4 Stream Stability Analysis

As part of the Ranch Plan ROMP, 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 vertical response of San Juan Creek and its tributaries. The purpose of the analysis in this report is to update the hydrology and sediment yield/production based on the proposed PA-3&4 drainage patterns and land uses.

The stream stability analysis includes discussions on sediment yield, stream stability, and lateral bank migration. The results of the study will be used to document the impacts of the change in hydrology and sediment yield on stream stability along both Gobernadora Canyon and San Juan Creek.

4.1 Existing Geomorphic Characteristics

The approved Ranch Plan ROMP characterized the existing geomorphology of San Juan Creek, Chiquita Canyon, and Gobernadora Canyon. A brief summary of these characterizations is provided below except for Chiquita, which was not evaluated for stream stability as part of the PA-3&4 ROMP.

4.1.1 San Juan Creek

Channel pattern. Channel pattern relationships were evaluated using empirical relationships formulated by Lane (1952), Leopold and Wolman (1957), and Henderson (1961). San Juan Creek main stem channel form was categorized as a “braided channel” system.

Longitudinal profile. Indications of historical behavior were derived from the plotted longitudinal profile. The main stem profile was considered to be slightly concave up, which suggests San Juan Creek has been a reasonably graded, braided watercourse for a long period of time. A braided system can be considered near equilibrium.

Historical movement and trends. A qualitative overview of historical movement and trends was conducted using a sequence of historical aerial photographs (1930, 1938, 1986, and 2005), focusing on the planimetric form and relative width as well as the encroachment of development and agricultural operations. Long-term lateral movement was evaluated based on changes in channel width and thalweg position throughout the historical period of record. The results of this historical assessment identified the channel shape as remaining consistent; however, the channel width has decreased roughly 40 percent.

Geometric relationships. The stability of the channel was evaluated using empirical channel geometry relationships developed by Bray (1979), Hey (et al, 1982), Ackers and Charlton (1971), Lacey (1929), Chang (1988), Kellerhals (1967), AMAFCA (1994), and Moody and Odem (1999). Hydraulic geometry regression relationships (Leopold and Maddock, 1952) were attained using HEC-RAS data and results.

Allowable velocity. Empirical methods used to evaluate allowable or permissible velocities include Fortier and Scobey (1926), modified Mavis and Laushey (BUREC; Jurnikis, 1971), Neill (1975), and USACE (1970; 1990; 1995). The computed reach-averaged results show that San Juan Creek is marginally erosive in the lower reaches. The most erosive conditions will occur at bridge locations within channelized reaches. Erosion on the upper terraces of the floodplain are expected during the 100-year flood. While lateral stability is difficult to predict, the allowable velocity results suggest the channel banks will erode, even in small floods, if the banks are not cohesive, and the presence of cohesive soils will provide some measure of resistance.

Equilibrium slope. Empirical relationships used to evaluate the equilibrium slope include AMAFCA (1994), BUREC (MacBroom, 1981), Bray (1979), Henderson (1961), Schoklitsch (Shulits, 1935), Meyer-Peter Muller (1948), Shields (1936), and Lane (1952). The computed reach-averaged equilibrium slopes do not show a distinct trend. The results vary more than two orders of magnitudes and there is poor correlation between the various method parameters and the measured data for San Juan Creek, which contributes to widespread results.

Armoring potential. Empirical methods related to the initiation of sediment movement that are recommended by the Bureau of Reclamation (BUREC; Pemberton and Lara, 1984) include Meyer-Peter Muller (1948), Mavis and Lushey (1948), Shields (1936), and Yang (1973). The average computed results indicate that a generalized depth to armor roughly varies from 0.1 feet (2-year event) to 1 foot (100-year event) throughout the PA-3&4 study reach. Field evidence suggests armoring may not fully develop. The formation of an armor layer can lead to an increased potential for lateral erosion.

4.1.2 Gobernadora Canyon

Physical setting. Gobernadora Canyon is a relatively steep stream oscillating between incised channel sections disconnected from the flood plain to shallow channels sections connected to a wide floodplain. The flow regime alternates between subcritical and supercritical flow. The bed and banks are generally comprised of sandy soils with intermittent sections of moderately cohesive soils.

Longitudinal profile. The profile is relatively steep with an average slope of approximately 1.2 percent. There are significant head-cut formations that are active and can be expected to continue with or without development activities.

Allowable velocity. Gobernadora Canyon is considered moderately erosive for events as frequent as the 2-year flood.

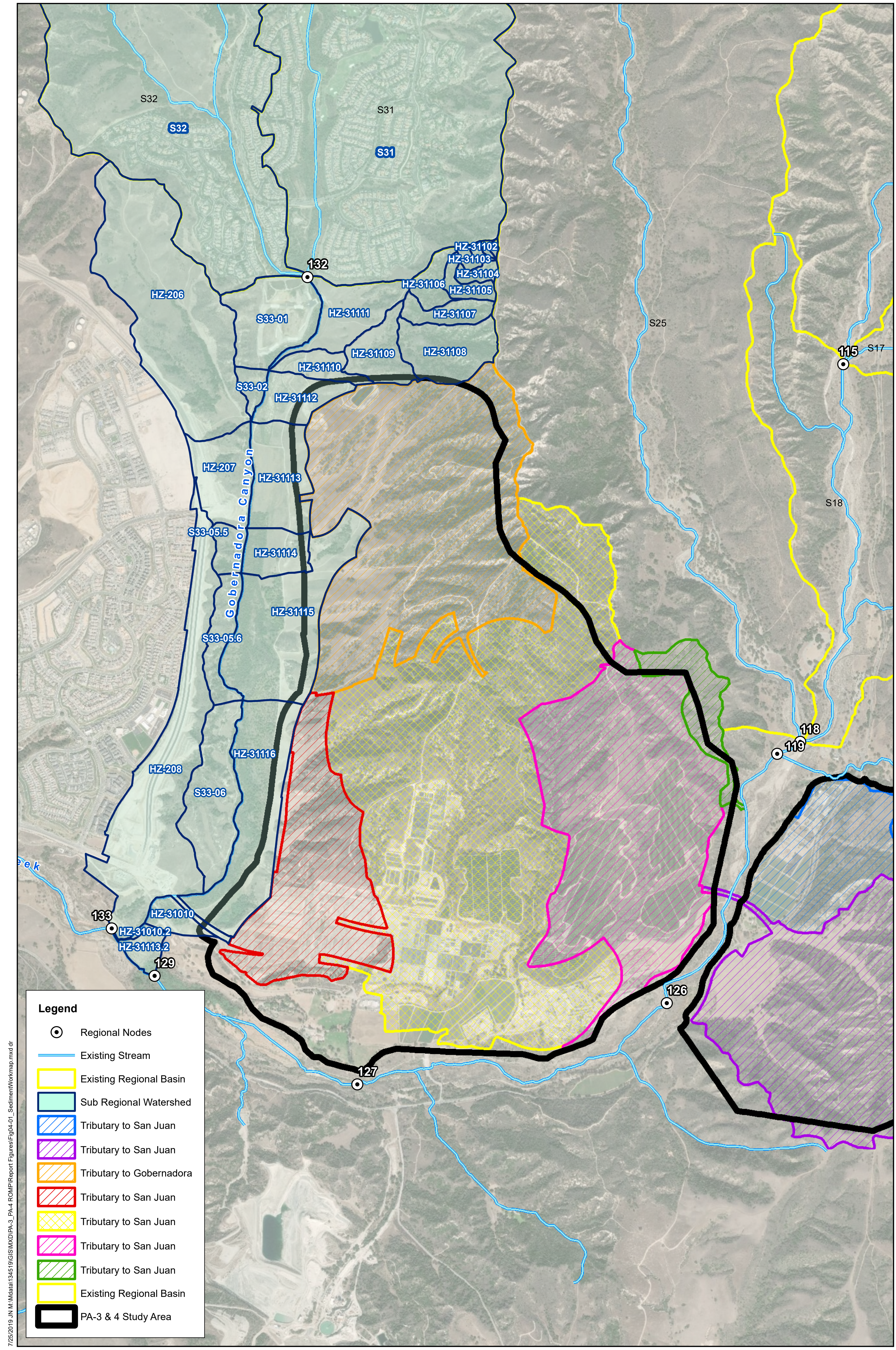
Equilibrium slope. The AMAFCA (1994) methodology produced the only results that were within an order of magnitude of the existing conditions. The equilibrium slope is generally flatter than the existing slope, which suggests that there will be a tendency for the watercourse to degrade over time.

Armoring potential. No significant evidence of armoring was observed during field reconnaissance.

4.2 Sediment Yield

One of the factors effecting stream stability is sediment. Sediment production contributes to the relationship of stream erosion/stability due to the balance between sediment yield and the transport capacity of the stream.

Watershed transport capacity corresponds to the amount of sediment capable of being delivered by the channel system. Sediment yield is the amount of erosional debris produced by a watershed. The Modified Universal Soil Loss Equation (MUSLE) was used to predict the sediment yield within the San Juan Creek, Chiquita Canyon, Gobernadora Canyon watersheds using an approach similar to what was used in the approved Ranch Plan ROMP. In this update, the MUSLE regional coefficient (β) was revised to adapt the MUSLE to the ordinate (“instantaneous”) discharges, which form a flood hydrograph and its application in the sediment transport model using rating curves to define the sediment inflow boundary conditions and tributary contributions. Figure 4-1 shows the sediment work map.



Michael Baker INTERNATIONAL

Source: PACE, Huitt-Zollars, Geosyntec, ESRI Online

RANCHO MISSION VIEJO - PA3&4

Sediment Work Map

Figure 4-1

The MUSLE predicts sediment yield for individual storm events using the following equation:

$$Y_s = \alpha \times (Q_p \times V)^{\beta} \times K \times LS \times C \times P \text{ (Equation 1)}$$

Where:

Y_s = Sediment yield (tons)
V = event runoff volume (acre-feet or ac-ft)
Q_p = event peak runoff rate (cubic feet per second or cfs)
K = soil erodibility factor
LS = hillslope length-slope factor
C = cover management factor
P = erosion management practice factor
α = Regional coefficient = 95
β = Regional coefficient = 0.56 (For entire watershed)

Assumptions:

1. LS, K, C values are as presented in the Ranch Plan ROMP and used in this study.
2. Proposed Land Use (LU) was updated to reflect changes within the PA-3&4 area.

Procedure:

The steps used herein to determine the sediment yield are consistent with the approved Ranch Plan ROMP except for these modifications.

1. The updated sub-watersheds for the existing, and ultimate conditions were used to determine portions of the watershed at each concentration point (inflow points).
2. Table 4-1 shows the subareas at each inflow point.

Table 4-1: Gobernadora Canyon inflow points and corresponding subareas

HEC-RAS XS	Hydrology Node	Subareas
14183	13222	S31, S32
2096	13305	HZ-31100, HZ-31101, HZ-31102, HZ-31103, HZ-31104, HZ-31105, HZ-31106, HZ-31107, HZ-31108, HZ-31109, HZ-31110, HZ-31111, S33-01, HZ-206, S33-02, HZ-31112, HZ-207, HZ-31113, S33-05.5, HZ-31114, S33-05.6, HZ-31115
544	13308	HZ-31116, S33-06, HZ-208, HZ-31010, HZ-31010.2, HZ-31113.2

3. In order to find the instantaneous sediment yield contributing from each sub-watershed, the product of the total volume and peak discharge at each concentration point was equated to the summation of volume and discharge at each time increment (See Equation 2). The equation was applied for the 2- thru 100-year storm events unit hydrographs at each of the concentration points to calculate the minimum and maximum regional coefficient (β) for the Gobernadora sub-watershed.

$$(QpV)^{0.56} = (\sum_{i=1}^{n}(QiVi))^{\beta} \text{ (Equation 2)}$$

4. The minimum regional coefficient was selected for the sediment yield analysis to represent all storm events because it produces the least sediment for the watershed. Table 4-2 summarizes the results of the regional coefficient for each storm event.

Table 4-2: Gobernadora Canyon Sub-watershed Regional Coefficient (β)

Event	Node 132C	Node 133T	β
100	0.459	0.455	0.455
50	0.459	0.455	0.455
25	0.458	0.454	0.454
10	0.460	0.453	0.453
5	0.448	0.442	0.442
2	0.435	0.429	0.429
-		**Max**	0.455
-	-	**Min**	0.429

5. The sediment yield at each inflow point was calculated for a range of discharges using the MUSLE equation (Equation 1) with the minimum regional coefficient (β) as shown in Tables 4-2 and 4-3.

$$Y_s = 95 \times (Q_p \times V)^{\beta} \times K \times LS \times C \times P$$

6. The cumulative sediment yield from each watershed condition (Existing, Phased, and Ultimate) was used in the development of the San Juan Creek sediment transport model.
7. The PA-3&4 developed condition assumes zero sediment production from the planning area.
8. The coefficients for Chiquita Canyon were determined from the sediment yield calculations previously developed in the PA-2 ROMP. Table 4-3 summarizes the results of the regional coefficient for each storm event.
9. Sediment yield for San Juan Creek was determined using the sediment rating curve set up in the 2013 Ranch Plan ROMP at node 119.

Table 4-3: Chiquita Canyon Watershed Regional Coefficient (β)

Event	Ultimate Chiquita Node 134t (β)
100	0.456
50	0.454
25	0.452
10	0.450
5	0.428
2	0.404
Max	**0.456**
Min	**0.404**

4.2.1 Sediment Inflow

The Gobernadora Canyon sediment inflow was obtained using the relationship between the flood hydrograph and MUSLE sediment yield calculations as outlined above. The Gobernadora Canyon existing conditions subarea sediment yields are summarized in Table 4-4 for a range of discharges.

Table 4-4: Gobernadora Canyon Existing Conditions Sediment Yield

Q (cfs)	132C	133T
	tons	
1.00	2	5
5.00	20	31
10.00	34	96
50.00	107	317
100.00	326	524
250.00	596	1841
500.00	900	2877
1000.00	1260	4446
3000.00	2157	8022

The Gobernadora Canyon ultimate conditions subarea sediment yields are summarized in Table 4-5 for a range of discharges.

Table 4-5: Gobernadora Canyon Ultimate Conditions Sediment Yield

Q (cfs)	132C	133T
	tons	
1.00	2	2
5.00	20	15
10.00	34	44
50.00	107	143
100.00	328	278
250.00	602	857
500.00	909	1306
1000.00	1274	1960
3000.00	2184	3522

Table 4-6 summarizes the Chiquita Canyon existing and ultimate conditions subarea sediment yields computed for a range of discharges.

Table 4-6: Chiquita Canyon Sediment Yield

Q (cfs)	Existing	Ultimate
	Node 134T	
	Tons	
1.00	4	4
5.00	20	19
10.00	57	52
50.00	174	170
100.00	314	318
250.00	912	904
500.00	1440	1379
1000.00	2152	2033
3000.00	3835	3552

Table 4-7 summarizes the San Juan Creek existing and ultimate conditions subarea inflow sediment yields computed for a range of discharges at regional node 119. Development is not proposed upstream of 119 so existing and ultimate yields are the same.

Table 4-7: San Juan Creek Sediment Yield

Q (cfs)	Existing	Ultimate
	Node 119T	
	Tons	
1.00	21	21
5.00	135	135
10.00	283	283
50.00	1326	1326
100.00	2314	2314
500.00	10975	10975
1000.00	23326	23326
25000.00	400771	400771
50000.00	608124	608124

4.3 Sediment Transport Model Development

As part of the Ranch Plan ROMP, 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 San Juan Creek and its tributaries.

The methods, procedures, and applications used to previously evaluate the streambed stability of San Juan Creek and its tributaries (Chiquita and Gobernadora) are generally intended for reconnaissance-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. A budget analysis was conducted to determine the relative streambed vertical response trends (developed versus existing conditions) for the sequence of subreaches associated with the watercourse of interest.

As part of this previous assessment, San Juan Creek was segmented into 10 subreaches, ranging in streambed length from roughly 2,400 feet to 6,900 feet with an average length of nearly one mile. For each subreach, the net streambed vertical adjustment was determined for each set of conditions; however, variability with regard to deposition and/or scour that may occur within a subreach is unknown. For example, a subreach of constant streambed width may experience 5 feet of deposition along half its length and 5 feet of scour along the remaining half. From a subreach perspective, no vertical change would be observed, because the occurrence of deposition and scour offset each other; As a result, this type of analysis may falsely suggest that a subreach or a sequence of subreaches are unaffected.

To reduce the potential of a false assessment as it relates to streambed stability, a more detailed approach was pursued herein using HEC-6T v5.13.22.5 (MBH, 2005), a one-dimensional mobile boundary hydraulic and sediment transport computer model. HEC-6T is a proprietary version of HEC-6 v4.1.0 (USACE, 1993), which was developed based on the HEC-2 platform. However, HEC-6T does not use all of the capabilities implemented in HEC-2 (e.g., special bridge routines and split flow analysis).

HEC-6T theoretical assumptions and limitations. HEC-6T is a one-dimensional, quasi-dynamic, continuous simulation model that applies a sequence of steady flows to represent a flood hydrograph. The cross section is subdivided into two parts: one that has a moveable bed and one that does not. The moveable bed is constrained within the limits of the wetted perimeter. The entire wetted part of the cross section is normally moved uniformly up or down. Alternatively, HEC-6T can be directed to adjust the bed elevation in horizontal layers when deposition occurs. Secondary currents, transverse movement, transverse variation, lateral diffusion, and transmission losses are ignored; therefore, the model cannot simulate phenomena such as river meandering, point bar formation, pool-riffle formation, and many other planform changes. Bed forms are not simulated but can be emulated indirectly by assigning n-values as functions of discharge. Local erosion and deposition caused by water diversion, bridges, and other in-stream structures may not be simulated. Only one closed loop and one distributary can be defined.

HEC-6T event-based analysis. HEC-6T is designed to analyze long-term scour and deposition. Single flood event analyses should be performed with caution. The HEC-6T bed-material transport algorithms assume that equilibrium conditions are reached within each time step; however, the model is often influenced by unsteady non-equilibrium conditions during flood events. Equilibrium may not occur under these conditions because of the continuously changing hydraulic and sediment dynamics. If such situations predominate, single event analyses should be performed only on a qualitative basis. For gradually changing sediment and hydraulic conditions, such as for large rivers with slow rising and falling hydrographs, single event analyses may be performed with confidence.

4.3.1 HEC-6T Model Definitions

San Juan Creek. The previously developed San Juan Creek baseline HEC-6T model (PACE, 2010) was modified to support the streambed stability analysis for PA-3&4, performed herein, truncating the model to only consider the reach from 1,000 feet below La Novia Bridge up to regional node 119.

Gobernadora Canyon. The previously developed Gobernadora HEC-6T model (Michael Baker International, 2017) was modified to support the streambed stability analysis for PA-3&4.

Chiquita Canyon. There are no planned outfalls or diversions associated with PA-3&4 that would affect Chiquita Canyon, therefore, no evaluation was performed for this tributary, which borders the west side of PA-2.

4.3.1.1 Selection of Sediment Transport Relationships

There are 21 sediment transport relationships that are available for use in HEC-6T. The selection process of one or more appropriate transport functions for testing is imperfect at best. 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. 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.

The sediment transport relationships available in HEC-6T include the following:

- Toffaleti (1968)
- Madden’s (1963) modification of Laursen’s (1958) relationship
- Yang’s stream power (1973)
- Duboy’s (Brown, 1950)
- Einstein
- Ackers-White (1973)
- Colby (1964)
- Toffaleti and Schoklitsch combination

- Meyer-Peter and Muller (MPM) gravel transport (1948)
- Schoklitsch gravel transport
- Toffaleti (1968) – MPM (1948) combination
- Madden's (1985) modification of Laursen's (1958) relationship
- Laursen-Copeland
- Engelund-Hansen
- Parker gravel transport (1990)
- Profitt (Sutherland)
- Brownlie with transport normalized at D50
- Brownlie with transport based on each grain size
- Yang high concentration formula (1996)

Comparing the tested parameter ranges of those sediment transport functions defined in HEC-6T (Table 4-8) to the average hydraulics and sediment gradation for San Juan Creek and Gobernadora Canyon 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 San Juan Creek and Gobernadora Canyon; in addition, several other functions were evaluated as a means of gauging relative performance: (1) Toffaleti (1969), (2) Yang (1973), (3) Ackers-White (1973), (4) Toffaleti (1969) combined with Schoklitsch (1930), (5) Laursen (1958) modified by Madden (1985), and (6) Laursen (1958) modified by Copeland and Thomas (1989).

Table 4-8: HEC6T available sediment transport functions and their original developed parameter range (USACE, 2003)

Available HEC6T sediment transport relationships	Data Source	Median Sediment Size (mm)	Sediment Size Range (mm)	Velocity (fps)	Depth (ft)	Effective Width (ft)	Energy Gradient (ft/ft)
Toffaleti (1968)	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 (1968) and MPM (1948), combined		see individual listings for Toffaleti (1968) and MPM (1948)					
Toffaleti (1968) 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

4.3.1.2 Sediment Inflow Boundary Conditions

4.3.1.3 Gobernadora Canyon Creek

The inflow curve from the Gobernadora Scour Report (September 2017) was used for the Gobernadora HEC-6T model. The inflow curve was based on data collection conducted by GMU Geotechnical along Gobernadora Canyon Creek along the study reach (2006 and 2016). HEC-6 gradation classifications use the American Geophysical Union Scale. The transport function is selected using the U.S. Army Corps of Engineers (USACOE) SAM Hydraulic Design Package for Channels SAM.AID function.

4.3.1.4 San Juan Creek

The Modified Universal Soil Loss Equation (MUSLE) was generally used as prescribed in the Approved Ultimate ROMP to determine the watershed coarse sediment contributions to San Juan Creek and its tributaries for all applicable conditions to evaluate the streambed stability impacts related to a reduction in coarse sediment production and delivery. The MUSLE was originally parameterized to compute the sediment yield for a total storm, relying on the event peak discharge and total runoff volume. In order to relate the results in the form of a rating curve at inflow points defined within the HEC-6T model format, the exponent coefficient requires adjustment to correlate the summation of computed ordinate-based sediment yields to the computed total storm sediment yield. The total storm sediment yield exponent coefficient is defined as 0.56 for the southern California region. To satisfy the correlation between total storm and ordinate-based calculations, the exponent coefficient was adjusted to a value of 0.46. This approach was used to develop the HEC-6T sediment inflow rating curves for the San Juan Creek local inflow points.

4.3.1.5 Hydraulic Boundary Conditions

The downstream hydraulic controls for San Juan Creek were determined from the hydraulic model previously developed as part of the Approved Ultimate ROMP. The applied rating curve is shown in Table 4-9. The Gobernadora model uses a normal depth water surface elevation based on the slope of 0.0001 as the downstream boundary condition to initiate the hydraulic calculations. Figure 4-2 shows cross section 18111 location.

Table 4-9: San Juan Creek Downstream Hydraulic Control at XS 18111

Q (cfs)	WSE (ft)	Flow Depth (ft)
0	82.72	0.00
1,000	86.79	4.07
2,000	87.79	5.07
3,000	88.79	6.07
4,000	89.79	7.07
5,000	90.78	8.06
6,000	91.38	8.66
7,000	91.98	9.26
8,000	92.57	9.85
9,000	93.17	10.45
10,000	93.77	11.05

Q (cfs)	WSE (ft)	Flow Depth (ft)
11,000	94.12	11.40
12,000	94.47	11.75
13,000	94.81	12.09
14,000	95.16	12.44
15,000	95.51	12.79
16,000	95.86	13.14
17,000	96.21	13.49
18,000	96.55	13.83
19,000	96.90	14.18
20,000	97.25	14.53
21,000	97.45	14.73
22,000	97.65	14.93
23,000	97.84	15.12
24,000	98.04	15.32
25,000	98.24	15.52
26,000	98.44	15.72
27,000	98.64	15.92
28,000	98.83	16.11
29,000	99.03	16.31
30,000	99.23	16.51

4.3.1.6 Bed-material Gradation Curves

The bed-material gradation curves are based on the sampling and analysis presented in the Approved Ultimate ROMP (Section 12.3.2). For San Juan Creek, samples OC3, OC5, OC6, and OC7 were defined in the model at the downstream terminus (XS 18111), downstream of the Gobernadora Canyon confluence (XS 38665), upstream of the Gobernadora confluence (XS 42073), and the upstream terminus (XS 52124) respectively. For Gobernadora Canyon, the distribution data used for the sediment and scour analysis was an average of various samples. The samples are a result of data collection conducted by GMU along Gobernadora Canyon in their 2006 study.

4.3.1.7 Hydrology

Event-based and long-term flood hydrographs were defined for each set of conditions modeled, which include the existing, phased-mitigated, and ultimate-mitigated conditions for San Juan Creek and the existing and ultimate conditions for Gobernadora Canyon.

The main stem upstream inflow boundary for San Juan Creek corresponds to hydrologic Node 126 and hydraulic cross section 52124, located downstream of the PA-4 Outfall 22. The tributary inflow points defined for San Juan Creek are as follows:

- Node 126 (XS 52124) – located immediately downstream from PA-4 Outfall 22
- Node 127 (XS 45373) – located immediately downstream of PA-3 Outfall 13
- Node 133U (39524) – located immediately downstream of regional node 129 and PA-3 Outfall 11

- Node 133T (2096) – located at the confluence of Gobernadora Canyon and San Juan Creek
- Node 133c (XS 39524) – located immediately downstream from the Gobernadora Canyon confluence; includes the hydrologic contribution from PA-2 Outfall 7
- Node 134u (XS 36074) – located immediately upstream from the Chiquita Canyon confluence; includes the hydrologic contribution from PA-2 Outfall 5
- Node 134c (XS 35121) – located immediately downstream from the Chiquita Canyon confluence
- Nodes 137, 138, and 139 (XS 27634, 22946, and 19802, respectively) – located downstream from PA-2 with Node 139 occurring immediately downstream from the La Novia Bridge; these nodes represent the hydrologic contributions received from areas located below the planned development

The main stem upstream inflow boundary for Gobernadora Canyon corresponds to hydrologic node 132C and hydraulic cross section 52124, located northwest of PA-3 Subwatershed A. The tributary inflow points defined for Gobernadora Canyon are as follows:

- Nodes 13222, regional node 132 (XS 14717) – located northwest of PA-3 Subwatershed A
- Node 133t (XS 6873)– located immediately upstream from the San Juan Creek confluence

Event-based flood hydrographs. A sequence of interval-averaged discharges was defined for each flood hydrograph evaluated, which included the 2-, 5-, 10-, 25-, 50-, and 100-year expected value events. Tributary inflows were defined as incremental discharges, which were added to the main stem discharge.

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 flood hydrographs for San Juan Creek and Gobernadora Canyon.

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 flood 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 of 45 minutes (based on County guidance) was assigned to the annual maximum flow, centered within the daily mean 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:

$$\cancel{V}_m = 0.015\cancel{V}_{100} + 0.015\cancel{V}_{50} + 0.04\cancel{V}_{25} + 0.08\cancel{V}_{10} + 0.2\cancel{V}_5 + 0.4\cancel{V}_2 \text{ (Chang, 1988)}$$

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 cubic feet per second, 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.

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. 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, shown in Table 4-10 and Table 4-11, this hydrograph is input into the HEC-6 model to run the long-term scour for Gobernadora.

Table 4-10: Gobernadora Long-term Discharge Adjustment Factors

Node Translation	Adjustment Factor	
	Existing Conditions	Ultimate-Mitigated Conditions
139 to 133c	0.92	0.92
133C to 133t	0.118	0.118
133t to 132u	0.7017	0.7017

Table 4-11: San Juan Creek Long-term Discharge Adjustment Factors

Node Translation	Adjustment Factor		
	Existing Conditions	Phased-Mitigated Conditions	Ultimate-Mitigated Conditions
139 to 137	0.98	0.98	0.98
139 to 134C	0.97	0.97	0.97
139 to 134u	0.93	0.93	093
139 to 133c	0.92	0.92	0.92
139 to 133u	0.86	086	0.86
139 to 127	0.85	0.84	0.84
139 to 126	0.84	0.84	0.83

4.3.2 Summary and Discussion of Event-based and Long-term HEC-6T Model Simulation Results

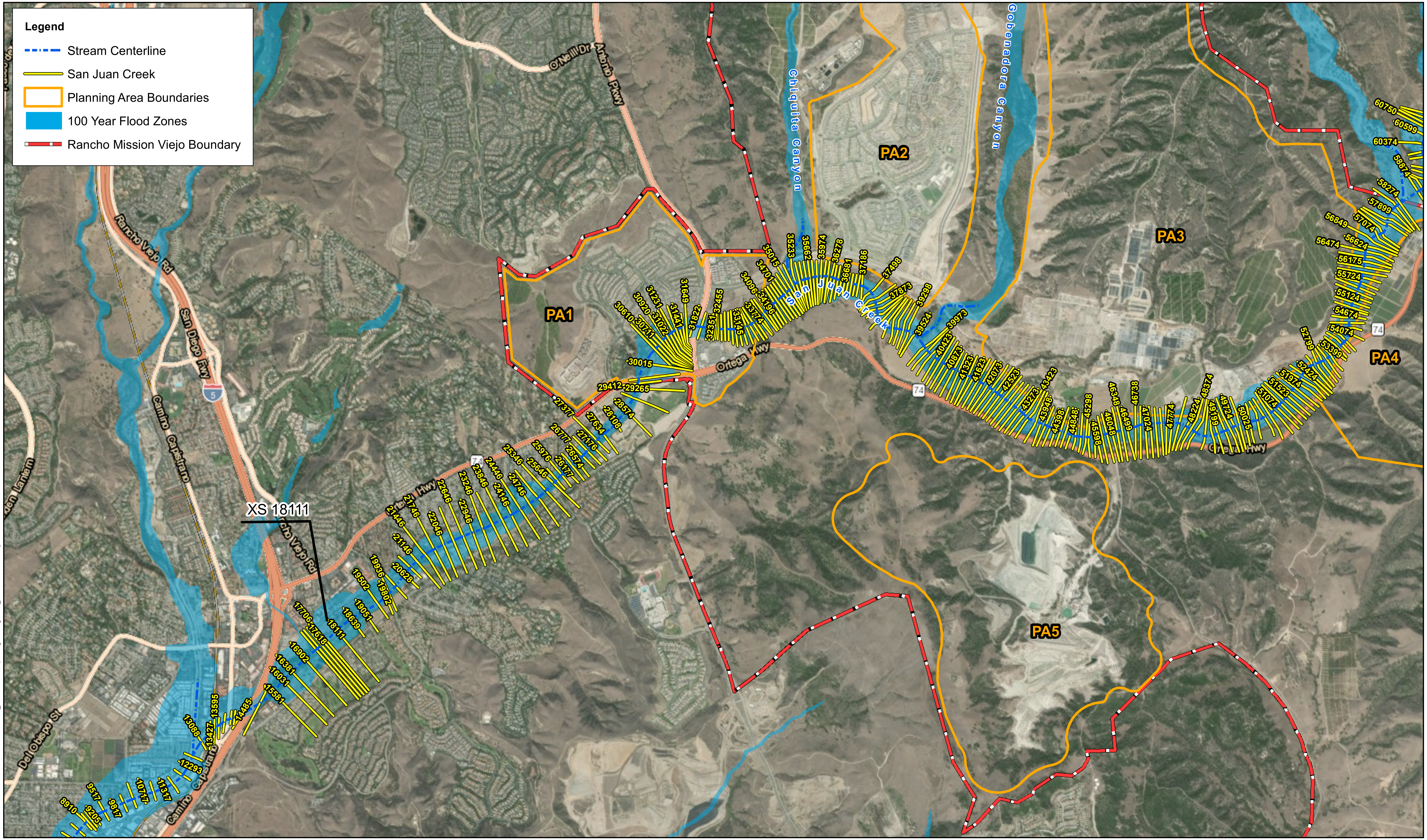
4.3.2.1 San Juan Creek

The HEC-RAS and HEC-6T models used herein were carried over PA-2 ROMP (2014), approved by the County of Orange and extended to include sections up to regional node 119 and the Gibby Road improvements.

Fixed-bed Water Surface Profile Comparison

A fixed-bed version of the HEC-6T existing conditions model was analyzed for unsteady flow based on the 100-year event and the results compared to the 100-year steady flow water surface profile computed using HEC-RAS. The water surface profiles are depicted graphically in Figure 4-3. This comparison for the entire modeled reach is presented in the Appendix J.

The HEC-RAS and HEC-6T water surface profiles are generally consistent except in the vicinity of sections 440+00, 480+00, 520+00, 550+00, where some divergence occurs. The divergence is likely caused by differences in the computational algorithms between HEC-RAS and HEC-6T, which is based on a HEC-2 platform; and more specifically, the program routines related to conveyance and critical depth computations.



Michael Baker INTERNATIONAL

0 1,000 2,000 Feet

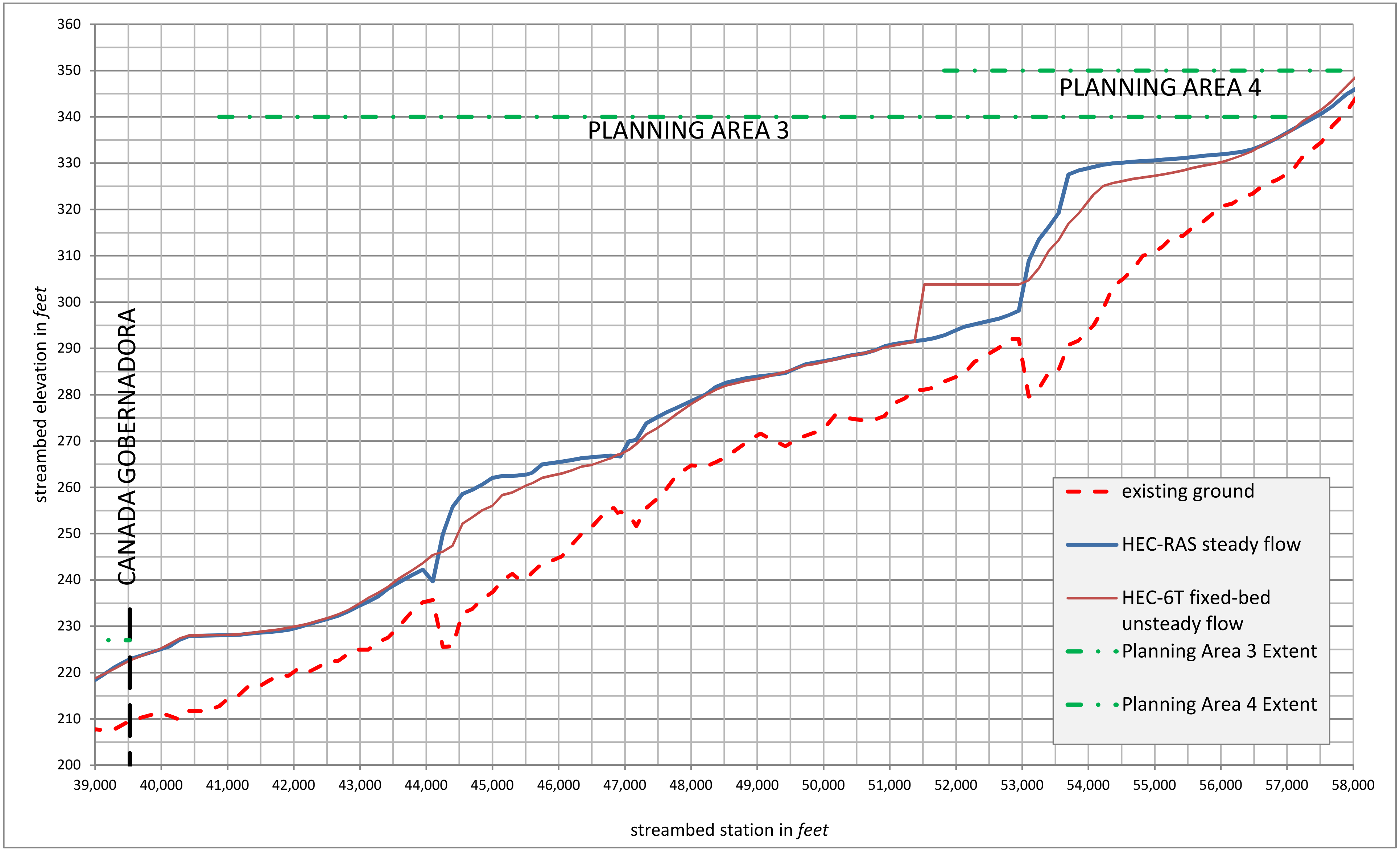
Source: PACE, Huitt-Zollars, Geosyntec, ESRI Online

RANCHO MISSION VIEJO - PA3&4 ROMP

San Juan Creek Downstream Hydraulic Control

Figure 4-2

Figure 4-3: San Juan Creek Existing Condition 100-yr EV Water Surface Profile Comparison



These variations in the water surface profile are generally expected to be transparent in determining the relative changes in the streambed profile between the modeled conditions (existing, phased, and ultimate).

Event-based Sediment Transport Model Simulation Results

Figure 4-4 graphically presents a comparison of event-based and long-term resultant streambed profiles for the existing conditions. The event-based results generally follow the long-term trends and the magnitude of change is proportional to the extreme nature of each event.

Long-term Sediment Transport Model Simulation Results and Trends

Figure 4-5 graphically compares the long-term resultant streambed profiles based on each set of modeled conditions. These results are based the San Juan Creek historical flow record, which far exceeds Orange County hydrology standards, therefore, no event-based flood hydrographs were appended to the long term record to further assess impacts to the watercourse. Model input and output files and supporting technical data are provided in the Technical Appendix J.

The HEC-6T long-term simulations suggest San Juan Creek is, on average, near equilibrium, only appearing to be mildly degrading below the Gobernadora Canyon confluence down to La Novia. Above the Gobernadora Canyon confluence, there is a localized zone of significant deposition, but otherwise, it remains relatively unchanged. There is no change in trends between the modeled conditions and the relative change in streambed profile caused by planned development (phased and ultimate conditions) is insignificant.

Comparison with Previous Studies

The HEC-6T ultimate conditions general simulation performed was compared to the HEC-6T baseline general simulation conducted by PACE (2010) as shown in Figure 4-6. The current baseline is 0.03 ft lower, on average, which can be attributed to the variations in the assumptions related to the hydrograph minimum flow threshold, sediment gradation, local sediment inflow, main stem boundary conditions, and transport function.

Figure 4-4: San Juan Creek Streambed Profile Comparison Based on the Existing Condition Following Selected Events

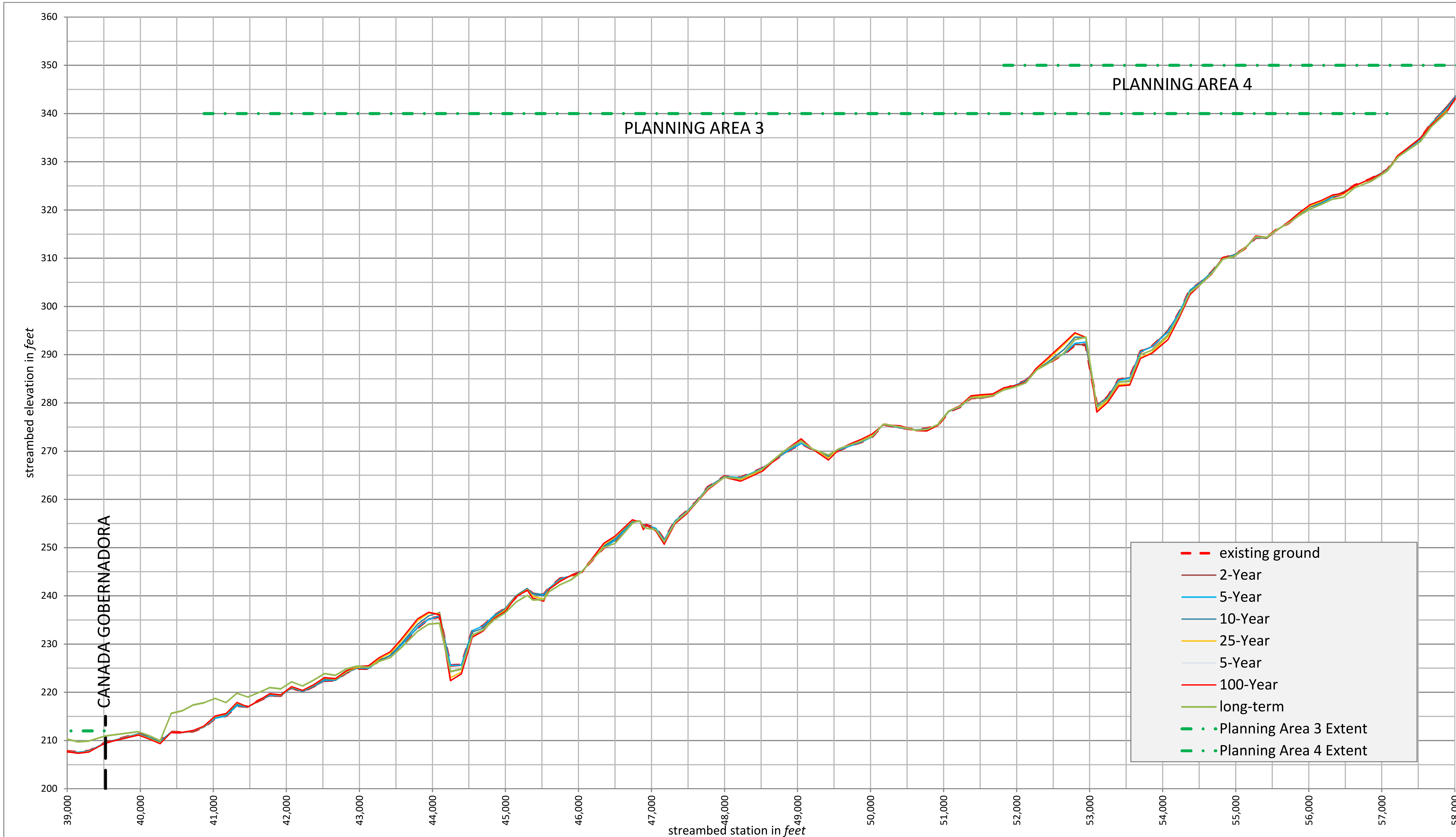


Figure 4-5: San Juan Creek Streambed Profile Comparison of Conditions Following a Continuous Flow Simulation of 84 years (WY1929 – 2012)

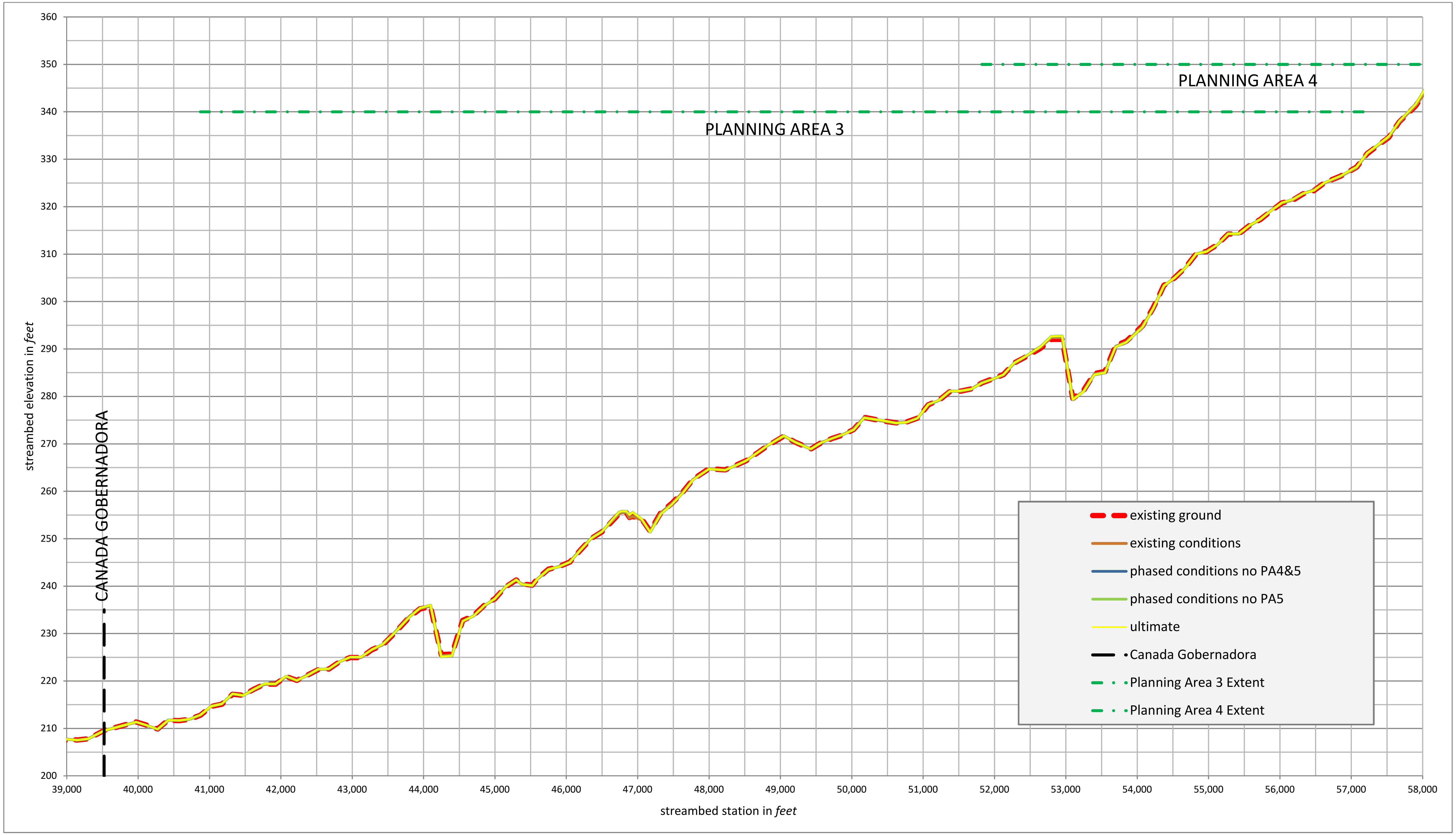
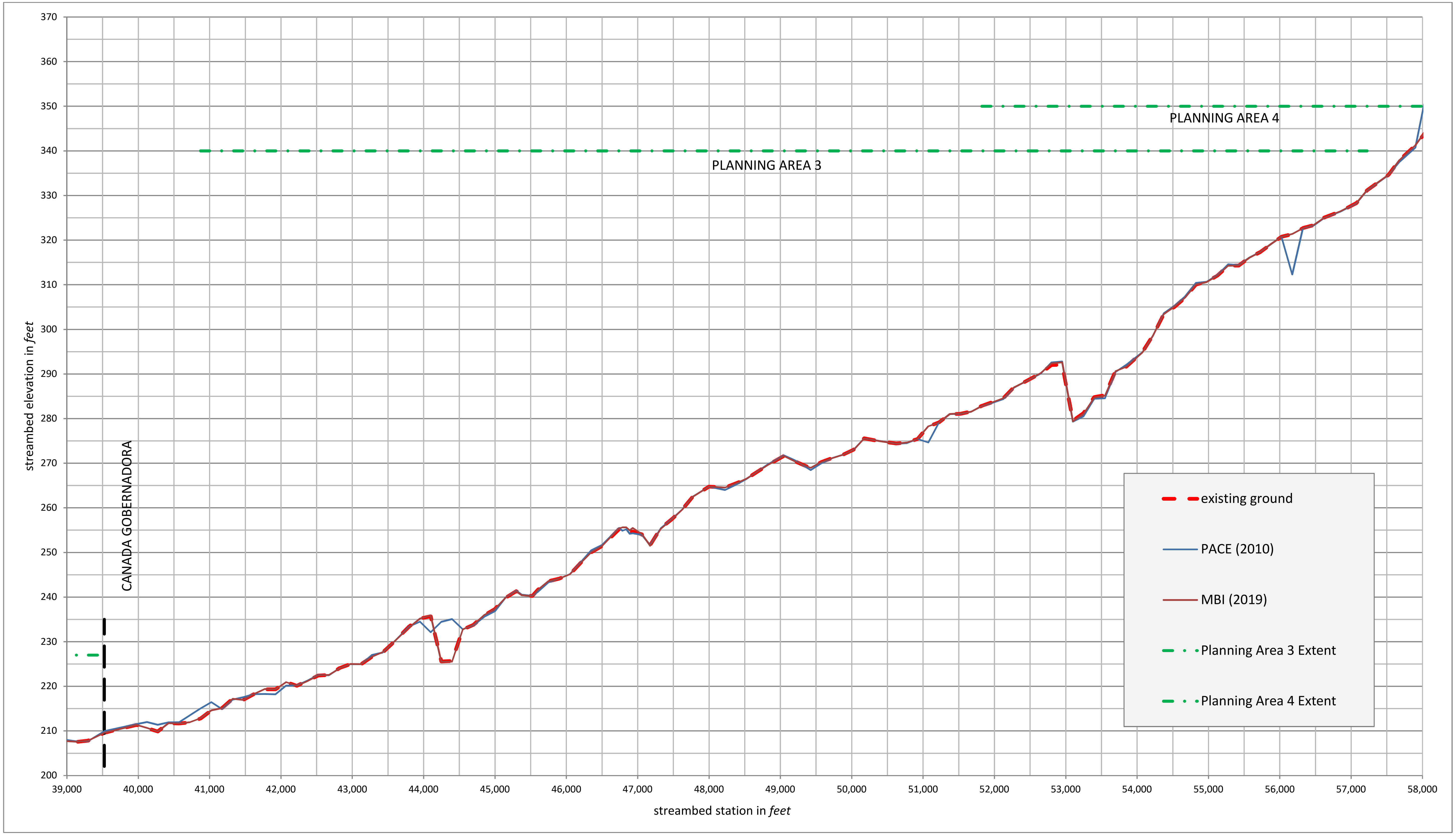


Figure 4-6: San Juan Creek Baseline Streambed Profile Comparison Following a Long-term Continuous Flow Simulation



4.3.2.2 Gobernadora Canyon

The HEC-RAS model and HEC-6T model used herein was carried over from the approved Gobernadora Scour Report (MBI, 2017).

Fixed-bed Water Surface Profile Comparison

A fixed-bed version of the HEC-6T existing conditions model was analyzed for unsteady flow based on the 100-year event and the results compared to the 100-year steady flow water surface profile computed using HEC-RAS. The water surface profiles are depicted graphically in Figure 4-7. This comparison for the entire modeled reach is presented in the Appendix J.

Event-based Sediment Transport Model Simulation Results

Figure 4-8 graphically presents a comparison of event-based and long-term resultant streambed profiles for the existing conditions.

Long-term Sediment Transport Model Simulation Results and Trends

Figure 4-9 graphically compares the long-term resultant streambed profiles based on each set of modeled conditions. These results are based the San Juan Creek historical flow record, which far exceeds Orange County hydrology standards, therefore, no event-based flood hydrographs were appended to the long term record to further assess impacts to the watercourse. Model input and output files and supporting technical data are provided in the Technical Appendix J.

Comparison with Previous Studies

The 100-year event model results were compared between what was performed specifically for the Planning Area 3&4 ROMP herein versus what was prepared for the approved Gobernadora Scour Report (2017), as seen in Figure 4-10.

Figure 4-7: Gobernadora Existing Condition 100-yr EV Water Surface Profile Comparison

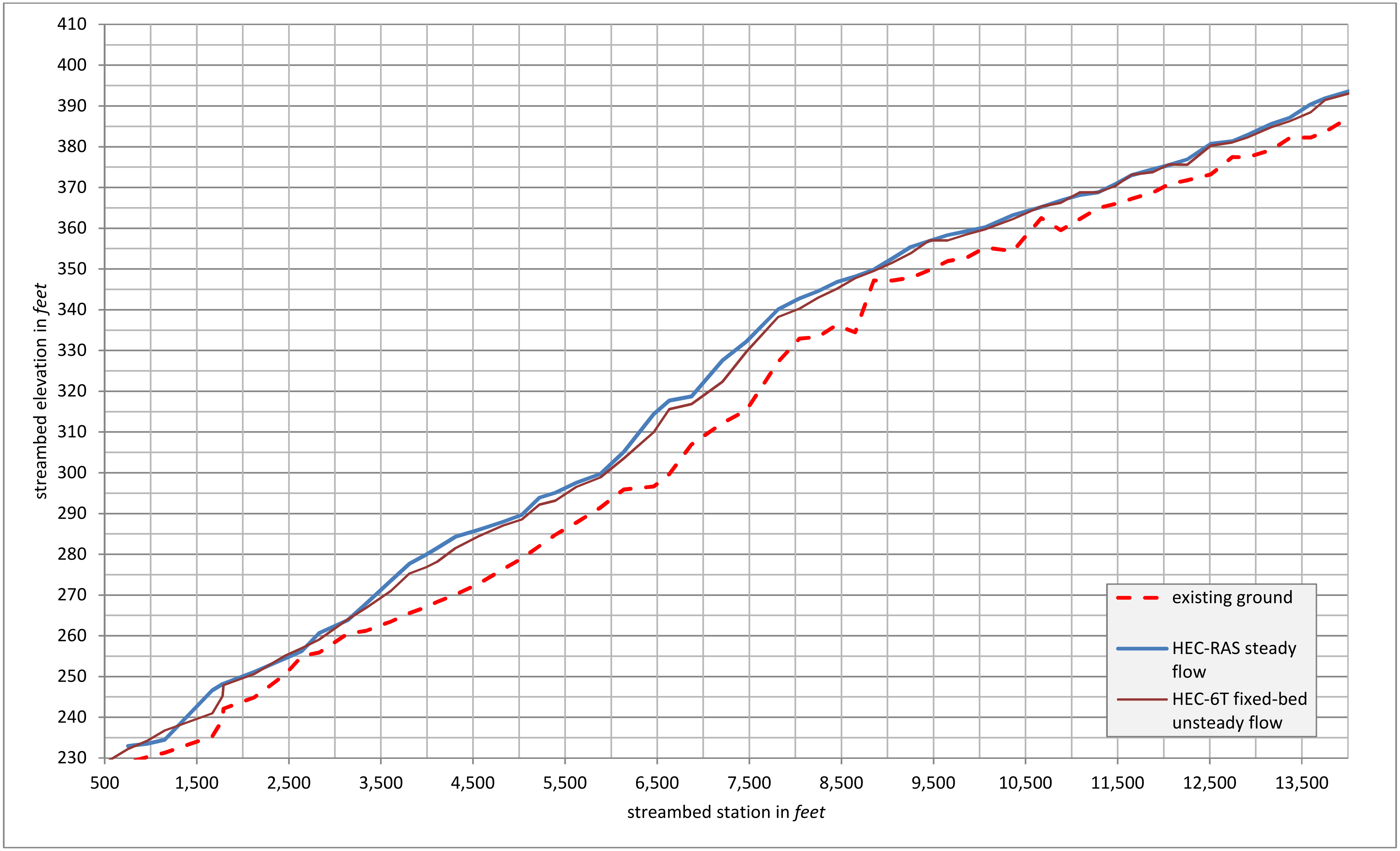


Figure 4-8: Gobernadora Streambed Profile Comparison Based on the Existing Condition Following Selected Events

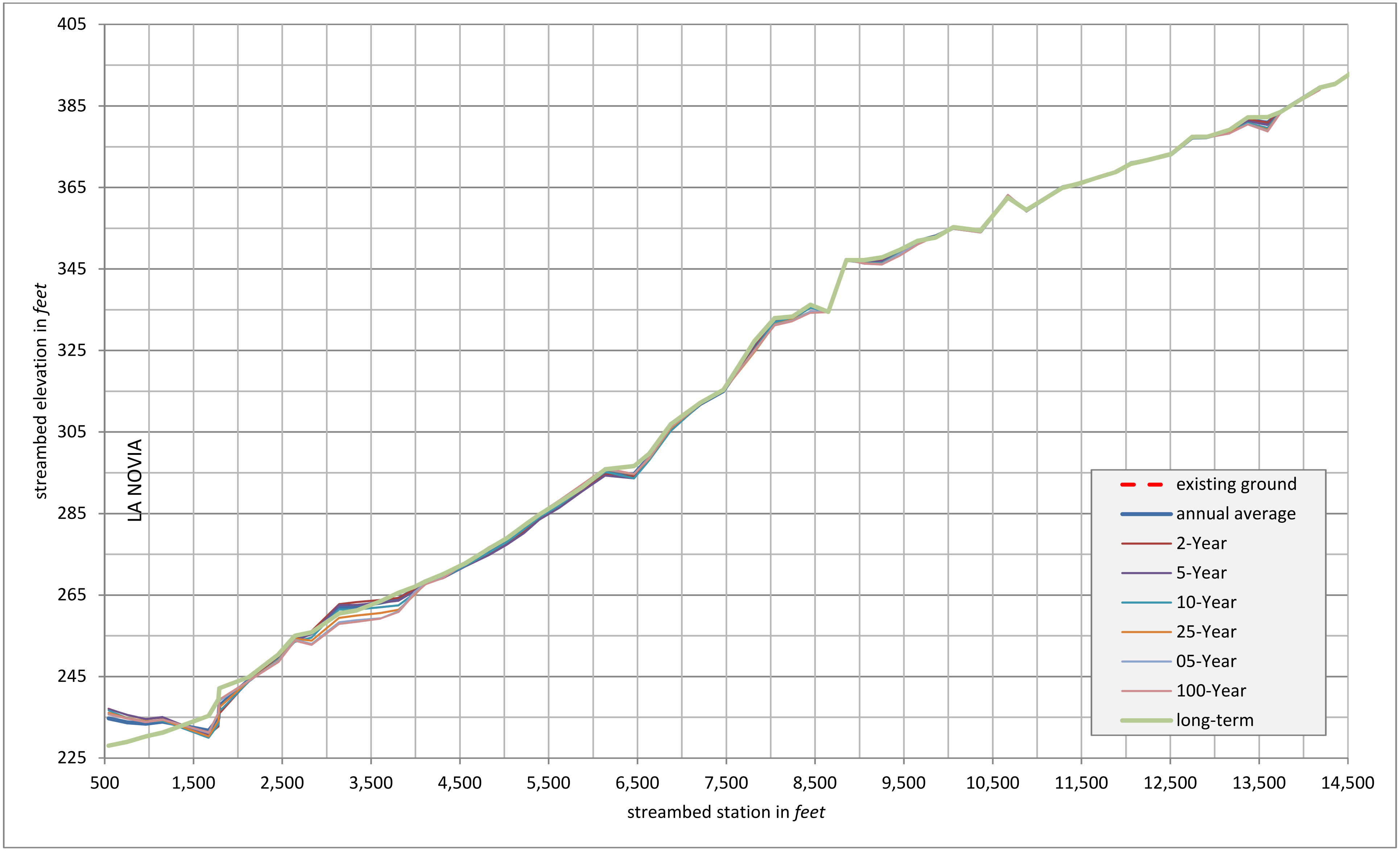


Figure 4-9: Gobernadora Streambed Profile Comparison of Conditions Following a Continuous Flow Simulation of 84 years

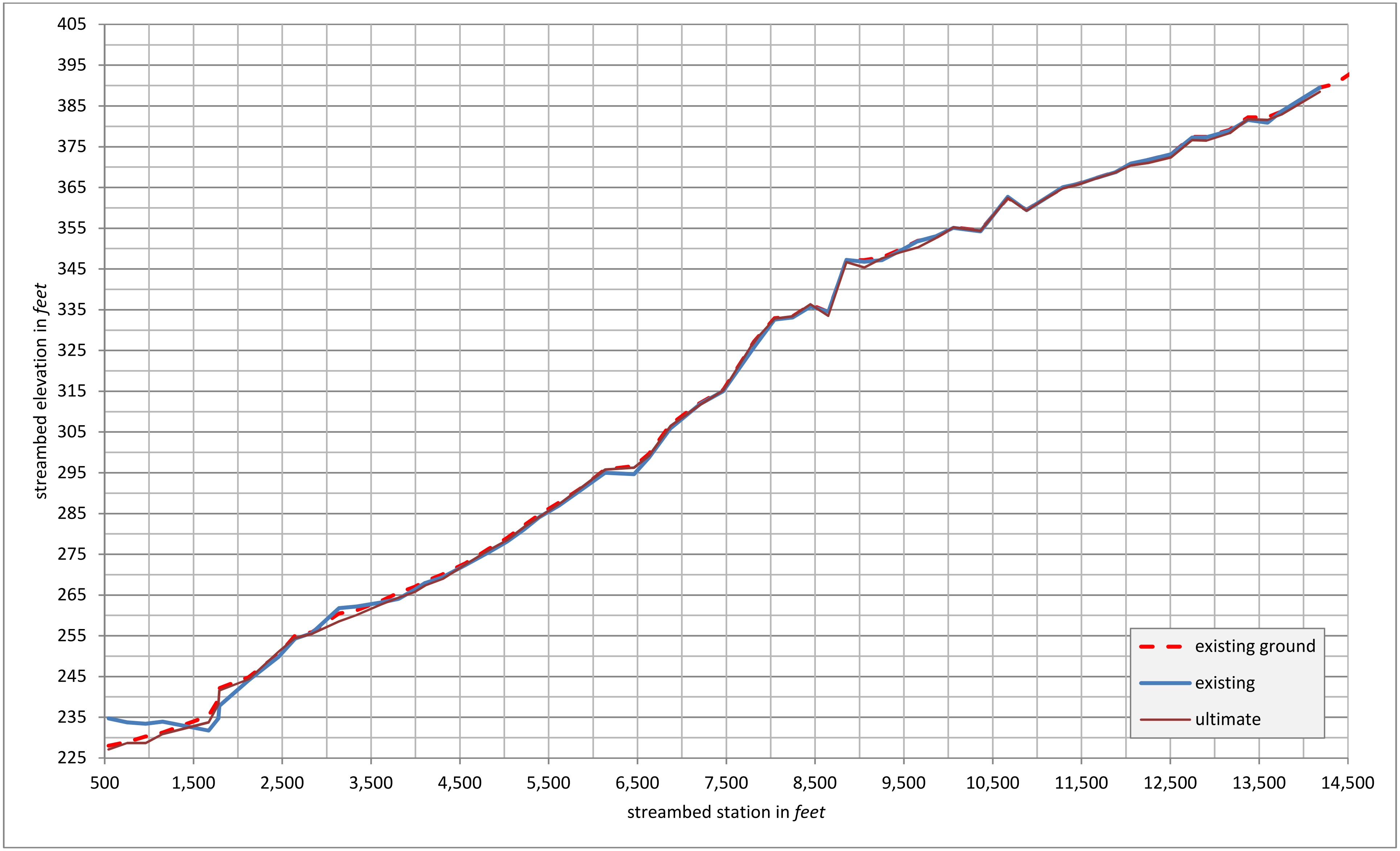
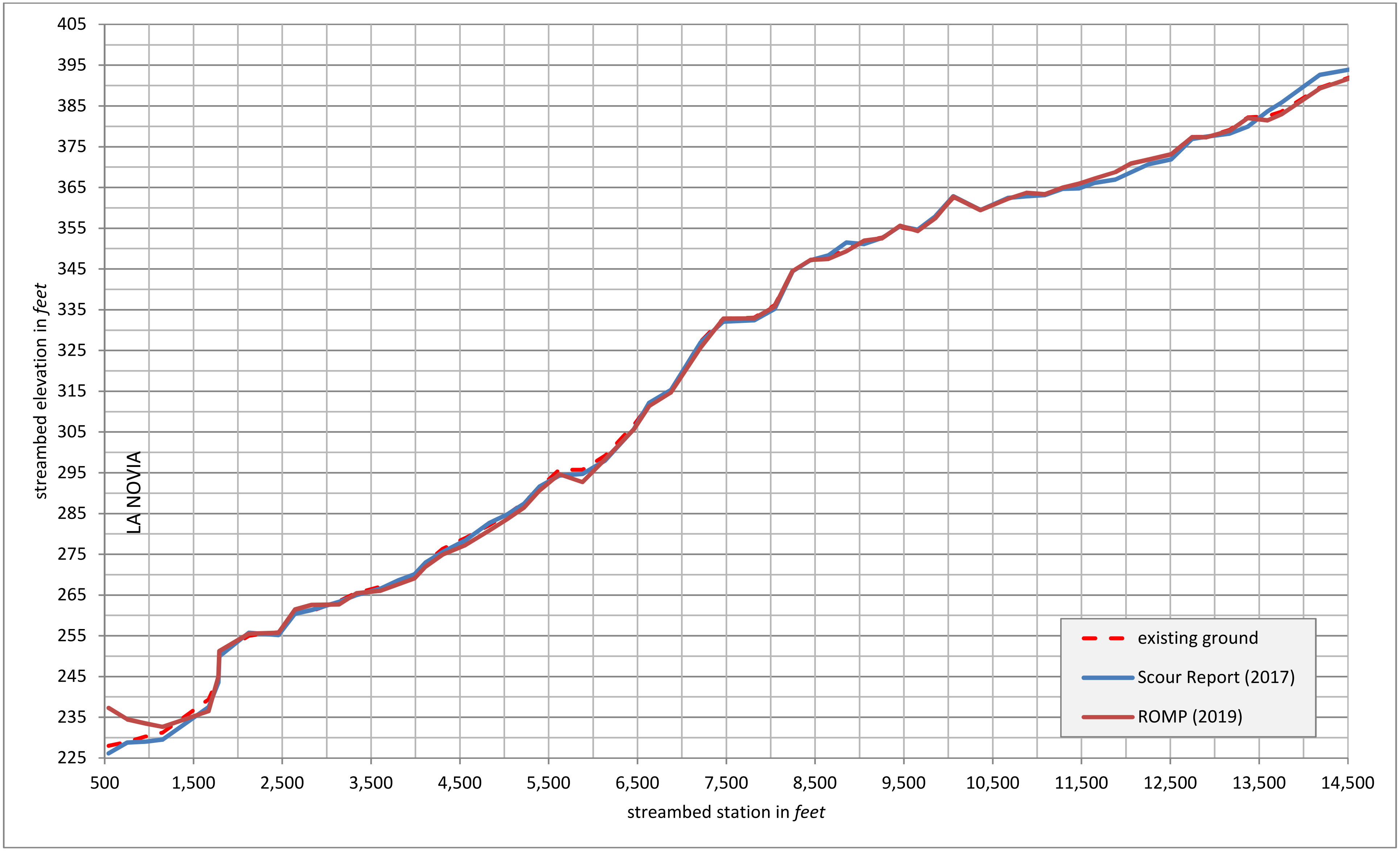


Figure 4-10: Gobernadora Baseline Streambed Profile Comparison Following a Long-term Continuous Flow Simulation



4.4 Lateral Bank Migration

A lateral bank migration analysis is required based on the Ranch Plan ROMP Table 19-1. This section addresses the potential for lateral migration for both San Juan Creek and Gobernadora Canyon.

4.4.1 San Juan Creek

A technical memorandum *RMV Ranch Plan Updated Assessment for Lateral Streambank Erosion Analysis for PA1/PA2* (2018) updated the lateral erosion limits adjacent to PA-1 and PA-2 as well as extend through the PA-3, PA-4 and PA-5 areas. A specialized procedure was developed that used HEC-6T computed results to determine the amount of lateral erosion. This procedure involved using the HEC-6T computed total sediment deficit (scour) or surplus (deposition) for the computation of total eroded sediment volume for each channel cross section during entire storm hydrograph. This total eroded sediment volume was used to adjust the horizontal erosion boundary of either the right or left bank of the channel cross section. The total volume was divided by the average distance between the next adjacent cross section, assuming all the bank erosion occurred on only one side of the channel, which determined the bank erosion area. Although this procedure does not directly analyze the additional erosion forces on the streambank for bends or curves, it does provide a conservative and reasonable estimate of the lateral streambank erosion distance, since the total eroded volume of the entire streambed is applied to only one bank at a time. The PACE procedure, adopted from Maricopa County Flood Control District studies, applies the total eroded volume for the cross section to just one side of the streambank and converts streambed erosion to lateral streambank erosion.

The analysis illustrating the long-term erosion distance is summarized in Appendix O.3 for the study portion of San Juan Creek extending from the downstream Gobernadora Canyon confluence to the upstream RMV boundary. The updated PA-3&4 developments will not have a significant impact on the lateral migration. The flows determined in this ROMP are less than the existing condition flows and similar to previous study discharges. See Table 7.1 for the tabulated discharges.

The historical stream bank data for San Juan Creek is plotted on Exhibit 12. The bank erosion lines are shown on Exhibit 13. All permanent engineered structures (i.e., buildings, roadways, utilities, etc.) must be located north or south of this structural setback line. Non-structural improvements (i.e., trails, parks, or landscaped areas) can be placed between the geotechnical setback line and the daylight line produced by the 1:1 cut slope, assuming little or no irrigation.

4.4.2 Gobernadora

The lateral bank erosion for Gobernadora was determined by using the sediment deficit from the HEC-6T models. The bank erosion distance equivalent to the HEC-6T future conditions sediment deficit at each section was applied over an 84-year planning period. This sediment deficit was integrated over the reach length and used to compute the volume of bank erosion required to satisfy the sediment deficit. The deficit was applied to the project-side bank only as if none of the deficit were satisfied from the opposite bank. The bank volume required to satisfy the sediment deficit was accomplished by determining a thalweg offset followed by a 1:1 cut slope beginning at the revised thalweg that would fulfill the sediment deficit computed by HEC-6T. This process was conducted using the hydraulic sections, which form the channel geometry defined in the HEC-RAS and HEC-6T models. If the end of a section was reached prior to satisfying the sediment deficit then the elevation at the zero station was extended horizontally until sediment deficit was satisfied. Once a revised thalweg location was established, a 2:1 cut slope was established, and its daylight location would define the geotechnical setback. All permanent engineered structures (i.e., buildings, roadways, utilities, etc.) must be located east of this structural setback line. Non-structural improvements (i.e., trails, parks, or landscaped areas) can be placed between the geotechnical setback line and the daylight line produced by the 1:1 cut slope, assuming little or no irrigation.

The historical stream bank data for Gobernadora Canyon is plotted on Exhibit 14. The exhibit indicates the location of the east and west bank from 1938 to 2005 based on the available aerial photography. The calculated east bank lateral migration limits are plotted for the existing and ultimate conditions based on the HEC-6T results and sediment deficit analysis. The worst case lateral migration setback from the calculated analysis was also used to compare with the information from the historical data. The worst case at each hydraulic cross section was identified and re-plotted on Exhibit 15. The results of the comparison generally show that the calculated lateral migration is consistent with the variations of the bank based on the historical data. The overall results of the analysis suggest that the PA-3&4 development area is outside of the potential lateral erosion areas along Gobernadora Canyon.

4.5 Stream Monitoring

As part of the sediment transport study, an amendment to the “PA-1 Development Area and the Ranch Development Plan San Juan Creek Watershed Stream Monitoring Program” prepared by PACE dated December 2011 was prepared. The amendment identifies 3 monitoring cross sections on Gobernadora Canyon and extends the annual sight inspection limits along San Juan Creek up through regional node 119. The proposed amendment is included in Appendix L.