APPENDIX H
HYDRAULICS AND SCOUR REPORT

Technical Memorandum

Quasi–Two-Dimensional Hydraulics & Scour Analysis
Santa Ana River

Prepared for:

Orange County Public Works Department
OC Planning Services
300 N. Flower Street
P.O. BOX 4048
Santa Ana, California 92702-4048
Contact: Jeff Dickman

Prepared by:

AECOM
999 West Town & Country Road, 4th floor
Orange, California 92868
Contact: David A. Jaffe, PhD, PE, D.WRE

JUNE 2014

TABLE OF CONTENTS

Section **Page No.**

LIST OF TABLES

LIST OF FIGURES

LIST OF EXHIBITS

APPENDIX

1.0 INTRODUCTION AND PURPOSE

The following technical investigation provides a detailed and focused evaluation of the quasi–-two-dimensional hydraulics and bed scour of a reach of Santa Ana River located in Orange County, California. The purpose of the study was to provide hydraulic impacts analysis related to a proposed design of the Santa Ana River Parkway Extension Project. Orange County Planning Services is considering three bridges over the Santa Ana River as part of its Santa Ana River Parkway Extension Project Draft Environmental Impact Report. For study purposes, the proposed bridges in this analysis have a span of approximately 400 feet (ft) each.

The study reach is downstream of the Prado Dam in eastern Orange County (Figure 1-1). The existing floodplain generally consists of an alluvial stream system within the Santa Ana River Watershed.

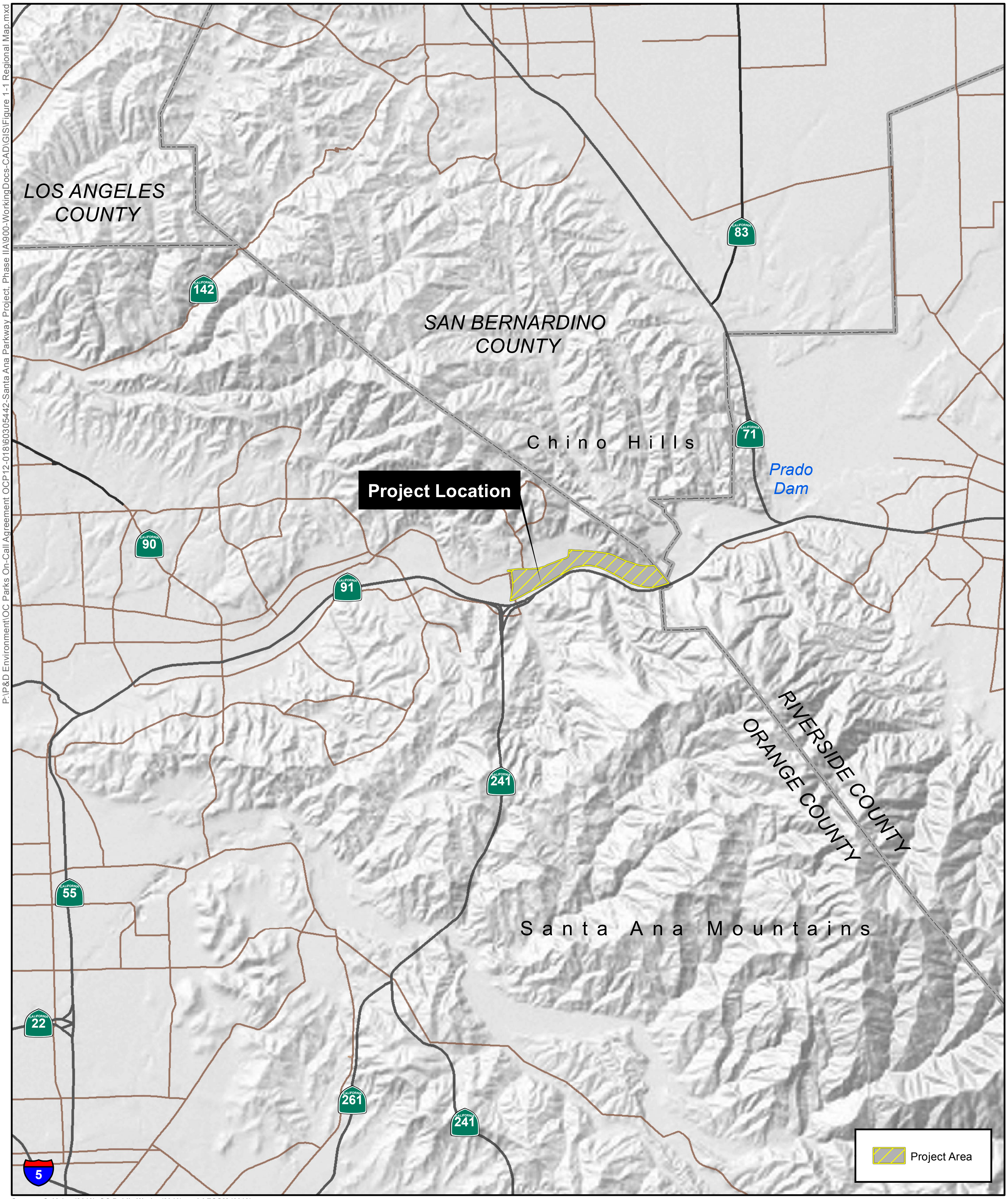
The purpose of this analysis is to evaluate the impacts to: 1) hydraulic changes to the stream flow during the design event; and 2) changes to the fluvial operation over the streambed resulting from the implementation of the project.

1.1 Study Location

The study location (Figure 1-2) of the Santa Ana River extends from approximately 2,000 ft upstream to approximately 2,000 ft downstream of proposed Bridge 1, or a total study reach length of approximately 9,400 feet (Figure 1-3). The proposed bridges are located approximately in the middle of the study reach. Only two minor drainages confluence within the study reach. The area upstream from the dam contains 2,255 square miles of the watershed's 2,650 square miles. This portion of Santa Ana River is a natural alluvial stream system, although it has experienced a variety of human activity, including the construction of bridge crossings, historic sand/gravel mining operations, the construction of Prado Dam, and agricultural activities, that have all influenced the channel hydraulics and fluvial mechanics.

1.2 Channel Hydraulics

Several types of models can be used to simulate flood flows in both channel and overland settings. These include steady and unsteady models in one or two spatial dimensions. In one-dimensional models, which are generally limited to channel discharges, spatial dimension is given as distance along the channel centerline and the variables being solved for, stage and velocity, are cross-sectionally averaged quantities. Two-dimensional models may be used for very complex channels (i.e., channels with hydraulic jumps, abrupt bends, etc.) or overland flow problems. In two-dimensional models, the spatial dimensions are along- and cross-channel distances and solve for stage and depth-averaged discharge. Both of these models make an important assumption that vertical pressure is hydrostatic, so that the flows are said to be



Source: CalAtlas (2013), OC Public Works (2013), and AECOM (2013).

P:\P&D Environment\OC Parks On-Call Agreement OCP12-018\60305442-Santa Ana Parkway Project, Phase IIA\900-WorkingDocs-CAD\GIS\Figure 1-1 Regional Map.mxd

Scale 1 : 126720
1" = 2 miles

0 1 2 4 Miles

Figure 1-1
Regional Map

Source: Aerial Imagery: Microsoft (2010), OC Public Works (2014), and AECOM (2014).

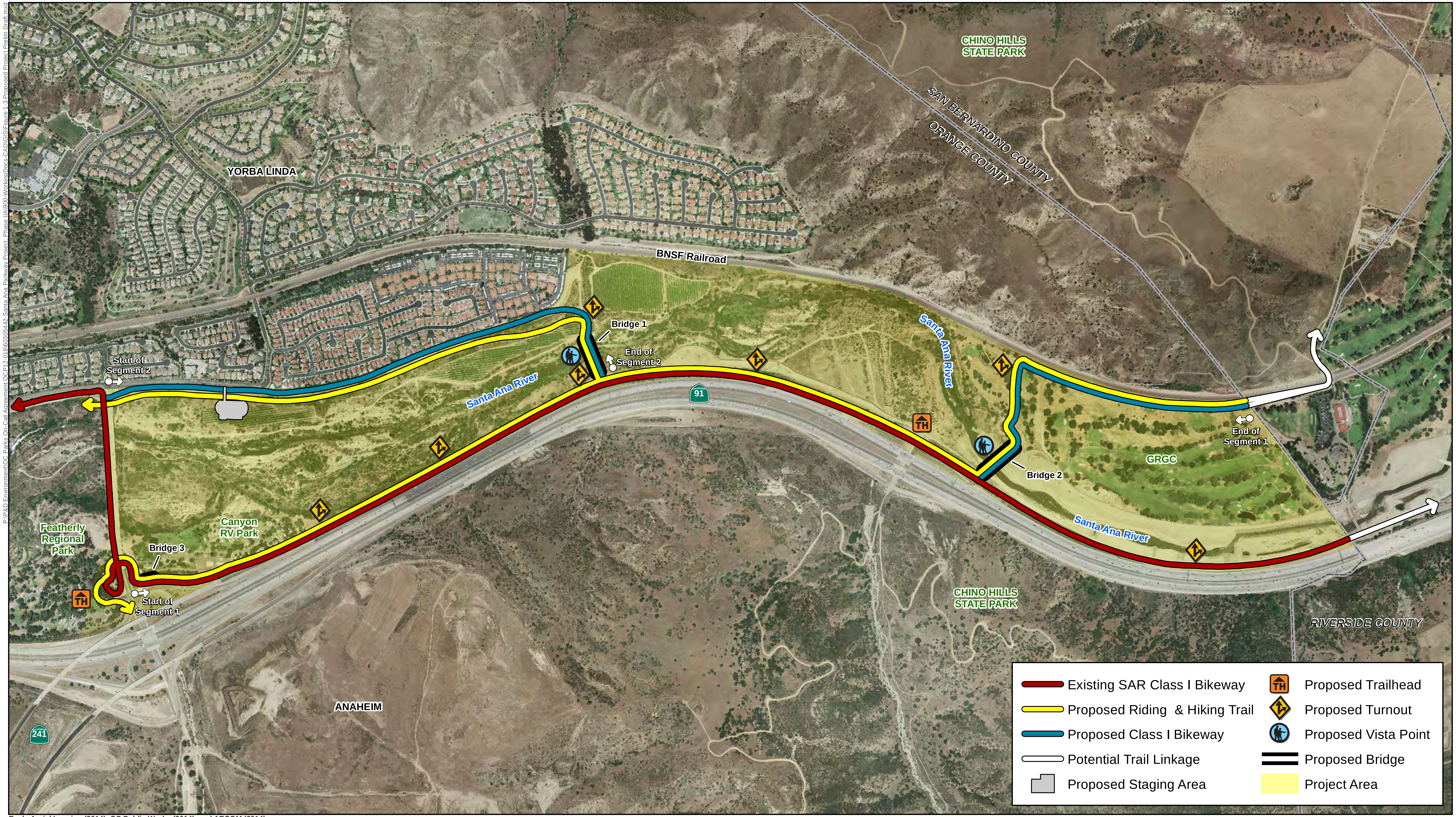
Scale 1 : 47,520
1" = 0.75 mile

0 0.375 0.75 1.5 2.25 Miles

Figure 1-2
Vicinity Map

Santa Ana River Parkway Extension Project

P:\P&D Environment\OC Parks On-Call Agreement OCP12-018\60305442-Santa Ana Parkway Project, Phase II\A900-WorkingDocs-CAD\GIS\Figure 1-2 Vicinity Map.mxd



Eagle Aerial Imaging (2014), OC Public Works (2014), and AECOM (2014).

Note: Project Elements Not Drawn to Scale

Figure 1-3
Proposed Project

gradually varied. Additional calculations can be made in one-dimensional models so that estimates of two-dimensional flow distribution are estimated, and this estimate is referred to here as quasi-two-dimensional flow. In the present study quasi-two-dimensional flow, described in greater detail below, is used for analysis.

1.3 Types of Adjustment

Modifications to the stream bed are measured as vertical bed adjustment in ft. Positive adjustment indicates bed aggradation, while negative adjustment indicates bed degradation. Several types of adjustment are considered in this study including general adjustment and other scour. General adjustment consists of scour that occurs during 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 will occur, or the bed may become armored. Other scour is comprised of local scour, bend scour, low-flow incisement, and bed form formation. These are discussed in detail in the sections below. Long-term adjustment, which consists of fluvial processes that occur over many rainy seasons, is outside the scope of the present study and not considered herein.

2.0 STUDY AREA DESCRIPTION

2.1 Overview

This section provides basic information about the following characteristics of the Santa Ana River study area within the study reach:

- Watershed Description;
- Geologic Setting;
- Climate; and
- Study Area Description.

The interrelated watershed, geologic, hydraulic, and hydrologic characteristics of a stream combine to determine its unique geomorphology.

2.2 Santa Ana Watershed Description

The Santa Ana River watershed drains portions of four counties in southern California and encompasses a drainage area of approximately 2,650 square miles (United States Geological Survey [USGS] 2011). The counties include San Bernardino, Riverside, Los Angeles, and Orange. The Santa Ana River (River) has several major tributaries including Mill, San Timoteo, Temescal Creek/San Jacinto River, Santiago, Bear, City, Lytle, Chino and Salt Creeks, as well as Perris Valley Drain. The River is approximately 96 miles long from the headwaters to the Pacific Ocean.

2.3 Geologic Setting

Two major faults define the geology of the greater watershed. The San Andreas Fault crosses northern portions of the watershed, creating the San Bernardino Mountains. The Elsinore–Whittier Fault Zone crosses the Santa Ana River near the Orange County/Riverside County line. This fault caused the rising of the Santa Ana Mountains and the coastal Peninsular Ranges. The San Andreas Fault thrust the Transverse Ranges to approximately 10,000 feet in elevation, while the Peninsular Ranges are generally less than 5,000 feet.

2.4 Climate

Climate within the watershed varies by geography. Mountainous areas have cold winters and mild summers, while valley floors have mild winters and hot, dry summers. Snow may occur in the mountains during winter with average precipitation of approximately up to 47 inches in the San Jacinto Mountains. Precipitation for the watershed as a whole averages approximately 17 inches (Thiros 2010). Precipitation for the watershed primarily occurs in the winter months and most of the runoff in the watershed is produced from these storms. Runoff is produced in the River primarily during and immediately after intense or prolonged precipitation with intense periods of rainfall (Riverside County Flood Control and Water Conservation District [RCFCD] 1975, RCFCD 1994).

2.5 Study Area

The present study reach is approximately 9,400 feet long, beginning three miles downstream of Prado Dam. There are two minor confluences within the study reach.

3.0 HYDROLOGY

3.1 Watershed Description

The Santa Ana River watershed is comprised of parts of four counties in southern California (Figure 3-1). The watershed encompasses a drainage area of approximately 2,650 square miles. Santa Ana River is the major stream in the watershed. The headwater of Santa Ana River originates from the San Bernardino National Forest and drains southwesterly. Two minor drainages exist within the study reach. The project does not, however, alter the hydrology of the River in any way.

Figure 3-1 – Regional Watersheds

3.2 Flood History - Santa Ana River

A long history of recurrent but infrequent flood problems in southern California is revealed in records kept by missions and other historical sources, including diaries from Mission Fathers, early travelers, and settlers. There are accounts of floods occurring as far back as 1770. Of these early southern California accounts, the floods of 1780, 1825, 1862, 1884, 1891, and 1916 were of major proportions. The 1916 event saw levels in Lake Elsinore reach stages such that flow from Jacinto River (RCFCD 1975, RCFCD 1994). Floods occurring since 1851 have been described in more detail than previous floods and provide some basis for determining the relative magnitudes of major flood events and their recurrence intervals. Recorded data from 1897 to present show medium to large winter floods occurring in January 1910, January 1916, February 1937, March 1938, January 1943, January and February 1969, February and March 1978, February 1980, March 1983, January, February and March 1995, and December, January and February 1998. The 1938 event was particularly significant in Riverside County history, since this event ultimately lead to the formation of the Flood Control District. The Federal Register (V. 22, N. 139, p. 39802) (Federal Register 2003) cites that the Santa Ana Levee project (1961) provided sufficient protection from the 1969 event. The 1980 event, although smaller in discharge, caused the levee to fail and resulted in severe flooding in the City of Santa Ana. Prado Dam, immediately upstream of the project site in the Chino Hills' Lower Santa Ana River Canyon, was completed in 1941 and built by the Army Corps of Engineers.

4.0 PREVIOUS STUDIES

4.1 Previous Reports

Numerous regional watershed hydrology, floodplain hydraulics, and sediment transport studies have been done for Santa Ana River and the proposed project over the last decade. Since impacts to local hydraulics and fluvial mechanics related to the proposed project are the main subjects of this report, only two of the previous studies are discussed. Other documents not discussed herein include the following: Army Corps of Engineers (AEOE), Quantitative Vegetation Survey Results, 2010; County of Orange, SAR Mitigation Sites Annual Report, 2011; Reach 9 Phase 21 Final SEA, 2011; WEST, Lower Santa Ana River Baseline Hydraulic and Sediment Modeling Final Hydrology & Hydraulics Study, 2011; and OCWD, Santa Ana River Bed Sediment Gradation Characterization Study Phase II, 2009.

RBF, SAR Parkway Draft IS/MND, 2011 – Among other things, the IS/MND addresses Section 15063 of Title 14 of California Code of Regulations (CCR). Most pertinent to the present study, the IS/MND includes a complete description of the project as addressed herein. The document defines the project location as:

“The Santa Ana River Parkway Project (herein referenced as the “project”) is located on the north and south sides of the Santa Ana River between Gypsum Canyon Road on the west and the Orange/Riverside/San Bernardino County boundaries on the east, and between the Burlington Northern Santa Fe (BNSF) railroad and La Palma Avenue on the north and State Route (SR) 91 freeway on the south. The majority of the project area is located within the City of Yorba Linda. The easternmost portion of the project area is located within unincorporated Orange County. The project area is also known as the “Santa Ana River Narrows”.

Additionally, the project characteristics are defined in the document as: “The proposed project involves a Class 1 Bikeway, Riding and Hiking Trail, and associated amenities on the north and south banks of the SAR from Gypsum Canyon Road eastward to the Orange County border”. A typical cross section for the Bikeway and Riding and Hiking Trail is 30 feet wide and includes a minimum 2.0-foot shoulder width and a minimum 3.0-foot buffer area between the two paths.”

On the south river bank the document describes a parallel Bikeway and Riding and Hiking Trail, including the proposed Bridge 3, with a “proposed span and length are 12 feet and 100 feet, respectively.” The south bank portion of the proposed project also includes Bridge 1, which joins the bikeway on the north and south banks by crossing over Santa Ana River: “Bridge 1 proposed span and length are 115 feet and 345 feet, respectively, and would accommodate both this Bikeway and the Riding and Hiking Trail.”

The final structure is described as follows: “At mid-point the Riding/Hiking Trail would branch off to the north, cross the SAR over proposed Bridge 1, and join the proposed north bank Riding/Hiking

Trail. At its eastern terminus in the vicinity of the GRGC, the Riding and Hiking Trail would branch off to the north, cross the SAR over proposed Bridge 2 and join the proposed north bank Riding/Hiking Trail adjacent to the BNSF Railroad. Bridge 2 proposed span and length are 120 feet and 360 feet, respectively, and would accommodate the Riding and Hiking Trail.

Section 4.9(h), Hydrology and Water Quality details “Place within a 100-year flood hazard area structures, which would impede or redirect flood flows.” The section found “Less Than Significant Impacts,” for the proposed project.

LSA, HMP Maintenance and Monitoring, 2013 – The MMR addresses the conservation measures set forth in HMPs in the vicinity of the proposed project, particularly the habitat composition within the HMP areas. The MMR notes: “The current distribution of the plant communities and their subtypes present … was obtained from the results of a habitat survey performed by LSA Associates, Inc. (LSA) in 2012. Mapping was performed using the Orange County (County) Habitat Classification System (HCS).”

The MMR analysis includes an assessment of the 2004/2005 controlled release from Prado Dam in excess of 10,000 cubic feet per second (cfs). To accomplish this task “a delineation of the high-water limits of the flood event, the ordinary high-water mark (OHWM) immediately prior to the flood event and the current OHWM within the HMA could be beneficial. The 2004 and 2012 OHWMs were approximated by tracing the open water limits of the Santa Ana River on 2004 and 2011 aerial photographs.” No numerical model appears to have be undertaken as part of this analysis.

4.2 Sediment Characterization and Analysis

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 stream 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.

Sediment data as percent finer was provided by Tetra Tech as a part of their HEC-6T model, described below. No changes have been made to the data as a part of the current effort.

5.0 BRIDGE DESCRIPTIONS

5.1 Existing Condition

No bridges are existent at the proposed bridge locations; all bridges studied in this memorandum are new construction. The existing Gypsum Canyon Bridge is not part of the proposed project, but is located downstream of the Canyon RV Park and Featherly Regional Park at Gypsum Canyon Road. The bridge is immediately downstream of proposed Bridge 3, described below.

5.2 Proposed Condition

Preliminary design for the three bridges is based on RBF's administrative Draft Initial Study/Mitigated Negative Declaration (RBF 2011). Some minor design changes have been made as a part of the present effort, and are noted below.

Bridge 1 (SRE1) (Figure 5-1) would connect the proposed north and south river bank bikeways and trails as described in RBF (2011). Bridge 1 is to be located immediately downstream of the confluence of Brush Canyon and the River. Bridge 1 is proposed to have a deck span of 346 feet and two piers (compared to RBF's preliminary design of 345 feet with two piers, or three spans of 115 feet each). The bridge would be designed for a 25-foot width (compared to an original design of a 20-foot width). The bridge is meant to connect the bikeway and riding and hiking trails on the north and south River banks.

Bridge 2 (SRE2) (Figure 5-2) is intended to connect the proposed riding and hiking trail on the north and south sides of the River. This bridge would also provide an opportunity for users to utilize a future railroad crossing, and provide access to Chino Hills State Park. This bridge is to be located just upstream of the Chino Hills State Park and would span the river to reach the golf course. Bridge 2 would have a bridge deck length of 461 feet and two piers (compared to the RBF design of 360 feet with two piers, or three spans of 120 feet each). The bridge would be 25 feet wide (compared to the original design of 12 feet wide).

Bridge 3 located adjacent to Canyon RV Park and spans the existing Gypsum storm control channel. Bridge 3's proposed span and length are 12 feet and 100 feet, respectively. The intent of Bridge 3 is to accommodate both the bikeway and the riding and hiking trail. It is anticipated that Bridge 3 would be a pre-fabricated metal truss bridge that would be 100 feet long with no piers. Based on its proposed location, Bridge 3 will not impact hydraulics in the River.

The development of the bridges for the present analysis was coordinated with, and reviewed by, County staff prior to the commencement of modeling (J. Dickman, G. Tran, personal communication 11/12/13).

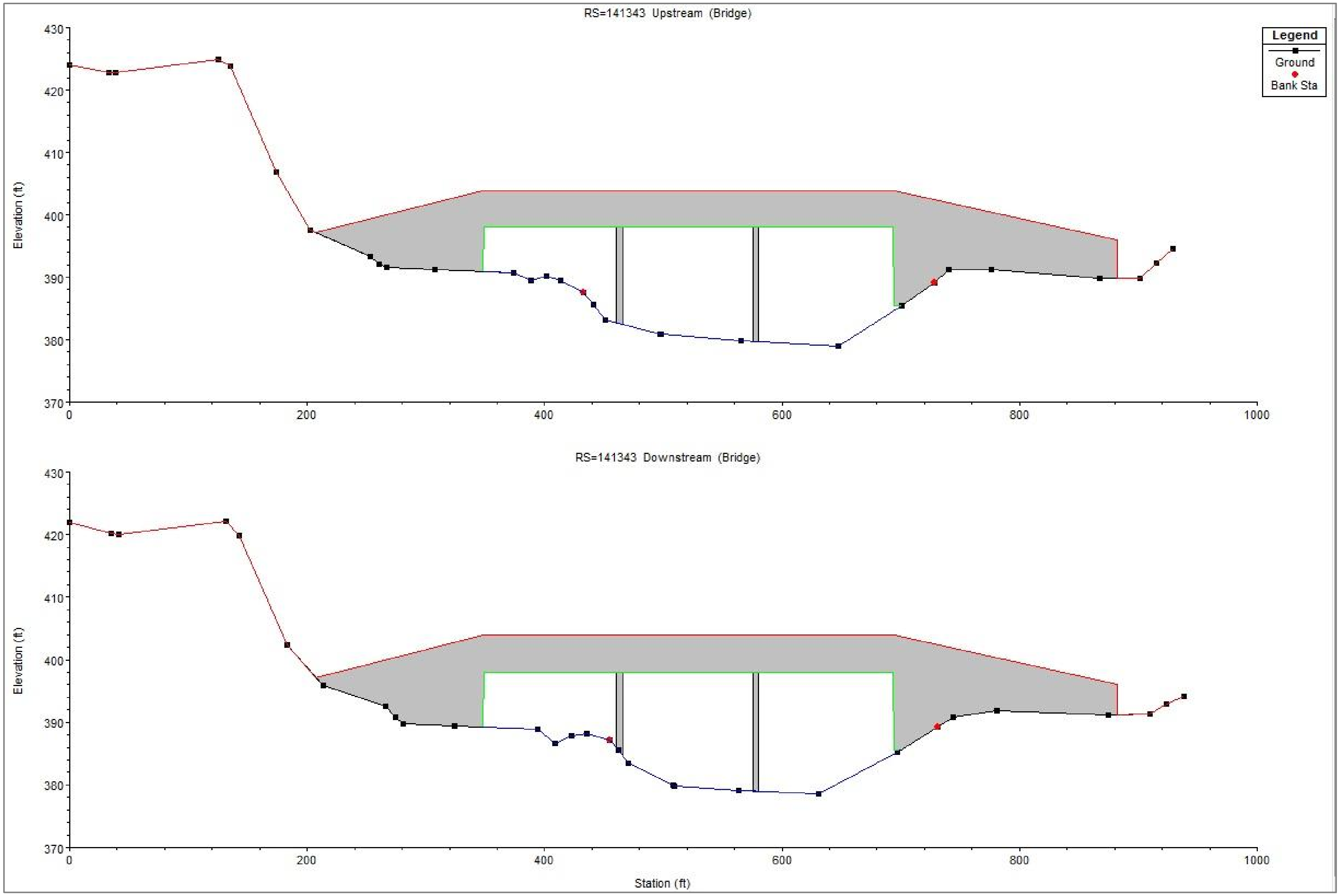


Figure 5-1 – Bridge SRE1

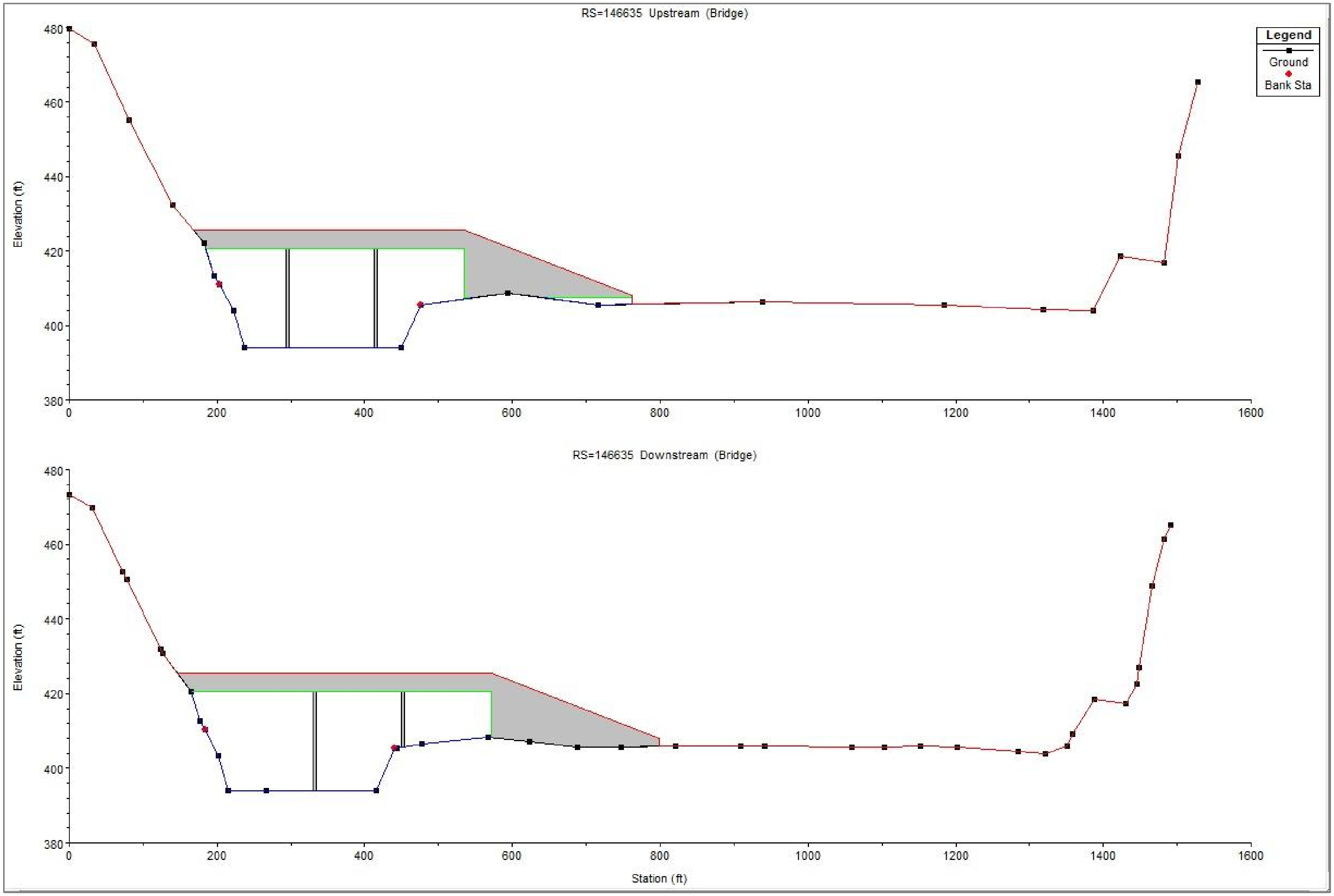


Figure 5-2 – Bridge SRE2

6.0 HEC-RAS

The U.S. Army Corps of Engineers' HEC-RAS numerical model was designed to calculate water surface profiles in channels assuming a steady flow and uniform discharge based on site hydrology. The HEC-RAS model is a one-dimensional model widely used throughout the United States for analysis of open channels.

6.1 Equations of Motion

The equations of motion in one dimension consider two dependent variables, depth *(h)* and volumetric discharge *(Q)*. For the purposes of this study the equations of motion are essentially simplified versions of the St. Venant equations comprising a mass balance and a momentum balance equation. These equations take the form (Cunge *et al*. 1980):

$$\frac{\partial \eta}{\partial t} + \frac{1}{w}\frac{\partial Q}{\partial x} = 0 \qquad (1)$$

$$\frac{\partial Q}{\partial t} + \frac{\partial}{\partial x}\left(\frac{Q^2}{A}\right) + gA\frac{\partial \eta}{\partial x} = -gAS_f \qquad (2)$$

where η is the free surface elevation, *Q* is the discharge, *w* is the channel top width, *A* is the cross-sectional area, *g* is the gravitational constant, *x* is the distance along the channel center line, and *t* is time.

The friction slope, the energy loss in units of length over the length of a channel segment, is represented by the variable S_f.

6.2 One Dimensional HEC-RAS Model Equations in Steady State

In steady-state time dependent terms of equations (1) and (2) drop out leaving, after rearranging,

$$\frac{\partial}{\partial x}\left(\frac{v^2}{2g}\right) + \frac{\partial}{\partial x}\eta = -S_f \qquad (3)$$

where *v* is the cross-sectionally averaged velocity in the *x*, or along-stream, direction. Upon integration over a single channel reach located from x_1 to x_2, becomes,

$$\left[\frac{v^2}{2g} + \eta\right]_{x_1}^{x_2} = -\int_{x_1}^{x_2} S_f\,dx \qquad (4)$$

Examination of this equation shows that the HEC-RAS model essentially balances momentum and loss terms in steady state between two specific river stations.

6.3 HEC-RAS Numerical Scheme

To employ Equation (4) for use in the HEC-RAS model, the study channel must be broken into reaches and then the equation may be applied to individual reaches. To use Equation (4) for water surface calculations, rearranging gives,

$$(\eta_2 - \eta_1) + \frac{1}{2g}\left(\alpha_{v_2} v_2^2 - \alpha_{v_1} v_1^2\right) = L_e \qquad (5)$$

$$L_e = X_w S_f + + \frac{C_c}{2g}\left(\alpha_{v_2} v_2^2 - \alpha_{v_1} v_1^2\right) \qquad (6)$$

where C_c is the contraction coefficient, L_e is the energy head loss within each reach, and subscripts 1 and 2 represent the downstream and upstream ends of a channel reach, respectively.

Friction slope cross-sectional variability occurs when floodwaters inundate the flood plain and the coefficient α_v accounts for this as,

$$\alpha_v = \left(\frac{A_{ttl}^2}{K_{ttl}^3}\right)\left(\frac{K_{lob}^3}{A_{lob}^2} + \frac{K_{ch}^3}{A_{ch}^2} + \frac{K_{rob}^3}{A_{rob}^2}\right) \qquad (7)$$

where the conveyance, K, is derived from the Manning/Strickler equation,

$$K = \frac{1.49}{n} A R_h^{2/3} \qquad (8)$$

where n is Manning's number, R_h is the hydraulic radius of the reach, and the subscripts *ttl*, *lob*, *ch*, and *rob* represent the total, left overbank, main channel, and right overbank portions of the reach, respectively. The discharge-weighted reach length, x_w, can then be defined as:

$$x_w = \frac{x_{lob}\bar{Q}_{lob} + x_{ch}\bar{Q}_{ch} + x_{rob}\bar{Q}_{rob}}{\bar{Q}_{lob} + \bar{Q}_{ch} + \bar{Q}_{rob}} \qquad (9)$$

where $\bar{Q}$ is the arithmetic mean of the discharge at the end of each reach. Finally, the friction slope, S_f, is given by,

$$S_f = \left(\frac{\bar{Q}_1 + \bar{Q}_2}{K_1 + K_2}\right) \qquad (10)$$

No special numerical methods are required to employ the proceeding equations (5)-(10), and the simplicity of the HEC-RAS model is ideal for calculating water surface elevations in mild-slope channels in the presence of culverts and bridges.

6.4 HEC-RAS Flow Distribution

The sectional calculations described present a distribution of flow in three divisions within each section representing the two overbanks and the main channel. HEC-RAS has the option of showing the distribution of flow for multiple divisions in the overbanks and channels. The first step in determining the distribution is to define the locations where the distribution will be calculated within the model. Next, the number of slices used by the model calculations is defined for each of the three primary flow divisions. Each major division is required to have at least one slice and the user can prescribe up to 45 slices for all three divisions. The third step is to calculate the water surface profile and other hydraulic parameters.

The water surface profile is calculated in six steps, the first of which is to calculate the water surface profile for the three primary divisions and balance the energy equation. After the water surface elevation is computed, the program divides the flow based on the user-defined slices and computes an area, hydraulic depth and wetted perimeter for each slice. The third step uses the friction slope, S_f, for the whole section and computes the conveyance and percentage discharge for each slice using the Manning's values and the slice-based wetted perimeter. HEC-RAS then must sum the computed conveyances for each slice (the caveat to this approach is that as the number of slices increases, so too does the water surface elevation). To correct for the difference in computed conveyances, the model calculates a ratio of the total conveyance without slices to the conveyance with slices and applies the ratio to each slice. The sixth step is to compute the average velocity, discharge divided by area, for each slice.

7.0 FLOODPLAIN HYDRAULICS ANALYSIS

7.1 Procedure

Hydraulic modeling was performed using a HEC-RAS model provided by the County, which resides in a geo-referenced coordinate system. HEC-RAS, computer modeling software developed by the U.S. Army Corps of Engineers (ACOE) is a rigid boundary hydraulic model, which assumes the channel bed does not fluctuate (ACOE 2008). Bed scour analysis based on empirical equations was performed by AECOM and is discussed below. 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 the coefficient and 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.

The design hydrograph for sediment modeling, as provided by Tetra Tech, is shown in Figure 7-1. The peak design discharge of this hydrograph is Q_{Peak}=30,000 cfs. No modifications have been made to the existing conditions HEC-RAS or sediment transport models. The proposed conditions model modifies the updated existing conditions model by adding the proposed bridges.

7.2 Existing Conditions Analysis

The main purpose of the existing conditions analysis is to serve as a basis of comparison for the post-development impacts analysis. The existing condition HEC-RAS model analysis shows that flow depths for the peak design discharge (Q=31,000 cfs) ranges from 11.8 to 24.8 feet, and channel velocity ranges from 5.1 feet per second (fps) to 18.6 fps. The hydraulic output files are presented in the Appendix.

7.3 Proposed Condition Analysis

The proposed condition models differ from the existing condition model in that the proposed condition models include the proposed bridges in the study area. The proposed condition analysis shows that flow depths for the design event range from 11.8 to 24.8 feet. Channel velocity for the design event ranges from 4.0 to 18.6 fps. Table 7-1 compares the flow depths and velocities from the two conditions and the differences that arise as a result. The proposed condition increases the depth by as much as 0.7 feet during the design event compared to the existing condition. Velocity decreases by as much as -1.2 fps compared to the existing condition. All expected changes occur within approximately 1,500 feet of the proposed structure, and thus are very localized to within approximately five bridge lengths.

Figure 7-1 - Model Design Hydrograph

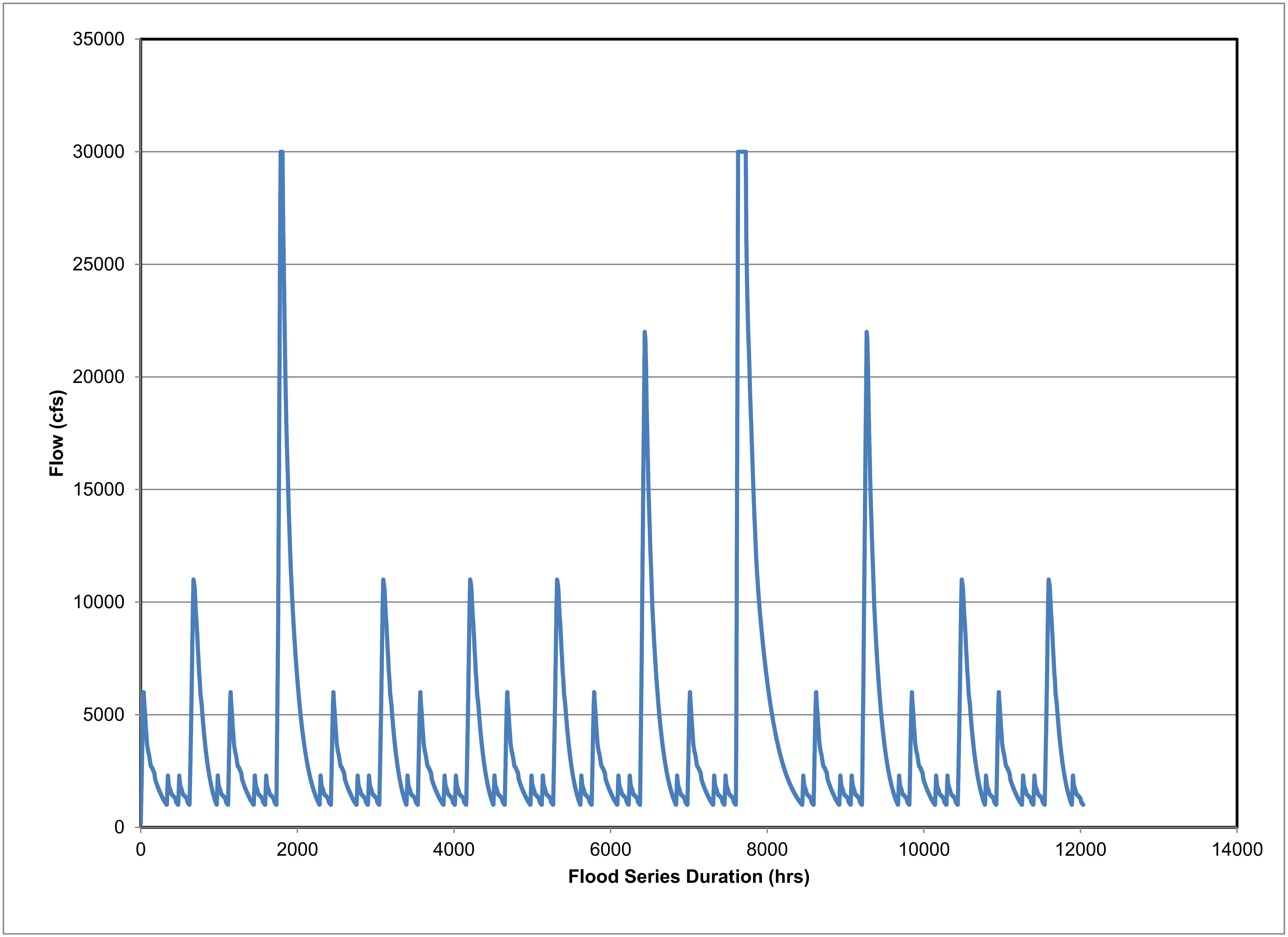


Figure 7-1 LSAR_TetraTech_HEC-6T_Flood_Hydrographs_Dec2013.xlsx\Chart1

TABLE 7-1 - EXISTING AND PROPOSED HEC-RAS MODEL OUTPUT FOR DEPTH AND VELOCITY FOR EXISTING AND PROPOSED CONDITIONS

River Sta	Depth (ft)			Velocity (ft/s)		
	Ex	Pr	D (Pr-Ex)	Ex	Pr	D (Pr-Ex)
148726*	18.3	18.3	0.0	14.5	14.5	0.0
148606*	18.2	18.2	0.0	14.6	14.6	0.0
148486*	18.4	18.4	0.0	13.9	13.9	0.0
148366*	18.3	18.3	0.0	13.8	13.8	0.0
148245	17.8	17.8	0.0	14.5	14.5	0.0
148130*	18.3	18.3	0.0	13.3	13.2	-0.1
148014*	18.7	18.7	0.0	12.3	12.2	-0.1
147898	19.1	19.1	0.0	11.5	11.4	-0.1
147751*	19.2	19.2	0.0	11.4	11.4	-0.1
147603	19.3	19.3	0.0	11.3	11.2	-0.1
147477*	20.0	20.0	0.0	10.0	9.9	-0.1
147351*	20.7	20.7	0.0	9.1	9.1	0.0
147225*	21.4	21.4	0.0	8.5	8.5	0.0
147099	22.0	22.0	0.0	8.1	8.1	0.0
146984*	22.0	22.1	0.0	8.1	8.1	0.0
146868	22.1	22.1	0.0	7.8	7.8	0.0
146752*	22.6	22.7	0.0	6.3	6.3	0.0
146636	23.2	23.2	0.1	5.1	4.0	-1.2
Bridge						
146597.**		**23.2**			**4.2**	
146558.**		23.1			5.7	
146519.*	23.0	23.0	0.0	5.9	5.9	0.0
146480.**		23.0			6.2	
146441.**		22.9			6.6	
146402	22.8	22.8	0.0	6.8	6.8	0.0
146269*	23.3	23.3	0.0	6.3	6.3	0.0
146136	23.8	23.8	0.0	6.0	6.0	0.0
146002*	23.6	23.6	0.0	6.3	6.3	0.0
145867*	23.5	23.5	0.0	6.5	6.5	0.0
145732	23.4	23.4	0.0	6.4	6.4	0.0
145594*	23.1	23.1	0.0	7.0	7.0	0.0
145456*	22.8	22.8	0.0	7.6	7.6	0.0
145318	22.6	22.6	0.0	7.8	7.8	0.0
145180*	23.2	23.2	0.0	8.0	8.0	0.0
145042*	23.9	23.9	0.0	7.8	7.8	0.0
144904	24.7	24.7	0.0	7.4	7.4	0.0
144792*	24.8	24.8	0.0	8.8	8.8	0.0
144679	24.5	24.5	0.0	11.2	11.2	0.0
144549*	24.1	24.1	0.0	12.6	12.6	0.0
144419	20.4	20.4	0.0	18.6	18.6	0.0
144305*	18.6	18.6	0.0	17.6	17.6	0.0
144190*	16.8	16.8	0.0	17.3	17.3	0.0
144076*	15.3	15.3	0.0	16.7	16.7	0.0
143961	13.8	13.8	0.0	16.0	16.0	0.0
143813	14.3	14.3	0.0	10.0	10.0	0.0
143715*	13.6	13.6	0.0	11.1	11.1	0.0
143617	13.3	13.3	0.0	11.5	11.5	0.0
143470*	15.4	15.4	0.0	9.0	9.0	0.0
143323	17.8	17.8	0.0	6.1	6.0	0.0
143190*	17.9	17.9	0.0	6.7	6.6	0.0
143057*	18.0	18.0	0.0	7.4	7.3	0.0
142923	18.1	18.1	0.0	8.0	7.9	0.0
142793*	16.3	16.3	0.0	10.0	10.0	0.0
142663	14.8	14.9	0.0	10.4	10.3	0.0
142533*	14.3	14.4	0.1	12.8	12.6	-0.2
142402	15.2	15.4	0.1	10.5	10.3	-0.2
142282*	14.9	15.0	0.2	10.0	9.9	-0.2
142161	14.8	14.9	0.2	8.9	8.7	-0.2
142054*	14.5	14.8	0.3	10.8	10.4	-0.4
141947*	14.8	15.2	0.4	11.0	10.6	-0.4
141840	15.4	15.8	0.4	9.9	9.6	-0.4
141718*	14.9	15.4	0.5	10.6	10.0	-0.6
141595*	14.9	15.5	0.6	9.9	9.3	-0.6
141472	15.1	15.7	0.6	8.4	7.9	-0.5
141344*	15.0	15.8	0.7	9.1	8.5	-0.7
Bridge						
141216*	**14.8**	**14.8**	**0.0**	**10.0**	**10.0**	**0.0**
141088*	14.4	14.4	0.0	11.2	11.2	0.0
140959	13.9	13.9	0.0	12.4	12.4	0.0
140815*	13.1	13.1	0.0	12.5	12.5	0.0
140671*	12.7	12.7	0.0	11.2	11.2	0.0
140526	12.6	12.6	0.0	9.7	9.7	0.0
140378*	12.7	12.7	0.0	10.3	10.3	0.0
140229*	12.7	12.7	0.0	10.9	10.9	0.0
140081*	12.6	12.6	0.0	11.3	11.3	0.0
139932	12.6	12.6	0.0	11.4	11.4	0.0
139782*	12.2	12.2	0.0	11.3	11.3	0.0
139632*	11.9	11.9	0.0	10.7	10.7	0.0
139482*	11.8	11.8	0.0	9.3	9.3	0.0
139332	12.0	12.0	0.0	7.8	7.8	0.0

* Identifies interpolated sections.

** Identifies interpolated sections related to proposed conditions bridges.

7.4 Bridge Hydraulics

The bridge routines in HEC-RAS allow the modeler to analyze a bridge with several different methods. The bridge routines have the ability to 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 sections in the computation of energy loss at structures. In addition, the program formulates two sections inside the bridge. The first section is located downstream enough 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, generally at the toe of the embankment. Sections three and four are similarly situated to sections 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. Losses due to contraction and expansion 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 head increases in the downstream direction, a contraction coefficient is used, and when the head decreases in the downstream direction an expansion coefficient is used.

Bridge routines in HEC-RAS analyze bridge hydraulics using several different methods. Bridge routines have the ability to model low flow, combined low and weir flow, pressure flow, combined pressure and weir flow, and submerged flows. For low flows, the program first identifies the class of flow using the momentum equation, and the controlling section is identified. The momentum at critical depth in the controlling section is compared to the momentum of the flow downstream of the bridge. Friction and contraction losses are then determined. Several different methods are available to determine losses, and the reader is encouraged to review the HEC-RAS manual for a full description of these options.

In the present modeling the standard step approach is used for the modeling approach. Contraction and expansion coefficients are set in the model as 0.3 and 0.5 in the vicinity of the bridges (one section downstream of the bridge and two sections upstream of the bridge), respectively, and 0.1 and 0.3 distant from structures, respectively. All other bridge data is taken from RBF (2011) and adjusted as described in Section 5.

Table 7-2 shows detailed output of the bridge hydraulics as computed by HEC-RAS. Output files can be found in the digital files in the Appendix.

TABLE 7.2 - PROPOSED CONDITIONS BRIDGE HYDRAULICS				
SRE1 DETAILED OUTPUT				
E.G. US. (ft)	395.7	Element	Inside BR US	Inside BR DS
W.S. US. (ft)	394.7	E.G. Elev (ft)	395.5	395.3
Q Total (cfs)	35800.0	W.S. Elev (ft)	393.7	393.4
Q Bridge (cfs)	35505.5	Crit W.S. (ft)	389.6	390.0
Q Weir (cfs)	-	Max Chl Dpth (ft)	14.8	14.9
Weir Sta Lft (ft)	-	Vel Total (ft/s)	9.8	10.0
Weir Sta Rgt (ft)	-	Flow Area (sq ft)	3658.7	3588.8
Weir Submerg	-	Froude # Chl	0.5	0.5
Weir Max Depth (ft)	-	Specif Force (cu ft)	33446.9	33076.4
Min El Weir Flow (ft)	391.2	Hydr Depth (ft)	9.7	9.4
Min El Prs (ft)	398.0	W.P. Total (ft)	457.5	454.4
Delta EG (ft)	0.9	Conv. Total (cfs)	572570.4	547866.8
Delta WS (ft)	1.3	Top Width (ft)	377.0	382.5
BR Open Area (sq ft)	4969.8	Frctn Loss (ft)	0.1	0.3
BR Open Vel (ft/s)	10.1	C & E Loss (ft)	0.0	0.2
Coef of Q	-	Shear Total (lb/sq ft)	2.0	2.1
Br Sel Method	Energy onl	Power Total (lb/ft s)	0.0	0.0
SRE2 DETAILED OUTPUT				
E.G. US. (ft)	417.4	Element	Inside BR US	Inside BR DS
W.S. US. (ft)	417.2	E.G. Elev (ft)	417.4	417.4
Q Total (cfs)	35000.0	W.S. Elev (ft)	417.2	417.2
Q Bridge (cfs)	23948.3	Crit W.S. (ft)	403.5	403.7
Q Weir (cfs)	-	Max Chl Dpth (ft)	23.2	23.2
Weir Sta Lft (ft)	-	Vel Total (ft/s)	2.4	2.5
Weir Sta Rgt (ft)	-	Flow Area (sq ft)	14590.4	13841.1
Weir Submerg	-	Froude # Chl	0.1	0.1
Weir Max Depth (ft)	-	Specif Force (cu ft)	116971.8	109562.3
Min El Weir Flow (ft)	404.0	Hydr Depth (ft)	13.0	12.6
Min El Prs (ft)	420.6	W.P. Total (ft)	1504.5	1176.8
Delta EG (ft)	0.0	Conv. Total (cfs)	2617172.0	2698727.0
Delta WS (ft)	0.1	Top Width (ft)	1122.3	1094.8
BR Open Area (sq ft)	7611.9	Frctn Loss (ft)	0.0	0.0
BR Open Vel (ft/s)	3.7	C & E Loss (ft)	0.0	0.0
Coef of Q	-	Shear Total (lb/sq ft)	0.1	0.1
Br Sel Method	Energy onl	Power Total (lb/ft s)	0.0	0.0

8.0 HABITAT IMPACTS ANALYSIS

8.1 Procedure

Hydraulic modeling was performed using the geo-referenced WEST HEC-RAS model, which had been modified by AECOM. The modified model was run by AECOM using the velocity distribution function described above. Once the model runs were completed for the existing and proposed conditions, the HEC-GeoRAS GIS plug-in was used to extract the geo-referenced velocity and depth distribution data. The original topography used to create the model was not available during analysis; however, the County provided appropriate topographic data to be used.

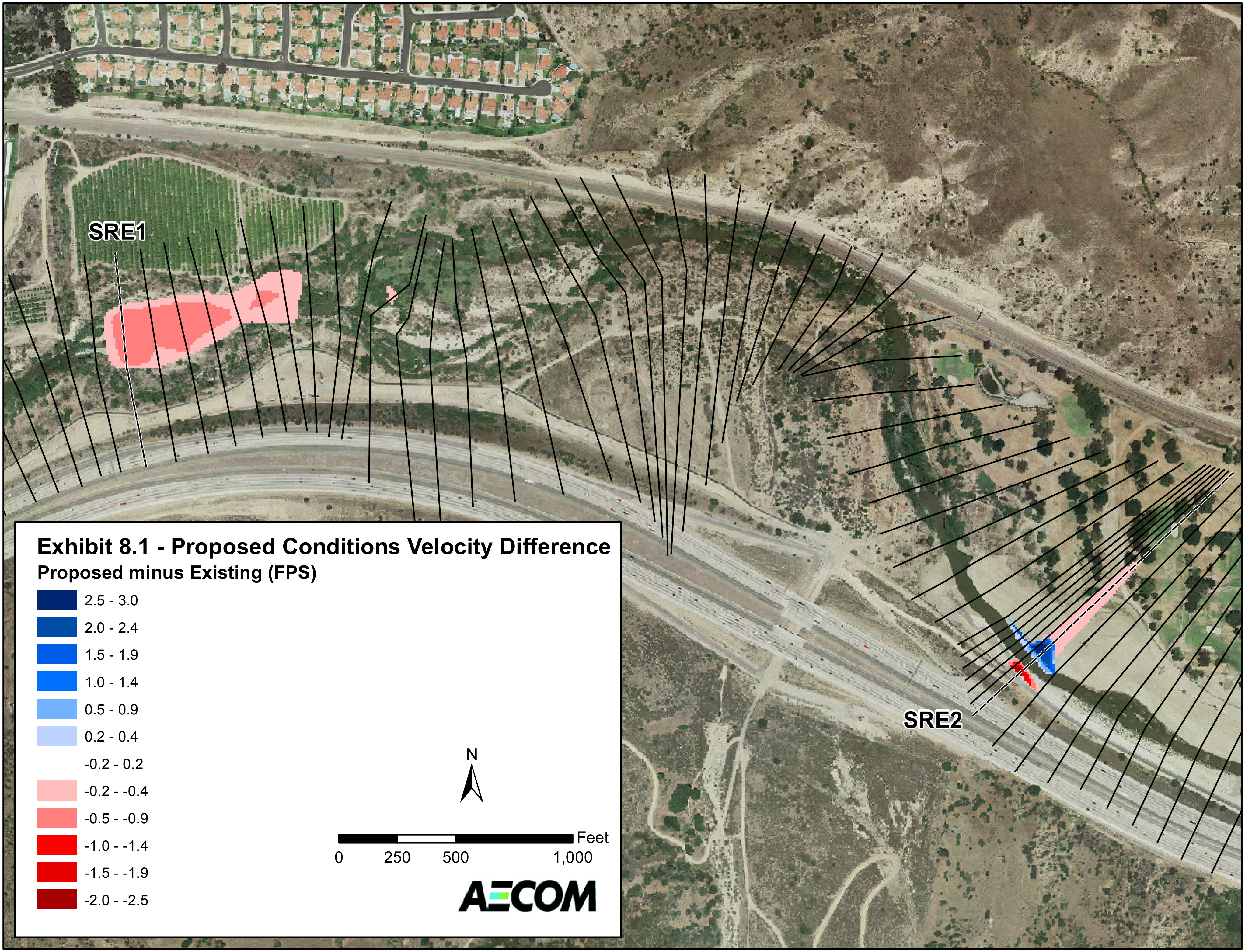
After the model data was extracted into GIS, the difference between the existing and proposed velocity and depth were calculated for each slice. This difference is given by:

$$\Delta_{v,h}^{i} = E_{v,h}^{i} - P_{v,h}^{i}$$

where Δ is the difference for slice i of the velocity, v, or depth, h, and E and P represent the existing and proposed condition, respectively. Since the location in space of the slice i is known, the difference in hydraulic parameters from the model output can easily be represented in space according to magnitude and its sign. The sign convention used herein is that a negative value represents a decrease in parameter from the existing condition, while a positive value represents an increase in parameter from the existing condition.

Next, the model output differences were overlain with geo-referenced habitat data provided by LSA and augmented with data from AECOM to assess which habitat types would be impacted by the proposed changes, and to calculate the areas of those impacts. The results of this analysis are shown in Exhibits 8-1 through 8-2.

The results of the analysis indicate that the impacts to habitat are primarily limited to the Cottonwood-Willow Riparian Forrest. There are 2.4 acres (ac) of discernible impacts to the flood regime that would occur in this habitat and, therefore, impact the existing plant populations from the proposed project during the design storm. It is important to note that these impacts are limited to decreases in velocity between Δv = -0.25 to -1.0 fps only: no increase in velocity is expected to impact this habitat type during the design event. The other habitats impacted by the proposed condition during the design event are largely either disturbed or non-native. The impacts are tabulated by habitat type and velocity in Table 8-1. Additionally, the modeling results indicate the following: 1) the overall hydrology will not be impacted by the proposed project; 2) the hydraulic impacts to Santa Ana River are expected to be limited only to the vicinity of the proposed bridges SRE1 and SRE2 during the design event; 3) the impacts to local hydraulics during the design are expected to primarily be limited to small decreases in velocity ($\Delta v <$ -0.25 fps); 4) the acreage of impacts with a decrease in velocity greater than Δv = -1.0 fps during the design event is expected to be ΔA = 0.0 ac; and 5) the acreage of impacts with an increase in velocity greater than $\Delta v = 1.0$ fps during the design event is expected to be $\Delta A = 0.2$ ac, with all of this category of impact occurring in disturbed or barren habitat.



SRE1
SRE2
Exhibit 8.1 - Proposed Conditions Velocity Difference
Proposed minus Existing (FPS)
2.5 - 3.0
2.0 - 2.4
1.5 - 1.9
1.0 - 1.4
0.5 - 0.9
0.2 - 0.4
-0.2 - 0.2
-0.2 - -0.4
-0.5 - -0.9
-1.0 - -1.4
-1.5 - -1.9
-2.0 - -2.5
N
Feet
0
250
500
1,000
AECOM

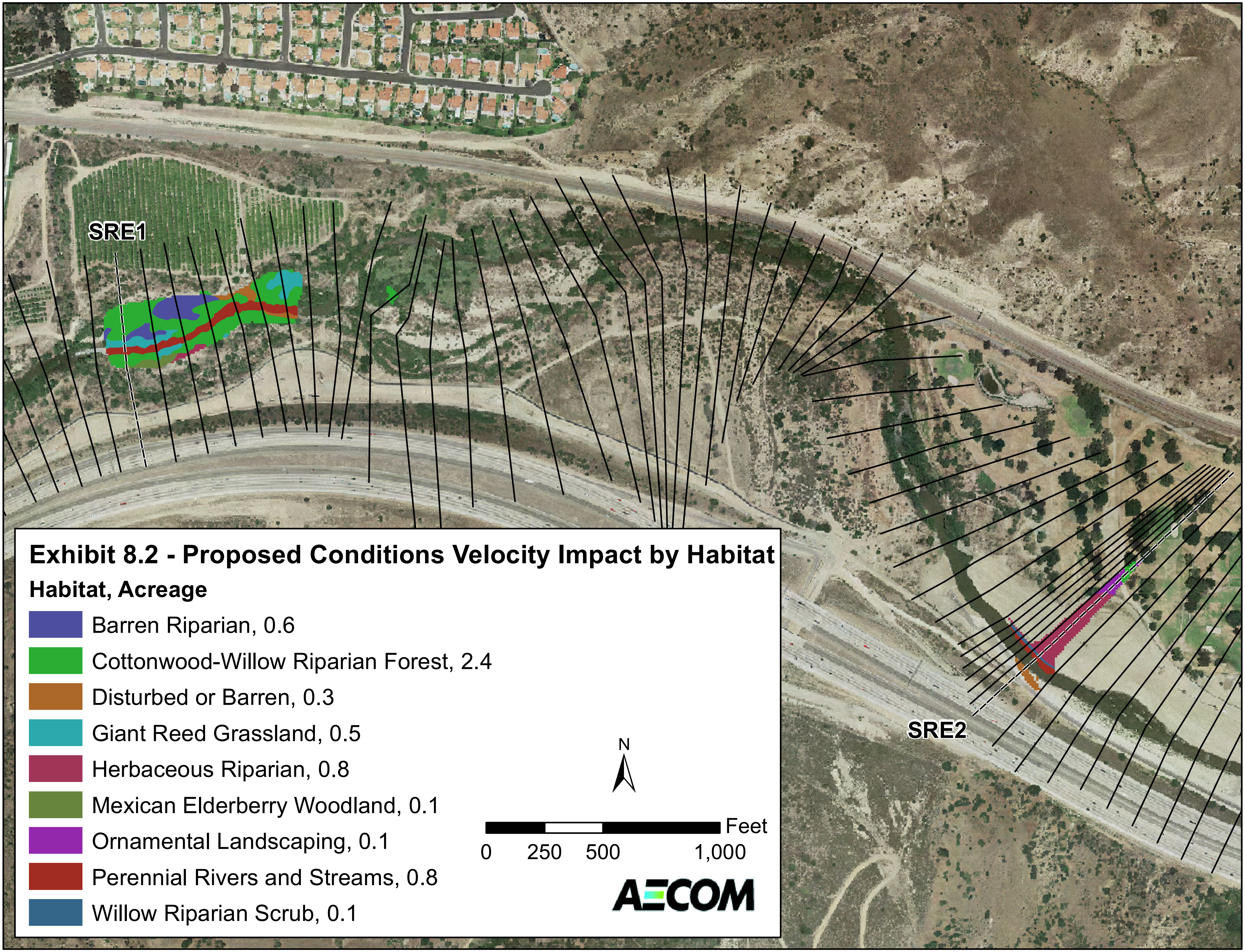

SRE1
SRE2
Exhibit 8.2 - Proposed Conditions Velocity Impact by Habitat
Habitat, Acreage
Barren Riparian, 0.6
Cottonwood-Willow Riparian Forest, 2.4
Disturbed or Barren, 0.3
Giant Reed Grassland, 0.5
Herbaceous Riparian, 0.8
Mexican Elderberry Woodland, 0.1
Ornamental Landscaping, 0.1
Perennial Rivers and Streams, 0.8
Willow Riparian Scrub, 0.1
N
0 250 500 1,000 Feet
AECOM

Table 8-1 - Habitat Impacts by Velocity Range and Habitat Type - Existing vs. Proposed Conditions												
Habitat	Velocity Change (fps)											
	0.25 - 0.49	-0.25 - -0.49	0.5 - 0.99	-0.5 - -0.99	1.0 - 1.49	-1.0 - -1.49	1.5 - 1.99	-1.5 - -1.99	2.0 - 2.49	-2.0 - -2.5	2.5 - 3.0	Total
Barren Riparian		0.2		0.4								0.6
Cottonwood-Willow Riparian Forest		1.3		1.1								2.4
Disturbed or Barren	0.0	0.2		0.0		0.0		0.0		0.0		0.3
Giant Reed Grassland		0.3		0.2								0.5
Herbaceous Riparian	0.0	0.6	0.0	0.0	0.0		0.0		0.1		0.0	0.8
Mexican Elderberry Woodland		0.1		0.0								0.1
Ornamental Landscaping		0.1										0.1
Perennial Rivers and Streams	0.1	0.3	0.0	0.4	0.0		0.0		0.0			0.8
Willow Riparian Scrub	0.0		0.0		0.0		0.0		0.0		0.0	0.1
Total	0.1	3.2	0.1	2.2	0.0	0.0	0.1	0.0	0.1	0.0	0.0	5.7

9.0 SCOUR ANALYSIS

Three forms of scour are considered in the present scour analysis following Federal Highway Administration's (FHWA) (FHWA 2001) HEC-18 criteria: general adjustment, long-term adjustment and local scour. Each of these components, as well as the total scour, are discussed in detail, below.

9.1 HEC-6T General Adjustment

The ACOE 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 hydrograph 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). From the hydraulic parameters, potential sediment transport rates are estimated for each model reach and scour, or deposition is next estimated so that cross-section shape can be updated. Sediment calculations are based on grain size distribution so that sorting and armoring can be considered. HEC-6 considers the interactions between sediment behavior in rivers with local hydraulics and bed geometry and conditions.

9.1.1 HEC-6T 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 bed friction. The model also uses both an up- and down-stream 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 criteria. Because the model is one-dimensional, there is no way to simulate meander development or specify lateral erosion.

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. Sediment transport functions are user selectable, and 13 different equations are possible. 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. Details describing the implementation of specific model parameters and functions are described below.

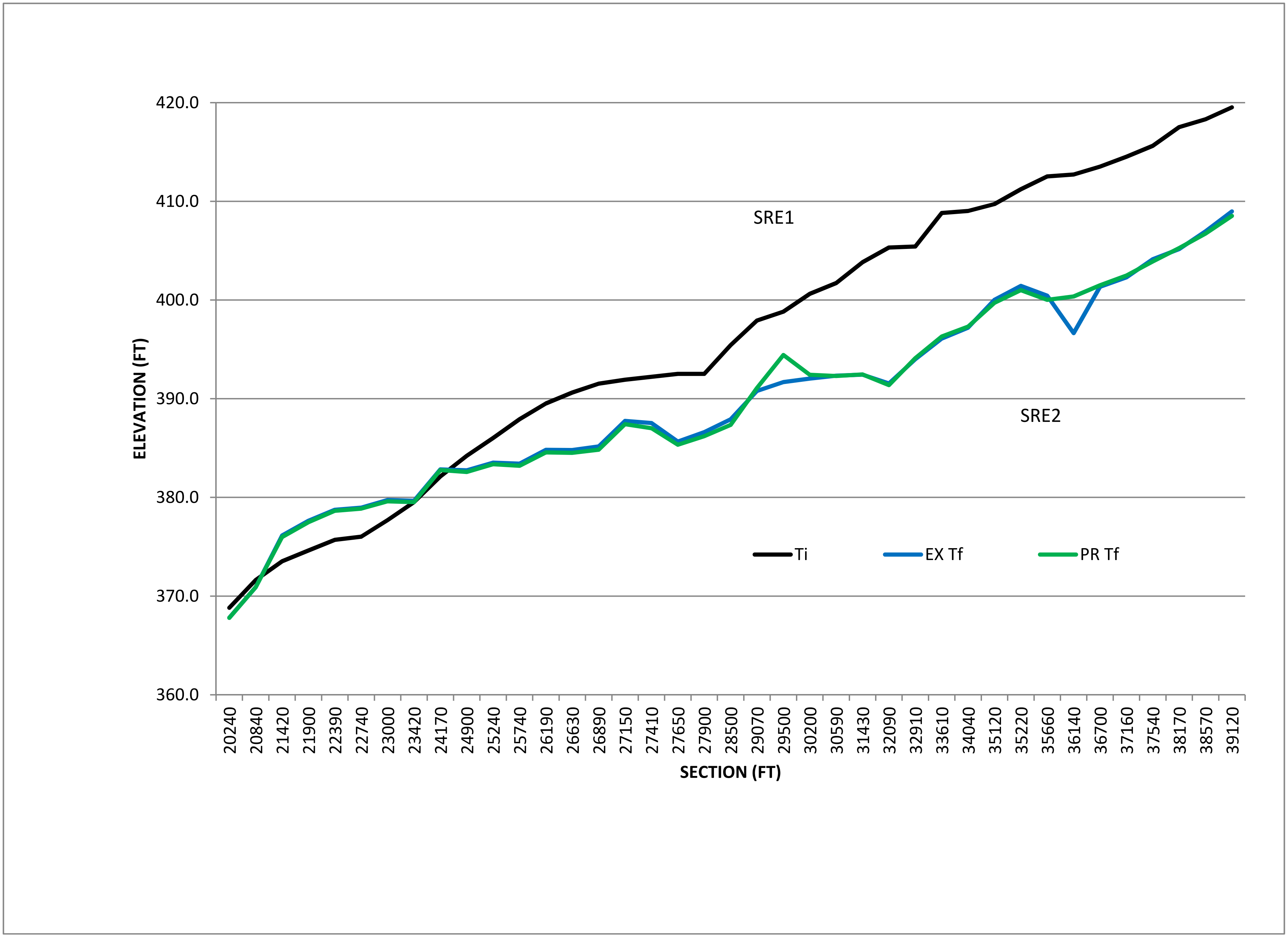
9.1.2 HEC-6T Model Assembly

The present study uses the HEC-6T model developed by Tetra Tech. The only changes made to the model are adjustments to the proposed condition cross-sections to represent the proposed conditions bridge abutment placement and related bridge elements.

9.1.3 HEC-6T General Adjustment

General adjustment based on HEC-6T modeling is presented in Figure 9-1 and Table 9-1 for the existing and proposed conditions, for both the inital and end-of-the-hydrograph (final) condition. Model bed adjustment results for existing conditions HEC-6T range from -16.1 to 3.0 feet. The average bed change for all sections is -6.5 feet. Model bed adjustment results for proposed conditions HEC-6T range from -13.9 to 2.9 feet. The average bed change for all sections is 6.4 feet. Table 9-1 also indicates that average bed change between the existing and proposed conditions is 0.0 feet for the study reach as a whole. The results generally indicate, then, that the proposed condition will have slightly less degradation than when compared to the existing condition, which appears to be degrading as a result of the placement and operation of Prado Dam.

Figure 9-1 - Comparison of Existing vs Proposed HEC-6T General Adjustment (ft), Santa Ana River



HEC6T ex-pr diff.xlsx\Chart1

TABLE 9-1 - COMPARISION OF EXISTING AND PROPOSED INITIAL AND FINAL SECTIONAL AREA FOR SECTION 29500 BY STATION ELEVATION (FT) AND SUBAREA (FT^2) FOR HEC-6T RESULTS

STA PR	STA EX	PR Ti	PR Tf	Δ PR	Δ AREA	EX Ti	EX Tf	Δ EX	Δ AREA	ΔΔ
0	0	443.3	443.3	0.0		443.3	443.3	0.0		0.0
13	13	443.0	443.0	0.0	0.0	443.0	443.0	0.0	0.0	0.0
22	22	442.5	442.5	0.0	0.0	442.5	442.5	0.0	0.0	0.0
31	31	442.6	442.6	0.0	0.0	442.6	442.6	0.0	0.0	0.0
32	32	433.4	433.4	0.0	0.0	433.4	433.4	0.0	0.0	0.0
50	50	428.6	428.6	0.0	0.0	428.6	428.6	0.0	0.0	0.0
60	60	424.2	424.2	0.0	0.0	424.2	424.2	0.0	0.0	0.0
65	65	421.9	421.9	0.0	0.0	421.9	421.9	0.0	0.0	0.0
74	74	418.2	418.2	0.0	0.0	418.2	418.2	0.0	0.0	0.0
77	77	416.3	416.3	0.0	0.0	416.3	416.3	0.0	0.0	0.0
79	79	416.2	416.2	0.0	0.0	416.2	416.2	0.0	0.0	0.0
84	84	416.2	416.2	0.0	0.0	416.2	416.2	0.0	0.0	0.0
89	89	415.6	415.6	0.0	0.0	415.6	415.6	0.0	0.0	0.0
91	91	415.2	415.2	0.0	0.0	415.2	415.2	0.0	0.0	0.0
93	93	413.2	413.0	-0.2	-0.4	413.2	409.9	-3.3	-6.6	3.1
95	95	412.1	412.7	0.5	1.1	412.1	407.8	-4.3	-8.7	4.9
98	98	409.6	411.8	2.2	6.5	409.6	404.5	-5.1	-15.3	7.3
103	103	407.9	411.5	3.6	17.8	407.9	403.3	-4.6	-23.1	8.2
111	111	403.4	410.0	6.6	53.0	403.4	398.0	-5.4	-43.0	12.0
112	112	403.4	410.0	6.6	6.6	403.4	398.0	-5.4	-5.4	12.0
113	113	402.8	410.0	7.1	7.1	402.8	397.1	-5.7	-5.7	12.9
114	114	402.5	410.0	7.4	7.4	402.5	396.6	-5.9	-5.9	13.4
120	120	400.2	409.7	9.5	57.0	400.2	393.1	-7.1	-42.8	16.6
123	123	400.5	409.8	9.3	27.9	400.5	393.4	-7.1	-21.4	16.4
126	126	400.5	409.8	9.3	27.9	400.5	393.4	-7.1	-21.4	16.4
132	132	399.0	395.0	-4.1	-24.4	399.0	391.9	-7.1	-42.8	3.1
139	139	398.5	394.4	-4.1	-28.4	398.8	391.7	-7.1	-50.0	3.1
220	171.9706	398.5	394.4	-4.1	-329.1	398.9	391.8	-7.1	-235.4	3.1
225	220	398.5	394.4	-4.1	-20.3	399.1	392.0	-7.1	-342.8	3.1
234	225	398.5	394.4	-4.1	-36.6	399.3	393.6	-5.8	-28.8	1.7
239	234	398.5	394.4	-4.1	-20.3	401.1	396.5	-4.6	-41.3	0.5
243.35101	239	398.5	394.4	-4.1	-17.7	404.1	399.5	-4.6	-23.0	0.5
248	248	398.5	394.4	-4.1	-18.9	414.5	409.6	-4.9	-44.3	0.9
249	249	398.5	394.4	-4.1	-4.1	414.3	411.5	-2.8	-2.8	-1.2
257	257	398.5	394.4	-4.1	-32.5	414.8	414.1	-0.7	-5.7	-3.4
296	296	398.5	394.4	-4.1	-158.5	415.2	415.2	0.0	0.0	-4.1
310	310	398.5	394.4	-4.1	-56.9	414.6	414.6	0.0	0.0	-4.1
324	324	398.5	394.4	-4.1	-56.9	414.3	414.3	0.0	0.0	-4.1
351	337	398.5	397.7	-0.8	-21.9	413.2	409.9	-3.3	-42.8	2.5
362	362	412.5	410.4	-2.1	-22.9	412.5	408.3	-4.2	-104.7	2.1
373	373	412.0	412.6	0.6	6.8	412.0	407.6	-4.5	-49.0	5.1
388	388	411.7	412.6	0.9	12.9	411.7	407.2	-4.5	-67.5	5.4
409	409	412.0	412.9	0.9	18.5	412.0	412.2	0.2	4.3	0.7
428	428	412.5	413.1	0.6	10.5	412.5	412.7	0.2	3.0	0.4
438	438	412.4	413.0	0.6	6.0	412.4	412.6	0.2	1.7	0.4
468	468	413.2	413.5	0.3	9.5	413.2	413.3	0.1	3.7	0.2
480	480	413.9	413.9	0.0	0.3	413.9	413.9	0.0	0.0	0.0
487	487	413.9	413.9	0.0	0.1	413.9	413.9	0.0	0.0	0.0
495	495	414.2	414.2	0.0	0.0	414.2	414.2	0.0	0.0	0.0
498	498	414.2	414.2	0.0	0.0	414.2	414.2	0.0	0.0	0.0
521	521	414.8	414.8	0.0	0.0	414.8	414.8	0.0	0.0	0.0
533	533	414.9	414.9	0.0	0.0	414.9	414.9	0.0	0.0	0.0
546	546	415.3	415.3	0.0	0.0	415.3	415.3	0.0	0.0	0.0
571	571	415.1	415.1	0.0	0.0	415.1	415.1	0.0	0.0	0.0
590	590	415.5	415.5	0.0	0.0	415.5	415.5	0.0	0.0	0.0
602	602	415.5	415.5	0.0	0.0	415.5	415.5	0.0	0.0	0.0
635	635	414.9	414.9	0.0	0.0	414.9	414.9	0.0	0.0	0.0
695	695	414.4	414.4	0.0	0.0	414.4	414.4	0.0	0.0	0.0
703	703	414.1	414.1	0.0	0.0	414.1	414.1	0.0	0.0	0.0
718	718	414.0	414.0	0.0	0.0	414.0	414.0	0.0	0.1	0.0
745	745	412.9	413.3	0.4	10.3	412.9	413.1	0.1	3.5	0.2
794	794	413.1	413.5	0.3	16.6	413.1	413.2	0.1	6.2	0.2
888	888	412.6	413.1	0.5	45.4	412.6	412.8	0.1	13.9	0.3
932	932	412.2	413.0	0.7	32.9	412.2	412.4	0.2	8.4	0.6
982	982	411.5	412.8	1.3	63.0	411.5	411.8	0.3	14.5	1.0
996	996	411.7	412.8	1.1	15.6	411.7	412.0	0.2	3.5	0.9
1042	1042	411.3	412.8	1.4	66.5	411.3	411.6	0.3	15.0	1.1
1057	1057	411.4	412.8	1.4	20.3	411.4	411.7	0.3	4.6	1.0
1088	1088	411.0	412.7	1.7	52.5	411.0	411.4	0.4	11.6	1.3
1144	1144	411.7	412.8	1.1	62.3	411.7	412.0	0.2	13.8	0.9
1169	1169	412.3	413.0	0.7	17.2	412.3	412.5	0.2	4.4	0.5
1199	1199	412.6	413.1	0.5	14.5	412.6	412.8	0.1	4.4	0.3
1211	1211	412.6	413.1	0.5	5.8	412.6	412.8	0.1	1.8	0.3
1258	1258	413.0	413.4	0.4	16.8	413.0	413.1	0.1	6.0	0.2
1298	1298	412.8	413.2	0.4	16.3	412.8	413.0	0.1	5.5	0.3
1324	1324	412.9	413.3	0.4	9.9	412.9	413.1	0.1	3.4	0.2
1344	1344	412.8	413.2	0.4	8.1	412.8	413.0	0.1	2.7	0.3
1369	1369	413.0	413.4	0.4	8.9	413.0	413.1	0.1	3.2	0.2
1443	1443	412.6	413.1	0.5	35.7	412.6	412.8	0.1	11.0	0.3
1456	1456	412.3	413.0	0.7	9.0	412.3	412.5	0.2	2.3	0.5
1489	1489	412.1	412.9	0.8	27.0	412.1	412.3	0.2	6.5	0.6
1506	1506	411.8	412.9	1.0	17.6	411.8	412.1	0.2	4.0	0.8
1547	1547	411.5	412.8	1.3	51.7	411.5	411.8	0.3	11.9	1.0
1551	1551	411.7	412.8	1.1	4.4	411.7	412.0	0.2	1.0	0.9
1582	1582	412.1	412.9	0.8	25.4	412.1	412.3	0.2	6.1	0.6
1597	1597	412.9	413.3	0.4	5.7	412.9	413.1	0.1	2.0	0.2
1617	1617	412.6	413.1	0.5	9.7	412.6	412.8	0.1	3.0	0.3
1622	1622	413.3	413.6	0.3	1.5	413.3	413.4	0.1	0.5	0.2
1628	1628	412.6	413.1	0.5	2.9	412.6	412.8	0.1	0.9	0.3
1630	1630	413.1	413.5	0.3	0.7	413.1	413.2	0.1	0.3	0.2
1631	1631	413.1	413.5	0.3	0.3	413.1	413.2	0.1	0.1	0.2
1634	1634	413.9	413.9	0.0	0.1	413.9	413.9	0.0	0.0	0.0
1653	1653	422.8	422.8	0.0	0.0	422.8	422.8	0.0	0.0	0.0
1658	1658	423.8	423.8	0.0	0.0	423.8	423.8	0.0	0.0	0.0
1662	1662	425.6	425.6	0.0	0.0	425.6	425.6	0.0	0.0	0.0
1689	1689	425.0	425.0	0.0	0.0	425.0	425.0	0.0	0.0	0.0
1692	1692	426.0	426.0	0.0	0.0	426.0	426.0	0.0	0.0	0.0
1702	1702	425.6	425.6	0.0	0.0	425.6	425.6	0.0	0.0	0.0
			SUM=	32.2	101.8		SUM=	-123.1	-1091.5	155.3
								PERCENT CHANGE =		-9.3

TABLE 9-1 - COMPARISION OF EXISTING AND PROPOSED INITIAL AND FINAL THALWEG ELEVATIONS BY SECTION FOR HEC-6T RESULTS (FT)

	SECTION	Ti	EX Tf	Δ EX	PR Tf	Δ PR	ΔΔ
	20240	368.8	367.8	-1.0	367.8	-1.0	0.0
	20840	371.6	370.9	-0.7	370.9	-0.7	0.0
	21420	373.5	376.1	2.6	376.0	2.5	-0.1
	21900	374.6	377.6	3.0	377.5	2.9	-0.1
	22390	375.7	378.7	3.0	378.6	2.9	-0.1
SRE2	**22740**	**376.0**	**379.0**	**2.9**	**378.9**	**2.8**	**-0.1**
	23000	377.7	379.7	2.0	379.6	1.9	-0.1
	23420	379.5	379.7	0.1	379.5	0.0	-0.1
	24170	382.1	382.8	0.7	382.8	0.7	-0.1
	24900	384.2	382.8	-1.5	382.6	-1.6	-0.2
	25240	386.0	383.5	-2.5	383.4	-2.7	-0.2
	25740	387.9	383.4	-4.5	383.2	-4.7	-0.2
	26190	389.5	384.8	-4.7	384.6	-5.0	-0.3
	26630	390.6	384.8	-5.8	384.5	-6.1	-0.3
	26890	391.5	385.2	-6.4	384.8	-6.7	-0.3
	27150	391.9	387.8	-4.2	387.4	-4.5	-0.3
	27410	392.2	387.5	-4.7	387.0	-5.2	-0.5
	27650	392.5	385.7	-6.9	385.3	-7.2	-0.3
	27900	392.5	386.6	-5.9	386.2	-6.3	-0.4
	28500	395.4	387.9	-7.5	387.3	-8.1	-0.6
	29070	397.9	390.8	-7.1	391.1	-6.8	0.3
SRE1	**29500**	**398.8**	**391.7**	**-7.1**	**394.4**	**-4.1**	**3.1**
	30200	400.6	392.0	-8.6	392.4	-8.2	0.4
	30590	401.7	392.3	-9.4	392.3	-9.4	0.0
	31430	403.8	392.4	-11.4	392.5	-11.4	0.0
	32090	405.3	391.5	-13.8	391.4	-13.9	-0.2
	32910	405.4	394.0	-11.4	394.1	-11.3	0.1
	33610	408.8	396.1	-12.7	396.3	-12.5	0.2
	34040	409.0	397.2	-11.8	397.3	-11.7	0.1
	35120	409.7	400.0	-9.7	399.7	-10.0	-0.3
	35220	411.2	401.4	-9.8	401.0	-10.2	-0.4
	35660	412.5	400.4	-12.1	400.0	-12.5	-0.4
	36140	412.7	396.6	-16.1	400.4	-12.4	3.7
	36700	413.5	401.3	-12.2	401.5	-12.0	0.1
	37160	414.5	402.3	-12.2	402.5	-12.0	0.2
	37540	415.6	404.1	-11.5	403.9	-11.7	-0.2
	38170	417.5	405.2	-12.4	405.3	-12.3	0.1
	38570	418.3	407.0	-11.4	406.7	-11.6	-0.2
	39120	419.5	409.0	-10.5	408.5	-11.0	-0.5

10.0 REFERENCES

Federal Highway Administration (FHWA). 2001. Hydraulic Engineering Circular Number 18. May.

Federal Register. 2003. V. 22, N. 139, p. 39802.

LSA. 2013. *Santa Ana River Canyon habitat Management Plan Maintenance and Monitoring Report* (Final Draft). February.

RBF. 2011. *Administrative Draft Initial Study/Mitigated Negative Declaration: Santa Ana River Parkway*. April 21.

Riverside County Flood Control and Water Conservation District (RCFCD). 1994. *Report on Santa Ana River Hydrology, Zone 4*. January.

Riverside County Flood Control and Water Conservation District (RCFCD). 2000. *Evaluation of the Hydrologic and Hydraulic Effects of Santa Ana River Channelization on Ordinary Flood Events in the Lower Perris Valley California*. June.

Thiros, S.A. 2010. *Conceptual Understanding and Groundwater Quality of the Basin-Fill Aquifers in the Santa Ana Basin, California. In Conceptual Understanding and Groundwater Quality of Selected Basin-Fill Aquifers in the Southwestern United States*. S. A. Thiros, L. M. Bexfield, D. W. Anning, and J. M. Huntington, Eds. National Water-Quality Assessment Program, Professional Paper 1781, U.S. Department of the Interior.

United States Army Corps of Engineers (ACOE). 2008. HEC-RAS River Analysis System. March.

United States Geological Survey (USGS). 2011. National Hydrography Dataset h\High-Resolution Flowline Data. March 16.

APPENDIX

HEC-RAS *(Digital Files provided on Compact Disc)*

HEC-6T *(Digital Files provided on Compact Disc)*

- Existing
- Proposed