FINAL DESIGN HYDRAULIC STUDY

ENNIS ROAD BRIDGE AT SAND CREEK

Bridge Number 42C0697

Fresno County, CALIFORNIA

AVILA & ASSOCIATES

Final Design Hydraulic Study

ENNIS ROAD BRIDGE OVER SAND CREEK

Fresno County, CALIFORNIA

Bridge #42C0697

SEPTEMBER 15, 2020

PREPARED FOR:

BKF ENGINEERS AND FRESNO COUNTY DEPARTMENT OF PUBLIC WORKS

Prepared by:

AVILA AND ASSOCIATES CONSULTING ENGINEERS, INC.

Catherine M.C. Avila, P.E

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The Ennis Road Bridge (Bridge) at Sand Creek in Fresno County, California is proposed for replacement by Fresno County in 2019/2020. The proposed bridge is a 101-foot long single span cast-in-place precast box girder bridge supported by reinforced concrete abutments on spread footings. The bridge is 26 feet-10 inches wide and will accommodate two travel lanes and shoulders as shown in the attached General Plans (see Appendix A).

Sand Creek flows southwesterly through the central part of Fresno County (County) draining an approximate 18.2-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 the proposed bridge

	Design	Base	Flood of Record
Frequency (years)	50	100	< 50
Discharge (cubic feet per second)	2,770	3,345	2,200
Water Surface (elevation in feet at upstream face of Bridge)	950.2	951.2	949.2
Available Freeboard (in feet at upstream face of Bridge)[1]	5.4	4.4	6.4

This study used hydraulic modeling based on a HEC-RAS[2] model 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 lower. With a proposed minimum soffit elevation of 955.6, there will be approximately 5.4 feet of freeboard over the 50-yr WSE and approximately 4.4 feet of freeboard over the 100-yr WSE.

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 2020) and Memos to Designers 16-1 [3].

The proposed bridge will be higher and longer than the existing bridge thus increasing the available flow area and decreases the water surface elevation relative to existing conditions.

[1] Based on a proposed minimum soffit elevation of 955.6.

[2] 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.

[3] Caltrans Memo to Designers 16-1 December 2017 (http://www.dot.ca.gov/hq/esc/techpubs/manual/bridgemanuals/bridge-memo-to-designer/page/Section%201/16-1m.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 Ennis Road Bridge over Sand Creek in Fresno County. 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. Prepare draft report for comment
5. Prepare final report
6. Complete location hydraulic study
7. Coordinate with the Central Valley Flood Protection Board

The existing bridge is located approximately 14 miles northeast of Reedley, as shown in Figure 1. The existing bridge was constructed in 1975. It is a single span bridge with timber stringers on timber sills with a reinforced concrete deck and plywood subfloor supported by reinforced concrete abutments. It has a sufficiency rating, as of 2012, of 58.2 and is functionally obsolete. The Fresno County Public Works Department proposes to replace the existing bridge using Highway Bridge Program (HBP) funds.

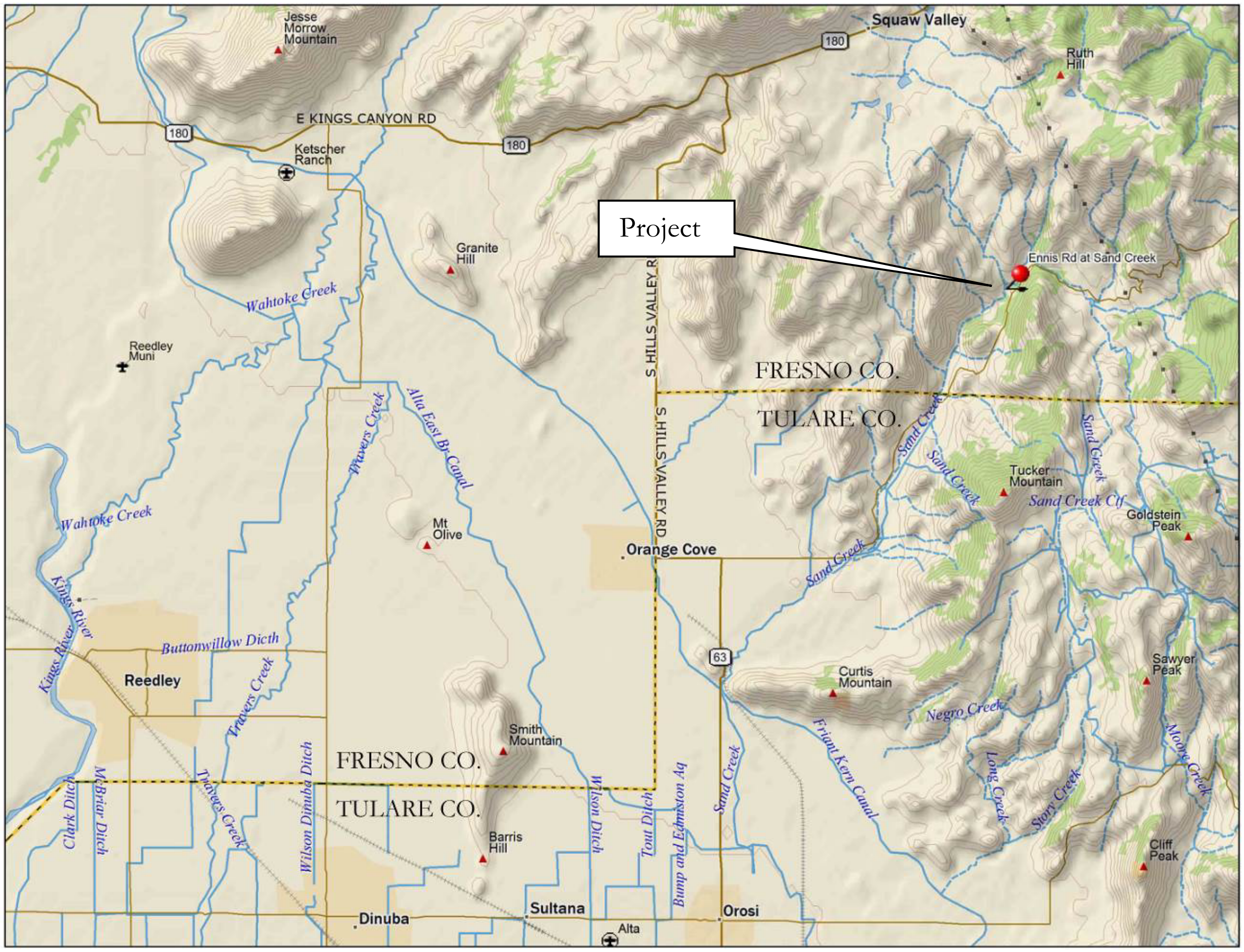


Figure 1. Bridge location map

The datum elevation used for this study is NAVD-88[4]. The proposed bridge will be a 101-foot-long one span cast-in-place pre-stressed box girder bridge supported by reinforced concrete abutments, as shown in Figure 2. The bridge will accommodate two travel lanes and shoulders as shown in the attached General Plan (see Appendix A). As part of this bridge replacement project, the alignment of Ennis Road is proposed to be simplified by removing a tight radius curve that approaches the existing bridge on the east side. The location of the proposed bridge is the same as the existing bridge; however, due to the proposed realignment, the proposed bridge will be significantly skewed with respect to the existing bridge.

[4] E-mail from Sheila Amparo, Project Engineer, BKF Engineers to Cathy Avila, Project Manager, Avila and Associates dated September 16, 2015.

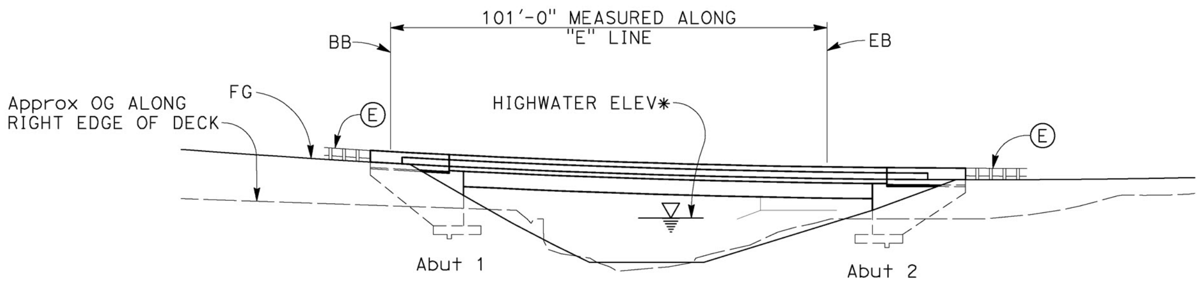


Figure 2. Proposed bridge profile view

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

	Ennis Road
Bridge Number	42C0697
Bridge Length (ft)	31
Span Lengths (ft)	1 @ 28.5
Bridge Type	Simply- supported single-span timber stringer (24), with CIP/RC deck and plywood subfloor, on timber sills on RC abutments founded on large boulders and bedrock.
Debris Challenges	None noted
Cross Sections Available for	1993, 2006
NBIS Item 113 (scour) code	8
ELI Flag 361 Condition State	N/A
Pier Type	N/A
Year Built	1975
Year Widened	N/A
Scour Challenges	1985[5], 1987[6], 1989[7], 1993[8]

[5] The channel is degrading.
[6] There is a minor erosion at the end of the left wingwall at Abutment 1.
[7] Same as 1987.
[8] There is an erosion hole at Abutment 2 left edge of deck.

The watershed draining to the bridge is 18.2 square miles as shown in Figure 3. The average annual rainfall for the watershed is approximately 25 inches per year[9]. Sand Creek carries flow southwesterly to the bridge site.

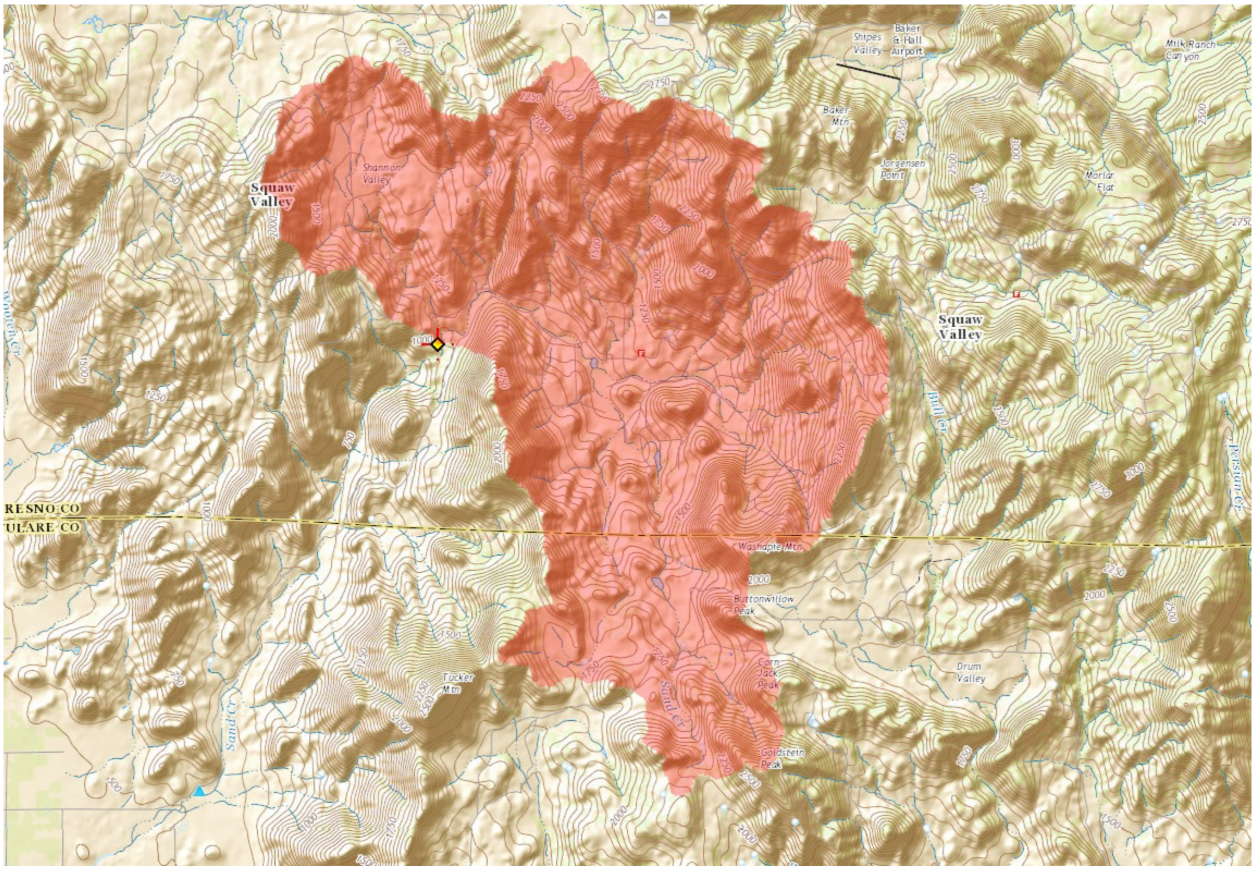


Figure 3. Basin contributing to the bridge (USGS streamstats)

Discharge at the bridge reach was 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 regression and HEC-HMS analyses yielded the discharge estimates shown in Table 3.

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

Table 3. Regression and HEC-HMS analyses results

Method	Discharge (cfs) 50-yr	100-yr
Regression	1,739	2,185
HEC-HMS	2,770	3,345

The results from the HEC-HMS analysis are considered conservative when compared to the regression analysis and were used for design as shown in Table 4. A complete summary of the regression and HEC-HMS analysis is included in Appendix B.

Table 4. Discharges used for design

	Design	Base
Frequency (Years)	50	100
Discharge (cfs)	2,770	3,345

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 4.1.0 model based on: 1) survey information supplied by BKF Engineers, 2) as-built data contained in the bridge maintenance records provided by Caltrans, and 3) a field investigation by Avila and Associates on June 17, 2016. Cross sections surveyed for the HEC-RAS model are shown in Figure 4.

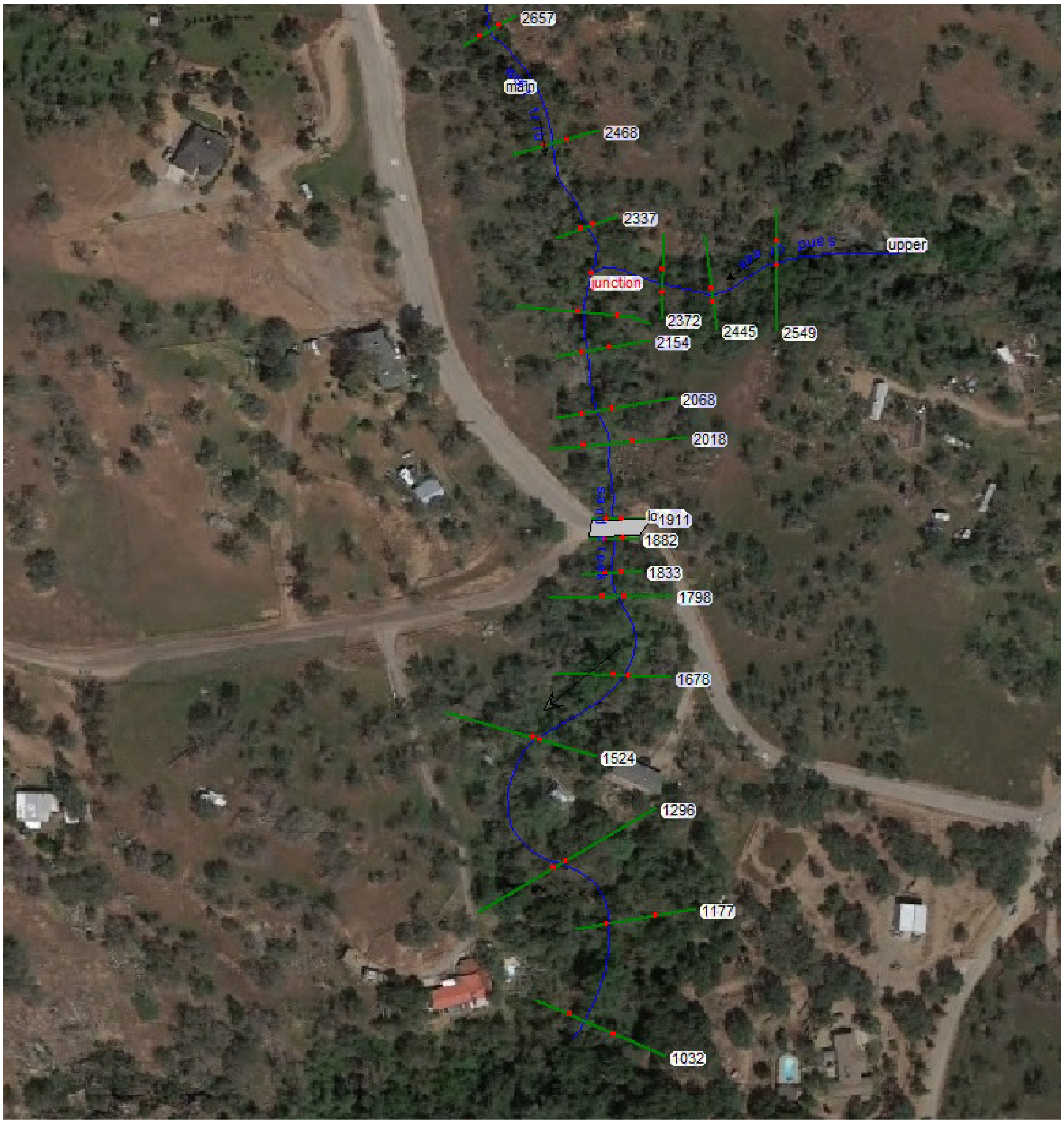


Figure 4. Plan view of HEC-RAS cross section

Existing Conditions

The Manning “n” values of 0.045 for the channel and 0.055 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 5.

Figure 5. Looking upstream at the channel. The creek bottom is heavily vegetated and the bank and overbank areas are vegetated with higher manning “n” values.

The existing bridge was input into the model as a single-span bridge with a minimum soffit elevation of 951.2 feet, as illustrated in Figure 6.

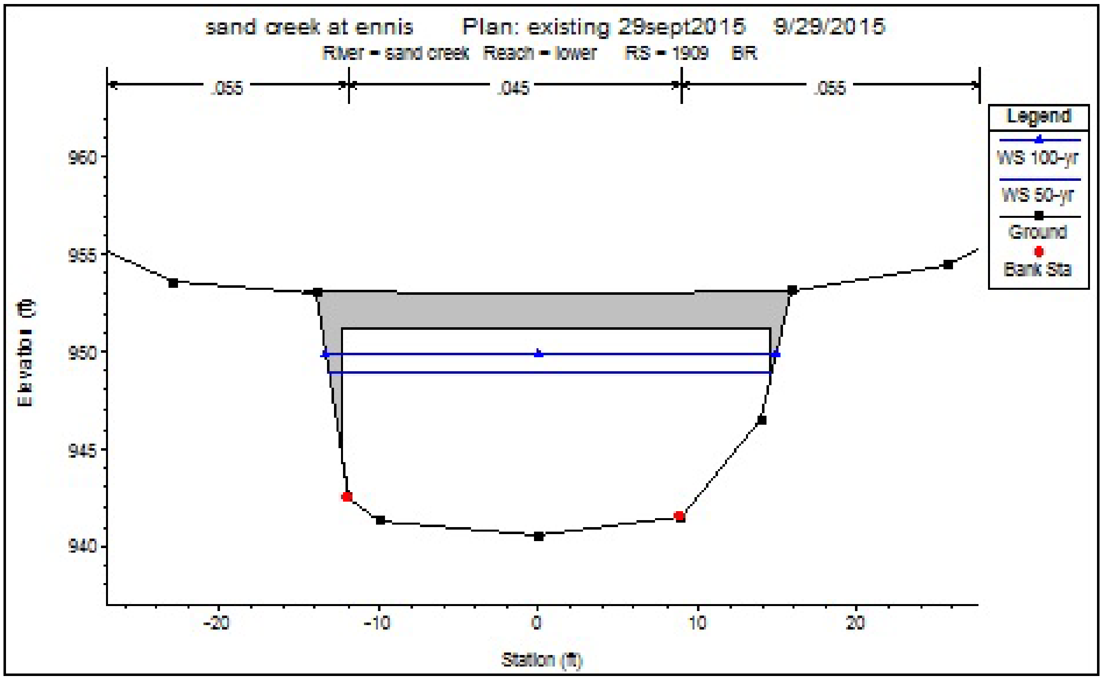


Figure 6. HEC-RAS cross section for the upstream existing conditions for the 50- 100-year Q's

Starting Water Surface Elevation

Various starting water surface elevations were evaluated. In all cases, the WSE profile converged approximately 200 feet downstream from the bridge as shown in Figure 7.

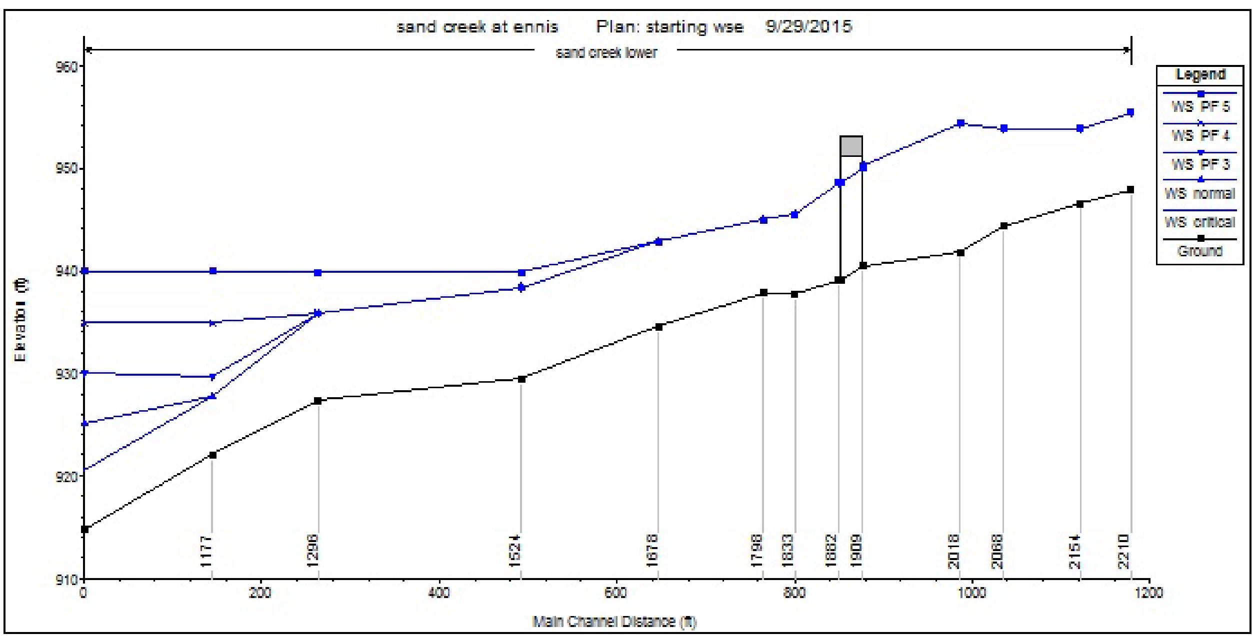


Figure 7. Starting Water Surface Elevation convergence for the 100-year discharge

Proposed Bridge Model

The HEC-RAS model was re-run after replacing the existing bridge with the proposed bridge which is a 101-foot single-span bridge. The proposed bridge will be approximately 70 feet longer than the existing bridge. The minimum soffit elevation of the proposed bridge is 955.6. Compared to the minimum soffit elevation of 951.2 for the existing bridge, the bridge will be approximately 4.4 ft higher. The bridge will be approximately 3 feet wider than existing as shown in Figure 8.

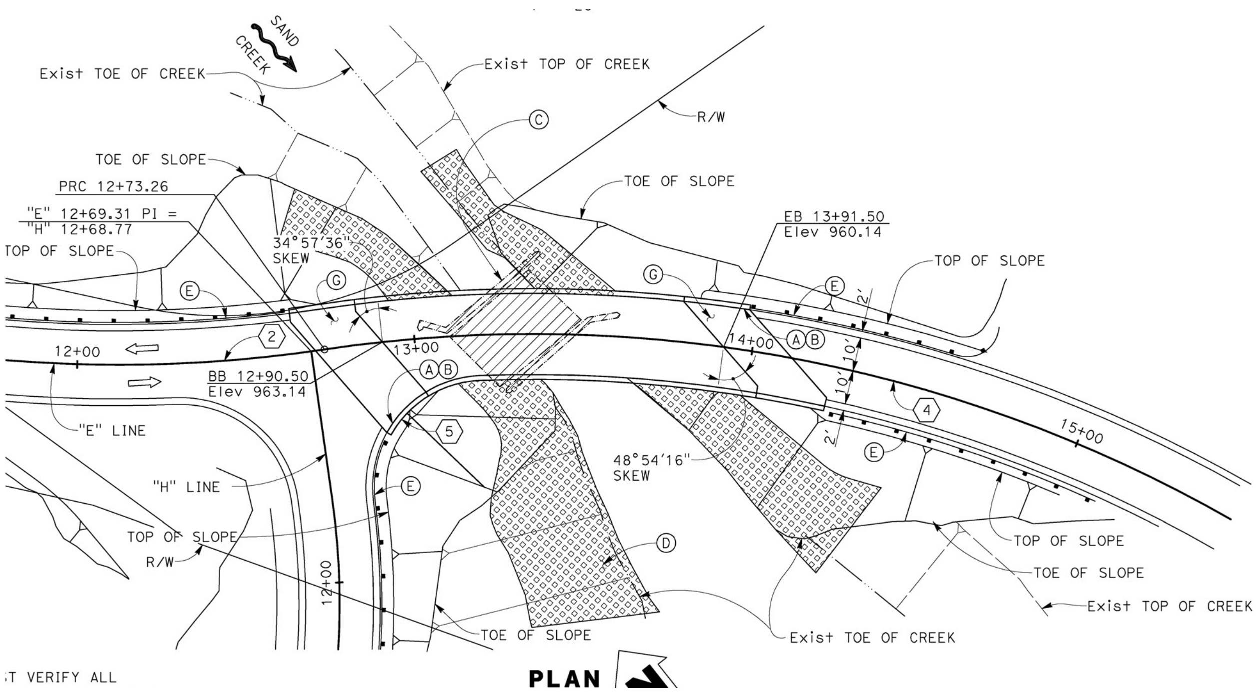


Figure 8. Existing and proposed bridge shown in plan view

Based on the General Plan (Appendix A), there is some grading proposed for the banks of the channel in the vicinity of the bridge as shown in Figure 8.

As shown in Figure 9 and close up in Figure 10, the water surface elevations for the proposed bridge for the 50-year and 100-year discharges are lower or not significantly changed from existing. Through the bridge reaches, however, the water surface elevations are slightly higher for the proposed bridge. The increase is most likely due to the shorter existing bridge contracting the section creating a sharper drawdown curve.

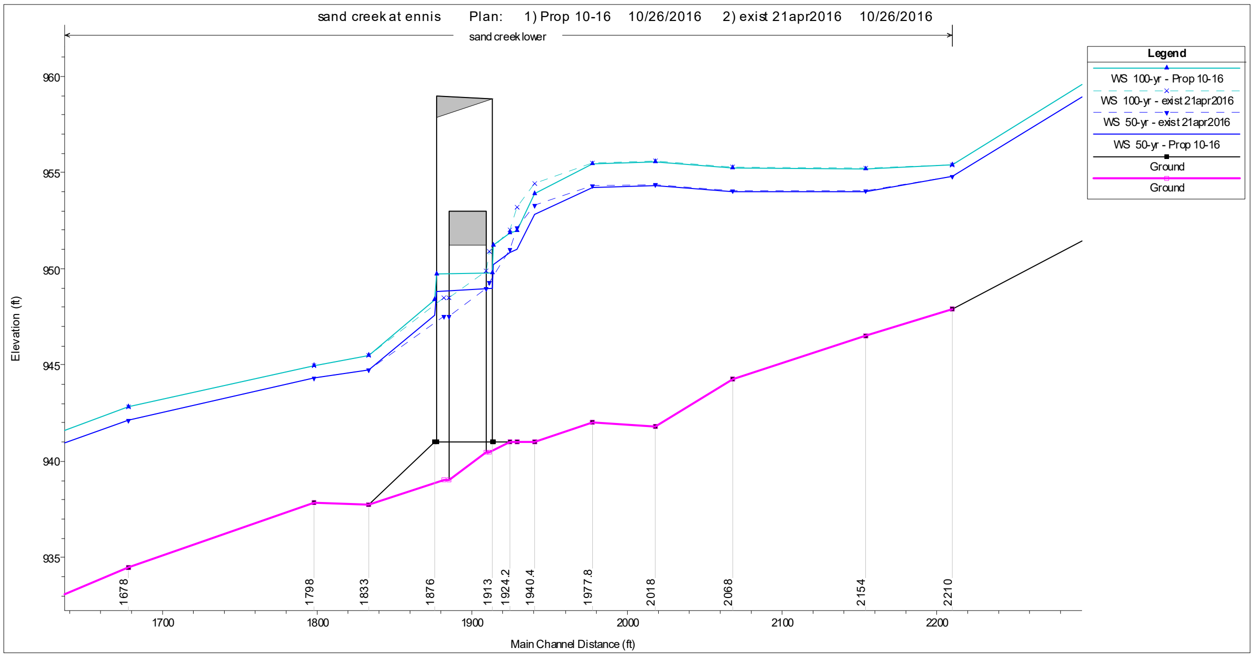


Figure 9. 50--year and 100-yr water surface elevation comparison existing vs. Proposed bridge

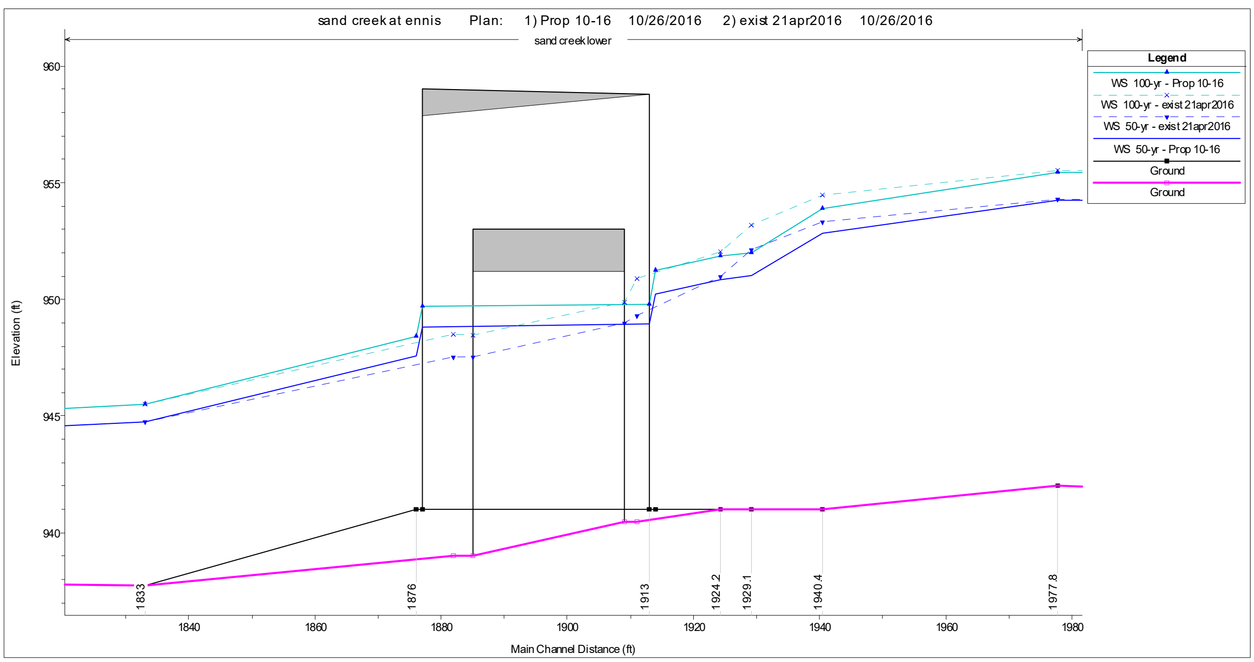


Figure 10. Close up of Figure 9

Table 5 shows a comparison of the 100-yr water surface elevations for the proposed bridge to the existing.

Table 5. 100 yr WSE comparisons for the proposed bridge

Station	Existing	Proposed	Difference
1678	942.81	942.81	0.00
1798	944.98	944.99	0.01
1833	945.50	945.51	0.00
Downstream Proposed Bridge 1877		949.72	
Downstream Existing Bridge 1885	948.48		
Upstream Existing Bridge 1909	949.87		
Upstream Proposed Bridge 1913		949.80	
1924.2	952.02	951.84	-0.17
1929.1	953.19	951.99	-1.21
1940.4	954.46	953.89	-0.57
1977.8	955.51	955.44	-0.06

See Appendix C for detailed HEC-RAS output and Appendix D for the Flood of Record.

HYDRAULIC CRITERIA

Chapter 820 of the Caltrans Highway Design Manual (HDM) delineates the hydraulic design criteria for bridges (Caltrans, 2020). 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 955.6, 5.4 feet of freeboard will be provided above the 50-year water surface elevation and 4.4 feet above the 100-year water surface elevation which meets the HDM criteria.

The Central Valley Flood Protection Board (CVFPB), however, has jurisdiction over this river (California Code of Regulations Title 23, Article 8, Section 112) and requires 3 feet of freeboard on the 100-year discharge. Since the proposed bridge will meet the criteria, no 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. There were no instances of debris being caught on the bridge noted.

The proposed bridge will improve the hydraulics by providing more available flow area due to the raised roadway and longer bridge spans which will also reduce the potential for drift accumulation.

The Ennis Road Bridge was determined to have no significant scour problems by Caltrans and the Item 113 was rated an "8" meaning bridge foundation determined to be not scour critical.

Available bridge cross-section data since 1993 indicates that there has been no history of channel bed degradation at the bridge, as shown in Figure 11.

According to the Draft Geotechnical Report, two borings encountered predominately decomposed granite bedrock or colluvium in the upper 7-8 feet. It is assumed that the foundations will be embedded into rock and no scour analysis will be needed.

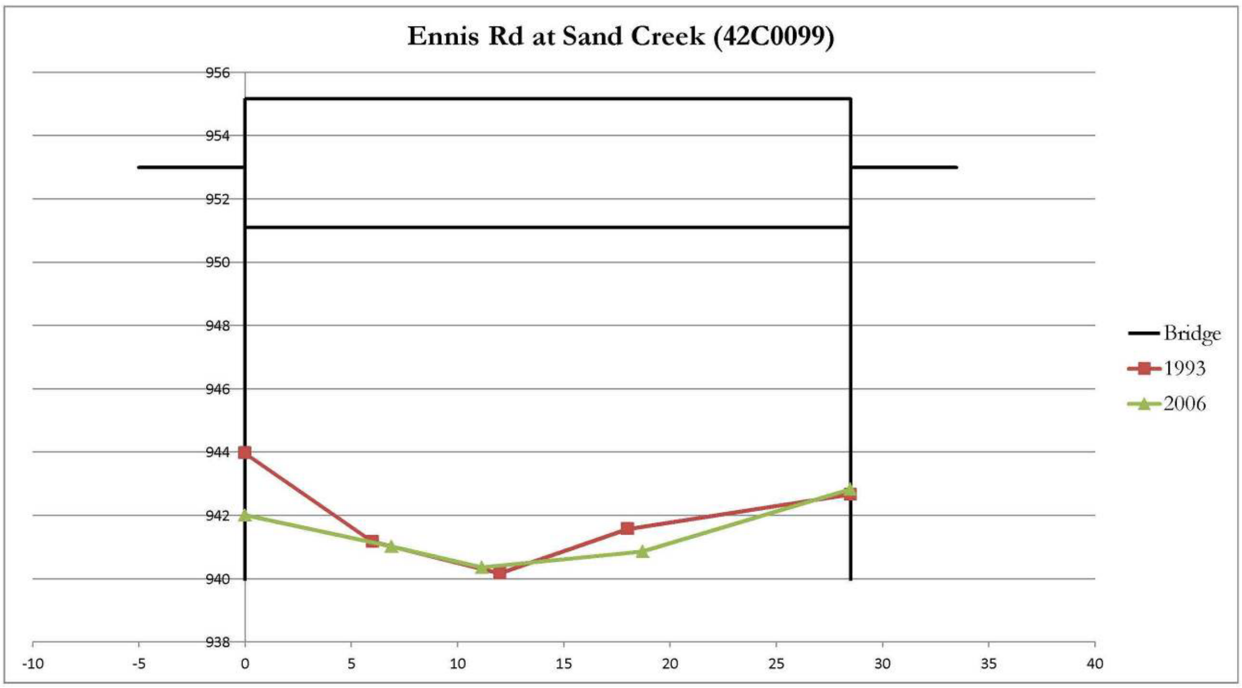


Figure 11. Channel cross-sections over time at the existing bridge

BANK PROTECTION

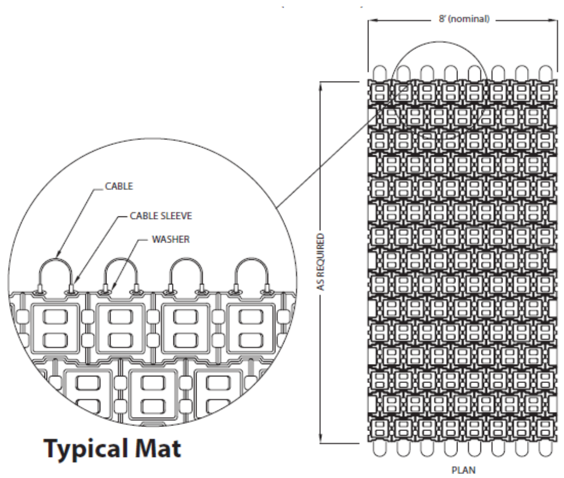
The FHWA Hydraulic Engineering Circular No. 23 (HEC 23) guidelines for rock slope protection (RSP) which were adopted by the California Bank and Shore Protection Committee were used to size the rock riprap (Lagasse et al. 2009). The RSP sizes are outlined Table 5. See Appendix E for rock slope protection.

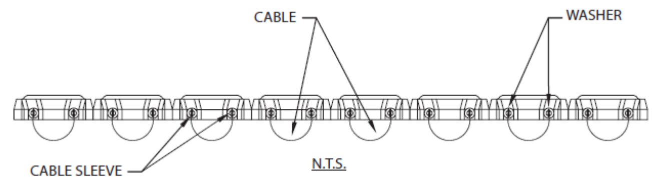
Table 5. Rock Slope Protection based upon HEC-23

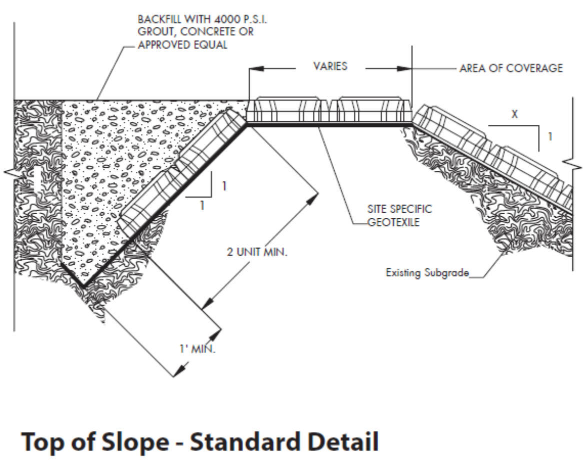
Velocity	D50	Thickness	Class	Size	Extents*
ft/sec	inches	feet		Tons	feet
13.3	35.6	4.5	IX	2	25

** Extents refer to the extent along the roadway embankment and in front of the abutments, the toe will be keyed into the bed and/or mounded*

The required RSP is size and resulting extents are large. Thus, Articulated Concrete Blocks (ACB) as shown in Figure 12, were chosen to provide bank protection. The hydraulic parameters for the ACBs were provided for the use of the ACB manufacturer in the Technical Memorandum included in Appendix F.







ArmorFlex Unit Specification

Concrete Block Class	Open/Closed Cell	Nom. Dimensions (in.)			Gross Area/ (sq. ft.)	Min. Block Weight		Open Area %
		L	W	H		lbs	lbs/sq. ft.	
30S	Open	13	11.6	4.75	0.98	33	35	20
50S	Open	13	11.6	6	0.98	42	50	20
40	Open	17.4	15.5	4.75	1.77	59	40	20
50	Open	17.4	15.5	6	1.77	76	50	20
70	Open	17.4	15.5	8.5	1.77	108	70	20
40L	Open	17.4	23.6	4.75	2.58	97	40	20
50L	Open	17.4	23.6	6	2.58	116	50	20
70L	Open	17.4	23.6	8.5	2.58	174	70	20
45S	Closed	13	11.6	4.75	0.98	39	45	10
55S	Closed	13	11.6	6	0.98	50	55	10
45	Closed	17.4	15.5	4.75	1.77	71	45	10
55	Closed	17.4	15.5	6	1.77	91	55	10
85	Closed	17.4	15.5	8.5	1.77	136	85	10
45L	Closed	17.4	23.6	4.75	2.58	109	45	10
55L	Closed	17.4	23.6	6	2.58	138	55	10
85L	Closed	17.4	23.6	8.5	2.58	207	85	10
High Velocity Application Block Classes								
40-T	Open	17.4	15.5	4.75	1.77	58	40	20
50-T	Open	17.4	15.5	6.00	1.77	75	50	20
70-T	Open	17.4	15.5	8.50	1.77	109	70	20

Figure 12. Articulated Concrete block (from http://www.conteches.com/products/erosion-control/hard-armor/armorflex)

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

Drainage Area: 18.2 Square miles

	Design	**Base**	**Flood of Record**
Frequency (Years)	50	100	< 50
Discharge (Cubic feet per second)	2,770	3,345	2,200
Water Surface (Elevation at u/s face of Bridge)	950.2	951.2	949.2
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 following Scour Data Table is provided for placement on the Foundation Plan

Support No.	Long Term (Degradation and Contraction) Scour Elevation (ft)	Short Term (Local) Scour Depth (ft)
A1	n/a*	n/a*
A2	n/a*	n/a*
* The foundations will be embedded into rock thus no scour analysis was required.		

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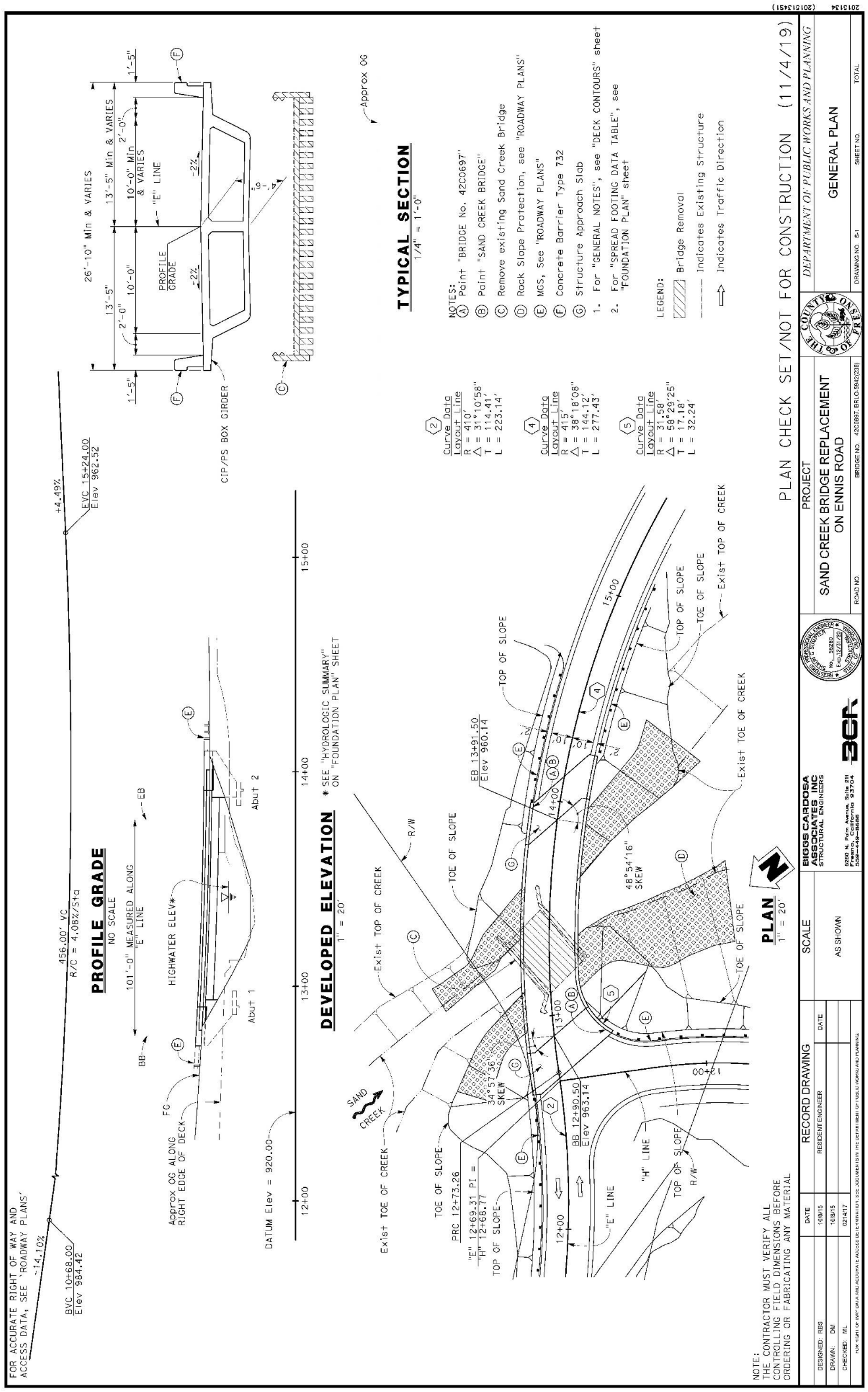
APPENDICES

APPENDIX A – GENERAL PLAN



REGRESSION ANALYSIS

Sierra Region

Area (A) = 18.2 sq mi (per USGS Streamstats)

Mean Annual Precipitation (MAP) = 25 (per USGS Streamstats)

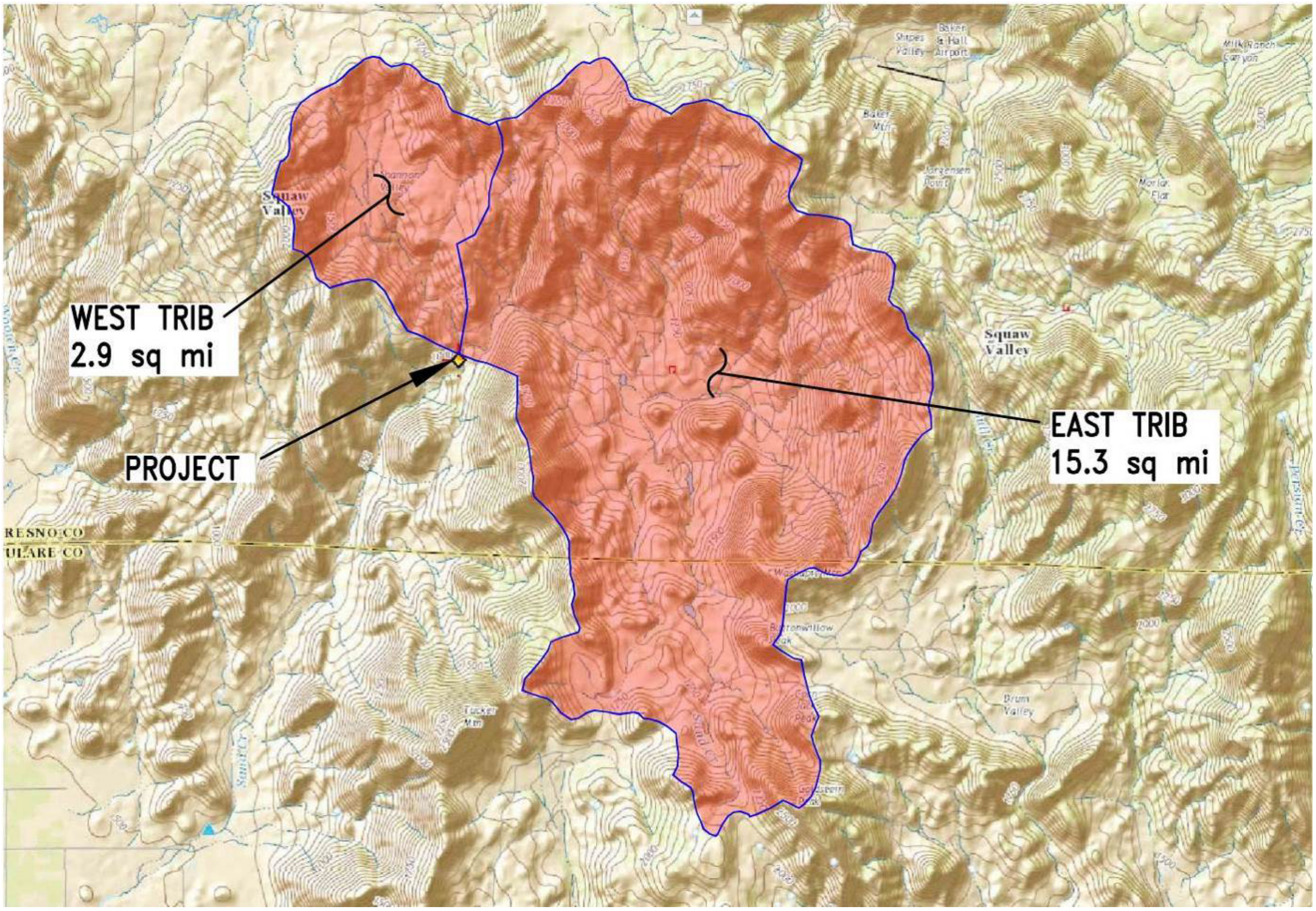
Mean watershed elevation (E) = 1726 (per USGS Streamstats)

		A			MAP				E		Q (cfs)	Recurrence
2	2.43	18.2	0.924	35.47417	25	2.06	758.1522	-0.646	1726	0.008107	**218**	2
5	11.6	18.2	0.907	161.1917	25	1.7	237.9567	-0.566	1726	0.014718	**565**	5
10	17.2	18.2	0.896	231.5008	25	1.54	142.1764	-0.486	1726	0.026718	**879**	10
25	20.7	18.2	0.885	269.8569	25	1.39	87.72767	-0.386	1726	0.056299	**1,333**	25
50	21.1	18.2	0.879	270.3244	25	1.31	67.8112	-0.316	1726	0.094863	**1,739**	50
100	20.6	18.2	0.874	260.1175	25	1.24	54.13095	-0.25	1726	0.155146	**2,185**	100
200	19.4	18.2	0.87	242.1385	25	1.18	44.62407	-0.188	1726	0.246284	**2,661**	200
500	17.4	18.2	0.865	214.0479	25	1.11	35.6216	-0.11	1726	0.440479	**3,359**	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. The watershed was broken up into sub basins as shown on the hydrology map.

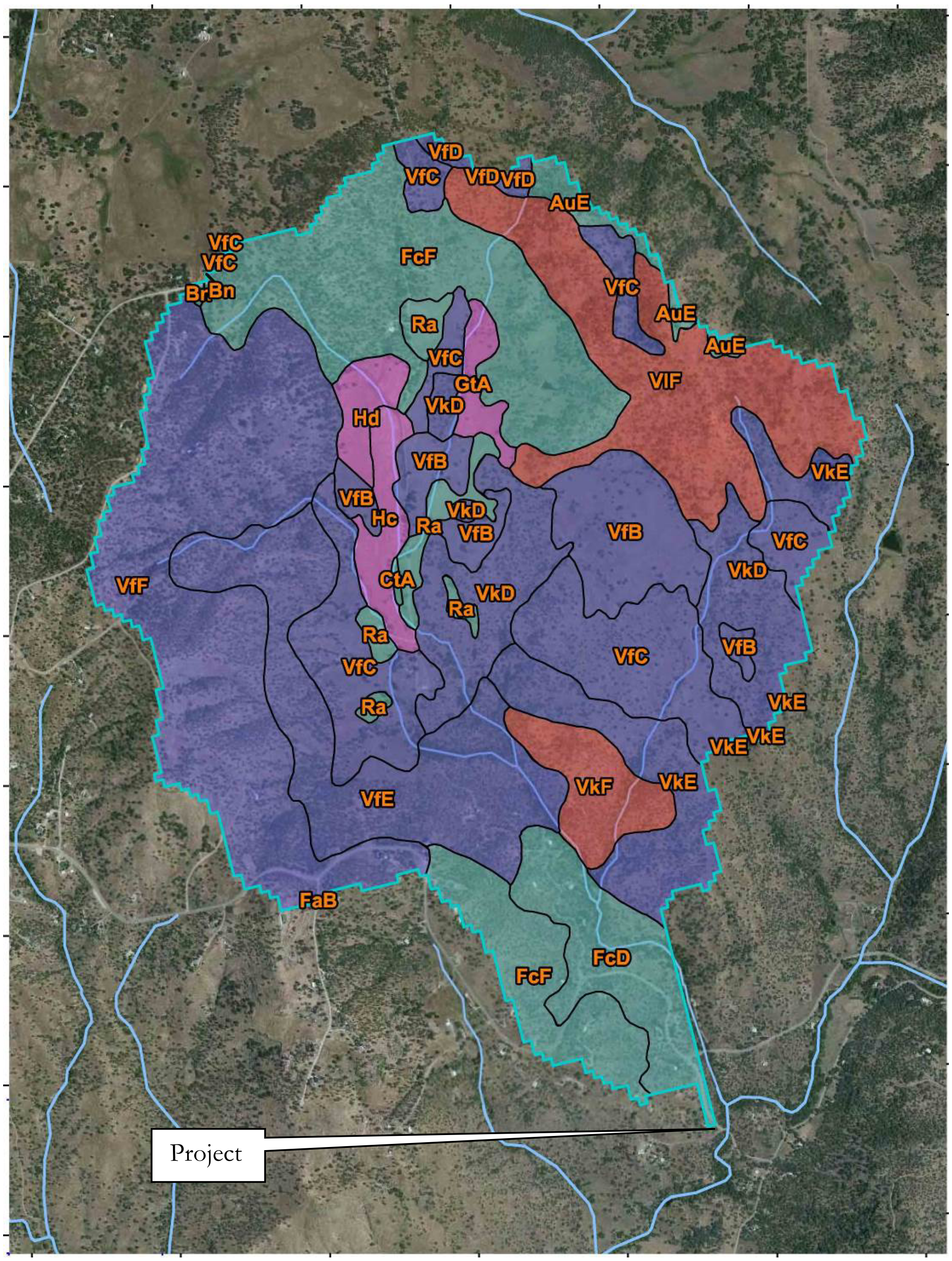


Hydrology Map

The following methods and parameters were used for the analysis:

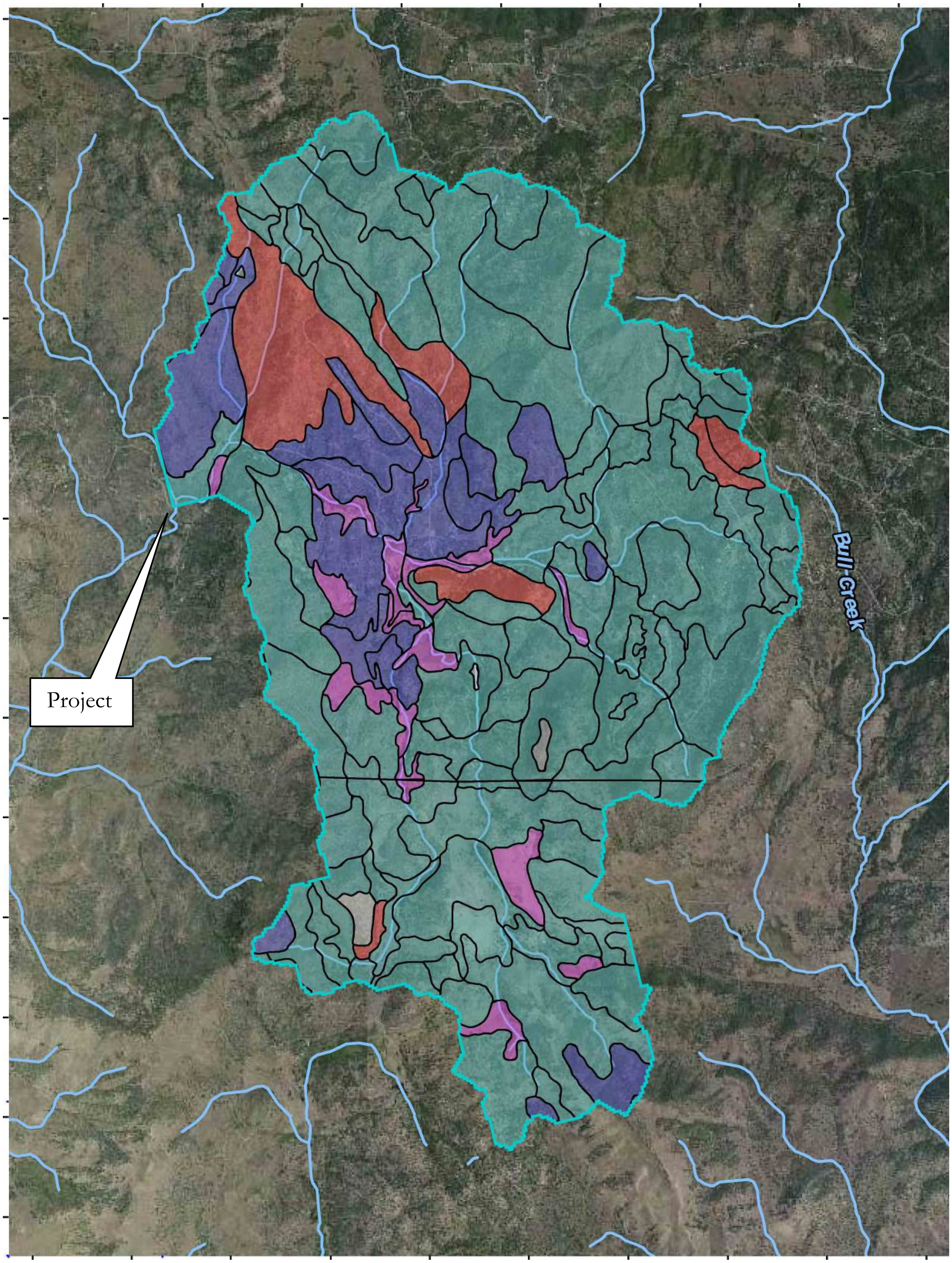
- SCS Curve Number loss method
    - Initial Abstraction = 0.2
- SCS Unit Hydrograph transform method
    - Type 1A storm distribution
    - Lag time = 0.6 x time of concentration

The Sand Creek watershed is composed of soils from all four hydrologic soils groups as shown on the Watershed Soils Map for each sub-basin.



Magenta = Class A, Blue = Class B, Aqua = Class C, Salmon = Class D, Gray = other

West Trib Sub-Basin Watershed Soils Map (USDA NRCS Web Soil Survey)

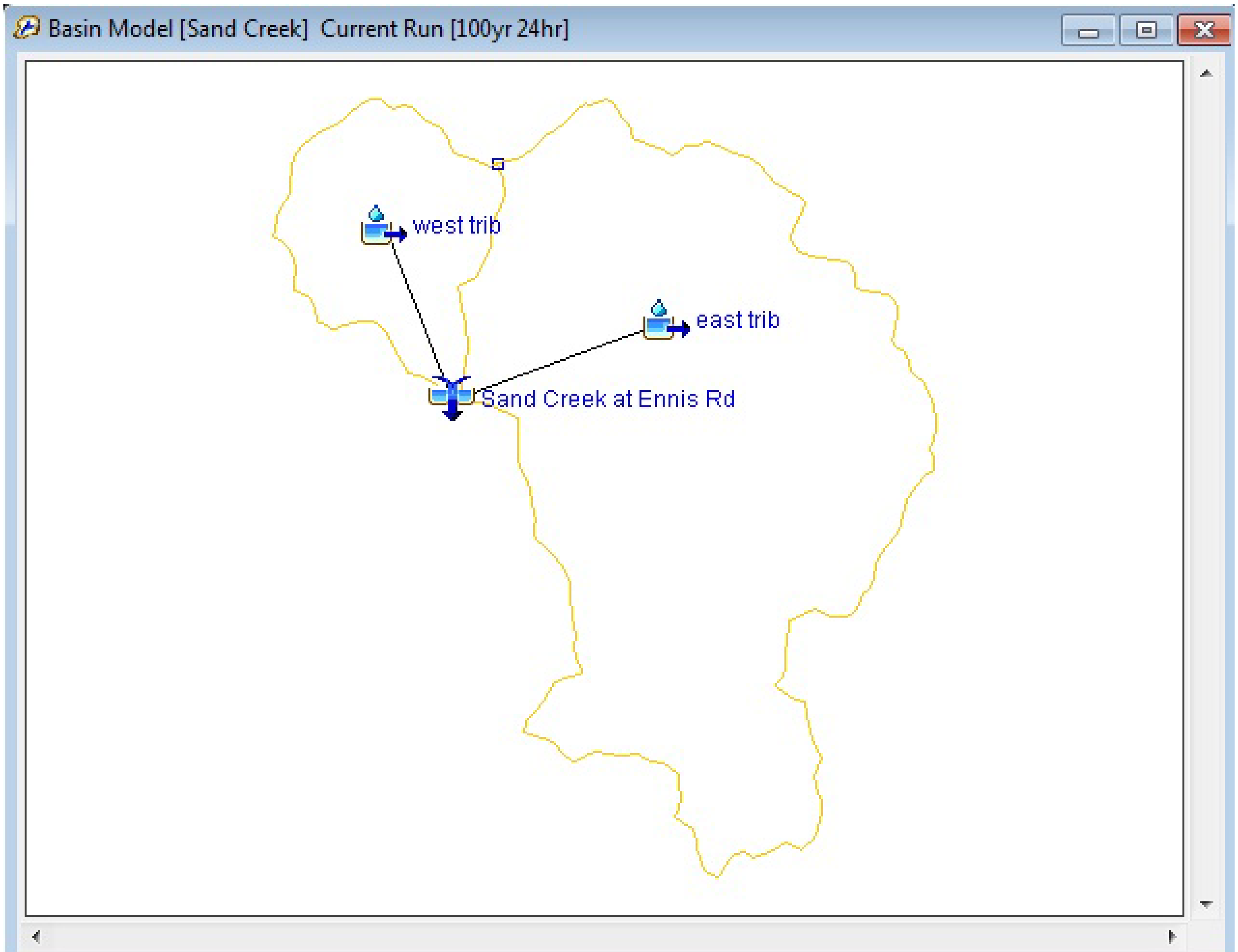


Magenta = Class A, Blue = Class B, Aqua = Class C, Salmon = Class D, Gray = other
East Trib Sub-Basin Watershed Soils Map (USDA NRCS Web Soil Survey)

By sub-basin, the breakdown of soils class, CN number, and composite CN is:

Sub-Basin	**Soil Class**	**Area**	**% of Total**	**CN**
		(acres)	(%)	
West Trib				
	A	68.9	3.8	36
	B	1090.0	59.8	65
	C	424.9	23.3	76
	D	237.8	13.1	82
	Other	0.0	0.0	99
			Composite CN	**69**
East Trib				
	A	411.4	4.2	36
	B	1354.8	13.9	65
	C	7166.3	73.4	76
	D	786	8.0	82
	Other	50.2	0.5	99
			Composite CN	**73**

Precipitation data was obtained from the NOAA's National Weather Service Hydrometerological Design Studies Center Precipitation Frequency Data Server by manually entering the latitude and longitude of the centroid of the watershed area. **http://hdsc.nws.noaa.gov/hdsc/pfds/pfds_map_cont.html?bkmrk=ca** (NOAA Atlas 14) For this analysis, the 24 hour precipitation depths for the 50-yr and 100-yr storms according to NOAA Atlas 14 are 4.80 inches and 5.40 inches respectively.



HEC-HMS Basin Model Schematic

Results:

Global Summary Results for Run "50yr 24hr"

Project: Sand Creek at Ennis Rd   Simulation Run: 50yr 24hr

Start of Run: 01Jan2015, 00:00   Basin Model: Sand Creek
End of Run: 02Jan2015, 00:05   Meteorologic Model: 50yr 24hr
Compute Time: 29Sep2015, 12:04:37   Control Specifications: 24 hours

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

Hydrologic Element	Drainage Area (MI2)	Peak Discharge (CFS)	Time of Peak	Volume (IN)
east trib	15.2636	2459.9	01Jan2015, 10:15	2.351
west trib	2.8463	672.2	01Jan2015, 08:30	2.282
Sand Creek at Ennis Rd	18.1099	2768.1	01Jan2015, 10:10	2.340

50-yr 24 hr

Global Summary Results for Run "100yr 24hr"

Project: Sand Creek at Ennis Rd   Simulation Run: 100yr 24hr

Start of Run: 01Jan2015, 00:00   Basin Model: Sand Creek
End of Run: 02Jan2015, 00:05   Meteorologic Model: 100yr 24hr
Compute Time: 29Sep2015, 12:03:26   Control Specifications: 24 hours

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

Hydrologic Element	Drainage Area (MI2)	Peak Discharge (CFS)	Time of Peak	Volume (IN)
east trib	15.2636	2971.9	01Jan2015, 10:15	2.807
west trib	2.8463	818.9	01Jan2015, 08:30	2.737
Sand Creek at Ennis Rd	18.1099	3344.9	01Jan2015, 10:05	2.796

100-yr 24 hr

Existing Conditions

HEC-RAS Plan: exist 21apr2016

River	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)	
west trib	main	2657	50-yr	672.00	994.37	998.83	998.83	1000.17	0.023129	9.31	72.20	26.93	1.00
west trib	main	2657	100-yr	820.00	994.37	999.27	999.27	1000.73	0.022590	9.71	84.45	29.00	1.00
west trib	main	2468	50-yr	672.00	978.70	983.60	983.60	984.94	0.023385	9.27	72.49	27.28	1.00
west trib	main	2468	100-yr	820.00	978.70	984.04	984.04	985.49	0.022686	9.64	85.07	29.49	1.00
west trib	main	2337	50-yr	672.00	961.16	966.51	966.51	968.11	0.019006	10.26	69.46	24.38	0.93
west trib	main	2337	100-yr	820.00	961.16	967.03	967.03	968.77	0.017745	10.80	82.67	26.87	0.92
sand creek	upper	2549	50-yr	2460.00	959.64	967.95		969.31	0.008220	9.86	295.10	69.95	0.69
sand creek	upper	2549	100-yr	2970.00	959.64	968.92		970.24	0.006854	9.89	366.39	77.33	0.64
sand creek	upper	2445	50-yr	2460.00	956.00	965.39	965.39	968.09	0.013647	14.09	213.57	44.30	0.90
sand creek	upper	2445	100-yr	2970.00	956.00	966.26	966.26	969.13	0.012916	14.73	254.38	49.63	0.89
sand creek	upper	2372	50-yr	2460.00	954.73	962.75	962.75	965.21	0.015515	12.76	206.71	46.92	0.94
sand creek	upper	2372	100-yr	2970.00	954.73	963.51	963.51	966.17	0.014471	13.38	243.80	50.96	0.92
sand creek	lower	2210	50-yr	2770.00	947.91	954.79	954.79	956.94	0.019847	11.75	235.83	55.28	1.00
sand creek	lower	2210	100-yr	3345.00	947.91	955.38	955.38	957.79	0.019039	12.44	269.11	57.34	1.00
sand creek	lower	2154	50-yr	2770.00	946.52	954.04		955.65	0.008933	10.53	290.75	57.33	0.74
sand creek	lower	2154	100-yr	3345.00	946.52	955.22		956.78	0.007009	10.46	360.78	61.56	0.68
sand creek	lower	2068	50-yr	2770.00	944.27	954.06		954.96	0.003788	7.82	388.81	62.90	0.50
sand creek	lower	2068	100-yr	3345.00	944.27	955.27		956.19	0.003277	8.01	467.14	67.14	0.47
sand creek	lower	2018	50-yr	2770.00	941.82	954.38		954.69	0.001067	4.56	644.49	79.41	0.27
sand creek	lower	2018	100-yr	3345.00	941.82	955.59		955.93	0.001056	4.80	743.22	83.76	0.27
sand creek	lower	1977.8	50-yr	2770.00	942.00	954.30		954.65	0.000968	5.02	657.44	81.46	0.27
sand creek	lower	1977.8	100-yr	3345.00	942.00	955.51		955.89	0.000954	5.34	758.00	85.85	0.27
sand creek	lower	1940.4	50-yr	2770.00	941.00	953.30		954.50	0.004230	9.65	365.95	55.86	0.53
sand creek	lower	1940.4	100-yr	3345.00	941.00	954.46		955.73	0.004024	10.11	433.83	61.92	0.53
sand creek	lower	1929.1	50-yr	2770.00	941.00	952.12	951.01	954.33	0.008496	12.67	264.05	42.87	0.74
sand creek	lower	1929.1	100-yr	3345.00	941.00	953.19	951.99	955.56	0.008052	13.28	312.20	46.90	0.73
sand creek	lower	1924.2	50-yr	2770.00	941.00	950.99	950.99	954.18	0.014143	15.02	215.57	37.62	0.93
sand creek	lower	1924.2	100-yr	3345.00	941.00	952.02	952.02	955.42	0.013124	15.67	256.07	41.35	0.91
sand creek	lower	1911	50-yr	2770.00	940.47	949.32	948.89	952.62	0.012552	14.98	205.33	27.96	0.92
sand creek	lower	1911	100-yr	3345.00	940.47	950.89	949.86	954.22	0.010124	15.10	249.84	28.72	0.85
sand creek	lower	1909		Bridge									

HEC-RAS Plan: exist 21apr2016 (Continued)

River	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)	
sand creek	lower	1882	50-yr	2770.00	939.03	947.55	947.55	951.00	0.015555	14.96	192.37	29.67	0.99
sand creek	lower	1882	100-yr	3345.00	939.03	948.52	948.52	952.37	0.014703	15.84	221.98	31.44	0.98
sand creek	lower	1833	50-yr	2770.00	937.72	944.75	944.75	947.30	0.015218	13.99	240.42	49.63	0.97
sand creek	lower	1833	100-yr	3345.00	937.72	945.50	945.50	948.30	0.014609	14.76	278.79	51.98	0.97
sand creek	lower	1798	50-yr	2770.00	937.87	944.32	944.32	946.47	0.014765	12.89	265.94	65.99	0.95
sand creek	lower	1798	100-yr	3345.00	937.87	944.98	944.98	947.31	0.014111	13.55	311.27	70.65	0.94
sand creek	lower	1678	50-yr	2770.00	934.48	942.13	942.13	944.37	0.013463	13.99	270.14	60.59	0.93
sand creek	lower	1678	100-yr	3345.00	934.48	942.81	942.81	945.26	0.013324	14.79	312.41	64.14	0.94
sand creek	lower	1524	50-yr	2770.00	929.37	937.80		939.57	0.013628	14.72	294.29	63.21	0.93
sand creek	lower	1524	100-yr	3345.00	929.37	938.33	938.01	940.39	0.014731	15.98	328.27	65.91	0.98
sand creek	lower	1296	50-yr	2770.00	927.25	935.42	935.42	936.98	0.009226	12.38	365.79	109.56	0.78
sand creek	lower	1296	100-yr	3345.00	927.25	935.88	935.88	937.58	0.009724	13.21	417.17	112.45	0.81
sand creek	lower	1177	50-yr	2770.00	921.94	927.27	927.27	928.94	0.020045	10.60	275.24	85.26	1.00
sand creek	lower	1177	100-yr	3345.00	921.94	927.74	927.74	929.61	0.018974	11.22	315.56	86.90	1.00
sand creek	lower	1032	50-yr	2770.00	914.78	920.00	920.00	921.88	0.019967	11.00	251.89	68.24	1.01
sand creek	lower	1032	100-yr	3345.00	914.78	920.53	920.53	922.63	0.018623	11.61	288.69	70.87	1.00

Proposed Conditions

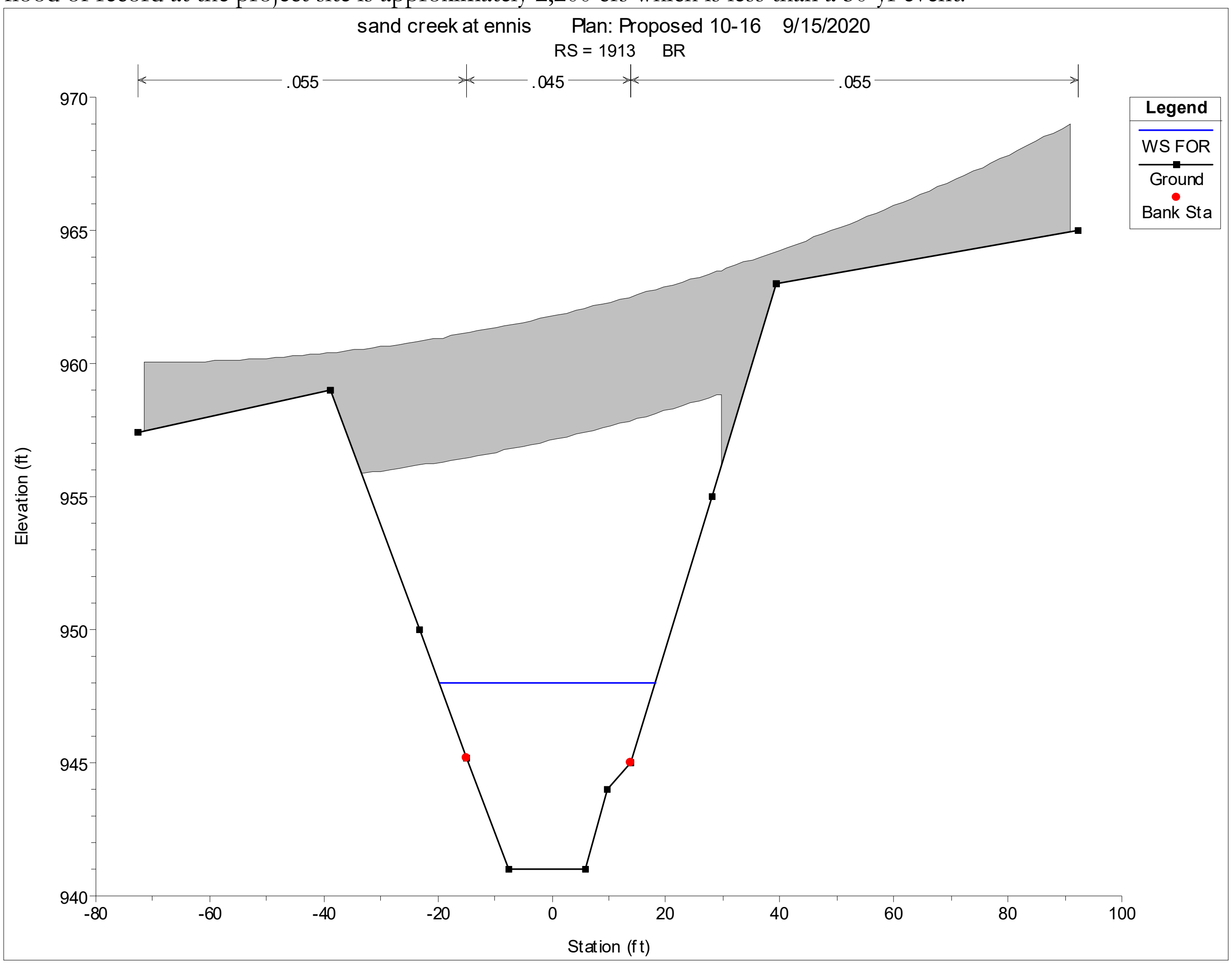
HEC-RAS Plan: Prop 10-16

River	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)	
west trib	main	2657	50-yr	672.00	994.37	998.83	998.83	1000.17	0.023129	9.31	72.20	26.93	1.00
west trib	main	2657	100-yr	820.00	994.37	999.27	999.27	1000.73	0.022590	9.71	84.45	29.00	1.00
west trib	main	2468	50-yr	672.00	978.70	983.60	983.60	984.94	0.023385	9.27	72.49	27.28	1.00
west trib	main	2468	100-yr	820.00	978.70	984.04	984.04	985.49	0.022686	9.64	85.07	29.49	1.00
west trib	main	2337	50-yr	672.00	961.16	966.51	966.51	968.11	0.019006	10.26	69.46	24.38	0.93
west trib	main	2337	100-yr	820.00	961.16	967.03	967.03	968.77	0.017745	10.80	82.67	26.87	0.92
sand creek	upper	2549	50-yr	2460.00	959.64	967.95		969.31	0.008220	9.86	295.10	69.95	0.69
sand creek	upper	2549	100-yr	2970.00	959.64	968.92		970.24	0.006854	9.89	366.39	77.33	0.64
sand creek	upper	2445	50-yr	2460.00	956.00	965.39	965.39	968.09	0.013647	14.09	213.57	44.30	0.90
sand creek	upper	2445	100-yr	2970.00	956.00	966.26	966.26	969.13	0.012916	14.73	254.38	49.63	0.89
sand creek	upper	2372	50-yr	2460.00	954.73	962.75	962.75	965.21	0.015515	12.76	206.71	46.92	0.94
sand creek	upper	2372	100-yr	2970.00	954.73	963.51	963.51	966.17	0.014471	13.38	243.80	50.96	0.92
sand creek	lower	2210	50-yr	2770.00	947.91	954.79	954.79	956.94	0.019847	11.75	235.83	55.28	1.00
sand creek	lower	2210	100-yr	3345.00	947.91	955.38	955.38	957.79	0.019039	12.44	269.11	57.34	1.00
sand creek	lower	2154	50-yr	2770.00	946.52	953.98		955.63	0.009216	10.63	287.64	57.14	0.75
sand creek	lower	2154	100-yr	3345.00	946.52	955.16		956.76	0.007204	10.55	357.34	61.36	0.69
sand creek	lower	2068	50-yr	2770.00	944.27	954.00		954.92	0.003888	7.88	385.32	62.70	0.50
sand creek	lower	2068	100-yr	3345.00	944.27	955.21		956.15	0.003353	8.07	463.40	66.95	0.48
sand creek	lower	2018	50-yr	2770.00	941.82	954.33		954.64	0.001085	4.59	640.58	79.23	0.27
sand creek	lower	2018	100-yr	3345.00	941.82	955.54		955.89	0.001072	4.83	739.01	83.58	0.27
sand creek	lower	1977.8	50-yr	2770.00	942.00	954.24		954.60	0.001011	5.11	644.45	81.19	0.27
sand creek	lower	1977.8	100-yr	3345.00	942.00	955.44		955.84	0.000992	5.42	744.61	85.58	0.27
sand creek	lower	1940.4	50-yr	2770.00	941.00	952.82		954.40	0.005525	10.64	309.53	45.95	0.61
sand creek	lower	1940.4	100-yr	3345.00	941.00	953.89	951.53	955.63	0.005397	11.29	360.46	49.50	0.61
sand creek	lower	1929.1	50-yr	2770.00	941.00	951.02	951.02	954.15	0.014489	15.18	219.91	38.37	0.94
sand creek	lower	1929.1	100-yr	3345.00	941.00	951.99	951.99	955.37	0.013745	15.94	258.61	41.50	0.93
sand creek	lower	1924.2	50-yr	2770.00	941.00	950.87	950.87	953.97	0.014331	15.73	226.20	39.15	0.94
sand creek	lower	1924.2	100-yr	3345.00	941.00	951.84	951.84	955.18	0.013665	16.49	265.99	42.23	0.94
sand creek	lower	1914	50-yr	2770.00	941.00	950.23	948.94	952.13	0.008207	11.36	270.35	44.82	0.71
sand creek	lower	1914	100-yr	3345.00	941.00	951.23	949.78	953.30	0.007776	11.96	316.61	47.96	0.70
sand creek	lower	1913		Bridge									

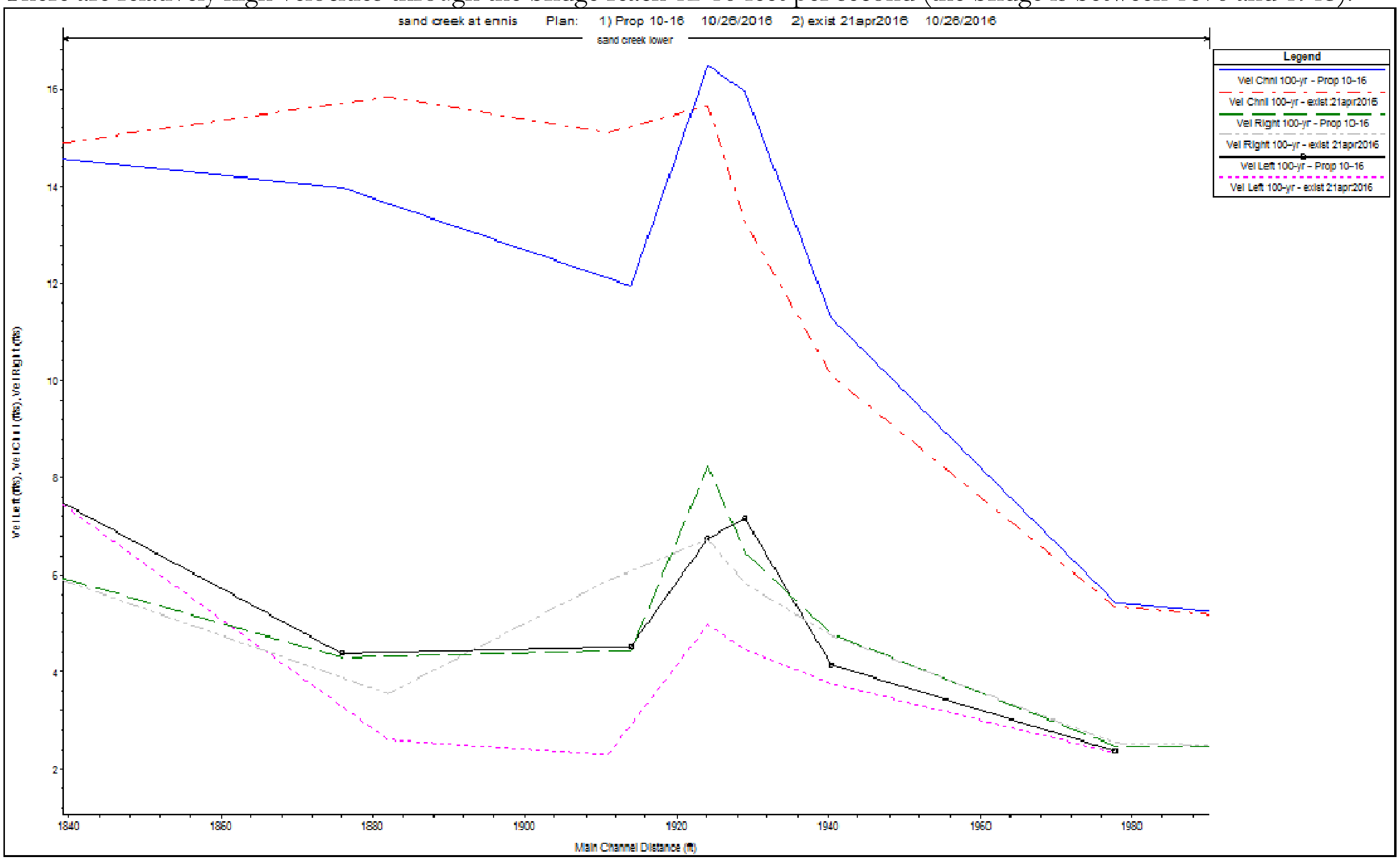
HEC-RAS Plan: Prop 10-16 (Continued)

River	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)	
sand creek	lower	1876	50-yr	2770.00	941.00	947.59	947.59	950.30	0.016668	13.29	216.54	43.65	0.97
sand creek	lower	1876	100-yr	3345.00	941.00	948.40	948.40	951.36	0.015515	13.97	252.82	46.35	0.95
sand creek	lower	1833	50-yr	2770.00	937.72	944.77	944.77	947.26	0.014948	13.89	243.64	50.92	0.97
sand creek	lower	1833	100-yr	3345.00	937.72	945.51	945.51	948.25	0.014423	14.67	282.26	53.39	0.97
sand creek	lower	1798	50-yr	2770.00	937.87	944.30	944.30	946.47	0.014883	12.92	264.29	65.01	0.95
sand creek	lower	1798	100-yr	3345.00	937.87	944.99	944.99	947.31	0.014031	13.53	310.55	69.55	0.94
sand creek	lower	1678	50-yr	2770.00	934.48	942.13	942.13	944.37	0.013463	13.99	270.14	60.59	0.93
sand creek	lower	1678	100-yr	3345.00	934.48	942.81	942.81	945.26	0.013324	14.79	312.41	64.14	0.94
sand creek	lower	1524	50-yr	2770.00	929.37	937.80		939.57	0.013628	14.72	294.29	63.21	0.93
sand creek	lower	1524	100-yr	3345.00	929.37	938.33	938.01	940.39	0.014731	15.98	328.27	65.91	0.98
sand creek	lower	1296	50-yr	2770.00	927.25	935.42	935.42	936.98	0.009226	12.38	365.79	109.56	0.78
sand creek	lower	1296	100-yr	3345.00	927.25	935.88	935.88	937.58	0.009724	13.21	417.17	112.45	0.81
sand creek	lower	1177	50-yr	2770.00	921.94	927.27	927.27	928.94	0.020045	10.60	275.24	85.26	1.00
sand creek	lower	1177	100-yr	3345.00	921.94	927.74	927.74	929.61	0.018974	11.22	315.56	86.90	1.00
sand creek	lower	1032	50-yr	2770.00	914.78	920.00	920.00	921.88	0.019967	11.00	251.89	68.24	1.01
sand creek	lower	1032	100-yr	3345.00	914.78	920.53	920.53	922.63	0.018623	11.61	288.69	70.87	1.00

There is an existing USGS stream gage (Gage #11212000) on Sand Creek downstream from the project. The gage has 38 peak discharges recorded between 1945-1997. The maximum peak discharge recorded by the gage was 3,520 cfs in January 1969. The drainage area at the gage is approximately 31.6 square miles. An area ratio calculation known as a basin transfer was performed to determine the discharge at the project site during the 1969 storm. Results of the basin transfer estimate that the flood of record at the project site is approximately 2,200 cfs which is less than a 50-yr event.



There are relatively high velocities through the bridge reach 12-16 feet per second (the bridge is between 1876 and 1913):



Based on HEC-23 (RSP) design, the rock size ends up being 3-ft or 2 ton rock or Class IX.

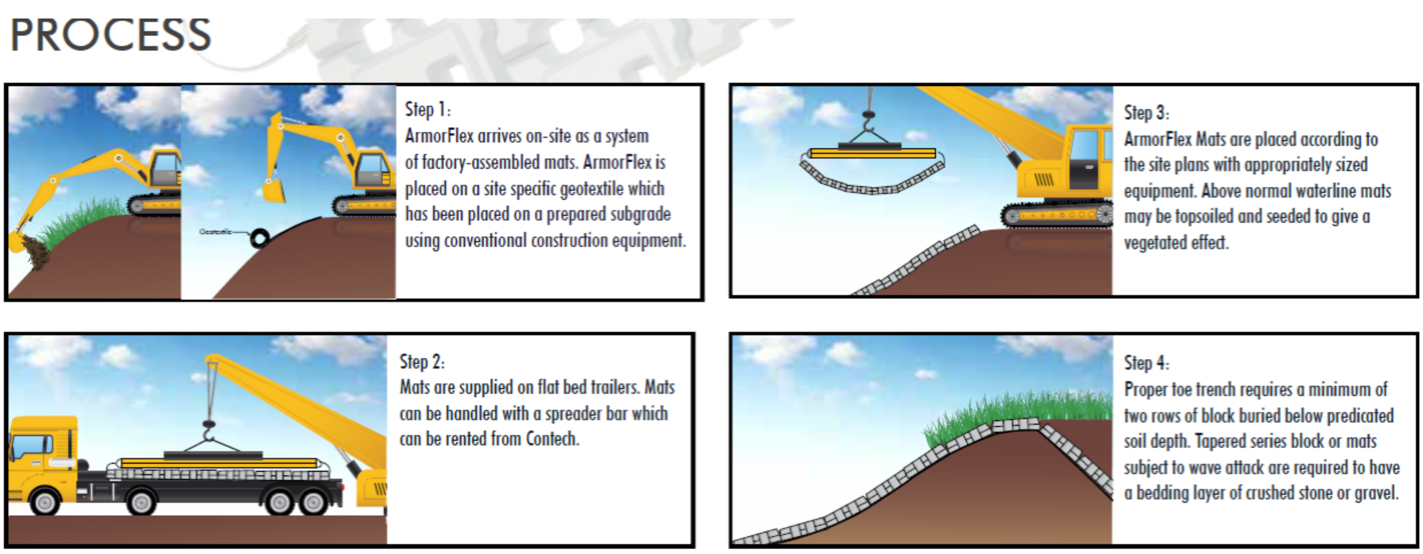
y	5.78	
K	0.89	
Ss	2.65	
V	13.3	
g	32.2	
V^2/gy	0.95	
K/(Ss-1)	3.12	
D50	2.97	feet
	35.61	inches
Rock thickness		
1.5*D50	4.5	feet
		from Table
Class	IX	4.1

Size 2 Ton

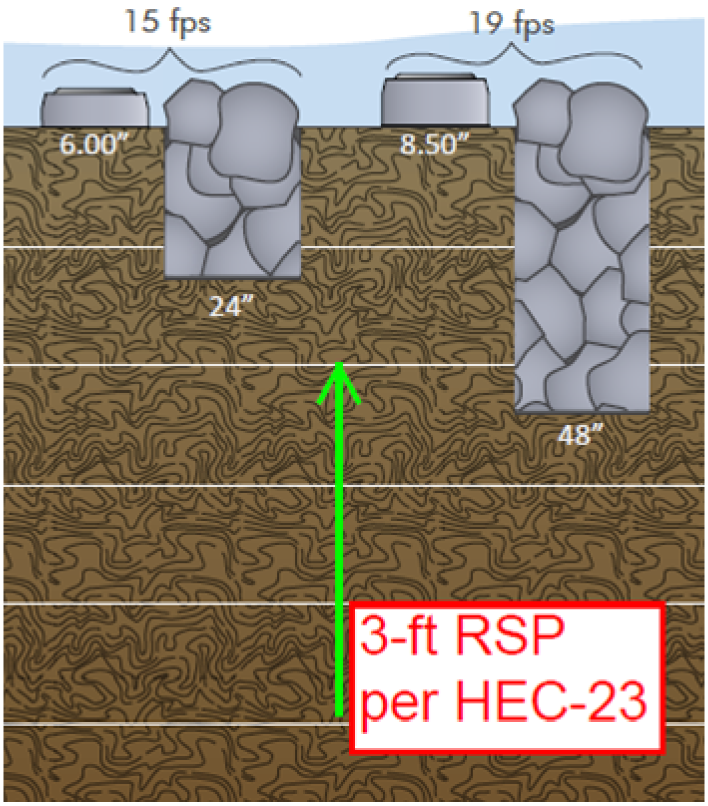
Table 4.2. Minimum and Maximum Allowable Particle Weight in Pounds.								
Nominal Riprap Class by Median Particle Weight		W_{15}		W_{50}		W_{85}		W_{100}
Class	Weight	Min	Max	Min	Max	Min	Max	Max
I	20 lb	4	12	15	27	39	64	140
II	60 lb	13	39	51	90	130	220	470
III	150 lb	32	93	120	210	310	510	1100
IV	300 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.

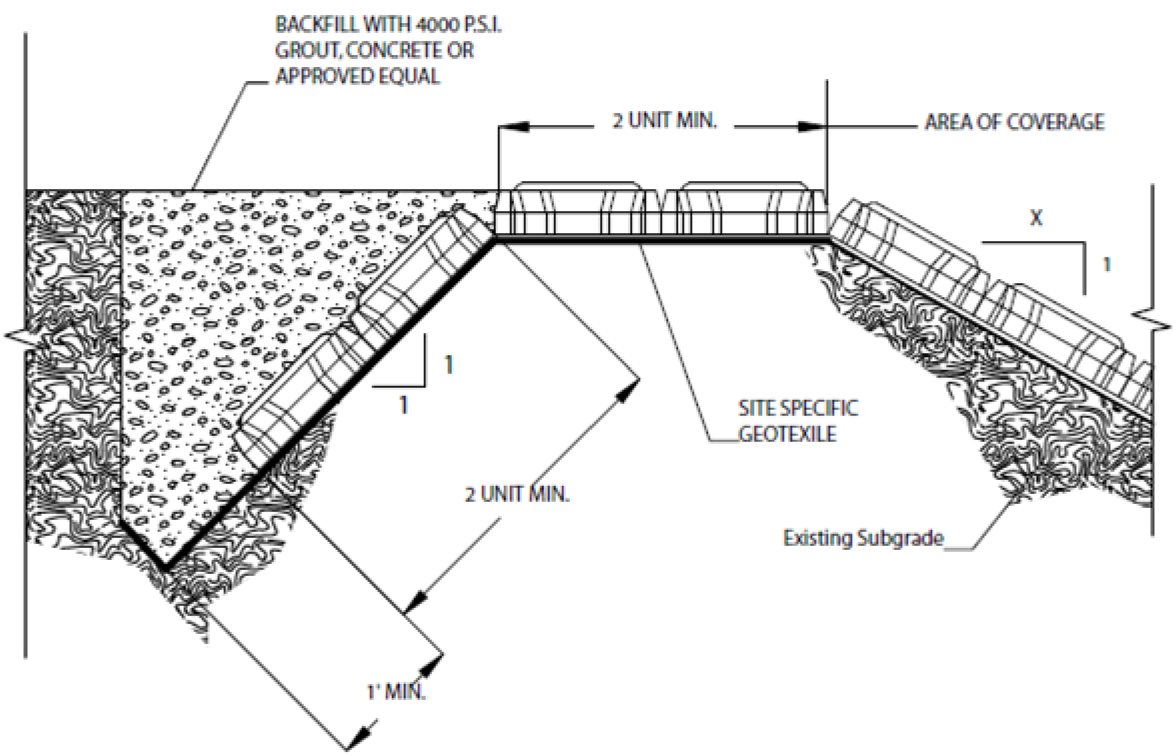
This large rock would require significant excavation and/or rock encroaching into the channel, therefore articulated concrete block is considered in lieu of classic rock slope protection as shown below:



A sizing request has been sent to Contech to provide a size for the block. Preliminary sizing was obtained from the Contech literature.. From the velocity profile above, a 8.5" block is assumed for preliminary design.



The top of slope detail is shown below.



APPENDIX F – ARTICULATED CONCRETE BLOCK TECHNICAL MEMORANDUM

Technical Memorandum

To: Sheila Amparo, PE, BKF Engineers

From: Cathy Avila, PE, Principal, Avila and Associates

Date: October 30, 2019

RE: Articulated Concrete Block (ACB) safety factor and hydraulic parameters

REGISTERED PROFESSIONAL ENGINEER
CATHERINE M.C. AVILA
No. C 048947
Exp. 09/20
CIVIL
STATE OF CALIFORNIA

The purpose of this technical memorandum is to provide the safety factor and hydraulic parameters for, Articulated Concrete Block (ACB) sizing for scour and erosion prevention at Ennis Road over Sand Creek. Articulated Concrete Block systems provide bank and channel protection as an alternative to rock riprap or concrete lining. The systems consist of performed units which interlock, are held together by cables, or both, to form a continuous block matrix.

The factor of safety method outlined in the *Hydraulic Engineering Circular (HEC) No. 23*[1] is used to determine the size of ACBs. The method for determining the ideal safety factor for ACBs is outlined in Figure 8.3 in HEC-23 Volume 2, Design Guideline 8. The safety factor is based on the ACB application, consequence of failure, and uncertainty in hydrologic/hydraulic modeling. For Ennis Road, the ACB application is bridge piers and abutments, and the hydraulic model is a deterministic model (HEC-RAS) resulting in lower uncertainty than other model types. The consequence of failure was determined to be low as the structural stability of the bridge will not depend on the ACB system. The safety factor for the protection of Ennis Road Bridge ranges from 1.5 to 2.7 (Table 1).

Since ACB systems differ between manufacturers in size, shape, and performance, each system will have unique design parameters. It is the responsibly of the ACB manufacturers to test their products and develop design parameters using the results of these tests. The relevant results from the hydraulic modeling for use by the manufacturer in sizing the ACBs for this project are included in Table 2.

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[1] Lagasse et. al. 2009. "Bridge Scour and Stream Instability Countermeasures: Experience, Selection, and Design Guidance – Third Edition" Hydraulic Engineering Circular No. 23. September.

Table 1. Safety factor determination

SF_B	Based on Application			
	1.2-1.4	Channel bed or bank		
	1.5-1.7	**Bridge pier or abutment**		
	1.8-2.0	Overtopping spillway		
X_c	Based on consequence of failure			
	1.0-1.2	**Low**		
	1.3-1.5	Medium		
	1.6-1.8	High		
	1.9-2.0	Extreme or loss of life		
X_m	Based on uncertainty in hydrologic/hydraulic modeling			
	1.0-1.3	**Deterministic (e.g. HEC-RAS, RMA-2V)**		
	1.4-1.7	Empirical or Stochastic (e.g. Manning or Rational Equation)		
	1.8-2.0	Estimates		
SF_T	Based on equation below			
	$SF_T = SF_b X_c X_m$			
SF_T	SF_B	X_c	X_m	
1.5	1.5	1.0	1.0	Low
2.7	1.7	1.2	1.3	High

Table 2. Relevant hydraulic results

Location		Upstream		Upstream Face	Downstream Face	Downstream	
River Station		**1924.2**	**1914**	**1913 BR U**	**1913 BR D**	**1876**	**1833**
Channel Discharge (cfs)	Q	2433.5	3081.1	3166.8	3199.2	3261.2	2518.7
Cross section average velocity (fps)	V_{avg}	12.6	10.6	13.3	10.6	13.2	11.9
Maximum velocity (fps)	V_{des}	16.5	12.0	14.6	11.5	14.0	14.7
Hydraulic radius (ft)	R	5.5	5.9	5.2	5.7	5.0	5.0
Maximum depth (ft)	y	10.8	10.2	8.8	8.7	7.4	7.8
Side slope	V:H	1.5V:1H	1.5V:1H	1.5V:1H	1.5V:1H	1.5V:1H	1.5V:1H
Average bed slope	S_0	0.003	0.003	0.003	0.003	0.003	0.003
Slope of energy grade line	S_f	0.013665	0.007776	0.014649	0.008193	0.015515	0.014423
Channel top width	T	42.2	48.0	43.5	50.8	46.4	53.4
Radius of curvature	R_c	530	530	530	530	530	530
R_c/T	R_c/T	12.55	11.05	12.20	10.44	11.43	9.93
Bend coefficient	K_b	1.05	1.05	1.05	1.05	1.05	1.05