0.4
508.2	644.8	644.4	-0.4	645.8	645.1	-0.7
572.1	644.8	644.4	-0.4	645.7	645.0	-0.7
612.9	644.7	644.3	-0.4	645.6	644.9	-0.7

See Appendix C for detailed HEC-RAS output for the two flow conditions.

HYDRAULIC CRITERIA/DRIFT

Chapter 800 of the Caltrans Highway Design Manual (HDM) delineates the hydraulic design criteria for bridges (2). 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 also be granted if sufficient evidence is provided. The HDM notes that 2 feet of freeboard is often assumed 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.

The minimum soffit elevation of the proposed bridge at elevation 644.6 will provide approximately 0.7 feet of freeboard above the 50-yr WSE in Watson Creek during the peak flow in Grindstone Creek (WSE 643.9) and approximately 1.6 feet of freeboard above the 50-yr WSE during the peak flow in Watson Creek (WSE 643.0).

Similarly, the proposed bridge will provide approximately 0.6 feet of freeboard above the 100-yr WSE in Watson Creek during the peak flow in Grindstone Creek (WSE 644.0) and approximately 0.9 feet of freeboard above the 100-yr WSE during the peak flow in Watson Creek (WSE 643.7).

Avila and Associates researched the available bridge maintenance records for the existing bridge to determine if debris catches on the bridge. Based upon the review of the records, drift potential is high with numerous occurrences of debris accumulation noted.

The minimum soffit elevation for the proposed bridge will be approximately 1.8 feet higher than existing. With a higher bridge soffit elevation and pier walls in lieu of square multi-column bents, the potential for drift accumulation is expected to be somewhat reduced with the proposed bridge. Larger pier columns (circular piers that are wider than 4-ft) tend to shed debris better than pier walls.

SCOUR

The bridge's Item 113 Code was changed from a "U" meaning unknown foundation to a "3" meaning scour critical in the August 2013 Bridge Inspection Report. Although it has proven relatively unsuccessful and been undermined, the County installed concrete paving as shown in Figure 18 to mitigate the scour problems at the bridge.



Figure 18: Looking upstream through the bridge showing significant debris caught on the pier and undermined concrete paving

According to the 1948 Bridge Inspection Report, there was "5' average clear height under girders. Since the soffit elevation is approximately 643, 5-ft of clear height would put the thalweg at approximately elevation 638. The current thalweg (2011) is at 635. That means 3-ft of degradation has occurred in 63 years. If the degradation continues into the future, during the anticipated 75-year life of the bridge, an additional 4-ft of degradation could occur, therefore, preliminary degradation was estimated to be 4-feet.

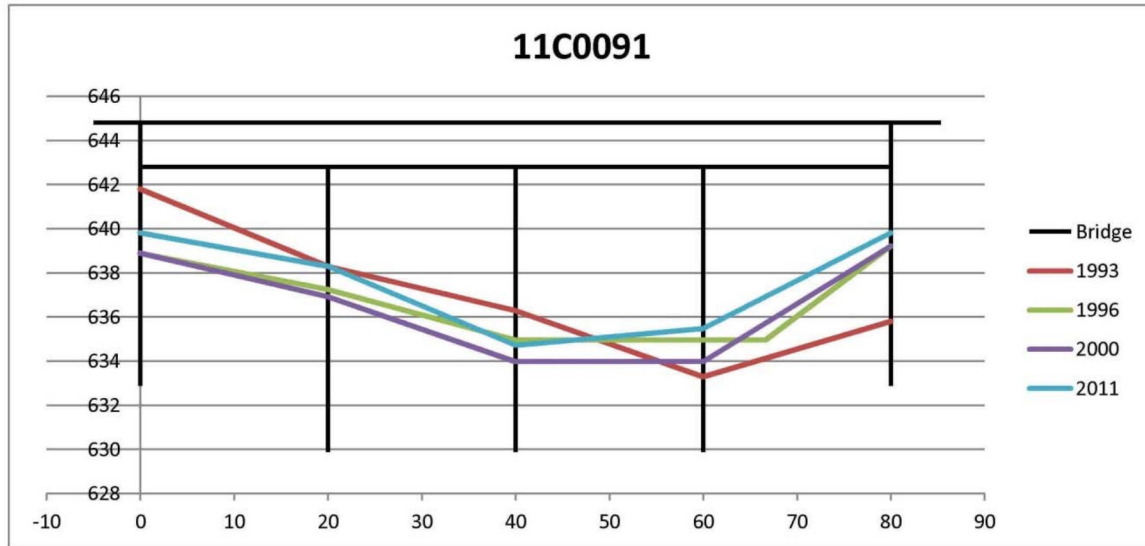


Figure 19: Channel Sections over time

The Colorado State University Equation (CSU) was used for estimating local pier scour as recommended by the Federal Highway Administration (Arneson et al, 2012). There are only test borings at the proposed abutments, but no borings in the main channel. A main channel boring is highly recommended if piers are proposed in the channel. See Appendix D for local scour calculations.

According to the Log of Test Borings (Willdan, 2016), on the east side of the bridge at boring A-16-002, the channel material is composed of sand and gravel to elevation 630 and at boring A-16-001 the channel materials are composed of sand and gravel to elevation 639. Below elevation 630/639, the sand and gravel contains clay and is more dense. On the west side of the bridge at boring A-16-003, the channel material is composed of sand and gravel to elevation 635 and at A-16-004 the channel materials are composed of sand and gravel to elevation 630. Below elevation 630/635, the sand and gravel contains clay and is more dense.

In conformance with Caltrans LRFD Specification 2.6.4.4.2, it is recommended that the abutments should be checked for stability at the non-scourable material elevation (630/639 at the east abutment and 630/635 at the west abutment). The geotechnical consultant should be consulted to validate the elevation of the non-scourable material.

Table 6: Scour Elevations for proposed CR 305 Bridge over Watson Creek for various pier widths

	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6
Pier Width (ft)	1	1.5	2	3	4	5
Skew Angle (degrees)	0	0	0	0	0	0
Velocity (Q_{100}) (ft/s)	8.6	8.6	8.6	8.6	8.6	8.6
Pier Scour	2	4	5	7	10	11
Degradation (ft)	4	4	4	4	4	4
Total Scour	6	8	9	11	14	15
Thalweg Elevation (ft)	632.5	632.5	632.5	632.5	632.5	632.5
Total Scour elevation (ft)	626	625	624	621	619	617

SUMMARY TABLES

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

Drainage Area: 15.9 Square miles

	Peak in Grindstone	Peak in Watson	Overtopping
Frequency (Years)	100	100	50-yr Grindstone 200-yr Watson
Discharge (Cubic feet per second)	2,914	4,425	5,500
Water Surface (Elevation at u/s face of Bridge)	644.0	643.7	647.0

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.

The Location Hydraulic Study and Summary Floodplain Encroachment Report as outlined in 44 CFR Part 65.6 (a) (2) will be included in the Final Hydraulic Report.

REFERENCES

1. California Department of Transportation (Caltrans), February, 1998 "Local Assistance Procedures Manual, Processing Procedures for Implementing Federal and/or State Funded local Public Transportation Projects"
2. California Department of Transportation (Caltrans), May, 2001 "Highway Design Manual Chapter 800".
3. California Department of Transportation (Caltrans), October, 2003 "Bridge Memos to Designers 1-23.
4. California Department of Transportation (Caltrans) Division of Maintenance – Structure Maintenance and Inspection, October , 2008 "Element Level Inspection Manual"
5. Glenn County, Maintenance Records and As-Built Plans for the Co. Rd. 305 Bridge (#11C0091)
6. Federal Highway Administration, "Recording and Coding Guide for the Structure Inventory and Appraisal of the Nation's Bridges". Report No. FHWA-RD-96-0001, Revised November 4, 2015.
7. Willdan, "Log of Test Borings County Road 305 Bridge Replacement Project, Glenn County, California" February 2016.

ATTACHMENTS

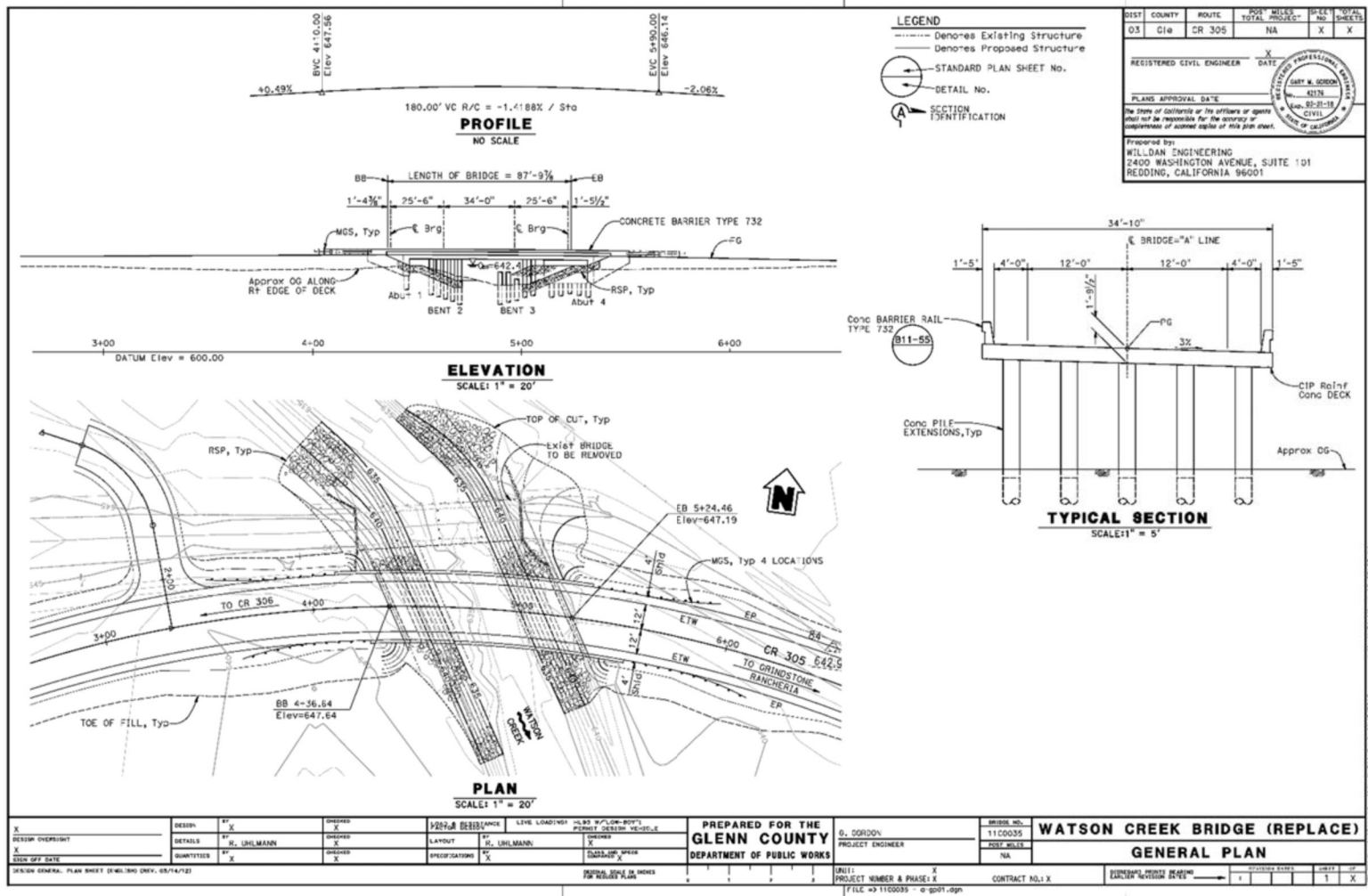
Appendix A – General Plan

Appendix B – Hydrology

Appendix C – HEC-RAS Output (to be included in the final report)

Appendix D – Overtopping

Appendix E – Local Scour Estimates



APPENDIX B –HYDROLOGY

REGRESSION ANALYSIS

Watson Creek

North Coast Region

Area (A) = 15.9 sq. mi.

Mean Annual Precipitation (MAP) = 24.6 (per Streamstats)

Recurrence	C	A	n	CxA^n	MAP	m	MAP^m	Q (cfs)	Recurrence
2	1.82	15.9	0.904	22.18883	24.6	0.983	23.29642	517	2
5	8.11	15.9	0.887	94.33223	24.6	0.772	11.85228	1,118	5
10	14.8	15.9	0.88	168.8462	24.6	0.696	9.291607	1,569	10
25	26	15.9	0.874	291.739	24.6	0.628	7.473211	2,180	25
50	36.3	15.9	0.87	402.8303	24.6	0.589	6.595698	2,657	50
100	48.5	15.9	0.866	532.2941	24.6	0.556	5.934169	3,159	100
200	61	15.9	0.863	663.9503	24.6	0.531	5.477552	3,637	200
500	79.3	15.9	0.86	856.0019	24.6	0.503	5.007724	4,287	500

Source: Methods for Determining Magnitude and Frequency of Floods in California, Based on Data through Water Year 2006 (USGS SIR 2012-5113)

Grindstone Creek (upstream from Confluence)

North Coast Region

Area (A) = 156 sq. mi.

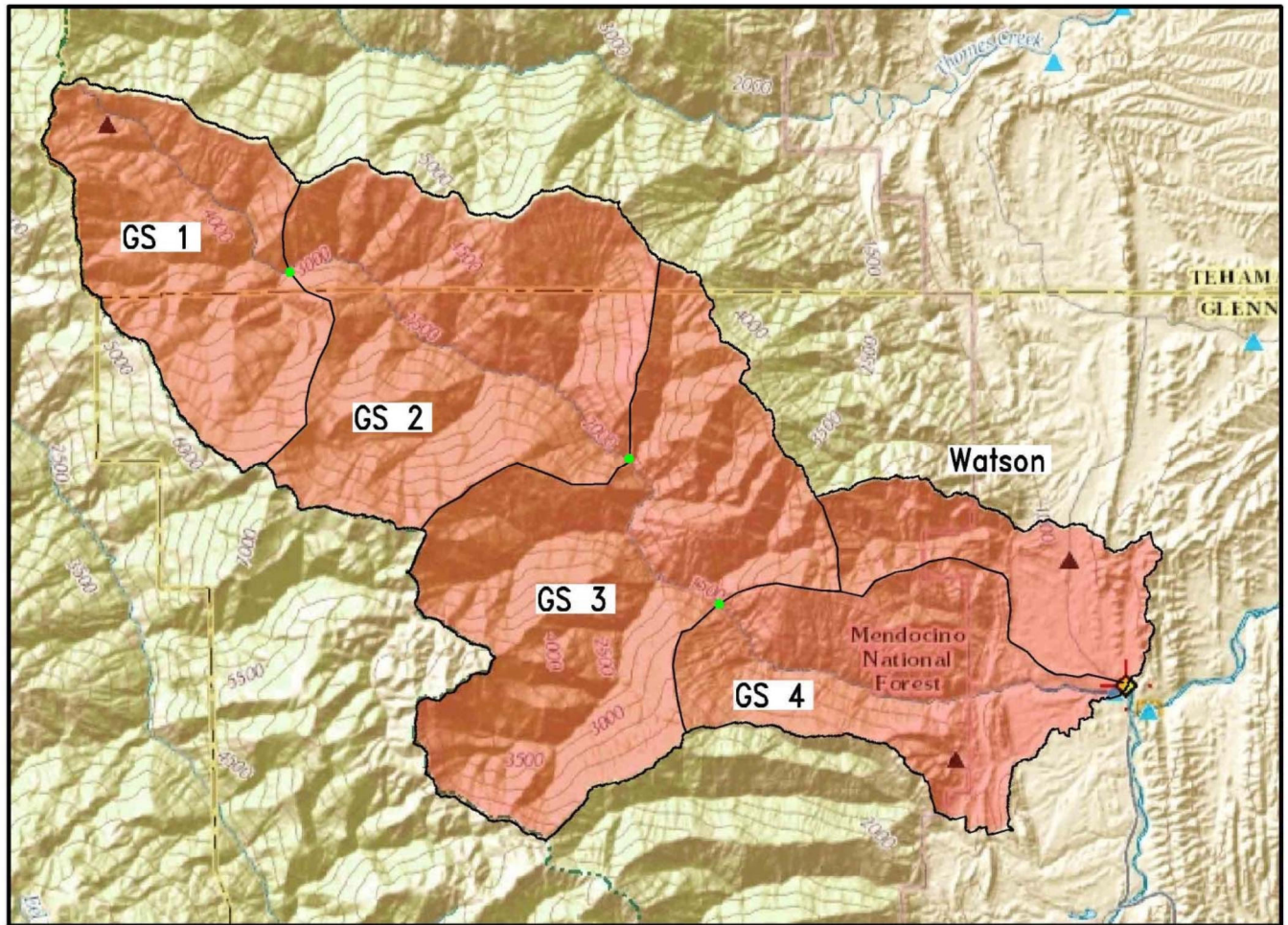
Mean Annual Precipitation (MAP) = 35.1 (per Streamstats)

Recurrence	C	A	n	CxA^n	MAP	m	MAP^m	Q (cfs)	Recurrence
2	1.82	156	0.904	174.8461	35.1	0.983	33.03976	5,777	2
5	8.11	156	0.887	715.0269	35.1	0.772	15.5947	11,151	5
10	14.8	156	0.88	1259.538	35.1	0.696	11.89964	14,988	10
25	26	156	0.874	2146.665	35.1	0.628	9.34228	20,055	25
50	36.3	156	0.87	2937.143	35.1	0.589	8.131785	23,884	50
100	48.5	156	0.866	3845.808	35.1	0.556	7.230873	27,809	100
200	61	156	0.863	4764.27	35.1	0.531	6.61543	31,518	200
500	79.3	156	0.86	6100.429	35.1	0.503	5.988106	36,530	500

Source: Methods for Determining Magnitude and Frequency of Floods in California, Based on Data through Water Year 2006 (USGS SIR 2012-5113)

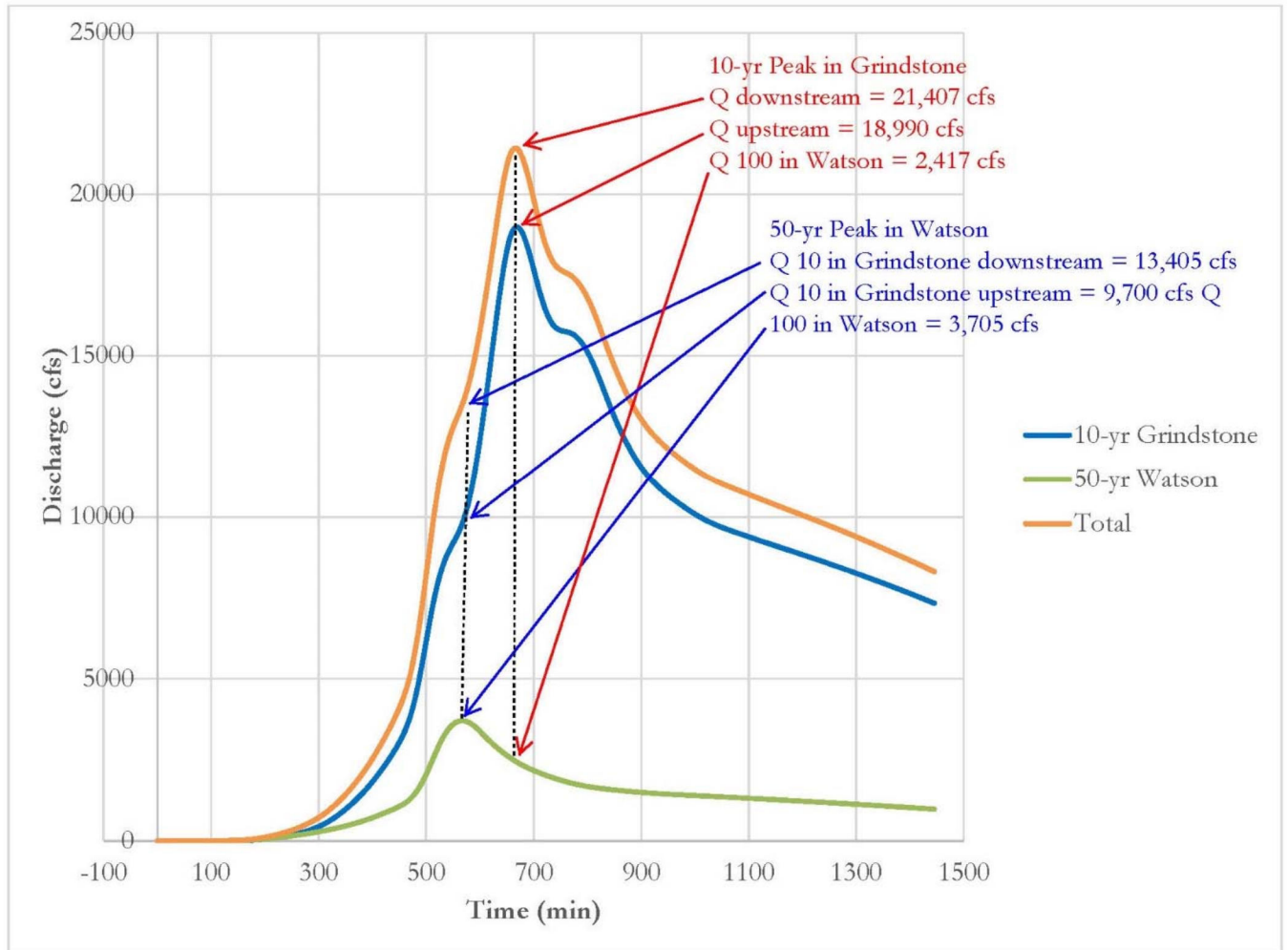
HEC-HMS ANALYSIS

A hydrologic analysis was performed using computer program HEC-HMS. Two basins were analyzed; 1) the area contributing runoff to Grindstone Creek upstream from the confluence of Watson Creek, and 2) the area contributing runoff to the project site in Watson Creek. The Grindstone Creek basin was divided up into 4 sub-basins as shown on the Hydrology Map.

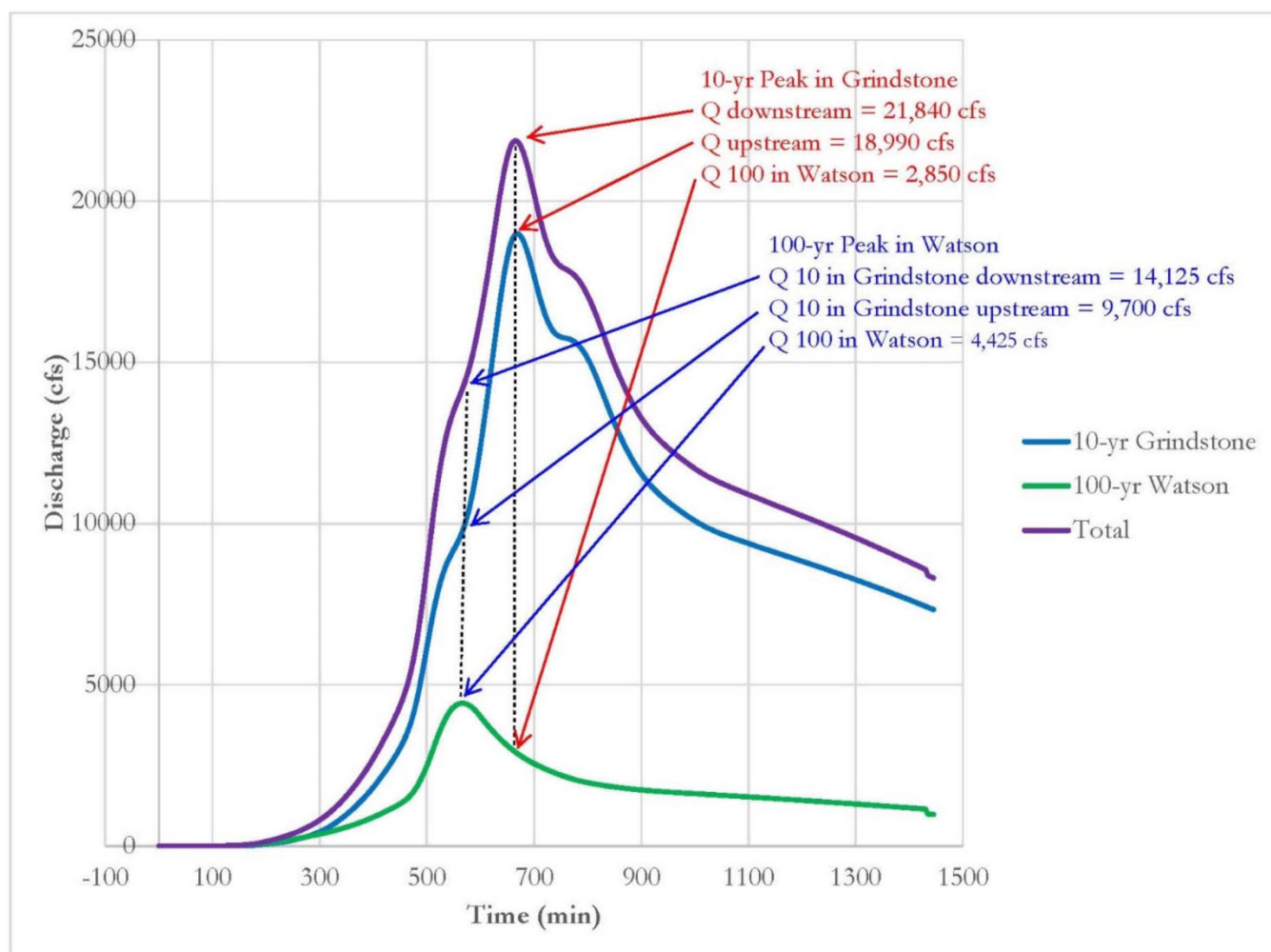


Hydrology Map

The 10-yr runoff hydrograph was calculated for Grindstone Creek upstream from the confluence and added to the computed 100-yr runoff hydrograph for Watson Creek. The resulting hydrograph is shown below.



10-yr runoff hydrograph for Grindstone Creek added to 50-yr runoff hydrograph for Watson Creek



10-yr runoff hydrograph for Grindstone Creek added to 100-yr runoff hydrograph for Watson Creek

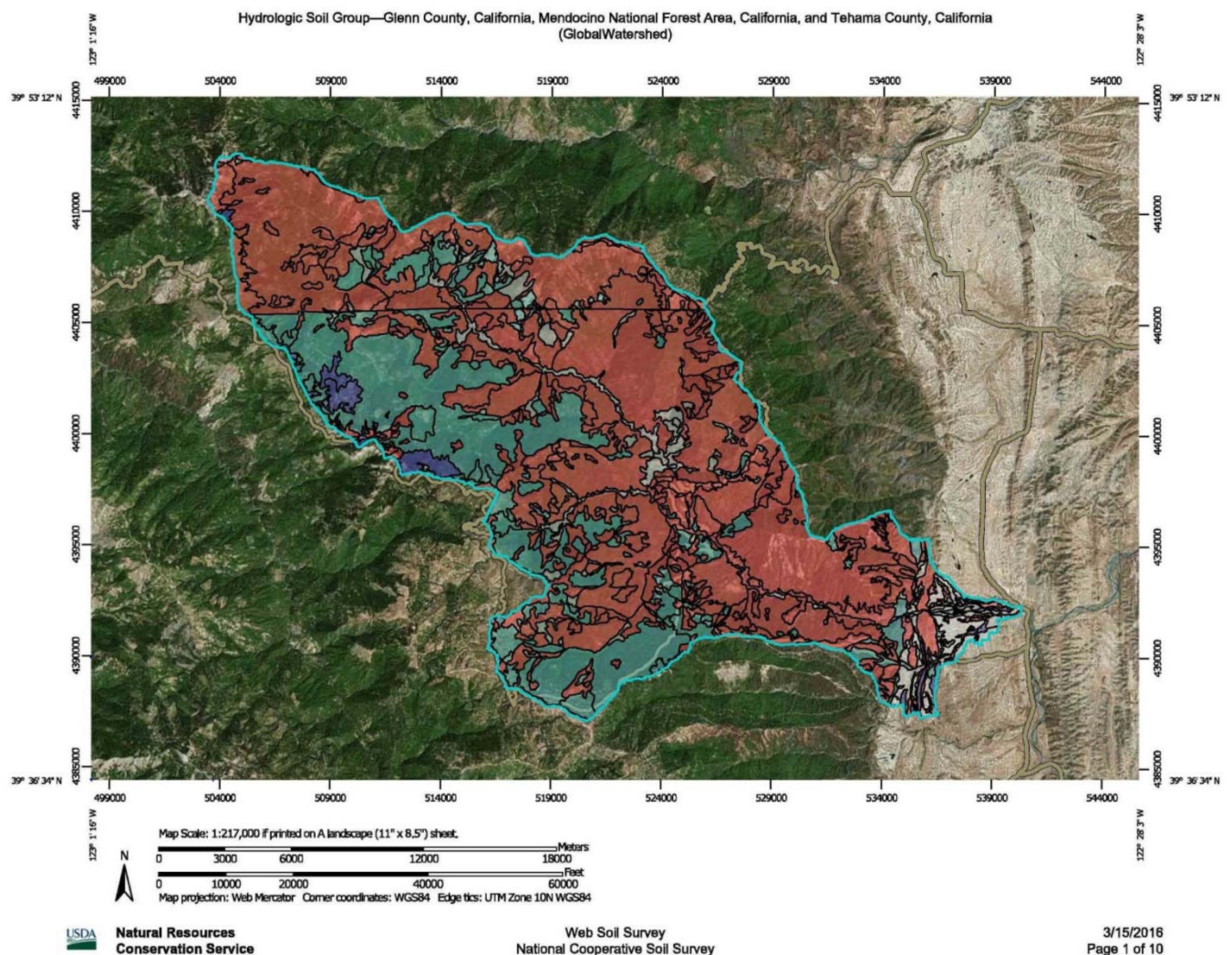
From the hydrographs above, the following flow distributions were analyzed in the Hec-Ras model for the two flow conditions considered for this report (1. 50-yr and 100-yr discharges in Watson at the time of the peak 10-yr discharge in Grindstone Creek, and 2. 10-yr discharge in Grindstone Creek at the time of the peak 50-yr and 100-yr discharges in Watson Creek) :

	Flow Condition			
	Peak in Grindstone Creek (Condition 1)		Peak in Watson Creek (Condition 2)	
Recurrence Interval	50-yr	100-yr	50-yr	100-yr
Grindstone Creek				
<i>Upper Reach</i>	18,990	18,990	9,700	9,700
<i>Lower Reach</i>	21,407	21,840	13,405	14,125
Watson Creek	2,417	2,850	3,705	4,425

The following methods and parameters were used for the analysis:

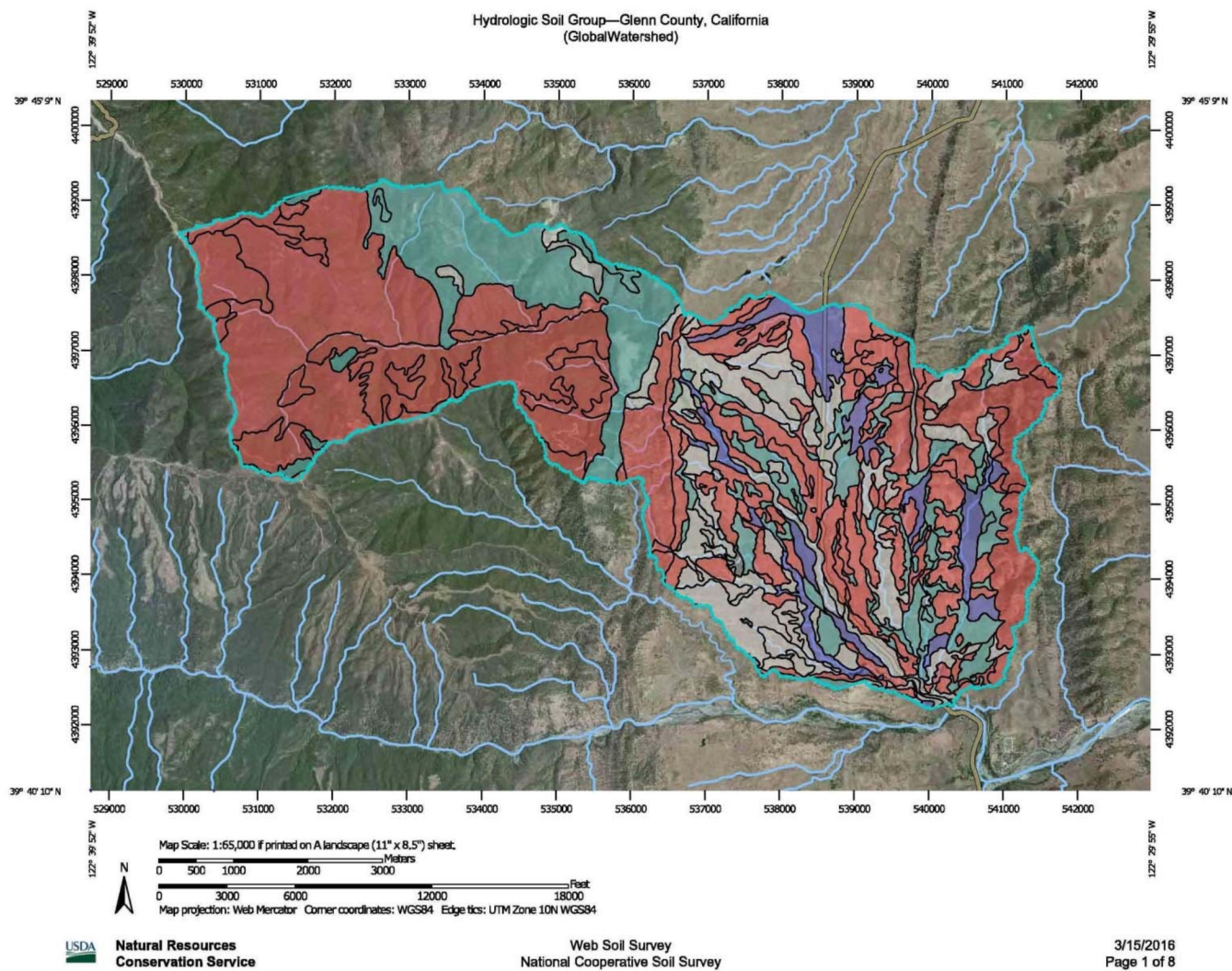
- SCS Curve Number loss method
 - Initial Abstraction = 0.2
- SCS Unit Hydrograph transform method
 - Type 1A storm distribution
 - Lag time = 0.6 x time of concentration

The Grindstone Creek watershed is composed of soils from three hydrologic soils groups as shown on the Grindstone Creek Watershed Soils Map.



Magenta = Class A, Blue = Class B, Aqua = Class C, Salmon = Class D, Gray = other
Grindstone Creek Watershed Soils Map (USDA NRCS Web Soil Survey)

The Watson Creek watershed is composed of soils from all four hydrologic soils groups as shown on the Watson Creek Watershed Soils Map.

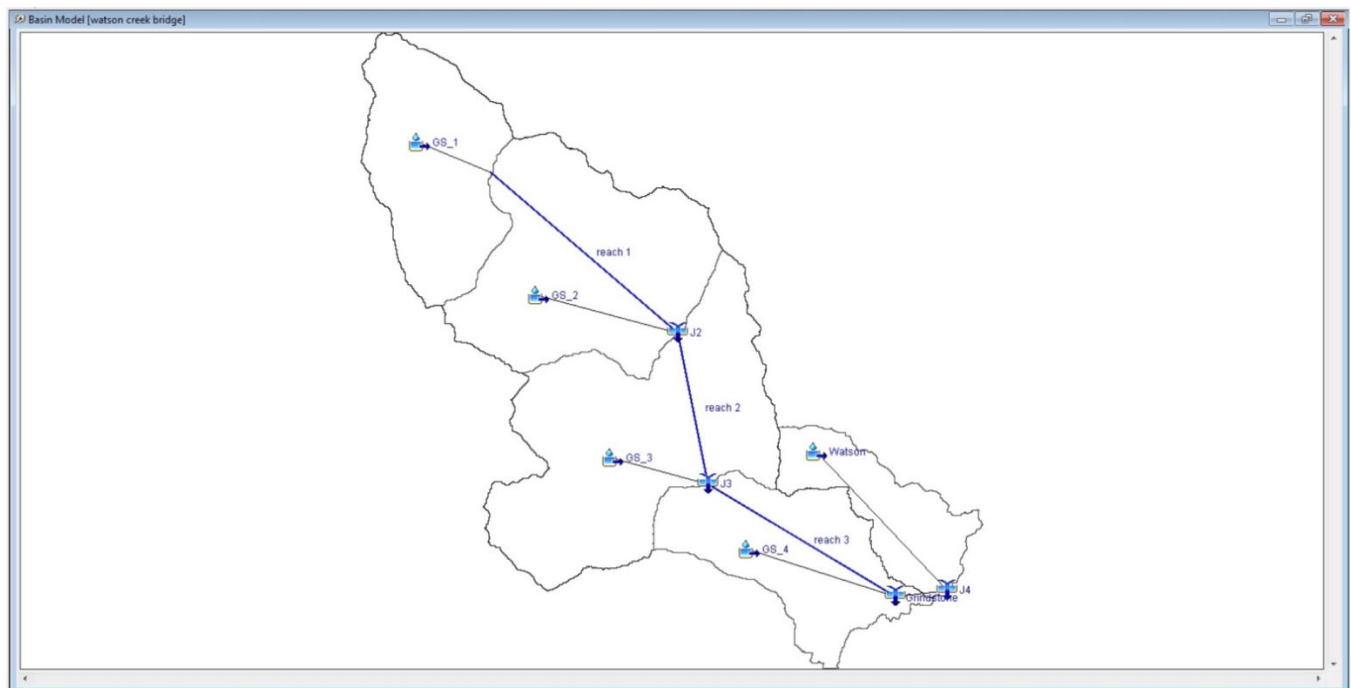


Magenta = Class A, Blue = Class B, Aqua = Class C, Salmon = Class D, Gray = other
Watson Creek Watershed Soils Map (USDA NRCS Web Soil Survey)

The following table summarizes the area, composite CN value, and time of concentration for each sub-basin :

Sub-Basin	Area	Composite CN	Time of Concentration	Lag Time
	(sq. mi.)		(min)	(min)
<i>Grindstone Creek</i>				
GS_1	29.3	74	123	74
GS_2	45.4	75	105	63
GS_3	53.7	76	128	77
GS_4	27.6	76	100	60
<i>Watson Creek</i>				
Watson	15.9	74	138	83

Precipitation data was obtained from the NOAA's National Weather Service Hydrometeorological Design Studies Center Precipitation Frequency Data Server by manually entering the latitude and longitude of the centroid of the two watershed areas. http://hdsc.nws.noaa.gov/hdsc/pfds/pfds_map_cont.html?bkmrk=ca (NOAA Atlas 14) For this analysis, the 24 hour precipitation depth for the 10-yr storm in Grindstone Creek is 3.99 inches. The 24 hour precipitation depth for the 50-yr and 100-yr storm in Watson Creek is 5.36 and 6.01 inches respectively.



HEC-HMS Basin Schematic

HEC-RAS River: Watson Creek Reach: main Profile: Grindstone peak

Reach	River Sta	Profile	Plan	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	771.2659	Grindstone peak	prop 50yr	2417.00	635.79	643.37	642.86	645.15	0.004077	10.72	231.84	54.11	0.84
main	771.2659	Grindstone peak	ex 50yr	2417.00	635.79	643.76	642.86	645.28	0.003201	9.93	253.88	58.59	0.75
main	710.5268	Grindstone peak	prop 50yr	2417.00	634.83	643.88	641.50	644.73	0.001363	7.54	373.85	103.70	0.51
main	710.5268	Grindstone peak	ex 50yr	2417.00	634.83	644.18	641.50	644.94	0.001148	7.12	405.98	105.78	0.47
main	673.36	Grindstone peak	prop 50yr	2417.00	633.99	643.95	641.19	644.64	0.001041	6.75	419.11	111.21	0.45
main	673.36	Grindstone peak	ex 50yr	2417.00	633.99	644.25	641.19	644.86	0.000888	6.41	450.50	118.91	0.42
main	612.9198	Grindstone peak	prop 50yr	2417.00	634.75	644.12	640.26	644.50	0.000536	5.03	542.84	144.33	0.33
main	612.9198	Grindstone peak	ex 50yr	2417.00	634.75	644.40	640.26	644.74	0.000468	4.82	575.88	169.14	0.31
main	572.0831	Grindstone peak	prop 50yr	2417.00	634.39	644.16	639.90	644.46	0.000422	4.47	603.36	180.84	0.29
main	572.0831	Grindstone peak	ex 50yr	2417.00	634.39	644.43	639.90	644.70	0.000370	4.29	635.76	201.14	0.27
main	508.1873	Grindstone peak	prop 50yr	2417.00	634.12	644.18	639.78	644.41	0.000335	3.90	648.04	186.83	0.26
main	508.1873	Grindstone peak	ex 50yr	2417.00	634.12	644.45	639.78	644.67	0.000294	3.74	677.51	213.08	0.25
main	424	Grindstone peak	prop 50yr	2417.00	633.19	643.82	640.10	644.35	0.000685	5.96	467.68	254.96	0.37
main	424	Grindstone peak	ex 50yr	2417.00	633.19	644.13	640.10	644.61	0.000596	5.69	492.23	280.00	0.35
main	360	Grindstone peak	prop 50yr	2417.00	633.74	643.94	639.36	644.24	0.000492	4.40	552.27	274.67	0.31
main	360	Grindstone peak	ex 50yr	2417.00	633.74	644.11	640.21	644.56	0.000563	5.38	450.62	278.99	0.34
main	327	Grindstone peak	prop 50yr	2417.00	632.49	643.87	638.86	644.22	0.000433	4.77	521.37	263.67	0.30
main	327	Grindstone peak	ex 50yr	2417.00	632.49	643.84	638.83	644.13	0.000371	4.35	555.89	269.93	0.28
main	323	Grindstone peak	prop 50yr	2417.00	632.11	643.88	638.55	644.22	0.000400	4.64	535.32	281.86	0.29
main	323	Grindstone peak	ex 50yr	2417.00	632.11	643.85	638.91	644.11	0.000352	4.10	590.22	299.09	0.27
main	318		Bridge										
main	268	Grindstone peak	prop 50yr	2417.00	632.66	643.82	638.74	644.16	0.000398	4.74	548.26	539.53	0.29
main	268	Grindstone peak	ex 50yr	2417.00	632.66	643.80	639.02	644.09	0.000382	4.44	660.56	652.38	0.28
main	187.1931	Grindstone peak	prop 50yr	2417.00	632.58	643.95	636.84	644.01	0.000069	2.20	1387.69	690.61	0.13
main	187.1931	Grindstone peak	ex 50yr	2417.00	632.58	643.95	636.84	644.01	0.000069	2.20	1387.69	690.61	0.13
main	125.8394	Grindstone peak	prop 50yr	2417.00	632.06	643.70	639.14	643.98	0.000428	4.49	648.62	443.25	0.29
main	125.8394	Grindstone peak	ex 50yr	2417.00	632.06	643.70	639.14	643.98	0.000428	4.49	648.62	443.25	0.29

Condition 1 50-yr

HEC-RAS River: Watson Creek Reach: main Profile: Grindstone peak

Reach	River Sta	Profile	Plan	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
main	771.2659	Grindstone peak	exist 04apr2016	2850.00	635.79	643.74	643.40	645.87	0.004503	11.75	252.75	58.40	0.89
main	771.2659	Grindstone peak	prop 04apr2016	2850.00	635.79	643.40	643.40	645.84	0.005564	12.57	233.43	54.48	0.98
main	710.5268	Grindstone peak	exist 04apr2016	2850.00	634.83	644.42	642.09	645.38	0.001403	8.05	431.10	106.54	0.53
main	710.5268	Grindstone peak	prop 04apr2016	2850.00	634.83	643.95	642.09	645.11	0.001818	8.77	381.49	104.48	0.59
main	673.36	Grindstone peak	exist 04apr2016	2850.00	633.99	644.51	641.69	645.28	0.001080	7.23	478.23	127.21	0.47
main	673.36	Grindstone peak	prop 04apr2016	2850.00	633.99	644.06	641.69	644.97	0.001364	7.80	430.69	112.77	0.52
main	612.9198	Grindstone peak	exist 04apr2016	2850.00	634.75	644.69	640.74	645.13	0.000564	5.43	614.38	192.14	0.34
main	612.9198	Grindstone peak	prop 04apr2016	2850.00	634.75	644.29	640.74	644.79	0.000684	5.77	563.43	159.83	0.37
main	572.0831	Grindstone peak	exist 04apr2016	2850.00	634.39	644.74	640.35	645.08	0.000445	4.83	672.62	231.35	0.30
main	572.0831	Grindstone peak	prop 04apr2016	2850.00	634.39	644.34	640.35	644.74	0.000536	5.12	625.57	195.44	0.33
main	508.1873	Grindstone peak	exist 04apr2016	2850.00	634.12	644.76	640.18	645.03	0.000354	4.22	711.95	238.21	0.27
main	508.1873	Grindstone peak	prop 04apr2016	2850.00	634.12	644.38	640.18	644.68	0.000424	4.46	669.25	206.23	0.29
main	424	Grindstone peak	exist 04apr2016	2850.00	633.19	644.34	640.69	644.96	0.000755	6.52	508.85	301.80	0.39
main	424	Grindstone peak	prop 04apr2016	2850.00	633.19	643.87	640.69	644.59	0.000931	6.97	471.71	257.97	0.43
main	380	Grindstone peak	exist 04apr2016	2850.00	633.74	644.31	640.64	644.90	0.000719	6.18	462.35	286.33	0.39
main	380	Grindstone peak	prop 04apr2016	2850.00	633.74	644.04	639.88	644.45	0.000650	5.11	561.76	279.88	0.36
main	356			Bridge									
main	327	Grindstone peak	exist 04apr2016	2850.00	632.49	643.89	639.38	644.29	0.000505	5.09	559.72	274.00	0.33
main	327	Grindstone peak	prop 04apr2016	2850.00	632.49	643.94	639.38	644.42	0.000585	5.58	526.54	285.13	0.35
main	323	Grindstone peak	exist 04apr2016	2850.00	632.11	643.91	639.39	644.27	0.000477	4.80	594.92	303.86	0.31
main	323	Grindstone peak	prop 04apr2016	2850.00	632.11	643.96	639.10	644.41	0.000539	5.43	540.90	286.42	0.33
main	288	Grindstone peak	exist 04apr2016	2850.00	632.66	643.85	639.54	644.24	0.000521	5.21	665.45	653.16	0.33
main	288	Grindstone peak	prop 04apr2016	2850.00	632.66	643.87	639.29	644.34	0.000543	5.56	551.81	540.62	0.34
main	187.1931	Grindstone peak	exist 04apr2016	2850.00	632.58	644.04	637.15	644.13	0.000092	2.57	1404.18	691.03	0.15
main	187.1931	Grindstone peak	prop 04apr2016	2850.00	632.58	644.04	637.15	644.13	0.000092	2.57	1404.18	691.03	0.15
main	125.8394	Grindstone peak	exist 04apr2016	2850.00	632.06	643.69	639.69	644.09	0.000596	5.30	648.04	443.23	0.34
main	125.8394	Grindstone peak	prop 04apr2016	2850.00	632.06	643.69	639.69	644.09	0.000596	5.30	648.04	443.23	0.34

Condition 1 100-yr

HEC-RAS River: Watson Creek Reach: main Profile: Watson peak

Reach	River Sta	Profile	Plan	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
main	771.2659	Watson peak	prop 50yr	3705.00	635.79	644.48	644.48	647.20	0.004993	13.33	298.72	65.68	0.95
main	771.2659	Watson peak	ex 50yr	3705.00	635.79	644.48	644.48	647.20	0.004993	13.33	298.72	65.68	0.95
main	710.5268	Watson peak	prop 50yr	3705.00	634.83	643.41	643.41	645.84	0.004205	12.61	326.33	99.13	0.89
main	710.5268	Watson peak	ex 50yr	3705.00	634.83	643.87	643.41	645.89	0.003208	11.56	373.55	103.67	0.79
main	673.36	Watson peak	prop 50yr	3705.00	633.99	643.42	642.71	645.40	0.003307	11.39	364.48	104.69	0.79
main	673.36	Watson peak	ex 50yr	3705.00	633.99	644.15	642.71	645.64	0.002204	9.99	439.57	113.85	0.66
main	612.9198	Watson peak	prop 50yr	3705.00	634.75	644.04	641.56	644.96	0.001312	7.82	533.37	136.33	0.51
main	612.9198	Watson peak	ex 50yr	3705.00	634.75	644.56	641.56	645.33	0.001018	7.21	596.78	182.98	0.46
main	572.0831	Watson peak	prop 50yr	3705.00	634.39	644.14	641.16	644.85	0.001002	6.88	600.99	178.53	0.45
main	572.0831	Watson peak	ex 50yr	3705.00	634.39	644.64	641.16	645.24	0.000786	6.37	661.16	224.89	0.40
main	508.1873	Watson peak	prop 50yr	3705.00	634.12	644.20	640.94	644.74	0.000781	5.96	649.85	188.51	0.40
main	508.1873	Watson peak	ex 50yr	3705.00	634.12	644.69	640.94	645.16	0.000618	5.55	703.91	231.49	0.36
main	424	Watson peak	prop 50yr	3705.00	633.19	642.70	641.74	644.50	0.002628	10.93	377.71	122.12	0.74
main	424	Watson peak	ex 50yr	3705.00	633.19	643.74	641.74	645.00	0.001674	9.24	461.06	250.02	0.58
main	360	Watson peak	prop 50yr	3705.00	633.74	643.18	640.81	644.10	0.001781	7.69	482.11	94.74	0.58
main	360	Watson peak	ex 50yr	3705.00	633.74	643.69	641.44	644.87	0.001597	8.72	425.69	239.56	0.57
main	327	Watson peak	prop 50yr	3705.00	632.49	642.96	640.35	644.03	0.001534	8.29	452.79	76.57	0.55
main	327	Watson peak	ex 50yr	3705.00	632.49	642.81	640.32	643.74	0.001419	7.71	480.44	76.73	0.53
main	323	Watson peak	prop 50yr	3705.00	632.11	643.01	640.07	644.00	0.001377	8.00	469.32	77.10	0.52
main	323	Watson peak	ex 50yr	3705.00	632.11	642.86	640.23	643.68	0.001349	7.28	509.57	81.37	0.51
main	318			Bridge									
main	268	Watson peak	prop 50yr	3705.00	632.66	642.64	640.25	643.76	0.001585	8.56	457.21	348.25	0.56
main	268	Watson peak	ex 50yr	3705.00	632.66	642.47	640.56	643.57	0.001813	8.55	499.80	389.48	0.59
main	187.1931	Watson peak	prop 50yr	3705.00	632.58	643.07	637.71	643.26	0.000230	3.78	1233.69	686.66	0.23
main	187.1931	Watson peak	ex 50yr	3705.00	632.58	643.07	637.71	643.26	0.000230	3.78	1233.69	686.66	0.23
main	125.8394	Watson peak	prop 50yr	3705.00	632.06	641.01		643.03	0.004207	11.58	358.16	176.44	0.87
main	125.8394	Watson peak	ex 50yr	3705.00	632.06	641.01		643.03	0.004207	11.58	358.16	176.44	0.87

Condition 2 50-yr

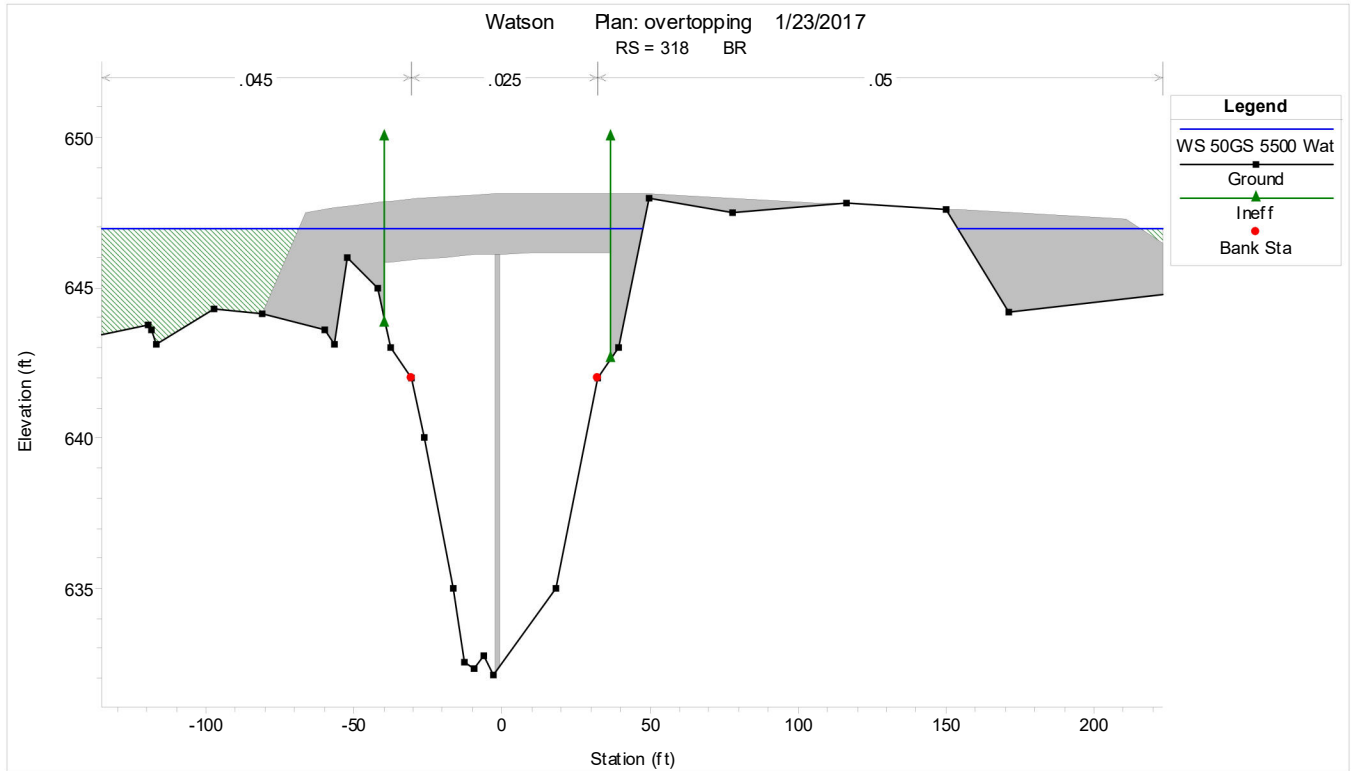
HEC-RAS River: Watson Creek Reach: main Profile: Watson peak

Reach	River Sta	Profile	Plan	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
main	771.2659	Watson peak	exist 04apr2016	4425.00	635.79	645.26	645.26	648.21	0.004776	13.96	351.88	70.91	0.93
main	771.2659	Watson peak	prop 04apr2016	4425.00	635.79	645.26	645.26	648.21	0.004776	13.96	351.88	70.91	0.93
main	710.5268	Watson peak	exist 04apr2016	4425.00	634.83	645.07	644.21	646.87	0.002409	11.17	501.53	108.59	0.70
main	710.5268	Watson peak	prop 04apr2016	4425.00	634.83	644.21	644.21	646.72	0.003782	12.97	409.32	105.88	0.86
main	673.36	Watson peak	exist 04apr2016	4425.00	633.99	645.28	643.69	646.68	0.001774	9.89	565.00	167.61	0.61
main	673.36	Watson peak	prop 04apr2016	4425.00	633.99	644.29	643.69	646.30	0.002918	11.65	454.54	120.46	0.76
main	612.9198	Watson peak	exist 04apr2016	4425.00	634.75	645.64	642.23	646.42	0.000879	7.31	747.09	282.35	0.43
main	612.9198	Watson peak	prop 04apr2016	4425.00	634.75	644.90	642.23	645.88	0.001234	8.17	641.79	211.58	0.51
main	572.0831	Watson peak	exist 04apr2016	4425.00	634.39	645.71	641.82	646.34	0.000699	6.55	802.46	310.46	0.39
main	572.0831	Watson peak	prop 04apr2016	4425.00	634.39	645.00	641.82	645.77	0.000950	7.22	705.39	271.07	0.45
main	508.1873	Watson peak	exist 04apr2016	4425.00	634.12	645.76	641.46	646.27	0.000556	5.75	827.29	337.95	0.35
main	508.1873	Watson peak	prop 04apr2016	4425.00	634.12	645.07	641.46	645.67	0.000744	6.29	746.17	309.34	0.40
main	424	Watson peak	exist 04apr2016	4425.00	633.19	644.81	642.48	646.11	0.001487	9.49	546.90	373.63	0.56
main	424	Watson peak	prop 04apr2016	4425.00	633.19	643.43	642.48	645.42	0.002771	11.58	436.29	152.27	0.74
main	360	Watson peak	exist 04apr2016	4425.00	633.74	644.73	642.08	646.02	0.001458	9.11	487.15	355.51	0.56
main	360	Watson peak	prop 04apr2016	4425.00	633.74	644.00	641.50	644.99	0.001602	7.99	557.59	278.51	0.56
main	356		Bridge										
main	327	Watson peak	exist 04apr2016	4425.00	632.49	643.45	640.97	644.54	0.001482	8.39	527.58	201.73	0.55
main	327	Watson peak	prop 04apr2016	4425.00	632.49	643.67	641.09	644.91	0.001585	8.98	505.93	244.91	0.57
main	323	Watson peak	exist 04apr2016	4425.00	632.11	643.51	640.85	644.47	0.001384	7.88	562.58	260.05	0.53
main	323	Watson peak	prop 04apr2016	4425.00	632.11	643.71	640.82	644.88	0.001437	8.89	522.61	270.51	0.54
main	268	Watson peak	exist 04apr2016	4425.00	632.66	643.17	641.45	644.36	0.001760	9.02	584.36	640.17	0.59
main	268	Watson peak	prop 04apr2016	4425.00	632.66	643.31	641.04	644.62	0.001664	9.30	508.54	527.40	0.58
main	187.1931	Watson peak	exist 04apr2016	4425.00	632.58	643.81	638.14	644.03	0.000243	4.10	1363.64	689.99	0.24
main	187.1931	Watson peak	prop 04apr2016	4425.00	632.58	643.81	638.14	644.03	0.000243	4.10	1363.64	689.99	0.24
main	125.8394	Watson peak	exist 04apr2016	4425.00	632.06	641.58	641.58	643.79	0.004244	12.21	418.78	203.66	0.89
main	125.8394	Watson peak	prop 04apr2016	4425.00	632.06	641.58	641.58	643.79	0.004244	12.21	418.78	203.66	0.89

Condition 2 100-yr

APPENDIX D – OVERTOPPING

The proposed roadway will overtop at an elevation of approximately 647.0. By trial and error, and assuming the 50-yr peak discharge is in Grindstone Creek, the discharge in Watson Creek that resulted in a WSE of 647.0 was determined to be approximately 5,500 cfs which is estimated to be equivalent to a 200-yr discharge.



APPENDIX E – PRELIMINARY SCOUR ANALYSIS

Pier Width			Hydraulic depth	8.9		
Pier Width	1	1.5	2	3	4	5
y1	8.9	8.9	8.9	8.9	8.9	8.9
a	1.00	1.50	2.00	3.00	4.00	5.00
v	8.6	8.6	8.6	8.6	8.6	8.6
Fr	0.51	0.51	0.51	0.51	0.51	0.51
K1	1.1	1.1	1.1	1.1	1.1	1.1
K2	1	1.00	1.00	1.00	1.00	1.00
K3	1.1	1.1	1.1	1.1	1.1	1.1
L/a	1	1.00	1.00	1.00	1.00	1.00
ys	3.89	5.06	6.10	7.94	9.57	11.07
max						
scour	2.4	3.6	4.8	7.2	9.6	12.0
use	2	4	5	7	10	11
