HYDRAULIC AND HYDROLOGIC ANALAYSIS OF

LOWER FEATHER RIVER SETBACK LEVEE

AT STAR BEND

(Revision 1)

Prepared for:

Levee District No.1 of Sutter County

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1.0 INTRODUCTION

This report documents the hydraulic modeling performed for the proposed 3,400-foot-long Setback Levee at Star Bend (right bank) on the Lower Feather River. Two types of hydraulic modeling were undertaken to confirm the hydraulic benefits of the proposed setback levee at Star Bend: (1) an unsteady one-dimensional model using HEC-RAS; and (2) a steady-state, two-dimensional (horizontal) model using RMA2. The HEC-RAS model provides a single horizontal water surface elevation and velocity component for each cross section of the river hydraulic model. The RMA2 model computes water surface elevations and depth-averaged horizontal velocity components at each of the elements of the finite element grid of the river system. The maximum water surface elevations calculated by the HEC-RAS models were used in the HEC-Flood Damage Assessment (HEC-FDA) model for the benefit-cost analyses. The HEC-RAS models are an integral part of the modeling effort since these were used to develop the boundary conditions for the more detailed, two-dimensional RMA2 models. Due to the significant river meander near Star Bend on the Feather River, the one-dimensional HEC-RAS model alone is deemed inadequate for estimating and quantifying the hydraulic benefits. The two-dimensional capabilities of the RMA2 model provide a better description of flow fields for a meandering, curved channel that exists particularly along the right bank of the Feather River in the Star Bend Area. Thus, the water surface elevations and velocities along the right bank levee of the Lower Feather River computed by the RMA2 models were used to assess the hydraulic benefits of the setback levee at Star Bend. RMA2 models also permit a detailed look at the distribution of water surface elevations and depth-averaged velocities across the select sections of the Lower Feather River channel. Development of HEC-RAS models for the Lower Feather River is described first to set the stage for the more complex RMA2 Models.

2.0 HEC-RAS MODELS

HEC-RAS models of the Feather River system were obtained from the U.S. Army Corps of Engineers (USACE) Sacramento District and MBK Engineers, Inc (MBK). The HEC-RAS model, shared by the USACE in August of 2006, provided a wide range of river flows needed for the HEC-FDA model and assisted with establishing boundary conditions for the MBK HEC-RAS model and the subject RMA2 models. The storm-centering aspects of hydrology are reported in the USACE report titled, "Lower Feather River Floodplain Mapping Study," dated February 17, 2005. MBK's HEC-RAS model was documented in the report titled, "Basis of Design for Bear River Setback Levee Project," dated April 2006.

Two sets of unsteady HEC-RAS models were developed for the existing conditions (without any setback levee at Star Bend) and the proposed conditions (with the proposed 3,400-foot setback levee at Star Bend). The existing conditions HEC-RAS model was created by combining the HEC-RAS model from USACE and from MBK. The geometry file of the existing conditions HEC-RAS model was taken from MBK's HEC-RAS model because it was re-calibrated by MBK to the high-water conditions of the 1997 event and included the geometry of the recently completed setback levee on the right bank of the Bear River with its confluence with the Feather River. The cross sections of the MBK model were already modified to conservatively represent an improved levee system that would allow overtopping of selected levee sections without levee failures occurring. The MBK HEC-RAS model included all the levee improvements proposed and completed in Yuba County by the Three Rivers Levee Improvement Authority (TRLIA) with the exception of the 6.5-mile-long setback levee under consideration by TRLIA on the Feather River above Star Bend. The flows for the model were taken from the USACE HEC-RAS model, which was developed from storms with centering along the "Feather River at Shanghai with Yuba River emphasis." (SHY). For the existing conditions model, eight (8) Annual Exceedence Probability (AEP) flow conditions were analyzed, including the 1-in-500 (AEP), 1-in-200 AEP, 1-in-150 AEP, 1-in-100 AEP, 1-in-50 AEP, 1-in-25 AEP, 1-in-10 AEP, and 1-in-2 AEP.

To reflect the levee alignment changes for the proposed setback levee at Star Bend it was necessary to modify a select number of the MBK HEC-RAS cross sections in the immediate project area. These modifications were necessary along the right overbank area to ensure that the model accurately depicts river flow parallel to the new levee alignment instead of at an oblique alignment dictated by the original cross sections. The cross sections in the right overbank area were made perpendicular to the flow in that area. The specific cross sections requiring modification are shown in Figure 1. The subject cross sections correspond closely with River Miles (RM) 18.0, 17.75, 17.5, 17.25, 17.0, and 16.75. The modified cross sections also incorporate a planned earth mound that will be developed to protect a known area of cultural significance. Similar with the existing conditions model, eight (8) AEP flow conditions were analyzed (from the 1-in-2 AEP event to 1-in-500 AEP event as noted above) for the proposed setback conditions.

3.0 RMA2 MODELS

A set of RMA2 models was developed for the existing and proposed conditions. Several RMA2 simulations were available from MBK for the Lower Feather River and Bear River confluence, which included Star Bend. The MBK RMA2 models that were referenced and utilized are listed in Table 1. Included as Appendix A to this report is the MBK RMA2 Star Bend Levee Hydraulic Analysis, dated June 2004. The hydrologic boundary conditions updated for the RMA2 models were developed from the HEC-RAS models that were specifically updated by Wood Rodgers for the setback levee at Star Bend. The RMA2 models were developed for 1-in-100 and 200 AEP flow events and the USACE 1957 Design Flow of 300,000 cfs.

3.1 Existing Conditions Without Setback Levee at Star Bend

The geometry file of the existing conditions RMA2 model was developed based upon the as-built conditions and Manning's "n" values of the O'Connor Lakes Restoration Project (Model 3 in Table 1) and the proposed conditions model of the Bear River Setback Levee Project by TRLIA (Model 4 in Table 1). Presented in Figure 2 is the geographic extent of the Star Bend RMA2 model including the water surface elevation contours for the 1-in-100 AEP event under existing, pre-project conditions. The model extent is the same for the Bear River Levee Setback Project RMA2 model (Model 4 in Table 1). The O'Conner Lakes Restoration Area as-built conditions were modeled by MBK Engineers with Manning's "n" values varying between .035 and .070, with 0.070 being used for the existing restoration area immediately adjacent to the proposed setback levee. The MBK model was calibrated to the 1997 flood. The Manning's "n" values for the new water-side area of the Setback Levee near Star Bend were updated to a Manning's "n" value of 0.07 for woody trees and shrubs, which matches the information contained in the model of as-built conditions of the O'Connor Lakes Restoration Project (Model 3 in Table 1).

To develop the boundary conditions for the steady-state, existing conditions RMA2 model, flow conditions within the unsteady HEC-RAS model were evaluated for two snapshots in time. The two snapshots in time are: (1) time of a maximum flow in the Lower Feather River at RM 18.0; and (2) time of a maximum stage at RM 18.0. For each snapshot, the stage of the Feather River at Nicolaus (RM 8.0), the flow at Feather River (RM 23.0), and the flow at Bear River (RM 3.95) were extracted from the HEC-RAS model output files. Table 2 shows the flow condition variables for each of the two snapshots in time for the 1-in-200 AEP flow event. The flow variables corresponding to the maximum flow at RM 18.0 were selected as the boundary condition for the existing conditions RMA2 model since the higher flow at RM 23.0 was likely to have a larger hydraulic impact at Star Bend. All elevations are based on NGVD 1929.

Similar evaluations were conducted for 1-in-100 and 1-in-500 AEP flow events for the maximum flow and maximum stage height scenarios. It was observed for both AEPs that the inflow of the Feather River at RM 23.0 is greater for the maximum flow scenario than the maximum stage scenario. Table 3 lists the boundary conditions for the existing conditions RMA2 model for the 1-in-100 AEP, 1-in-200 AEP, and 1-in-500 AEP flow events.

Presented in Figures 3 and 4 are the water surface elevation contours for the 1-100-AEP flow event under pre- and post-project conditions, respectively, for the Star Bend area between RM 15.0 and RM 21.0. Presented in Figure 5 are the incremental changes in the water surface elevations between the pre- and post-project conditions. Presented in Figure 6 through Figure 8 are the pre- and post project velocity contour conditions for the same 1-in-100 AEP flow event for the same section of the Lower Feather River near Star Bend. Figure 9 through Figure 15 show the pre- and post-project water surface elevations and velocity conditions for the 1-in-200 AEP flow event.

Under existing pre-project conditions for the 1-in-100 and 200 AEP events shown respectively in Figures 3, and 10, all indicate steep drops in the water surface elevation above RM 18.0 between elevation contours 64 and 63. Under pre-project conditions Figures 6 and 13 indicate high velocity contours are present at RM 18.0 that approach 7 to 8 feet per second.

3.2 Proposed Conditions with Setback Levee at Star Bend

The proposed conditions model was developed with the site-specific topographic data (one-foot contour intervals) of the Star Bend setback area by Wood Rodgers in 2006. This site-specific survey data was supplemented beyond the immediate project area with survey data (two-foot contour intervals) from the USACE Comprehensive Study of 2002, and the geometric data files included in MBK's existing models. The geometry of the existing levee was removed from the site-specific topographic information and the preferred alignment of the setback levee (approximately 3,400 feet in length) was incorporated into the final geometric files. As noted above, in connection with the HEC-RAS model cross-section modifications, the geometric grid for the proposed setback levee at Star Bend also incorporates a raised earthen mound over a known culturally sensitive area.

The RMA2 boundary conditions for the proposed setback model were developed by Wood Rodgers based upon the proposed setback levee conditions of the HEC-RAS model modifications. As with the existing conditions model, snapshots of maximum flow and maximum stage were tested at Feather River RM 18.0, to identify the scenario that produced the most critical boundary conditions with the setback levee. It was determined that for 1-in-100 AEP, 1-in-200 AEP, and 1-in-500 AEP flow events, the maximum flow at Feather River RM 18.0 produced the most critical boundary conditions. Table 4 presents the boundary conditions for the RMA2 model for the proposed setback levee at Star Bend.

4.0 QUANTITATIVE RESULTS OF HYDRAULIC MODEL OF SETBACK LEVEE AT STAR BEND

Figure 4 and Figure 7 present water surface elevation contours and velocity contours computed by the RMA2 model for the 1-in-100 AEP flow event for the proposed conditions of the setback levee at Star Bend. Due to the radial acceleration at Star Bend under existing conditions, Figure 3 shows a rapid drop in water levels between water surface elevation contours 64 and 63 near Feather River RM 18.0. The rapid drop flattens out under the proposed setback conditions (Figures 4 and 11) due to a wider flood conveyance channel and an increase in flow conveyance along the right overbank area, which is facilitated by the proposed setback levee. To compare the water surface elevations along the right and left bank levees of the Feather River between the existing and proposed setback conditions, water surface elevations were extracted from the RMA2 solution file along with observation profiles for each of the levee alignments. Figure 16 and Figure 17 show the water surface profiles along the right and left banks, respectively. The profiles are drawn along the respective waterward levee toes with the corresponding HEC-RAS cross-section stationing markers that coincide with the thalweg River Mile (RM) stationing of the Feather River. Figure 18 shows a detail of the pre- and post-project water surface profiles for the Feather River right bank at Star Bend for the 1-in-100 and 200 AEP events and the USACE 300,000 cfs design flow in relation to the USACE 1957 design profile. A summary of the pre- and post-project water surface elevations for the 1-in-100 and 200 AEP flow events and for 300,000 cfs in comparison to the USACE 1957 Design Profile of the Lower Feather River for the right and left bank levees are provided in Appendix B, Table B.1 and Table B.2.

Figure 16, an output file from the RMA2 model, presents the water surface elevations along the right bank observation profile and demonstrates that the water surface elevation is lowered by 0.61 foot under the proposed setback levee conditions at Station 29+162 (between HEC-RAS cross sections at RM 18.0 and RM 18.25). The decrease in water surface elevation can be attributed to the increase in flow conveyance width in the right overbank area with the proposed setback levee in place. Due to the river meander at Star

Bend at cross section 18.0 (RM 18.0), the water surfaces near the river meander have a radial surface slope that is commonly known as a super-elevation. Due to flow in the bend, the water surface elevation along the right bank levee is dropped sharply downstream of Star Bend under existing conditions. This drop is more noticeable along the right bank in comparison to the left bank. Under proposed conditions, the sharp drop in water surface elevation in the longitudinal direction disappears because the flows are no longer forced through a bend, but are spread out over a wider floodplain. Due to the same river meander in the river cannel, the water surface elevation for the 1-in-200 AEP flow event with the proposed setback levee only drops 0.32 feet along the left bank in comparison to the 0.61 foot reduction in stage along the right bank. Noticeable downstream impacts of the Star Bend setback levee cease along both the right and left banks at RM 17.25.

The HEC-RAS model results in Table 5 indicate that there is not an appreciable amount of increased flow that is conveyed downstream of Star Bend with the construction of the proposed 3,400-foot-long setback levee. Although the flow channel conveyance is increased with the setback levee, both the water surface elevation contours and the velocity contours drop in the project area, netting an insignificant increase in flood flows downstream of less than 0.04%.

Figure 13 and Figure 14, collectively, demonstrate the velocity magnitudes of the existing and proposed conditions for the 1-in-200 AEP flow event in the Feather River near Star Bend. These Figures show that velocity impinging on the levee at Star Bend reduces from 7-8 feet per second to 3 feet per second due to the proposed setback levee at Star Bend. The reduction in velocity along the levee significantly reduces the erosion potential at the Star Bend right levee and the upstream end of the O'Conner Lakes Restoration Area.

5.0 ADDITIONAL FINDINGS OF HYDRAULIC MODELING OF FEATHER RIVER IN STAR BEND AREA

The widening of the Feather River floodway at Star Bend may reduce the strength of the secondary current triggered by radial acceleration during high flow conditions in the bend way. As a result, the scour potential in the river will be reduced. A collective review of the HEC-RAS model results presented herein for the Star Bend Setback Levee and in a report prepared by Phillip Williams and Associates for TRLIA titled, "Geomorphic Assessment of Project Alternatives for Feather River Improvements Between the Bear and Yuba Rivers," dated July 28, 2006, suggest there will be a decrease in the shear stress index along the left and right overbank areas with the proposed 3,400-foot-long setback levee. The increase in channel width coupled with the reduction in flow depths and flow velocities is conducive to reducing the shear stresses. There will be a slight, insignificant increase in channel shear stresses of less than 0.02 lbs/sf. along the channel and the right bank overflow area near the proposed setback levee. Table 6 shows a small increase in post-project shear stresses in comparison to the existing pre-project conditions.

The HEC-RAS and the RMA2 modeling results indicate that the greatest reductions in water depths and water velocities are occurring upstream along both banks of Star Bend between RM 18.0 and RM 20.0. These findings are fairly consistent with the findings of the model conducted by MBK in June 2004 for the same 3,400-foot setback alignment proposed by Levee District No. 1 at Star Bend. The model conducted by MBK in June 2004 found that flood stages with the proposed setback alignment along the right bank of the Feather River at Star Bend could be reduced by 0.80 foot above Star Bend for the 1997 flood event, whereas the findings herein of the current modeling show a reduction of 0.61 foot, for the 1-in-200 AEP. This slightly smaller reduction in flood stage is likely due to minor differences in the reported flow values, the configuration of the proposed setback levee, differing Manning's "n" values, and additional contouring in the degraded levee section to protect a known area of cultural significance.

Alternative setback levee alignments extending further downstream to the south (south of the existing waterside ramp and at the easterly extension of Tudor Road opposite

RM 16.75) will not yield additional significant reductions in water depths and velocities because the reductions are occurring upstream of the sharp bend located at RM 18.0. The hydraulic effectiveness of an alternative setback levee extended further to the south would also be limited due to the hydraulic constriction of the existing waterside ramp that will remain in place at the downstream terminus end of the planned setback levee. Alternative setback levee alignments extending further north towards Abbott Lake were also discounted due to the diminishing hydraulic benefits of setting back the levee parallel and a short distance landward of the existing levee alignment. The proposed 3,400-foot-long setback levee at Star Bend offers the greatest hydraulic benefit by removing a large right-angle obstruction to the river's right overbank flow area with the shortest possible setback alignment.

There are a number of distinct hydraulic benefits to the Star Bend Setback Levee Project. These benefits include: (1) lower water levels along the right and left bank levees of the Feather River, (2) reduced flow velocities along the right bank levee at Star Bend, (3) reduced erosion potential of the Feather River, (4) reduced shear stress indexes in the river channel and overbank areas at and just upstream of the Star Bend area, and (5) removal of a constriction to the natural migration of the river meander at Star Bend.

Regional and local geomorphic studies performed by DWR, the USACE, and Ayres Associates suggest that erosion rates estimated at 1.6 feet per year along the right bank levee near Star Bend may have an estimated time span of only 35 years before the levee is endangered. Setting back the levee at Star Bend is a preferred alternative that will ensure the long-term integrity of the Feather River right bank levee at Star Bend. Regional geomorphology evaluations and considerations are discussed in Appendix C to this Hydraulic and Hydrologic Analysis Report.

6.0 REFERENCES

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Wood Rodgers, Inc

Table 1

List of RMA2 Models Obtained from MBK Engineers

Hydraulic Model		Project	Upstream Extent	Downstream Extent	Model Dates	Remarks
1	Evaluation of 1997 High-Water Conditions at Star Bend for Sutter County	Setback Levee Project at Star Bend Hydraulic Analysis	Feather River at RM 23.0; Bear River at RM 2.0	Feather River at RM 7.75; Bear River to Confluence with Feather River	6/9/2004	Includes geometry of the Star Bend setback area.
2	Evaluation of 1997 High-Water Conditions at Star Bend for River Partners	Proposed Conditions O'Connor Lakes Restoration Project	Feather River at RM 23.0	Feather River at RM 13.0	5/9/2006	Contains information on proposed re-vegetation of the flood-plain near Star Bend.
3	Evaluation of 1997 High-Water Conditions at Star Bend for River Partners	As-Built Conditions of O'Connor Lakes Restoration Project	Feather River at RM 23.0	Feather River at RM 13.0	8/10/2006	Contains as-built information on re-vegeta-tion of the floodplain near Star Bend.
4	Evaluation of 100-year and 200-year Conditions at Confluence of Bear and Feather Rivers for TRLIA	Bear River Levee Setback Project by TRLIA at Confluence of Bear and Feather Rivers	Feather River at RM 23.0; Bear River at RM 5.0	Feather River at RM 8.0; Bear River to Confluence with Feather River	2/27/2006	Includes geometry and boundary conditions for the Bear River setback levee at the confluence of the Bear River and Feather River.

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Table 2

Flow Variables for Maximum Flow Conditions at Star Bend

	1-in-200 AEP	
	Maximum Flow, RM 18	**Maximum Stage, RM 18**
Snapshot of Time	Jan 19 1700 hrs	Jan 19 1800 hrs
Feather River Stage at RM 8.0	48.89 ft	49.03 ft
Feather River Flow at RM 23.0	350,986 cfs	349,663 cfs
Bear River Flow at RM 3.95	52,017 cfs	52,611 cfs

* All River Stage Elevations based on 1929 NGVD

Wood Rodgers, Inc.

Table 3

RMA2 Model Boundary Conditions for Existing Conditions

	1-in-100 AEP	**1-in 200 AEP**	**1-in-500 AEP**
	Maximum Flow, RM 18	**Maximum Flow, RM 18**	**Maximum Flow, RM 18**
Snapshot of Time	19 Jan 0800 hrs	19 Jan 1700 hrs	19 Jan 1700 hrs
Feather River Stage at RM 8.0	45.94 ft	48.89 ft	51.81 ft
Feather River Flow at RM 23.0	274,064 cfs	350,986 cfs	497,910 cfs
Bear River Flow at RM 3.95	35,480 cfs	52,017 cfs	54,162 cfs

* All River Stage Elevations based on 1929 NGVD

Wood Rodgers, Inc.

Table 4

RMA2 Model Boundary Conditions for Proposed Setback Levee at Star Bend

	1-in-100 AEP	**1-in-200 AEP**	**1-in-500 AEP**
	Max. Flow at RM 18	**Max. Flow at RM 18**	**Max. Flow at RM 18**
Snapshot of Time	19 Jan 0800 hrs	19 Jan 1700 hrs	19 Jan 1700 hrs
Feather River Stage at RM 8.0	45.94 ft	48.89 ft	51.81 ft
Feather River Flow at RM 23.0	274,184 cfs	351,153 cfs	499,271 cfs
Bear River Flow at RM 3.95	35,459 cfs	52,000 cfs	54,177 cfs

* All River Stage Elevations based on 1929 NGVD

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Table 5

Increases in Flood Flows Downstream of Star Bend

With Setback Levee at Star Bend

	Existing Condition Peak Flow at RM 18.0	**Proposed Condition Peak Flow at RM 18.0**	**Increase in Discharge**	
	(cfs)	(cfs)	(cfs)	%
1-in-100 AEP	273,618	273,718	100	0.036
1-in-200 AEP	350,563	350,696	133	0.038

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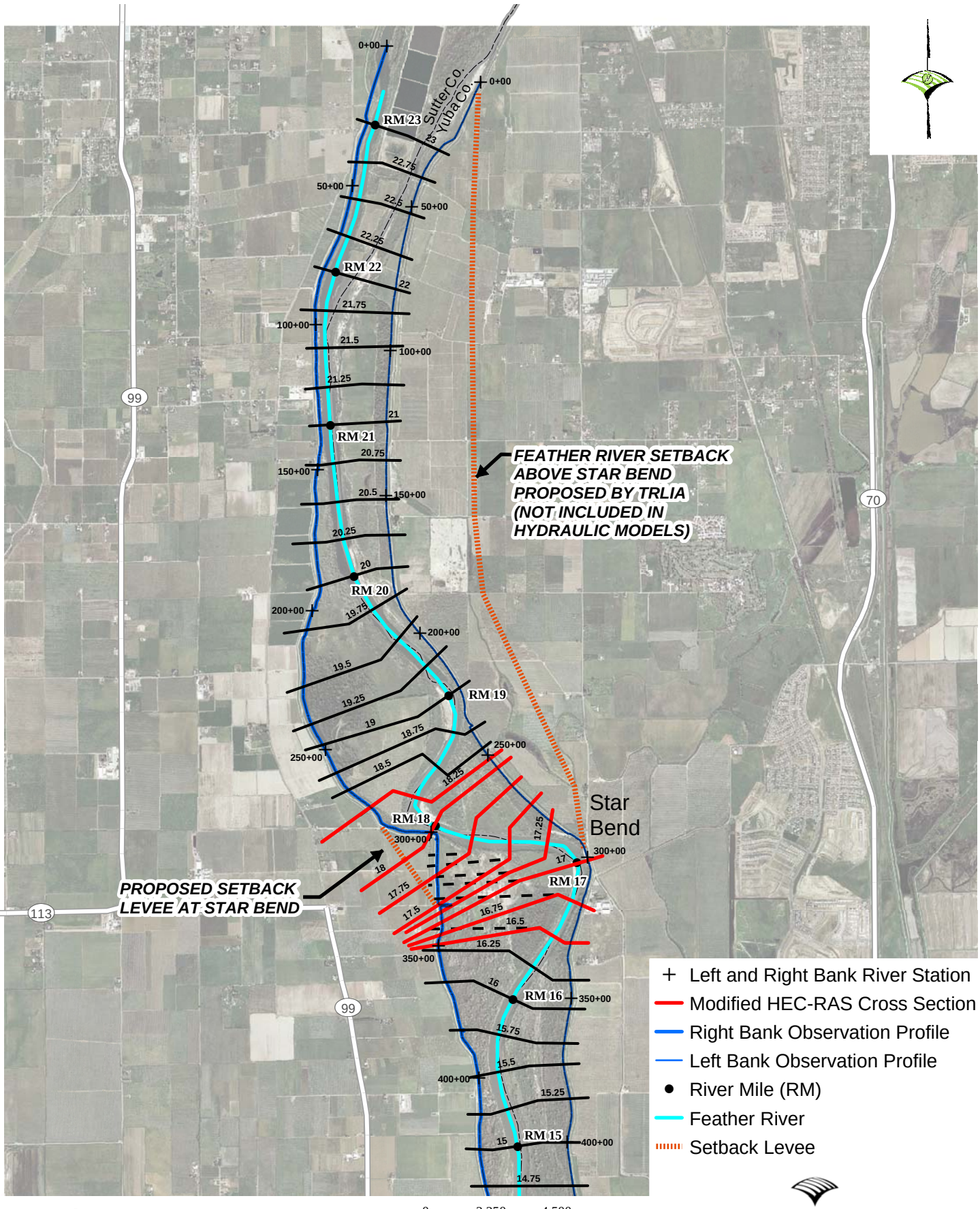
Table 6

Impact on Channel Shear Stress for 1-in-100 AEP Flow Event

Feather River	**Pre-Project**	**Post- Project**	**Difference**
River Mile (RM)	**Channel Shear**	**Channel Shear**	
	lbs/sf.	**lbs/sf.**	**lbs/sf.**
24	0.36	0.37	0.01
23.75	0.41	0.42	0.01
23.5	0.31	0.31	0
23.25	0.59	0.6	0.01
23	0.67	0.68	0.01
22.75	0.79	0.8	0.01
22.5	0.86	0.87	0.01
22.25	0.81	0.82	0.01
22	0.52	0.53	0.01
21.75	0.83	0.85	0.02
21.5	0.7	0.71	0.01
21.25	0.82	0.84	0.02
21	0.81	0.82	0.01
20.75	0.73	0.75	0.02
20.5	0.68	0.69	0.01
20.25	0.76	0.78	0.02
20	0.61	0.62	0.01
19.75	0.5	0.52	0.02
19.5	0.37	0.38	0.01
19.25	0.19	0.2	0.01
19	0.25	0.26	0.01
18.75	0.35	0.36	0.01
18.5	0.39	0.4	0.01
18.25	0.5	0.52	0.02
18	1.04	0.73	-0.31
17.75	0.67	0.56	-0.11
17.5	0.57	0.58	0.01
17.25	0.71	0.65	-0.06
17	0.82	0.78	-0.04
16.75	0.68	0.5	-0.18

LEVEE DISTRICT NO. 1 OF SUTTER COUNTY

RIGHT AND LEFT BANK RMA2 OBSERVATION PROFILES AND
MODIFIED HEC-RAS CROSS SECTIONS FOR SETBACK LEVEE AT STAR BEND



November 2007

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DEVELOPING INNOVATIVE DESIGN SOLUTIONS

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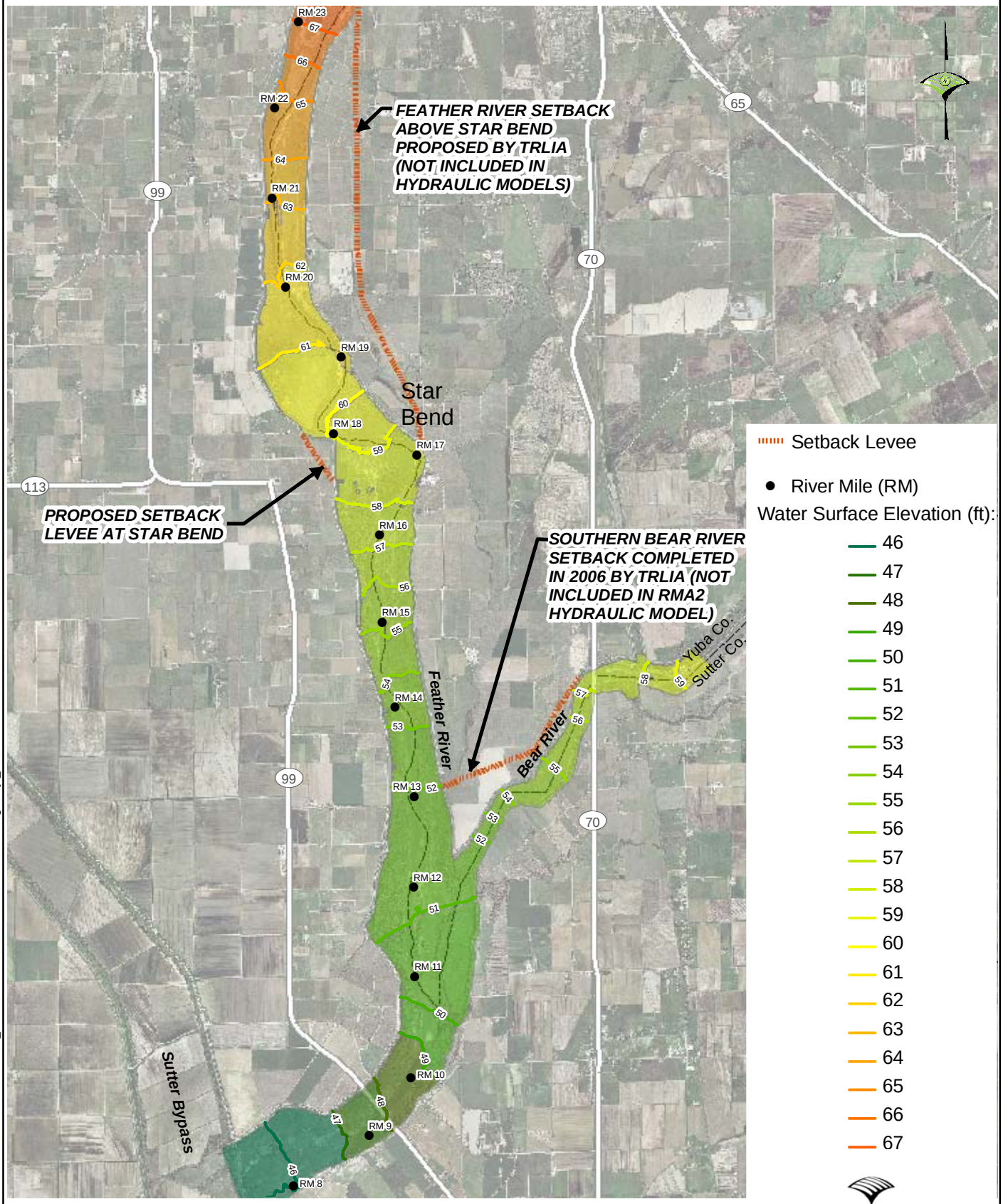
FIGURE 1

LEVEE DISTRICT NO. 1 OF SUTTER COUNTY

LIMITS OF RMA2 TWO-DIMENSIONAL MODEL FOR SETBACK LEVEE AT STAR BEND AND WATER SURFACE ELEVATION CONTOURS FOR 1-IN-100 AEP FLOW EVENT FOR EXISTING CONDITIONS



November 2007

WOOD RODGERS
DEVELOPING INNOVATIVE DESIGN SOLUTIONS

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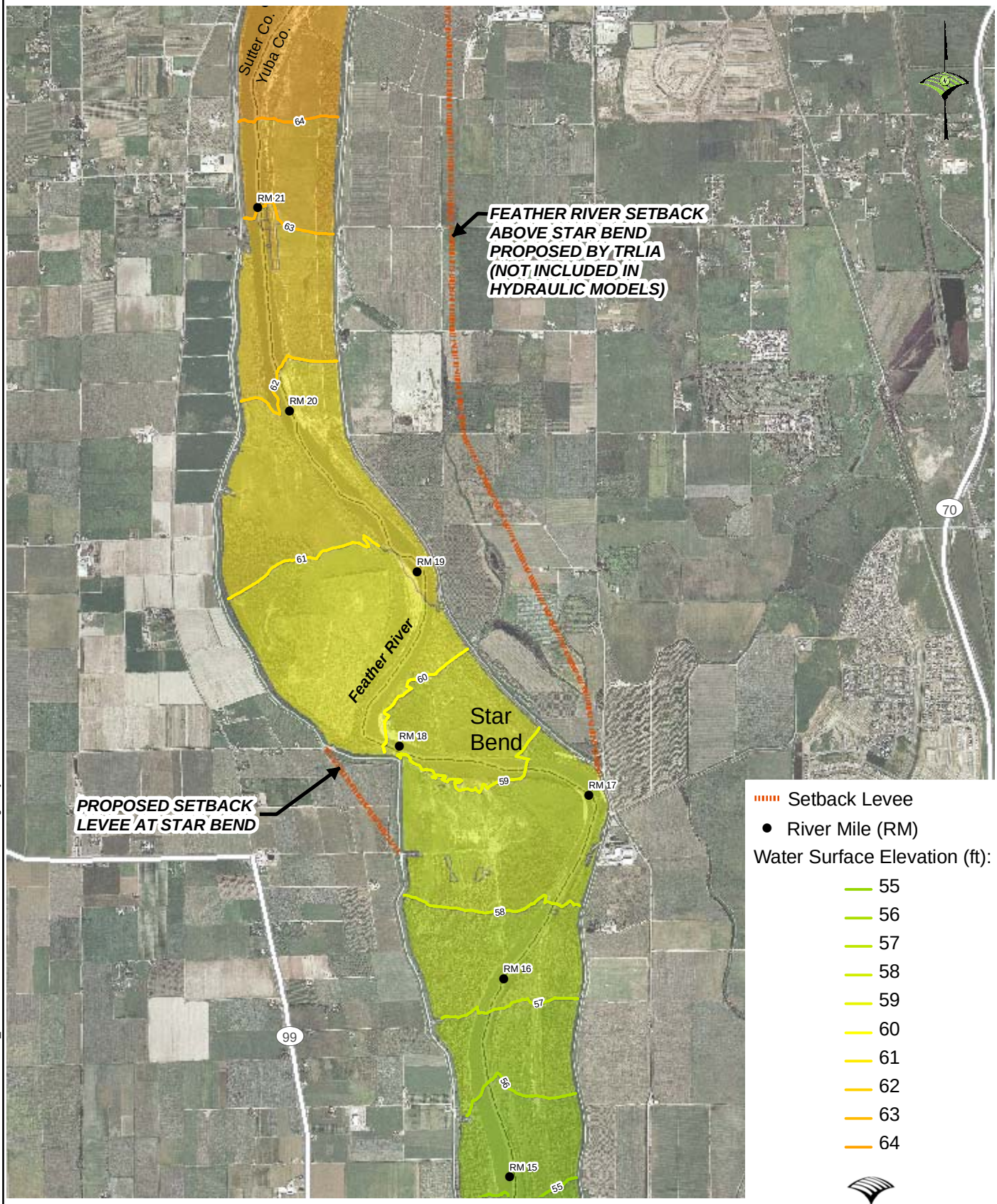
FIGURE 2

LEVEE DISTRICT NO. 1 OF SUTTER COUNTY

WATER SURFACE ELEVATION CONTOURS OF EXISTING CONDITIONS
AT STAR BEND FOR 1-IN-100 AEP FLOW EVENT



November 2007

0 1,750 3,500 Feet

WOOD RODGERS
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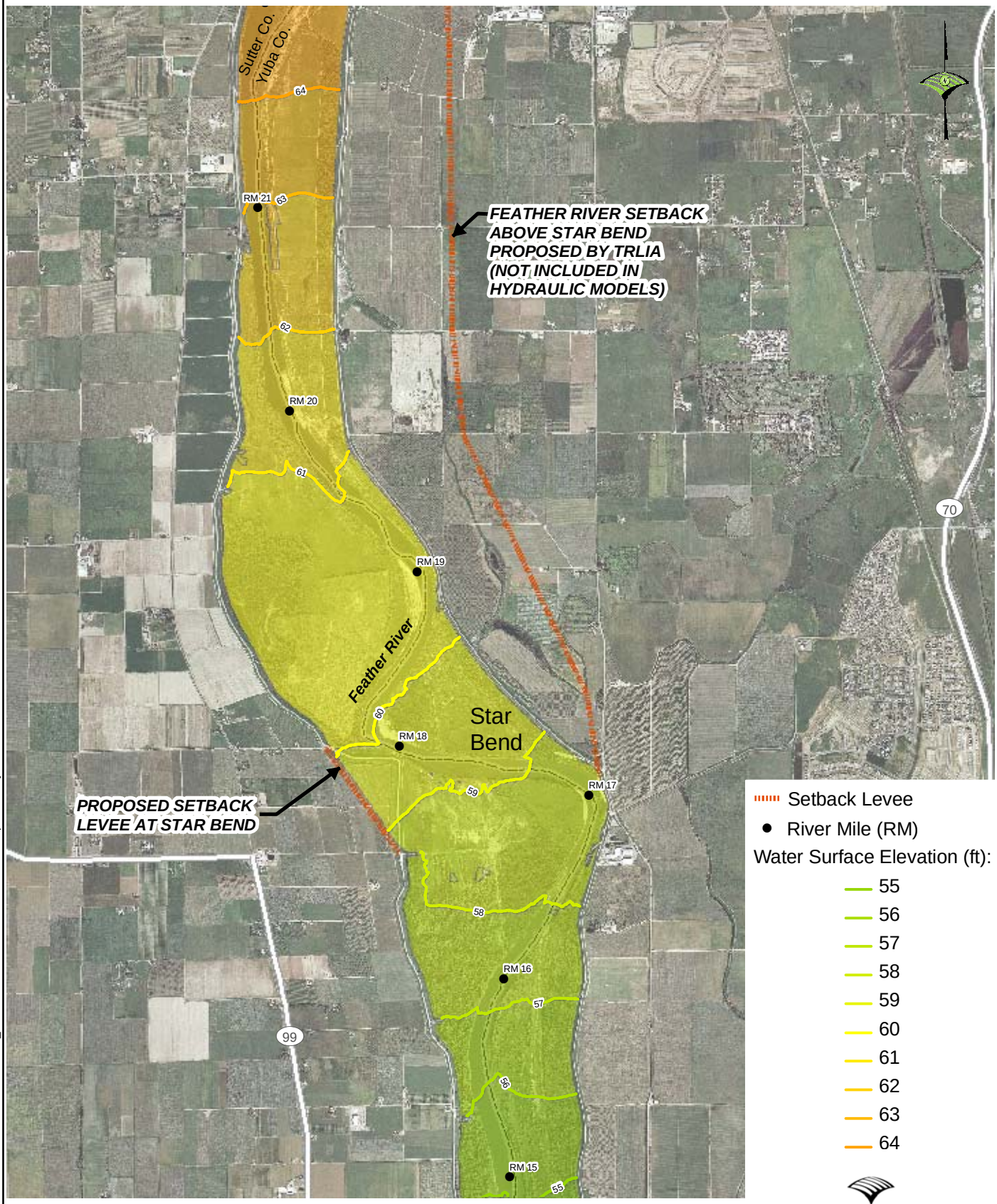
FIGURE 3

LEVEE DISTRICT NO. 1 OF SUTTER COUNTY

WATER SURFACE ELEVATION CONTOURS OF PROPOSED CONDITIONS
AT STAR BEND FOR 1-IN-100 AEP FLOW EVENT



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WOOD RODGERS
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FIGURE 4

LEVEE DISTRICT NO. 1 OF SUTTER COUNTY

WATER SURFACE ELEVATION DIFFERENCES BETWEEN EXISTING AND PROPOSED CONDITIONS AT STAR BEND FOR 1-IN-100 AEP FLOW EVENT

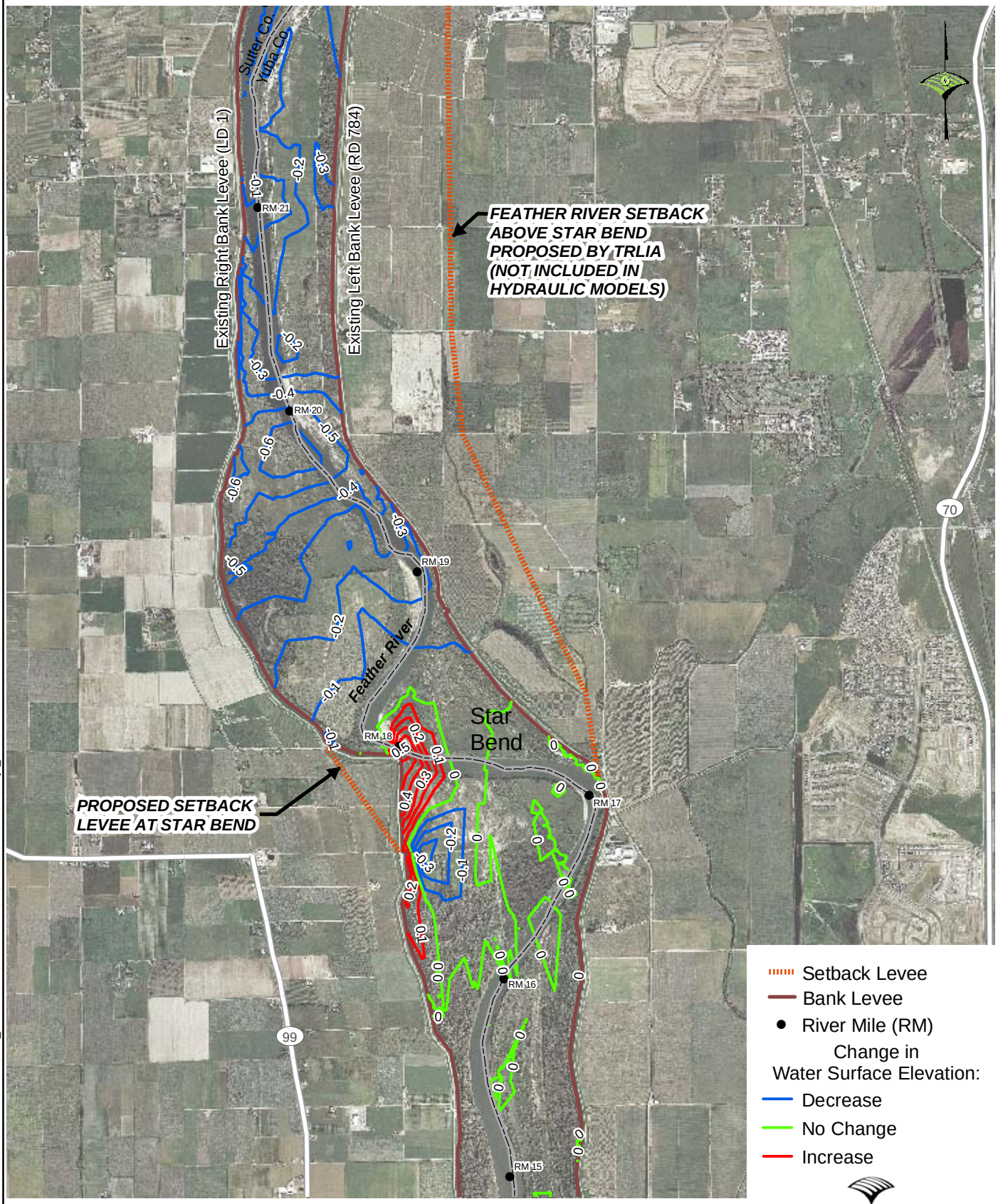

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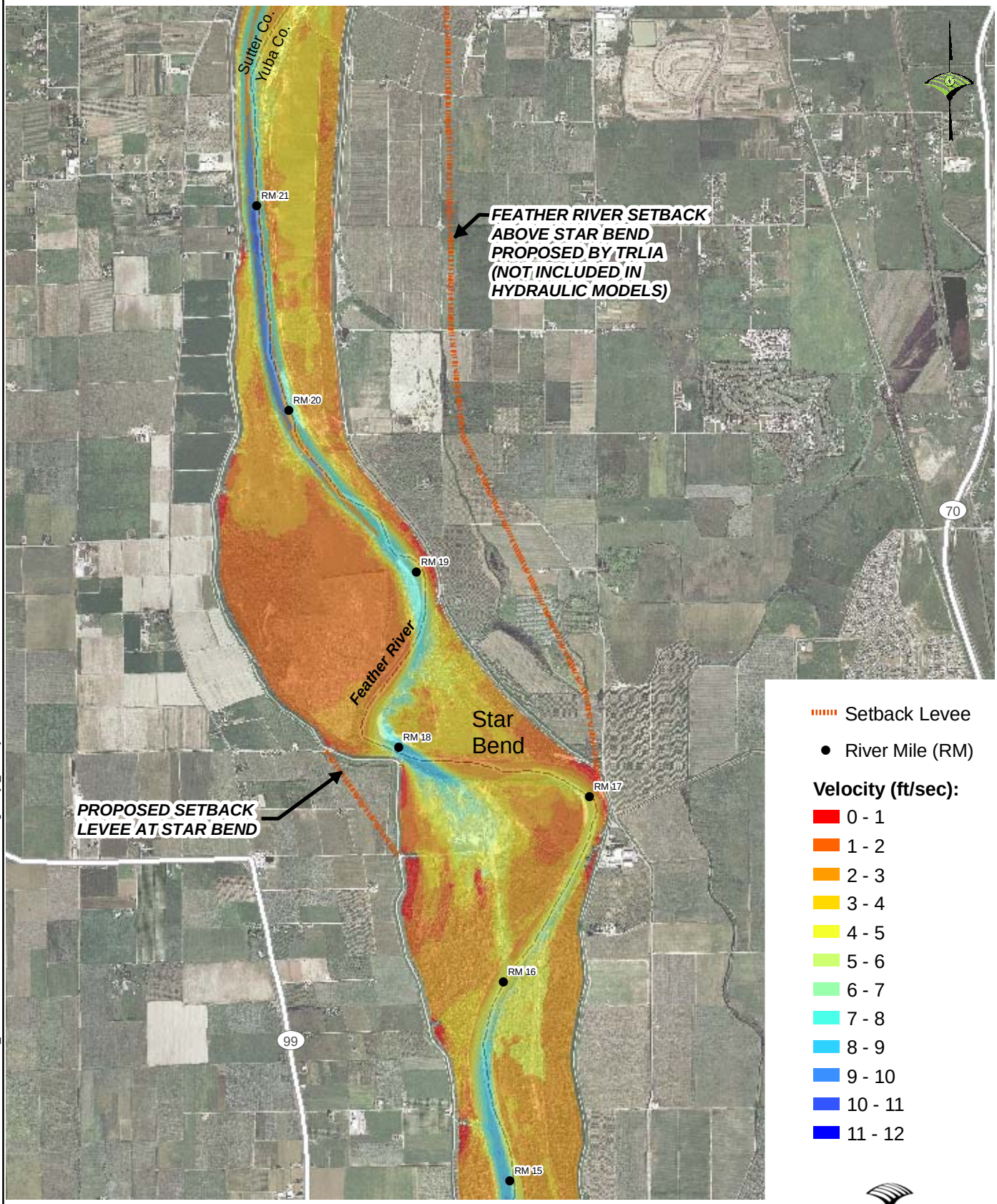
FIGURE 5

LEVEE DISTRICT NO. 1 OF SUTTER COUNTY

VELOCITY CONTOURS OF EXISTING CONDITIONS
AT STAR BEND FOR 1-IN-100 AEP FLOW EVENT



November 2007

0 1,750 3,500 Feet

WOOD RODGERS
DEVELOPING INNOVATIVE DESIGN SOLUTIONS

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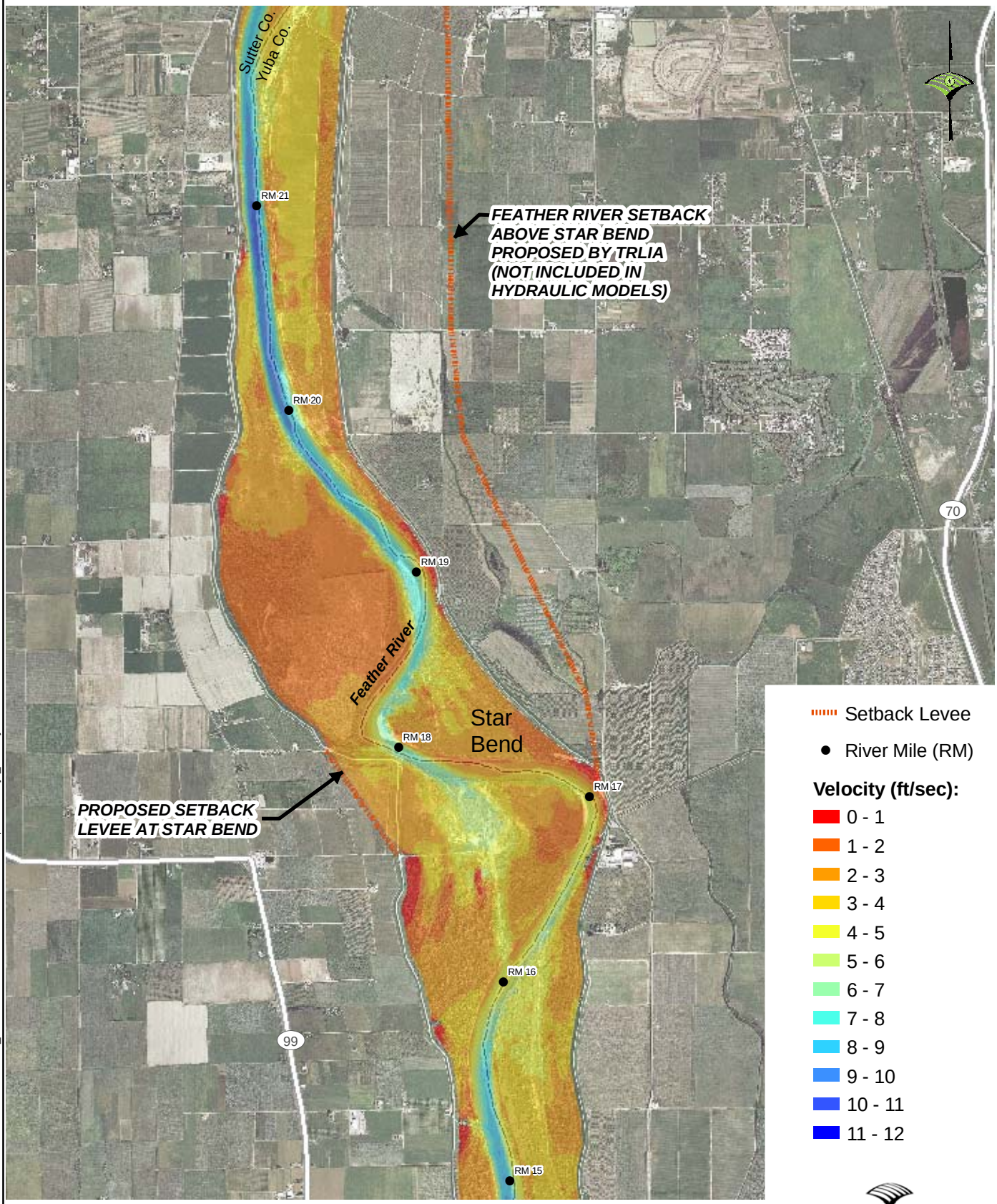
FIGURE 6

LEVEE DISTRICT NO. 1 OF SUTTER COUNTY

VELOCITY CONTOURS OF PROPOSED CONDITIONS WITH SETBACK LEVEE AT STAR BEND FOR 1-IN-100 AEP FLOW EVENT



November 2007

0 1,750 3,500 Feet

WOOD RODGERS
DEVELOPING INNOVATIVE DESIGN SOLUTIONS

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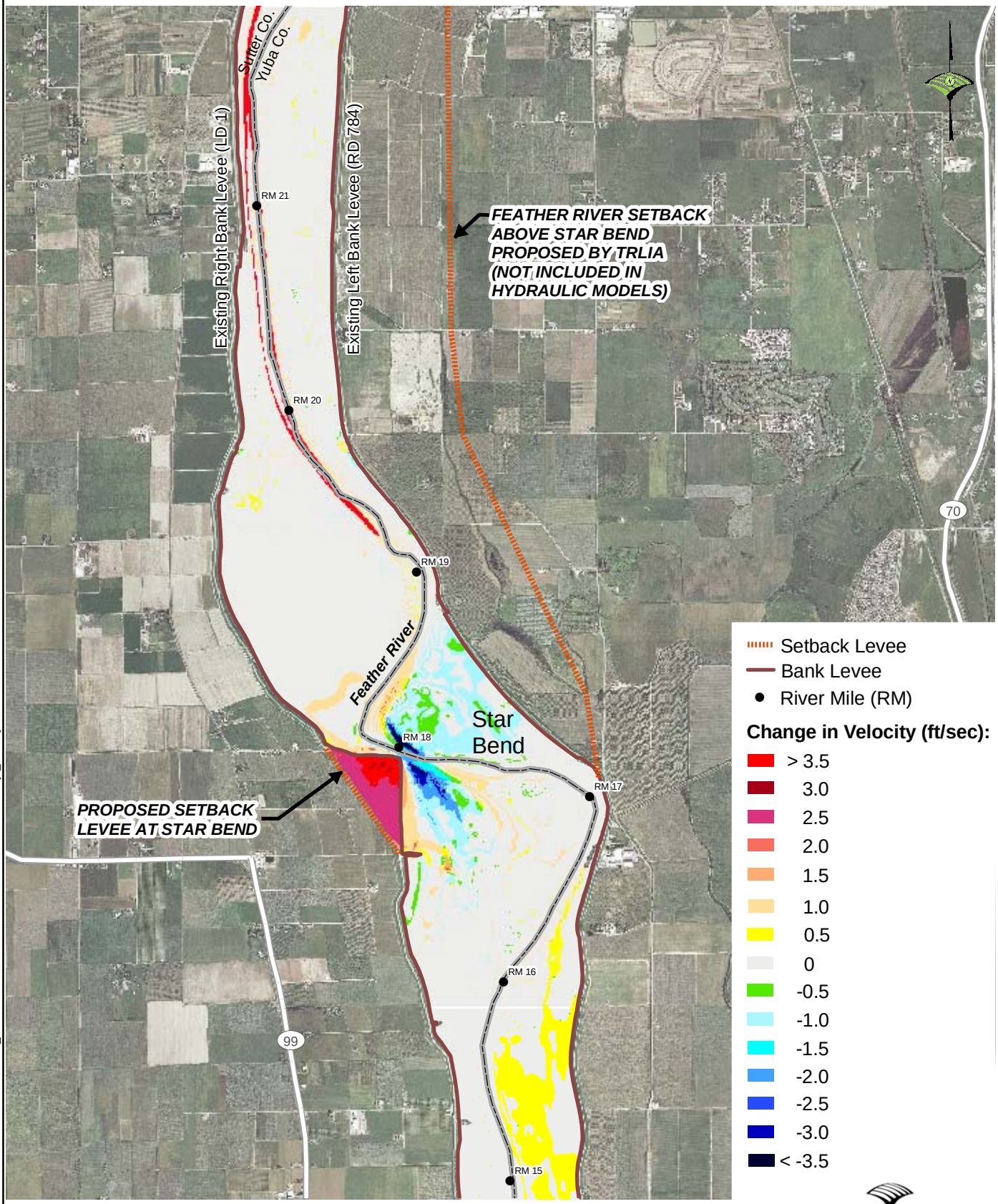
FIGURE 7

LEVEE DISTRICT NO. 1 OF SUTTER COUNTY

VELOCITY DIFFERENCES BETWEEN EXISTING AND PROPOSED CONDITIONS
AT STAR BEND FOR 1-IN-100 AEP FLOW EVENT



November 2007

0 1,750 3,500 Feet

WOOD RODGERS
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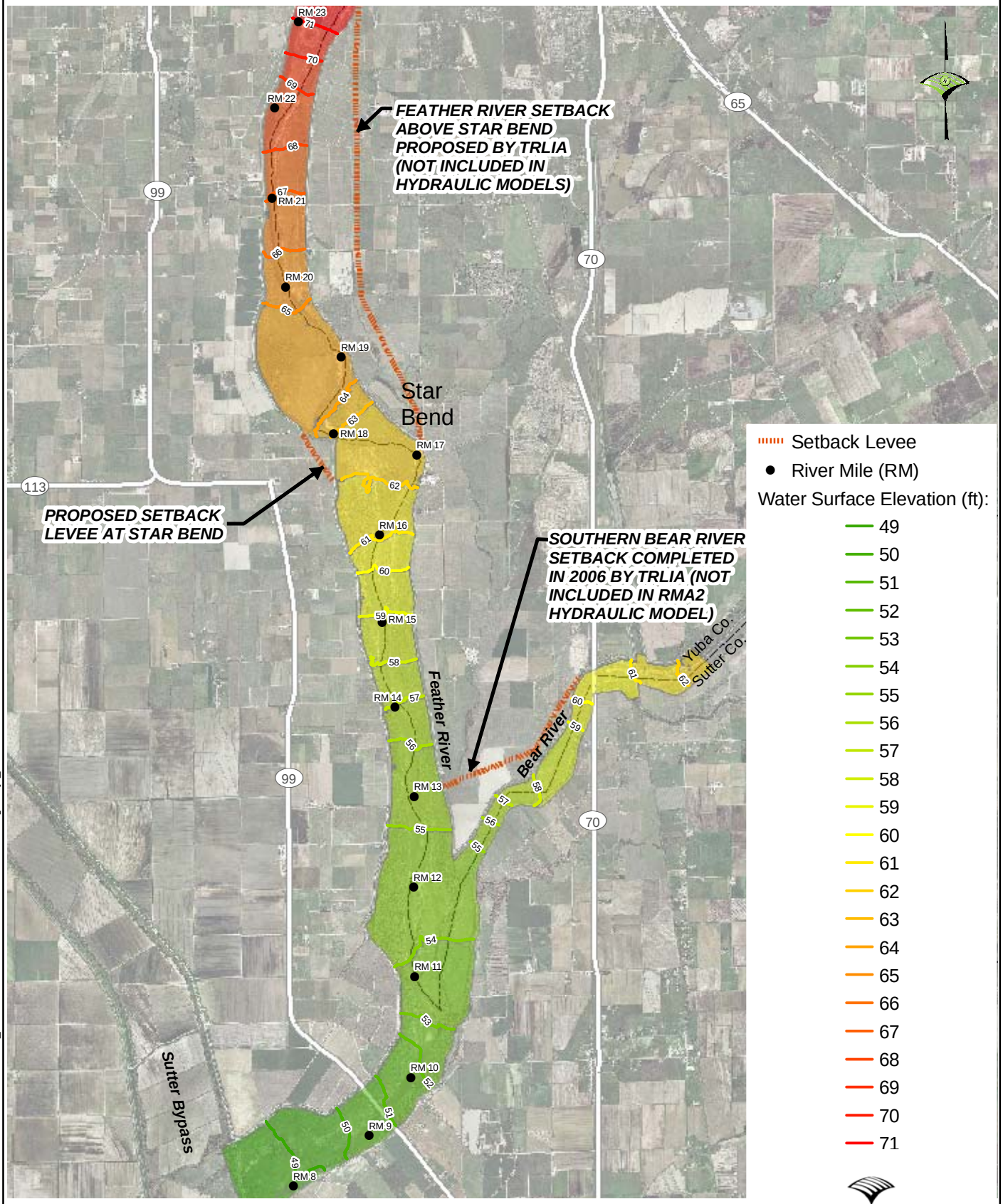
FIGURE 8

LEVEE DISTRICT NO. 1 OF SUTTER COUNTY

LIMITS OF RMA2 TWO-DIMENSIONAL MODEL FOR SETBACK LEVEE AT STAR BEND AND WATER SURFACE ELEVATION CONTOURS FOR 1-IN-200 AEP FLOW EVENT FOR EXISTING CONDITIONS



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WOOD RODGERS
DEVELOPING INNOVATIVE DESIGN SOLUTIONS

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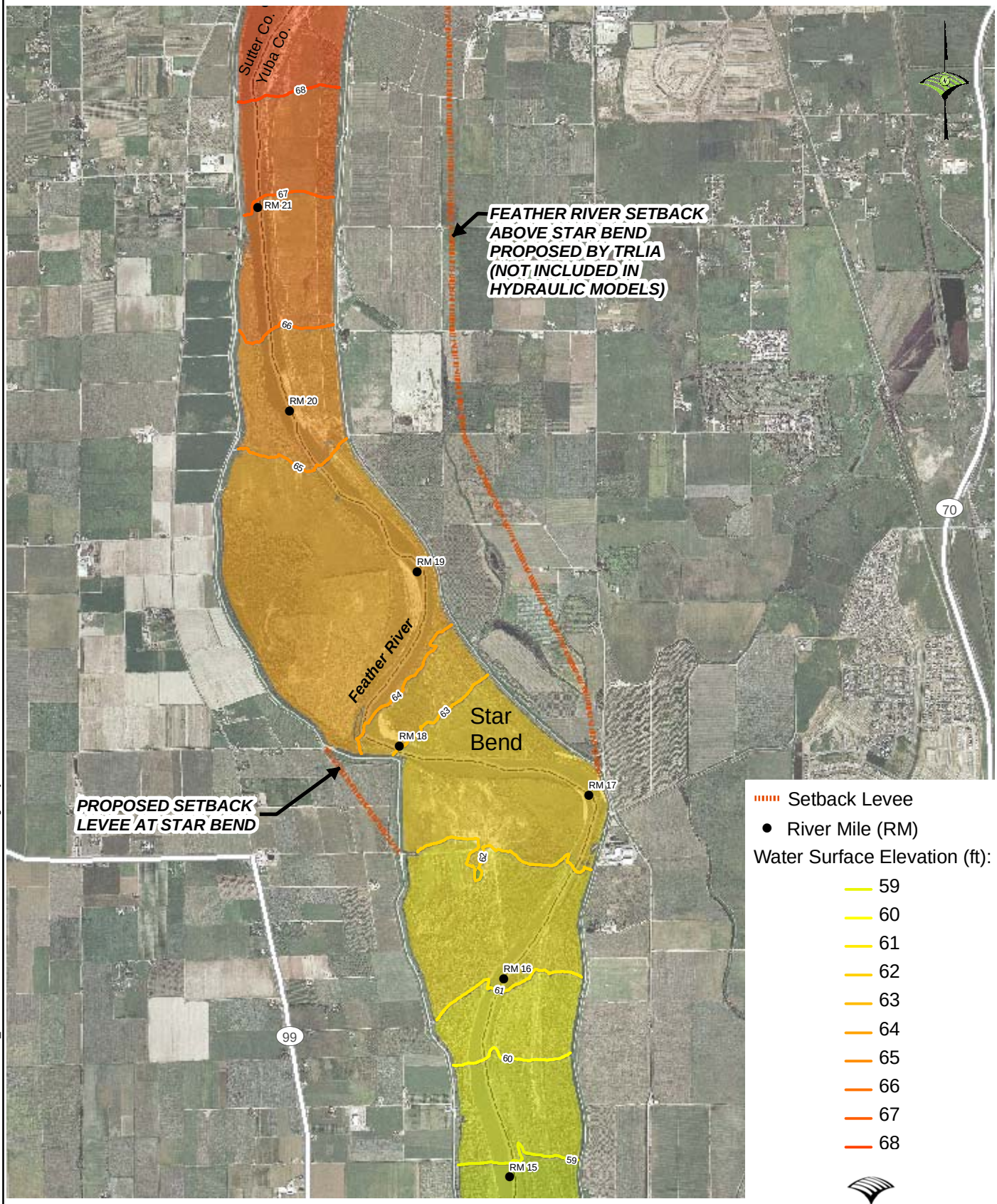
FIGURE 9

LEVEE DISTRICT NO. 1 OF SUTTER COUNTY

WATER SURFACE ELEVATION CONTOURS OF EXISTING CONDITIONS
AT STAR BEND FOR 1-IN-200 AEP FLOW EVENT



November 2007

0 1,750 3,500 Feet

WOOD RODGERS
DEVELOPING INNOVATIVE DESIGN SOLUTIONS

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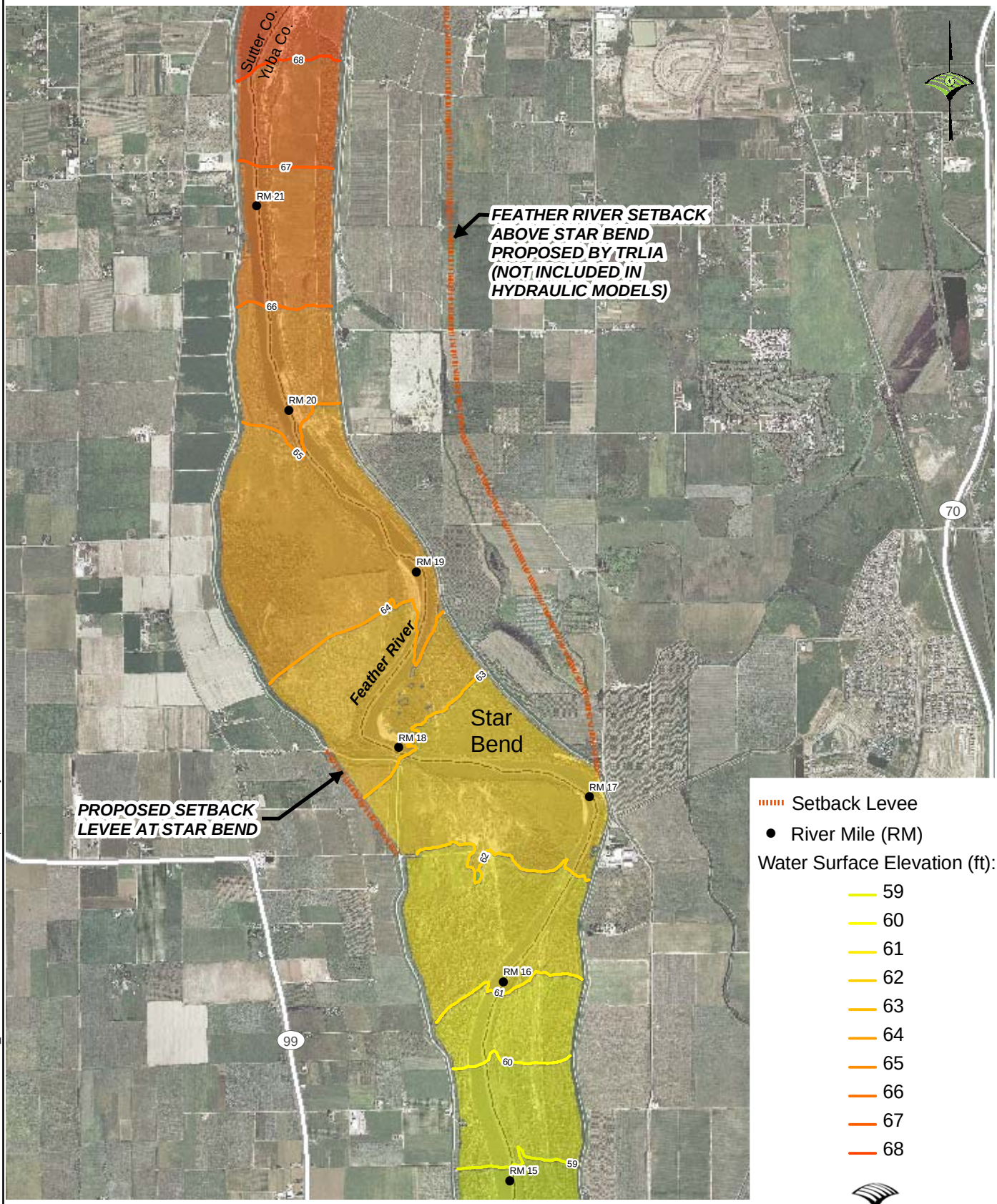
FIGURE 10

LEVEE DISTRICT NO. 1 OF SUTTER COUNTY

WATER SURFACE ELEVATION CONTOURS OF PROPOSED CONDITIONS WITH SETBACK LEVEE AT STAR BEND FOR 1-IN-200 AEP FLOW EVENT



November 2007

0 1,750 3,500 Feet

WOOD RODGERS
DEVELOPING INNOVATIVE DESIGN SOLUTIONS

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FIGURE 11

LEVEE DISTRICT NO. 1 OF SUTTER COUNTY

WATER SURFACE ELEVATION DIFFERENCES BETWEEN EXISTING AND PROPOSED CONDITIONS AT STAR BEND FOR 1-IN-200 AEP FLOW EVENT

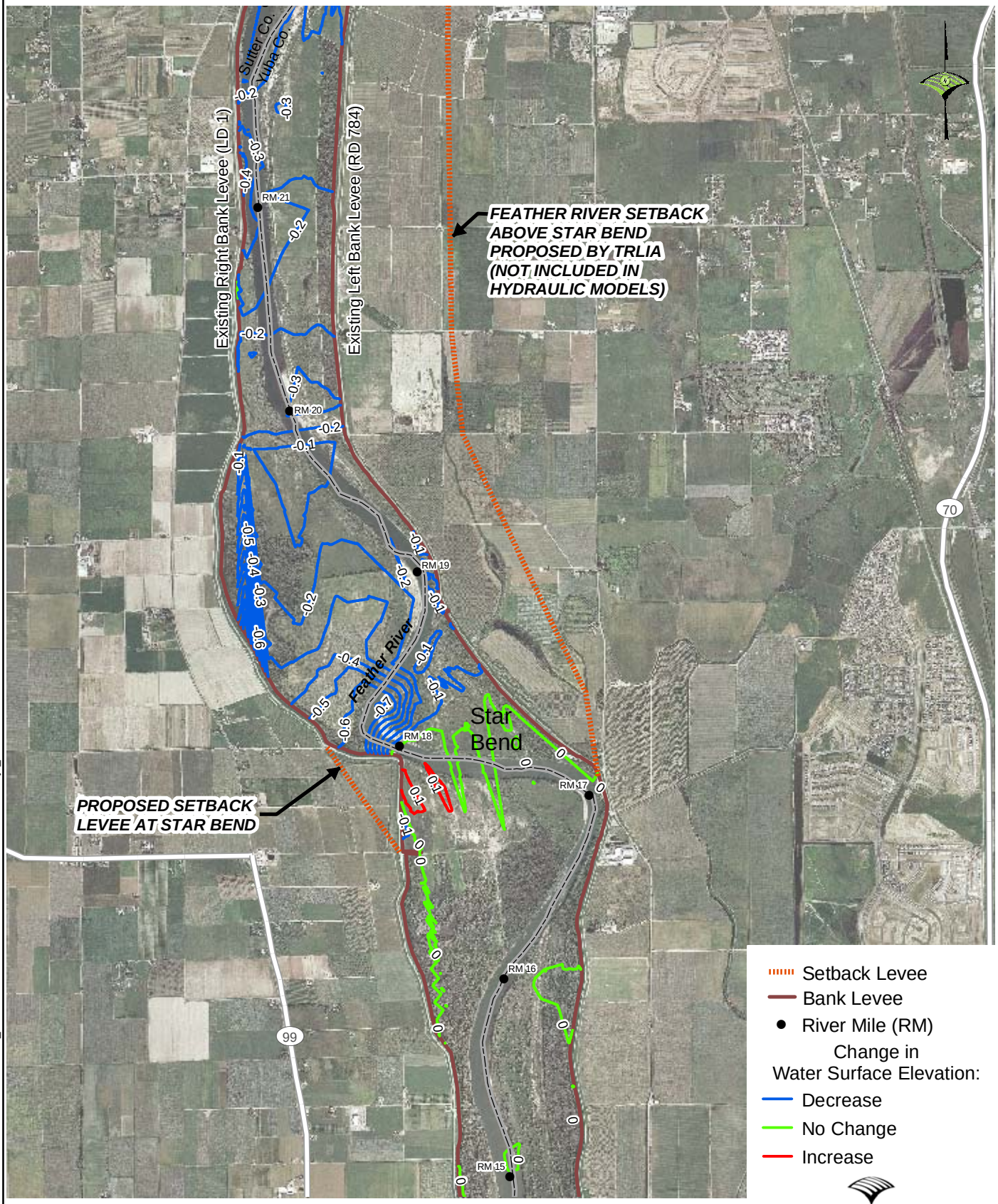

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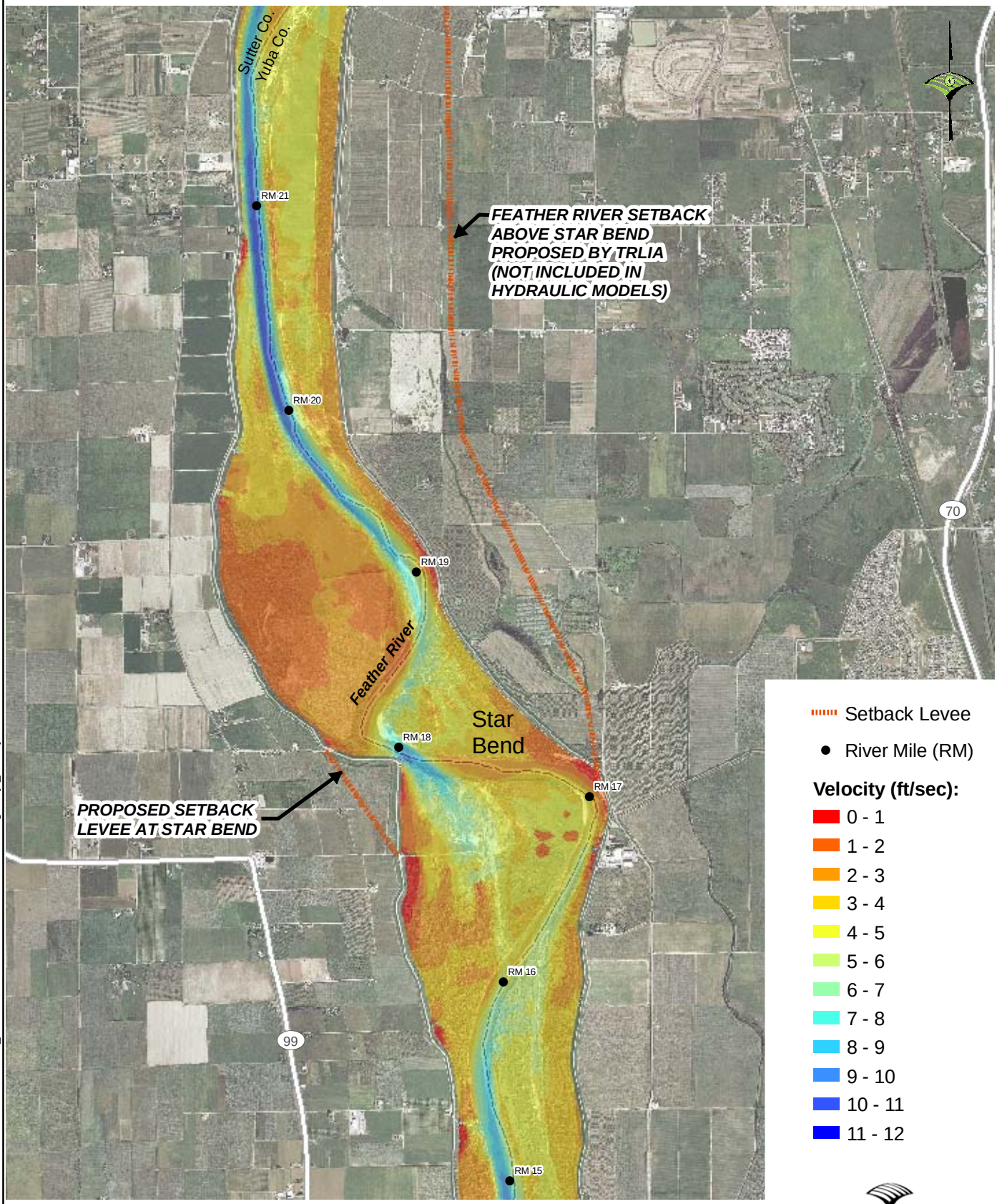
FIGURE 12

LEVEE DISTRICT NO. 1 OF SUTTER COUNTY

VELOCITY CONTOURS OF EXISTING CONDITIONS
AT STAR BEND FOR 1-IN-200 AEP FLOW EVENT



November 2007

0 1,750 3,500 Feet

WOOD RODGERS
DEVELOPING INNOVATIVE DESIGN SOLUTIONS

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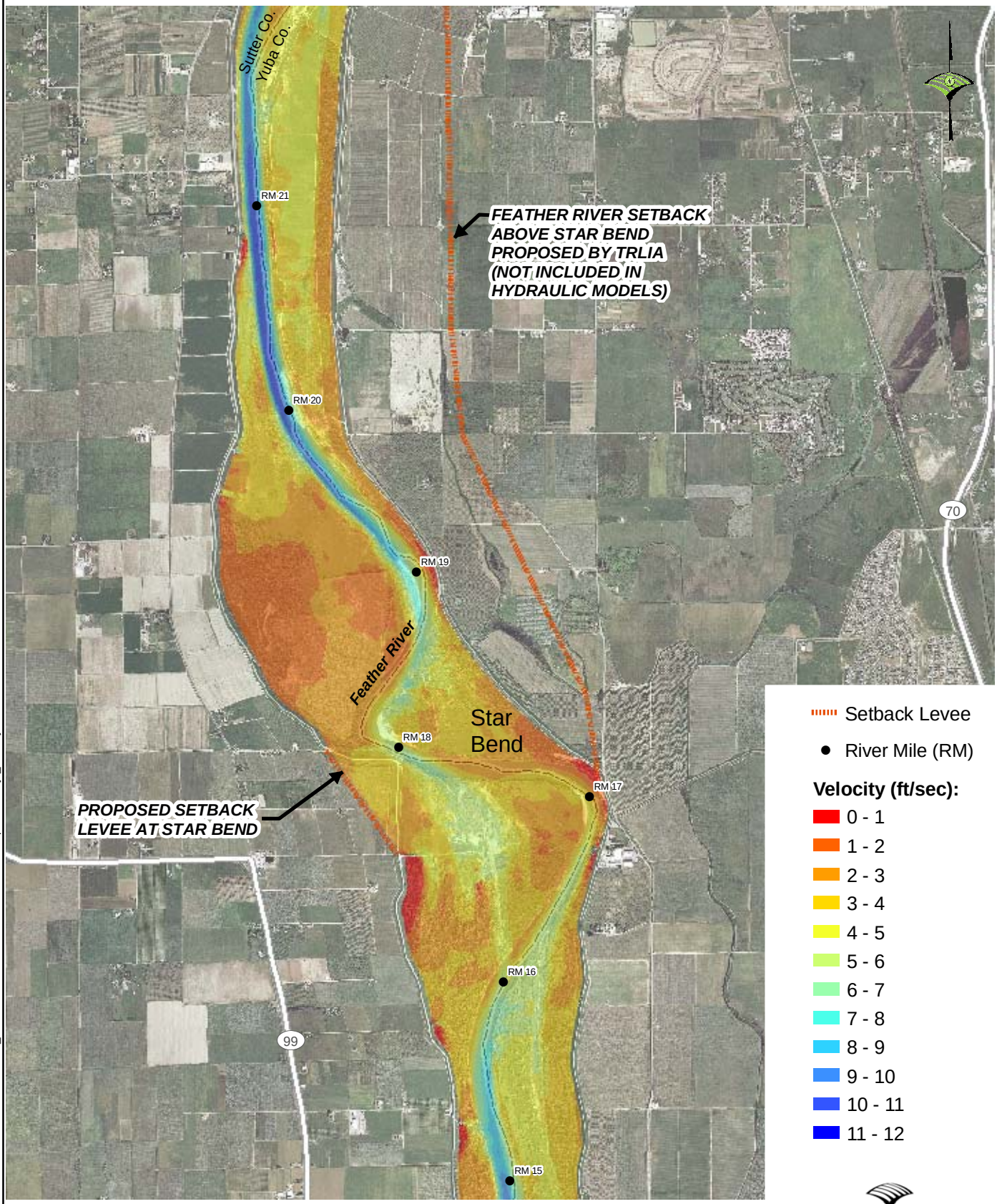
FIGURE 13

LEVEE DISTRICT NO. 1 OF SUTTER COUNTY

VELOCITY CONTOURS OF PROPOSED CONDITIONS WITH SETBACK LEVEE AT STAR BEND FOR 1-IN-200 AEP FLOW EVENT



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0 1,750 3,500 Feet

WOOD RODGERS
DEVELOPING INNOVATIVE DESIGN SOLUTIONS

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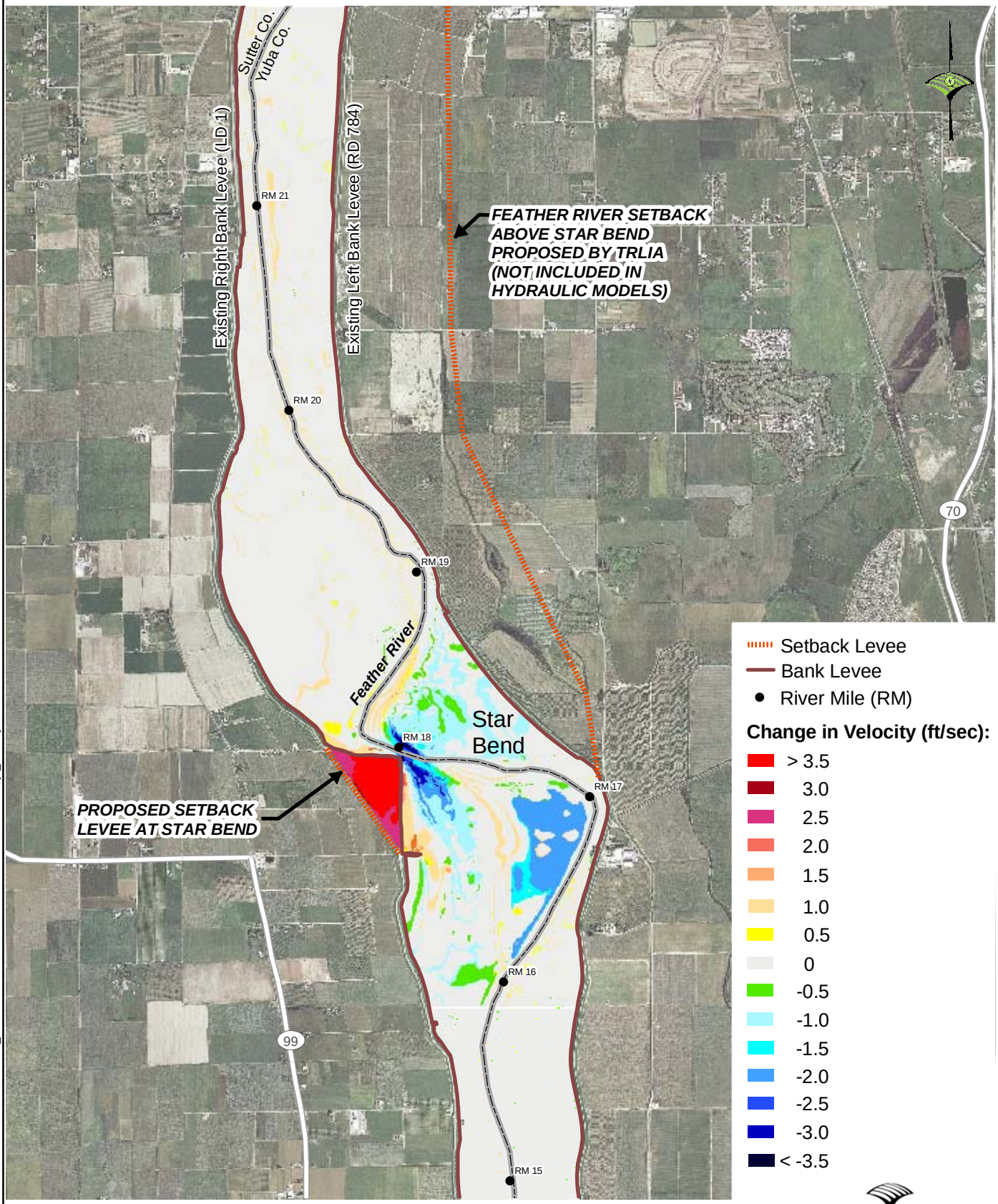
FIGURE 14

LEVEE DISTRICT NO. 1 OF SUTTER COUNTY

VELOCITY DIFFERENCES BETWEEN EXISTING AND PROPOSED CONDITIONS
AT STAR BEND FOR 1-IN-200 AEP FLOW EVENT



November 2007

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WOOD RODGERS
DEVELOPING INNOVATIVE DESIGN SOLUTIONS

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FIGURE 15

FIGURE 16

PRE- AND POST-PROJECT WATER SURFACE PROFILES OF LOWER FEATHER RIVER RIGHT BANK WITH SETBACK LEVEE AT STAR BEND FOR 1-IN-100 AND 200 AEP FLOW EVENTS, THE USACE 1957 DESIGN PROFILE, AND 300,000 CFS FLOW EVENT

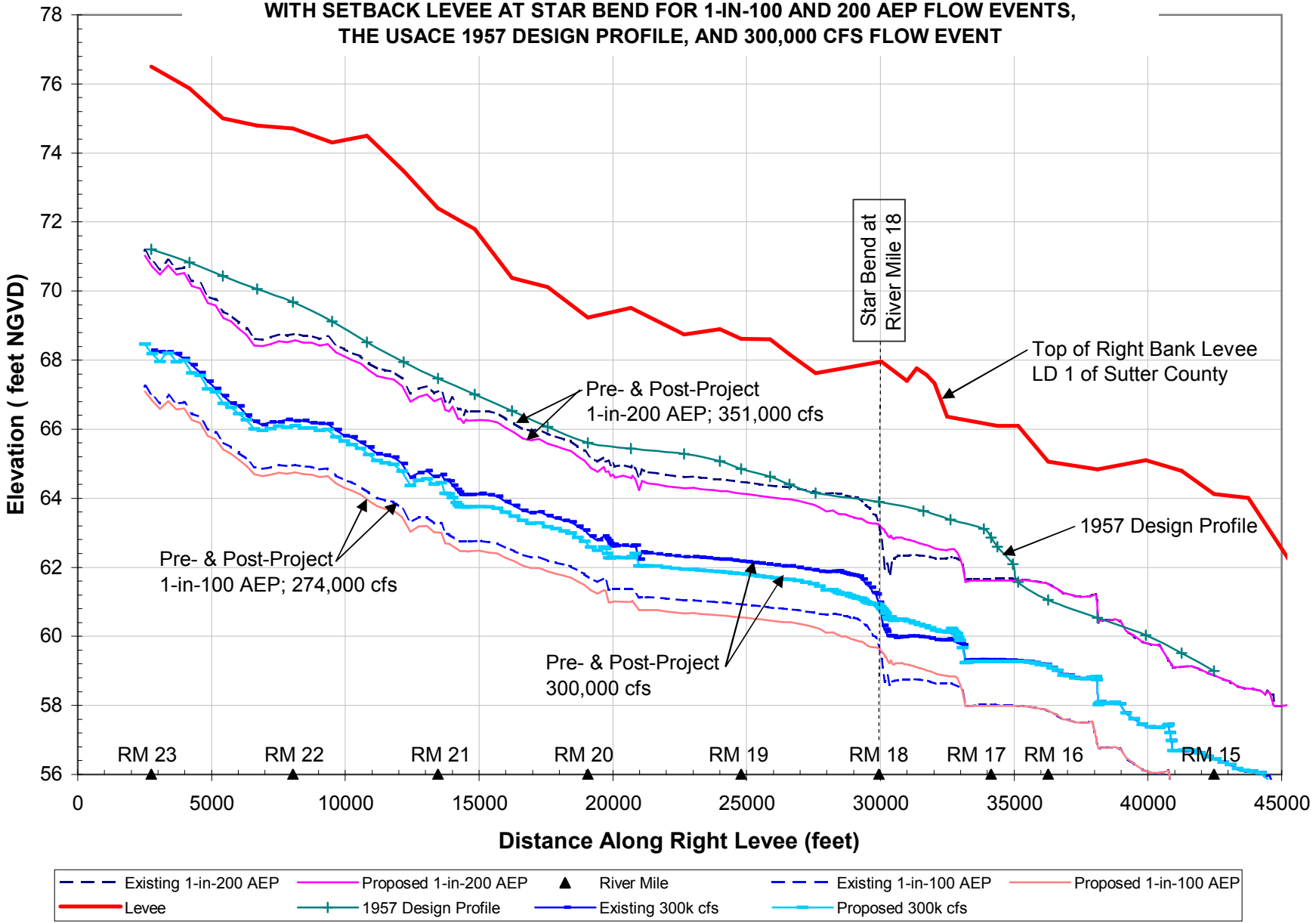

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FIGURE 17

PRE- AND POST-PROJECT WATER SURFACE PROFILES OF LOWER FEATHER RIVER LEFT BANK WITH SETBACK LEVEE AT STAR BEND FOR 1-IN-100 AND 200 AEP FLOW EVENTS, THE USACE 1957 DESIGN PROFILE, AND 300,000 CFS FLOW EVENT

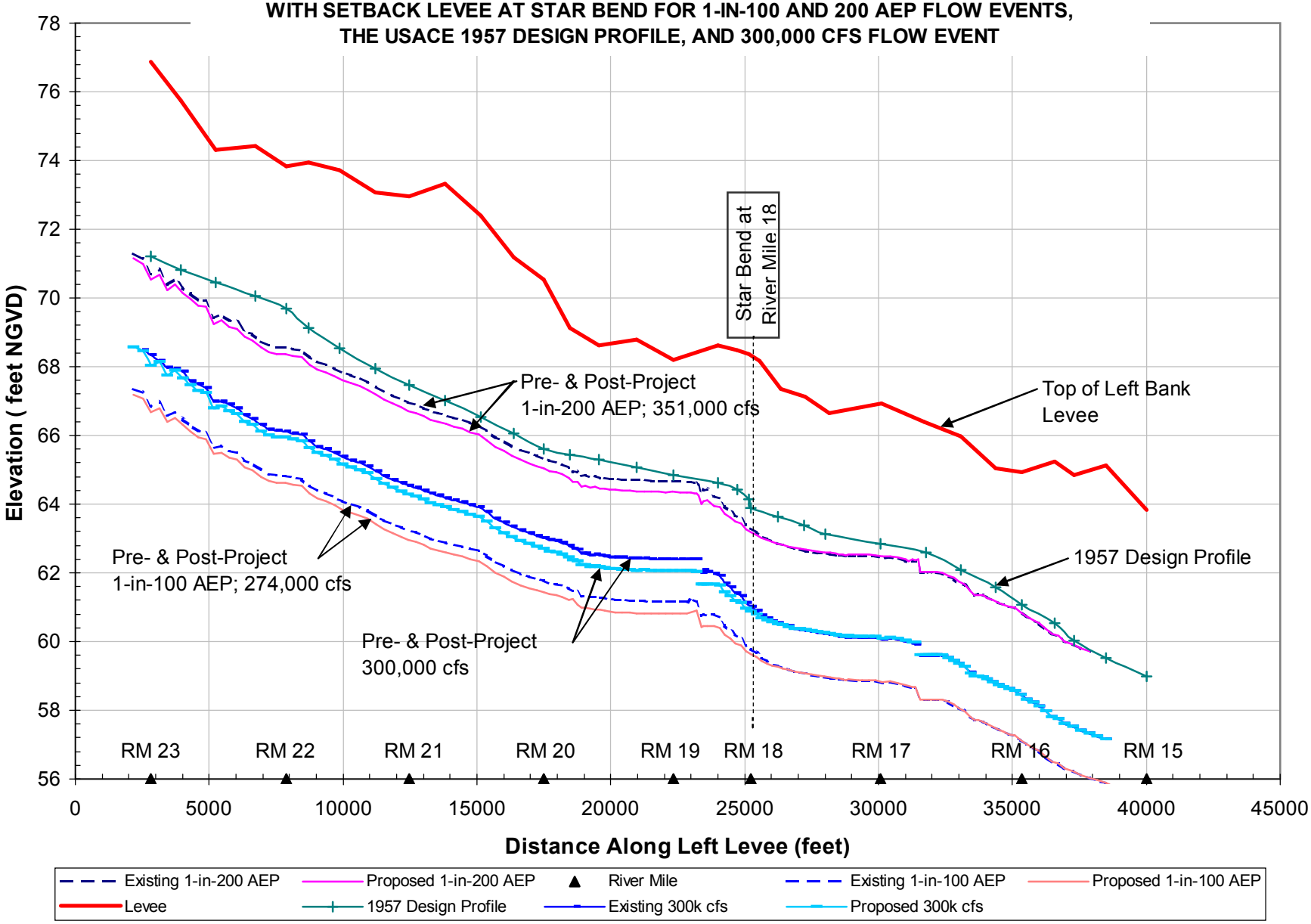

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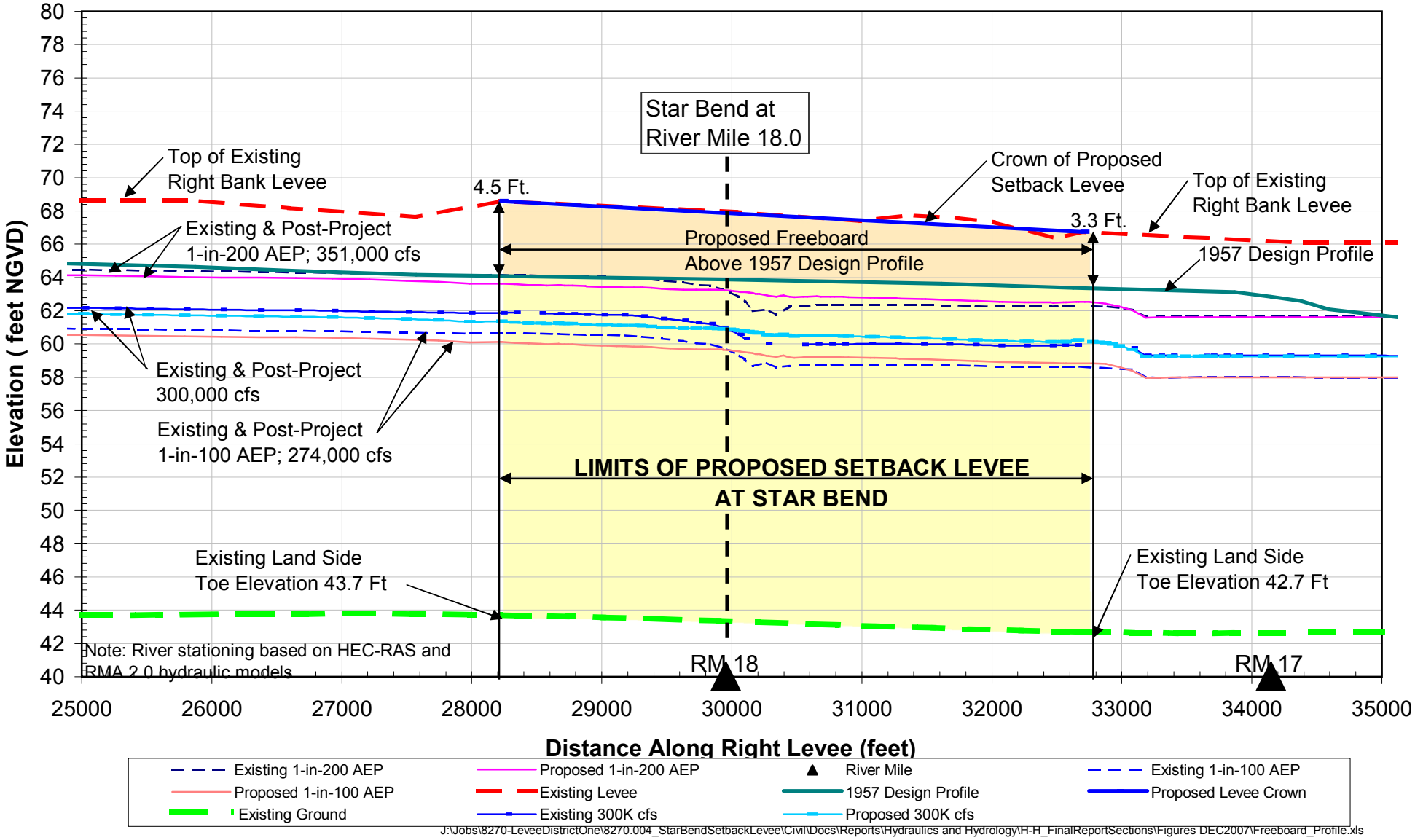
FIGURE 18

PRE- AND POST-PROJECT WATER SURFACE PROFILES OF RIVER RIGHT BANK FEATHER RIVER AT STAR BEND SETBACK LEVEE FOR 1-IN-100 AND 200 AEP FLOW EVENTS, 300,000 CFS, AND THE USACE 1957 DESIGN PROFILE



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APPENDIX A

Star Bend Setback Levee Hydraulic Analysis - Memorandum to Sutter County Public Works, Prepared by MBK Engineers, June 2004

MBK ENGINEERS

Water Resources • Flood Control • Water Rights

M E M O R A N D U M

DATE: June 28, 2004

TO: Sutter County Public Works File

FROM: Don Trieu

SUBJECT: Star Bend Setback Levee Hydraulic Analysis

MBK Engineers has completed a preliminary hydraulic analysis of the setback levee on the right bank Feather River at Star Bend. A hydraulic analysis was performed to determine the potential stage and velocity impacts associated with the project.

The existing levee on the right bank Feather River at Star Bend has experienced numerous problems due to the alignment of the levee. The levee runs due east-west at the end of Star Bend Road then turns 90 degrees north-south at the Feather River. The proposed setback levee alignment would start at the end of Star Bend Road then continue diagonally to the projected intersection of Tudor Road and the Feather River right bank levee. The setback levee is approximately 10,000 lineal feet. It was assumed that the existing orchard would be removed and replanted with native vegetation and trees. The existing levee would be degraded to the existing ground elevation ~ 42.0 feet NGVD. In addition, the access ramp to O'Connor Lakes that runs due east-west is removed.

The hydraulic analysis was performed using RMA2. RMA2 is a two dimensional finite element program for solving hydrodynamic problems. It will calculate water surface elevations and flow velocities. The 2-d model begins at River Mile 23 and extends downstream to the Nicholas gage, ~ RM 7.75. It also includes approximately 2 miles of the Bear River. The model was calibrated to the January 1997 flood. The peak flow in the Feather River below Yuba River was estimated to be 311,000 cfs.

To evaluate potential hydraulic impacts, the setback levee alignment was modeled and the results compared to the January 1997 results. Both water surface elevations and flow velocity were compared. The results are as follows.

Results:

The results of the January 1997 calibration are shown in Figure 1 and 2. Figure 1 shows the water surface in the vicinity upstream and downstream of the Feather River at Star Bend. The water surface in the model reach shown varies from elevation 59.0 feet NGVD to elevation 67.0 feet NGVD. At Star Bend, the water surface elevation is approximately 61.5 feet NGVD. The velocity in the Feather River varies throughout the river reach (Figure 2). At Star Bend, the

velocities in the river adjacent to the levee are as high as 9 to 10 feet per second. The flood plain velocities at Star Bend are approximately 1 to 4 fps.

Figures 3 and 4 show the water surface elevation and velocities, respectively, for the setback levee. The figures also show the setback levee alignment. With the setback levee alignment, the velocity along the setback levee is 3 to 4 fps. The velocity in the river at Star Bend is 7 to 8 fps.

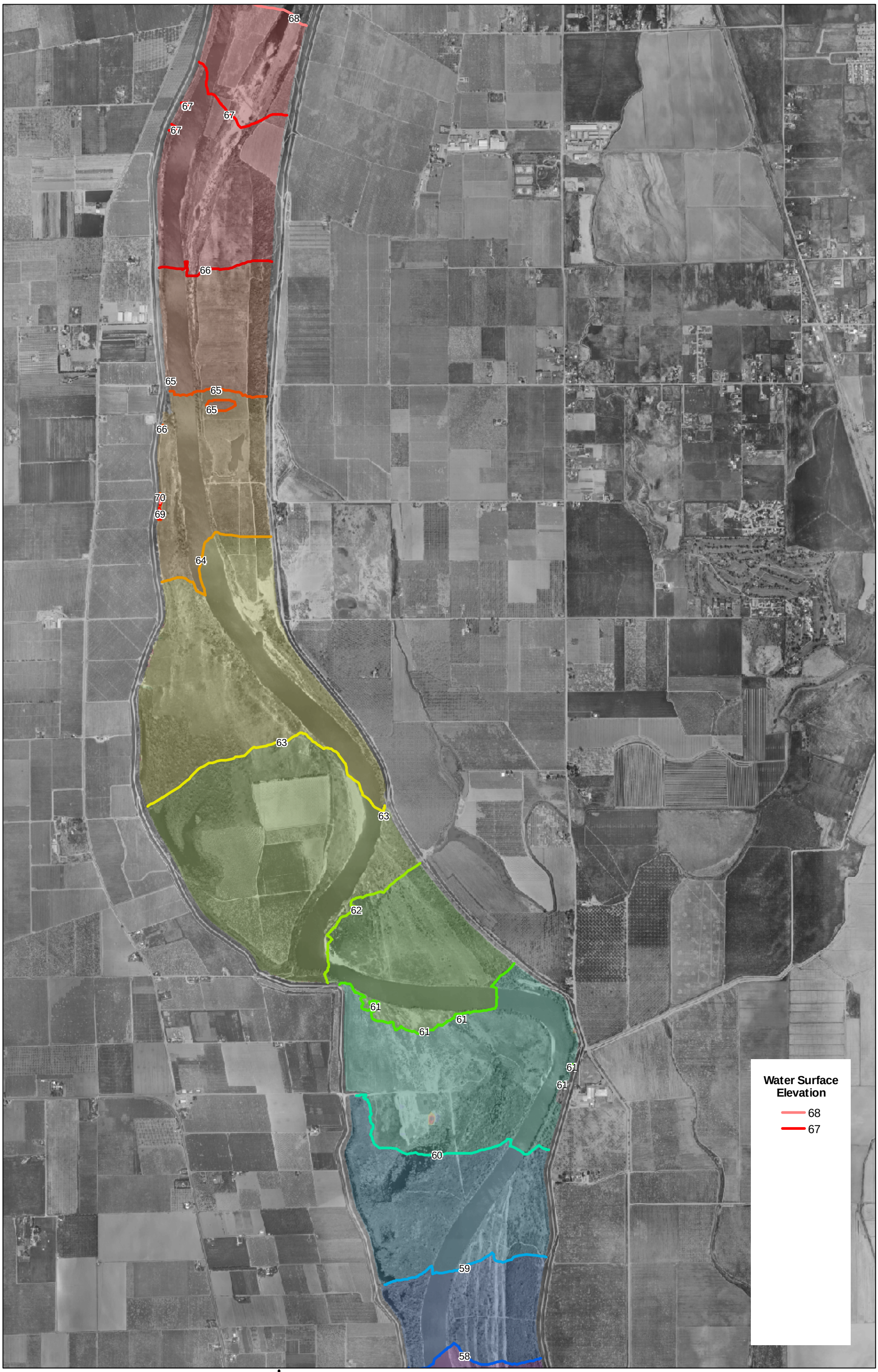
The water surface elevation and velocities for the setback levee were compared to the January 1997 condition in Figures 5 and 6, respectively. A positive number indicates an increase in water surface elevation or velocity as a result of the setback levee. A negative number indicates a decrease in water surface elevation or velocity. Figure 5 shows the difference in water surface elevation. Upstream of Star Bend, the water surface elevation would decrease by 0.3 to 0.5 feet with the setback levee. There would be minimal increases in water surface elevations downstream of the setback levee. The velocity difference is shown in Figure 6. Velocities would decrease by as much 3 to 5 fps in the river at Star Bend with the setback levee. Just downstream of the setback levee where the setback levee transition back to the existing levee, the velocity would increase by 1 to 4 fps.

Conclusion and Recommendations:

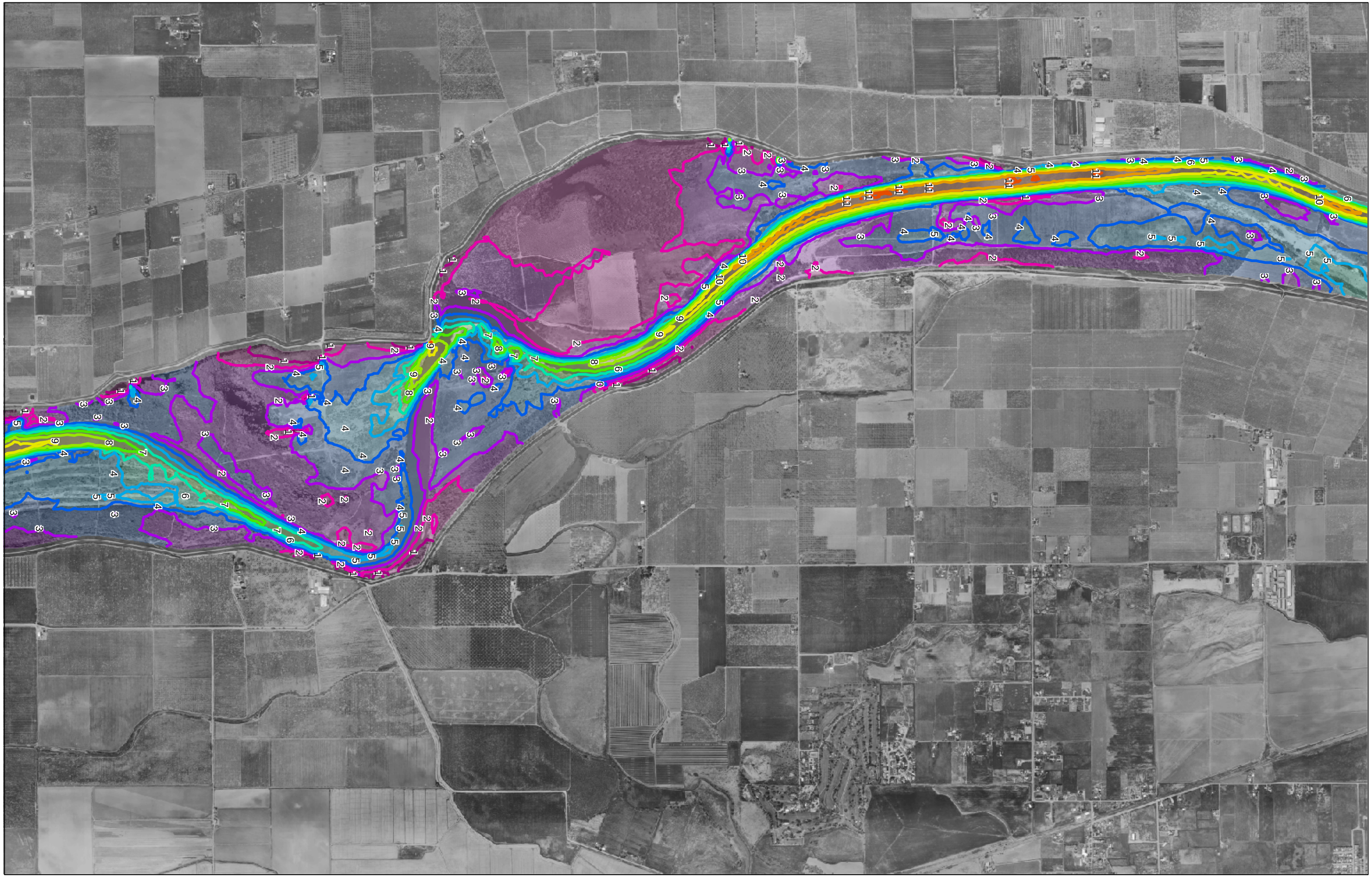
The proposed Star Bend setback levee could have beneficial impacts with minimal downstream impacts. The results show that setback levee could decrease the water surface elevation upstream of Star Bend without increasing the stages downstream. In addition, the velocities at Star Bend would also decrease. There would be minimal impacts to the velocity downstream of the setback levee. This area adjacent to the levee currently has a low velocity due to shading of the access ramp that runs due east-west. Further analysis and field investigation may be warranted to determine the impacts at this location. Additional hydraulic analysis is recommended once the setback levee alignment and details are finalized.

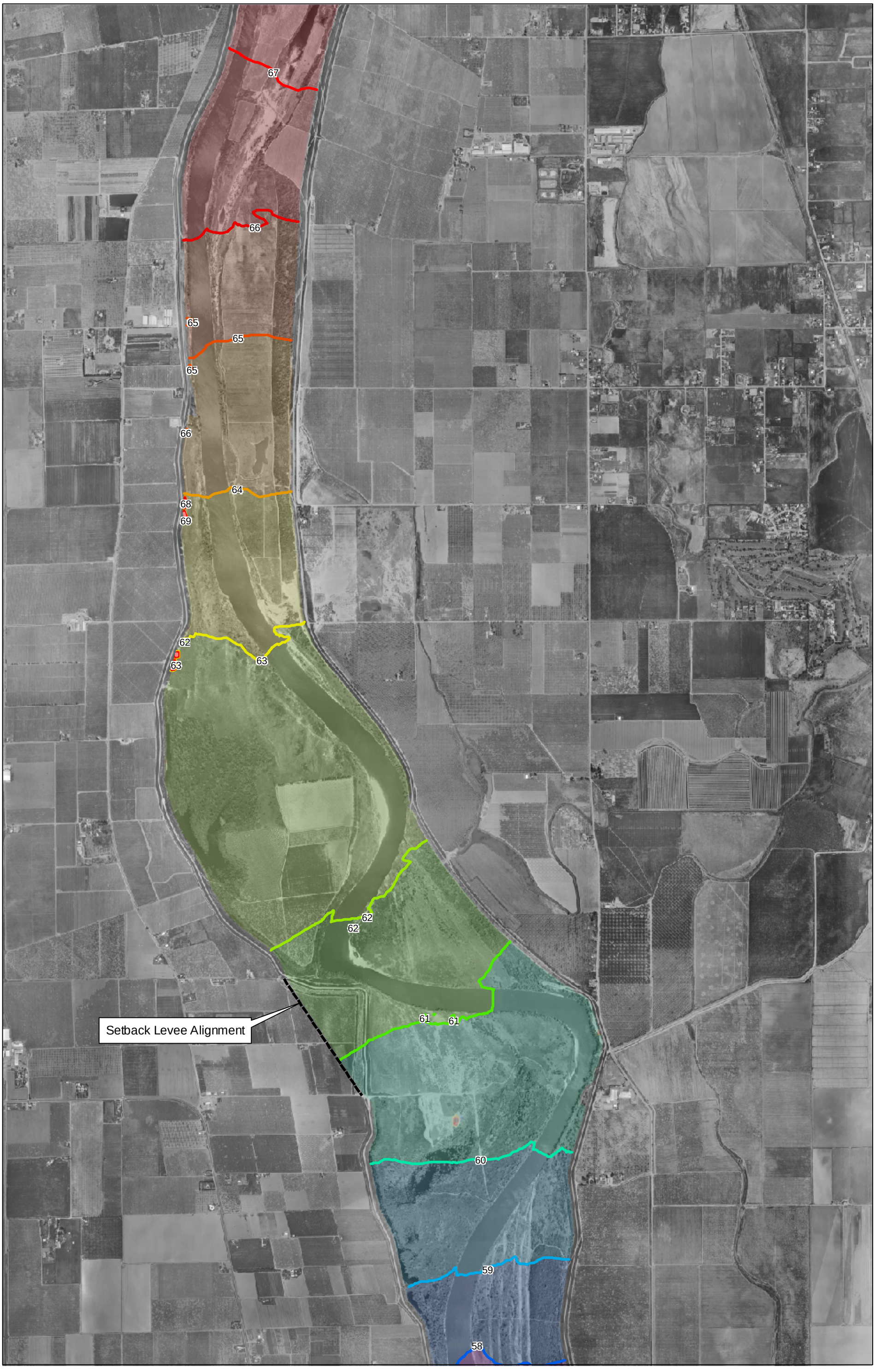
_____
Don Trieu

DT/ dt
Starbend Setback



MBK ENGINEERS

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Setback Levee Alignment
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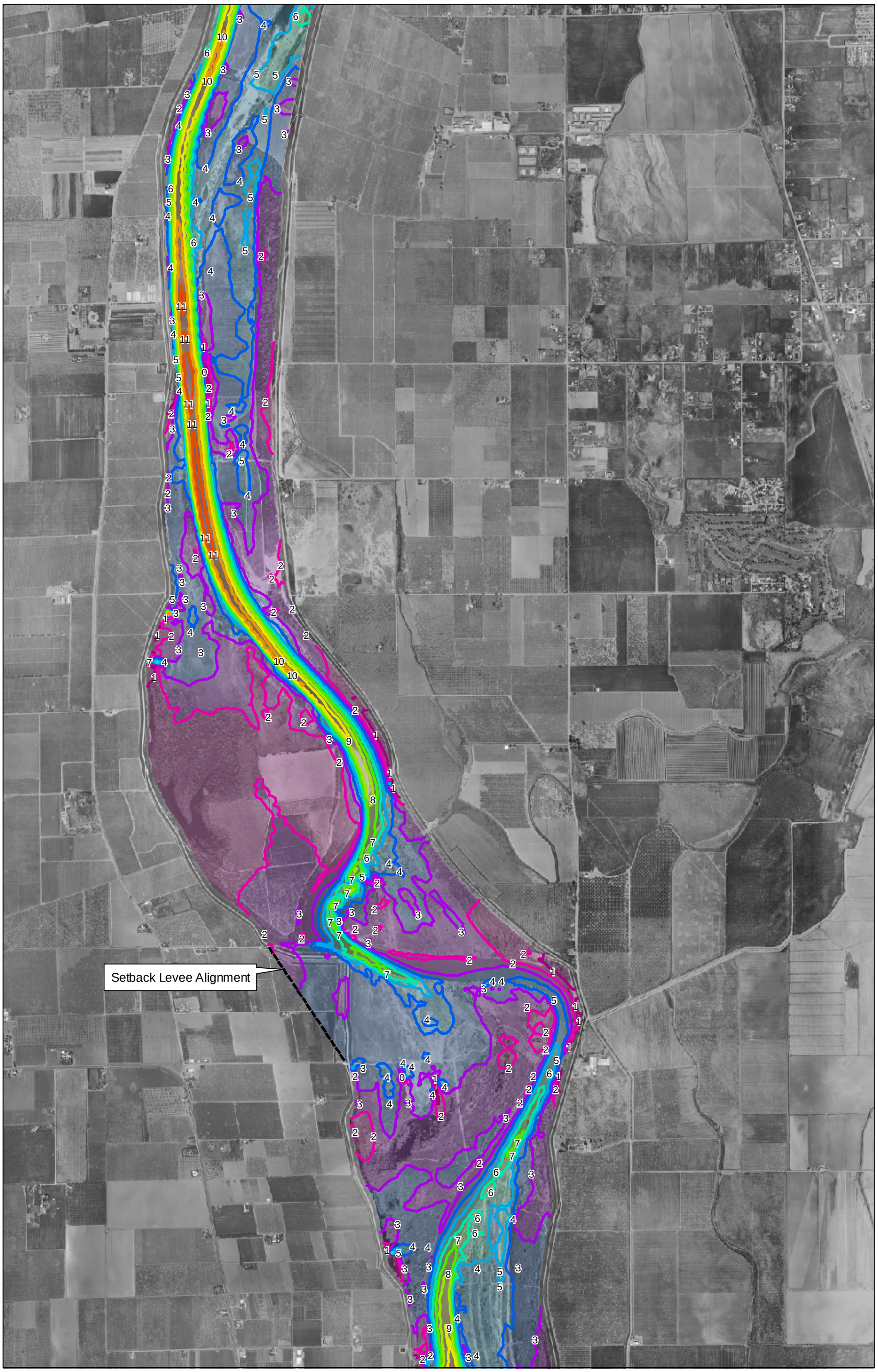
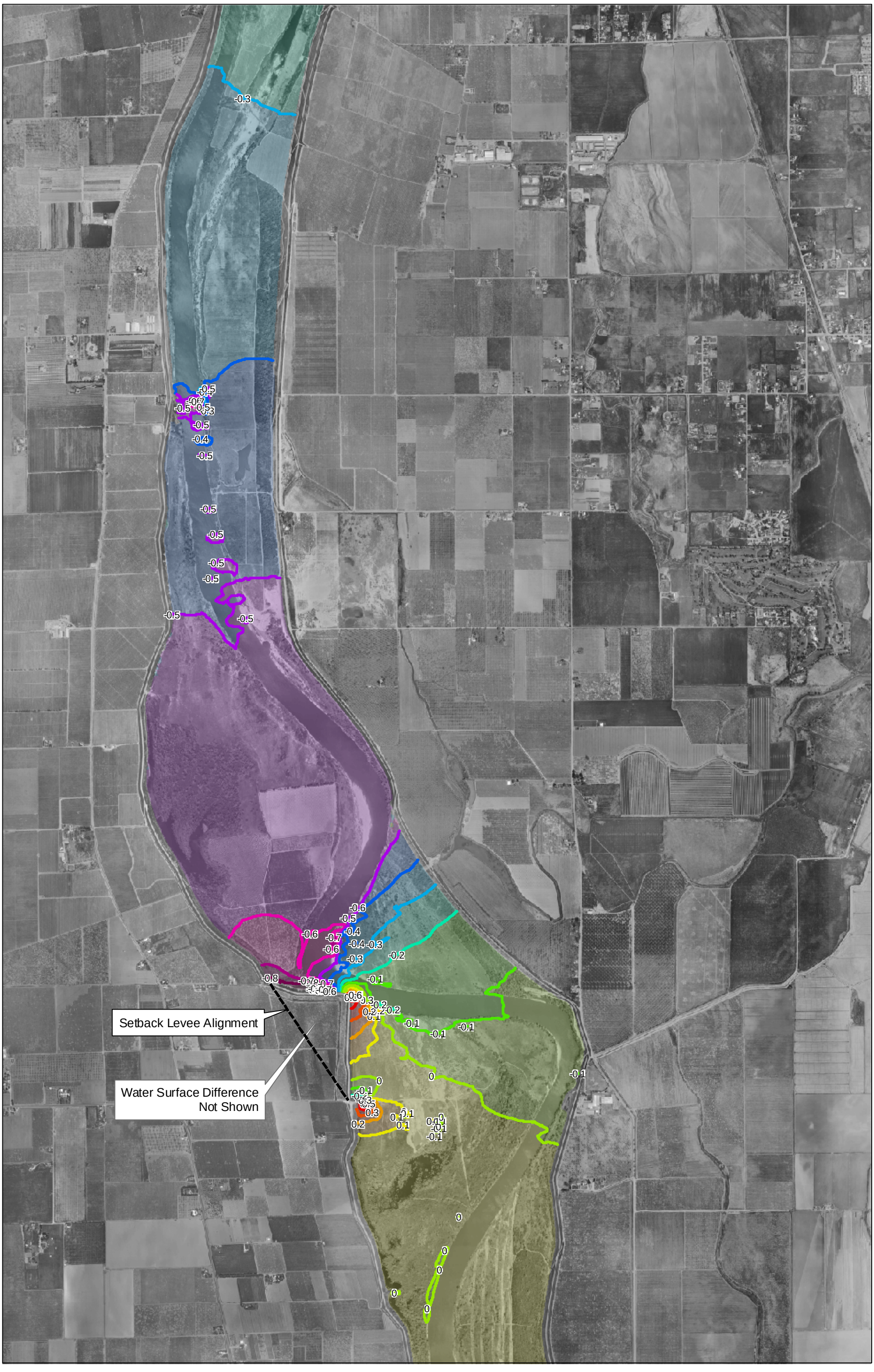
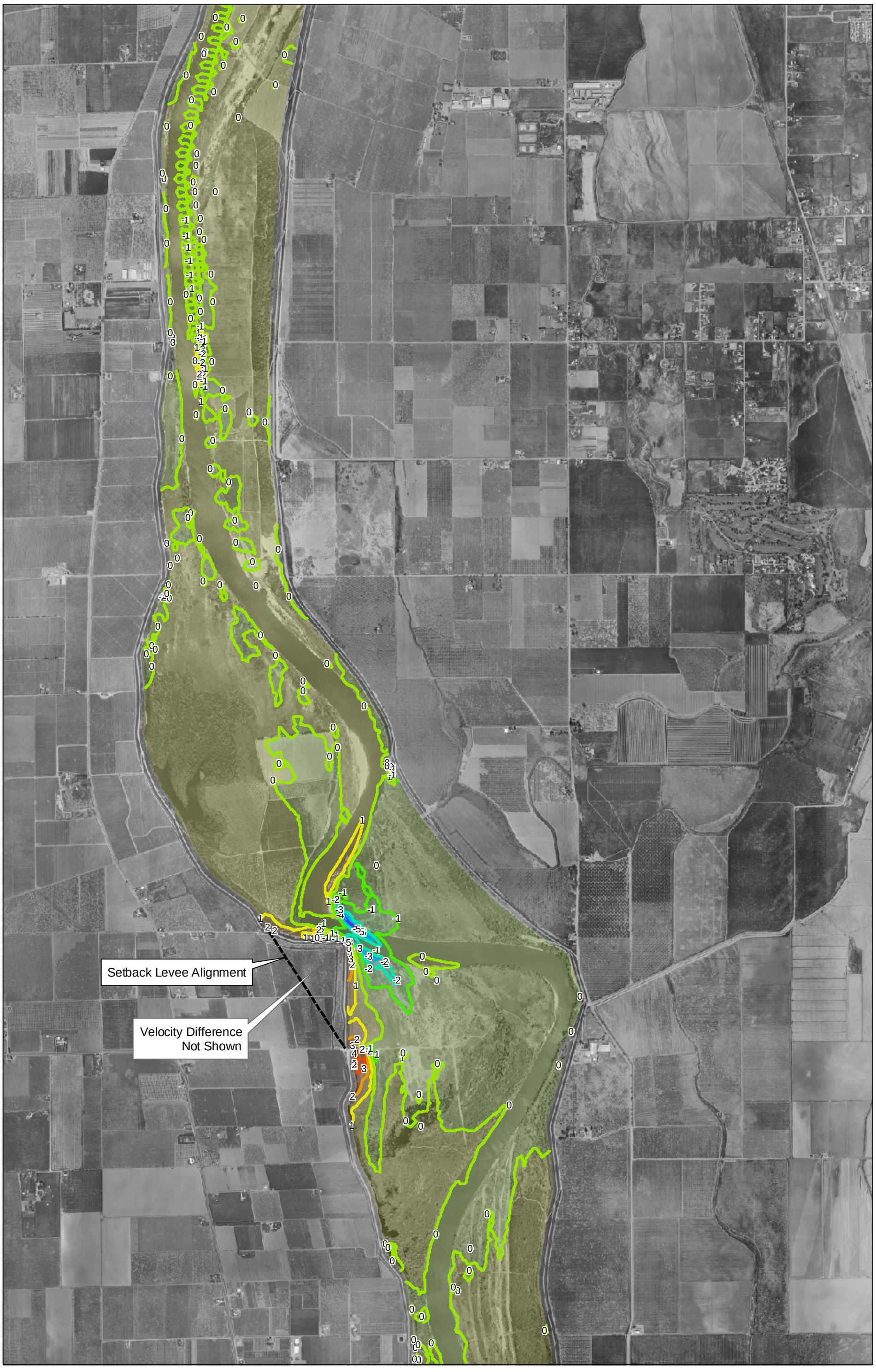

Setback Levee Alignment


Setback Levee Alignment
Water Surface Difference Not Shown


Setback Levee Alignment
Velocity Difference
Not Shown

APPENDIX B

Pre- and Post-Project Water Surface Elevation Tables for the 1-in-100 and 200 AEP flow events in comparison to the USACE 1957 Design Profile and 300,000 cfs design flow event for the Lower Feather River: Right Bank Table B.1; Left Bank Table B.2

TABLE B.1
RIGHT BANK

Pre- and Post-Project Water Surface Elevations for the 1 in 100 and 200 AEP Flow Events in Comparison to the USACE 1957 Design Profile and 300,000 cfs Design Flow Event for the Lower Feather River - Right Bank											
Stationing		1 in 100 AEP Flow Event			300,000 cfs Flow Event			1 in 200 AEP Flow Event			1957 USACE
RMA2 Model Sta.	River Mile Sta.	Pre-Project	Post Project	Post vs. Pre	Pre-Project	Post Project	Post vs. Pre	Pre-Project	Post Project	Post vs. Pre	Design Profile
025+19	23.042	67.24	67.09	-0.16	68.47	68.47	0.00	71.18	71.03	-0.15	#N/A
027+79	22.996	66.98	66.82	-0.16	68.28	68.18	-0.10	70.86	70.71	-0.15	71.21
030+80	22.943	66.76	66.59	-0.17	68.23	67.96	-0.28	70.63	70.48	-0.15	71.21
033+81	22.890	66.98	66.81	-0.16	68.24	68.19	-0.05	70.89	70.74	-0.15	71.21
036+81	22.837	66.75	66.58	-0.17	68.19	67.95	-0.24	70.64	70.48	-0.16	71.21
039+82	22.784	66.77	66.60	-0.17	68.05	67.98	-0.07	70.68	70.53	-0.15	71.21
042+73	22.730	66.44	66.27	-0.18	67.86	67.63	-0.23	70.30	70.14	-0.16	70.82
045+64	22.673	66.36	66.18	-0.18	67.64	67.55	-0.08	70.24	70.08	-0.16	70.82
048+55	22.615	65.99	65.81	-0.19	67.39	67.16	-0.22	69.83	69.66	-0.17	70.82
051+46	22.557	65.90	65.71	-0.19	67.18	67.07	-0.11	69.76	69.58	-0.17	70.82
054+36	22.499	65.60	65.40	-0.20	66.97	66.75	-0.22	69.40	69.22	-0.18	70.44
057+27	22.442	65.49	65.29	-0.20	66.76	66.63	-0.13	69.30	69.12	-0.18	70.44
060+18	22.385	65.32	65.12	-0.20	66.67	66.45	-0.22	69.09	68.91	-0.18	70.44
063+09	22.327	65.14	64.93	-0.21	66.41	66.27	-0.14	68.92	68.73	-0.19	70.44
066+00	22.270	64.91	64.69	-0.21	66.22	66.01	-0.22	68.61	68.42	-0.19	70.44
069+03	22.213	64.86	64.64	-0.22	66.13	65.96	-0.16	68.60	68.40	-0.20	70.06
072+18	22.154	64.90	64.68	-0.22	66.21	66.01	-0.20	68.66	68.47	-0.20	70.06
075+11	22.100	64.96	64.74	-0.22	66.21	66.08	-0.14	68.74	68.55	-0.19	70.06
078+21	22.042	64.93	64.72	-0.22	66.28	66.05	-0.23	68.71	68.52	-0.20	70.06
081+30	21.986	64.97	64.75	-0.22	66.24	66.09	-0.14	68.77	68.58	-0.20	69.68
084+32	21.934	64.91	64.70	-0.22	66.26	66.03	-0.22	68.70	68.50	-0.20	69.68
087+41	21.881	64.90	64.69	-0.22	66.18	66.03	-0.15	68.70	68.51	-0.20	69.68
090+41	21.829	64.83	64.61	-0.22	66.17	65.95	-0.22	68.62	68.42	-0.20	69.68
093+46	21.776	64.86	64.64	-0.22	66.15	65.99	-0.16	68.67	68.47	-0.20	69.68
096+52	21.721	64.66	64.44	-0.22	65.99	65.77	-0.22	68.43	68.23	-0.20	69.12
099+55	21.662	64.53	64.30	-0.23	65.81	65.64	-0.16	68.32	68.12	-0.21	69.12
102+56	21.604	64.45	64.22	-0.23	65.78	65.55	-0.22	68.21	68.01	-0.21	69.12
105+64	21.545	64.34	64.10	-0.24	65.62	65.44	-0.18	68.12	67.91	-0.21	69.12
108+81	21.485	64.16	63.92	-0.24	65.47	65.25	-0.22	67.92	67.70	-0.22	68.53
111+84	21.430	64.02	63.77	-0.25	65.29	65.09	-0.19	67.76	67.54	-0.22	68.53
114+97	21.373	63.93	63.68	-0.25	65.24	65.02	-0.22	67.71	67.48	-0.22	68.53
118+06	21.317	63.90	63.64	-0.25	65.19	64.98	-0.21	67.66	67.43	-0.22	68.53
121+19	21.260	63.71	63.45	-0.26	65.00	64.78	-0.22	67.47	67.24	-0.23	68.53
124+28	21.201	63.31	63.03	-0.27	64.59	64.36	-0.23	67.04	66.80	-0.24	67.94
127+37	21.141	63.45	63.18	-0.27	64.74	64.52	-0.22	67.18	66.94	-0.24	67.94
130+47	21.081	63.47	63.20	-0.27	64.79	64.56	-0.23	67.24	67.00	-0.24	67.94
133+23	21.027	63.29	63.02	-0.27	64.63	64.41	-0.22	67.05	66.81	-0.24	67.94
135+98	20.976	63.28	63.01	-0.27	64.68	64.45	-0.23	67.13	66.89	-0.24	67.48
137+36	20.951	62.97	62.70	-0.28	64.51	64.13	-0.38	66.80	66.55	-0.25	67.48

Shaded Areas Indicate Location(s) of Greatest Reduction in Flood Stage

TABLE B.1
RIGHT BANK

Stationing		1 in 100 AEP Flow Event			300,000 cfs Flow Event			1 in 200 AEP Flow Event			1957 USACE
RMA2 Model Sta.	River Mile Sta.	Pre-Project	Post Project	Post vs. Pre	Pre-Project	Post Project	Post vs. Pre	Pre-Project	Post Project	Post vs. Pre	Design Profile
138+74	20.925	62.96	62.68	-0.28	64.50	64.13	-0.38	66.77	66.52	-0.25	67.48
143+01	20.848	62.75	62.46	-0.28	64.11	63.74	-0.37	66.57	66.31	-0.26	67.48
144+29	20.825	62.75	62.46	-0.28	64.11	63.74	-0.37	66.42	66.18	-0.24	67.48
145+04	20.811	62.75	62.46	-0.28	64.11	63.74	-0.37	66.53	66.28	-0.26	67.48
145+72	20.799	62.75	62.46	-0.28	64.11	63.74	-0.37	66.50	66.25	-0.25	67.48
147+07	20.774	62.75	62.46	-0.28	64.11	63.74	-0.37	66.51	66.26	-0.25	67.48
150+16	20.718	62.76	62.48	-0.28	64.13	63.76	-0.37	66.52	66.27	-0.25	67.01
150+67	20.709	62.76	62.47	-0.28	64.14	63.76	-0.38	66.52	66.27	-0.25	67.01
153+78	20.653	62.72	62.43	-0.29	64.09	63.74	-0.35	66.51	66.25	-0.26	67.01
156+89	20.597	62.69	62.40	-0.29	64.05	63.70	-0.35	66.46	66.20	-0.26	67.01
160+02	20.541	62.57	62.28	-0.30	63.91	63.58	-0.32	66.31	66.04	-0.26	67.01
163+14	20.484	62.48	62.17	-0.30	63.78	63.47	-0.31	66.16	65.90	-0.27	66.54
166+26	20.426	62.36	62.05	-0.31	63.65	63.35	-0.30	66.01	65.74	-0.27	66.54
169+38	20.368	62.29	61.98	-0.31	63.58	63.27	-0.31	65.95	65.68	-0.28	66.54
172+50	20.310	62.30	61.98	-0.31	63.60	63.29	-0.31	65.99	65.72	-0.28	66.54
175+62	20.252	62.20	61.88	-0.32	63.49	63.18	-0.31	65.86	65.58	-0.28	66.54
178+76	20.199	62.13	61.82	-0.32	63.42	63.11	-0.31	65.79	65.51	-0.28	66.07
181+89	20.147	62.08	61.76	-0.32	63.35	63.04	-0.31	65.71	65.42	-0.28	66.07
184+37	20.105	62.03	61.70	-0.32	63.30	62.99	-0.31	65.66	65.37	-0.29	66.07
186+87	20.063	61.92	61.59	-0.32	63.18	62.86	-0.32	65.50	65.21	-0.29	66.07
189+36	20.022	61.82	61.49	-0.33	63.07	62.75	-0.32	65.37	65.08	-0.29	66.07
191+83	19.982	61.67	61.34	-0.33	62.91	62.59	-0.32	65.18	64.88	-0.29	65.60
194+33	19.943	61.57	61.24	-0.34	62.80	62.48	-0.32	65.06	64.76	-0.30	65.60
196+60	19.908	61.66	61.33	-0.33	62.90	62.58	-0.31	65.20	64.90	-0.30	65.60
197+38	19.896	61.65	61.32	-0.33	62.83	62.54	-0.29	65.07	64.77	-0.29	65.60
198+51	19.879	61.34	60.98	-0.36	62.70	62.28	-0.42	65.08	64.77	-0.31	65.60
199+18	19.868	61.34	60.99	-0.36	62.61	62.26	-0.36	64.96	64.64	-0.32	65.60
200+13	19.854	61.36	61.01	-0.36	62.66	62.29	-0.38	65.00	64.69	-0.31	65.60
200+74	19.844	61.37	61.01	-0.36	62.62	62.29	-0.34	64.92	64.60	-0.31	65.60
203+80	19.797	61.36	61.00	-0.36	62.63	62.28	-0.35	64.96	64.65	-0.31	65.60
206+87	19.750	61.36	61.00	-0.36	62.60	62.28	-0.33	64.89	64.58	-0.31	65.44
207+34	19.744	61.38	61.02	-0.36	62.64	62.31	-0.33	64.97	64.66	-0.31	65.44
209+80	19.713	61.13	60.76	-0.37	62.23	62.04	-0.19	64.57	64.24	-0.33	65.44
210+86	19.699	61.13	60.76	-0.37	62.44	62.04	-0.40	64.82	64.50	-0.32	65.44
211+78	19.688	61.13	60.76	-0.37	62.42	62.04	-0.38	64.80	64.47	-0.33	65.44
213+09	19.671	61.14	60.76	-0.37	62.41	62.04	-0.37	64.75	64.43	-0.33	65.44
216+68	19.626	61.13	60.76	-0.37	62.39	62.03	-0.36	64.72	64.40	-0.33	65.44
219+97	19.584	61.09	60.72	-0.37	62.36	61.99	-0.37	64.68	64.35	-0.33	65.44
223+37	19.541	61.07	60.69	-0.38	62.33	61.96	-0.36	64.64	64.32	-0.33	65.44
226+89	19.495	61.04	60.66	-0.38	62.30	61.93	-0.37	64.62	64.29	-0.33	65.28
230+31	19.431	61.05	60.67	-0.38	62.31	61.94	-0.37	64.63	64.30	-0.33	65.28
232+80	19.384	61.02	60.65	-0.38	62.28	61.91	-0.37	64.60	64.27	-0.33	65.28
235+28	19.337	61.01	60.63	-0.38	62.27	61.90	-0.37	64.58	64.25	-0.33	65.28

Shaded Areas Indicate Location(s) of Greatest Reduction in Flood Stage

TABLE B.1
RIGHT BANK

Stationing		1 in 100 AEP Flow Event			300,000 cfs Flow Event			1 in 200 AEP Flow Event			1957 USACE
RMA2 Model Sta.	River Mile Sta.	Pre-Project	Post Project	Post vs. Pre	Pre-Project	Post Project	Post vs. Pre	Pre-Project	Post Project	Post vs. Pre	Design Profile
237+77	19.291	61.00	60.62	-0.38	62.25	61.88	-0.37	64.56	64.23	-0.33	65.28
240+26	19.240	60.98	60.61	-0.38	62.24	61.87	-0.37	64.54	64.21	-0.33	65.07
242+74	19.163	60.97	60.60	-0.38	62.23	61.86	-0.37	64.53	64.20	-0.33	65.07
245+22	19.087	60.95	60.57	-0.38	62.20	61.83	-0.37	64.50	64.17	-0.33	65.07
247+69	19.011	60.93	60.55	-0.38	62.18	61.81	-0.37	64.48	64.14	-0.33	65.07
250+15	18.951	60.92	60.54	-0.38	62.17	61.80	-0.37	64.46	64.13	-0.34	64.85
252+62	18.893	60.90	60.51	-0.38	62.14	61.77	-0.37	64.43	64.09	-0.34	64.85
255+09	18.835	60.88	60.49	-0.38	62.12	61.74	-0.37	64.41	64.07	-0.34	64.85
257+93	18.769	60.85	60.46	-0.39	62.09	61.71	-0.38	64.37	64.03	-0.34	64.85
260+77	18.680	60.82	60.44	-0.39	62.06	61.69	-0.38	64.35	64.00	-0.34	64.63
263+61	18.581	60.80	60.42	-0.39	62.04	61.66	-0.38	64.33	63.98	-0.35	64.63
266+45	18.487	60.79	60.40	-0.39	62.03	61.65	-0.38	64.31	63.97	-0.35	64.41
269+30	18.415	60.76	60.37	-0.39	62.00	61.62	-0.38	64.27	63.93	-0.35	64.41
272+14	18.342	60.73	60.33	-0.40	61.96	61.57	-0.39	64.23	63.87	-0.36	64.41
274+98	18.269	60.69	60.28	-0.41	61.92	61.51	-0.41	64.19	63.81	-0.38	64.41
277+42	18.232	60.66	60.21	-0.44	61.88	61.44	-0.44	64.15	63.73	-0.42	64.15
279+82	18.207	60.64	60.11	-0.53	61.86	61.34	-0.53	64.13	63.62	-0.51	64.15
282+31	18.181	60.65	60.11	-0.53	61.88	61.35	-0.53	64.15	63.64	-0.51	64.15
283+30	18.170	60.65	60.07	-0.58	61.88	61.30	-0.58	64.15	63.60	-0.55	64.15
285+30	18.149	60.62	60.00	-0.62	61.85	61.24	-0.62	64.12	63.54	-0.58	64.15
286+70	18.135	60.59	60.01	-0.59	61.82	61.24	-0.58	64.09	63.54	-0.56	64.15
287+72	18.124	60.57	59.98	-0.60	61.80	61.21	-0.59	64.07	63.51	-0.56	64.15
288+74	18.113	60.56	59.94	-0.61	61.78	61.18	-0.61	64.06	63.48	-0.58	64.15
290+06	18.099	60.54	59.90	-0.64	61.77	61.14	-0.63	64.04	63.44	-0.60	64.15
291+62	18.083	60.52	59.86	**-0.65**	61.74	61.10	**-0.64**	64.02	63.41	**-0.61**	64.15
293+10	18.068	60.43	59.85	-0.58	61.66	61.09	-0.57	63.93	63.40	-0.53	64.15
294+61	18.052	60.31	59.76	-0.55	61.54	61.01	-0.53	63.81	63.33	-0.48	64.15
296+26	18.034	60.19	59.70	-0.49	61.42	60.95	-0.46	63.70	63.28	-0.42	64.15
297+30	18.023	60.04	59.68	-0.35	61.27	60.94	-0.34	63.55	63.27	-0.29	64.15
298+34	18.013	59.98	59.68	-0.30	61.22	60.93	-0.28	63.51	63.26	-0.24	64.15
299+31	18.002	59.76	59.66	-0.10	60.99	60.92	-0.07	63.27	63.25	-0.02	64.15
299+88	17.995	59.60	59.63	0.02	60.83	60.88	0.05	63.09	63.20	0.11	63.89
300+53	17.985	59.34	59.55	0.21	60.57	60.81	0.23	62.84	63.14	0.31	63.89
300+99	17.978	59.10	59.52	0.42	60.31	60.78	0.47	62.54	63.12	0.58	63.89
301+61	17.969	58.67	59.45	0.78	60.20	60.71	0.51	61.97	63.06	1.09	63.89
302+71	17.952	58.87	59.29	0.41	60.02	60.56	0.54	62.10	62.92	0.82	63.89
303+43	17.941	58.60	59.23	0.63	60.00	60.49	0.49	61.75	62.86	1.11	63.89
304+46	17.926	58.69	59.21	0.52	60.00	60.48	0.48	62.26	62.84	0.58	63.89
305+48	17.910	58.72	59.21	0.49	59.97	60.48	0.51	62.26	62.85	0.58	63.89
306+52	17.895	58.72	59.23	0.50	59.97	60.50	0.52	62.33	62.86	0.53	63.89
307+58	17.879	58.73	59.23	0.49	59.98	60.50	0.51	62.33	62.86	0.53	63.89
308+59	17.864	58.74	59.21	0.47	59.99	60.47	0.48	62.34	62.83	0.49	63.89
310+66	17.832	58.75	59.17	0.42	60.00	60.44	0.44	62.35	62.80	0.44	63.89

Shaded Areas Indicate Location(s) of Greatest Reduction in Flood Stage

TABLE B.1
RIGHT BANK

Stationing		1 in 100 AEP Flow Event			300,000 cfs Flow Event			1 in 200 AEP Flow Event			1957 USACE
RMA2 Model Sta.	River Mile Sta.	Pre-Project	Post Project	Post vs. Pre	Pre-Project	Post Project	Post vs. Pre	Pre-Project	Post Project	Post vs. Pre	Design Profile
312+64	17.803	58.75	59.13	0.38	60.00	60.40	0.39	62.35	62.75	0.40	63.89
314+62	17.773	58.75	59.08	0.34	60.00	60.34	0.35	62.34	62.70	0.36	63.89
316+61	17.738	58.73	59.04	0.31	59.98	60.30	0.32	62.33	62.66	0.33	63.63
318+60	17.689	58.69	58.99	0.30	59.95	60.25	0.30	62.30	62.61	0.31	63.63
320+57	17.640	58.64	58.92	0.29	59.90	60.19	0.28	62.26	62.55	0.29	63.63
322+56	17.591	58.63	58.88	0.26	59.90	60.15	0.26	62.25	62.52	0.26	63.63
324+53	17.543	58.63	58.86	0.23	59.90	60.13	0.23	62.26	62.50	0.24	63.63
325+49	17.519	58.65	58.85	0.20	59.92	60.12	0.20	62.28	62.51	0.23	63.63
326+50	17.495	58.65	#N/A	#N/A	59.92	60.20	0.28	62.28	62.53	0.24	63.38
330+79	17.409	58.48	58.40	-0.08	59.75	59.67	-0.07	62.07	62.04	-0.02	63.38
331+84	17.388	58.00	57.97	-0.03	59.30	59.24	-0.07	61.64	61.57	-0.06	63.38
332+88	17.367	57.97	57.98	0.01	59.30	59.25	-0.05	61.65	61.61	-0.05	63.38
336+38	17.296	58.02	57.99	-0.03	59.32	59.26	-0.06	61.66	61.61	-0.05	63.38
336+91	17.286	58.02	57.99	-0.03	59.32	59.26	-0.06	61.66	61.61	-0.05	63.38
337+91	17.266	58.02	57.99	-0.03	59.32	59.26	-0.06	61.66	61.61	-0.05	63.38
338+89	17.231	58.02	57.99	-0.03	59.32	59.26	-0.06	61.66	61.61	-0.05	63.12
340+87	17.053	58.03	57.99	-0.04	59.32	59.26	-0.06	61.66	61.61	-0.05	63.12
342+83	16.852	58.02	57.99	-0.03	59.32	59.26	-0.06	61.67	61.61	-0.06	62.86
344+85	16.703	58.01	57.99	-0.01	59.31	59.27	-0.05	61.67	61.61	-0.06	62.60
346+98	16.610	58.00	57.99	-0.01	59.31	59.27	-0.04	61.67	61.62	-0.05	62.60
349+18	16.513	58.00	57.99	-0.01	59.31	59.27	-0.04	61.67	61.62	-0.05	62.60
351+36	16.267	57.99	57.99	0.00	59.29	#N/A	#N/A	61.66	#N/A	#N/A	62.09
353+51	16.205	57.97	57.98	0.01	59.28	59.26	-0.02	61.65	61.63	-0.02	61.57
355+65	16.157	57.96	57.96	0.01	59.26	59.25	-0.01	61.63	61.62	-0.02	61.57
357+80	16.110	57.93	57.93	0.00	59.23	#N/A	#N/A	61.61	#N/A	#N/A	61.57
359+88	16.063	57.90	57.90	0.00	59.20	59.18	-0.02	61.58	61.56	-0.02	61.57
361+97	16.017	57.88	57.88	0.00	59.18	59.17	-0.01	61.56	61.54	-0.01	61.57
364+14	15.981	57.80	57.80	0.00	59.09	#N/A	#N/A	61.46	#N/A	#N/A	61.06

Shaded Areas Indicate Location(s) of Greatest Reduction in Flood Stage

TABLE B.2
LEFT BANK

Pre- and Post-Project Water Surface Elevations for the 1 in 100 and 200 AEP Flow Events in Comparison to the USACE 1957 Design Profile and 300,000 cfs Design Flow Event for the Lower Feather River - Left Bank											
Stationing		1 in 100 AEP Flow Event			300,000 cfs Flow Event			1 in 200 AEP Flow Event			1957 USACE
RMA2 Model Sta.	River Mile HEC-RAS Sta.	Pre-Project	Post Project	Post vs. Pre	Pre-Project	Post Project	Post vs. Pre	Pre-Project	Post Project	Post vs. Pre	Design Profile
021+52	23.152	67.34	67.18	-0.16	68.58	68.58	0.00	71.30	71.16	-0.14	#N/A
025+40	23.065	67.23	67.07	-0.16	68.49	68.45	-0.04	71.14	70.99	-0.15	#N/A
028+34	23.000	66.84	66.67	-0.16	68.34	68.03	-0.31	70.69	70.54	-0.15	71.21
031+28	22.934	66.95	66.78	-0.16	68.18	68.15	-0.03	70.83	70.68	-0.15	71.21
034+21	22.868	66.56	66.39	-0.17	67.98	67.74	-0.24	70.38	70.23	-0.16	71.21
037+16	22.802	66.68	66.51	-0.17	67.95	67.87	-0.08	70.55	70.39	-0.16	71.21
040+03	22.739	66.48	66.31	-0.17	67.86	67.65	-0.21	70.30	70.14	-0.16	70.82
042+91	22.684	66.30	66.12	-0.18	67.57	67.47	-0.10	70.14	69.98	-0.16	70.82
045+80	22.628	66.13	65.95	-0.18	67.50	67.30	-0.20	69.95	69.78	-0.17	70.82
048+68	22.573	66.08	65.90	-0.18	67.37	67.25	-0.12	69.92	69.76	-0.17	70.82
051+59	22.517	65.65	65.45	-0.19	66.99	66.79	-0.20	69.42	69.24	-0.18	70.82
054+48	22.466	65.70	65.51	-0.19	66.99	66.85	-0.14	69.52	69.34	-0.18	70.44
057+37	22.417	65.56	65.36	-0.20	66.90	66.70	-0.20	69.34	69.16	-0.18	70.44
060+25	22.368	65.49	65.29	-0.20	66.78	66.63	-0.15	69.29	69.11	-0.18	70.44
063+14	22.320	65.27	65.07	-0.20	66.59	66.40	-0.19	69.05	68.87	-0.19	70.44
066+19	22.268	65.18	64.97	-0.21	66.48	66.31	-0.17	68.96	68.77	-0.19	70.44
069+24	22.208	65.01	64.80	-0.21	66.30	66.12	-0.18	68.74	68.55	-0.19	70.06
072+29	22.142	64.89	64.67	-0.21	66.17	65.99	-0.18	68.63	68.43	-0.20	70.06
075+34	22.077	64.84	64.63	-0.21	66.13	65.94	-0.18	68.57	68.37	-0.20	70.06
078+37	22.012	64.83	64.61	-0.22	66.11	65.93	-0.18	68.57	68.37	-0.20	70.06
081+42	21.925	64.79	64.57	-0.22	66.07	65.88	-0.19	68.51	68.31	-0.20	69.68
084+46	21.834	64.74	64.52	-0.22	66.03	65.84	-0.18	68.48	68.28	-0.20	69.68
087+50	21.745	64.54	64.31	-0.23	65.82	65.63	-0.19	68.27	68.06	-0.20	69.12
090+54	21.678	64.39	64.16	-0.23	65.67	65.48	-0.20	68.13	67.92	-0.21	69.12
093+58	21.611	64.31	64.08	-0.23	65.60	65.40	-0.20	68.05	67.84	-0.21	69.12
096+71	21.543	64.20	63.96	-0.24	65.49	65.29	-0.20	67.94	67.73	-0.21	69.12
099+84	21.478	64.08	63.84	-0.24	65.37	65.16	-0.21	67.82	67.61	-0.22	68.53
102+97	21.419	63.99	63.74	-0.25	65.28	65.07	-0.21	67.73	67.51	-0.22	68.53
106+10	21.360	63.92	63.67	-0.25	65.21	65.00	-0.21	67.66	67.44	-0.22	68.53
109+23	21.300	63.82	63.56	-0.25	65.10	64.89	-0.21	67.56	67.33	-0.23	68.53
112+35	21.241	63.66	63.40	-0.26	64.95	64.73	-0.22	67.40	67.17	-0.23	67.94
115+48	21.182	63.52	63.26	-0.27	64.81	64.59	-0.23	67.27	67.03	-0.24	67.94
118+61	21.123	63.42	63.15	-0.27	64.71	64.48	-0.23	67.16	66.92	-0.24	67.94
121+74	21.056	63.32	63.05	-0.27	64.61	64.37	-0.24	67.05	66.80	-0.24	67.94
124+49	21.002	63.24	62.97	-0.27	64.53	64.29	-0.24	66.95	66.71	-0.24	67.94
127+27	20.950	63.18	62.90	-0.28	64.47	64.23	-0.25	66.90	66.66	-0.25	67.48
130+01	20.899	63.08	62.81	-0.28	64.38	64.13	-0.25	66.80	66.55	-0.25	67.48
132+77	20.847	63.00	62.71	-0.28	64.30	64.03	-0.26	66.71	66.45	-0.25	67.48
135+52	20.796	62.94	62.66	-0.28	64.24	63.97	-0.27	66.64	66.39	-0.25	67.48
138+27	20.744	62.88	62.60	-0.29	64.18	63.91	-0.27	66.58	66.32	-0.25	67.01
141+34	20.687	62.82	62.54	-0.29	64.12	63.84	-0.28	66.51	66.25	-0.26	67.01
144+49	20.628	62.77	62.48	-0.29	64.07	63.79	-0.28	66.45	66.19	-0.26	67.01
147+60	20.570	62.69	62.40	-0.29	63.98	63.70	-0.29	66.36	66.10	-0.26	67.01

Shaded Areas Indicate Location(s) of Greatest Reduction in Flood Stage

TABLE B.2
LEFT BANK

Pre- and Post-Project Water Surface Elevations for the 1 in 100 and 200 AEP Flow Events in Comparison to the USACE 1957 Design Profile and 300,000 cfs Design Flow Event for the Lower Feather River - Left Bank

Stationing		1 in 100 AEP Flow Event			300,000 cfs Flow Event			1 in 200 AEP Flow Event			
RMA2 Model Sta.	River Mile HEC-RAS Sta.	Pre-Project	Post Project	Post vs. Pre	Pre-Project	Post Project	Post vs. Pre	Pre-Project	Post Project	Post vs. Pre	1957 USACE Design Profile
150+72	20.511	62.64	62.35	-0.29	63.93	63.64	-0.29	66.29	66.03	-0.26	67.01
153+77	20.450	62.50	62.21	-0.30	63.78	63.49	-0.29	66.13	65.87	-0.27	66.54
156+90	20.387	62.31	62.00	-0.31	63.59	63.29	-0.30	65.94	65.66	-0.27	66.54
160+02	20.324	62.19	61.88	-0.31	63.48	63.17	-0.31	65.82	65.54	-0.28	66.54
163+14	20.260	62.07	61.75	-0.32	63.35	63.03	-0.32	65.69	65.41	-0.28	66.54
166+26	20.192	61.96	61.64	-0.32	63.24	62.92	-0.32	65.57	65.29	-0.29	66.07
169+39	20.123	61.88	61.56	-0.32	63.15	62.83	-0.32	65.48	65.19	-0.29	66.07
172+51	20.053	61.81	61.48	-0.33	63.07	62.75	-0.32	65.39	65.10	-0.29	66.07
174+86	20.001	61.76	61.44	-0.33	63.02	62.70	-0.32	65.34	65.04	-0.29	66.07
177+21	19.941	61.70	61.37	-0.33	62.95	62.63	-0.33	65.26	64.96	-0.30	65.60
179+55	19.880	61.67	61.34	-0.33	62.92	62.59	-0.33	65.22	64.92	-0.30	65.60
181+90	19.820	61.63	61.30	-0.33	62.87	62.54	-0.33	65.16	64.86	-0.30	65.60
184+25	19.759	61.55	61.22	-0.33	62.78	62.45	-0.33	65.06	64.76	-0.30	65.60
185+86	19.721	61.47	61.25	-0.22	62.69	62.36	-0.33	64.96	64.66	-0.30	65.44
187+47	19.685	61.43	61.08	-0.34	62.66	62.33	-0.34	64.94	64.64	-0.31	65.44
189+01	19.650	61.33	60.98	-0.34	62.55	62.21	-0.34	64.81	64.50	-0.31	65.44
190+64	19.613	61.34	60.98	**-0.36**	62.57	62.23	-0.34	64.84	64.53	-0.31	65.44
192+27	19.576	61.29	60.95	-0.34	62.52	62.18	-0.34	64.78	64.47	-0.31	65.44
194+13	19.534	61.30	60.94	**-0.36**	62.53	62.19	-0.34	64.81	64.49	-0.31	65.44
195+99	19.493	61.27	60.92	-0.35	62.50	62.16	-0.34	64.77	64.46	-0.31	65.28
197+79	19.462	61.26	60.90	**-0.36**	62.49	62.15	-0.34	64.77	64.45	-0.31	65.28
199+66	19.429	61.23	60.88	-0.35	62.46	62.12	-0.34	64.74	64.42	-0.31	65.28
201+53	19.396	61.22	60.86	**-0.36**	62.45	62.10	-0.35	64.73	64.41	**-0.32**	65.28
204+27	19.347	61.20	60.85	**-0.36**	62.44	62.09	-0.35	64.71	64.40	**-0.32**	65.28
207+02	19.299	61.20	60.84	**-0.36**	62.43	62.08	-0.35	64.71	64.39	**-0.32**	65.28
209+71	19.251	61.18	60.83	**-0.36**	62.42	62.07	-0.35	64.69	64.37	**-0.32**	65.28
212+46	19.200	61.19	60.83	**-0.36**	62.42	62.07	-0.35	64.70	64.38	**-0.32**	65.07
215+21	19.150	61.17	60.81	**-0.36**	62.40	62.05	-0.35	64.67	64.35	**-0.32**	65.07
217+87	19.101	61.17	60.81	**-0.36**	62.40	62.05	-0.35	64.67	64.36	**-0.32**	65.07
220+52	19.052	61.16	60.81	**-0.36**	62.40	62.05	-0.35	64.67	64.35	**-0.32**	65.07
223+18	19.003	61.17	60.81	**-0.36**	62.40	62.05	-0.35	64.67	64.35	**-0.32**	65.07
225+83	18.963	61.17	60.81	**-0.36**	62.40	62.05	-0.35	64.67	64.35	**-0.32**	64.85
228+49	18.922	61.16	60.81	**-0.36**	62.39	62.05	-0.35	64.66	64.34	**-0.32**	64.85
229+84	18.902	61.26	#N/A	#N/A	62.40	62.05	-0.35	64.66	64.34	-0.31	64.85
231+93	18.870	61.15	60.90	-0.25	62.39	62.03	-0.36	64.61	64.30	-0.31	64.85
233+99	18.839	60.77	60.44	-0.33	62.01	61.66	-0.34	64.31	64.01	-0.30	64.85
234+74	18.828	60.78	60.44	-0.34	62.09	61.68	**-0.42**	64.40	64.09	-0.31	64.85
235+95	18.810	60.77	60.44	-0.33	62.02	61.67	-0.35	64.41	64.10	-0.31	64.85
238+65	18.769	60.78	60.45	-0.33	61.98	61.67	-0.31	64.23	63.95	-0.28	64.85
240+62	18.724	60.71	60.39	-0.32	61.92	61.62	-0.29	64.18	63.90	-0.27	64.63
242+59	18.656	60.48	60.20	-0.28	61.70	61.43	-0.27	63.94	63.71	-0.23	64.63
244+56	18.589	60.35	60.09	-0.26	61.57	61.33	-0.24	63.83	63.62	-0.22	64.63
246+54	18.520	60.19	59.95	-0.23	61.41	61.19	-0.22	63.67	63.48	-0.19	64.63

Shaded Areas Indicate Location(s) of Greatest Reduction in Flood Stage

TABLE B.2
LEFT BANK

Pre- and Post-Project Water Surface Elevations for the 1 in 100 and 200 AEP Flow Events in Comparison to the USACE 1957 Design Profile and 300,000 cfs Design Flow Event for the Lower Feather River - Left Bank

Stationing		1 in 100 AEP Flow Event			300,000 cfs Flow Event			1 in 200 AEP Flow Event			
RMA2 Model Sta.	River Mile HEC-RAS Sta.	Pre-Project	Post Project	Post vs. Pre	Pre-Project	Post Project	Post vs. Pre	Pre-Project	Post Project	Post vs. Pre	1957 USACE Design Profile
248+51	18.421	60.10	59.89	-0.21	61.33	61.13	-0.20	63.60	63.43	-0.17	64.41
250+48	18.309	59.90	59.73	-0.17	61.12	60.96	-0.16	63.40	63.27	-0.13	64.41
252+44	17.995	59.78	59.63	-0.15	61.01	60.88	-0.14	63.31	63.19	-0.11	63.89
254+41	17.946	59.67	59.55	-0.12	60.90	60.79	-0.11	63.20	63.11	-0.09	63.89
256+38	17.898	59.52	59.43	-0.09	60.76	60.68	-0.08	63.06	63.00	-0.06	63.89
258+35	17.850	59.43	59.36	-0.07	60.67	60.61	-0.06	62.98	62.94	-0.04	63.89
260+31	17.801	59.36	59.31	-0.05	60.60	60.56	-0.04	62.92	62.90	-0.02	63.89
262+25	17.753	59.29	59.26	-0.04	60.54	60.51	-0.03	62.85	62.85	-0.01	63.89
264+22	17.703	59.24	59.22	-0.03	60.49	60.47	-0.02	62.80	62.81	0.00	63.63
266+42	17.647	59.19	59.18	-0.01	60.44	60.43	0.00	62.76	62.77	0.02	63.63
268+60	17.591	59.12	59.13	0.00	60.37	60.38	0.01	62.69	62.72	0.03	63.63
270+79	17.535	59.09	59.10	0.01	60.34	60.36	0.01	62.67	62.70	0.03	63.63
272+98	17.475	59.06	59.07	0.01	60.30	60.33	0.02	62.63	62.67	0.04	63.38
275+19	17.406	59.03	59.04	0.02	60.28	60.30	0.03	62.61	62.65	0.04	63.38
277+40	17.337	58.99	59.01	0.02	60.24	60.27	0.03	62.58	62.62	0.04	63.38
279+61	17.268	58.96	58.99	0.02	60.22	60.25	0.03	62.55	62.60	0.05	63.38
281+90	17.229	58.94	58.97	0.02	60.20	60.23	0.03	62.54	62.58	0.05	63.12
284+19	17.201	58.92	58.94	0.02	60.17	60.20	0.03	62.51	62.56	0.05	63.12
285+35	17.187	58.89	58.92	0.02	60.15	60.18	0.03	62.50	62.54	0.05	63.12
286+48	17.173	58.89	58.91	0.02	60.15	60.18	0.03	62.49	62.54	0.05	63.12
287+56	17.160	58.85	58.87	0.02	60.11	60.14	0.03	62.47	62.51	0.05	63.12
288+77	17.145	58.88	58.90	0.02	60.13	60.16	0.03	62.48	62.53	0.05	63.12
292+40	17.100	58.86	58.88	0.02	60.12	60.15	0.03	62.48	62.52	0.05	63.12
293+70	17.084	58.86	58.88	0.02	60.12	60.15	0.03	62.48	62.53	0.05	63.12
296+21	17.054	58.86	58.88	0.02	60.12	60.15	0.03	62.48	62.52	0.05	63.12
298+91	17.021	58.84	58.87	0.02	60.11	60.14	0.03	62.47	62.51	0.05	63.12
301+61	16.985	58.79	58.82	0.02	60.07	60.10	0.03	62.43	62.48	0.04	62.86
304+47	16.943	58.81	58.83	0.02	60.08	60.11	0.03	62.45	62.49	0.05	62.86
307+22	16.903	58.77	58.79	0.02	60.04	60.07	0.03	62.41	62.46	0.04	62.86
309+99	16.862	58.70	58.73	0.02	59.99	60.02	0.03	62.34	62.38	0.04	62.86
312+77	16.821	58.65	58.67	0.02	59.94	59.96	0.02	62.34	62.38	0.04	62.86
313+80	16.806	58.65	58.67	0.02	59.92	59.96	0.04	62.33	62.37	0.04	62.86
315+59	16.780	58.30	58.32	0.01	59.59	59.60	0.01	62.01	62.03	0.02	62.86
316+54	16.766	58.30	58.32	0.01	59.59	59.60	0.01	62.01	62.03	0.02	62.86
317+69	16.749	58.30	58.32	0.01	59.59	59.60	0.01	62.01	62.03	0.01	62.60
318+73	16.729	58.30	58.32	0.01	59.59	59.60	0.02	62.03	62.03	0.01	62.60
319+81	16.708	58.30	58.32	0.01	59.60	59.60	0.00	62.02	62.04	0.02	62.60
320+78	16.689	58.30	58.32	0.01	59.59	59.61	0.02	62.01	62.04	0.03	62.60
321+85	16.669	58.30	58.32	0.01	59.59	59.60	0.01	62.00	62.03	0.03	62.60
323+93	16.629	58.31	58.32	0.01	59.58	59.59	0.01	61.97	62.00	0.03	62.60
326+01	16.589	58.24	58.25	0.01	59.52	59.53	0.01	61.90	61.93	0.03	62.60
328+09	16.549	58.15	58.16	0.01	59.44	59.45	0.01	61.82	61.85	0.02	62.60
330+15	16.510	58.05	58.06	0.01	59.34	59.34	0.00	61.72	61.74	0.01	62.60

Shaded Areas Indicate Location(s) of Greatest Reduction in Flood Stage

TABLE B.2
LEFT BANK

Pre- and Post-Project Water Surface Elevations for the 1 in 100 and 200 AEP Flow Events in Comparison to the USACE 1957 Design Profile and 300,000 cfs Design Flow Event for the Lower Feather River - Left Bank

Stationing		1 in 100 AEP Flow Event			300,000 cfs Flow Event			1 in 200 AEP Flow Event			
RMA2 Model Sta.	River Mile HEC-RAS Sta.	Pre-Project	Post Project	Post vs. Pre	Pre-Project	Post Project	Post vs. Pre	Pre-Project	Post Project	Post vs. Pre	1957 USACE Design Profile
332+16	16.471	57.97	57.98	0.00	59.26	59.26	0.00	61.64	61.65	0.01	62.09
334+21	16.432	57.80	57.80	0.00	59.09	59.08	0.00	61.46	61.46	0.00	62.09
335+78	16.402	57.71	57.71	0.00	58.99	58.99	0.00	61.36	61.36	0.00	62.09
337+36	16.372	57.71	57.71	0.00	58.99	58.99	0.00	61.37	61.37	0.00	62.09
339+01	16.340	57.67	57.67	0.00	58.96	58.95	0.00	61.34	61.34	0.00	62.09
340+56	16.310	57.61	57.61	0.00	58.90	58.89	0.00	61.28	61.28	0.00	62.09
342+61	16.271	57.52	57.52	0.00	58.81	58.81	-0.01	61.20	61.20	0.00	62.09
344+65	16.227	57.44	57.45	0.00	58.74	58.74	-0.01	61.14	61.13	0.00	61.57
346+70	16.175	57.37	57.37	0.00	58.67	58.67	-0.01	61.07	61.07	0.00	61.57
348+74	16.123	57.31	57.31	0.00	58.62	58.61	-0.01	61.03	61.02	0.00	61.57
350+80	16.071	57.26	57.26	0.00	58.57	58.57	-0.01	60.98	60.98	0.00	61.57
353+13	16.013	57.14	57.14	0.00	58.45	58.44	-0.01	60.86	60.86	0.00	61.57
355+46	15.962	57.01	57.01	0.00	58.32	58.31	-0.01	60.72	60.72	0.00	61.06
357+78	15.914	56.91	56.91	0.00	58.22	58.21	-0.01	60.63	60.62	0.00	61.06
360+11	15.865	56.82	56.82	0.00	58.13	58.12	0.00	60.53	60.53	0.00	61.06
362+44	15.817	56.66	56.66	0.00	57.96	57.96	0.00	60.37	60.37	0.00	61.06
364+77	15.768	56.51	56.51	0.00	57.82	57.81	0.00	60.23	60.22	0.00	61.06
367+10	15.700	56.45	56.45	0.00	57.75	57.75	0.00	60.16	60.16	0.00	60.54
369+43	15.620	56.31	56.31	0.00	57.61	57.60	0.00	60.00	60.00	0.00	60.54
372+52	15.514	56.22	56.22	0.00	57.51	57.51	0.00	59.91	59.91	0.00	60.54
375+60	15.444	56.12	56.12	0.00	57.41	57.41	0.00	59.80	59.80	0.00	60.03
378+69	15.380	56.03	56.04	0.00	57.32	57.32	0.00	59.72	59.72	0.00	60.03
381+78	15.316	55.96	55.96	0.00	57.24	57.24	0.00	59.64	59.64	0.00	60.03
384+86	15.251	55.88	55.88	0.00	57.16	57.16	0.00	59.55	59.55	0.00	60.03
387+94	15.201	55.78	55.79	0.00	#N/A	#N/A	#N/A	59.45	59.46	0.00	59.51
391+01	15.150	55.73	55.73	0.00	#N/A	#N/A	#N/A	59.40	59.40	0.00	59.51
394+08	15.100	55.59	55.60	0.00	#N/A	#N/A	#N/A	59.24	59.25	0.00	59.51
397+17	15.049	55.39	55.39	0.00	#N/A	#N/A	#N/A	59.01	59.02	0.00	59.51
400+23	14.998	55.10	55.10	0.00	#N/A	#N/A	#N/A	58.71	58.71	0.00	59.00

Shaded Areas Indicate Location(s) of Greatest Reduction in Flood Stage

APPENDIX C

Regional Geomorphology Evaluations and Considerations for Setback Levee on Lower Feather River Right Bank at Star Bend

APPENDIX C

REGIONAL GEOMORPHOLOGY EVALUATIONS AND CONSIDERATIONS FOR SETBACK LEVEE ON LOWER FEATHER RIVER RIGHT BANK AT STAR BEND

Prepared By:

Wood Rodgers, Inc.

November 2007

Geomorphic Studies of the Feather River were conducted by Water Engineering and Technology (1991), Ayres and Associates (1997), and the Department of Water Resources (DWR, 2004). These studies were reviewed by Philip William and Associates (PWA, 2006) for the Three Rivers Levee Improvement Authority (TRLIA) in connection with TRLIA's Feather River levee improvements between the Bear and Yuba Rivers. Excerpts relevant to the proposed setback levee on the Feather River at Star Bend are summarized below from PWA's Geomorphic Assessment.

1. **Water Engineering and Technology (WET):** Based upon historic data, in 1991 WET estimated a channel migration rate of 1.6 feet per year at Star Bend. They estimated a lifespan of 50 years for the levee based upon the migration rate and an 80-foot bench area at Star Bend between the channel bank and levee. Since 15 years have passed since the WET estimate, erosion encroaching into the waterward levee toe could be estimated at 35 years.

   Wood Rodgers Comments: At present, there is less than 50 feet of a water-side berm between the levee and Feather River channel near HEC-RAS Cross Section 18. Based on conditions observed by WET in 1991, there may have been a lateral migration of as much 50 feet in last 15 years, which yields an average migration rate of 3.33 feet per year. At this rate the waterward levee toe may be endangered in less than twenty years. The rate of channel migration may be the result of the high seasonal velocities in excess of nine feet per second that are encountered at Star Bend. It may be prudent to set back the levee from geomorphic considerations alone.

2. **Ayres Associates:** The Feather River made incisions into the hydraulic mining-derived sediments by the mid-1960s. There has not been mass bank failure that could lead to lateral migration and threaten the levees. The Feather River has a low sinuosity for a river of its size and type. Ayres considered the present situations as an anomaly that will be reversed as sediment delivery from the Yuba and Bear Rivers is curtailed. Ayers emphasizes that the reduction in sediment delivery will likely trigger lateral migration.

Wood Rodgers Comments: The river demonstrates a meandering pattern near Star Bend that is demonstrated by presence of pools at RM 17, RM 18, and RM 19 and intervening crossings at cross sections in-between the noted pools. The Ayres report makes general comments on the Feather River and does not mention localized channel migrations at Star Bend and Shanghai Bend where channel migrations have been observed.

3. **Philip Williams and Associates (PWA):** PWA notes the reach between RM 19 and RM 17 has experienced severe local erosion on the outer concave banks of the bend where the levee is close to the channel. A total of 0.4 miles of the west (left) bank and 0.6 miles of east (right) bank are highly eroded.

   Wood Rodgers Comments: The proposed set back levee will ease erosion threats to the west bank levee. However, it may also marginally reduce the threat of erosion to the east bank.

4. **Department of Water Resources (DWR):** DWR notes the channel migration on the Feather River has decreased from 2.3 to 1.7 feet per year since the construction and operation of Oroville Dam. The 2004 DWR study found that present day sinuosity is not substantially different from the 1920's. Because of the entrenchment of the Feather River into hydraulic mining debris and the flood control functions of Oroville Dam, sinuosity is not expected to change over the next 50 years.

   Wood Rodgers Comments: With the reduced channel migration rate of 1.7 feet per year estimated by DWR, the existing waterward toe of the levee at Star Bend Levee could be endangered in 17 years.

Based upon the above-referenced studies and Wood Rodgers' observations, three estimates of time could be derived for when the existing levee may be in danger: 9, 17, and 35 years. Without remedial action, the imminent threat of losing the existing bench between the river channel and the existing levee near RM 18 at Star Bend could occur somewhere within the next

10 to 20 years. With the proposed setback levee at Star Bend the velocities in the channel will be reduced, allowing the channel or bank migration to be significantly minimized. Accordingly, based upon the geomorphic considerations alone, the levee at Star Bend should be set back as proposed by Levee District No. 1 of Sutter County.

REFERENCES

Ayres and Associates. *Yuba River Basin, California Project: Geomorphic, Sediment Engineering and Channel Stability Analysis.* U.S. Army Corps of Engineers, Sacramento District, Contract No. DACW005-92-C-0077. 1997

California Department of Water Resources. *SP-G2: Effects of Project Operations on Geomorphic Processes Downstream of Oroville Dam. Task 6 – Channel Meanders and Bank Erosion Monitoring.* Oroville Facilities Relicensing, FERC Project No. 2100. 2004.

EDAW Flood Control Study Team. *Draft Environmental Impact Report for the Feather River Levee Repair Project An Element of the Yuba-Feather Supplemental Flood Control Project.* Volume I: Chapters I-11 and Volume II: Appendices. Prepared for Three Rivers Levee Improvement Authority. August 2006. State Clearinghouse #2006062071.

Philip Williams & Associates, Ltd. *Geomorphic Assessment of Project Alternatives for Feather River Levee Improvements Between the Bear and Yuba Rivers.* Prepared for Bookman Edmonston – GEI and Three Rivers Levee Improvement Authority. July 28, 2006. PWA Ref. # 1833.

Water Engineering & Technology, Inc. *Geomorphic Analysis and Bank Protection Alternative Report for Sacramento River (RM 0-78), Feather River (RM 28-61), Yuba River (RM 0-11), Bear River (RM 0-17), American River (RM 0-23), and Portions of Three Mile, Streamboat, Sutter, Miner, Georgian, Elk, and Cache Sloughs.* Prepared for Sacramento District, U.S. Army Corps of Engineers, Contract DACW05-88-D-0044. 1991, page 334.

APPENDIX D

Response to April 4, 2007 Review Comments of Reclamation Board Permit # 18191, Sutter, CA (Star Bend Setback Levee Project) Prepared by Ethan Thompson, P.E . of Hydraulic Design Section Sacramento District, USACE, CESPK-ED-DH

CESPK-ED-DH 4 April 2007

MEMORANDUM FOR: OPERATIONS BRANCH

SUBJECT: Review of Reclamation Board Permit #18191, Sutter, CA (Star Bend Setback Levee Project)

1. The Hydraulic Design Section has been tasked by Operations Branch to review the subject permit to check for any possible hydraulic impacts to the Federal Flood Control Project. The review by the Hydraulic Design Section is for this purpose only and is not to determine the most suitable setback alignment or certify the hydraulic models for purposes beyond this impact analysis. The proposed project would construct an earthen levee west of the Feather River at Star Bend. The project would replace a segment of the river's existing levee that currently constricts flood flows in the river during high flow events.

2. It is anticipated from a hydraulic perspective, that construction of the setback levee and removal of the existing levee segment will be beneficial to the existing Federal Flood Control Project. However, additional supporting hydraulic data is required for review by the Hydraulic Design Section to ascertain that no hydraulic impacts will result from the subject project. In addition to the required supporting data, clarification is needed on other items provided as part of the original permit package. All these required items and comments are listed below in paragraphs 4 and 5.

3. This review is based upon the 30% design. The Corps' Hydraulic Design Section should be given the opportunity to review the final design.

4. **Additional Items Required for Review**

   a. **All hydraulic models used in the analysis to be submitted to the Corps' Hydraulic Design Section for review.**

      Response: All models used in the analysis will be submitted to the Corps' Hydraulic Design Section for Review Upon completion of quality control by AE, currently scheduled for completion by December 2007.

   b. **AE to provide proof of quality control of the hydraulic modeling.**

      Response: AE will provide proof of quality control of hydraulic modeling by December 2007.

   c. **Model runs for the impact analysis to be made using the authorized design flow of 300,000 cfs. A graph should be provided showing the following water surface profiles: 1. 300k cfs flow**

without proposed project 2. 300k cfs with proposed project and 3. Existing 1957 design profile. A table of the profiles should also be provided that show values and differences in the water surface elevations at all cross sections.

Response: Models runs have been prepared for the authorized design flow of 300,000 cfs. Please refer to Figures 16-20. A set of graphs have also been provided that show the 300,000 cfs flows in comparison the USACE 1957 design profile. These profiles are included as Figures 21-23. Tables of the profiles are provided in Appendix B that show values and differences in water surface elevations for the right and left bank levees at all the pertinent cross sections.

d. **Plots (stages, velocities) to be provided of with and without project conditions of the 300k cfs design flow, in addition to more frequent flow events (2yr, 10yr, 25yr, 50yr, 100yr). Comparison plots should also be provided to show differences in stage and velocity under with and without project conditions for the design flow (300k cfs) and more frequent flow events. These plots should be generated using output from the 2-D model runs. Plots assessing change in flows due to the proposed project should also be provided.**

Response: Plots for 100-year, 200-year and the 300,000 cfs design flow are provided. Plots for other smaller flow events will be provided by December 2007.

e. **Provide a list of changes to Corps and MBK HEC-RAS models.**

Response: Two types of improvements have been made by Wood Rodgers to USACE HEC-RAS Model: (1) the levees constructed under Three Rivers Levee Improvement Authority (TRLIA) at the confluence of the Feather River and the Bear River have been incorporated in the model; and (2) new Storage areas (SA128, SA127, SA113 and SA784 South) have been added to the USACE Model from the MBK Model.

f. **Provide assessment of any potential sediment and/or geomorphological impacts.**

Response: Please refer to Appendix C which includes a discussion of regional geomorphic evaluations and considerations for the Setback Levee on the Lower Feather River Right Bank at Star Bend.

5. **Other Comments**

a. **Attachment A, pg. 2-13/14. Based on the fact that the future land use of the new setback area has not been determined, how was Manning's n chosen? What Manning's n was chosen? Impact should be assessed by choosing a roughness value that would equate to the expected greatest increase in roughness**.

   Response: Future land use in the setback area is planned as shrubs and trees which is same as the Area 1 of the O'Connor Lakes Restoration Area" as built conditions. MBK Engineer's has modeled Area 1 vegetation with a Manning's n value of 0.07. Wood Rodgers' used the same Manning's "n" value of 0.07 for the setback area.

b. **Attachment A, pg.2. Provide further discussion on how Corps and MBK HEC-RAS models were combined.**

   Response: Two types of improvement have been made to USACE RAS Model: (1) the levees constructed under Three Rivers Levee Improvement Authority (TRLIA) at the confluence of the Feather River and the Bear River have been incorporated in the model; and (2) new Storage areas (SA128, SA127, SA113 and SA784 South) have been added to the USACE Model from the MBK Model.

c. **Attachment A, pg.2. How does the MBK model not allow overtopping? In this type of analysis, overtopping should be allowed without levee failure**.
   Response: This was an inadvertent error. The text has been appropriately corrected. The MBK and the Wood Rodgers Models allow overtopping without levee failure.

d. **Attachment A, pg.3. Provide further data support for comparison to MBK model**.

   Response: No comparison is provided to the MBK Model. The comparison statement has been dropped from the Report.

e. **Attachment A, pg.4. Same base model should be used in comparing with and without project conditions. It is not clear by discussion of the models if this is the case or not. To make assessment of impacts, only differences in the model should be that attributable to the proposed project**.

   Response: The same base models are used in comparing the pre-and post-project conditions. The only differences in the models are attributable to the setback configuration – with and without the proposed setback levee. It is based on the existing conditions Model

for Hydraulic Model 4 shown in Table 1, but the "With Proposed Project Conditions" includes the proposed setback alignment.

f. **Attachment A, pg.5. Why were these 2 conditions chosen for comparison? What was basis for choosing one over the other (supporting data)?**

   Response: Two conditions were chosen to develop the maximum upstream boundary flow at RM 23. It is observed from Table 2 that a higher flow prevails at RM 23 (350,896 cfs) when maximum flow occurs at RM 18 which is near the location of the Setback Levee. It is noted that at the time of maximum stage at RM 18, the maximum flow does not develop at RM 23 (349,663 cfs). A similar trend is also noticed for 1-in-100 AEP.

g. **Attachment A, pg.9. Quantify "slight" increase in shear stresses**.

   Response: The increase near the Star Bend Reach is 0.01 lb/sft. Please refer to Table 6, entitled "Impact on Channel Shear Stress for 1-in-100 AEP Flow Event".

h. **Attachment A, Figure 1. It appears new cross section 16.75 now overlaps cross section 16.5. Cross sections should not overlap.**

   Response: Agreed. The Proposed Conditions HEC-RAS Model has been changed to remove the error due to oversight.

i. **Attachment A, Figure 5. Contour 64 does not seem correct.**

   Response: In two-dimensional models water surface elevation contours can be a curved line because of two-dimensional nature of flow.

6. Questions regarding any of these comments can be directed to Ethan Thompson, (916) 557-7142 or ethan.a.thompson@usace.army.mil.

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