THE RANCH PLAN PLANNED COMMUNITY

PLANNING AREAS 3 AND 4 RUNOFF MANAGEMENT PLAN

Michael Baker INTERNATIONAL

TECHNICAL APPENDIX O.4

Gobernadora Scour Report

Sediment Transport and Scour Analysis Report of Gobernadora Canyon for Cow Camp Road Bridge

Prepared for:

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September 2017

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Technical Appendices (CD ONLY)

1. Introduction

The following technical investigation provides a detailed and focused evaluation of the fluvial characteristics and long-term stability of Gobernadora Canyon Creek at the proposed Cow Camp Road Bridge, Rancho Mission Viejo, California. The Creek study reach is in coastal hills in southern Orange County, California. Gobernadora Canyon Creek within the study reach is from the San Juan Creek confluence to just downstream of the Gobernadora basin, within the boundary of Rancho Mission Viejo and is approximately 15,000 feet in length. The existing floodplain generally consists of a natural alluvial creek system within the larger San Juan Creek Watershed. A bridge is planned and construction of the bridge may result in changes in stream bed response. The intent of this analysis is to evaluate these impacts from (1) fluvial modification of the riverbed due to storm events, and (2) changes in the floodplain fluvial operation over the long term.

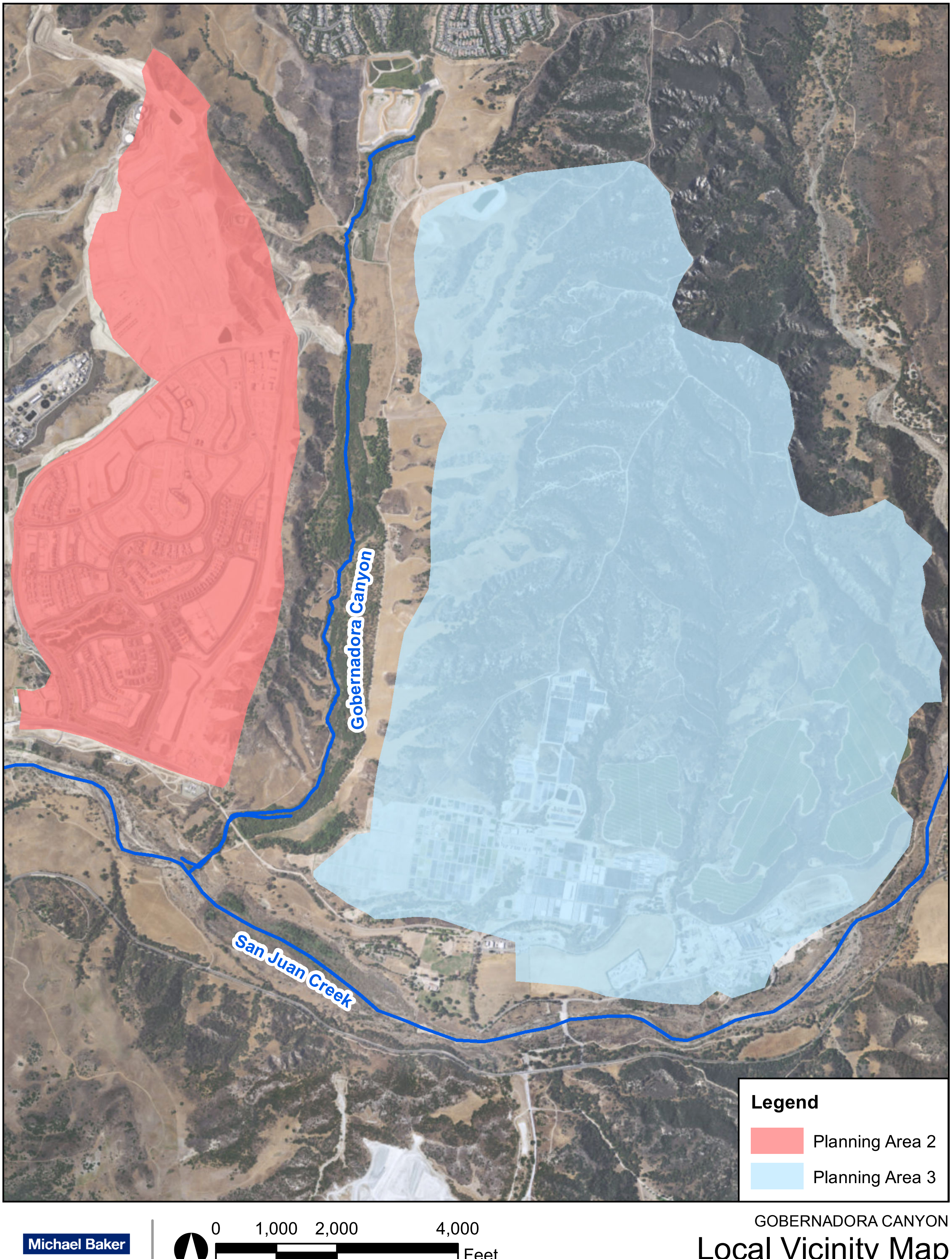
1.1. Study Location

The study portion of the Gobernadora Canyon extends from approximately 800 feet upstream from the San Juan Creek confluence to 14,000 feet upstream of the Cow Camp Road Bridge. The Cow Camp Road Bridge is located approximately 1,800 feet upstream of the San Juan Creek Confluence. The approximate total study reach length is 15,000 feet in length. The Rancho Mission Viejo Planning Area 2 (PA-2) and Planning Area 3 (PA-3) development areas are located within the unincorporated area of the County of Orange. A local vicinity map is shown on Figure 1.1. Gobernadora Canyon is a major watershed tributary which confluences with San Juan Creek within the PA-2 development area boundary. This portion of Gobernadora Canyon Creek is a natural alluvial stream system, although it has experienced a variety of human activity, including the construction of crossings and other activities that have influenced the fluvial mechanics.

1.2. Types of Scour

Modifications to the channel are measured as bed adjustments in feet. Positive adjustment indicates bed aggradation while negative adjustment indicates degradation. Several types of scour are considered in this study including general scour, long-term scour, and local scour. General scour consists of scour that occurs in an individual discharge event, and may be considered as the difference between sediment inflow and outflow. That is, if sediment inflow into a given reach is higher than sediment outflow for the same reach, aggradation will occur. In contrast, if sediment outflow exceeds inflow for a given reach, degradation in the form of scour will occur. Long-term scour is the result of fluvial processes that occur over many rainy seasons and contribute to the fluctuation of bed elevation of a river or creek. Local scour for this study is the result of pier scour. Local scour is due to an obstruction or abrupt change in the direction of flow. It is caused by an acceleration of flow, and resulting vortices due to the obstruction. Local scour occurs at bridge piers, abutments, embankments, and other structures obstructing flows. Pier scour will be assessed for this study at the proposed bridge.

Other common forms of scour measured in similar channel types and conditions are bend and contraction scour. Bend scour is associated with meandering channels which induce transverse or secondary currents which will scour sediment from the outside of a bend and cause it to be deposited along the inside of the bend. Contraction scour is general scour resulting from the acceleration of flow due to a natural channel constriction or bridge contraction. However, both bend and contraction scour are not considered for this study. This reach does not consist of sufficient bends to create the potential for bend scour. The reach also does not consist of any major natural constrictions or bridge contractions. The abutments for the proposed Cow Camp Road Bridge lie outside of the channel banks and do not restrict the channel.



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Source:

GOBERNADORA CANYON

Local Vicinity Map

Figure 1.1

2. Study Area Descriptions

2.1. Overview

This section provides basic information about characteristics of the Gobernadora study area within the study reach. The interrelated watershed, geologic, hydraulic, and hydrologic characteristics of a stream combine to determine its unique geomorphology. These types of data for this portion of Gobernadora Canyon Creek were used to define specific stream reaches for more detailed analyses.

This section provides basic information about the following characteristics of Gobernadora Canyon Creek study area:

- Watershed Description
- Geologic Setting
- Hydrologic Data
- Surface Characteristics

2.2. San Juan Creek & Gobernadora Canyon Creek Watershed Description

Gobernadora Canyon is located in southern Orange County, California and is part of the larger San Juan Creek Watershed. PA-3 discharges into Gobernadora Canyon, while PA-2 discharges into San Juan Creek. The larger San Juan Creek watershed encompasses a drainage area of approximately 176 square miles and extends from the Cleveland National Forest in the Santa Ana Mountains to the Pacific Ocean at Doheny State Beach near Dana Point Harbor. The upstream tributaries of the watershed flow out of steep canyons and widen into several alluvial floodplains.

The Gobernadora Canyon Creek watershed is bounded on the north by the Tijeras Canyon, Arroyo Trabuco and Oso Creek watershed, and on the south by the San Juan Creek watershed. The Bell Canyon watershed, which is a tributary of the San Juan Creek watershed, is adjacent to the eastern edge of the Gobernadora Canyon Creek watershed. For further details on the Gobernadora and San Juan Creek watershed see *The Ranch Plan Planned Community Planning Areas 3 and 4 Runoff Management Plan - Hydrology Submittal #2*, prepared by Michael Baker International dated May 2017.

2.3. Geologic Setting - Terrains

Terrain designations are largely based on soils, geology and topography, as these provide many of the fundamental factors that influence the hydrology and geomorphology characteristic of each terrain. Bedrock is the raw material from which soils are weathered, and, as such, it determines the size and types of particles that will comprise the soils. The resistance of different kinds of bedrock to weathering and erosion also controls the topography of the landscape within a given terrain and, therefore, influences the hydrology of the watersheds and morphology of the drainage networks. Watershed hydrology is also strongly influenced by the climatic patterns typical of Southern California.

Groundwater is present within the bridge alignment in the form of unconfined groundwater within the saturated alluvium/lake deposits. Within Gobernadora Canyon, groundwater fluctuates with season and climate, and the static groundwater level generally exists at 0-10 feet below ground surface. Based on the Seismic Hazard Zone for the Canada Gobernadora quadrangle, historic high groundwater is at the ground surface.

There are three major geomorphic terrains found within the Gobernadora Canyon Creek and San Juan Creek watershed: (a) sandy and silty-sandy; (b) clayey; and (c) crystalline.

2.4. Channel Characteristics of Specific Terrains

Sandy and silt sandy terrains are generally able to infiltrate larger volumes of water than are clayey and crystalline terrains. As a result: (a) sandy terrains play a vital role in groundwater recharge (b) undisturbed sandy terrains are typified by lower runoff rates than clayey or crystalline terrains (c) stream valleys in undisturbed sandy terrains tend to have wide floodplains and are often channel-less (d) flows tend to persist longer after storms or further into the summer within sandy watersheds, and there is a greater contrast between runoff conditions in undeveloped and urbanized watersheds in sandy terrains than in clayey or crystalline terrains.

Crystalline terrains are typified by narrow, well-defined stream valleys between steep mountainous slopes. Unlike sandy streams that are susceptible to incision, streams in crystalline areas often flow over bedrock and have stable grades. The topography, soils, and hydrography of the crystalline geomorphic terrain are all inherently controlled and influenced by the underlying bedrock.

In southern California, clayey terrains are also typified by more gentle topography than sandy or crystalline areas. Ridges tend to be lower and broader because the underlying bedrock is often more easily eroded. Clayey terrains also feature streams with well-defined channels that have evolved to handle the higher runoff rates associated with clayey slopes. Clayey terrains are generally less susceptible to many of the environmental problems that plague sandier soils.

Of the three terrains present in the Gobernadora Canyon Creek watershed, streams in sandy terrains are the most vulnerable to channel incision or channel widening associated with land use changes. The two main risks associated with development within sandy terrains are dramatically increased peak discharge and channel incision accompanied by headward erosion. To a certain extent, the two are inherently linked, and both result from the unique erosion and runoff properties of sandy watersheds. Studies have shown that urbanization in sandy watershed can result in a proportionately greater increase in storm peaks and associated alteration of downstream channel morphology than in more clayey watershed. Sandy terrains are often typified (under undisturbed conditions) by the presence of poorly defined channels along grassy, vegetated valley floors. Increased flood peaks due to urbanization can not only cause channel incision along grassy swales, but also channel incision itself further serves to increase flood peaks through enhanced conveyance. The result is an amplified cycle of erosion and downcutting that destroys floodplain interaction, increases sediment yields and the tendency for flooding downstream and significantly alters habitat.

3. Hydrology

The hydrology analyses used to study Gobernadora Canyon at Cow Camp Road Bridge were completed using the hydrology methodology described in *The Ranch Plan Planned Community Planning Areas 3 and 4 Runoff Management Plan – Hydrology Submittal #2*, prepared by Michael Baker International dated May 2017. The hydrology map used for the Gobernadora Canyon local analysis is included as Exhibit 1.

The hydrology analysis included hydrographs upstream (Nodes 133T and 132C), downstream (139), or at the confluence of Gobernadora Canyon Creek and San Juan Creek (Node 133C). An illustration of the Nodes used in the analysis can be found in Figure 9.1. The peak flows from the ultimate condition unit hydrographs at Nodes 132 and 133 were used to create the flow profile for the hydraulic model, described in the following section. The peak flows used in the hydraulic models were rounded up to the nearest hundred (4800cfs and 5300cfs). See Technical Appendix A for the unit hydrographs used in the analysis of Gobernadora Canyon.

In addition to the ultimate condition hydrology, the Gobernadora Canyon analysis also consisted of studying the long-term hydrology. This was used to determine the long-term scour for the Cow Camp Road Bridge. The existing and ultimate condition volumes and related data used to analyze the long-term hydrology can be found in Technical Appendix A. The description of the hydrology used in the long-term model can be found in Section 9 – Long Term Scour.

4. Floodplain Hydraulics Analysis

4.1. Procedure

Hydraulic modeling was performed using HEC-RAS computer modeling software developed by the U.S. Army Corps of Engineers (ACOE). HEC-RAS is a rigid boundary hydraulic model, which assumes the channel bed does not fluctuate. HEC-RAS executes a one-dimensional solution of the energy equation, where energy losses are evaluated by friction through Manning's equation and contraction/expansion based on change in velocity head. When bridges and confluences are present, the momentum equation is used to manage these situations of rapidly varying water surface profile. The "mixed flow" option is available to accommodate the potential for subcritical and supercritical flow regimes within the model.

A detailed water surface profile model was developed to analyze the hydraulics representative of the "baseline" floodplain for the natural river system. The hydraulic model provides an accurate estimate of the actual flow depths and variation of different hydraulic parameters for a specific flowrate or steady state conditions using basic hydraulic principles. The hydraulic model is useful in assessing the changes within the floodplain that reflect different sets of conditions, allowing for quantification of the impacts. Using channel cross-section data, the hydraulic analysis can be performed for several discharges corresponding to various recurrence intervals. Boundary conditions for the design 100-year discharge are entered to initiate hydraulic calculations. The channel cross-section data is first obtained from existing topography for the project site at approximately 100 foot intervals within the study reach. A Manning's roughness coefficient is then applied to the study reach and a discharge selected for analysis. Boundary conditions for the design 100-year discharge are entered to initiate hydraulic calculations. Finally, the model is computed based on a specified flow regime.

The objectives of the HEC-RAS hydraulic analyses for the study area were to provide basic hydraulic data for use in the sediment transport analysis. The basic hydraulic data developed for use in the engineering analyses were generated from the results of the HEC-RAS, which allowed generation of the general channel characteristic hydraulic parameters and provides a general understanding of the trends. Figure 4.2 illustrates a detailed view of the project site for which the hydraulic results were analyzed.

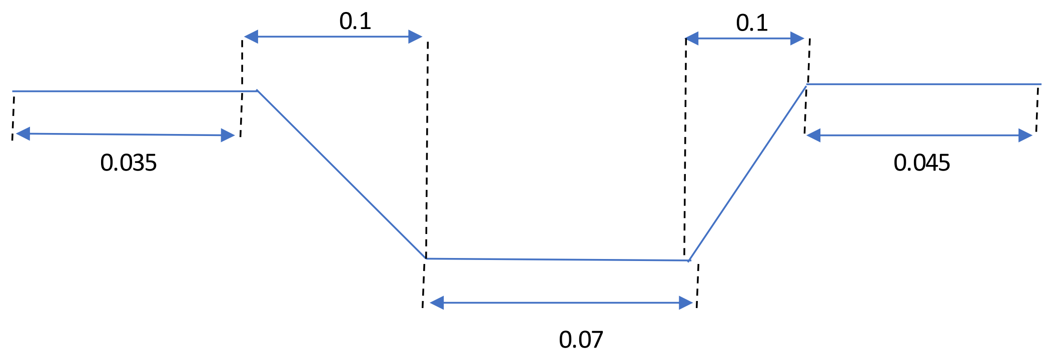
4.2. Parameters

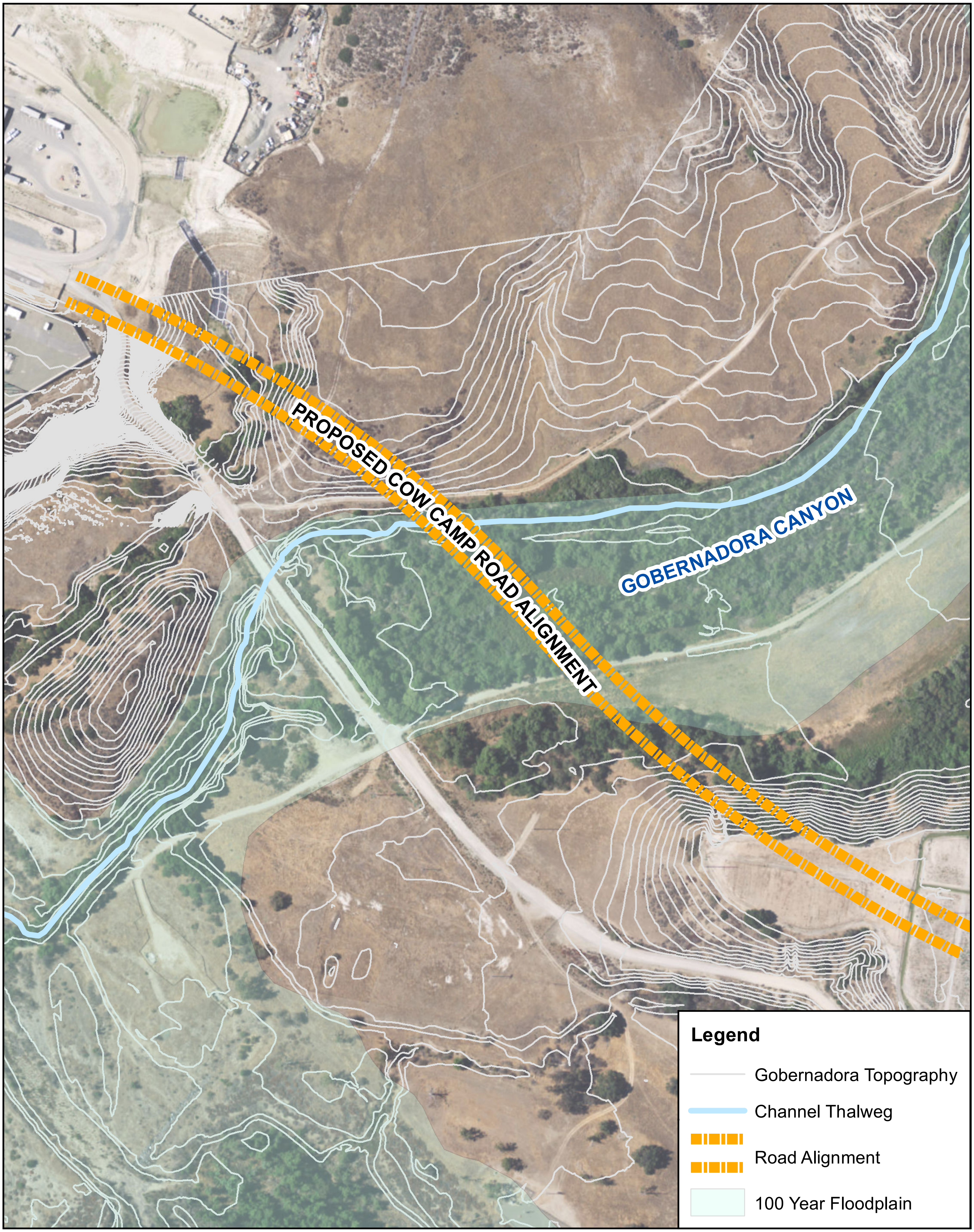
The following guidelines and assumptions were used to develop the various hydraulic analysis with the HEC-RAS model:

- Design Flow: The design flow used for the hydraulic analysis of the channel is the 100-year high confidence discharge.
- Channel Cross-Section Data: The channel geometric data was obtained from existing topography for the project site. Modifications were made to represent improvements in the proposed condition.
- Channel Roughness: The manning coefficients used in the hydraulic analysis were determined based on the field observation and aerial photography. The roughness values range from 0.035 to 0.07 within the cross section depending on the type of vegetation at the cross-section location. A typical section roughness coefficient variation can be seen on Figure 4.1.

- Flow Data: The high confidence 100-year peak discharge of this study was obtained from the hydrology study conducted by Michael Baker International for PA 3 & 4.
- Boundary Conditions: The model utilizes a normal depth water surface elevation based on the slope of 0.0001 as the downstream boundary condition to initiate the hydraulic calculations.

Figure 4.1: Cross Section – Typical Roughness Coefficient Variation





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GOBERNADORA CANYON

Project Site

Figure 4.2

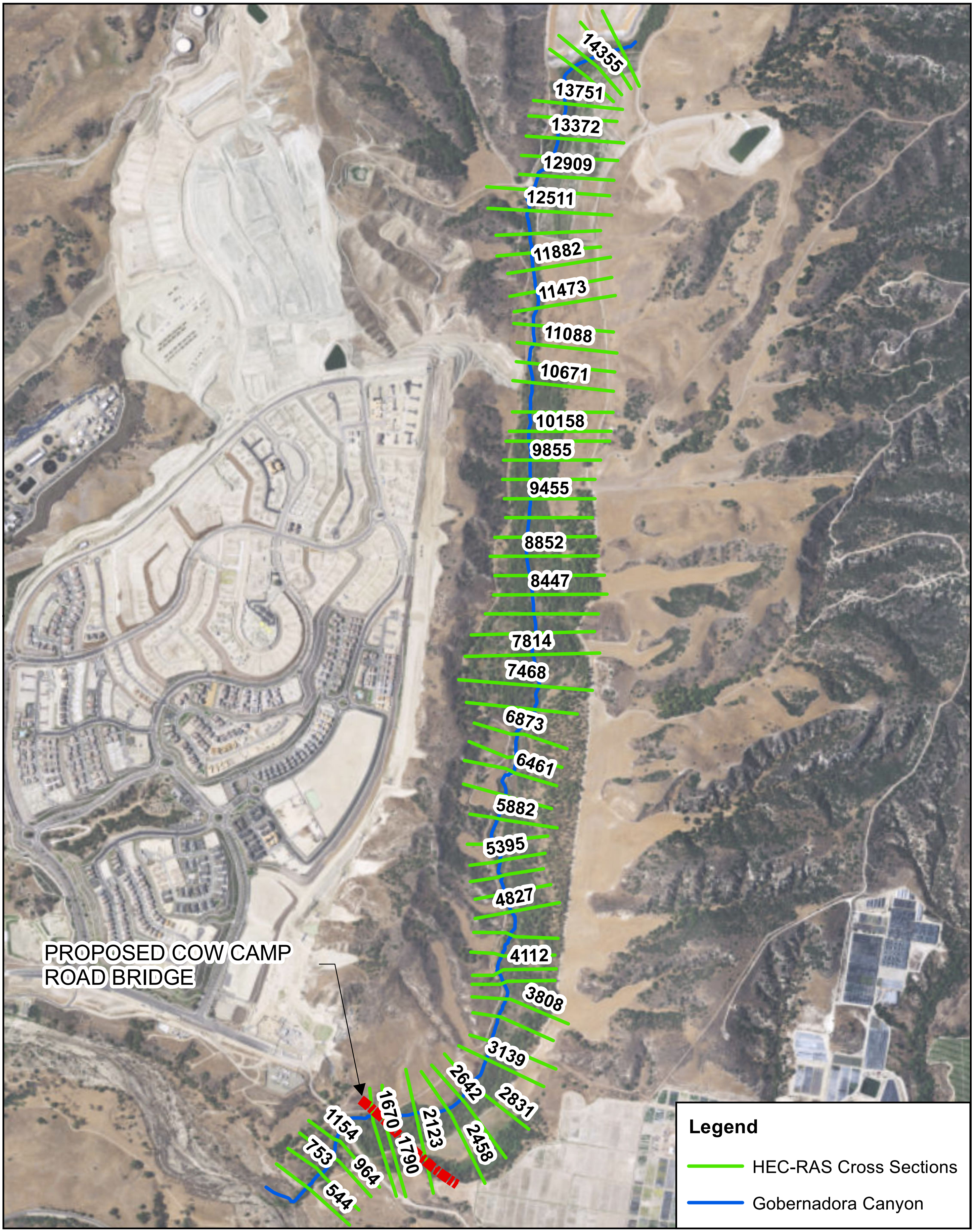
4.3. Existing Condition Analysis

The main purpose of the existing condition analysis is to serve as a basis of comparison for the post-development analysis. The existing condition analysis shows that flow depths for the 100-year event range from 1.6 to 19.1 feet and channel velocity ranges from 1.4 to 16 fps. The existing condition cross sections used in the HEC-RAS model are shown in Figure 4.3. The depth and velocities can be found in Table 4.1. The complete hydraulic results for the existing condition analysis is presented in Technical Appendix B.1.

4.4. Project Condition Analysis

The project condition model differs from the existing condition model in that the project condition model includes the proposed bridges. The project condition analysis shows that flow depth for the 100-year event range from 1.5 to 19.1 feet and channel velocity ranges from 1.5 to 16.8 fps. The project condition increases the depth of flow at the location of the proposed bridge by approximately 0.7 feet and the velocity at the location of the proposed bridge increases by approximately 3 ft/s. The project condition cross sections used in the HEC-RAS are shown in Figure 4.4. The depth and velocities can be found in Table 4.2. The complete hydraulic results for the project condition analysis is presented in Technical Appendix B.2.

See Section 6 – Bridge Hydraulics for a discussion of hydraulic impacts in the channel as a result of the bridge construction.



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0 500 1,000 2,000 Feet

Source:

GOBERNADORA CANYON

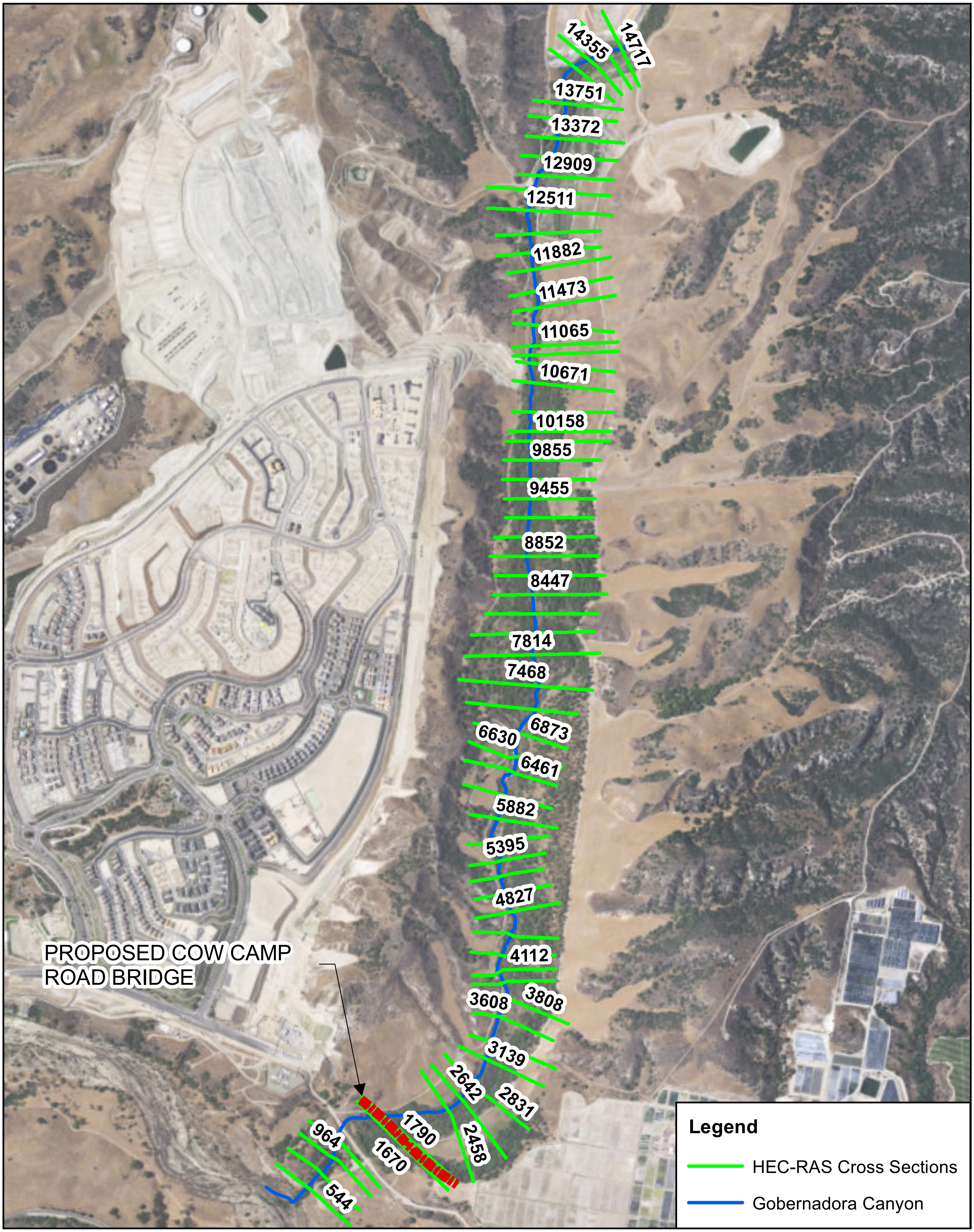
Existing Condition HEC-RAS Cross Sections

Figure 4.3

Table 4.1: Existing Condition Hydraulic Summary Table

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Max Chl Dpth	Vel Chnl
			(cfs)	(ft)	(ft)	(ft)	(ft/s)
GOB_CL	14717	100YR-HC	4800	396	399.66	3.66	3.7
GOB_CL	14552	100YR-HC	4800	395	398.54	3.54	3.51
GOB_CL	14355	100YR-HC	4800	393	396.41	3.41	5.06
GOB_CL	14183	100YR-HC	4800	392	394.99	2.99	4.57
GOB_CL	13751	100YR-HC	4800	389	392.22	3.22	4.71
GOB_CL	13595	100YR-HC	4800	388	390.75	3.39	4.55
GOB_CL	13372	100YR-HC	4800	385	387.39	2.39	6
GOB_CL	13169	100YR-HC	4800	383	385.93	2.93	4.01
GOB_CL	12909	100YR-HC	4800	380.02	383.16	3.14	6.78
GOB_CL	12745	100YR-HC	4800	378.11	381.67	3.56	1.99
GOB_CL	12511	100YR-HC	4800	375.02	380.94	5.92	4.94
GOB_CL	12255	100YR-HC	4800	370.02	377.14	7.12	6
GOB_CL	12055	100YR-HC	4800	369.22	375.75	6.53	3.74
GOB_CL	11882	100YR-HC	4800	369.33	374.73	5.4	4.19
GOB_CL	11652	100YR-HC	4800	368	373.28	5.28	4.08
GOB_CL	11473	100YR-HC	4800	367	370.98	3.98	6
GOB_CL	11289	100YR-HC	4800	365	369.16	4.16	3.66
GOB_CL	11088	100YR-HC	4800	364	368.38	4.38	2.92
GOB_CL	10881	100YR-HC	4800	363	367.06	4.06	4.69
GOB_CL	10671	100YR-HC	4800	361.03	365.58	4.55	2.51
GOB_CL	10362	100YR-HC	4800	359.38	363.69	4.31	3.07
GOB_CL	10057	100YR-HC	4800	356	360.81	4.81	3.54
GOB_CL	9855	100YR-HC	4800	354.97	359.86	4.89	2.25
GOB_CL	9655	100YR-HC	4800	354	358.92	4.92	3.04
GOB_CL	9455	100YR-HC	4800	353	357.49	4.49	3.21
GOB_CL	9254	100YR-HC	4800	351.95	355.93	3.98	3.43
GOB_CL	9053	100YR-HC	4800	349.87	352.95	3.08	4.18
GOB_CL	8852	100YR-HC	4800	347	350.28	3.28	2.85
GOB_CL	8649	100YR-HC	4800	345.33	348.54	3.21	2.46
GOB_CL	8447	100YR-HC	4800	343.94	347.07	3.13	2.24
GOB_CL	8246	100YR-HC	4800	342.62	344.88	2.26	3.47
GOB_CL	8045	100YR-HC	4800	339	343.09	4.09	2.39
GOB_CL	7814	100YR-HC	4800	337.96	340.38	2.42	3.65
GOB_CL	7468	100YR-HC	4800	326	333.15	7.15	7.21
GOB_CL	7208	100YR-HC	4800	320.6	328.42	7.82	11.58
GOB_CL	6873	100YR-HC	5300	311	320.32	9.32	7.39
GOB_CL	6630	100YR-HC	5300	307.98	319.37	11.39	7.49

GOB_CL	6461	100YR-HC	5300	303	315.62	12.62	14.11
GOB_CL	6136	100YR-HC	5300	295	306.8	11.8	6.25
GOB_CL	5882	100YR-HC	5300	290	301.5	11.5	13.37
GOB_CL	5620	100YR-HC	5300	287.31	299.28	11.97	7.18
GOB_CL	5395	100YR-HC	5300	285	296.9	11.9	8.57
GOB_CL	5223	100YR-HC	5300	282.64	295.65	13.01	7.21
GOB_CL	5031	100YR-HC	5300	280	291.23	11.23	12.78
GOB_CL	4827	100YR-HC	5300	277.83	289.36	11.53	8.46
GOB_CL	4561	100YR-HC	5300	275	287.24	12.24	8.17
GOB_CL	4307	100YR-HC	5300	272.17	285.88	13.71	7.68
GOB_CL	4112	100YR-HC	5300	270	282.98	12.98	10.51
GOB_CL	3990	100YR-HC	5300	268.79	280.67	11.88	10.47
GOB_CL	3808	100YR-HC	5300	268.2	278.18	9.98	11.51
GOB_CL	3608	100YR-HC	5300	265	274.18	9.18	12.78
GOB_CL	3336	100YR-HC	5300	260	267.55	7.55	16
GOB_CL	3139	100YR-HC	5300	259.12	264.43	5.31	6.2
GOB_CL	2831	100YR-HC	5300	257.74	260.9	3.16	5.46
GOB_CL	2642	100YR-HC	5300	255	256.62	1.62	4.6
GOB_CL	2458	100YR-HC	5300	253.46	254.74	3.27	1.54
GOB_CL	2123	100YR-HC	5300	250	251.53	2.51	4.87
GOB_CL	1790	100YR-HC	5300	245	248.66	3.66	2.61
GOB_CL	1780	100YR-HC	5300	245	248.6	3.6	2.65
GOB_CL	1670	100YR-HC	5300	245	247.11	2.11	4.75
GOB_CL	1154	100YR-HC	5300	224.55	236.01	11.46	9.16
GOB_CL	964	100YR-HC	5300	220	234.71	14.71	6.34
GOB_CL	753	100YR-HC	5300	217.49	233.92	16.43	4.95
GOB_CL	544	100YR-HC	5300	215	234.11	19.11	1.48



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Source:

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Project Condition HEC-RAS Cross Sections

Figure 4.4

Table 4.2: Proposed Condition Hydraulics Summary Table

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Max Chl Dpth	Vel Chnl
			(cfs)	(ft)	(ft)	(ft)	(ft/s)
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GOB_CL	12745	100YR-HC	4800	378.11	381.69	3.58	1.98
GOB_CL	12511	100YR-HC	4800	375.02	380.7	5.68	6.12
GOB_CL	12255	100YR-HC	4800	370.02	377.55	7.53	4.53
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GOB_CL	4307	100YR-HC	5300	272.17	286.01	13.84	7.49
GOB_CL	4112	100YR-HC	5300	270	283.65	13.65	9.44
GOB_CL	3990	100YR-HC	5300	268.79	278.93	10.14	13.58
GOB_CL	3808	100YR-HC	5300	266.99	277.57	10.58	9.25
GOB_CL	3608	100YR-HC	5300	265	274.55	9.55	11.54
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GOB_CL	3139	100YR-HC	5300	259.12	264.38	5.26	6.3
GOB_CL	2831	100YR-HC	5300	257.74	260.98	3.24	5.18
GOB_CL	2642	100YR-HC	5300	255	256.53	1.53	4.91
GOB_CL	2458	100YR-HC	5300	253.46	256.07	4.6	1.52
GOB_CL	2123	100YR-HC	5300	253.46	254.42	2.82	3.21
GOB_CL	1790	100YR-HC	5300	245	249.42	4.42	5.23
GOB_CL	1780 CCR BR US	100YR-HC	5300	245	249.29	4.29	5.65
GOB_CL	1780 CCR BR DS	100YR-HC	5300	245	247.76	2.76	4.93
GOB_CL	1670	100YR-HC	5300	245	247.48	2.48	5.68
GOB_CL	1154	100YR-HC	5300	224.55	236.01	11.46	9.16
GOB_CL	964	100YR-HC	5300	220	234.71	14.71	6.34
GOB_CL	753	100YR-HC	5300	217.49	233.92	16.43	4.95
GOB_CL	544	100YR-HC	5300	215	234.11	19.11	1.48

5. Bridge Descriptions

5.1. Existing Condition

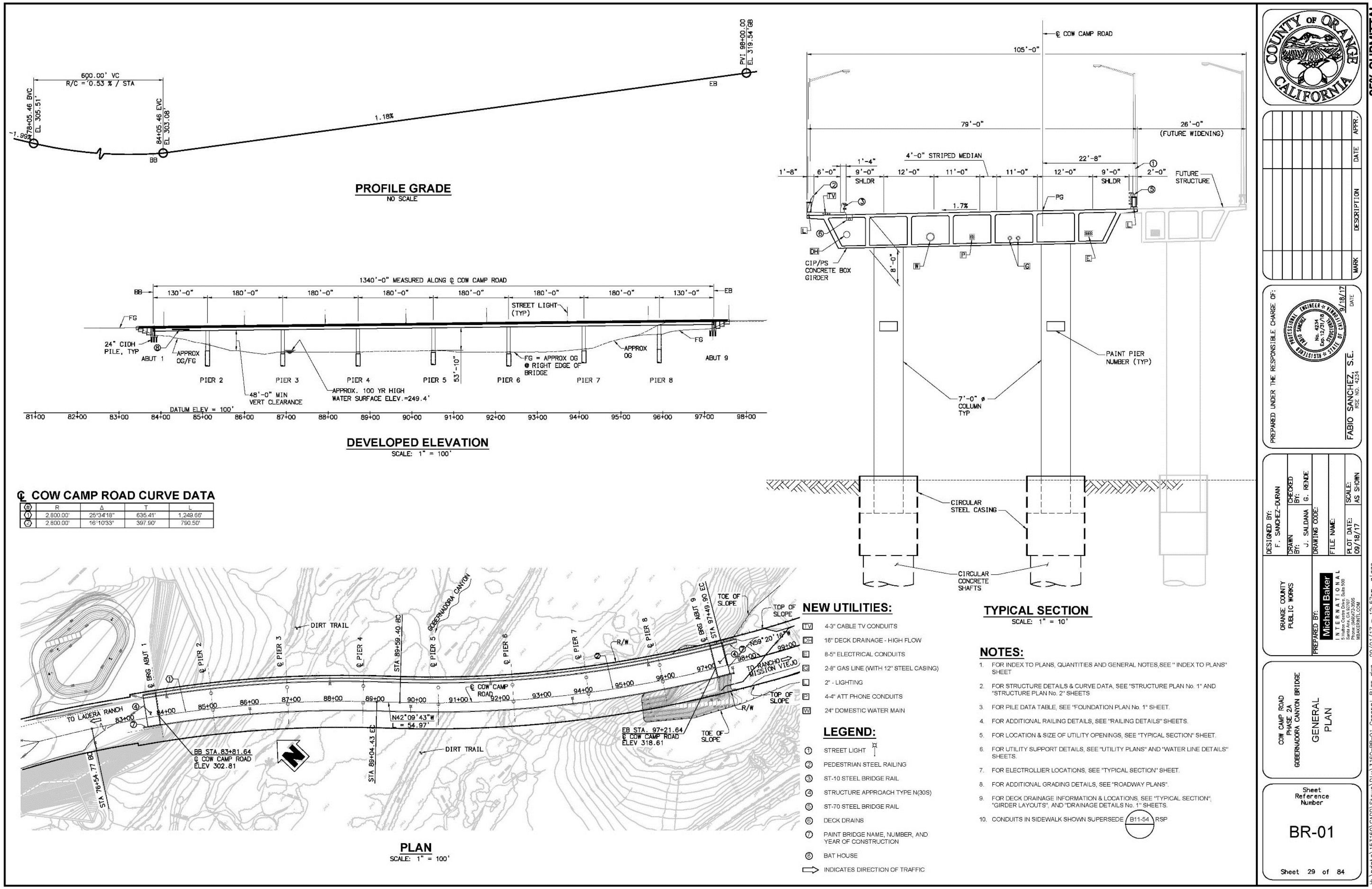
There is no existing crossing at the site of the proposed Cow Camp Road Bridge crossing. However, a section has been added to the existing condition analysis for comparison to the proposed condition.

5.2. Proposed Condition

The Cow Camp Road Bridge over Gobernadora Canyon is proposed to be a twin-bridge, multiple-pier, cast-in-place pre-stressed concrete box girder design that traverses Gobernadora Canyon Creek at Cow Camp Road. The proposed bridge is approximately 1,340 feet long with 79 feet width. After the projected widening during Phase 2, the bridge will have a total width of 105 feet. The bridge will consist of 8 spans – two end spans of 130 feet and six main spans of 180 feet. The abutments will be high cantilever type and will be supported on Cast-In-Drilled Hole (CIDH) concrete piles. The bents will have two 7-foot diameter columns for Phase 1 and an additional 7-foot diameter column for the construction of Phase 2. The total number of piers along the length of the bridge is 14 at the completion of Phase 1 and at the completion of the project widening, the total number of piers will be 21 at the completion of Phase 2. Figure 5.1 illustrates the general plan for the proposed bridge.

As shown in Figure 5.1, the length of the proposed bridge extends past Gobernadora Canyon on both sides of the channel bank. Therefore, through hydraulic analysis outlined in the following section it is determined that abutments 1 and 10, and piers 2 and 8 lie outside of the 100-year floodplain.

Figure 5.1: Cow Camp Road Bridge General Plan



6. Bridge Hydraulics

6.1. Modeling

The bridge routines in HEC-RAS allow the modeler to analyze a bridge with several different methods. The bridge routines can model low flow, combined low and weir flow, pressure flow, and submerged flow. HEC-RAS computes the energy losses at bridges in three steps. First, losses downstream of the bridge are calculated at the expansion in the flow. Next, the losses associated with the structure are calculated, and finally losses occurring upstream of the bridge are determined. A brief description follows.

Bridge routines use four cross sections in the computation of energy loss at structures. The first section is located downstream from the structure such that flow is not impacted by the presence of the structure. The second section is located a short distance downstream from the bridge. Sections three and four are similarly situated to section two and one, respectively, except they are upstream of the bridge. The two additional sections created by the model are a combination of sections two and three and the bridge geometry, including the deck, abutments, and piers. The two additional sections are assumed to be just inside the limits of the bridge width. Losses due to contraction and expansion of flow are determined using step-profile calculations. Manning's equation is used to determine friction losses, and other losses are described as a function of a coefficient times the change in velocity head between adjacent sections. For sections where the head decreases in the downstream direction an expansion coefficient is used.

6.2. Results

At the proposed location of the Cow Camp Road Bridge, the depth of flow is 3.7 feet and the flow velocity is 2.61 fps for the existing condition (*see XS 1780 in Figure 4.3*). In the project condition, the depth of flow is 4.3 feet and the flow velocity is 5.7 fps (*see XS 1780 in Figure 4.4*). Just downstream of the proposed bridge in the project condition, the depth of flow is 2.5 feet and velocity is 5.7 fps (*see XS 1670 in Figure 4.4*). The complete hydraulic results for both existing and project conditions can be found in Technical Appendix B.

The existing condition results were used for the purposes of determining long term scour of the entire Gobernadora Canyon reach. The project condition results were used to determine local pier scour at the proposed bridge.

6.3. Discussion of Results

Table 6.1 below provides a comparison of depths and velocities in the vicinity of the bridge between the existing and proposed condition. Cross sections approximately 500-1000 feet upstream and downstream of the bridge have been analyzed in the table.

Table 6.1: Hydraulics Comparison Table

CROSS SECTIONS	DEPTH (Feet)			VELOCITY (Ft/s)		
	EXIST	PROP	DELTA	EXIST	PROP	DELTA
3139	5.3	5.3	***0***	6.3	6.3	***0***
2831	3.16	3.24	***0.08***	5.46	5.18	***-0.28***
2642	1.62	1.53	***-0.09***	4.6	4.91	***0.31***
2458	3.27	4.6	***1.33***	1.54	1.52	***-0.02***
2123	2.51	2.82	***0.31***	4.87	3.21	***-1.66***
1790	3.66	4.42	***0.76***	2.61	5.23	***2.62***
Cow Camp Road Bridge 1780	3.6	4.29	***0.69***	2.65	5.65	***3***
1670	2.11	2.48	***0.37***	4.75	5.68	***0.93***
1154	11.46	11.46	***0***	9.16	9.16	***0***

As seen in Table 6.1, at the location of the proposed bridge there is a general increase in both depth and velocity between the existing and proposed conditions. Considering the entirety of Gobernadora Canyon, these localized increases at the bridge do not adversely impact the channel. The increases in water depths compared to the width of the channel (approximately 200ft at the bridge) and heights of the banks (approximately 60ft from the lowest elevation of the channel at the bridge) do not result in any overtopping of flows in the channel. The increases in velocity are taken into consideration in the pier scour calculations (See Section 10), therefore no additional design implementations are needed to address these increases. Overall, the construction of Cow Camp Road Bridge will not result in significant impacts to the depths or velocity of Gobernadora Canyon at the proposed location of the bridge.

7. Sediment Characterization Analysis

7.1. Sediment Data Collection

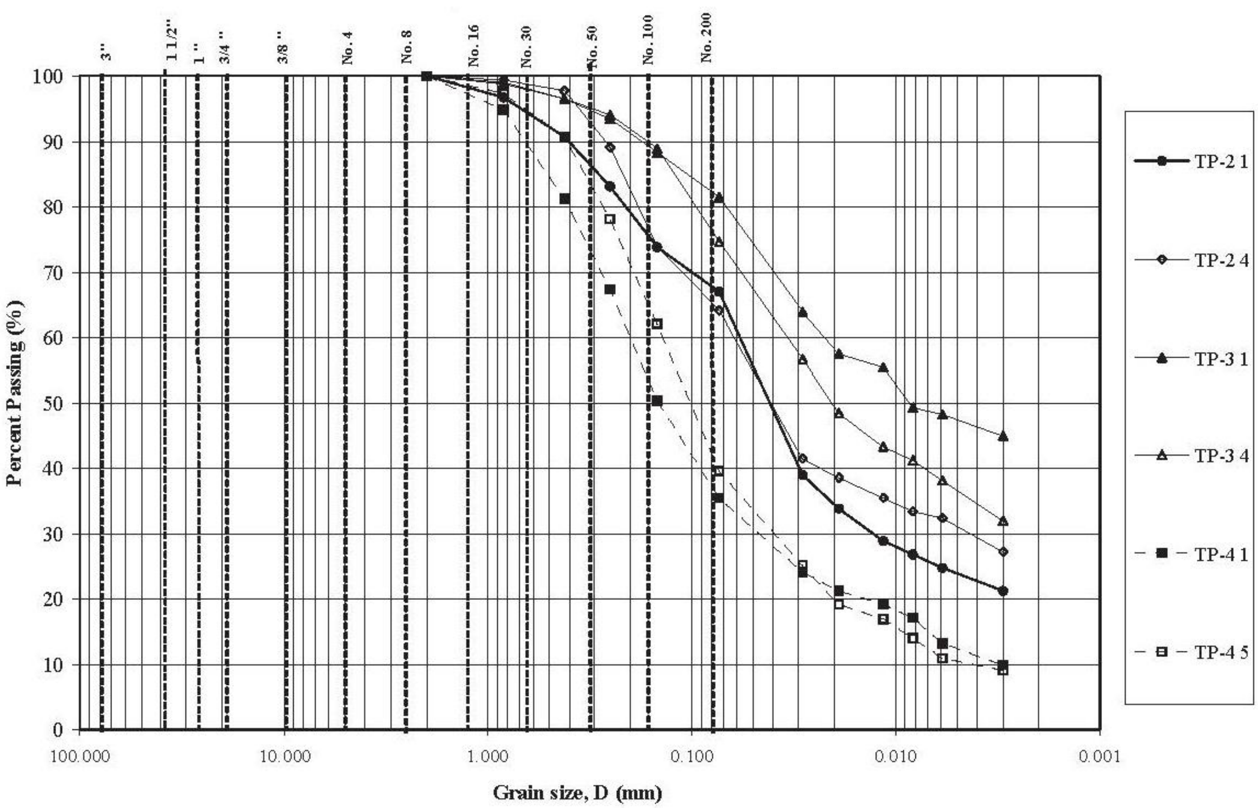
To characterize the sediment of the creek bed and by extension the possible bed load of sediment during discharge events, a sediment grain size analysis was conducted. The goal of the analysis is to gain a statistical representation of the size distribution of soil components of the creek bed. Grain size distribution analysis is a powerful tool because the results can represent both a qualitative description of soil make up as well as quantitative input for further predictive measures, such as fluvial modeling.

High quality sediment collection for the Gobernadora Canyon Creek along the study reach was conducted by GMU Geotechnical, Inc. Two studies from GMU (one conducted in 2006 and one in 2016) were used to properly characterize the soil.

7.2. Sediment Gradation Analysis

Sediment distributions are plotted on semi-log plots by percent finer for a given sample size. For this study, no fine material is included in analysis because fine material is generally transported as wash load, which is not of concern here. The distribution data used for the sediment and scour analysis of this study is an average of various samples. The samples are a result of data collection conducted by GMU along Gobernadora Canyon in their 2006 study. The raw grain size distribution can be found in Figure 7.1 below.

Figure 7.1: Raw Grain Size Distribution



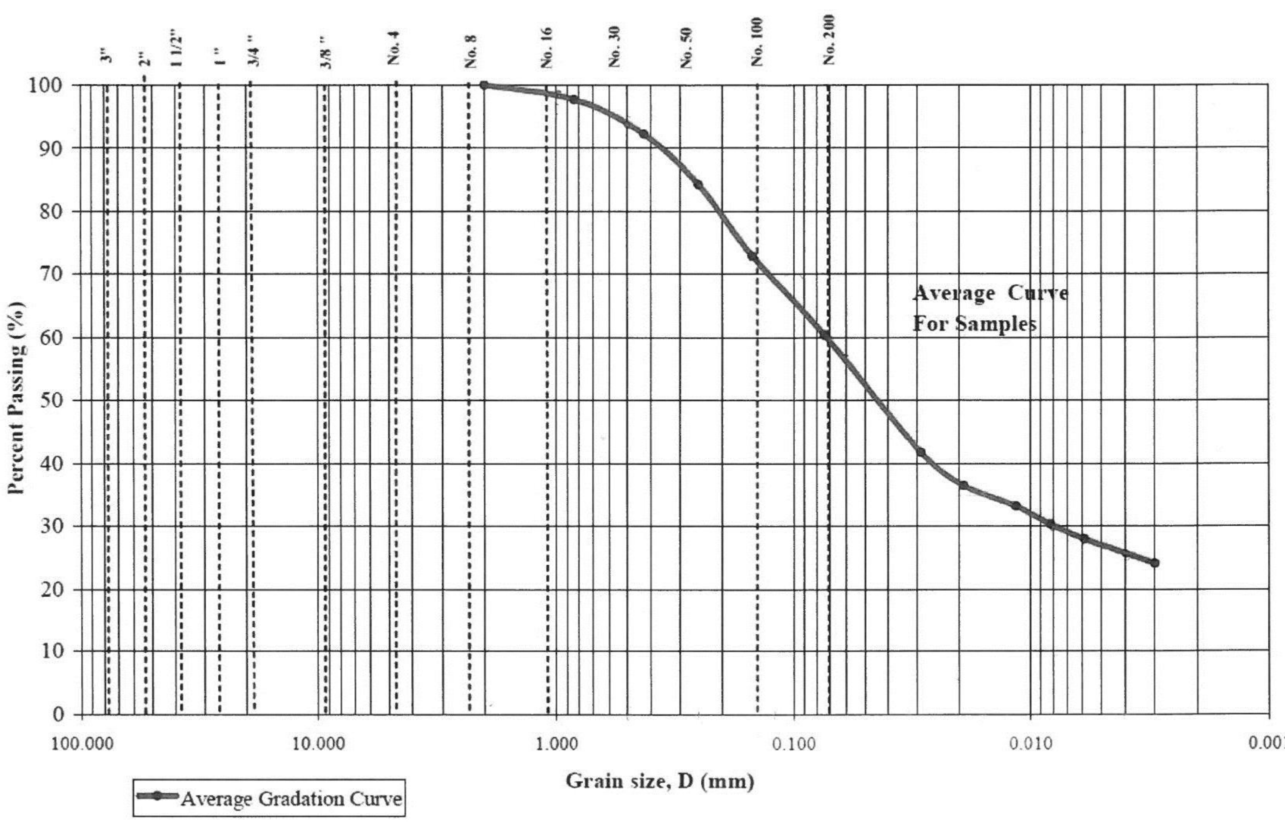
Averaging provides a single representative sediment grain size distribution that can be used for numerical modeling or other analysis. Using the raw grain size data, an average distribution was determined for various sieve diameters. See Table 7.1 and Figure 7.2 below for the resulting average grain size distribution and curve.

The resulting average grain size distribution is used to run the long-term analysis in HEC 6, discussed in the section 8. The 2016 grain size distribution conducted specifically for Cow Camp Road Bridge is used to determine the D_{50} (0.149mm) and D_{84} (0.195mm) diameter sizes for the pier scour calculations described in Section 10. The bridge grain size distribution pier scour calculations can be found in Technical Appendix D.

Table 7.1: Average Grain Size Distribution

Sieve Size	Grain Size (Diameter in mm)	Percent Passing (%)
3/8"	9.5	100
No.4	4.75	100
No. 10	2	100
No. 20	0.841	97
No. 40	0.425	93
No. 60	0.25	84
No. 100	0.15	72
No. 200	0.075	60

Figure 7.2: Average Gradation Curve



8. HEC6-T Sediment Transport Model

A stream stability analysis was performed to evaluate the hydrologic (peak discharge, runoff volume, flow duration) and geomorphic (coarse sediment production and delivery) impacts of planned development and the effectiveness of proposed mitigation as it relates to the event-based and long-term streambed behavior of Canada Gobernadora and San Juan Creek.

The methods, procedures, and applications used to evaluate the streambed stability of Canada Gobernadora and San Juan Creek are generally intended for inspection-level planning studies. The calculations performed were static in nature as no dynamic or quasi-dynamic model simulation was developed and implemented; instead, sediment transport rates were computed based on single cross sections, each representative of a designated subreach, at a single point in time. The sediment transport yield for an event was determined for each cross section based on the product summation of ordinate sediment transport rates and the ordinate time interval.

The Army Corps of Engineers HEC-6 model is a one-dimensional, moveable bed, open channel hydraulic and sediment model. The model was designed to simulate change in riverbed profiles resulting from sediment, scour and deposition over long periods of time. The model segments hydrography data into a progression of steady flow events with varied discharge and duration. Every segment of flow is used to calculate a water surface profile and associated hydraulic parameters (e.g. velocity, depth, etc.). From the hydraulic parameters, potential sediment transport rates are estimated for each model reach and scour or deposition is estimated so that cross-section shape can be updated. Sediment calculations are based on grain size distribution. HEC-6 considers the interactions between sediment behavior in rivers with local hydraulics and bed geometry and conditions.

8.1. HEC-6 Model Theory and Limitations

Capability of a river to transport sediment in the model is based on yield from upstream locations. Computation of transport is partitioned into bed and suspended load after Einstein (1950). This assumes that the reach transports the same types of materials as those which comprise the bed (an alluvial reach), and thus reflects a record of the past and present sediment transport. Transport is constrained to the limits of the wetted perimeter.

A one-dimensional energy approximation to the equations of motion is used for hydraulic calculations in HEC-6. Manning's equation is utilized to incorporate the effects of bed friction. The model also uses both an up- and downstream boundary condition with internal conditions optional. Flow conveyance, levee flow containment and ineffective flow are modeled in a manner similar to the Army Corps' HEC-2 model. Supercritical flow is approximated by normal depth and sediment transport is calculated using this criterion. Because the model is one-dimensional, meander development or lateral erosion cannot be simulated. These adjustments can be estimated outside the model using engineering judgement and additional analysis.

Each cross-section represents a sediment control volume and sediment continuity equations are evaluated for this volume. The only two sediment sources that are considered by HEC-6 are the bed (sediment control volume) and sediment in the inflowing water. Only vertical adjustment of the bed is considered and is calculated through sediment continuity using iterations of the Exner equation. Krone's method (1962) is used for deposition of fines in HEC-6, and the method of

Ariathurai and Krone (1976) is used for scour. Colby's method (1964) is used to adjust transport potential for high wash loads and armoring is simulated using Gessler's method (1970). Sediment boundary conditions operate such that inflowing sediment load is a function of inflow discharge. The total sediment discharge at each section, as well as the volume of deposition or scour at each section, is computed for all time steps.

The "T" enhancement of the HEC-6 program, created by Mobile Boundary Hydraulics, is used in this study. Fundamental differences between the "T" and standard versions of the model are minimal and are described in the HEC-6T user's manual. Additional details describing model numerics are described in the HEC-6 user's manual.

8.2. Sediment Input Data and Selection of Transport Functions

Representation of sediment grain size distribution in HEC-6 takes the form of percent finer data obtained from sieve analysis of channel sediment grab samples. The average data is input into the model. All sampling and sieve analysis was conducted by GMU Geotechnical, Inc. Data used is described previously in Section 7. HEC-6 gradation classifications use the American Geophysical Union Scale. The transport function is selected using the U.S. Army Corps of Engineer's (USCOE) SAM's SAM.AID function.

Due to sediment characterization and the amount of clay in the study reach, sensitivity analysis was run by creating several models with various particle distribution. Three main models were created: (1) model with sandy soils lowest percent finer, (2) model with clay, and (3) model with the average particle distribution. This analysis helped determine the effect of clays on the bed adjustment to better model the long-term adjustment. The sensitivity analysis is based on a former 2010 study conducted on Walnut Creek in California by Allen Teeter, CHT.

Using the existing condition analysis, the three models were run and results were compared. The minimum bed elevation of the cross section nearest the location of the proposed Cow Camp Road Bridge (XS 1780) was analyzed for each model. As shown in Table 8.1 below, model 2 produces the lowest bed elevation. Therefore, the soil profile consisting of both sand and clay was used in determining the long-term scour for Gobernadora Canyon.

Table 8.1: Sensitivity Analysis Comparison

Section	**Channel Minimum Elevation (feet)**	**Model 1 Minimum Bed Elevation (feet)**	**Model 2 Minimum Bed Elevation (feet)**	**Model 3 Minimum Bed Elevation (feet)**
1780	245	241.2	237.2	239.8

Sediment transport functions are user selectable and 13 different equations are possible. The selection process of one or more appropriate transport functions for testing is a trial and error process. The predefined relationships have been tested to a specific set of conditions, which does not necessarily translate well to other watercourse environments, despite having similar characteristics. Figure 8.1 illustrates the parameters of various transport functions that are used for testing. A simplistic selection process involves a comparison of basic information, which includes a range of velocities, hydraulic depths, effective widths, energy gradient or streambed slope, and sediment gradation. The influence of cohesive soils and armoring is also considered. Without some form of correlation or calibration the uncertainty in the results determined from the application of any transport function is unknown.

Comparing the tested parameter ranges of those sediment transport functions defined in HEC-6T to the average hydraulics and sediment gradation for Canada Gobernadora and San Juan Creek suggests that several of the available sediment transport relationships generally satisfy this simplified screening/selection process; among those, the combination of Toffaleti (1969) and MPM (1948) was chosen to analyze the streambed stability of Canada Gobernadora and San Juan Creek; in addition, several other functions were evaluated as a means of gauging relative performance.

The model consisted of the Toffaleti and Meyer-Peter Muller (TMPM) equation to conduct the HEC-6 analysis. Sediment inflow is determined by running the HEC-6 model with the recirculation functionality. Once the sediment data is compiled, the data is then entered on the LT, LF, and PF cards in the HEC-6 model. Each of the cards are described below.

HEC-6 Input Descriptions

- LT – Total sediment load in tons per day
- LF – The fraction of the sediment load in each grain size class
- PF – The bed material gradation at each cross section

Figure 8.1: Sediment Transport Functions and Parameter Ranges

available HEC6T sediment transport relationships	data source	median sediment size {mm}	sediment size range {mm}	velocity {fps}	depth {feet}	effective width {feet}	energy gradient {ft/ft}
Toffaleti (1969)	river	0.095 - 0.76	0.062 - 4	0.7 - 7.8	0.7 - 56.7	63 - 3,640	0.000002 - 0.0011
	flume	0.91 - 0.45	0.062 - 4	0.7 - 6.3	0.07 - 1.1	0.8 - 8	0.00014 - 0.019
Meyer-Peter and Muller (1948)	flume	-	0.4 - 29	1.2 - 9.4	0.03 - 3.9	0.5 - 6.6	0.0004 - 0.02
Schoklitsch (1930)	flume	-	0.3 - 29	0.8 - 4.5	0.037 - 0.74	0.23 - 2	0.00012 - 0.055
Toffaleti (1969) and MPM (1948), combined	see individual listings for Toffaleti (1968) and MPM (1948)						
Toffaleti (1969) and Schoklitsch (1938), combined	see individual listings for Toffaleti (1968) and Scholltsch (1938)						
Yang (1973, 1984)	river	-	0.15 - 1.7	0.8 - 6.4	0.04 - 50	0.44 - 1,750	0.000043 - 0.028
	flume	-	2.5 - 7	1.4 - 5.1	0.08 - 0.72	0.7 - 1.3	0.0012 - 0.029
Duboy (Brown, 1950)	flume	0.1 - 4	-	-	-	-	-
Einstein (1950)	flume	-	0.78 - 29	0.9 - 9.4	0.03 - 3.6	0.66 - 6.6	0.00037 - 0.018
Ackers-White (1973)	flume	-	0.04 - 7	0.07 - 7.1	0.01 - 1.4	0.23 - 4	0.00006 - 0.037
Colby (1964)	river	-	0.18 - 0.7	0.7 - 8.0	0.2 - 57	0.88 - 3,000	0.000031 - 0.01
Laursen (1958), modified (Copeland and Thomas, 1989)	river	0.08 - 0.7	-	0.068 - 7.8	0.67 - 54	63 - 3,640	0.0000021 - 0.0018
	flume	0.011 - 29	-	0.7 - 9.4	0.03 - 3.6	0.25 - 6.6	0.00025 - 0.025
Laursen (1958), modified (Madden, 1963)	data not available						
Laursen (1958), modified (Madden, 1985; 1993)	river	-	0.04 - 4.8	0.85 - 7.7	0.25 - 54	3 - 3,640	0.0001 - 0.1
Engelund and Hansen	data not available						
Parker (1990)	river	18 - 28	2 - 102	2.6 - 3.7	1 - 1.5	16 - 20	0.0097 - 0.011
Ackers-White (1973), modified (Proffitt-Sutherland, 1983)	river	-	2.9 - 12	2 - 3.4	0.35 - 0.84	2 - 2	0.003 - 0.003
Brownlie (1981)	river	-	0.086 - 1.4	1.2 - 7.9	0.35 - 57	6.6 - 3,640	0.00001 - 0.0018
	flume	-	0.086 - 1.4	0.7 - 6.6	0.11 - 1.8	0.83 - 8	0.00027 - 0.017

9. Long-Term Scour

FEMA's Riverine Erosion Hazard Areas Mapping Feasibility Study recommends a time scale of decades for delineation of scour activities. Continuous simulation modeling is one recommended approach to long-term analysis because the method is systematic and repeatable. In this study, the HEC-6T model is used in a continuous simulation mode to assess possible long-term temporal variation in stream geometry.

The long-term hydrograph for hydraulic input is developed from gage data from the vicinity of the site. The mean daily averaged gage data covers a period of 84 years (1929-2012). For this particular study the mean daily was combined with the annual maximum for years where data was available. The hydrograph was plotted such that only non-zero discharges were considered. This hydrograph, along with the sediment data detailed above in Section 8, are entered into the HEC-6 model and run. The process assumes that the future hydrology and grain size distribution will be consistent with present conditions.

A description of the methodology used to create the long-term hydrographs inputted into the HEC-6T model can be found below. The same methodology as described in *The Ranch Plan Planned Community Planning Area 2 Runoff Management Plan – Update*, prepared by Michael Baker International dated April 2014, is used for this study.

The final scour results can be found in Section 11 and the full HEC-6 analysis can be found in Technical Appendix C.3.

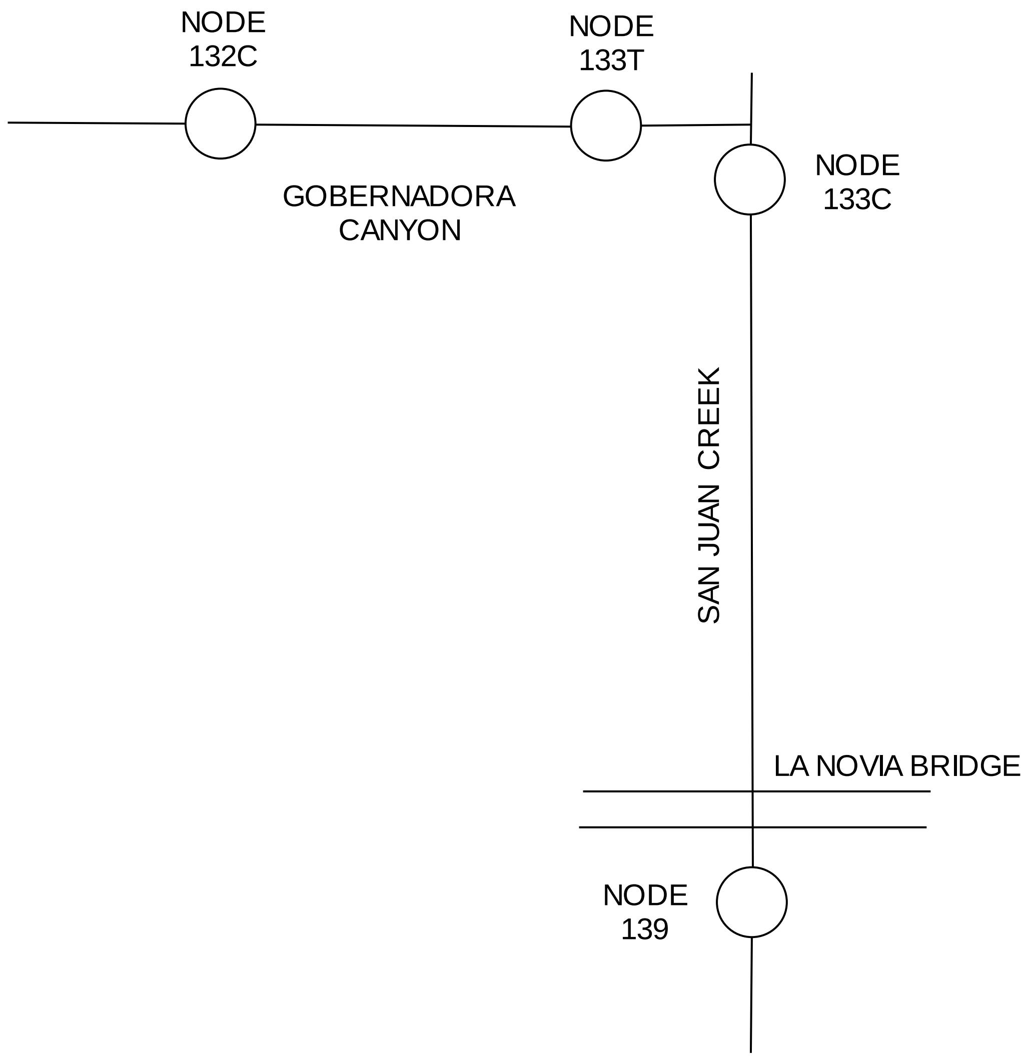
9.1. Hydrology

Long-term flood hydrographs were defined for each set of conditions modeled, which include the existing conditions for San Juan Creek and the ultimate conditions for Canada Gobernadora. The tributary inflow points defined for San Juan Creek and Gobernadora are as follows:

- Node 139 – Located downstream from PA-2, occurring immediately downstream from the La Novia Bridge
- Node 133C – Located immediately downstream from the Canada Gobernadora confluence with San Juan Creek
- Node 133T – Located in Gobernadora Canyon upstream of the confluence with San Juan Creek
- Node 132C – Located downstream of the Gobernadora Canyon confluence with Gobernadora Basin

The concentration points described above are shown in Figure 9.1.

Figure 9.1: Gobernadora and San Juan Tributary Points



9.2. Long-Term Flood Hydrographs

Long-term flood hydrographs were constructed to encompass at least a 60-year planning period. The USGS streamflow records for San Juan Creek were used to develop the long-term hydrographs for San Juan and Canada Gobernadora. The USGS data can be found in Technical Appendix C.1.

Historical annual maximum and daily mean flows are available for the following:

- USGS gauging station 11046500, Ortega Highway Bridge, WY1929-1969 (41 water years)
- USGS gauging station 11046550, Camino Capistrano Bridge, WY1970-1985 (16 water years)
- USGS gauging station 11046530, La Novia Bridge, WY1986-2012 (27 water years)
  Instantaneous flows at 15-minute intervals are available for the following:
- USGS gauging station 11046530, La Novia Bridge, WY1989-2007 (19 water years)

The instantaneous flow record only accounts for 19 years, therefore, the daily mean flow record, which spans 84 years, was considered as an alternative for developing the long-term flood hydrographs. To evaluate the sensitivity of time intervals and the influence of peak flows, a test model based on the existing conditions was simulated to compare the following long-term hydrographs, which span water years 1989 through 2007:

- Daily mean flows (Qm; 24-hour intervals)
- Daily mean flows (24-hour intervals) combined with annual maximum flows (Qm+p) – for those days where an annual maximum flow occurs, a time interval 45 minutes (based on County guidance) was assigned to the annual maximum flow, centered within the daily flow 24-hour interval; the daily mean flow was applied to the remainder of the 24-hour interval, reduced to offset the volume added by the annual maximum flow, and split evenly on each side of the annual maximum flow interval.
- Instantaneous flow at 15-minute intervals (Q15)

The sensitivity test is not a part of this report, because it was previously completed for the PA-2 ROMP. For further details on the test and the results see *The Ranch Plan Planned Community Planning Area 2 Runoff Management Plan – Update.* Per the request of the County (during the PA-2 ROMP Update), the long-term flood hydrograph was based on the combined daily mean and annual maximum flow records.

The three available gauged records were combined and assumed to represent the historical flow record at La Novia Bridge (Hydrologic Node 139), spanning 84 water years from 1929-2012. The long-term flood hydrograph record was translated to subsequent hydrologic nodes upstream based on the frequency volume linear relationships between Node 139 and each upstream node.

The ratio of probability-weighted annual average runoff volumes was used to translate discharge values between the modeled conditions:

$$\forall_m = 0.015\forall_{50} + 0.04\forall_{25} + 0.08\forall_{10} + 0.2\forall_5 + 0.4\forall_2 \quad (Chang, 1988)$$

To translate the long-term flood hydrograph from the existing conditions at San Juan Creek (Node 139) to the ultimate-mitigated conditions at Gobernadora (Nodes 133T and 132C), two factors were applied to each existing condition discharge value. A minimum flow threshold was established at 68 cfs, which is comparable to a 1.25-year event based on Bulletin 17B (USGS

1982); velocities below this threshold are generally well below 3 feet per second are not expected to significantly influence stream behavior.

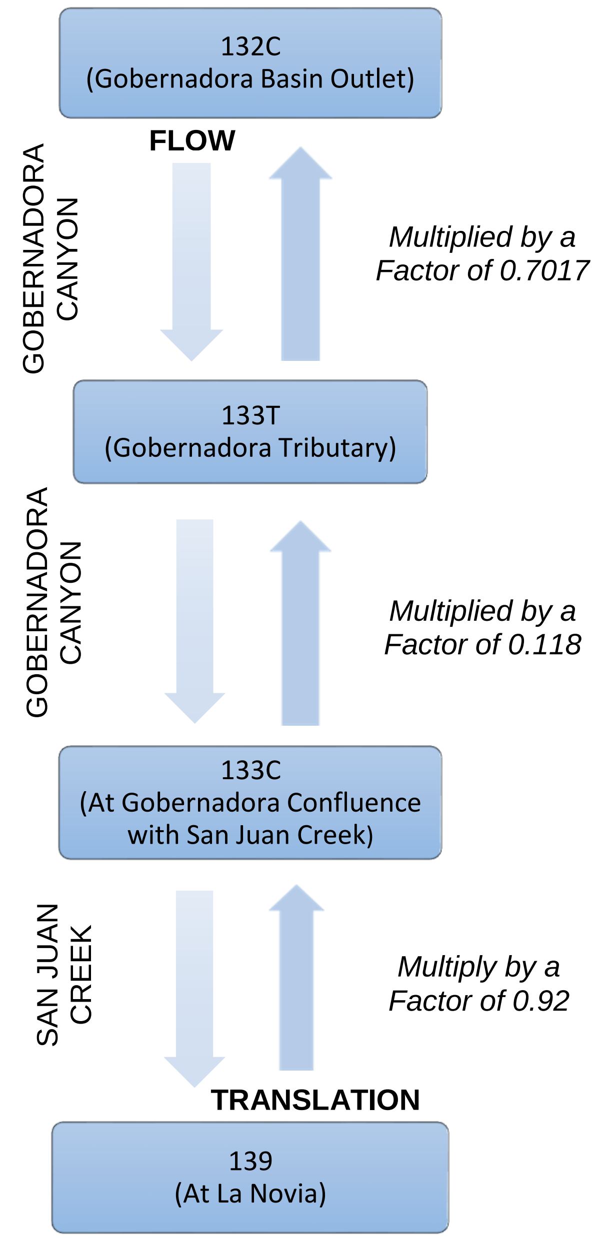
9.3. Long Term Hydrology Translation

The available 84 years of long-term hydrology data was taken from the La Novia record at node 139. To model the long-term along Gobernadora Canyon, the 84 years of data was translated from existing San Juan Creek conditions to ultimate Gobernadora conditions with the use of factors. See Figure 9.2 below for an illustration of this translation. The adjustment factors for Gobernadora Canyon were determined using existing and ultimate condition volumes at nodes 133T and 132C. To translate the long-term record from La Novia to Gobernadora Canyon, the long-term data was first translated up San Juan Creek to the confluence of San Juan and Gobernadora. This translation is described in detail in the previously completed and submitted study - *The Ranch Plan Planned Community Planning Area 2 Runoff Management Plan – Update.* In the study, it was determined that to translate the data to the confluence of San Juan Creek and Gobernadora (Node 133C) it must be multiplied by a factor of 0.92.

The second factor then translates the data from the existing San Juan Creek confluence to the ultimate condition of Gobernadora (133T and 132C). This factor is the relationship between the ultimate conditions at Gobernadora and the existing condition at San Juan Creek. Since the entirety of Gobernadora Canyon hydrology consists of two flow profiles – the flow from the tributary area of Gobernadora and the flow from the basin at the north end of Gobernadora, the long-term data is translated to a combined hydrograph. After converting the long-term data from the San Juan Creek Confluence to Gobernadora with a factor of 0.118, an additional factor is used to translate the new gobernadora long-term data to account for the flow from the north basin. This additional factor is calculated by plotting the ultimate condition volumes for Node 133T versus 132C for frequency years 2 through 100. The slope of this line results in an adjustment factor for translating the long-term data through Gobernadora to the north basin of 0.7017.

After applying the three factors to the long-term data, this hydrograph is inputted into the Hec-6 model to run the long-term scour for Gobernadora. The hydrograph volumes and adjustment factors used in the Gobernadora long-term translation can be found in Technical Appendix C.2.

Figure 9.2: Long Term Hydrograph Translation (Adjustment Factors)



10. Other Scour

10.1 Overview

Other scour is comprised of local scour components. For this study, these components are a result of the presence of a bridge. The impacts of these scour components are generally limited to the vicinity of the bridge that causes them; however, they are significant because they are frequently many times larger than the long-term or general adjustment components of scour. In this study, the scour components considered are pier scour, bend scour and contraction scour. In the vicinity of the bridge the channel is generally straight. Therefore, bend scour is considered negligible. The bridge abutments will be constructed outside the wetted perimeter of the channel; therefore, contraction scour is also considered negligible. Pier scour is the only other scour component analyzed in this study and is calculated using HEC No. 18 equations shown in Figure 10.1.

10.1.1. Local Scour at Piers

Pier scour is a function of the acceleration of flow around the pier and the formation of flow vortices. The vortices remove material from the base of the pier, forming a scour depression. As the depth of scour increases, the magnitude of the vortex decreases reducing the rate of scour. The factors that control the depth of local scour at a pier are: velocity of the flow; depth of flow; width of pier; length of the pier in the flow; gradation of bed material; angle of attack of flow; shape of the pier; and debris.

10.2 Modeling

10.1.2. Local Scour at Piers

The proposed bridge consists of piers with various widths along the vertical length of the pier, which is identified as a complex pier. Therefore, the *Federal Highway Administration HEC 18 Evaluating Scour at Bridges* recommends the use of the Colorado State University equation (CSU) for the computation of scour for complex pier foundations. Total scour is determined by separating the scour producing components, determining the scour depth for each component and adding the results. The method is called “Superposition of the Scour Components.” Figure 10.1 illustrations the method and equations used for calculating the total scour.

In the superposition method, three main components are considered (1) scour component for the pier stem in the flow, (2) scour component for the pier cap or footing in the flow, and (3) scour component for the piles exposed to the flow. The first computation is the scour estimate, ys pier, for a full depth pier that has the width and length of the pier stem using the basic pier equation.

The second computation is the pile cap or footing scour depth component. There are two cases to consider in estimating the scour caused by the pile cap or footing. In this study, the bottom of the pile cap or footing is on or below the bed therefore case 2 is considered. An inherent assumption in this second case is that the footing is deeper than the expected scour depth so it is not necessary to add the pile group scour as a third component in this case. Therefore, the pile group scour depth component is not considered in the pier scour calculations.

All pier scour calculations can be found in Technical Appendix D. The final scour results can be found in section 11.

Figure 10.1: Pier Scour Method

Cow Camp Bridge at Gobernadora Canyon
Complex Pier Scour
Reference: HEC 18 Evaluating Scour at Bridges Section 7.5

Equation 7.22 - Total scour from superposition of components is given by:

$$y_s = y_{spc} + y_{spg}$$

Where:

y_s = *Total scour depth, ft*
$y_{s\ pier}$ = *Scour component for the pier stem in the flow, (ft) – Equation 7.23*
$y_{s\ pc}$ = *Scour component for the pier cap or footing in the flow, (ft) – Equation 7.26*
$y_{s\ pg}$ = *Scour component for the piles exposed to the flow, ft*

Equation 7.23 - Pier Stem Scour Depth Component

$$\frac{y_{s\ pier}}{y_1} = K_{hpier}\left[2.0K_1K_2K_3\left(\frac{a_{pier}}{y_1}\right)^{0.65}\left(\frac{V_1}{\sqrt{gy_1}}\right)^{0.43}\right]$$

Where:

K_{hpier} = *Coefficient to account for height of pier stem above bed and shielding effect by pile cap overhand distance "f" in front of pier stem*
a_{pier} = *pier width*

Equation 7.26* - Pile Cap (Footing) Scour Depth Component
**Case 2: Bottom of the Pile Cap (Footing) Located On or Below the Bed*
**Per section 7.5.4, Case 2 - An inherent assumption in this second case is that the footing is deeper than the expected scour depth so it is not necessary to add the pile group scour as a third case component*

$$\frac{y_{spc}}{y_f} = 2.0K_1K_2K_3K_w\left(\frac{a_{pc}}{y_f}\right)^{0.65}\left(\frac{V_f}{\sqrt{gy_1}}\right)^{0.43}$$

$$\frac{V_f}{V_2} = \frac{\ln\left(10.93\frac{y_f}{k_s}+1\right)}{\ln\left(10.93\frac{y_2}{k_s}+1\right)}$$

Where:

a_{pc} = *width of original pile*
$y_f = h_1 + y_{s\ pier}/2$ = *distance from the bed (after degradation, contraction scour, and pier stem scour) to the top of*
V_f = *Average velocity in the flow zone below the top of the footing, ft/s*
k_s = *Grain roughness of the bed (normally taken as the D84 for sand size bed material and 3.5D84 for gravel and coarser*
K_w = *Correction factor for wide piers in shallow flow*

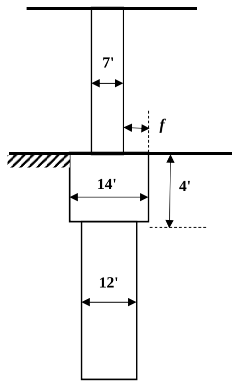
$$K_w = 1.0\left(\frac{y}{a}\right)^{0.13} Fr_1^{0.25} \quad for\ V/V_c \geq 1$$

For Case 2:

$$y_s = y_{s\ pier} + y_{s\ pc}$$

Variables Used in Computations:

f = *Distance between front edge of pile cap or footing and pier, ft*
h_o = *Height of the pile cap above bed at beginning of computation*
$h_1 = h_o + T$ = *height of the pier stem above the bed before scour, ft*
$h_2 = h_o + y_{s\ pier}/2$ = *height of pile cap after pier stem scour component has been computed, ft*
$h_3 = h_o + y_{s\ pier}/2 + y_{s\ pc}/2$ = *height of pile group after the pier stem and pile cap scour compononents have been computed, ft*
S = *Spacing between columns of piles, pile center to pile center, ft*
T = *Thickness of pile cap or footing, ft*
y_1 = *Approach flow depth at the beginning of computations, ft*
$y_2 = y_1 + y_{s\ pier}/2$ = *adjusted flow depth for pile cap computations, ft*
$y_3 = y_1 + y_{s\ pier}/2 + y_{s\ pc}/2$ = *adjusted flow depth for pile group computations, ft*
V_1 = *Approach velocity used at the beginning of computation, ft/sec*
$V_2 = V_1(y_1/y_2)$ = *adjusted velocity for pile cap computations, ft/sec*
$V_3 = V_1(y_1/y_3)$ = *adjusted veolocity for pile group computations, ft/sec*
K_1 = *Correction factor for pier nose shape*
K_2 = *Correction factor for angle of attach of flow*
K_3 = *Correction factor for bed condition*
g = *Acceleration of gravity* $(32.2\ ft/s^2)$



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11. Total Scour at Cow Camp Road Bridge

To be conservative, long-term adjustment and local pier scour are summed to determine total potential bed adjustment. In the proposed condition, Cow Camp Road Bridge results in 19 feet of pier scour and 8 feet of long-term scour. Therefore, the total scour depth at the bridge is 27 feet at the location of the channel bed (thalweg). Accounting for lateral movement of the channel, the total scour depth needs to be applied to each pier within the floodplain, assuming the thalweg (current elevation of 245 feet) can relocate to each pier.

Table 11.1: Gobernadora Canyon Scour Results

Support	Long Term Scour Depth (ft)	*Long Term Scour Elevation (ft)	Local Pier Scour Depth (ft)	Total Scour (Long term + Pier scour) Depth (ft)	*Total Scour (Long term + Pier scour) Elevation (ft)
Abut 1	-	-	-	-	-
Pier 2	-	-	-	-	-
Pier 3	8	237	19	27	218
Pier 4	8	237	19	27	218
Pier 5	8	237	19	27	218
Pier 6	8	237	19	27	218
Pier 7	8	237	19	27	218
Pier 8	-	-	-	-	-
Abut 10	-	-	-	-	-

**Elevations are based on a thalweg elevation of 245 feet*

Considering the bridge is skewed and has multiple columns, there are several adjustments to be made to the piers at the edge of the floodplain. Pier 7 (refer to Figure 5.1) supports the last bent (7) on the right side (looking upstream) within the floodplain. Per the latest GMU soils report, it is determined that a portion of bent 7 will sit on bedrock material. Therefore, each of the three piers supporting the bent will be affected slightly differently by scour. The most upstream pile, part of the future structure, will consist of a total scour depth down to an elevation of 218 feet as show in the table above. For the middle pier, the scour elevation to be considered is 224 feet, due to presence of bedrock material. Similarly, for the downstream pile, a scour elevation of 248 feet is to be considered due to presence of bedrock material.

As seen on the table, several piers and abutments have been determined to not be affected by scour, because they are either out of the floodplain or the projected scour depth results in an elevation above the existing ground. Pier 2 is at a current embankment slope of 20%. In order to determine the appropriate scour depth, the scour depth for pier 2 was calculated by projecting a stable slope of 2:1 from the scour depth at the thalweg. This produced an elevation above the existing ground. Therefore, it was determined that pier 2, which is 150 feet from the current thalweg, will not be affected by any scour from the channel's potential lateral movements. As for pier 8, it will be outside of the floodplain by approximately 150 feet.

12. References

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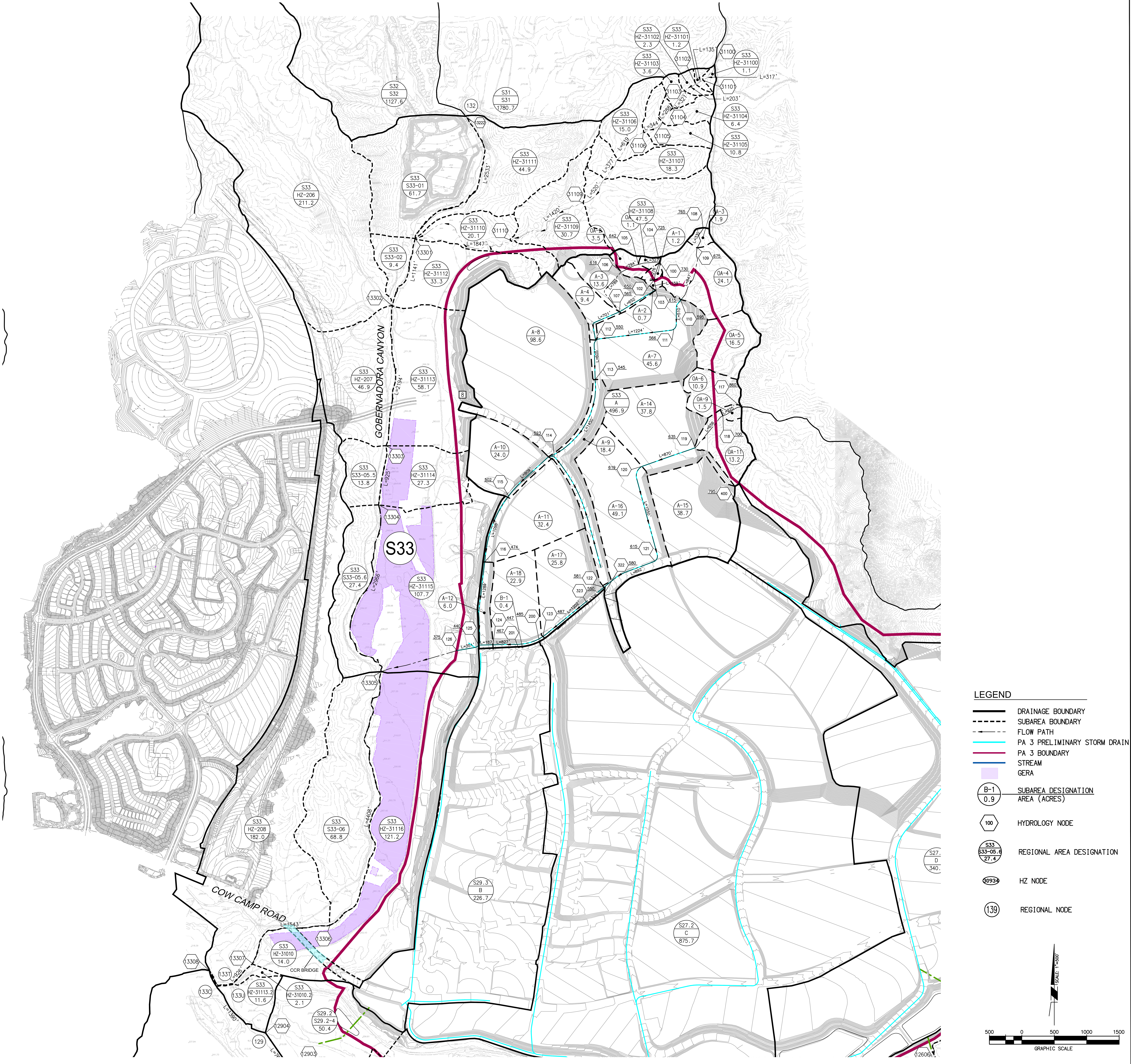

EXHIBIT 1
RANCHO MISSION VIEJO
GOBERNADORA CANYON LOCAL HYDROLOGY MAP

Sediment Transport and Scour Analysis of Gobernadora Canyon for Cow Camp Road Technical Appendices (CD ONLY)