Flood Risk Analysis in the Lower San Joaquin River System

By

Romain Didier Maendly

B.S. (University of California Berkeley) 2008

THESIS

Submitted in partial satisfaction of the requirements for the degree of

MASTER OF SCIENCE

in

Civil and Environmental Engineering

in the

OFFICE OF GRADUATE STUDIES of the UNIVERSITY OF CALIFORNIA DAVIS

Approved:

____

Jay R Lund, Chair

____

Samuel Sandoval-Solis

____

William E Fleenor

Committee in Charge

2014

ABSTRACT

In 2012, the California Department of Water Resources released its Central Valley Flood Protection Plan to improve the overall flood management system for the Sacramento and Joaquin River. While the plan included several opportunities to reduce flood risk within the Sacramento River Valley, the solution was more limited in the San Joaquin River. This study investigated the possible increase of flow capacity in a bypass of the San Joaquin River system located 12 miles South from Stockton, CA, named Paradise Cut. The San Joaquin River is connected to Paradise Cut with a weir which spills during large floods and diverts water from its main river stem. In a first step, a hydraulic model of the Lower San Joaquin River was built, then calibrated and finally evaluated by simulating the 10-, 25-, 50-, 100-, 200- and 500-year flood events. Once the model was calibrated, several feature modifications at Paradise Cut weir and its surroundings were created and evaluated hydraulically (stage, flow, out-of-system volume) and economically (construction cost, expected annual damage, benefits-cost ratio). It was found that lowering and lengthening the weir, and dredging the upper portion of Paradise Cut creates great hydraulic improvement in the upper and mid-section of the study area, but very little flood enhancement once entering the California Delta. From a solely economic stand point, the inundation reduction benefits in comparison to construction cost do not make any of the modifications feasible.

ACKNOWLEDGEMENTS

The author would like to first thank his thesis committee, Jay Lund, Samuel Sandoval and Bill Fleenor for their patience and help throughout this process. It was a slow development, but at the end the product is not too bad.

The author would also like to thank his colleagues at the California Department of Water Resources: Jenny Marr, who brought this flood project into our branch. Steve Cimpermann, for his trust in the author's capacity to complete work in house, he knows what the author means. And finally David Arrate and Shem Stygar, without both of you, the author would not have made it!

Finally, the author would like to thanks his parents, who are living on the other side of the planet, to have support and cheered for him throughout his academic endeavor in The United States.

I dedicate this thesis to

My wife, Stefanne and my three daughters, Natalie, Zoé and Geneviève,

for their constant support, patience and unconditional love.

I deeply love you all.

TABLE OF CONTENT

LIST OF FIGURES

LIST OF TABLES

Chapter 1

INTRODUCTION AND BACKGROUND

1.1 BACKGROUND

California is prone to floods. Extreme precipitation from the Pacific Ocean has always created fear of loss of life and assets in the Central Valley. To protect the local population and assets from flooding; the Federal, State and local governments have built and maintained levees, bypasses and dams to reduce floods. In recent years more proactive actions have been undertaken to prepare and respond to these hazardous events, ranging from the inspection/repair of levees, building regulations, system reoperation and flood protection plans.

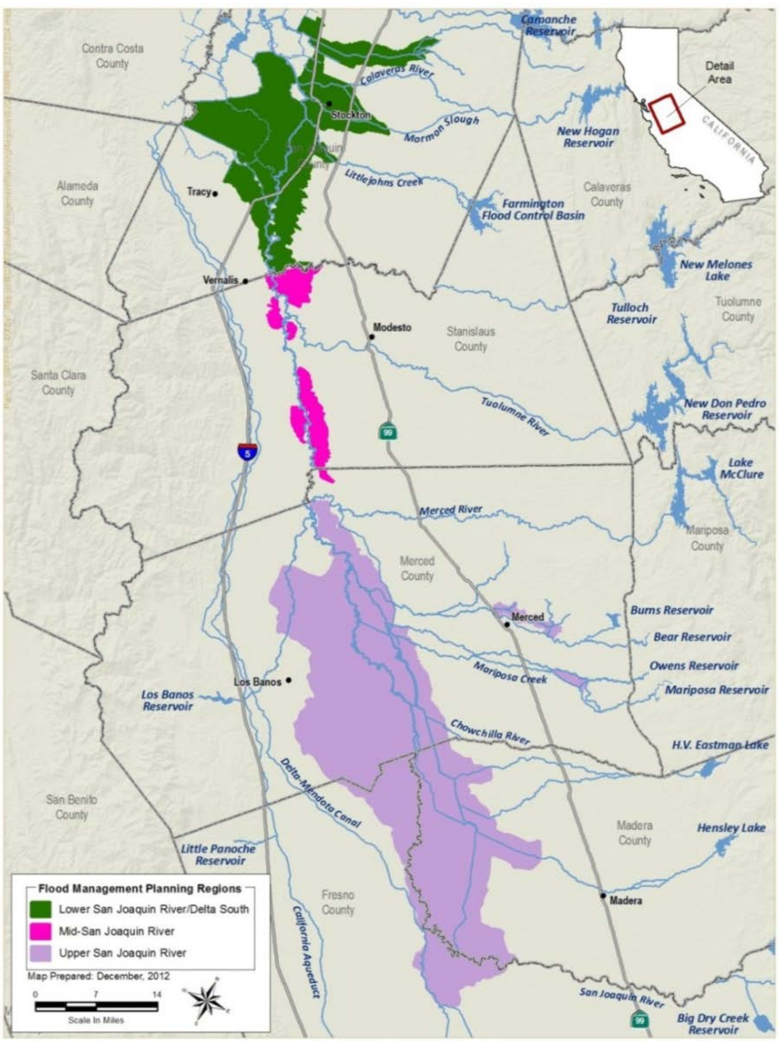


Figure 1-1. Geographic Scope of Central Valley Flood Protection Plan – San Joaquin River Basin

The Central Valley Flood Protection Plan (CVFPP) (DWR, 2011a) examines a range of approaches for improving flood management. These approaches range from major physical improvements in the CVFPP study area to land use adaptation. The boundary of this plan corresponds to the hydrologic basin boundary through the Sacramento-San Joaquin Delta (Delta). Figure 1-1 presents the boundary of this plan for the San Joaquin river basin.

One chapter of this plan focuses on enhancing flood system storage and conveyance capacity to achieve multiple benefits by using bypasses. While the Sacramento River Basin has major existing bypasses to achieve this goal, the San Joaquin River basin has only one potential bypass located in the Lower San Joaquin River (LSJR) in-between Vernalis and Stockton (see Figure 1-2). This potential bypass is on the South side of Stewart Tract Island and is named Paradise Cut.

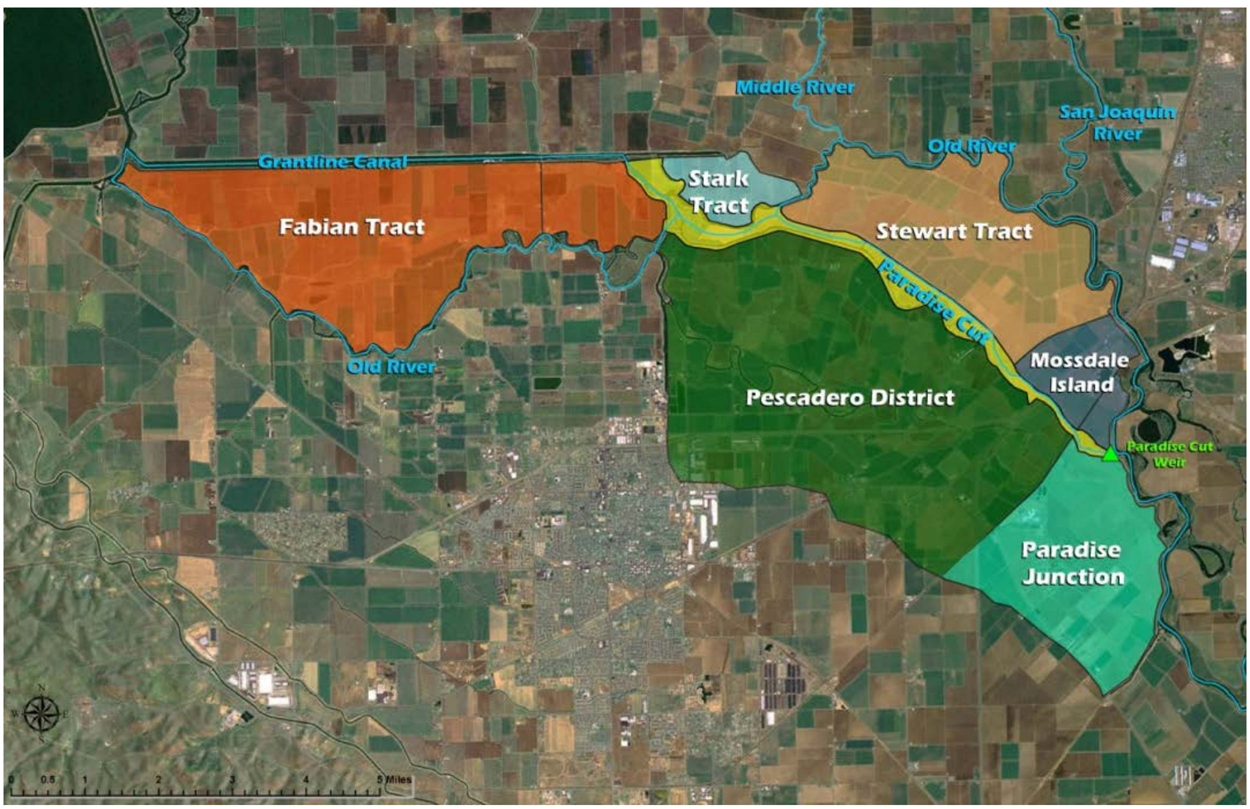


Figure 1-2. Paradise Cut Location

1.2 PURPOSE

This study presents the calibration and work done with a one-dimensional hydraulic model on the LSJR to produce flood stage results from Vernalis to 20 miles downstream in the Delta for estimated 10-, 25-, 50-, 100-, 200- and 500-year flood events.

This study also evaluates in two steps the effects of weir modification, dredging and bridges along Paradise Cut on the study area. The first step presents a hydraulic application of the model by evaluating stage (water surface elevation), flow and out-of-system volume. The second presents preliminary evaluation of costs and benefits, or inundation reduction benefits from each feature. The end goal is to present useful and insightful information concerning this critical location on the border between the San Joaquin Valley and the Sacramento – San Joaquin River Delta.

1.3 STUDY AREA

The study area is within the LSJR and Delta South Regions (See Figure 1-1). The study area, which is also the boundary of the one-dimensional model, follows the San Joaquin River from the Vernalis gage station to Stockton Deep Water Ship Channel. It includes Old River down to the west end of Fabian Tract close to Tracy Pumping Plant, Middle River from Old River to Highway 4, Paradise Cut, Salmon Slough and Grantline/Fabian. The areas/islands adjacent to these rivers are also included in the study area as they control out of system volume and the cost of flood damage from water stage increase or reduction. Figure 1-3 shows the extent of the study area with its rivers and channels network.

1.4 REPORT ORGANIZATION

Chapter 2 of this report includes the method to develop a one-dimensional hydraulic model, the calibration and testing of the model and presents the existing physical feature limitations and capacity of Paradise Cut. Chapter 3 provides the hydraulic and economic evaluation and discussion of possible feature modifications along Paradise Cut. Conclusion and thoughts for improvement and future studies are included in Chapter 4

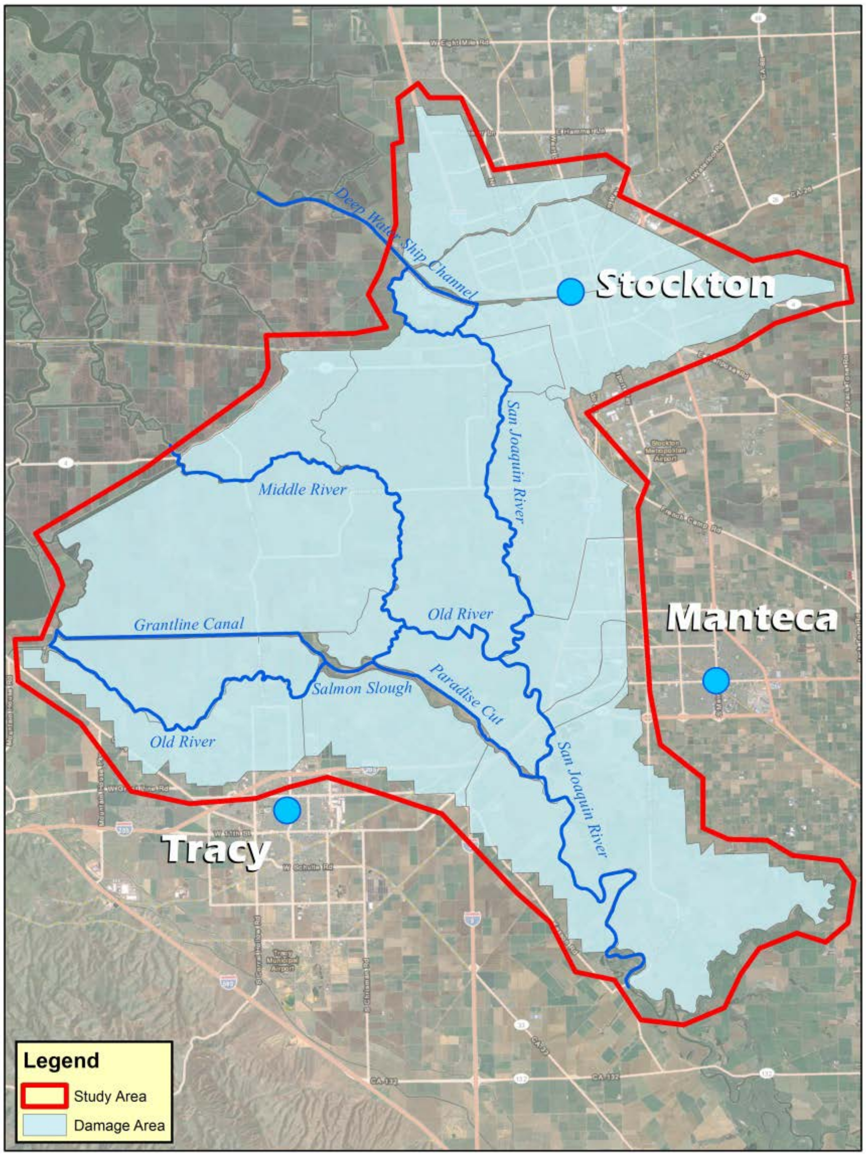


Figure 1-3. Study Area

Chapter 2

MODEL DEVELOPMENT AND TESTING

2.1 INTRODUCTION

This chapter presents the method to develop the one-dimensional model. The unsteady flow option in HEC-RAS model is used for flood simulation, implemented in three steps: (1) processing geometry data in HEC-RAS, (2) integration of hydrologic data as initial conditions and boundary conditions in HEC-RAS unsteady flow data files, and (3) calibration and simulation of floods. The model was then tested for validation. Finally, the existing physical feature limitations and capacity of Paradise Cut were presented

2.2 MODEL BACKGROUND

A one-dimensional hydraulic simulation model of the San Joaquin River Basin was developed in late 1996 by David Ford Consulting Engineers using the HEC UNET computer program, the predecessor of the HEC-RAS software (Version 4.1). This model was later used in 2002 for the comprehensive flood management study (comp study) developed by the U.S. Army Corps of Engineers and the Reclamation Board using HEC-RAS (USACE, 2002). This model was updated with new topographic information and is currently used for The Central Valley Hydrology Study (CVHS) to create new flow frequency curves for the Central Valley Floodplain Evaluation and Delineation program (CVFED). The model used in this report was developed starting with the geometric data from the comp study model.

2.3 MODEL EXTENT AND GEOMETRY

The original HEC-RAS model domain is similar to the study area described above (See Section 1.3). The model extent includes the San Joaquin River from the Vernalis gage to the Rindge Pump gage downstream of Stockton, Old River from its head to the west end of Fabian Tract, Middle River from Old

River to Highway 4, Grantline Canal from Old River to the west end of Fabian Tract, and Paradise Cut. Figure 2-1 shows the model extent schematic. The horizontal datum used in the model is NAD 83 and the vertical datum is NAVD 88 converted from NGVD 29 via ARC MAP (Version 10.1).

The model consists of streams, cross-sections, and lateral weirs that act as levees. Each stream segment is divided into reaches, summarized in Table 2-1. During flood events simulations where levees overtop, the model conveys the floodwater into storage areas by way of the lateral weirs. The storage areas are simple bucket-like areas defined by an elevation-volume relationship. The model also has connections between the storage areas. The storage areas and their connections are shown in Figure 2-2.

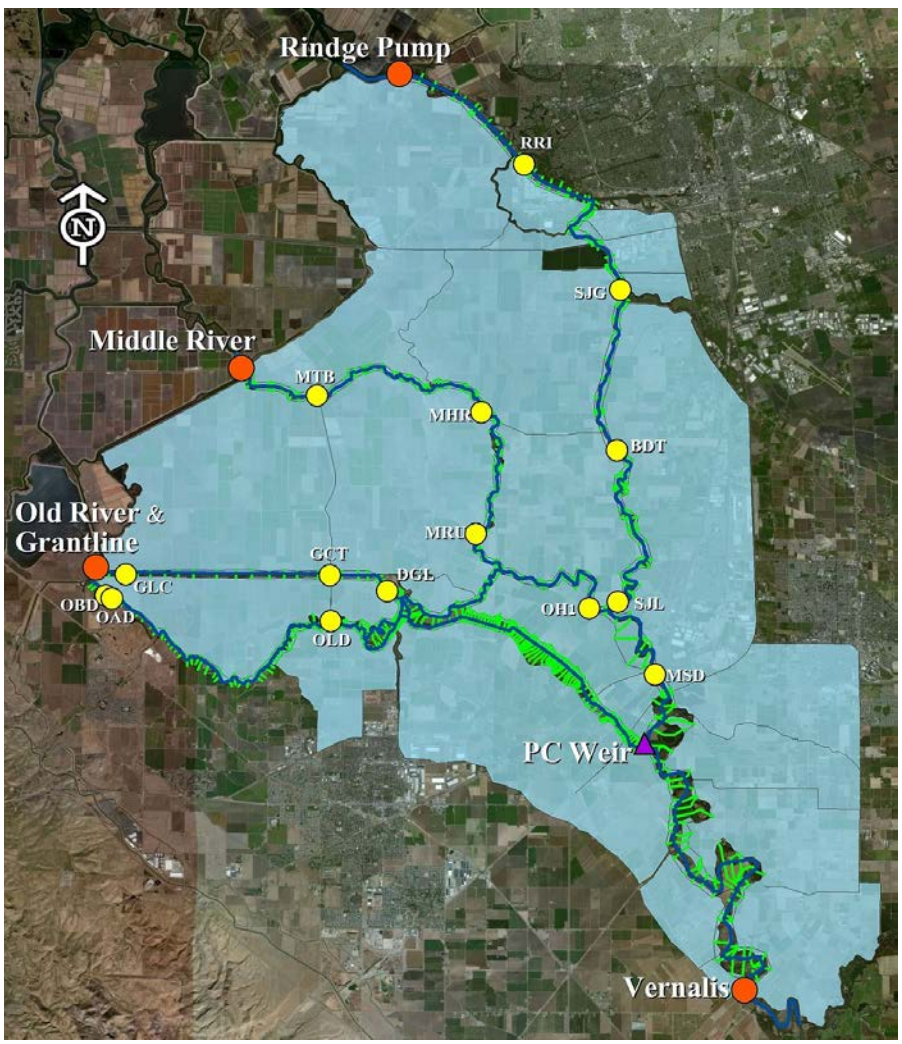


Figure 2-1. Model Schematic with Reaches, Boundaries, Index Points and Storage Areas

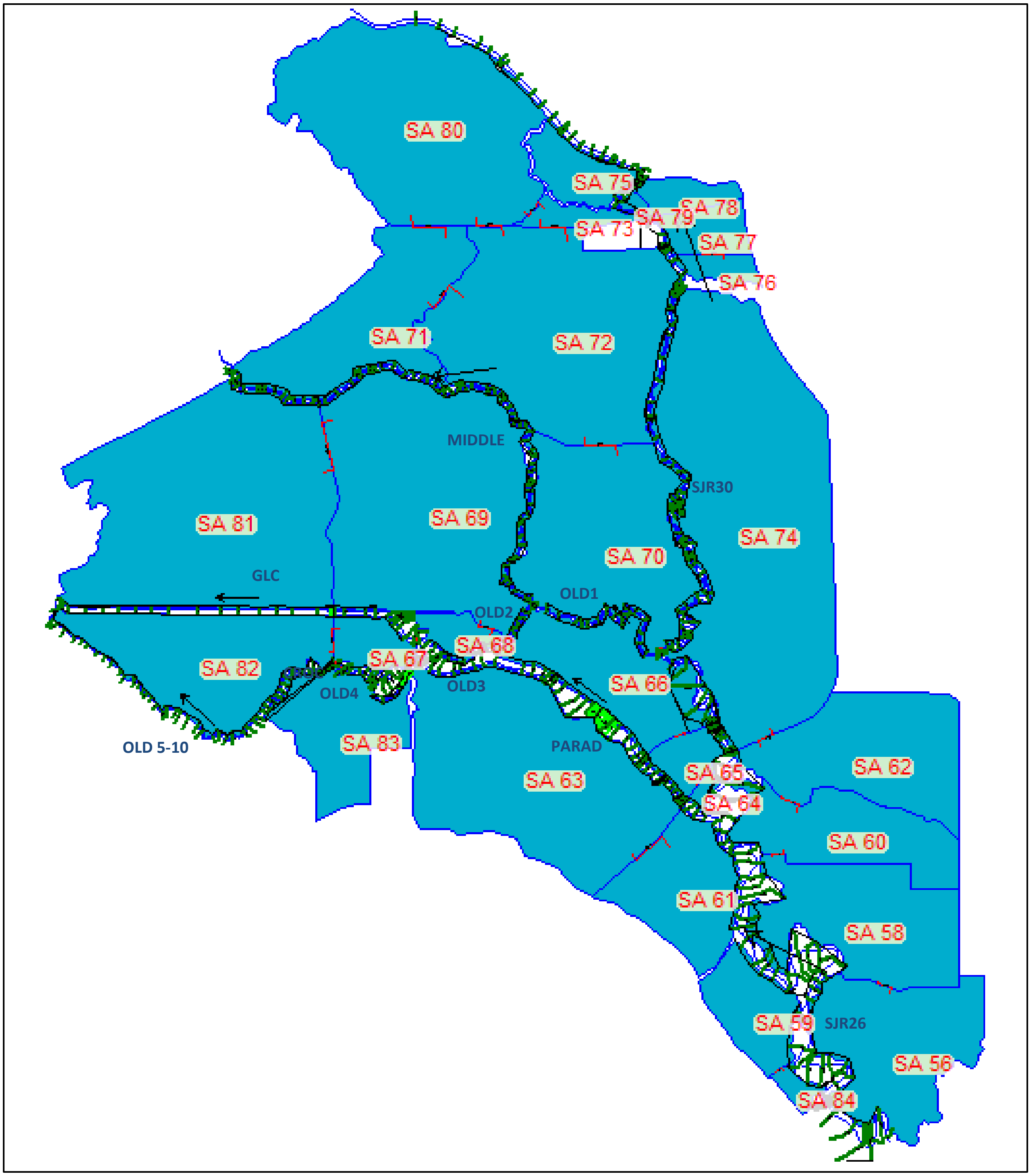


Figure 2-2. Model Schematic with Storage Areas and Connections

Table 2-1. Model Reaches

Reach Name	Stream	Upstream End	Downstream End
SJR26	San Joaquin River	Vernalis Gage	Old River & SJ River Split
SJR30	San Joaquin River	Old River & SJ River Split	Rindge Pump Gage
OLD1	Old River	Head of Old River	Old River & Middle River Split
OLD2	Old River	Old River & Middle River Split	Old River & Grantline Canal Split
OLD3	Old River	Old River & Grantline Canal Split	Old River & Paradise Cut Convergence
OLD4	Old River	Old River & Paradise Cut Convergence	Old River & Salmon Slough Split
OLD5-10	Old River	Old River & Salmon Slough Split	West end of Fabian Tract
MIDDLE	Middle River	Head of Middle River	Highway 4 Bridge
CROC	Salmon Slough	Old River & Grantline Canal Split	Old River & Salmon Slough Split
GLC	Grantline Canal	Head of Salmon Slough	West end of Fabian Tract
PARAD	Paradise Cut	Paradise Cut Weir	Old River & Paradise Cut Convergence

2.4 GEOMETRY EXTENSION

In the original model geometry, the San Joaquin River reach (SJR 30) ended at the north end of Rough and Ready Island near Stockton, Middle River reach (MIDDLE) ended at Tracy Road Bridge, and Old River and Grantline Canal did not join at their extremity near Clifton Court Bay. To reduce the downstream boundary condition effect on stage at these locations, the model geometry was extended. The San Joaquin River reach (SJR 30) was extended 6 miles north (downstream) using additional LIDAR and bathymetry data from the Delta Simulation Model II (DSM2). The Middle River reach was extended to Highway 4 with the DSM2 cross-sections, so that it would end at the western side of storage area 71 (SA 71). Finally Old River and Grantline Canal were joined at Clifton Court Bay (see figure 2-1 and 2-2).

2.5 BOUNDARY CONDITIONS

The model has four types of boundary conditions: interior, upstream, downstream, and internal. Interior boundary conditions define reach connections and ensure continuity of flow. Upstream boundary conditions are needed for all reaches that are not connected to another reach at their upstream end and can be defined with a flow or stage hydrograph. Downstream boundary conditions are needed for all reaches that are not connected to another reach at their downstream end and can be defined with a flow hydrograph, stage hydrograph, rating curve or normal depth calculation. Internal boundary conditions can represent levee breaches, gated spillways, overflow weirs, bridge and culvert hydraulics, flow diversions and lateral inflows.

The HEC-RAS model applies flow continuity to reaches upstream of flow splits and downstream of flow combinations and applies stage continuity for all other reaches. The upstream boundary for the South Delta model is at the USGS Vernalis gage. The upstream boundary condition is set by a flow hydrograph using observed flow data from the USGS Vernalis gage.

The Paradise Cut reach has an upstream boundary not connected to another river reach, but connected to a lateral weir (Paradise Cut Weir) off the San Joaquin River reach SJR26. Due to this setup, the Paradise Cut reach also needs an upstream boundary condition. A synthetic flow hydrograph with a minimal, constant inflow of 10 cubic feet per second (cfs) sets an upstream boundary condition. Additional flow is contributed from the San Joaquin River reach over the connecting weir. The artificial flow input at the first cross section of the Paradise Cut reach has a negligible effect on the system.

Four downstream boundaries exist in the model, shown in Table 2-2. The downstream boundary conditions were set with stage hydrographs using observed stage data from the DWR Water Data Library. In the model, Grantline Canal and Old River reaches both end near the Old River at Clifton Court Ferry gage, so this gage is used as a downstream boundary for both reaches.

Table 2-2. Downstream Boundaries

Downstream Boundary	Gage	Gage Data Source
San Joaquin River	San Joaquin River at Rindge Pump	Water Data Library B95620
Middle River	Middle River at Borden Highway	Water Data Library B95500
Grantline Canal	Old River at Clifton Court Ferry	Water Data Library B95340
Old River	Old River at Clifton Court Ferry	Water Data Library B95340

Paradise Cut Weir is an overflow weir that diverts water from the San Joaquin River to Paradise Cut Bypass when the stage in the San Joaquin River exceeds approximately 15 feet at the weir. This overflow stage is estimated to occur when the San Joaquin River flow exceeds around 16,000 cfs. The weir is on the left bank of the river at model river station 58.56 and is approximately 200 feet long with a crest elevation of about 15 feet. Overflow lateral weirs have also been included to represent levees that may be subject to overtopping during large floods.

2.6 CALIBRATION

The original model was calibrated for the Comp Study; however the focus of the Comp Study was the Central Valley and not the Delta, which is subject to tides. Moreover, the calibration for the Comp Study was done prior to 2002 and did not account for current conditions within the Delta. Finally, the geometry of the original model was modified as described above. For these reasons a new calibration of this model was needed.

The updated model was calibrated using 15-minute observed stage data from December 2009 to May 2011. The modeled peak inflow calibration at Vernalis ranged from 1,400 cfs to 28,900 cfs. Table 2-3 shows the date and duration of the events used in the calibration. This date range for inflows at Vernalis includes the most recent set of data with a large range of flows. It was also assumed that the more recent gage data would be more reliable in quality and availability.

Table 2-3. Observed calibration data

Date	Peak Flow
December 10, 2009 – December 25, 2009	1,470 cfs
January 17, 2010 – February 3, 2010	4,210 cfs
February 23, 2010 – March 7, 2010	5,010 cfs
February 3, 2011 – February 16, 2011	7,430 cfs
February 14, 2011 – March 3, 2011	12,400 cfs
December 26, 2010 – January 16, 2011	15,600 cfs
March 18, 2011 – April 16, 2011	28,800 cfs

Sixteen stream gages are available within the model domain. These gages were used as index points in calibrating the model stage, flow and lag time for both peak stage and flow. The time lag is a good indicator of the hydrodynamics of tides along the channels and the flow from flood event coming downstream. The data sources for these stream gages are the DWR Water Data Library (DWR, 2013a), California Data Exchange Center (DWR, 2013b), and USGS National Water Information System (USGS, 2013a). The gages are shown in Figure 2-1 and summarized in Table 2-4.

Table 2-4. Gages used for calibration

Gage	Source	Model Location (Index Point)	Gage Code
San Joaquin River at Mossdale	Water Data Library	SJR 26 56.112	MSD - B95820
San Joaquin River near Lathrop	Water Data Library	SJR 30 52.95	SJL - B95765
San Joaquin River at Brandt Bridge	Water Data Library	SJR 30 47.32	BDT - B95740
San Joaquin River at Garwood Bridge	CDEC	SJR 30 41.5	SJG
Stockton Ship Channel at Burns Cutoff	Water Data Library	SJR 30 37.93	RRI - B95660
Old River at Head	Water Data Library	OLD 1 35.23	OH1 - B95400
Old River near Tracy Rd. Bridge	CDEC	OLD 10 28.683	OLD
Old River Barrier above DMC	Water Data Library and CDEC	OLD 10 1.735757	OAD ODM - B95366
Old River Barrier below DMC	Water Data Library	OLD 10 1.565757	OBD - B95365
Middle River at Mowry Bridge	Water Data Library	MIDDLE 27.025	MRU - B95540
Middle River at Howard Rd. Bridge	Water Data Library	MIDDLE 23.195	MHR - B95530
Middle River at Tracy Rd. Bridge	Water Data Library	MIDDLE 18.117	MTB - B95503
Doughty Cut above Grantline Canal	Water Data Library	GLC 27.518	DGL - B95325
Grantline Canal at Tracy Rd. Bridge	Water Data Library	GLC 26.071	GCT - B95300
Grantline Canal	USGS	GLC 0.09	GLC

The method of model calibration was to start with the smallest event (1,470 cfs) and finish with the largest (28,800 cfs) recorded in recent years. This method allowed adjustment to the coefficients of friction (Manning's coefficients) in a coherent way starting from the bed of the river to its bank, then floodplain and finally the leveed portion consecutively.

The Manning coefficients were first defined by observation in the field and Google Earth (Version 7.1.1.1888) depending on the ground cover. An assumption was made that areas closer to tidal influence should have lower Manning coefficients. Table 2-5 presents the range of Manning friction values used in the model, defined in four categories: bed, bank, floodplain and levee with their description.

The Manning coefficients were adjusted to the simulated stage and flow hydrograph in relation to observed hydrographs. For example, if the simulated stage hydrographs was too low compared to the observed hydrograph, the Manning coefficient would have been raised to increase the friction of the river bed on the water flow to reduce the flow and increase the stage. Similarly if the simulated stage hydrograph was too high compared to the observed hydrograph, the Manning coefficient would have been lowered to decrease the friction of the river bed on the water flow to increase the flow and decrease the stage.

Table 2-5. Manning coefficient used range

Categories of Channel and Description	Manning Range
River Bed (Low slope & deep channel – main river bed – Paradise Cut bed	0.018 - 0.023 - 0.03
River Bank (dirt wall – riprap – vegetation)	0.03 - 0.045 - 0.07
Floodplain (grass with some bush – heavy vegetation)	0.05 - 0.12
Levees (some vegetation, riprap – heavy vegetation)	0.45-0.70

Calibrating Delta hydraulic models is not easy. The flow is not only influenced by upstream discharge at Vernalis, but also tides coming in and out of the Delta. So an approach using several steps was used to calibrate the model. The model was first calibrated for the lowest flow and tides stage that the HEC-RAS model could handle without instability. This calibration was specifically done for the upper reaches of the model and focused on the river bed. The next step was to take a similar flow event as the first step, but with higher tide at the lower end of the model. This step was used to calibrate the lower end of the river bed which allows a refined calibration of tidal movement observed as high as Vernalis. The next steps repeated of the first two, with greater flows and similar tides (low and high). These calibration steps enabled the model to have a more refined representation of the observed data from the bed to the bank and finally the floodplain and leveed river reaches.

The calibration itself was not the only issue. The observed data did not always record accurately the stage elevation due to malfunctions of the recording gage. These elements affect the observed flow data developed from flow-stage rating curve. This problem is common in the Delta were a similar stage can have very different flow hydrodynamic mechanisms. For example, Figure 2-3 shows the flow-stage rating curve observed from March 18, 2011 – April 16, 2011, event and its simulation from the calibration. While observing Figure 2-3, one can see the complexity of tidal cycle effects on the stage-flow relationship. Tides retreating to the ocean increase the flow downstream and therefore decrease water stage, while advancing tides slowdown the flow and increase water stage.

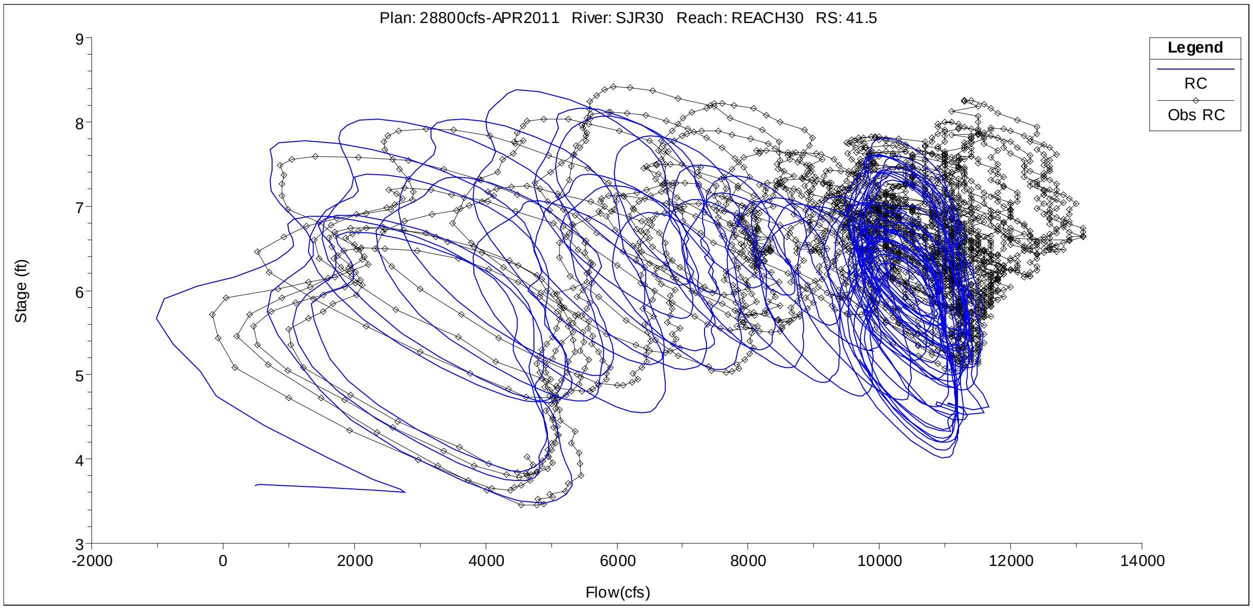


Figure 2-3 Flow-Stage Rating Curve, March 17, 2011 – May 7, 2011 (28,900 cfs) San Joaquin River at Garwood Bridge (USGS) (SJG).

2.7 CALIBRATION RESULTS

The calibration results are presented in Appendix A. The peak observed stage, the peak simulated stage, and the differences between the peak observed and simulated stage for every index point appears in Table A-1. In most simulations, the model reproduced the stage peaks within +/- 0.3 feet (a 1-4% margin of error), depending on the index point and event.

In general, the larger differences between the observed and simulated peak stage occurred at Grantline Canal near the pumps of the Central Valley Project (CVP) and State Water Project (SWP) which were not included in the model as well as along Middle River. The pumps of the CVP and SWP influence the hydrodynamics of the system in a way that the model cannot perceive by increasing the flow leaving the system and decreasing the stage, however these influences would be further reduced during any type of flooding event which the model is used to simulate. The differences of peak stage along Middle River are due to the topography of this channel which is shallow without slope and therefore has small flow discharges which are difficult to simulate. Other differences might be due to errors at the gage or general inaccuracy of the model due to Manning coefficient or cross-sections in the model.

Below is an index for selected stage hydrograph figures developed from the model, which show the observed and simulated results (Table 2-6). The December 15, 2010 – January 14, 2011 (15,600 cfs) event peak flow is just below the threshold for the Paradise Cut Weir spilling. The March 17, 2011 – May 7, 2011 (28,900 cfs) event was the only event used in the calibration where flow spilled over the Paradise Cut Weir and into the bypass.

Table 2-6. Stage Hydrographs Index

Figure Number	Event (Vernalis Peak Flow)	Location
Figure A-1	December 15, 2010 – January 14, 2011 (15,600 cfs)	San Joaquin River at Mossdale (MSD)
Figure A-2	December 15, 2010 – January 14, 2011 (15,600 cfs)	San Joaquin River near Lathrop (SJL)
Figure A-3	December 15, 2010 – January 14, 2011 (15,600 cfs)	San Joaquin River at Brandt Bridge (BDT)
Figure A-4	December 15, 2010 – January 14, 2011 (15,600 cfs)	Middle River at Mowry Bridge (MRU)
Figure A-5	December 15, 2010 – January 14, 2011 (15,600 cfs)	Grantline at Tracy Rd. Bridge (GCT)
Figure A-6	December 15, 2010 – January 14, 2011 (15,600 cfs)	Old River at Tracy Rd. Bridge (OLD)
Figure A-7	March 17, 2011 – May 7, 2011 (28,900 cfs)	San Joaquin River at Mossdale (MSD)
Figure A-8	March 17, 2011 – May 7, 2011 (28,900 cfs)	San Joaquin River near Lathrop (SJL)
Figure A-9	March 17, 2011 – May 7, 2011 (28,900 cfs)	San Joaquin River at Brandt Bridge (BDT)
Figure A-10	March 17, 2011 – May 7, 2011 (28,900 cfs)	Middle River at Mowry Bridge (MRU)
Figure A-11	March 17, 2011 – May 7, 2011 (28,900 cfs)	Grantline at Tracy Rd. Bridge (GCT)
Figure A-12	March 17, 2011 – May 7, 2011 (28,900 cfs)	Old River at Tracy Rd. Bridge (OLD)

The peak observed discharge, the peak simulated discharge, and the percentage of difference between observed and simulated for eleven available index points are presented in Table A-3. The USGS categorizes their discharge flow data to be "good" if 95% of the daily discharge is within 10% of the actual value (USGS, 2013b). The USGS Vernalis flow gage data are used as the upstream boundary condition inflow for the model and the data at that gage are generally rated as "good". Other gages in the system are recorded by DWR and do not have same quality control of USGS data. In general, flow accuracy between observed and calibrated ranges within 20%, 75% of the time and within 30%, 90% of the time. It is relatively suitable considering the level of accuracy of the observed flow at Vernalis gage and the level of accuracy at the other gage locations for calibration. The discharge is also harder to calibrate due to the flow stage curve relationship described in the previous section.

Table 2-7. Flow Hydrographs Index

Figure Number	Event (Vernalis Peak Flow)	Location
Figure A-17	December 15, 2010 – January 14, 2011 (15,600 cfs)	San Joaquin River at Mossdale (MSD)
Figure A-18	December 15, 2010 – January 14, 2011 (15,600 cfs)	San Joaquin River at Brandt Bridge (BDT)
Figure A-19	December 15, 2010 – January 14, 2011 (15,600 cfs)	San Joaquin River at Garwood Bridge (SJG)
Figure A-20	December 15, 2010 – January 14, 2011 (15,600 cfs)	Grantline Canal (GLC)
Figure A-21	March 17, 2011 – May 7, 2011 (28,900 cfs)	San Joaquin River at Mossdale (MSD)
Figure A-22	March 17, 2011 – May 7, 2011 (28,900 cfs)	San Joaquin River at Brandt Bridge (BDT)
Figure A-23	March 17, 2011 – May 7, 2011 (28,900 cfs)	San Joaquin River at Garwood Bridge (SJG)
Figure A-24	March 17, 2011 – May 7, 2011 (28,900 cfs)	Grantline Canal (GLC)
Figure A-25	March 17, 2011 – May 7, 2011 (28,900 cfs)	Old River at Tracy Rd. Bridge (OLD)

Similarly to the stage calibration, the biggest flow differences occur at Grantline Canal and Middle River for the same reason as noted above. Larger differences occur also at the lower end of the model, near the boundary conditions, due to tides. The tides tend to slow the flow during high tide and increase the flow during low tides.

Table 2-7 is an index for selected flow hydrograph figures developed from the model, which show the observed and simulated results for the events as Table 2-6.

The lag time between simulated and observed data for peak stage and peak flow is presented in Appendix A, Table A-5. The lag time difference for peak stage and peak flow will rarely exceed 30 minutes, which is good considering that the model uses a 15 minutes time step. The largest lag time difference is observed for peak flow and can be attributed to the accuracy of the model calibration, the accuracy of the data collected, and hydrodynamic relations between tides and flow events.

The Stage-Discharge curves for Paradise Cut Weir and San Joaquin River at Mossdale Bridge are included in LSJR and Tributaries Project Design Memorandum No. 1, San Joaquin River Levees General Design, USACE, December 23, 1955 (USACE, 1955). The Design Memorandum does not provide any background information on the development of these curves; however it is interesting to compare them to the calibration simulation results. The simulation results are fairly close to the both curves (Figure 2-4 and 2-5). The Mossdale Bridge curve indicates that the San Joaquin River flow capacity is currently greater than estimated in 1955.

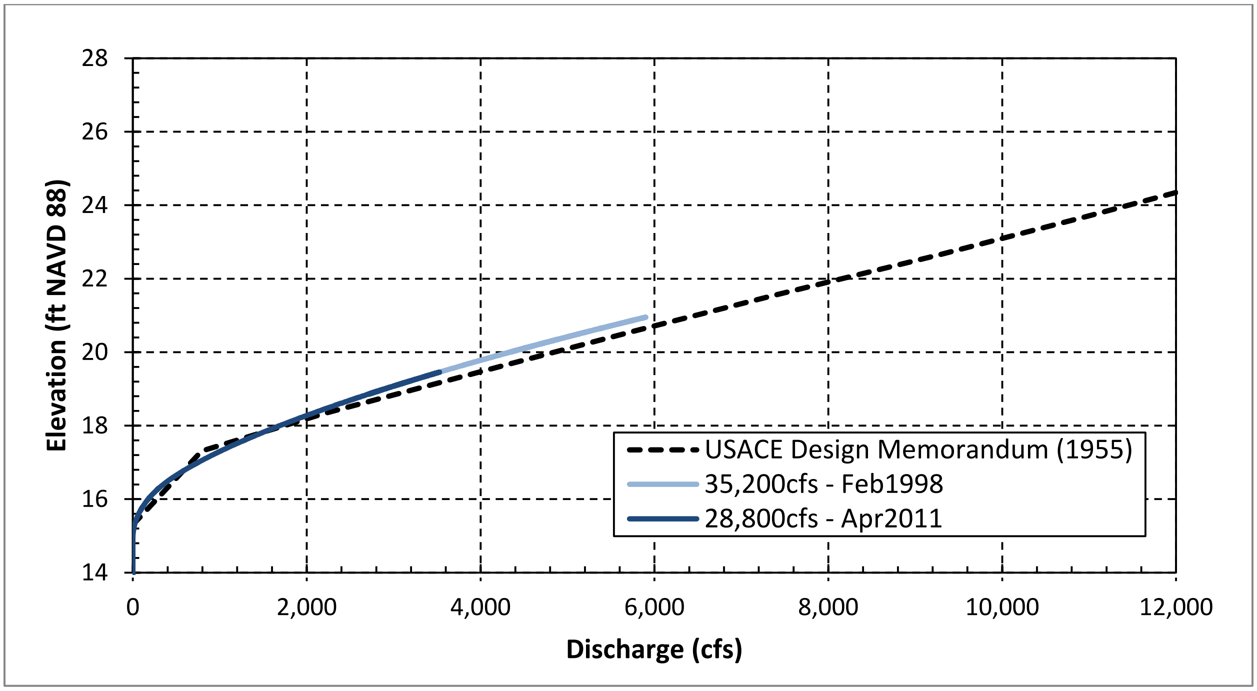


Figure 2-4. Stage-Discharge Curve at Paradise Cut Weir.

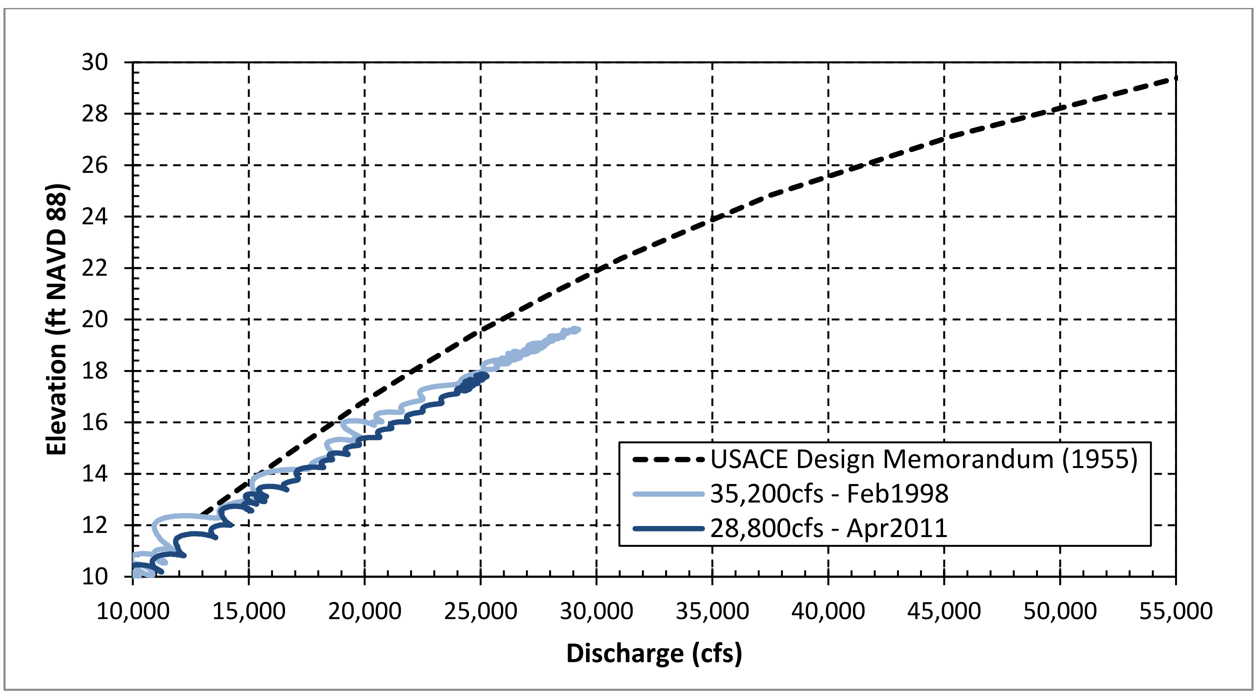


Figure 2-5. Stage-Discharge Curve at Mossdale Bridge

2.8 MODEL TESTING

Once the model was calibrated, it was important to test that the model can adequately reproduce other events. Five simulations were performed with older storms ranging from 1998 and 2006; those events are listed in the Table 2-8.

Table 2-8. Observed storm events for Model Testing

Date	Peak Flow
February 24, 2006 – March 13, 2006	12,800 cfs
May 18, 2005 – June 18, 2005	16,200 cfs
January 02, 2006 – January 21, 2006	19,800 cfs
Aril 1, 2006 – April 18, 2006	34,800 cfs
January 29, 1998 – March 03, 1998	35,200 cfs

For the older events, some index points had incomplete or missing historical observed data. Moreover, some observed data were in NGVD 29 instead of NAVD 88. The most weight should be placed on the most recent event simulations since further back in time more observed data are missing and inaccuracies are introduced from changes in the geomorphology and vegetation along the river.

While some larger differences exist between computed and observed peak stage at some locations, the computed peak stages are still fairly similar to the available observed data. The same can be said for the few index points corresponding to peak flow. The largest differences are observed during the 1998 event and are certainly due to inaccuracy in the stage observation and the calibrated model.

Table 2-9 and 2-10 lists the appendix figures for the March 3, 2006 – June 6, 2006 (34,800 cfs) event, respectively stage and peak hydrographs, developed from the calibrated model. These hydrographs show observed and simulated results for the most recent floods used for testing. This event is the second highest peak flow observed and modeled in this study.

The Table A-6 in the appendix A presents the peak stage and peak flow lag for the testing run. In general, the lag is less than 30 minutes. Significant differences can be attributed to the same reason cited in the calibration section and above

Table 2-9. Stage Hydrographs Index - March 3, 2006 – June 6, 2006 (34,800 cfs)

Figure Number	Location
Figure A-13	San Joaquin River at Mossdale (MSD)
Figure A-14	San Joaquin River near Lathrop (SJL)
Figure A-15	San Joaquin River at Brandt Bridge (BDT)
Figure A-16	Middle River at Mowry Bridge (MRU)
Figure A-17	Grantline at Tracy Rd. Bridge (GCT)
Figure A-18	Old River at Tracy Rd. Bridge (OLD)

Table 2-10. Flow Hydrographs Index - March 3, 2006 – June 6, 2006 (34,800 cfs)

Figure Number	Location
Figure A-26	San Joaquin River at Mossdale (MSD)
Figure A-27	San Joaquin River at Garwood Bridge (SJG)
Figure A-28	Head of Old River (OH1)
Figure A-29	Grantline Canal (GLC)

2.9 HYDROLOGY, SYSTEM CONFIGURATION, AND ASSUMPTIONS FOR FLOOD EVENTS

The hydrologic analysis of the study area was performed using the HEC-RAS model calibrated, described in the previous section. The hydrographs from the Comp Study which assumed no levee breaching upstream of Vernalis were used for a 10-, 25-, 50-, 100-, 200- and 500-year flood return periods. The downstream boundary conditions were determined with HEC-SSP software (Version 2.0) by using the data from Table 2-2. Table 2-11 provides peak flows at Vernalis and stage elevation for the model boundaries at various return periods.

The hydraulic model was evaluated without breaching which means that the only way that water could flow out of the system is by overtopping the levees. In reality, levees often fail before overtopping for moderate events. This no-levee breaching before overtopping assumption is generally true for floods less than the 50-year return period, but the LSJR system can be quickly overwhelmed by flood, as seen in the San Joaquin River in the 1997 flood, which was about an 85-year return period for the SJR, and 200-year return period for the Cosumnes river near the downstream boundary condition. For comparison, the Corps of Engineers wants levees to provide a 100-year protection. A 200-year flood return period protection will soon be required for urban areas by DWR (DWR, 2012a).

For this study, changes in flow and stage in Paradise Cut, downstream along the San Joaquin River and in the study area were evaluated to determine the level of flood capacity that the features (Bridges, levees, weir and channels) along the system could contain. Figure 2-6 illustrates the locations of the index points used to determine changes in flow and stage within the study area and Table 2-12 gives their descriptions. Table A-7 and A-8 in the Appendix provide flow and stage for the existing conditions.

Table 2-11. Estimated Peak Flow Rate at Vernalis and Stage Elevation for the Model Boundaries

Return Period	Estimated Flow Rate	San Joaquin River	Middle River	Grantline Canal and Old River
10-Year	35,100 cfs	9.6 ft.	9.3 ft.	9.3 ft.
25-Year	42,300 cfs	10.2 ft.	10.2 ft.	10.3 ft.
50-Year	47,700 cfs	10.7 ft.	10.8 ft.	11.1 ft.
100-Year	78,200 cfs	11.2 ft.	11.5 ft.	12.0 ft.
200-Year	124,600 cfs	11.7 ft.	12.3 ft.	13.0 ft.
500-Year	165,200 cfs	12.5 ft.	13.4 ft.	14.4 ft.

cfs = cubic feet per second; ft. = feet

Table 2-12 Flow and Stage Output Location for Analysis

Flow Output Location	Reach	XS
A. Paradise Cut Weir	SJR 26	58.54
B. Paradise Cut at UPRR Bridge	PARAD	6.74
C. San Joaquin River at Calaveras River	SJR 30	37.59
D. Old River-Grantline Canal Junction	OLD 2	30.00
Stage Output Location	**Reach**	**XS**
1. San Joaquin River Upstream of Banta-Carbona Canal	SJR 26	71.95
2. San Joaquin River Downstream of Banta-Carbona Canal	SJR 26	62.59
3. San Joaquin River upstream of UPRR Bridge	SJR 26	57.05
4. San Joaquin River at Mossdale Bridge	SJR 26	56.35
5. San Joaquin River at Old River Split	SJR 26	53.58
6. San Joaquin River Downstream of Old River Split	SJR 30	52.30
7. San Joaquin River at De Lima Road	SJR 30	49.86
8. San Joaquin River Downstream of French Camp Slough	SJR 30	42.86
9. San Joaquin River Upstream of Deep Ship Channel	SJR 30	40.40
10. San Joaquin River Upstream Calaveras River	SJR 30	38.14
11. San Joaquin River Downstream Calaveras River	SJR 30	36.94
12. Paradise Cut at west end of Stewart Tract	PARAD	1.60
13. Old River at west end of Stewart Tract	OLD 2	29.70
14. Old River Upstream of Tracy Blvd.	OLD 8	29.29
15. Grantline Canal Upstream of Tracy Blvd.	GLC	26.93
16. Middle River at Undine Road	MIDDLE	27.03
17. Middle River Upstream of HWY 4	MIDDLE	16.82

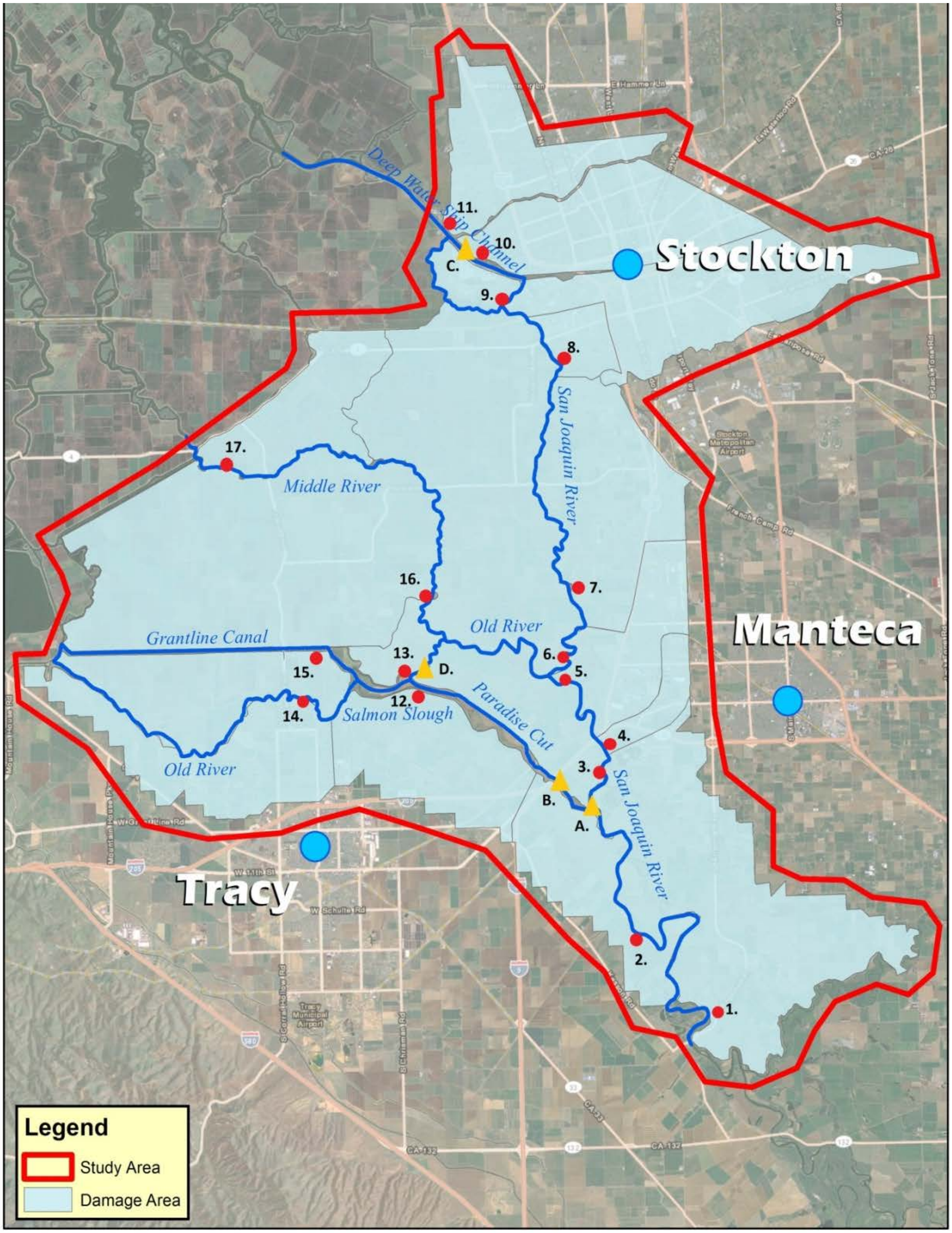


Figure 2-6. Locations of Index Points Used for the Analysis

2.10 CAPACITY OF PARADISE CUT FEATURES

The existing physical features of Paradise Cut that impacts its ability to pass flood flows include the following elements:

- Paradise Cut Weir
- Paradise Cut Levees
- Bypass/Channel
- Bridges

The following sections will describe these features and the effects on the system.

2.10.1 Paradise Cut Weir

Paradise Cut diverts excess flow from the San Joaquin River during floods to reduce downstream flood levels for urban areas along the LSJR. Inflow to Paradise Cut is regulated by Paradise Cut Weir, around River Mile 60 of the San Joaquin River. This weir is about 180 feet long with a crest elevation of 15 feet in NAVD 88. The riprap side of the weir faces downstream into Paradise Cut, while the San Joaquin River side is vegetated (see Figure 2-7). The weir is only over-topped during high-flow conditions of roughly 16,000cfs in the San Joaquin River depending on tidal conditions (DWR, 2012a).

Increasing the length or lowering the elevation of the weir would allow more high flows from the San Joaquin River into Paradise Cut.

2.10.2 Paradise Cut Levees

Paradise Cut is a narrow, linear channel bordered on both sides by State Plan of Flood Control (SPFC) levees. The height from the bed of the cut to the top of the levees is roughly 26ft. The levees along Paradise Cut are approximately 12ft high from the toe to the crest of the levee. The cut width can range from 400ft to 2000ft with a river bed which never pass 200ft. Figure 2.8 shows the locations of the SPFC levees in the study area.

Figure 2-7. Paradise Cut Weir Looking North (Photo taken December 3, 2012)

Paradise Cut levees protecting Stewart Tract and Paradise Junction have failed during previous floods. In 1997, 4,000 acres of the Stewart Tract and 3,500 acres of Paradise Junction were flooded. Historically, the levees along Paradise Cut have been susceptible to erosion, seepage, and slope instability, particularly just downstream of the weir and in the lower reaches along Pescadero District. The overall hazard classifications from DWR's Non-Urban Levee Evaluation (NULE) for Paradise Cut levees are moderate for the northern levee and high for the southern levee (DWR, 2011b). The locations of past failures, the NULE classifications, erosion sites, seepage sites, and slope instability are provided in the Appendix B, Figure B-1 to B-5 (DWR, 2013c).

Fixing levee deficiencies in place can reduce the risk of failure in future flood events. Additionally, setting levees back can replace deficient levees with modern levees and provide greater flood flow capacity.

Figure 2-8. SPFC Levees along Paradise Cut (DWR, 2012b)

2.10.3 Bypass/Channel

The design capacity of Paradise Cut is 15,000 cfs (DWR, 2011a). For illustrative purposes, simulated 100-year and 200-year flows at Paradise Cut Weir were 22,900 cfs and 25,800 cfs, respectively. For the 100-year event Paradise Cut seems to serve its purpose of conveying water out of the San Joaquin River. However levee breaching was not simulated in this model and could have happened since there was less than 1 foot of levee freeboard during this run. For the 200-year flood, the water overtopped the levees along Paradise Cut. Preliminary modeling of Paradise Cut indicates the current capacity of Paradise Cut may meet the design capacity but can be improved. From its construction, Paradise Cut has accumulated sediment with tidal influence which has certainly reduced its design capacity. Channel structures are not sufficient to protect against major flood events, as seen in the 1997 flood.

Figure 2-9 shows an area of Paradise Cut with significant sediment accumulation. Additionally, overgrown vegetated areas can reduce the capacity of Paradise Cut by increasing roughness (see Figure 2-10). Flow capacity within Paradise Cut can be increased by dredging accumulated sediment, removing or maintaining vegetation, or setting back levees.

Figure 2-9. Sediment Accumulation within Paradise Cut Reducing Bypass Capacity (Photo taken December 3, 2012)

Figure 2-10. Dense Vegetation within Paradise Cut (Photos taken December 3, 2012)

2.10.4 Paradise Cut Bridges

Several bridges cross Paradise Cut. Figure 2-11 illustrates bridge locations and Table 2-13 identifies the bridges from upstream to downstream and provides the estimated flow capacities under the bridges (existing conditions) and the owner. The flow capacity of the Railroad Bridge #1 was estimated to be 22,400 cfs which means that the stages for a 100- and 200-year flood hit the lower deck of the bridge (respectively 22,900 cfs and 25,800 cfs)

Bridges can act as chokepoints for flow. Widening the cross sections, lowering the bed of the channel or raising bridges can increase the flow capacity. Sediment can also accumulate on the upstream side of bridges when flow is slowed, further restricting flow. Removing accumulated sediment can restore the design capacity.

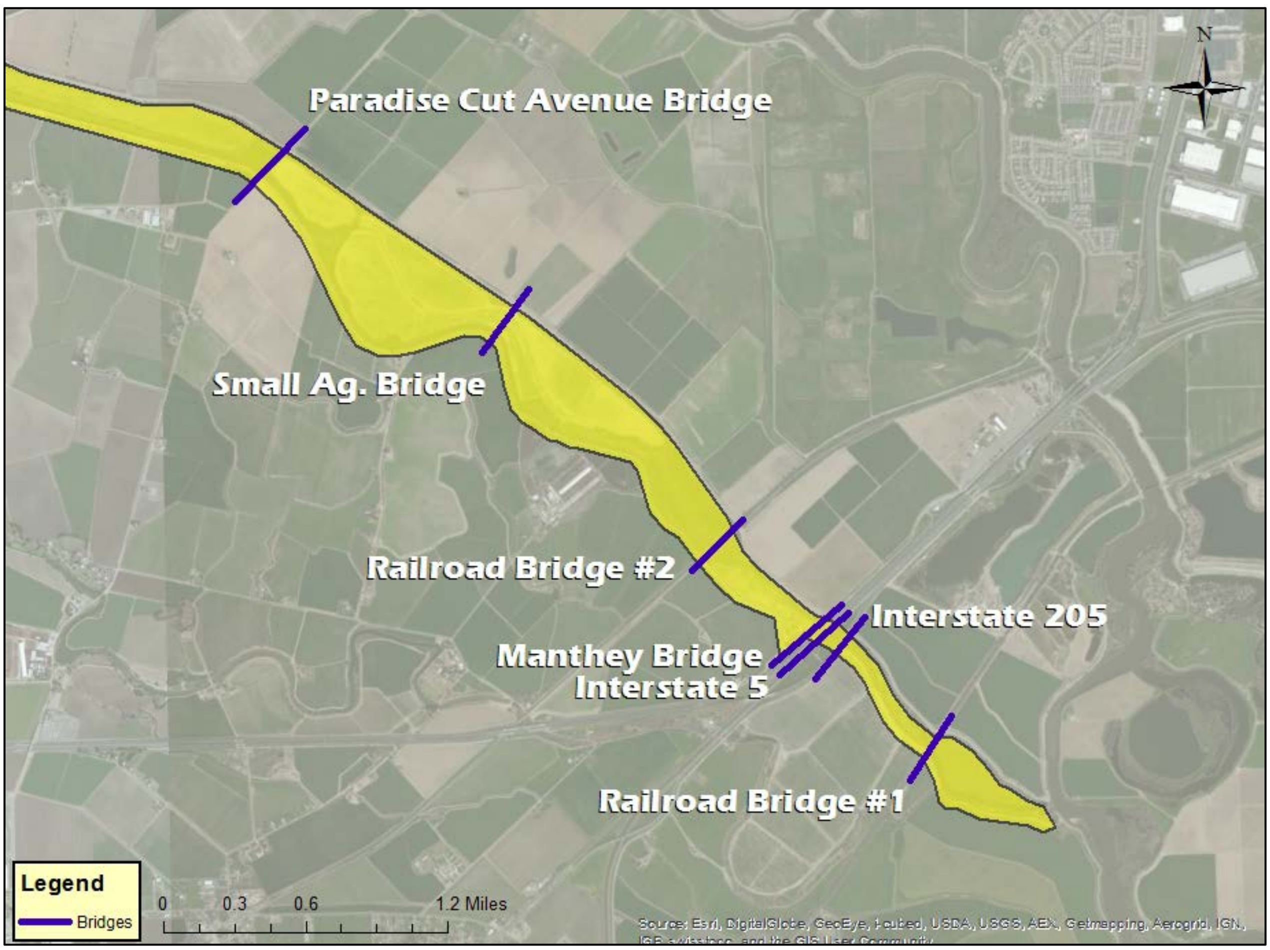


Figure 2-11. Bridge Locations within Paradise Cut

Table 2-13. Estimated Flow Capacities at Bridges

Bridge	Estimated Flow Capacity	Owner
Railroad Bridge #1	22,400 cfs	Union Pacific Railroad
Interstate 5	Not estimated (not a potential chokepoint)	State of California
Interstate 205	Not estimated (not a potential chokepoint)	State of California
Manthey Road Bridge	Not estimated (not a potential chokepoint)	San Joaquin County
Railroad Bridge #2	21,400 cfs (Section with steel deck) 29,400 cfs (Section with wood deck)	Union Pacific Railroad
Small Agricultural Bridge	29,500 cfs	N/A
Paradise Cut Avenue Bridge	31,500 cfs	N/A

cfs = cubic feet per second

TBD = to be determined

2.11 MODEL DISCUSSION

The HEC-RAS 1D model for this study was successfully calibrated and tested with flood events between 1998 and 2011 which corresponds to a range of flows at Vernalis within 1,470 cfs and 35,200 cfs.

The assumptions during the calibration phase and flood system configuration are important for the next step since they define the baseline for proposal evaluations. The most important assumptions are.

- The hydrographs set at the upstream boundary conditions are the largest computed. These hydrographs assume that no water is lost or flowing out of the system upstream of Vernalis. This assumption could generate stages higher than actual floods where breaching will likely happen upstream of Vernalis.
- Steady stages calculated for the downstream boundary conditions are a good starting point for this model. However, due to the flatness of the Delta the stage at the boundary condition might dictate were the flow should go and therefore affect the accuracy of the model results.
- Levee breaching before overtopping was ignored for this study, which would allow the water to spill out more frequently into adjacent storage areas. This assumption results in higher simulated stages than would be expected.

- The largest event used for calibration is smaller than a 50-year flood event used for the analysis. Therefore the 50-, 100-, 200- and 500-year flood events cannot be verified with tangible data and can differ depending on the accuracy of the calibration.

By incorporating these assumptions, the model results could differ from reality; nevertheless this model was calibrated with the best available data and land observation. It also used seven events for calibration and five for testing its accuracy, which is rarely done on any hydraulic model due to lack of time or/and money in the public/private world. This calibration needs to be precise since it will be used as a platform to evaluate hydraulic and economic flood risks management solutions which will add their own uncertainties.

Chapter 3

ALTERNATIVES EVALUATIONS

3.1 INTRODUCTION

The HEC-RAS model was calibrated and the baseline for the flood risk evaluation established for flood return periods of 10-, 25-, 50-, 100-, 200- and 500-year. In order to reduce flood risk in the study area, the next step was to create reasonable feature modifications along Paradise Cut as a result of the findings in section 2.10.

The following features were modified in this study:

1. Paradise Cut Weir (lengthen and/or lower weir) and some dredging
2. Overpasses/Bridges within Paradise Cut

These Paradise Cut feature modifications are described in the following subsections. The locations of Paradise Cut and its potential featuremodifications are shown on Figure 3-1.

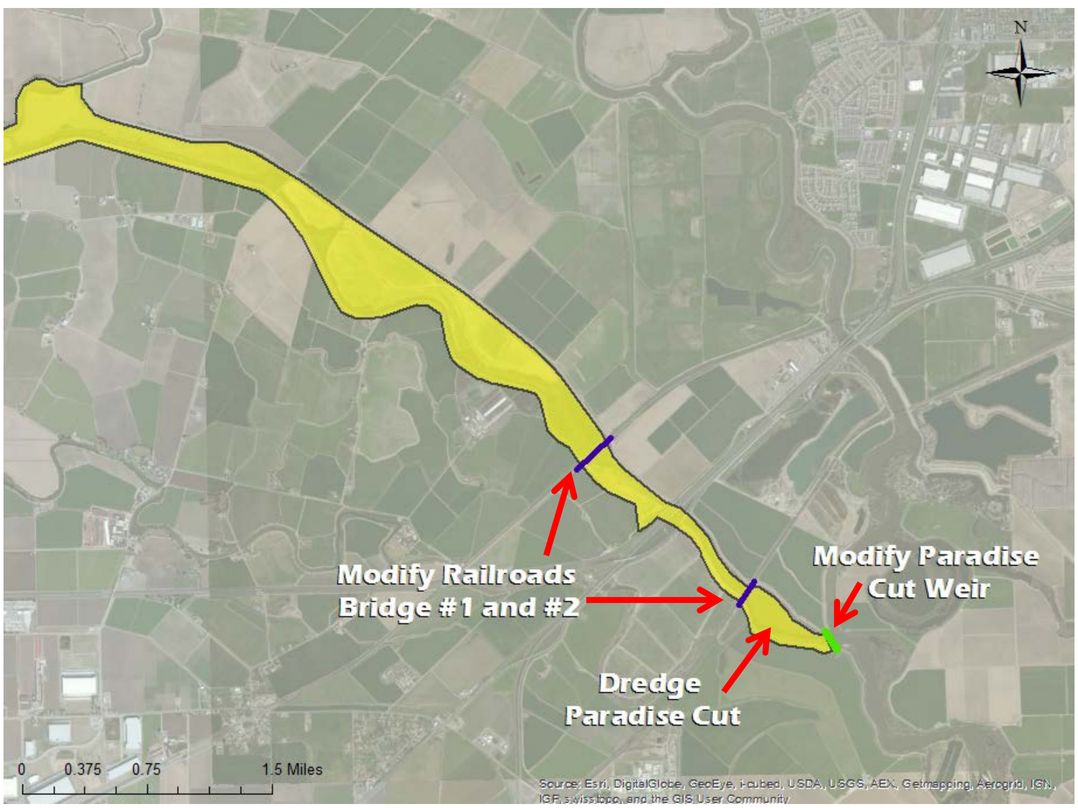


Figure 3-1. Paradise Cut System Element and Potential Feature Modifications

Once these alternatives were represented in HEC-RAS, hydraulic and economic metrics were evaluated; the hydraulic metrics evaluated are stage, flow, and out-of-system volume reduction. The economic evaluation was done in three steps: the first step was to evaluate three economic metrics: construction cost, operations and maintenance cost, and annualized total costs. Then, the expected annual damage and the inundation reduction benefits were assessed for each alternative. Finally, based on these two steps, benefit-cost ratio and net benefits results are evaluated and presented.

3.2 WEIR AND DREDGING FEATURE MODIFICATIONS

Lengthening and lowering Paradise Cut Weir would convey more flood flows through Paradise Cut, which could increase flood protection for downstream urban areas on the San Joaquin River. The following fifteen geometric modifications were created in HEC-RAS for Paradise Cut Weir. Figure 3-2 illustrates the feature modifications which required lengthening and lowering of the weir:

1. Lower Paradise Cut Weir to its as-built elevation (15ft)
2. Lower Paradise Cut Weir by 4 feet
3. Lower Paradise Cut Weir by 9 feet
4. Lower Paradise Cut Weir by 13 feet (this modification would lower the existing weir to the elevation of the sediment built up on the downstream side of the weir; therefore, no dredging is required)
5. Lower Paradise Cut Weir by 13 feet and dredge 1.5mile of the upper portion Paradise Cut (dredging is included on the downstream side of the weir to facilitate water conveyance into the cut at this elevation)
6. Widen Paradise Cut Weir by 200 feet and as built elevation
7. Widen Paradise Cut Weir by 200 feet and lower by 4 feet
8. Widen Paradise Cut Weir by 200 feet and lower by 9 feet
9. Widen Paradise Cut Weir by 200 feet and lower by 13 feet

10. Widen Paradise Cut Weir by 200 feet, lower by 13 feet, and dredge 1.5mile of upper Paradise Cut

11. Widen Paradise Cut Weir by 400 feet and as built elevation

12. Widen Paradise Cut Weir by 400 feet and lower by 4 feet

13. Widen Paradise Cut Weir by 400 feet and lower by 9 feet

14. Widen Paradise Cut Weir by 400 feet and lower by 13 feet

15. Widen Paradise Cut Weir by 400 feet, lower by 13 feet, and dredge 1.5mile of upper Paradise Cut

The maximum lengthening of the weir is limited by physical constraints. Increasing the length of the weir beyond 400 feet would require constructing new setback levees and would impact adjacent farm land. Longer weir lengths could be investigated with setback levees, but were not analyzed in this study.

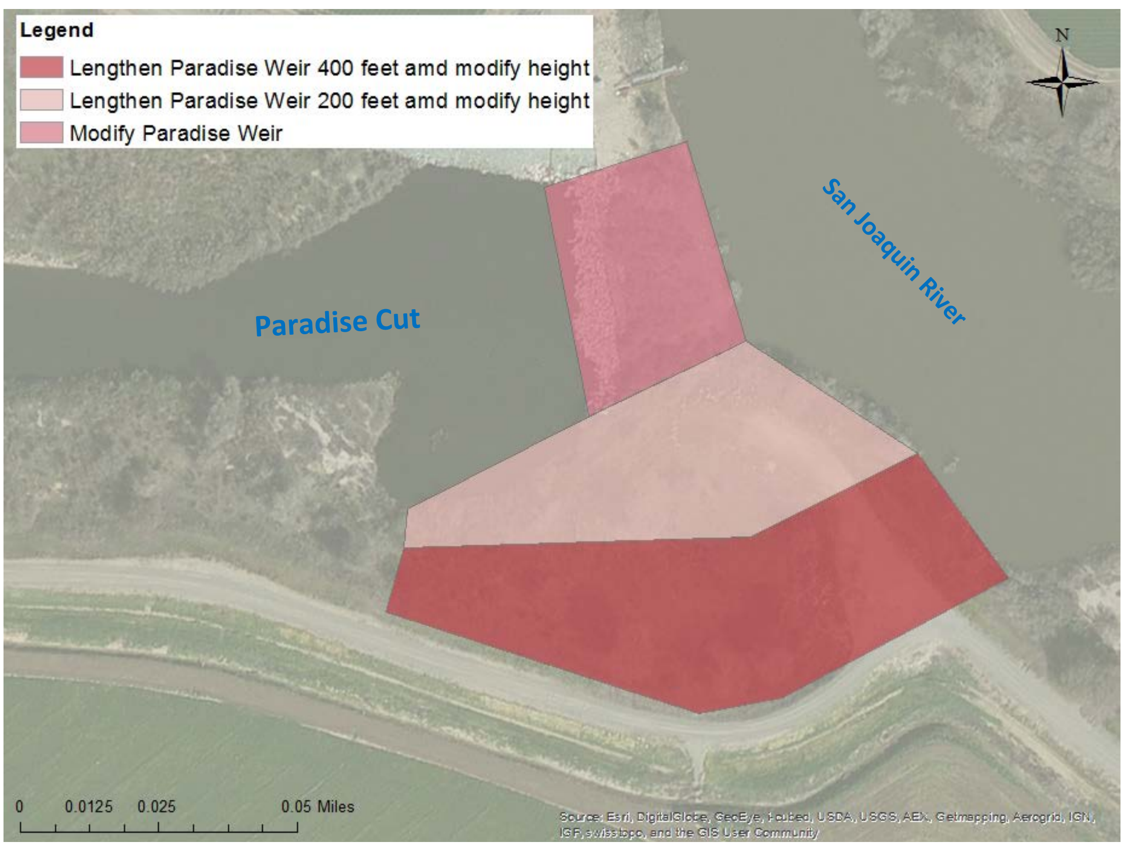


Figure 3-2. Potential Paradise Cut Weir Modifications

3.3 PARADISE CUT BRIDGES MODIFICATIONS

The *DRAFT Paradise Cut Bypass Investigation Technical Memorandum* (DWR, 2010) indicated that the UPRR bridge trestle in the Paradise Cut Bypass just upstream from Interstate-5 (herein, UPRR #1) impacts flows through Paradise Cut by impeding flows and thereby increasing flood depths upstream from the trestle. In fact, the modeling indicated the second (western) railroad bridge (UPRR #2) may have insufficient capacity for high flood flows as well as the channel itself. Interstate-5 was never impacted by high water flow in Paradise Cut. Figure 2-11 shows the location of the bridges.

The following four modifications were modeled for bridges that cross Paradise Cut:

1. Widen UPRR #1 by 400 feet
2. Raise UPRR #1
3. Widen UPRR #2 by 160 feet
4. Raise left portion of UPRR #2

Modifications 1 and 3 were designed in function of the topography of the terrain and by analyzing the cross sections at the bridges location. Figure 3-3 shows the new alignment of modifications 1 which requires setting back the levee and dredging in the channel. Figure 3-4 shows the location of dredging on the left bank of Paradise Cut at UPRR #2 (modification 3). In Appendix C, Figures B-1 to B-10 show the new cross sections design in the HEC-RAS model for these two modifications.

Modifications 2 and 4 are easy to model in HEC-RAS since the bridge can be removed from the model to represent the raising of the lower deck to remove flood stress on the bridges.

Figure 3-3. Widen UPRR #1 by 400 feet new alignment

Figure 3-4. Widen UPRR #2 by 160 feet new alignment

3.4 HYDRAULIC EVALUATION

The HEC-RAS model was used to test the effect of Paradise Cut feature modifications on flood flow and stage in the bypass, the San Joaquin River, and tributaries. Despite the limitations of a 1D hydraulic analysis with respect to the typical two-dimensional (2D) flow patterns, the 1D HEC-RAS model is able to provide important insights on the effects of modifications to Paradise Cut features throughout the study area.

Three hydraulic metrics, stage, flow, and out-of-system volume, were simulated through the South Delta HEC-RAS model and compared to characterize potential effects and benefits. The following provides a more detailed description of each hydraulic metric and its potential application in the analysis.

Hydraulic Evaluation Metric 1: Stage (water surface elevation)

A desired outcome from implementing Paradise Cut feature modifications is to reduce flood stage conditions along the main stem of the San Joaquin River downstream of the Paradise Cut weir. Reduced stages could improve system wide flood damage reduction benefits and/or reduce the frequency of SPFC facility failures.

The potential influence zone of the Paradise Cut feature modifications were determined for the 10-, 25-, 50-, 100- and 200-year Vernalis-centered storm at the 16 index points described in Table 2-12.

The change in stage between the current condition and a given feature modification was used as an indicator of levee reliability (i.e., lower stage corresponds to a lower likelihood of levee failure). Stage-frequency curves were also used in the flood damage analysis to define water surface elevations for any given return period.

Hydraulic Evaluation Metric 2: Flow

During high water events; bypass systems convey flood flows diverted from the river system. Therefore, flow is a direct measurement of the effectiveness of any bypass modification.

Based on the geographic extent of analysis, flow changes were measured for the 10-, 25-, 50-, 100- and 200-year Vernalis-centered storms at the locations described in Table 2-12

Hydraulic Evaluation Metric 3: Out-of-System Volume

One metric that can be used to account for potential realized benefits in increased protection is the reduction of out-of-system volume in the system.

Without knowing the out-of-system volume, a reduction in flow and stage at downstream locations might be interpreted as a benefit, when in actuality, there could be negative impacts if a modification increases out-of-system volume compared with the current conditions. For this study, out-of-system volumes were compared to the current conditions to determine potential benefits and impacts.

Although levee breaks can be simulated in HEC-RAS, this particular HEC-RAS model did not include simulated levee breaks that allow flood waters to leave the river channels and enter the floodplains. Therefore, the out-of-system volume should be taken with caution as a qualitative measure rather than a quantitative since it is certainly underestimated without the levee breaks.

3.4.1 Stage Results

Initial assessment of the weir modifications (with existing conditions as the basis of comparison) indicates that, as expected, weir modifications generally increase the stage in Paradise Cut, Grantline Canal and the lower portion of Old River. The stage decreases in the San Joaquin River downstream of Paradise Cut, and in Middle River. The impacts of weir modifications show stage reduction near the City of Manteca, and Lathrop up to approximately 1.5ft. However, simulations of the individual features indicate there is not a large change in stage near the City of Stockton. This can be explained for different reasons. First, the City of Stockton is located near the downstream end of the model and therefore near the boundary condition. The boundary condition was set at a fixed elevation for all alternatives; which would "pull" the result to this water surface elevation. Another cause could be that the San Joaquin

River at this location is more prone to tidal influence as explained in the calibration section than the flow in the river itself. The Deep Ship Channel which has a larger body of water and less channel bed slope than the upper portion of the San Joaquin River may restrain large stage reduction in comparison to stage reduction near the City of Manteca. Table 3-1 presents the simulated changes in stage for the 50-, 100- and 200-year flood simulated.

The alternative for the bridges which looks at the widening of Paradise Cut has a negligible stage change throughout the study area. Consequently, these alternatives were ignored for flood risk reduction purposes in the study area, but used as a mitigation solution to convey more water down to Paradise Cut.

Section 2.10.4 shows that bridges would have been impacted by flood during a 100 and 200-year flood. Table 3-2 presents the stage change for the different alternatives at UPRR #1 and #2. Modifications of the weir itself increase the impact of flood at both locations of the bridges for a 100-year flood. The bridge alternatives, which looked at widening the UPRR #1 and #2, did not help either. The dredge alternatives reduced the water elevation at UPRR#1 enough to let the water pass under the bridge without hitting the lower deck. However, these alternatives have a negative impact on UPRR #2 as they raise the stage by more than one foot at UPPRR #2.

In conclusion, raising one or both bridges is ultimately an alternative to take into consideration; as the peak stage for a 100-year flood event almost continuously impacts the lower deck of UPRR #1 and #2 no matter the feature modification.

Table 3-1. Simulated Maximum Changes in Stage as a Result of Weir Modifications (feet)

Location	Existing Weir Width, Lower Weir (13FT) & Dredging			Existing Weir Width, Lower Weir (13FT)			Existing Weir Width, Lower Weir (9FT)			Existing Weir Width, Lower Weir (4FT)			Existing Weir Width, Lower Weir (0FT)		
	50 Yr	100 Yr	200 Yr	50 Yr	100 Yr	200 Yr	50 Yr	100 Yr	200 Yr	50 Yr	100 Yr	200 Yr	50 Yr	100 Yr	200 Yr
Grantline Canal Upstream of Tracy Blvd.	0.17	0.22	-	-	0.11	-	-	0.11	-	-	-	-	-	-	-
Middle River at Undine Road	-0.36	-0.36	-0.16	-0.19	-0.14	-	-0.18	-0.13	-	-0.16	-	-	-	-	-
Middle River Upstream of HWY 4	-	-	-0.14	-	-	-	-	-	-	-	-	-	-	-	-
Old River at west end of Stewart Tract	0.23	0.27	-	0.12	0.14	-	0.12	0.13	-	0.11	-	-	-	-	-
Old River Upstream of Tracy Blvd.	0.21	0.25	-	0.11	0.13	-	-	0.12	-	-	-	-	-	-	-
Paradise Cut at west end of Stewart Tract	0.35	0.32	-	0.18	0.16	-	0.17	0.15	-	0.15	0.12	-	-	-	-
San Joaquin River Upstream of Banta-Carbona Canal	-0.21	-0.28	-	-0.12	-0.13	-	-0.11	-0.12	-	-0.10	-	-	-	-	-
San Joaquin River Downstream of Banta-Carbona Canal	-0.55	-0.61	-	-0.30	-0.27	-	-0.29	-0.25	-	-0.26	-0.20	-	-	-	-
San Joaquin River upstream of UPRR Bridge	-1.39	-1.28	-0.97	-0.73	-0.53	-0.52	-0.70	-0.49	-0.46	-0.61	-0.38	-0.31	-0.22	-0.12	-
San Joaquin River at Mossdale Bridge	-1.35	-1.25	-0.92	-0.70	-0.52	-0.49	-0.67	-0.48	-0.44	-0.59	-0.37	-0.29	-0.21	-0.11	-
San Joaquin River at Old River Split	-1.16	-1.09	-0.64	-0.61	-0.45	-0.33	-0.58	-0.42	-0.28	-0.51	-0.33	-0.19	-0.19	-	-
San Joaquin River Downstream of Old River Split	-1.14	-1.08	-0.56	-0.59	-0.44	-0.28	-0.57	-0.41	-0.24	-0.50	-0.32	-0.16	-0.18	-	-
San Joaquin River at De Lima Road	-1.06	-1.03	-0.37	-0.56	-0.43	-0.17	-0.53	-0.40	-0.15	-0.47	-0.31	-	-0.16	-	-
San Joaquin River Downstream of French Camp Slough	-0.25	-0.34	-	-0.13	-0.14	-	-0.13	-0.13	-	-0.11	-	-	-	-	-
San Joaquin River Downstream of French Camp Slough	-0.25	-0.34	-	-0.13	-0.14	-	-0.13	-0.13	-	-0.11	-	-	-	-	-
San Joaquin River Upstream of Deep Ship Channel	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
San Joaquin River Upstream Calaveras River	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
San Joaquin River Downstream Calaveras River	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table 3-1. (cont'd)

Location	Lengthen Weir (200FT), Lower Weir (13FT) & Dredging			Lengthen Weir (200FT), Lower Weir (13FT)			Lengthen Weir (200FT), Lower Weir (9FT)			Lengthen Weir (200FT), Lower Weir (4FT)			Lengthen Weir (200FT), Lower Weir (0FT)		
	50 Yr	100 Yr	200 Yr	50 Yr	100 Yr	200 Yr	50 Yr	100 Yr	200 Yr	50 Yr	100 Yr	200 Yr	50 Yr	100 Yr	200 Yr
Grantline Canal Upstream of Tracy Blvd.	0.18	0.24	-	-	0.13	-	-	0.13	-	-	0.13	-	-	0.12	-
Middle River at Undine Road	-0.37	-0.39	-0.22	-0.20	-0.17	-0.12	-0.20	-0.16	-0.12	-0.20	-0.16	-0.11	-0.18	-0.15	-
Middle River Upstream of HWY 4	-	-	-0.15	-	-	-	-	-	-	-	-	-	-	-	-
Old River at west end of Stewart Tract	0.24	0.29	-	0.13	0.16	-	0.13	0.16	-	0.13	0.15	-	0.12	0.14	-
Old River Upstream of Tracy Blvd.	0.22	0.27	-	0.11	0.15	-	0.11	0.14	-	0.11	0.14	-	-	0.13	-
Paradise Cut at west end of Stewart Tract	0.37	0.34	-	0.19	0.18	-	0.19	0.18	-	0.18	0.18	-	0.17	0.16	-
San Joaquin River Upstream of Banta-Carbona Canal	-0.21	-0.30	-	-0.12	-0.14	-	-0.12	-0.14	-	-0.12	-0.14	-	-0.11	-0.13	-
San Joaquin River Downstream of Banta-Carbona Canal	-0.58	-0.66	-0.11	-0.31	-0.30	-	-0.31	-0.30	-	-0.31	-0.29	-	-0.29	-0.27	-
San Joaquin River upstream of UPRR Bridge	-1.46	-1.40	-1.17	-0.76	-0.61	-0.69	-0.75	-0.61	-0.69	-0.75	-0.59	-0.64	-0.69	-0.54	-0.56
San Joaquin River at Mossdale Bridge	-1.42	-1.36	-1.11	-0.73	-0.59	-0.66	-0.73	-0.59	-0.65	-0.72	-0.58	-0.60	-0.67	-0.53	-0.53
San Joaquin River at Old River Split	-1.22	-1.19	-0.79	-0.63	-0.52	-0.45	-0.63	-0.52	-0.44	-0.63	-0.50	-0.41	-0.58	-0.46	-0.35
San Joaquin River Downstream of Old River Split	-1.19	-1.17	-0.70	-0.62	-0.51	-0.39	-0.62	-0.51	-0.38	-0.61	-0.49	-0.35	-0.56	-0.45	-0.30
San Joaquin River at De Lima Road	-1.11	-1.13	-0.47	-0.58	-0.49	-0.24	-0.58	-0.49	-0.24	-0.57	-0.48	-0.22	-0.53	-0.44	-0.19
San Joaquin River Downstream of French Camp Slough	-0.26	-0.36	-0.13	-0.14	-0.16	-	-0.14	-0.16	-	-0.14	-0.16	-	-0.13	-0.15	-
San Joaquin River Downstream of French Camp Slough	-0.26	-0.36	-0.13	-0.14	-0.16	-	-0.14	-0.16	-	-0.14	-0.16	-	-0.13	-0.15	-
San Joaquin River Upstream of Deep Ship Channel	-	-0.11	-	-	-	-	-	-	-	-	-	-	-	-	-
San Joaquin River Upstream Calaveras River	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
San Joaquin River Downstream Calaveras River	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table 3-1. (cont'd)

Location	Lengthen Weir (400FT), Lower Weir (13FT) & Dredging			Lengthen Weir (400FT), Lower Weir (13FT)			Lengthen Weir (400FT), Lower Weir (9FT)			Lengthen Weir (400FT), Lower Weir (4FT)			Lengthen Weir (400FT), Lower Weir (0FT)		
	50 Yr	100 Yr	200 Yr	50 Yr	100 Yr	200 Yr	50 Yr	100 Yr	200 Yr	50 Yr	100 Yr	200 Yr	50 Yr	100 Yr	200 Yr
Grantline Canal Upstream of Tracy Blvd.	0.18	0.24	-	-	0.13	-	-	0.13	-	-	0.13	-	-	0.13	-
Middle River at Undine Road	-0.37	-0.39	-0.22	-0.20	-0.17	-0.12	-0.20	-0.17	-0.12	-0.20	-0.17	-0.12	-0.20	-0.16	-0.11
Middle River Upstream of HWY 4	-	-	-0.15	-	-	-	-	-	-	-	-	-	-	-	-
Old River at west end of Stewart Tract	0.24	0.29	-	0.13	0.16	-	0.13	0.16	-	0.13	0.16	-	0.13	0.15	-
Old River Upstream of Tracy Blvd.	0.22	0.27	-	0.11	0.15	-	0.11	0.15	-	0.11	0.15	-	0.11	0.14	-
Paradise Cut at west end of Stewart Tract	0.37	0.34	-	0.19	0.18	-	0.19	0.18	-	0.19	0.18	-	0.18	0.18	-
San Joaquin River Upstream of Banta-Carbona Canal	-0.22	-0.30	-	-0.12	-0.14	-	-0.12	-0.14	-	-0.12	-0.14	-	-0.12	-0.14	-
San Joaquin River Downstream of Banta-Carbona Canal	-0.58	-0.67	-0.11	-0.31	-0.31	-	-0.31	-0.31	-	-0.31	-0.31	-	-0.31	-0.30	-
San Joaquin River upstream of UPRR Bridge	-1.47	-1.41	-1.18	-0.76	-0.62	-0.70	-0.76	-0.62	-0.70	-0.76	-0.61	-0.69	-0.74	-0.60	-0.66
San Joaquin River at Mossdale Bridge	-1.43	-1.37	-1.12	-0.74	-0.60	-0.66	-0.74	-0.60	-0.66	-0.73	-0.60	-0.66	-0.72	-0.58	-0.62
San Joaquin River at Old River Split	-1.23	-1.19	-0.80	-0.64	-0.52	-0.45	-0.64	-0.52	-0.45	-0.64	-0.52	-0.45	-0.62	-0.51	-0.42
San Joaquin River Downstream of Old River Split	-1.20	-1.18	-0.70	-0.62	-0.52	-0.39	-0.62	-0.52	-0.39	-0.62	-0.51	-0.39	-0.61	-0.50	-0.36
San Joaquin River at De Lima Road	-1.12	-1.13	-0.47	-0.58	-0.50	-0.25	-0.58	-0.50	-0.25	-0.58	-0.50	-0.24	-0.57	-0.48	-0.23
San Joaquin River Downstream of French Camp Slough	-0.26	-0.37	-0.14	-0.14	-0.17	-	-0.14	-0.17	-	-0.14	-0.17	-	-0.14	-0.16	-
San Joaquin River Downstream of French Camp Slough	-0.26	-0.37	-0.14	-0.14	-0.17	-	-0.14	-0.17	-	-0.14	-0.17	-	-0.14	-0.16	-
San Joaquin River Upstream of Deep Ship Channel	-	-0.11	-	-	-	-	-	-	-	-	-	-	-	-	-
San Joaquin River Upstream Calaveras River	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
San Joaquin River Downstream Calaveras River	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

\- = Stage change between -0.1 and 0.1 feet
UPRR = Union Pacific Railroad
Yr = year

Table 3-2. Difference between the Bridge Lower Deck and Peak Stage for a 100Yr Flood Event Depending on the Features

Features\Elevation (ft)	UPRR #1	Difference of Elevation between Lower Bridge Deck and Peak Stage	UPRR #2	Difference of Elevation between Lower Bridge Deck and Peak Stage
Bridge Deck Elevation	25.35		18.95	
Existing	25.64	0.29	19.50	0.55
Existing Weir Width, Lower Weir (13FT) & Dredging	25.05	-0.30	21.03	2.08
Existing Weir Width, Lower Weir (13FT)	26.53	1.18	19.97	1.02
Existing Weir Width, Lower Weir (9FT)	26.48	1.13	19.94	0.99
Existing Weir Width, Lower Weir (4FT)	26.31	0.96	19.85	0.90
Existing Weir Width, Lower Weir (0FT)	25.87	0.52	19.63	0.68
Lengthen Weir (200FT), Lower Weir (13FT) & Dredging	25.28	-0.07	21.30	2.35
Lengthen Weir (200FT), Lower Weir (13FT)	26.65	1.30	20.04	1.09
Lengthen Weir (200FT), Lower Weir (9FT)	26.65	1.30	20.03	1.08
Lengthen Weir (200FT), Lower Weir (4FT)	26.62	1.27	20.02	1.07
Lengthen Weir (200FT), Lower Weir (0FT)	26.55	1.20	19.98	1.03
Lengthen Weir (400FT), Lower Weir (13FT) & Dredging	25.30	-0.05	21.32	2.37
Lengthen Weir (400FT), Lower Weir (13FT)	26.66	1.31	20.04	1.09
Lengthen Weir (400FT), Lower Weir (9FT)	26.66	1.31	20.04	1.09
Lengthen Weir (400FT), Lower Weir (4FT)	26.66	1.31	20.04	1.09
Lengthen Weir (400FT), Lower Weir (0FT)	26.63	1.28	20.03	1.08
Widen UPRR #1 by 400 feet	25.71	0.36	19.51	0.56
Widen UPRR #2 by 190 feet	25.64	0.29	19.51	0.56

Note:
Green = Features that allowed to pass the 100 year event peak stage underneath the UPRR bridges without touching the bridges lower deck.

3.4.2 Flow Results

Similarly to the stage results, flow conveyance increases along Paradise Cut, and decreases along the San Joaquin River and Old River. Cleaning the weir to the as-built elevation has little effect on the flow leaving the San Joaquin River with a few hundred cfs of difference throughout the system, while dredging has a larger effect on the system. Table 3-3 presents the flow reduction for the 50-, 100- and 200-year flood.

The bridge modifications do not create noteworthy flow mitigation throughout the system and create little difference at the bridges UPRR #1 and #2 locations as depicted in Table 3-4.

Table 3-3. Simulated Changes in Flow as a Result of Weir Modifications (cubic feet per second)

Flood Event / Feature Modification	Location			
	Paradise Cut Weir	Paradise Cut at UPRR #1 Bridge	San Joaquin River at Calaveras River Confluence	Old River above Junction with Paradise Cut
50-Year				
Existing Weir Width, Lower Weir (13FT) & Dredging	4,810	4,810	-1,700	-2,912
Existing Weir Width, Lower Weir (13FT)	2,525	2,525	-902	-1,527
Existing Weir Width, Lower Weir (9FT)	2,418	2,418	-864	-1,463
Existing Weir Width, Lower Weir (4FT)	2,125	2,125	-761	-1,286
Existing Weir Width, Lower Weir (0FT)	755	755	-274	-452
Lengthen Weir (200FT), Lower Weir (13FT) & Dredging	5,050	5,047	-1,782	-3,056
Lengthen Weir (200FT), Lower Weir (13FT)	2,624	2,622	-935	-1,585
Lengthen Weir (200FT), Lower Weir (9FT)	2,617	2,615	-933	-1,581
Lengthen Weir (200FT), Lower Weir (4FT)	2,594	2,594	-925	-1,568
Lengthen Weir (200FT), Lower Weir (0FT)	2,391	2,391	-854	-1,445
Lengthen Weir (400FT), Lower Weir (13FT) & Dredging	5,081	5,079	-1,793	-3,076
Lengthen Weir (400FT), Lower Weir (13FT)	2,653	2,651	-946	-1,602
Lengthen Weir (400FT), Lower Weir (9FT)	2,649	2,647	-944	-1,600
Lengthen Weir (400FT), Lower Weir (4FT)	2,640	2,638	-941	-1,595
Lengthen Weir (400FT), Lower Weir (0FT)	2,577	2,577	-920	-1,558
Existing Weir Width, Lower Weir (13FT) & Dredging	4,810	4,810	-1,700	-2,912
100-Year				
Existing Weir Width, Lower Weir (13FT) & Dredging	5,806	5,815	-1,934	-3,399
Existing Weir Width, Lower Weir (13FT)	2,579	2,579	-809	-1,434
Existing Weir Width, Lower Weir (9FT)	2,424	2,424	-756	-1,342
Existing Weir Width, Lower Weir (4FT)	1,916	1,916	-585	-1,043
Existing Weir Width, Lower Weir (0FT)	649	649	-177	-325
Lengthen Weir (200FT), Lower Weir (13FT) & Dredging	6,293	6,298	-2,104	-3,704
Lengthen Weir (200FT), Lower Weir (13FT)	2,954	2,950	-931	-1,649
Lengthen Weir (200FT), Lower Weir (9FT)	2,942	2,938	-927	-1,643
Lengthen Weir (200FT), Lower Weir (4FT)	2,859	2,859	-901	-1,596
Lengthen Weir (200FT), Lower Weir (0FT)	2,649	2,649	-830	-1,472
Lengthen Weir (400FT), Lower Weir (13FT) & Dredging	6,324	6,332	-2,116	-3,725

Table 3-3. (cont'd)

Flood Event / Feature Modification	Location			
	Paradise Cut Weir	Paradise Cut at UPRR #1 Bridge	San Joaquin River at Calaveras River Confluence	Old River above Junction with Paradise Cut
100-Year (cont'd)				
Lengthen Weir (400FT), Lower Weir (13FT)	2,992	2,990	-945	-1,674
Lengthen Weir (400FT), Lower Weir (9FT)	2,986	2,982	-943	-1,671
Lengthen Weir (400FT), Lower Weir (4FT)	2,974	2,971	-938	-1,662
Lengthen Weir (400FT), Lower Weir (0FT)	2,902	2,902	-915	-1,621
Existing Weir Width, Lower Weir (13FT) & Dredging	5,806	5,815	-1,934	-3,399
200-Year				
Existing Weir Width, Lower Weir (13FT) & Dredging	6,341	5,493	-607	-1,753
Existing Weir Width, Lower Weir (13FT)	5,263	3,708	-282	-904
Existing Weir Width, Lower Weir (9FT)	4,657	3,216	-243	-803
Existing Weir Width, Lower Weir (4FT)	3,240	2,033	-154	-556
Existing Weir Width, Lower Weir (0FT)	778	224	-41	-154
Lengthen Weir (200FT), Lower Weir (13FT) & Dredging	7,242	6,343	-777	-2,077
Lengthen Weir (200FT), Lower Weir (13FT)	6,798	4,917	-399	-1,180
Lengthen Weir (200FT), Lower Weir (9FT)	6,753	4,881	-394	-1,169
Lengthen Weir (200FT), Lower Weir (4FT)	6,286	4,521	-360	-1,090
Lengthen Weir (200FT), Lower Weir (0FT)	5,631	4,006	-307	-965
Lengthen Weir (400FT), Lower Weir (13FT) & Dredging	7,302	6,397	-786	-2,094
Lengthen Weir (400FT), Lower Weir (13FT)	6,906	4,997	-407	-1,198
Lengthen Weir (400FT), Lower Weir (9FT)	6,894	4,989	-404	-1,192
Lengthen Weir (400FT), Lower Weir (4FT)	6,841	4,947	-399	-1,180
Lengthen Weir (400FT), Lower Weir (0FT)	6,542	4,719	-373	-1,121
Existing Weir Width, Lower Weir (13FT) & Dredging	6,341	5,493	-607	-1,753

UPRR = Union Pacific Railroad

Table 3-4. Estimated Flow Capacities at Bridges

Bridge	Existing Flow Capacity	Flow Capacity after Modification
Widen UPRR #1 by 400 feet	22,400 cfs	22,600cfs
Widen UPRR #2 by 160 feet	21,400 cfs (Section with steel deck) 29,400 cfs (Section with wood deck)	21,400 cfs (Section with steel deck) 29,500 cfs (Section with wood deck)

cfs = cubic feet per second

3.4.3 Out-of-System Volume Results

It is difficult to determine downstream impacts of Paradise Cut modifications just by observing the flow and stage at various locations along the San Joaquin River system. Uncontrolled out-of-system volume with the flooding of the storage areas in the HEC-RAS model can present this information.

To evaluate out-of-system volume, the model results were assessed from the total volume of water flooding the storage areas in the HEC-RAS. This out-of-system volume indicates that the modification of Paradise Cut does have an effect on the study area, such as reducing floods in specific areas. Tables 3-5 and 3-6 present the simulated inundated areas for the existing condition and the individual feature modifications during 50-, 100- and 200-year flood events. Appendix D shows graphically the location of the flood area and the reduction, or increase depending on the alternatives. A threshold of ±500 acre-feet was used to distinguish an improvement or worsened conditions in the study area. Figure 3-5 provides the study area identification numbers that correspond to the tables.

During a 10-Year event, SA71 (Drexler Tract) was flooding due to a low right levee height along Middle River. The weir modification for the different alternatives reduced more than 500 acre-feet of the flooding in SA71.

During a 25-Year event, SA71 floods and impacts Roberts Island by back watering SA72 due to a low connection in-between SA71 and SA72. The weir modification with dredging consistently reduces the flooding in SA72. Alternatives with a lowered and lengthened weir also reduced the flooding in SA72 except for limited cases. For example, lowering the weir by 13ft while lengthening it by 200ft does not show a reduction in flooding, while lowering the weir by 9ft and lengthening it by 200ft does. This anomaly can be explained for several reasons.

First, the magnitude of volume used in this report is ±500 acre-feet. While looking at the actual reduction by lowering the weir by 13ft and lengthening it by 200ft (~420 acre-feet) and lowering the weir by 9ft and lengthening it by 200ft (~484 acre-feet), both show a reduction of out-of-system volume, however one barely makes the cut, when the other one does not. Secondly, out-of-system volume is a very sensitive metric which is calculated with the integral of flow for every 15min, therefore lowering the weir by 13ft and lengthening it by 200ft might reduce the out-of-system volume by 500 acre-feet, but the precision used in the model does not report an accurate result.

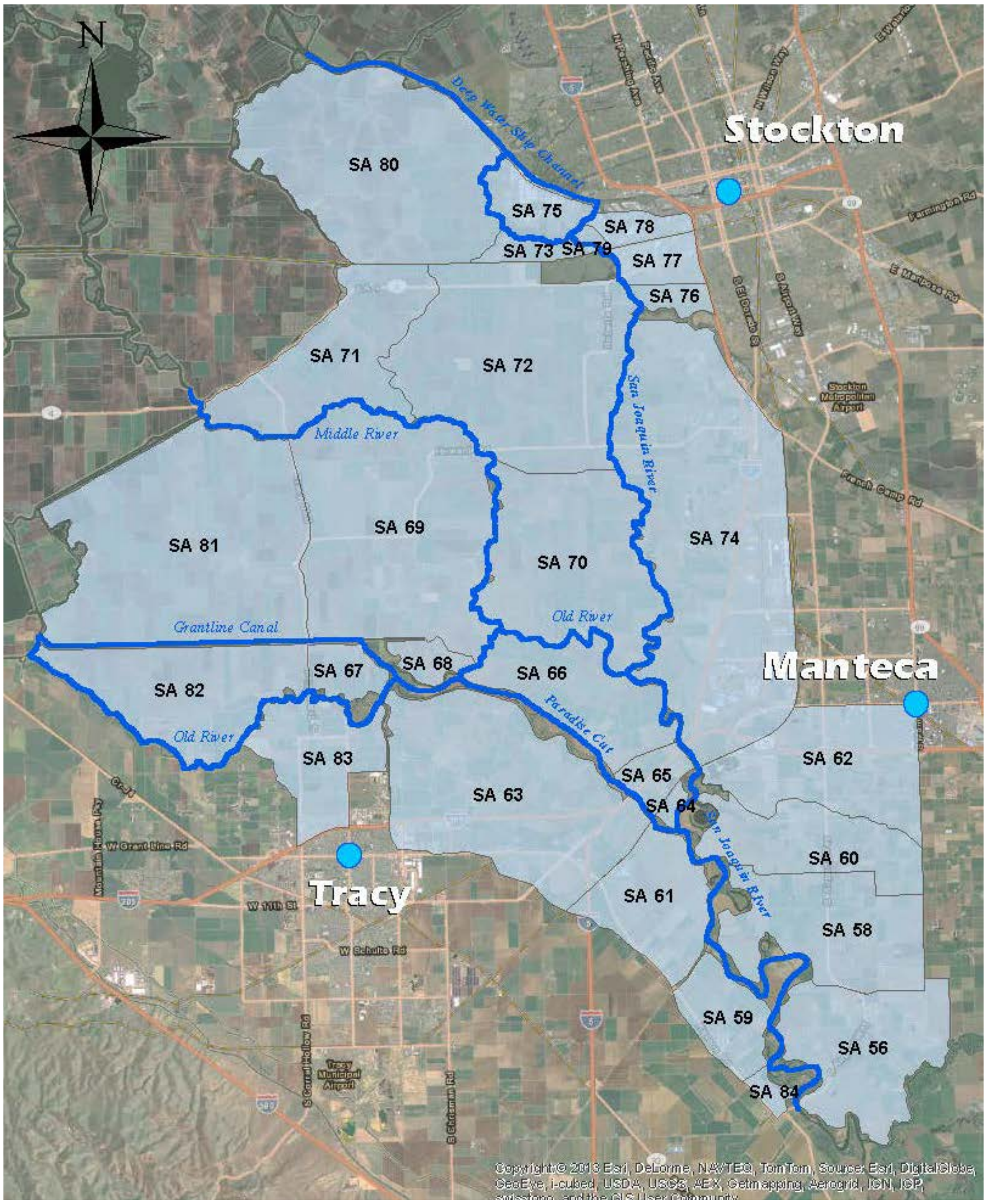


Figure 3.5 Damage Areas Location from the HEC-RAS model

Out of system volume for a 50-year flood affects SA70, 71 and 72. SA71 floods and impacts Roberts Island by back watering SA72 and then SA70 due to a low connection in-between SA71 and

SA72, and SA72 and SA70. The weir modifications did not provide an out-of-system volume reduction in the different storage areas.

The 100-year flood affects SA60, 70, 71 and 72. SA60 is flooded from the levee overtopping the right bank of the San Joaquin River near the Paradise Cut Weir. While SA70, 71 and 72 out-of-system volumes were not reduced significantly, the flooding in SA60 almost stopped for all proposed feature modifications. Weir modification without widening and small height reduction (less than 4ft) did not reduced flooding.

During the 200-year flood, the HEC-RAS model showed that SA56, 58, 59, 60, 61, 63, 64, 65, 66, 70, 71, 72 and 84 are impacted by out of system volume and the flood completely overwhelmed the system. The volume going out-of-system is concentrated in the upper portion of the San Joaquin River (SA56, 58, 59, 60, 61 and 84), along Paradise Cut (SA 61, 63, 64, 65 and 66) and near Middle River (SA 70, 71 and 72). Most flooding is from overtopping of the lateral structure or levee. SA56, 58, 59, 60, 64, 65 and 84 have been flooded from the levee adjacent to the San Joaquin River. SA61, 63, 64 and 65 are being flooded from overtopping along Paradise Cut. SA66 is flooded from the connection with SA65. SA70 and 72 are not getting flooded from backwatering from SA71, but from overtopping on the right bank of Old River and upper reach of Middle River.

It appeared that for the 200-Year flood, the dredging alternatives worked the best to reduce out-of-system volume in all the storage areas, except SA66. Also, the upper bridge widening helped greatly to reduce flooding along the left bank of Paradise Cut. Generally, the more water sent through the weir the less impact that is happening along the San Joaquin River, Old River and Middle River; and more flooding happens along Paradise Cut.

During a 500-Year flood the system is absolutely overwhelmed with the same storage areas flooding as for the 200-Year flood with the addition of SA81 (Union Island).

Table 3-5. Simulated Out-of-System Volume for a 10-, 25-, 50- and 100-Year Flood Events[a]

Conditions / Modifications	Study Area									
	10-Year Flood	25-Year Flood		50-Year Flood			100-Year Flood			
Location	SA71	SA71	SA72	SA70	SA71	SA72	SA60	SA70	SA71	SA72
Existing	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Existing Weir Width, Lower Weir (13FT) & Dredging	✓	✓	✓	✓	✓	✓		✓	✓	✓
Existing Weir Width, Lower Weir (13FT)	✓	✓	✓	✓	✓	✓		✓	✓	✓
Existing Weir Width, Lower Weir (9FT)	✓	✓	✓	✓	✓	✓		✓	✓	✓
Existing Weir Width, Lower Weir (4FT)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Existing Weir Width, Lower Weir (0FT)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Lengthen Weir (200FT), Lower Weir (13FT) & Dredging	✓	✓	✓	✓	✓	✓		✓	✓	✓
Lengthen Weir (200FT), Lower Weir (13FT)	✓	✓	✓	✓	✓	✓		✓	✓	✓
Lengthen Weir (200FT), Lower Weir (9FT)	✓	✓	✓	✓	✓	✓		✓	✓	✓
Lengthen Weir (200FT), Lower Weir (4FT)	✓	✓	✓	✓	✓	✓		✓	✓	✓
Lengthen Weir (200FT), Lower Weir (0FT)	✓	✓	✓	✓	✓	✓		✓	✓	✓
Lengthen Weir (400FT), Lower Weir (13FT) & Dredging	✓	✓	✓	✓	✓	✓		✓	✓	✓
Lengthen Weir (400FT), Lower Weir (13FT)	✓	✓	✓	✓	✓	✓		✓	✓	✓
Lengthen Weir (400FT), Lower Weir (9FT)	✓	✓	✓	✓	✓	✓		✓	✓	✓
Lengthen Weir (400FT), Lower Weir (4FT)	✓	✓	✓	✓	✓	✓		✓	✓	✓
Lengthen Weir (400FT), Lower Weir (0FT)	✓	✓	✓	✓	✓	✓		✓	✓	✓
Widen UPRR #1 by 400 feet	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Widen UPRR #2 by 190 feet	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

Note:
[a] Flooding or out-of-system flow was not indicated by simulation for study areas that are not included in this table.
Legend:
✓ = Overtopping causes out of system flow into study area
Green = Improvement, either no overtopping or decrease in out-of-system volume (≥500 acre-feet)
Red = Worsened condition, overtopping or increase in out-of-system volume (≤500 acre-feet)

Table 3-6. Simulated Out-of-System Volume for a 200-Year Event[a]

Conditions / Modifications	Study Area												
	SA56	SA58	SA59	SA60	SA61	SA63	SA64	SA65	SA66	SA70	SA71	SA72	SA84
Existing	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Existing Weir Width, Lower Weir (13FT) & Dredging	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Existing Weir Width, Lower Weir (13FT)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Existing Weir Width, Lower Weir (9FT)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Existing Weir Width, Lower Weir (4FT)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Existing Weir Width, Lower Weir (0FT)	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓
Lengthen Weir (200FT), Lower Weir (13FT) & Dredging	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Lengthen Weir (200FT), Lower Weir (13FT)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Lengthen Weir (200FT), Lower Weir (9FT)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Lengthen Weir (200FT), Lower Weir (4FT)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Lengthen Weir (200FT), Lower Weir (0FT)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Lengthen Weir (400FT), Lower Weir (13FT) & Dredging	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Lengthen Weir (400FT), Lower Weir (13FT)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Lengthen Weir (400FT), Lower Weir (9FT)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Lengthen Weir (400FT), Lower Weir (4FT)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Lengthen Weir (400FT), Lower Weir (0FT)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Widen UPRR #1 by 400 feet	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓
Widen UPRR #2 by 190 feet	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

Note:

[a] Flooding or out-of-system flow was not indicated by simulation for study areas that are not included in this table.

Legend:

✓ = Overtopping causes out of system flow into study area

Green = Improvement, either no overtopping or decrease in out-of-system volume (≥500 acre-feet)

Red = Worsened condition, overtopping or increase in out-of- system volume (≤500 acre-feet)

While levee breaching was not simulated in the HEC-RAS model, it is important to recognize that out-of-system volume upstream reduced the out-of-system volume downstream. For example, when less out-of-system volume occur in SA56, 58, 59, 61 and 84 flooding increases in SA63, 64, 65 and 66. Inversely when more out-of-system volume happens in SA56, 58, 59, 61 and 84, less flooding is experienced in SA63, 64, 65 and 66. Similar mechanisms would have been observed with breaching included in the HEC-RAS model. Out-of-system volume upstream would have increased, relieving downstream storage areas prone to flood. Levee breaching would have certainly given further relevant information on the study area; however the information presented in Table 3-5 and 3-6 are still valuable and needs to be used for mitigation along Paradise Cut for any feature modifications.

3.5 ECONOMIC EVALUATION

The economic analysis was done in three steps:

The first step was done by developing cost estimate at a reconnaissance-level for each feature modification. This cost estimate includes construction cost and operations and maintenance (O&M) cost. These two estimates were then annualized over a 50-year period with a 6% interest rate.

The next step calculated the expected annualized damage (EAD) and inundation reduction (IR) benefits for the different features of the entire study area. The EAD was calculated using flood stage results from the HEC-RAS model, levees fragility curve from the Urban Levee Program (ULE) and the Non-Urban Levee Program (NULE) and stage damage curve of the damaged area. The IR benefit was specifically defined as the value of damage prevented, that is, damage incurred without the project minus damage incurred with the project in place. For example, if a flood would produce one million dollars of damage to property in an impact area without the proposed risk-reduction features, and if that same flood would cause a $0.4 million with the new features, then the IR benefit (the damage reduced due to the project) is $0.6 million for that flood.

Finally, the last step was to evaluate the benefit-cost ratio (B/C) by taking the IR benefits of a feature modification over its construction cost and the net benefit by taking the IR benefits of a feature modification minus its construction cost. In general, a B/C ratio above one signifies that the economic benefits would be larger than the investment and is designated economically acceptable or feasible. The net benefit differentiates the set of optimal solutions by selecting the alternative which would maximize the sum of the net present values of the selected projects, subject to a capital budget constraint (Lund, 1992).

3.5.1 Reconnaissance-Level Cost Estimates

Cost estimates prepared for this study were based on costs developed for the 2012 CVFPP. The 2012 CVFPP estimates are based on 2011 price levels. The costs shown below were based on reconnaissance-level designs and remedial actions extracted from similar evaluation efforts. An appropriate level of contingency for planning efforts is included in the cost estimates. Using reconnaissance-level costs for comparison procedures is appropriate for a planning study and is an industry-wide practice. Although; reconnaissance-level costs are less accurate, adequate information is used to provide an indication (rough order of magnitude) of the final project cost and allow relative comparisons between feature options.

Cost Metric 1: Construction Costs

Following the assumptions used for the 2012 CVFPP, common flood protection elements and costs were used to estimate the costs for the Paradise Cut feature modifications. These common elements and costs were based on DWR Urban Levee Evaluation (ULE) and NULE methodology (DWR, 2011b) as shown in Tables 3-7 and 3-8. Table 3.9 presents other cost information from other sources.

Table 3-7. Common Elements – Direct Unit Costs (DWR, 2011a)

Item	Unit	Unit Cost
Excavation	cubic yard	$5
Clearing and Grubbing	Acre	$5,000
Stripping	Acre	$3,000
Waste Material	cubic yard	$4
Embankment Fill	cubic yard	$16
Fill	cubic yard	$4
Aggregate Road Base	ton	$35
Hydro-seeding	acre	$2,000
Permanent Right-of-Way[1]	acre	$17,000 ($10,000 – $300,000)[2]
Temporary Easement[1]	acre	$5,000
Unallocated Items	lump sum	5 percent
Mobilization and Demobilization	lump sum	5 percent
Environmental Mitigation[3]	lump sum	25 percent

Notes:

[1] These costs are highly variable based on location and local property values, and has a high degree of uncertainty. Generally higher values are assigned to property in urban areas and lower values are assigned to property in rural-agricultural areas.

[2] Refer to Table 4-2: Land Acquisition Costs for Bypass Expansion, Page 4-3 of the 2012 CVFPP.

[3] Assumes 25% land acquired for permanent easement could be used for environmental conservation projects.

Table 3-8. Common Elements – Indirect Unit Costs (DWR, 2011a)

Item	Indirect Unit Cost Multiplier
Escalation (to October 2011)	3 percent
Contingency	30 percent
Engineering and Design	15 percent
Permitting and Legal	5 percent
Engineering Services During Construction	2 percent
Construction Management	15 percent

Other cost considerations that were not included in ULE and NULE unit costs, include the costs for working in wet conditions (cofferdams and dewatering) and bridge modifications (railroad and vehicle), which were added to cost estimates developed for this study and are shown in Table 3-9.

For the 2012 CVFPP, unit costs were developed based on land type and levee function from other representative studies and construction projects for setback levees. Table 3-10 lists cost development assumptions for setback levees.

Table 3-9. Other Unique Elements and Unit Costs

Item	Unit	Unit Cost	Source of Information
Dewatering Extension	linear foot	$60	Sacramento Area Sewer District, 2011.
Dewatering	Lump Sum	$100,000	Department of Water Resources, 2010. Paradise Cut Bypass Investigation.
Cofferdam/River Diversion	each	$50,000	Department of Water Resources, 2010. Paradise Cut Bypass Investigation.
New Railroad Bridge Span	linear foot	$7,000	Union Pacific Railroad Employee Personal Communication (Cheney, 2013).
Demolish Railroad Bridge	linear foot	$3,500	Estimated Cost to 1/3 of New Railroad Bridge Cost (Similar to Levee).
Raise approach to Railroad Bridge	linear foot	$200	Estimated Cost of $1 million/mile.
New Riprap Placement	Cubic Yard	$50	DWR, NODOS Feasibility Study.
Temporary Removal of Riprap at Paradise Cut Weir	Cubic Yard	$12	Estimated Cost; $6 to remove and $6 to put back in place.

Table 3-10. Cost Assumptions for Setback Levees (DWR, 2011a)

Element	Cost or Percentage
Environmental, Permitting, Engineering, and Feasibility	25 percent
Right-of-Way Cost	$22,000 / acre
New Setback Levee Cost	$22.5M/Mile ($20-$25 million / mile)
Levee Removal Cost	$7.5M/Mile $5-$10 million / mile

The construction costs associated for each alternative are presented Appendix E and summarized in Table 3-12 below. The alternatives which require dredging or excavation along the channel cost more than $10 million. The one with small weir modification are much cheaper and cost in-between a few $100 thousand and a few million.

Widening or raising the railroad bridges are expensive and range from approximately $3 million to raise the UPRR#1 to $64 million in order to widen the same bridge.

Levee repair costs along Paradise Cut were also calculated to mitigate against the increased flood conveyance in the Cut. One cannot only remove the flow during large flood from the San Joaquin River and expect the levee along Paradise Cut to handle it. Otherwise, the flood impact is just transferred from one place to another.

Paradise Cut length is approximately 6 miles with levees on both sides. The total cost for the whole length will be around $84.5 million or $5.36 million annually (Kleinfelder, 2010). This value is very conservative as it assumes to fix-in-place the entire length of Paradise Cut. In the benefits cost evaluation (Section 3.5.3), two levels of levee repair are analyzed: One which assumes 50% of a repair ($42.25 million) and another which assumed full repair ($84.50 million).

Cost Metric 2: Operation and Maintenance Costs

Annual operations and maintenance (O&M) costs were estimated for all features and took into account the following quantities:

- Length of new levees
- Length of fix-in-place levees
- Length of legacy levees
- Acreage of additional channel area required
- Acreage of existing channel area

Quantities were multiplied by unit costs to arrive at yearly O&M costs. These unit costs were based on historical O&M records from USACE, DWR, and various local levee maintenance districts. O&M unit costs include inspection, reporting, vegetation removal, and minor repairs. O&M unit costs used in this analysis are presented in Table 3-11. Paradise Cut having approximately 700 acre of channel and 6 mile of levee on each side of the channel, the cost for O&M was estimated to be around $0.32 million annually. O&M for the railroad bridges modification were not calculated in this report but are likely to be small compared to the overall cost.

Table 3-11. Operations and Maintenance – Unit Costs (DWR, 2011a)

Quantity Description	Unit Cost
New & Fix-In-Place Levees (Nonurban)	$10,521 / mile-year
Legacy Levees (Nonurban)	$10,521 / mile-year
Acreage of Additional/Existing Channel Area	$281 / acre-year

Cost Metric 3: Annualized Costs

Lump sum estimated project construction costs (CCost) were annualized by assuming a constant discount rate, and solving a time value of money formula for the payment amount. The formula below was used in order to calculate the annualized construction cost (ACCost) with a discount rate (α) of 6 percent and a time period of 50-years (Y).

$$ACCost = CCost * \frac{\alpha * (1+\alpha)^{Y}}{(1+\alpha)^{y} - 1}$$

Total annual costs were calculated by summing the annualized construction costs and O&M costs and are presented in Table 3-12 and 3-13. Weir modifications are relatively cheap. Dredging and bridge alternatives increase the annual cost by one order of magnitude. This large increase of cost is in direct relation to the material movement (excavation and filling) which takes place during dredging and levee modification for the bridge features.

Table 3-12. Reconnaissance-level Weir Modification Cost Estimates

Increase in Weir Length	Decrease in Weir Elevation	Construction Cost ($ Million)	Annualized Construction Cost ($ Million/year)	O&M Costs ($ Million/year)	Total Annual Cost ($ Million/year)
0ft	0ft	0.35	0.02	0.32	0.34
0ft	4ft	0.50	0.03	0.32	0.35
0ft	9ft	1.13	0.07	0.32	0.39
0ft	13ft	1.21	0.08	0.32	0.40
0ft	13ft (dredged)	10.12	0.64	0.32	0.96
200ft	0ft	1.09	0.07	0.32	0.39
200ft	4ft	1.36	0.09	0.32	0.41
200ft	9ft	2.12	0.13	0.32	0.45
200ft	13ft	2.33	0.15	0.32	0.47
200ft	13ft (dredged)	11.05	0.70	0.32	1.02
400ft	0ft	1.81	0.11	0.32	0.43
400ft	4ft	2.71	0.17	0.32	0.49
400ft	9ft	3.11	0.20	0.32	0.52
400ft	13ft	3.41	0.22	0.32	0.54
400ft	13ft (dredged)	12.32	0.78	0.32	1.10

Notes: Values are rounded to the nearest tenth millions of dollars and are estimated

Table 3-13. Reconnaissance-Level Cost Estimates for Bridge Modifications

Bridge Modification	Construction Cost Estimated ($ Million)	Total Annual Cost Estimated ($ Million/year)
Widen UPRR #1 by 400 feet	64.38	4.08
Raise UPRR #1	12.91	0.82
Widen UPRR #2 by 160 feet	4.79	0.30
Raise UPRR #2	8.35	0.53

Note: Values are rounded to the nearest million dollars and are estimated.
Key: UPRR = Union Pacific Railroad

3.5.2 Economic Damage Evaluation

In the 2012 CVFPP, the EAD of seventeen damage areas (Figure 3-6) were evaluated in the study area. The Hydrologic Engineering Center Flood Damage Analysis software (HEC-FDA) was used to do this analysis. The HEC-FDA model combines interrelated hydrologic, hydraulic, geotechnical and economic data with uncertainties at an index points to calculate EAD. The EAD is not used to predict damages for any given year, but rather predicts the long term annualized average damage that would result from periodic flooding.

To evaluate each individual damage area can take a relatively long time, because only one damage area can be evaluated at a time for each of the features in HEC-FDA. Furthermore, this software requires to enter every piece of information (levee fragility, stage frequency,…) one entry at a time. Therefore, instead to use HEC-FDA; a spreadsheet was developed with Microsoft Excel to calculate EAD's.

The formula used in the spreadsheet to calculate EAD's is the following:

$$EAD = \int_{1}^{\infty} Pf(h(p)) * D(h(p)) * dp$$

Where, *p* = probability of flood event

Pf = probability of levee failure

h = water stage

D = Damage cost

The probability of a flood event is just the inverse of the flood event return period in a year. The probability of levee failure was collected from the CVFPP (DWR, 2011a) report and is presented for each index point associated with damage area in Appendix F. Finally, the stage results were determined from the HEC-RAS Model and presented for each index points in Appendix A for the baseline and Appendix D for the different feature modifications.

The HEC-FDA model of the LSJR was used once to determine the riverine stage-damage relationship derived from the interior-exterior stage association at an index point. This stage-damage cost relationship was determined by running the existing conditions stage results from HEC-RAS into HEC-FDA developed for the 2012 CVFPP. The HEC-FDA required the stage for the 1-, 2-, 5- and 6.67-year return period. The 2012 CVFPP used the toe of the levee to refer as the one year return period. However, especially in the delta, the toe of the levee is submerged by water all year long from low to high tide. Therefore the lowest flow run for calibration was used as the one year return period stage. The 2-, 5- and 6.67-year return period were logarithmically interpolated with the 1-, 10-, 25- and 50-year return period. These flood stage damages estimates are based on 2010 price levels.

In the CVFPP 2012, the damage areas around Stockton (STK 01, 06, 07, 08, 09, and 10) were originally evaluated from floods from the Calaveras River and the Stockton Diverting Canal and not the San Joaquin River. After closer evaluation, STK 06, 08 and 09 were removed from the analysis because there were never impacted by the San Joaquin River. STK 01 was also removed from this analysis due to its close location with the boundary conditions of the HEC-RAS model which would have result to a near no-change in the river stage for the different feature modifications. The final delineation of the damage areas evaluated in this study is presented in Figure 3-8 below.

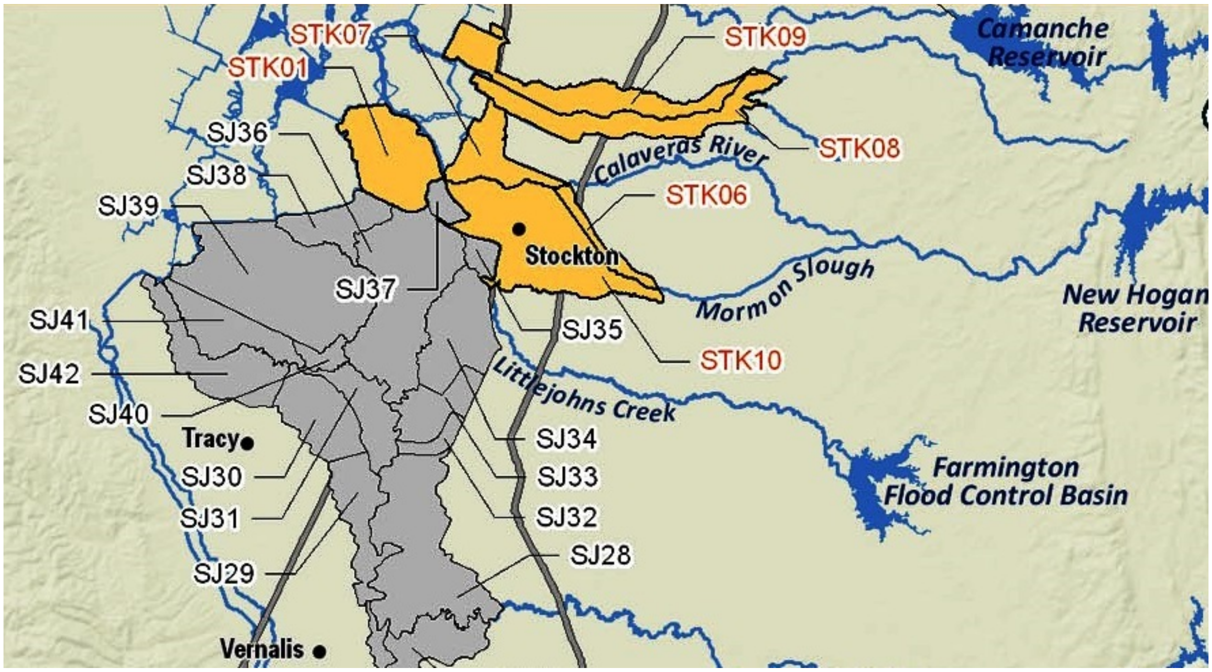


Figure 3-6. Original Damage Area in the Study Area (DWR, 2011a)

The 2012 CVFPP has one unique damage area for the City of Stockton (STK 10). The plan assumed that the flood risk was greater from the Stockton Diverting Canal situated on the East side of the city than by the San Joaquin River. The topography gradient of the valley conveys the water throughout STK 10 during a large flood as seen in the Preliminary Screening Appendix from the LSJR River Feasibility Study (SJAFCA, 2012) creating greater flood damage. However, to show flood reduction from feature modifications made along the San Joaquin River, STK 10 has been evaluated from flood arising from the San Joaquin River. The Preliminary Screening Appendix from the LSJR Feasibility Study (SJAFCA, 2012) presents the different flood sources around the Stockton area. Two of these flood sources are in Figure 3-7. One is close to index point 8 presented in Figure 3-8. In this scenario the water would enter the damage area SA 35 and pursue its path into STK 10_Up. The Stockton Deep Ship Channel being the delineation between STK 10_Up and STK 10_Down (Figure 3-8). To compute the stage damage relationship for both damage areas, the stage damage curve from each location was developed from STK 10 and then distributed by the ratio of the areas (STK 10_Up and STK 10_Down) at similar elevation. This method may not be the most accurate, but gives an estimate of the stage damage curve for STK 10_Up and STK 10_Down.

Three different damage areas do not use the actual levee fragility curve defined in the CVFPP 2012. STK 07, STK 10_Up and STK 10_Down have a different assigned index point location. STK 10_Up used the same index points than the damage area SJ 35 in consequence of the discussion above.

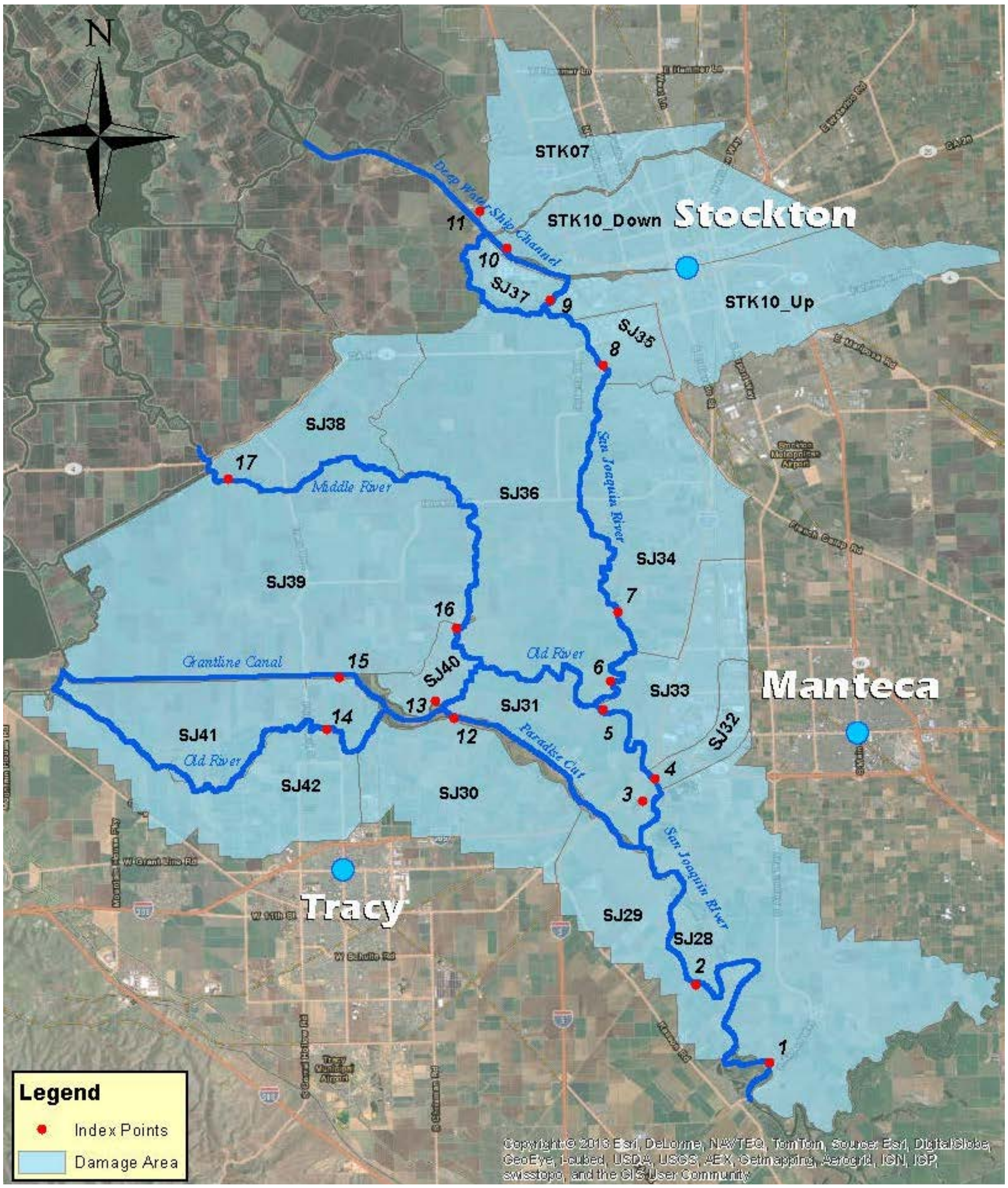


Figure 3-7. Damage Area Evaluated in the Study Area

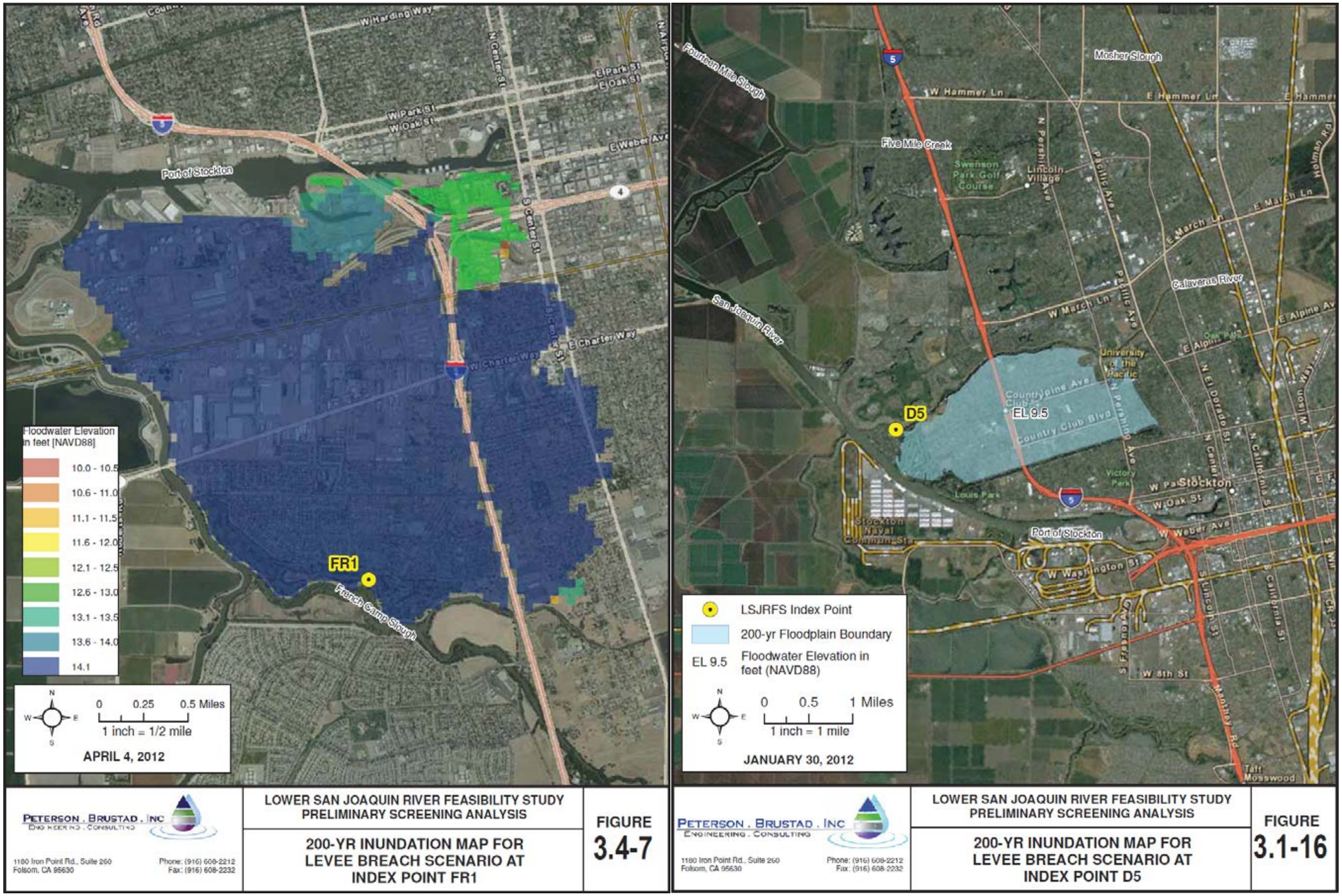


Figure 3-8. Two different flood sources in the Stockton area presented in the Preliminary Screening Appendix from the LSJR Feasibility Study (SJAFCA, 2012)

In a first effort, Point 63 and 67 from the delta fragility curve draft study developed from NULE ULE report were used respectively for STK 07 and STK 10_Down; however after evaluation it was discovered that the probability of failure at the toe of the levee was already at 15%, which would have created large EADs in the order of $10 and $100 million for these two damage areas. Without a fragility curve for these two index points, it has been decided to take the most resilient levee for similar levee size (toe-crest elevation). The levee height has a function of failure probability were plotted (Figure 3-9). Levees at STK 07 and STK 10_Down being around 10ft, the fragility curve at SJ 37 was chosen, adjusted for the top of the levee and scaled to the toe of the levee for both locations. The levee fragility curve relationships are presented in Appendix F.

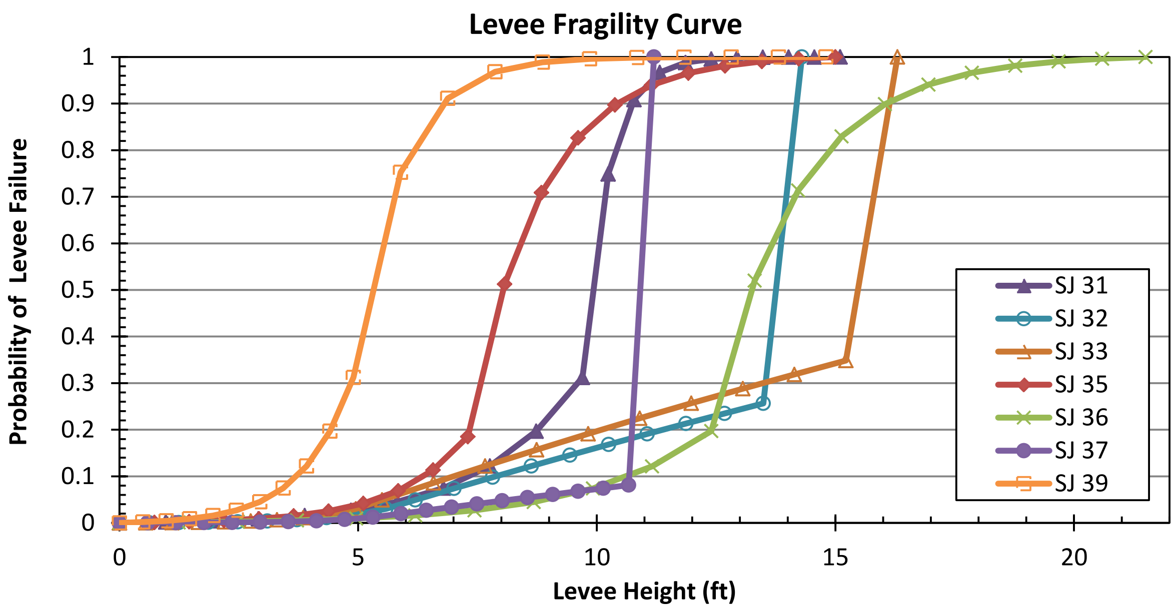


Figure 3-9. Levee Fragility Curve

Once the data are collected, the EAD can be computed. First, the probability of levee failure for each stage return period is derived by interpolation from the levee fragility curve. Then, the damage of each stage return period is derived by interpolation from the stage damage curve and multiplied by the probability of levee failure. This set of the damage cost associated with the return period creates the damage-frequency function. By integrating the function over the frequency the EAD is obtained. As used in the 2012 CVFPP, the EAD was calculated for six categories:

1. Annual business loss
2. Annual commercial damage
3. Annual crop damage
4. Annual industrial damage
5. Annual public damage
6. Annual residential damage

These categories are additive and were combined to give a total EAD. IR benefits were estimated as the reduction in flood damages as compared to the EAD calculated for the existing conditions. Table 3-14 shows the EAD by category for the existing condition in the South Delta and Figure

Approximately 70% of the total EAD is attributed to the annual residential damage. Crop has the second largest since most of the field along the Delta Channel and the LSJR are composed of agricultural field; followed by business loss and commercial loss. Public and industrial damages present less than two percent of the EAD in the study area.

The damage areas SJ 33, 35, 36, 38 and STK 07 created the most EAD. SJ 33, 35 and STK 07 larger EAD in the study area can be explained by the high density of population and therefore residency. SJ 33 is situated in the vicinity of Lathrop-Manteca while SJ 35 and STK 07 are near Stockton. SJ 36 and 38 high EAD comes from crop damage. Roberts Island (SJ 36) has a large agricultural surface area which explains the $0.97M of crop damage. SJ 38 is much smaller than Roberts Island; however the occurrence of flood in this damage area is largely due to flood overtopping the levees and weak levees.

Table 3-15 shows the IR benefits for each feature modifications. This was accomplished by first calculating the economic damages, in the form of EAD for both existing conditions, and with modification of the features. Then, the reduction in EAD or IR benefits were calculated by taking the difference between EAD at existing conditions and EAD under each feature modification.

Table 3-14. Estimated Annual Damages for the Study Area by Category and Damage Area for Existing Conditions

Damage Area	Business Loss ($ 1,000)	Commercial Damage ($ 1,000)	Crop Damage ($ 1,000)	Industrial Damage ($ 1,000)	Public Damage ($ 1,000)	Residential Damage ($ 1,000)	Total Damage ($ 1,000)
SJ28	$ 14.2	$ 0.6	$ 130.0	$ 0.5	$ 12.2	$ 77.0	$ 234.5
SJ29	$ 1.3	$ 0.0	$ 61.2	$ 1.1	$ 1.5	$ 150.8	$ 215.9
SJ30	$ 1.5	$ 0.4	$ 125.9	$ 1.5	$ 1.5	$ 18.1	$ 148.9
SJ31	$ -	$ -	$ 49.0	$ -	$ -	$ 2.7	$ 51.7
SJ32	$ 20.2	$ 6.3	$ 4.3	$ 6.9	$ 0.3	$ 1.4	$ 39.5
SJ33	$ 148.2	$ 68.2	$ 8.0	$ 19.6	$ 19.0	$ 1,701.5	$ 1,964.5
SJ34	$ 1.0	$ 2.6	$ 14.9	$ 1.8	$ 0.5	$ 71.9	$ 92.8
SJ35	$ 69.6	$ 30.1	$ 0.8	$ 28.9	$ 3.1	$ 418.6	$ 551.0
SJ36	$ 9.1	$ -	$ 970.7	$ -	$ 13.5	$ 155.2	$ 1,148.5
SJ37	$ 3.4	$ -	$ 2.2	$ 0.3	$ 0.2	$ -	$ 6.1
SJ38	$ 43.9	$ 41.6	$ 311.3	$ 1.9	$ -	$ 59.4	$ 458.1
SJ39	$ 7.4	$ -	$ 230.5	$ 2.1	$ 2.2	$ 22.1	$ 264.3
SJ40	$ -	$ -	$ 12.0	$ -	$ -	$ 9.7	$ 21.7
SJ41	$ 0.2	$ 0.1	$ 12.6	$ -	$ 0.0	$ 1.3	$ 14.2
SJ42	$ 0.4	$ 1.3	$ 15.8	$ 0.2	$ 0.7	$ 7.6	$ 26.0
STK 10_Up	$ 0.2	$ 0.3	$ 0.0	$ -	$ 1.4	$ 172.9	$ 174.8
STK 10_Down	$ 0.1	$ 0.2	$ 0.0	$ -	$ 1.0	$ 146.6	$ 148.0
STK 07	$ 21.4	$ 117.6	$ 0.1	$ 0.9	$ 62.7	$ 3,326.9	$ 3,529.7
Total	$ 341.9	$ 269.3	$ 1,949.3	$ 65.8	$120.0	$ 6,343.8	$ 9,090.2

Note:
The darker the cells are the greater the estimated annual damages.

Paradise Cut weir modifications lowered peak water surface elevations along various channels; in particular in the San Joaquin River, on the upper portion of Old River and Middle River as discussed in Section 3.4.1. Equally, it also increases water surface elevation in other ranges like Paradise Cut, the lower channel of Older River and Grant Line Canal. This increase and decrease in stage influences the IR benefits depending on the different feature modifications. The largest increases in IR benefits are from damage areas just below the weir along the San Joaquin River (SJ 33, 34, 35 and 36).

These results seem logical as Paradise Cut weir is the main feature modification in this study. At the same time, the IR benefits decrease in the damage areas below and along Paradise Cut (SJ 30, 40, 41 and 42). For the study area, the EAD was reduced (increase in IR benefits) up to $910,000 annually (see Table 3-15 and Figures in Appendix G). The smallest overall IR benefit evaluated is with the smaller weir modification and is $180,000 annually. The largest overall IR benefit was produced with the dredging alternatives on the upper portion of Paradise Cut and with a weir elevation at 2ft. Without dredging, the maximum IR benefit, approximately $607,000 annually, occurs with a weir at an elevation of 2ft and extended by 400ft. Once the Paradise Cut Weir is lowered by 9ft, the IR would only increase by 15% with any other configuration without dredging.

The damage areas close to the HEC-RAS model boundary conditions do not experience a large change in EAD and therefore IR benefits. The boundary conditions were always set at the same elevation for the different feature modifications based on the flood event. Refined information and figures can be found in Appendix G with both EAD and IR benefit results for the feature modifications.

Table 3-15. Reduction in Expected Annual Damages by Damage Area and Feature Modifications

Damage Areas	Weir 15ft	Weir 11ft	Weir 6ft	Weir 2ft	Weir 2ft Dredged	Weir 15ft 200ft	Weir 11ft 200ft	Weir 6ft 200ft	Weir 2ft 200ft	Weir 2ft 200ft Dredged	Weir 15ft 400ft	Weir 11ft 400ft	Weir 6ft 400ft	Weir 2ft 400ft	Weir 2ft 400ft Dredged
SJ 28	$1.0	$3.1	$4.0	$4.3	$8.4	$4.3	$4.6	$4.6	$4.6	$8.8	$4.6	$4.6	$4.6	$4.6	$8.8
SJ 29	$0.7	$2.3	$2.6	$2.7	$4.7	$2.6	$2.8	$2.8	$2.8	$5.0	$2.8	$2.9	$2.9	$2.9	$5.0
SJ 30	-$2.2	-$6.9	-$7.5	-$7.7	-$19.5	-$7.2	-$7.7	-$8.0	-$8.0	-$20.4	-$7.7	-$8.1	-$8.1	-$8.0	-$20.5
SJ 31	$1.5	$4.2	$4.6	$4.8	$9.2	$4.6	$4.9	$5.0	$5.0	$10.0	$4.9	$5.0	$5.0	$5.0	$10.1
SJ 32	$0.9	$3.0	$4.2	$4.6	$9.2	$4.9	$5.5	$5.8	$5.9	$10.7	$5.6	$5.9	$5.9	$6.0	$10.8
SJ 33	$109.7	$258.3	$295.6	$311.8	$468.0	$308.6	$332.1	$338.4	$340.0	$498.2	$332.9	$341.6	$342.0	$343.7	$499.5
SJ 34	$3.7	$10.2	$12.0	$12.5	$20.9	$12.6	$13.4	$13.7	$13.7	$22.8	$13.5	$13.8	$13.9	$13.9	$22.9
SJ 35	$11.2	$34.2	$41.8	$45.8	$86.5	$45.6	$51.1	$53.4	$53.4	$97.0	$51.1	$54.2	$54.2	$54.2	$100.0
SJ 36	$56.7	$148.9	$160.4	$163.5	$242.6	$157.8	$166.6	$168.1	$168.3	$250.5	$166.4	$168.8	$169.5	$169.5	$251.5
SJ 37	$0.0	$0.1	$0.1	$0.1	$0.1	$0.1	$0.1	$0.1	$0.1	$0.1	$0.1	$0.1	$0.1	$0.1	$0.1
SJ 38	$0.0	$0.1	$0.1	$0.1	$0.1	$0.1	$0.1	$0.1	$0.1	$0.2	$0.1	$0.1	$0.1	$0.1	$0.2
SJ 39	$0.8	$2.2	$2.6	$2.7	$5.2	$2.7	$2.9	$3.0	$3.0	$5.7	$2.9	$3.0	$3.0	$3.0	$5.7
SJ 40	-$0.2	-$0.7	-$0.7	-$0.8	-$1.9	-$0.7	-$0.8	-$0.8	-$0.8	-$1.9	-$0.8	-$0.8	-$0.8	-$0.8	-$1.9
SJ 41	-$0.1	-$0.3	-$0.4	-$0.4	-$1.4	-$0.3	-$0.4	-$0.4	-$0.4	-$1.4	-$0.4	-$0.4	-$0.4	-$0.4	-$1.4
SJ 42	-$0.5	-$1.3	-$1.4	-$1.5	-$5.1	-$1.4	-$1.5	-$1.5	-$1.5	-$5.1	-$1.5	-$1.5	-$1.5	-$1.5	-$5.2
STK 10_Up	$2.8	$8.6	$10.1	$10.9	$19.6	$10.6	$11.7	$11.9	$11.9	$21.3	$11.7	$12.1	$12.1	$12.1	$21.7
STK 10_Down	$0.0	-$0.2	$0.0	$0.0	$0.1	$0.0	-$0.2	$0.0	$0.0	$0.1	$0.0	$0.0	$0.0	$0.0	$0.1
STK 07	$0.0	$0.0	$2.9	$2.9	$3.5	$0.0	$2.9	$2.9	$2.9	$3.5	$0.0	$2.9	$2.9	$2.9	$3.5
Total	$186.2	$465.8	$531.0	$556.4	$850.3	$544.8	$588.2	$599.2	$601.0	$904.9	$586.3	$604.1	$605.4	$607.2	$910.7

Note:
The cells with darker color represent the greater change (±) in EADs.

3.5.3 Benefit Cost Evaluation

The benefit cost was evaluated with two different methodologies; the benefit cost ratio (B/C) and the net benefit (net B/C). The benefit cost ratio was developed by dividing the IR benefit for the different feature modifications developed in section 3.5.2 and the cost developed in section 3.5.1. When IR benefit exceeds the annualized construction cost of investment (B/C>1), the investment should be undertaken – as for every dollar invested (cost) the gain would be larger. If the IR benefit is beneath the annualized construction cost (B/C<1) then the investment should be restrained. The net benefit was developed by subtracting the IR benefits with the cost. When IR benefit exceeds the annualized construction cost of investment (net B/C>0), the investment should be undertaken. This economic indicator gives an extra piece of information that the B/C ratio cannot capture, which is the magnitude of the benefits. For example, if two alternatives come up with similar B/C ratio one would have a hard time differentiating the best alternative. The net benefits will help capture the alternative with the maximized net economic efficiency (Lund, 1992). The B/C and net B/C for the features described previously are presented in Table 3-16, 3-17 and 3-18.

Table 3-16 shows the results for the different feature modifications (weir modification and dredging). The B/C ratio ranges between 1.45 and 0.54. The net B-C ranges between -$0.12M and $0.18M. The lowest B/C ratio was for the smallest modification on the weir with just clearing and grubbing. While the cost of this alternative is small ($0.32M/Yr) the benefits are even smaller ($0.19M/Yr). The dredging alternatives created the most benefits (up to $0.91M/Yr), however they are also the most expensive (up to $1.10M/Yr) and never reach a B/C ratio above one nor a positive net B/C. Dropping the weir by 4ft and extending it by 200ft has the highest B/C ratio and net B/C from the alternatives developed in this study.

Table 3-16. Benefits Cost Ratio for Simple Feature Construction

Feature Modification	Annualized Inundation Reduction Benefits ($ Million)	Annualized Construction Cost ($ Million)	B/C Ratio	Net B/C ($ Million)
Existing Weir Width, Lower Weir (13FT) & Dredging	0.85	0.96	0.88	-0.11
Existing Weir Width, Lower Weir (13FT)	0.56	0.40	1.40	0.16
Existing Weir Width, Lower Weir (9FT)	0.53	0.39	1.36	0.14
Existing Weir Width, Lower Weir (4FT)	0.47	0.35	1.32	0.11
Existing Weir Width, Lower Weir (0FT)	0.19	0.34	0.54	-0.16
Lengthen Weir (200FT), Lower Weir (13FT) & Dredging	0.90	1.02	0.89	-0.12
Lengthen Weir (200FT), Lower Weir (13FT)	0.60	0.47	1.29	0.13
Lengthen Weir (200FT), Lower Weir (9FT)	0.60	0.45	1.32	0.14
Lengthen Weir (200FT), Lower Weir (4FT)	0.59	0.41	1.45	0.18
Lengthen Weir (200FT), Lower Weir (0FT)	0.54	0.39	1.40	0.16
Lengthen Weir (400FT), Lower Weir (13FT) & Dredging	0.91	1.10	0.83	-0.19
Lengthen Weir (400FT), Lower Weir (13FT)	0.61	0.54	1.13	0.07
Lengthen Weir (400FT), Lower Weir (9FT)	0.61	0.52	1.17	0.09
Lengthen Weir (400FT), Lower Weir (4FT)	0.60	0.49	1.23	0.11
Lengthen Weir (400FT), Lower Weir (0FT)	0.59	0.43	1.35	0.15

As shown in section 3.4.1, modifying the Paradise Cut Weir would not necessarily improve the bridge situation along the Paradise Cut. The deck for UPRR #2 was constantly hit by water during a 100Yr event and had to be raised. For UPRR #1, the dredging was able to reduce the stage enough to not hit the UPRR#1 deck. When the cost of one or both bridges raised is added to the annualized construction cost; the B/C ratio changed greatly (Table 3-17). The feature modifications with dredging were only required to raise the UPRR #2 as discussed in Section 4.3. For the other feature modifications both bridges needed to be raised. The annualized costs of the UPRR #1 and #2 were assumed to be $0.82 and $0.53 million respectively. The B/C ratio ranges from 0.11 to 0.58 and the net B/C ranges from -$1.51M and -$0.64M for the different configuration modification. The fact that dredging did not require modifications at UPRR #1 allowed it to have a B/C ratio ranging from 0.56 to 0.58 and a net B/C between -$0.64M to -$0.72M. The worst B/C ratio is for the configuration with the smallest feature modification, for this case the bridge cost increased construction cost by five times. The other feature modifications have B/C ratios between 0.11 and 0.34, and net B/C between -$1.17M and -$1.51M. Compared to the original B/C ratio and net B/C of Table 3-16, the B/C ratios in Table 3-17 never reached 1 or a net economic benefit.

Table 3-17. Benefits Cost Ratio for Simple Feature Construction with Bridge Raise

Feature Modification	Annualized Inundation Reduction Benefits ($ Million)	Annualized Construction Cost with Bridge Raise ($ Million)[a]	B/C Ratio	Net B/C ($ Million)
Existing Weir Width, Lower Weir (13FT) & Dredging	0.85	1.49	0.57	-0.64
Existing Weir Width, Lower Weir (13FT)	0.56	1.75	0.32	-1.19
Existing Weir Width, Lower Weir (9FT)	0.53	1.74	0.31	-1.21
Existing Weir Width, Lower Weir (4FT)	0.47	1.70	0.27	-1.24
Existing Weir Width, Lower Weir (0FT)	0.19	1.69	0.11	-1.51
Lengthen Weir (200FT), Lower Weir (13FT) & Dredging	0.90	1.55	0.58	-0.65
Lengthen Weir (200FT), Lower Weir (13FT)	0.60	1.82	0.33	-1.22
Lengthen Weir (200FT), Lower Weir (9FT)	0.60	1.80	0.33	-1.20
Lengthen Weir (200FT), Lower Weir (4FT)	0.59	1.76	0.34	-1.17
Lengthen Weir (200FT), Lower Weir (0FT)	0.54	1.74	0.31	-1.19
Lengthen Weir (400FT), Lower Weir (13FT) & Dredging	0.91	1.63	0.56	-0.72
Lengthen Weir (400FT), Lower Weir (13FT)	0.61	1.89	0.32	-1.28
Lengthen Weir (400FT), Lower Weir (9FT)	0.61	1.87	0.32	-1.26
Lengthen Weir (400FT), Lower Weir (4FT)	0.60	1.84	0.33	-1.24
Lengthen Weir (400FT), Lower Weir (0FT)	0.59	1.78	0.33	-1.20

Note:
[a] Dredging features only required UPRR2 to be raised, therefore $0.53M/Yr was added to the annualized construction cost. For all other features the annualized construction cost was raised by 1.35M/Yr.

A final economic analysis was examined to mitigate conveying more water along Paradise Cut. Two levels of levee repair were added in the total construction cost and the B/C ratio revaluated for both. The first levee repair considers a fixed-in-place levee over the whole Paradise Cut. The other considers half the cost of the entire levee repair. The annualized construction cost to repair the entire and half of the levee along Paradise Cut was estimated to be around $5.36M/Yr and $2.68M/Yr respectively, deduced from section 3.5.1. The net B/C ranges between a deficit of -$3.3M and -$6.9M. Table 3-18 presents the results with levee repair.

Table 3-18. Benefits Cost Ratio for Simple Feature Construction, Bridge Raise and Levee Repair

Feature Modification	Annualized Inundation Reduction Benefits ($ Million)	Annualized Construction Cost with Bridge Raise and Total Levee Repair ($ Million)	B/C Ratio	Annualized Construction Cost with Bridge Raise and Half Levee Repair ($ Million)	B/C Ratio
Existing Weir Width, Lower Weir (13FT) & Dredging	0.85	6.85	0.12	4.17	0.20
Existing Weir Width, Lower Weir (13FT)	0.56	7.11	0.08	4.43	0.13
Existing Weir Width, Lower Weir (9FT)	0.53	7.10	0.07	4.42	0.12
Existing Weir Width, Lower Weir (4FT)	0.47	7.06	0.07	4.38	0.11
Existing Weir Width, Lower Weir (0FT)	0.19	7.05	0.03	4.37	0.04
Lengthen Weir (200FT), Lower Weir (13FT) & Dredging	0.90	6.91	0.13	4.23	0.21
Lengthen Weir (200FT), Lower Weir (13FT)	0.60	7.18	0.08	4.50	0.13
Lengthen Weir (200FT), Lower Weir (9FT)	0.60	7.16	0.08	4.48	0.13
Lengthen Weir (200FT), Lower Weir (4FT)	0.59	7.12	0.08	4.44	0.13
Lengthen Weir (200FT), Lower Weir (0FT)	0.54	7.10	0.08	4.42	0.12
Lengthen Weir (400FT), Lower Weir (13FT) & Dredging	0.91	6.99	0.13	4.31	0.21
Lengthen Weir (400FT), Lower Weir (13FT)	0.61	7.25	0.08	4.57	0.13
Lengthen Weir (400FT), Lower Weir (9FT)	0.61	7.23	0.08	4.55	0.13
Lengthen Weir (400FT), Lower Weir (4FT)	0.60	7.20	0.08	4.52	0.13
Lengthen Weir (400FT), Lower Weir (0FT)	0.59	7.14	0.08	4.46	0.13

The B/C ratio for this configuration ranged from 0.03 to 0.13 for complete fix-in-place levee repair, and from 0.04 to 0.21 for half levee repair. The B/C ratios are quite low due to the very high cost of levee repair which outweighs the IR benefits. The greatest B/C ratio for both levels of levee repair results from the features which include lengthening the levee by 200ft or 400ft, lowering the weir to 2ft of elevation and dredging the first section of Paradise Cut. The IR benefits to the damage areas adjacent to Paradise Cut due to reinforcement of the levee were not considered. Only one damage area was evaluated in function of Paradise Cut (SJ 30), and its EAD without a project was evaluated to be about $150,000/Year. With levee improvements the same amount could have been attributed to IR benefits at this location. Yet, this would not have been enough to increase the B/C ratio to a reasonable level of feasibility (close to 1).

3.6 EVALUATION DISCUSSION

Fifteen feature modifications were described in a first-step, then evaluated hydraulically and economically. After evaluation; several conclusions can be drawn.

- Larger and wider weirs on Paradise Cut yield the greater stage and flow reductions along the San Joaquin River, the upper portion of Old River, and Middle River.
- Dredging the upper portion of Paradise Cut delivers more water from the San Joaquin River to Paradise Cut.
- Raising both bridges along Paradise Cut (UPRR#1 and UPRR#2) would be necessary to make sure that the water could pass underneath without touching the lower deck during a 100Yr flood event. Dredging the upper section of Paradise Cut could help convey water under UPRR#1.
- Removing water from the San Joaquin River to Paradise Cut shifts the flood impact from one storage area to another. The number of flooded areas does not necessarily decrease, but less water is getting out-of-system.
- Dredging a channel, building a new bridge or fix-in-place levees are very costly along Paradise Cut, especially when excavating.
- The EAD are principally in residential areas with exception of Roberts Island which is mainly composed of farmland.
- The greatest IR benefit is generated by the dredging alternatives, but these alternatives are also the most expensive.
- The best B/C ratios and the optimal net B/C show that the optimal solution without bridge modifications would be to lengthen the weir by 200ft and lower it by 4ft. This would be

economically feasible since for each dollar invested \$1.45 would be gained with a net gain of \$0.18M annually.

- The best B/C ratio with bridge modification would be to lengthen the weir by 200ft, lower it by 13ft and dredge the upper portion of Paradise Cut. However this solution would not be economically feasible since its B/C ratio would be 0.58. The optimal net B/C is attributed to the alternative with a weir lowered by 13ft with dredge in the upper portion of Paradise Cut, but the net B/C generate a net deficit of \$0.64M annually.
- Larger feature modifications along the Paradise Cut which would require dredging or levee repair would be too costly compared with the present IRs. Localized levee repair could be more judicious along the San Joaquin River.

The key findings were presented above, however much more information could be produced by the hydraulic and economic models.

Chapter 4

DISCUSSION – CONCLUSION

Numerous assumptions were taken throughout this study. It is important to have a good understanding of their implications and how changing them could modify the results.

Other evaluations can also be done to give insight for decision makers. For example, one could evaluate climate change impact in the study area by sea level raise or by increasing the peak flow arriving from the river upstream from Vernalis. It would also be possible to evaluate the flood return period for which the weir size should be design for by discretizing the EAD.

This section will go over the assumptions and limitations taken throughout this study; present some information concerning climate change and other important piece of information which can be retrieved from the data; and finally, present future possible directions and conclusions.

4.1 ASSUMPTIONS-LIMITATIONS

Assumptions were used throughout this study starting from the hydrology and hydraulics followed by the cost estimates to end up with the calculation of EAD, IR benefit and B/C ratio. This section reviews key assumption and presents limitations and solutions to improve future work.

4.2.1 Hydrology and hydraulics

The hydrology used for the upper boundary conditions to evaluate the flood frequency comes from the comprehensive study of 2002. This hydrology had a storm centering at Vernalis. The comprehensive study hydrology limits itself to major rivers in the Central Valley and did not account for smaller tributaries which might lead to larger floods event than expected at Vernalis. Furthermore, the comprehensive study used a composite floodplain concept which is created by designing storms based on iterative and subjective distribution of events to upstream watershed and balanced at targeted frequency curve (Ford Consultant, 2010). This might have created hydrographs which are more synthetic than realistic.

The downstream boundary conditions were created by developing a stage frequency curve from observed data. However, it does not consider both magnitudes of the tide and the frequency of the flood coming downstream. For example, if the tide ebbed at the same time as the flood peak, the peak stage would be diminished. However, if the tide is rising during a flood peak, a higher flood stage than predicted would occur.

The 1-D HEC-RAS model was calibrated and tested with relatively good success by using observed data from 1998 to recent years. However, the hydraulic model used old survey data from 1998. Since then, levees and river beds have changed and subsidence along the levee might have occurred. These geometric modifications could influence the final model accuracy. Another limitation is that the lower boundary conditions of the HEC-RAS model are not extended far enough downstream to limit the influence of the flatness and pumping in the Delta. Stage elevation at the lower end of the model might be pulled down or up depending on the stage elevation at the boundary conditions affecting the accuracy of results

The HEC-RAS model did not include breaching of levees. A levee breach could significantly affect stage and flow in the river channel adjacent to or downstream from the breach. The assumption of no levee breach decreases the possibility of out-of-system volume, since the water can only leave the system by overtopping the levee, and therefore increases the water stage elevation in the hydraulic model. The HEC-RAS model could have simulated levee breaches in the study area; however some water stage elevation at specific locations should have been adopted to trigger a levee breach. This is complicated since one cannot predict the exact location of a breach during a flood and the elevation at which the levee will fail.

4.2.2 Economics

The reconnaissance-level cost was estimated to an appropriate level for the planning study. However, they are not at a feasibility level. For example one cannot evaluate exactly the cost of environmental mitigation, construction oversight, engineering design, permitting and legal documentation and contingency, so percentages based on the construction cost were used to identify these costs. A change in these percentages can greatly influence the final cost estimate. For example changing the percentage of contingency cost to 10% instead of 30% for the feature modifications with a weir dropped to 2ft lengthen by 400ft and channel dredging would reduce the overall cost estimate by 15% or $0.12 million annually.

The cost estimates were annualized over a 50-year period and with an interest rate of 6%. 50-year is a representation of the life span of the structures (weir, bridges, and levees) evaluated in this study. These features can have a very different lifespan depending on their maintenance. The interest is also a key component of the annualized construction cost. Both variables were use in reference to the DWR standard and can influence the final results especially when evaluating the B/C ratio.

The O&M cost have a large influence on the final annualized cost. The O&M cost represents around 80% of the annualized cost for the alternative without dredging and about 30% for the feature modifications with dredging. Having visited Paradise Cut, it is hard to believe that any O&M has been recently done to the extent of the current channel area. The costs provided in Table 3-11 do not necessarily correspond to Paradise Cut but rather an overall estimate of the O&M cost in the Delta channel system. This value would again influence the B/C ratio result.

EADs were calculated by using water stage information from the HEC-RAS model and from hydrologic data for different flood return periods. As described above, the assumptions used in the model could create different outcomes in the water stage elevation leading to uncertainties in the economic model output. It is why HEC-FDA allows the user to enter standard deviation for each stage input while evaluating the EAD. The water stage elevation at an index point is not only used to evaluate the damage in a specific damage area but also the probability of failure of the levee which are both used to calculate the EAD. The stage damage curve was derived directly from HEC-FDA based on the water stage return period relationship. Therefore, a higher stage would increase both probability of failure of the levee and damage in a specific damage area and would increase the EAD results.

The B/C ratio and net B/C depends on the variables presented above and discussed through this study. Therefore, the B/C ratio and net B/C should not be taken as a hard value but rather as rough indicator. As discussed in section 3.5.3, modifying assumptions on the cost estimate affect the B/C ratio and net B/C from being to a "feasible level" (B/C ratio at 1.45, net B/C at $0.18M) to unlikely suitable (B/C ratio at 0.08, net B/C at -$0.19M for the same feature modification). Similar limitations can occur while using different assumptions from an EAD stand point. The difference in between the cost estimate and the IR benefits influence on the B/C ratio is that the annualized cost estimate is a cumulative function while an IR has an associative relationship in its computation. IR is relative from the assumption that if a hydrologic, hydraulic or economic modification was done, the EADs from both the current conditions and the feature modification configuration would change with a similar increment. Therefore, the annualized cost estimates, might have a greater effect on the B/C ratio than the IR.

Again, this study tries to give insightful and useful information to the decision makers rather than a precise solution.

4.2 FUTURE DIRECTIONS

These hydraulic and economic models could be used for other future projects. One could evaluate climate change with sea level rise at the downstream boundary conditions or with increasing of peak flow at the hydraulic model upper boundary. Another study could evaluate the effect of setback levees, levee breaching or the construction of super levee on the hydraulic and economic model. Finally ecosystem benefits could also be evaluated by modifying Manning's coefficient, increasing floodplain and investigate sediment movement along the channels.

Sections 4.3.1 and 4.3.2 present quick evaluations of climate change impacts with sea level rise and how one could focus on quick feature modifications by looking at EAD results.

4.3.1 Climate change

This section presents climate change results from sea level raise (SLR) at the downstream boundary condition of the HEC-RAS model. Two feet of SLR was added to the current conditions for each flood return period. This increase corresponds to the upper end projection of SLR for 2050 from the National Research Council report (NRC, 2012). Two different conditions were run, one at existing conditions and the other with the weir decreased in elevation by 2ft and lengthened by 200ft and Paradise Cut channel dredged.

Table 4.1 presents the water stage change at current conditions without climate change in comparison to current conditions with SLR for flood return corresponding to 50-, 100- and 200-year return periods. The impact of SLR can be observed up to Paradise Cut where the stage increased up to 0.25ft. The index points below the Paradise Cut intersection with the San Joaquin River all had higher water stages which increase towards the western Delta. The second column in Table 4-1 shows the water stage change between the feature modifications described above and conditions without climate change. The last column presents the same information with SLR. While comparing the stage differences with and without climate change for the feature modifications, the stage reduction rarely changes by more than 0.15ft. The larger change happens mostly for the 200-year flood which might be triggered by the water going out of system by overtopping the levee.

Table 4.2 and Appendix G shows the EADs for the current conditions with and without climate change, the EADs for the weir modification lengthened by 200ft, lowered by 13ft and Paradise Cut upper channel dredged with and without climate change, the EAD increase with and without climate change without project and finally the IR benefits with and without climate change.

The first observation is that the EAD increased from $9 million to $32 million for the current condition and from $8 million to $30 million for the weir modification lengthen by 200ft lowered by 13 ft & Paradise Cut upper channel dredged with and without climate change. SLR greatly influences the EAD by increasing the damage and the probability of failure of the levee. It can be observed that the EAD at the upper end of the HEC-RAS model does not change significantly (SJ 28, 29, 32). The closer to the downstream boundary conditions, the greater difference in EAD can be observed. Damage areas with the greatest assets also have the greatest change in EAD (SJ 30, SJ 33, SJ 35, SJ 36, SJ 38, STK 10_up, STK 10_down, STK 07). Damage areas near Stockton (SJ35, STK10_up, STK10_down and STK 07) are 85% of this increase in EAD.

The changed climate increases IR benefits from $0.9 million to $1.4 million when implementing the feature modification with a weir modification lengthen by 200ft lowered by 13ft & Paradise Cut upper channel dredged. The larger differences occur in SJ33, 35 and 36. These damage areas are located away from the boundary conditions which drive water stage elevation in the hydraulic model. These damage areas have more assets which drive a larger increase in IR benefits. The damage areas near the boundary conditions do not have a significant IR benefits despite large damageable assets. This is due to its close proximity with the lower boundary conditions.

In Summary climate change can greatly influence the hydraulic and economic results, and should be evaluated in making decisions for flood risk protection.

Table 4-1. Simulated Maximum Changes in Stage as a Result of Weir Modifications and Climate Change

Location	Existing Conditions with Climate Change - Existing Conditions without Climate Change			Without Climate Change Lengthen Weir (200FT), Lower Weir (13FT) & Dredging - Existing Conditions			With Climate Change Lengthen Weir (200FT), Lower Weir (13FT) & Dredging - Existing Conditions		
	50 Yr	100 Yr	200 Yr	50 Yr	100 Yr	200 Yr	50 Yr	100 Yr	200 Yr
Grantline Canal Upstream of Tracy Blvd.	1.50	1.15	1.05	0.18	0.24	-	0.14	0.21	-
Middle River at Undine Road	0.90	0.39	0.22	-0.37	-0.39	-0.22	-0.30	-0.27	-0.18
Middle River Upstream of HWY 4	2.00	2.00	1.86	-	-	-0.15	-	-	-
Old River at west end of Stewart Tract	1.22	0.88	0.79	0.24	0.29	-	0.19	0.29	0.13
Old River Upstream of Tracy Blvd.	1.51	1.11	1.00	0.22	0.27	-	0.16	0.24	0.11
Paradise Cut at west end of Stewart Tract	1.21	0.84	0.75	0.37	0.34	-	0.25	0.33	0.15
San Joaquin River Upstream of Banta-Carbona Canal	-	-	-	-0.21	-0.30	-	-0.21	-0.29	-
San Joaquin River Downstream of Banta-Carbona Canal	-	-	-	-0.58	-0.66	-0.11	-0.57	-0.66	-0.11
San Joaquin River upstream of UPRR Bridge	0.25	0.10	-	-1.46	-1.40	-1.17	-1.42	-1.34	-1.12
San Joaquin River at Mossdale Bridge	0.26	0.11	-	-1.42	-1.36	-1.11	-1.36	-1.30	-1.07
San Joaquin River at Old River Split	0.42	0.19	-	-1.22	-1.19	-0.79	-1.14	-1.10	-0.72
San Joaquin River Downstream of Old River Split	0.48	0.22	-	-1.19	-1.17	-0.70	-1.11	-1.08	-0.63
San Joaquin River at De Lima Road	0.63	0.31	-	-1.11	-1.13	-0.47	-1.00	-1.01	-0.39
San Joaquin River Downstream of French Camp Slough	1.65	1.39	1.29	-0.26	-0.36	-0.13	-0.20	-0.27	-
San Joaquin River Downstream of French Camp Slough	1.65	1.39	1.29	-0.26	-0.36	-0.13	-0.20	-0.27	-
San Joaquin River Upstream of Deep Ship Channel	1.93	1.85	1.81	-	-0.11	-	-	-	-
San Joaquin River Upstream Calaveras River	2.00	1.98	1.98	-	-	-	-	-	-
San Joaquin River Downstream Calaveras River	1.99	1.99	1.98	-	-	-	-	-	-

Table 4-2. EAD for the Study Area for Current Conditions and the Weir at 2ft, Lengthen By 200ft and Dredged With and Without Climate Change and Their Corresponding IR Benefits

Damage Area	Current Conditions EAD	Weir 2ft 200ft Dredged EAD	IR Without Climate Change	Current Conditions EAD With Climate Change	Weir 2ft 200ft Dredged EAD With Climate Change	IR Climate Change
SJ28	$ 234.5	$ 225.7	$ 8.8	$ 235.2	$ 226.4	$ 8.8
SJ29	$ 215.9	$ 210.9	$ 5.0	$ 216.5	$ 211.5	$ 5.0
SJ30	$ 148.9	$ 169.3	$ (20.4)	$ 267.2	$ 295.0	$ (27.8)
SJ31	$ 51.7	$ 41.7	$ 10.0	$ 54.8	$ 44.6	$ 10.2
SJ32	$ 39.5	$ 28.9	$ 10.7	$ 40.3	$ 29.9	$ 10.4
SJ33	$ 1,964.5	$ 1,466.4	$ 498.2	$ 2,262.1	$ 1,544.6	$ 717.4
SJ34	$ 92.8	$ 70.0	$ 22.8	$ 113.7	$ 79.8	$ 33.9
SJ35	$ 551.0	$ 454.0	$ 97.0	$ 2,640.3	$ 2,380.5	$ 259.7
SJ36	$ 1,148.5	$ 898.0	$ 250.5	$ 1,410.8	$ 1,079.3	$ 331.5
SJ37	$ 6.1	$ 5.9	$ 0.1	$ 28.3	$ 28.1	$ 0.2
SJ38	$ 458.1	$ 457.9	$ 0.2	$ 2,612.9	$ 2,612.2	$ 0.6
SJ39	$ 264.3	$ 258.6	$ 5.7	$ 284.7	$ 275.5	$ 9.2
SJ40	$ 21.7	$ 23.6	$ (1.9)	$ 36.9	$ 39.7	$ (2.8)
SJ41	$ 14.2	$ 15.6	$ (1.4)	$ 33.1	$ 36.2	$ (3.1)
SJ42	$ 26.0	$ 31.1	$ (5.1)	$ 64.4	$ 72.7	$ (8.3)
STK 10_Up	$ 174.8	$ 153.6	$ 21.3	$ 716.6	$ 668.4	$ 48.2
STK 10_Down	$ 148.0	$ 147.9	$ 0.1	$ 681.7	$ 681.2	$ 0.4
STK 07	$ 3,529.7	$ 3,526.2	$ 3.5	$19,980.5	$19,979.8	$ 0.7
Total	$ 9,090.2	$ 8,185.3	$ 904.9	$31,677.1	$30,285.4	$ 1,392.4

4.3.2 Other directions

From the previous section, potential future studies may focus on climate change. However, this is not the unique direction. One could focus on improving the hydraulic model by including levee breaching and designing more dredging in the channel, set back levees or levee improvement in the study area.

From an environmental perspective, one can investigate the benefits of sending more water down Paradise Cut. Water quality has been an issue at this location for State Water Project inflow (DWR, 2013e). Sending more water from the San Joaquin River may improve the water quality. Ecosystem improvement could also be investigated by modifying the hydraulic model and running a smaller flood event, however climate change should be taken into consideration for this kind of study since designing habitat at current conditions may prove itself unsupportive for an intended ecosystem with sea level rise creating a different ecosystem than originally designed for.

This study presented results which show limitations in feasibility due to very low B/C ratio. Therefore, it can be useful to evaluate the optimal return period to reduce flood risk to maximize the IR benefits. This can be done by breaking apart the integral presented in section 3.5.2 which calculated the EAD. For example, one could evaluate what are the best improvements to be done in a specific region. Figure 4.1 presents a breakdown of the integral for SJ 32, 33, 34 and 35 by return period. We can deduce from this figure that reducing peak stage or improving levees along these damage areas for a 50-100, 100-200 and 200-500 year flood should be prioritized to get the maximum IR benefits. The objective would be to evaluate inexpensive local solutions to reduce the peak stage for these particular flood events. This would be a short cut to bypass the hydraulic metrics evaluation and look at direct economic results.

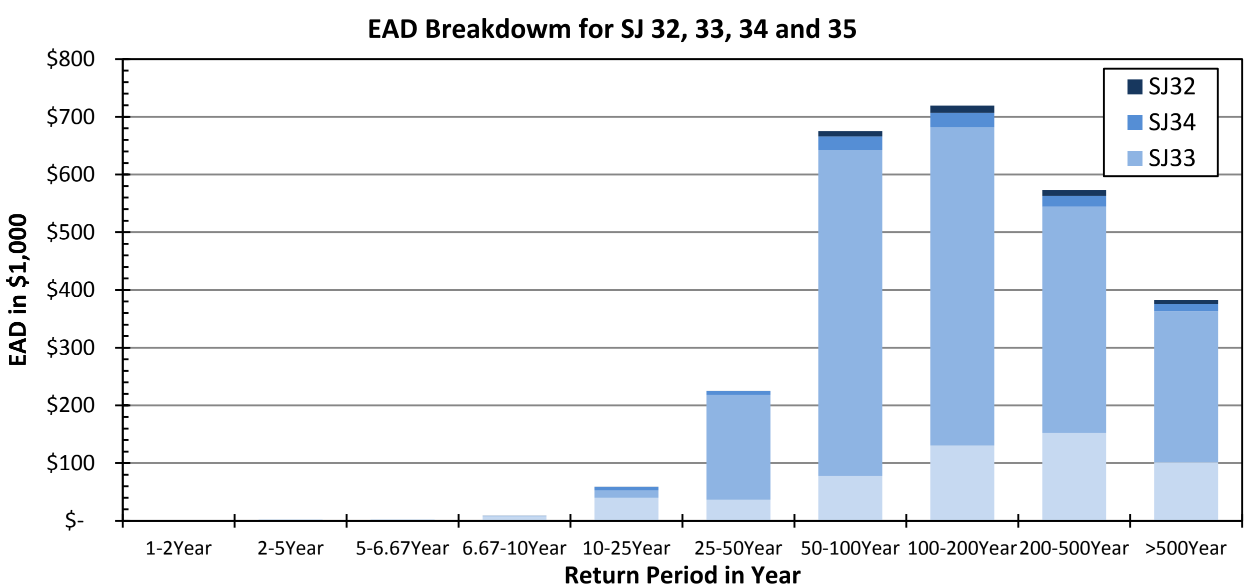


Figure 4-1. EAD Distribution Over Flood with Different Return Period for SJ 32, 33, 34 And 35.

4.3 CONCLUSION

The goal of this project was to present useful and insightful flood risk information and solutions concerning a critical location at the border between the San Joaquin Valley and the Sacramento – San Joaquin River Delta. Hydraulic and economic models were built, calibrated and evaluated for different flood events ranging from 10- to 500-year floods with different feature modifications. The metrics evaluated were hydraulic with stage, flow and out-of-system volume reduction and economic with annualized construction cost, EAD, IR benefits and B/C ratio.

Decent stage and flow reduction were observed by lowering or lengthening the weir. However, the dredging alternative proved to be the most efficient to reduce flood risk while reducing out-of-system volume in the study area. From an economic stand point, the IR benefits for dredging were also promising but end up being expensive compared to lowering or lengthening the weir. The optimal feature modification was to be lower the weir by 4ft and extend it by 200ft. The resulting B/C ratio from this feature modification is 1.45 with a net B/C of $0.18M.

Sending more water along Paradise Cut during flood events was evaluated and mitigation assessed by modifying UPRR #1 and #2, and fix-in-place levees. The dredging alternative which included lengthening the weir by 200ft and lowering it by 13ft had the best B/C ratio with 0.58. The dredging alternative which included lowering the weir by 13ft had the best net B/C with -$0.64M. B/C ratio dropped further while fixing half or the whole levees along Paradise Cut to range between 0.21 and 0.13, respectively. In this situation, environmental, water quality or other benefits might increase the B/C ratio to a feasible level of 1 or to a positive net B/C

As a final conclusion, the stage near Stockton never reached a significant level of flood reduction by modifying Paradise Cut weir. A more localized approach similar to levee repair at strategic locations or emergency response might prove itself to be more effective at reducing flood risk at this location considering approaching climate change and SLR.

REFERENCE

California Department of Water Resources (DWR), 2010. Paradise Cut Bypass Investigation. Draft. June.

_____, 2011a. 2012 Central Valley Flood Protection Plan - A Path for Improving Public Safety, Environmental Stewardship, and Long-Term Economic Stability. Sacramento, CA.

_____. 2011b. Overall Levee Conditions, Non-Urban Levee Evaluations (NULE), URS Corp., and Kleinfelder.

_____. 2012a. Urban Levee Design Criteria.

_____. 2012b. Appendix E – Lower San Joaquin River Bypass System Fact Sheet. December 31 2012.

_____. 2013a. Division of Statewide Integrated Water Management. Water Data Library. [Internet]. 2013. [cited: 2013 August]. Available at: http://www.water.ca.gov/waterdatalibrary/

_____. 2013b. Operational Hydrological Data. California Data Exchange Center. [Internet]. 2013. [cited: 2013 August]. Available at http://cdec.water.ca.gov/

_____. 2013c. Lower San Joaquin River/Delta South Region: Regional Flood Atlas-Draft.

_____. 2013d. North of Deltas Offstream Storage Feasibility Study Draft.

_____. 2013e. Comment on the Draft Substitute Environmental Document for Phase 1 of the Sab Francisco Bay/Sacramento-San Joaquin Delta Estuary Water Quality Control Plan Update. Available at http://www.waterboards.ca.gov/waterrights/water_issues/programs/hearings/baydelta_pdsed/docs/comments032913/paul_helliker.pdf

Cheney, Stephen L., 2013. Union Pacific Railroad Employee Email communication. May 8.

Ford Consultant. 2010 Hydrologic and hydraulic aspects of Corps planning/risk analysis studies: *Life after Central Valley hydrology Study.* December 1.

Kleinfelder. 2010. Geotechnical Assessment Report South NULE Study Area. Unpublished consulting report submitted to the California Department of Water Resources, Division of Flood Management. June 2011.

Lund, J.R., E. Hanak, W. Fleenor, W. Bennett, R. Howitt, J. Mount, and P. Moyle. 2008. Comparing Futures for the Sacramento-San Joaquin Delta. Public Policy Institute of California.

National Research Council (NRC), Committee on Sea Level Rise in California, Oregon, and Washington, Board on Earth Sciences and Resources and Ocean Studies Board. *Sea-Level Rise for the Coasts of California, Oregon, and Washington: Past, Present and Future*; The National Academies Press: Washington, DC, USA, 2012.

Sacramento Area Sewer District, 2011. Technical Memorandum Cost Criteria for 2010 System Capacity Plan. September 13.

San Joaquin Area Flood Control Agency (SJAFCA), 2012. Lower San Joaquin River, Preliminary Screening Appendix. Unpublished consulting report prepared by Peterson.Brustad.Inc

South Delta Water Agency. 2007. A comprehensive Flood Conveyance and Eco-System Restoration Plan for the South Delta: *A plan for Flood Control. October*

United States Army Corps of Engineers (USACE). 1955. *San Joaquin River and Tributaries Project Design Memorandum No. 1*: San Joaquin River Levees General Design.

_____. 2002. *Sacramento and San Joaquin River Basins California Comprehensive Study: Interim Report*. Prepared in coordination with the California Reclamation Board, December

United States Geological Survey (USGS), 2013a. USGS Water Data for the Nation. [Internet]. 2013. [cited: August 2013]. Available at: http://waterdata.usgs.gov/nwis

_____. 2013b USGS Water Data for the Nation Help System: Discharge Measurement Quality Code. [Internet]. 2013. [cited: August 2013]. Available at: http://waterdata.usgs.gov/usa/nwis/help?codes_help

Chapter 5

ACRONYMS AND ABBREVIATIONS

1D .... one-dimensional
2D .... two-dimensional
B/C ratio .... Benefit cost ratio
cfs .... cubic feet per second
Comp Study .... Sacramento and San Joaquin River Comprehensive Study
CVFED................................. Central Valley Flood Evaluation and Delineation
CVFPP .... Central Valley Flood Protection Plan
CVHS .... Central Valley Hydrology Study
CVP...................................... Central Valley Project
Delta..................................... Sacramento-San Joaquin River Delta
DWR .... California Department of Water Resources
EAD...................................... Expected Annual Damage
ft .... foot, feet
HEC-FDA .... Hydrologic Engineering Center's Flood Damage Reduction Analysis
HEC-RAS............................. Hydrologic Engineering Center’s River Analysis System 1-D Model
LIDAR .... Laser Interferometry Detection and Ranging
LSJR .... Lower San Joaquin River
NAD83 .... North American Horizontal Datum of 1983
NAVD88 .... North American Vertical Datum of 1988
Net B/C .... Net benefit cost
NGVD29............................... National Geodetic Vertical Datum of 1929
NULE .... Non-Urban Levee Evaluation
O&M..................................... operations and maintenance
PC .... Paradise Cut
RD.. Reclamation District
SLR .... Sea Level Rise
SPFC .... State Plan of Flood Control
State..................................... State of California
SWP .... State Water Project
TAF .... thousand acre-feet

ULE .... Urban Levee Evaluation

UNET .... A one-dimensional hydraulic computer model that simulates unsteady flow through a full network of open channels, weirs, bypasses, and storage areas; used by the Comprehensive Study to simulate the riverine channels of the Sacramento and San Joaquin basins

UPRR .... Union Pacific Railroad

USACE .... U.S. Army Corps of Engineers

USBR .... U.S. Bureau of Reclamation

USGS .... U.S. Geological Survey

APPENDIX

Appendix A – Calibration Results

The Following tables present the results of the calibration and testing of the HEC-RAS model

Table A-1 Calibration Results		Upper SJ River	Lower SJ River				Upper Old River	Middle River			Grantline Canal			Lower Old River		
Peak Flow @ Vernalis	**Station**	**MSD**	**SJL**	**BDT**	**SJG**	**RRI**	**OH1**	**MRU**	**MHR**	**MTB**	**DGL**	**GCT**	**GLC**	**OLD-OLR**	**OAD - ODM**	**OBD**
	XS	**SJR 26 56.112**	**SJR 30 52.95**	**SJR 30 47.32**	**SJR 30 41.5**	**SJR 30 37.93**	**OLD 1 35.23**	**MIDDLE 27.025**	**MIDDLE 23.195**	**MIDDLE 18.117**	**GLC 27.518**	**GLC 26.071**	**GLC 0.09**	**OLD 10 28.683**	**OLD 10 1.735757**	**OLD 10 1.565757**
	Indicator	**Stage (ft.)**	**Stage (ft.)**	**Stage (ft.)**	**Stage (ft.)**	**Stage (ft.)**	**Stage (ft.)**	**Stage (ft.)**	**Stage (ft.)**	**Stage (ft.)**	**Stage (ft.)**	**Stage (ft.)**	**Stage (ft.)**	**Stage (ft.)**	**Stage (ft.)**	**Stage (ft.)**
1,470cfs	**Observed**	**6.76**	**6.65**	**6.93**	**6.89**	**7.06**	**6.63**	**6.82**	**6.73**	**6.77**	**6.44**	**6.70**	**6.71**	**6.63**	**6.42**	**6.42**
Jan. - Feb.	**Modeled**	**6.80**	**6.72**	**6.90**	**7.14**	**7.17**	**6.72**	**6.67**	**6.69**	**6.70**	**6.55**	**6.50**	**6.41**	**6.57**	**6.40**	**6.40**
2010	**Difference**	**0.04**	**0.07**	**-0.03**	**0.25**	**0.11**	**0.09**	**-0.15**	**-0.04**	**-0.07**	**0.11**	**-0.20**	**-0.30**	**-0.06**	**-0.02**	**-0.02**
4,200cfs	**Observed**	**7.58**	**7.39**	**7.54**	**7.42**	**7.48**	**7.34**	**7.41**	**7.26**	**7.20**	**7.17**	**7.28**	**6.99**	**7.21**	**6.95**	**6.95**
Jan. - Feb.	**Modeled**	**7.69**	**7.54**	**7.50**	**7.60**	**7.60**	**7.51**	**7.27**	**7.20**	**7.15**	**7.13**	**7.08**	**6.91**	**7.14**	**6.95**	**6.94**
2010	**Difference**	**0.11**	**0.15**	**-0.04**	**0.18**	**0.12**	**0.17**	**-0.14**	**-0.06**	**-0.05**	**-0.04**	**-0.20**	**-0.08**	**-0.07**	**0.00**	**-0.01**
5,010cfs	**Observed**	**7.26**	**7.08**	**7.26**	**7.10**	**7.22**	**7.02**	**7.05**	**6.88**	**6.85**	**6.68**	**6.90**	**6.61**	**6.85**	**6.55**	**6.56**
Feb. - Mar.	**Modeled**	**7.34**	**7.20**	**7.21**	**7.34**	**7.34**	**7.16**	**6.89**	**6.80**	**6.78**	**6.75**	**6.70**	**6.53**	**6.77**	**6.56**	**6.55**
2010	**Difference**	**0.08**	**0.12**	**-0.05**	**0.24**	**0.12**	**0.14**	**-0.16**	**-0.08**	**-0.07**	**0.07**	**-0.20**	**-0.08**	**-0.08**	**0.01**	**-0.01**
7,400cfs	**Observed**	**8.44**	**7.55**	**6.92**	**6.54**	**6.59**	**7.44**	**6.47**	**6.05**	**5.97**	**5.90**	**6.24**	**5.89**	**6.10**	**5.81**	**5.81**
Feb.	**Modeled**	**8.31**	**7.49**	**6.90**	**6.68**	**6.64**	**7.47**	**6.35**	**6.05**	**5.96**	**5.98**	**5.93**	**5.75**	**5.97**	**5.77**	**5.76**
2011	**Difference**	**-0.13**	**-0.06**	**-0.02**	**0.14**	**0.05**	**0.03**	**-0.12**	**0.00**	**-0.01**	**0.08**	**-0.31**	**-0.14**	**-0.13**	**-0.04**	**-0.05**
12,400cfs	**Observed**	**11.33**	**9.75**	**8.22**	**7.24**	**7.15**	**9.60**	**7.56**	**6.85**	**6.60**	**6.40**	**6.67**	**6.19**	**6.54**	**6.13**	**6.13**
Feb. - Mar.	**Modeled**	**11.01**	**9.52**	**8.03**	**7.27**	**7.18**	**9.50**	**7.31**	**6.65**	**6.50**	**6.40**	**6.31**	**6.07**	**6.37**	**6.10**	**6.09**
2011	**Difference**	**-0.32**	**-0.23**	**-0.19**	**0.03**	**0.03**	**-0.10**	**-0.25**	**-0.20**	**-0.10**	**0.00**	**-0.36**	**-0.12**	**-0.17**	**-0.03**	**-0.04**
15,600cfs	**Observed**	**12.61**	**10.79**	**8.77**	**7.96**	**7.92**	**10.61**	**8.22**	**7.33**	**7.04**	**7.07**	**7.32**	**6.87**	**7.31**	**6.82**	**6.82**
Dec. - Jan.	**Modeled**	**12.63**	**10.92**	**8.67**	**7.96**	**7.90**	**10.90**	**8.16**	**7.05**	**6.83**	**7.11**	**7.01**	**6.74**	**7.07**	**6.78**	**6.78**
2011	**Difference**	**0.02**	**0.13**	**-0.10**	**0.00**	**-0.02**	**0.29**	**-0.06**	**-0.28**	**-0.21**	**0.04**	**-0.31**	**-0.13**	**-0.24**	**-0.04**	**-0.04**
28,900cfs	**Observed**	**17.87**	**15.35**	**11.80**	**8.42**	**8.21**	**15.22**	**11.18**	**8.94**	**7.81**	**8.71**	**8.54**	**7.84**	**8.18**	**7.83**	**7.83**
Mar. - May	**Modeled**	**17.88**	**15.37**	**11.69**	**8.39**	**8.25**	**15.35**	**11.13**	**8.58**	**7.77**	**8.60**	**8.26**	**7.68**	**8.34**	**7.71**	**7.71**
2011	**Difference**	**0.01**	**0.02**	**-0.11**	**-0.03**	**0.04**	**0.13**	**-0.05**	**-0.36**	**-0.04**	**-0.11**	**-0.28**	**-0.16**	**0.16**	**-0.12**	**-0.12**

Note: Stage in NGVD 29

- **Observed peak stage data**
- **Simulated peak stage data**
- **Peak stage difference between modeled and observed stage**
- **Peak stage difference between observed and simulated is more than 0.30ft**

Table A-2 Testing Results		Upper SJ River	Lower SJ River				Upper Old River	Middle River			Grantline Canal			Lower Old River		
Peak Flow @ Vernalis	Station	MSD	SJL	BDT	SJG	RRI	OH1	MRU	MHR	MTB	DGL	GCT	GLC	OLD-OLR	OAD	OBD
	XS	SJR 26 56.112	SJR 30 52.95	SJR 30 47.32	SJR 30 41.5	SJR 30 37.93	OLD 1 35.23	MIDDLE 27.025	MIDDLE 23.195	MIDDLE 18.117	GLC 27.518	GLC 26.071	GLC 0.09	OLD 10 28.683	OLD 10 1.735757	OLD 10 1.565757
	Indicator	Stage (ft.)	Stage (ft.)	Stage (ft.)	Stage (ft.)	Stage (ft.)	Stage (ft.)	Stage (ft.)	Stage (ft.)	Stage (ft.)	Stage (ft.)	Stage (ft.)	Stage (ft.)	Stage (ft.)	Stage (ft.)	Stage (ft.)
12,800cfs	Observed	11.44	10.35	8.47	N/A	7.15	10.35	7.96	7.20	7.01	7.13	7.21	N/A	7.11	6.82	6.82
Feb.	Modeled	11.55	10.12	8.27	7.29	7.18	10.10	7.93	7.10	6.92	7.14	7.06	6.82	7.10	6.86	6.85
2006	Difference	0.11	-0.23	-0.20	N/A	0.03	-0.25	-0.03	-0.10	-0.09	0.01	-0.15	N/A	-0.01	0.04	0.03
16,200cfs	Observed	N/A	11.99	9.70	N/A	8.61	11.90	9.10	8.50	8.03	8.37	8.40	N/A	8.25	7.76	7.86
May	Modeled	13.46	11.70	9.49	8.46	8.34	11.68	9.03	8.22	8.00	8.21	8.11	7.86	8.18	7.90	7.89
2006	Difference	N/A	-0.29	-0.21	N/A	-0.27	-0.22	-0.07	-0.28	-0.03	-0.16	-0.29	N/A	-0.07	0.14	0.03
19,800cfs	Observed	14.90	12.90	10.16	N/A	9.36	N/A	9.62	9.12	8.89	9.04	9.65	N/A	9.09	8.70	8.70
Dec. - Jan.	Modeled	15.08	13.00	10.11	9.48	9.40	12.97	9.59	9.01	8.83	8.99	8.89	8.66	9.00	8.70	8.69
2006	Difference	0.18	0.10	-0.05	N/A	0.04	N/A	-0.03	-0.11	-0.06	-0.05	-0.76	N/A	-0.09	0.00	-0.01
34,800cfs	Observed	19.14	17.11	13.18	N/A	8.03	17.08	12.38	9.55	8.34	10.38	9.80	8.52	9.63	8.50	8.37
Mar. - Jun.	Modeled	19.53	17.02	13.18	8.76	8.10	16.97	12.58	9.71	8.22	9.88	9.43	8.31	9.63	8.36	8.35
2006	Difference	0.39	-0.09	0.00	N/A	0.07	-0.11	0.20	0.16	-0.12	-0.50	-0.37	-0.21	0.00	-0.14	-0.02
35,200cfs	Observed	19.51	N/A	14.21	N/A	10.65	17.76	13.43	N/A	10.29	N/A	9.82	N/A	10.52	N/A	10.09
Jan. - Mar.	Modeled	19.70	17.25	13.73	10.58	10.39	17.19	12.96	10.39	10.14	10.53	10.40	10.12	10.49	10.17	10.16
1998	Difference	0.19	N/A	-0.48	N/A	-0.26	-0.57	-0.47	N/A	-0.15	N/A	0.58	N/A	-0.03	N/A	0.07

Note: Stage in NGVD 29

- Observed peak stage data (blue)
- Simulated peak stage data (green)
- Peak stage difference between modeled and observed stage (yellow)
- Peak stage difference between observed and simulated is more than 0.30ft (red)

Figure A-1 December 15, 2010 – January 14, 2011 (Peak Flow @ Vernalis 15,600 cfs) San Joaquin River at Mossdale (MSD)

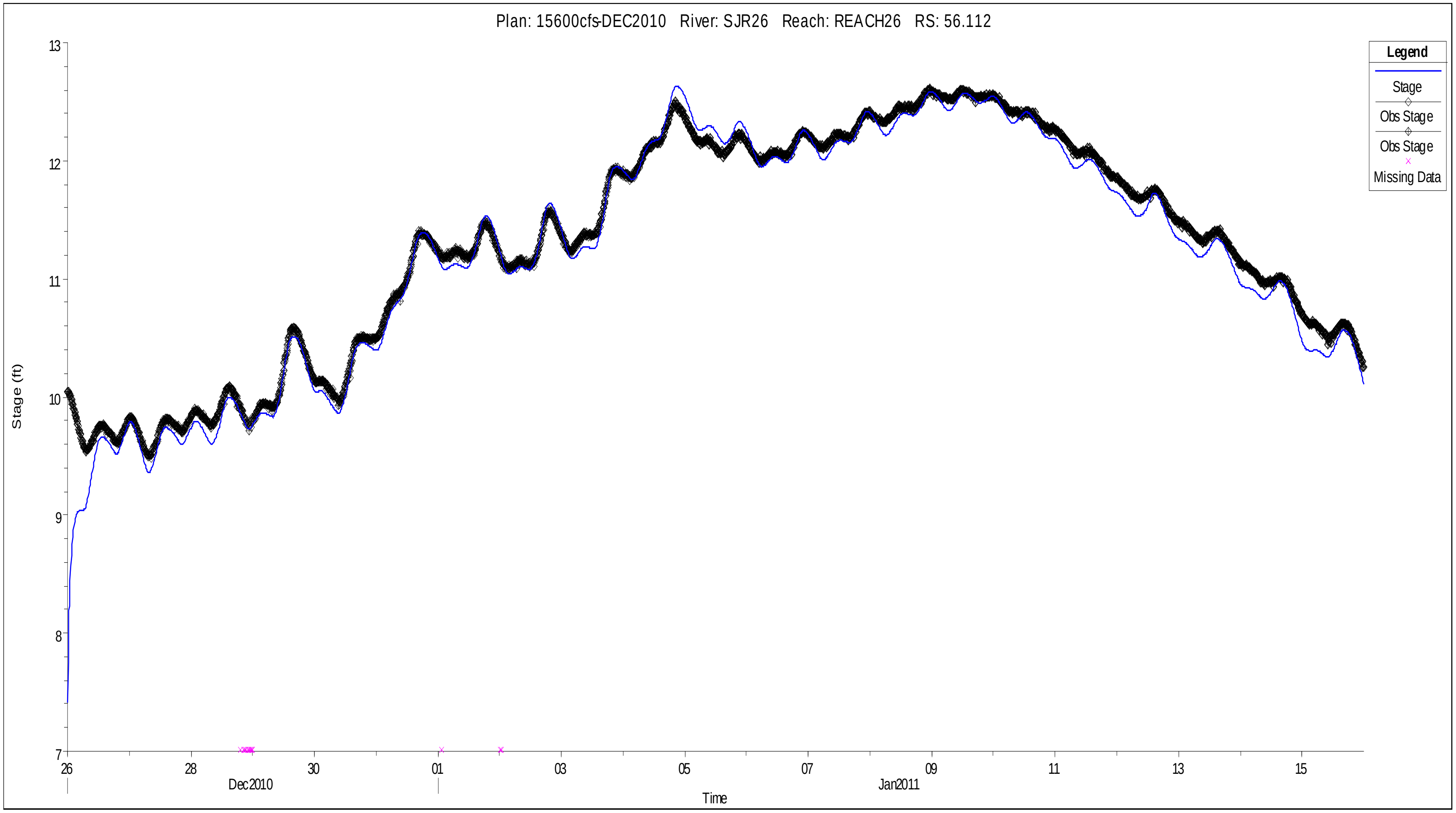


Figure A-2 December 15, 2010 – January 14, 2011 (Peak Flow @ Vernalis 15,600 cfs) San Joaquin River near Lathrop (SJL)

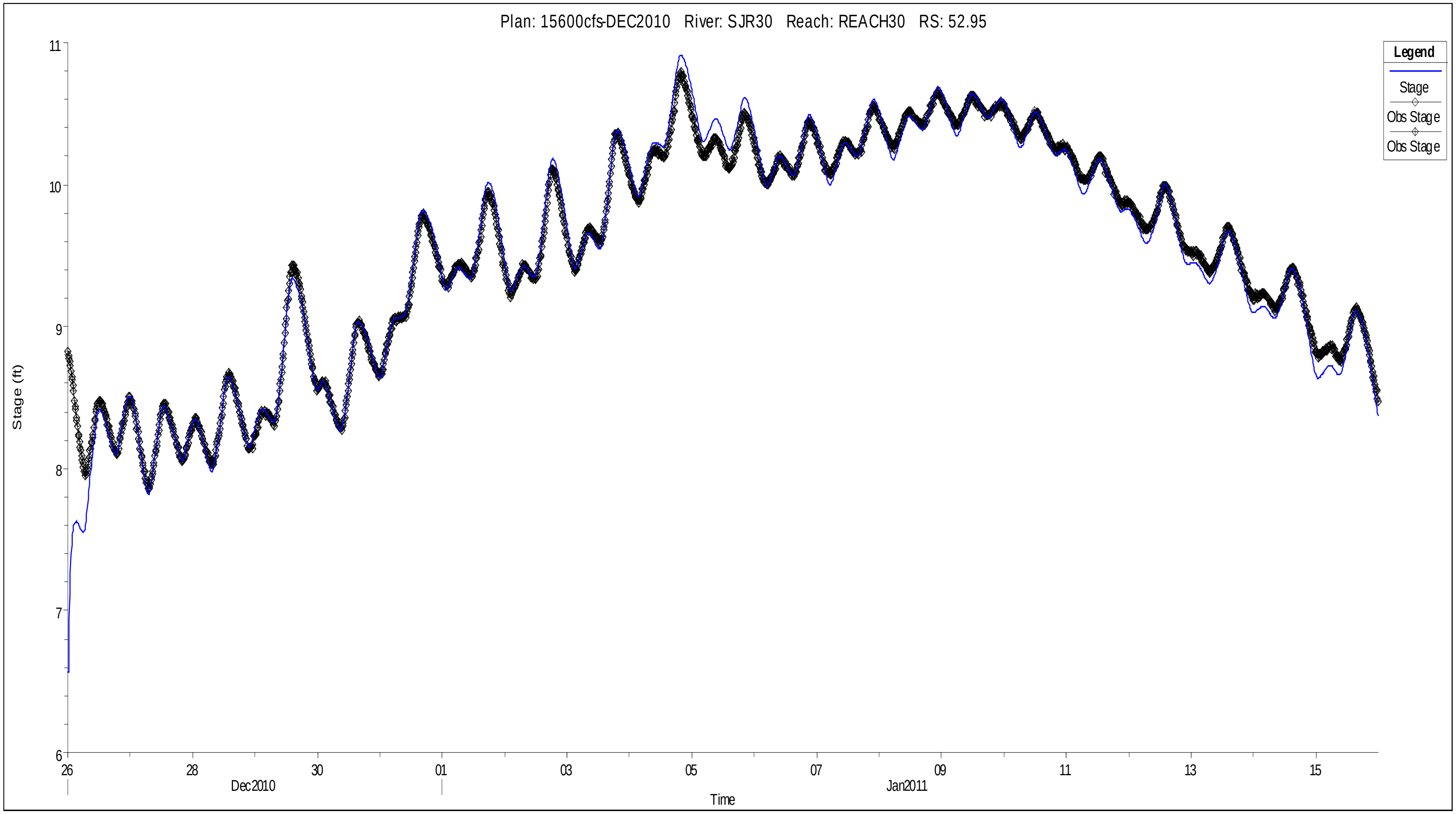


Figure A-3 December 15, 2010 – January 14, 2011 (Peak Flow @ Vernalis 15,600 cfs) San Joaquin River at Brandt Bridge (BDT)

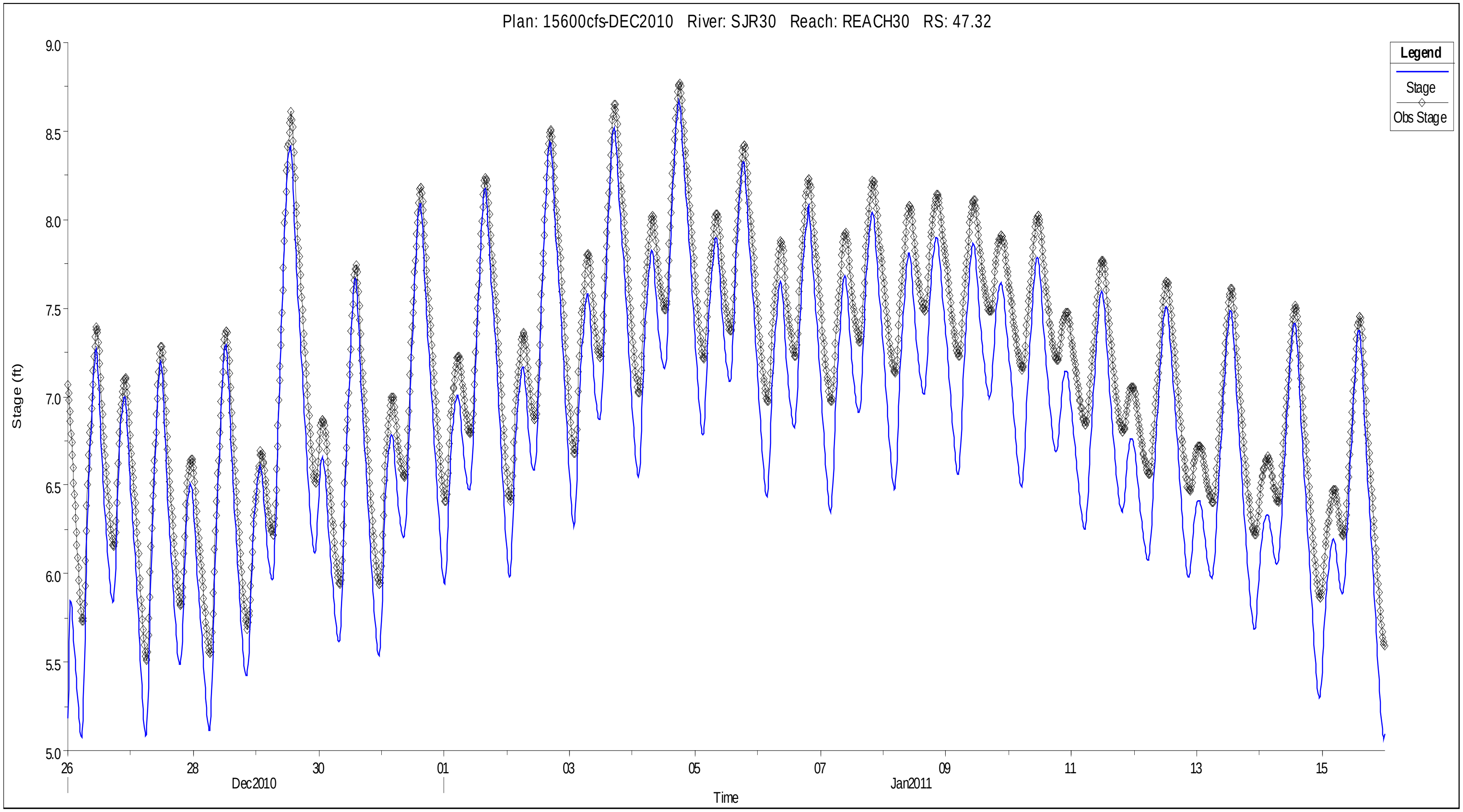


Figure A-4 December 15, 2010 – January 14, 2011 (Peak Flow @ Vernalis 15,600 cfs) Middle River at Mowry Bridge (MRU)

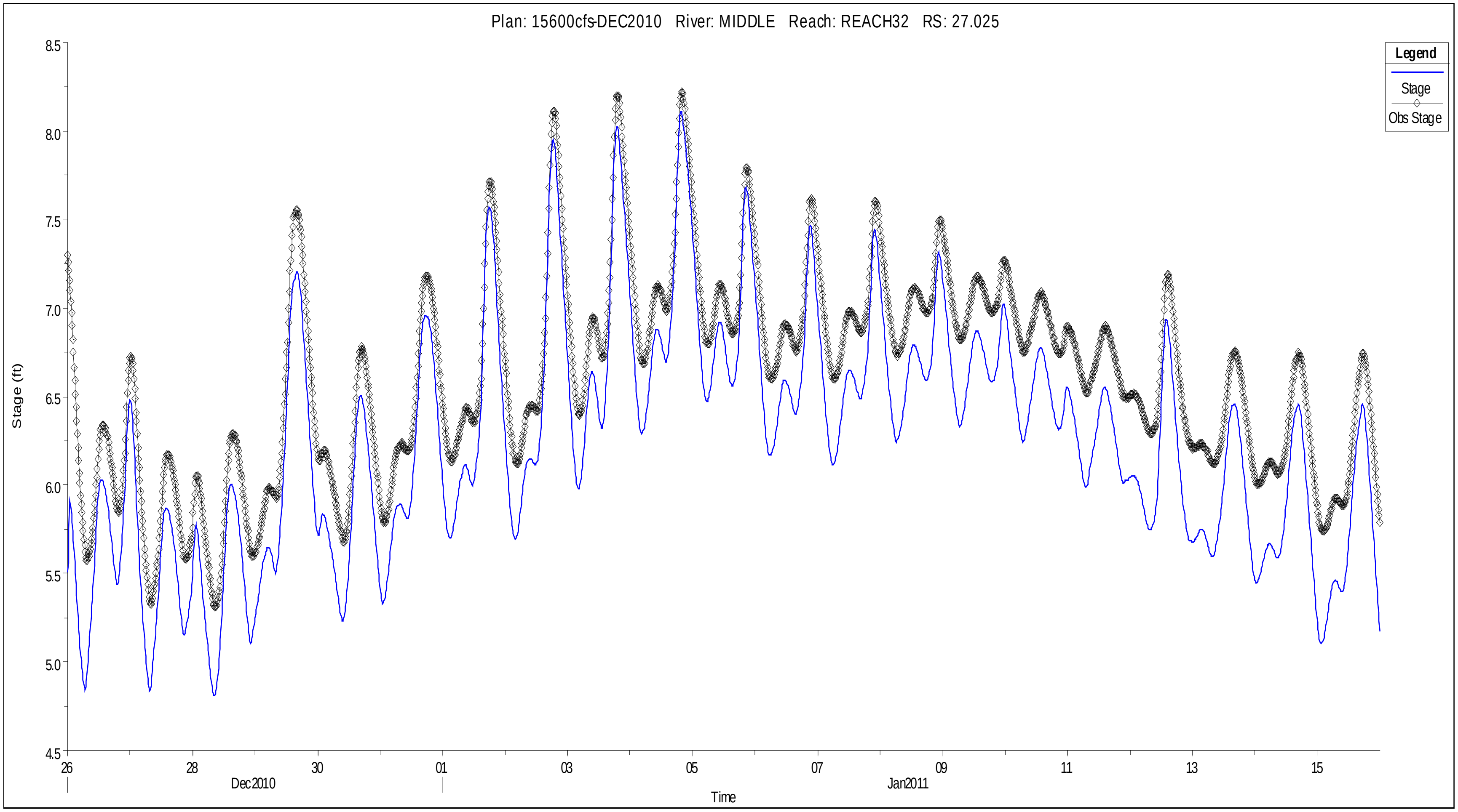


Figure A-5 December 15, 2010 – January 14, 2011 (Peak Flow @ Vernalis 15,600 cfs) Grantline at Tracy Rd. Bridge (GCT)

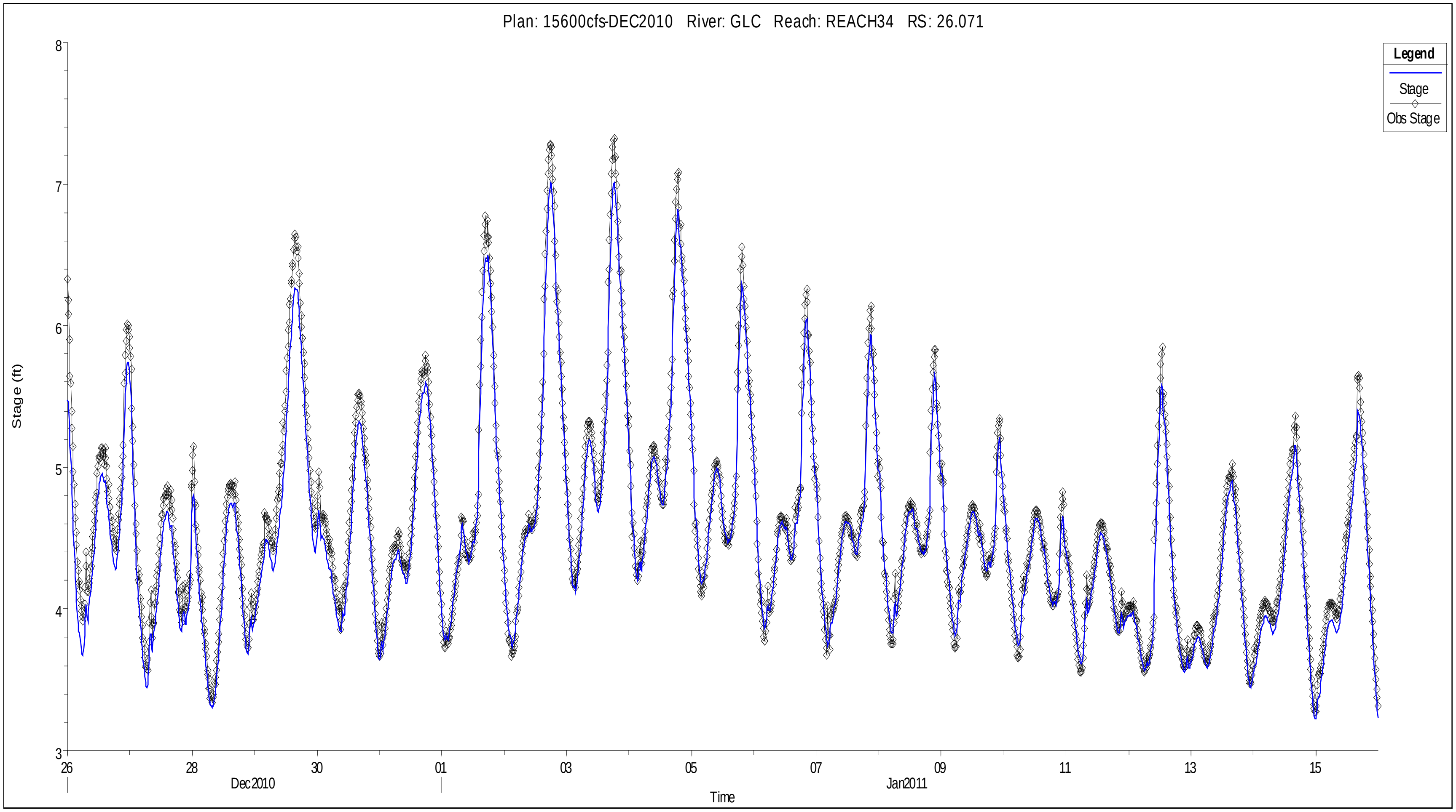


Figure A-6 December 15, 2010 – January 14, 2011 (Peak Flow @ Vernalis 15,600 cfs) Old River at Tracy Rd. Bridge (OLD)

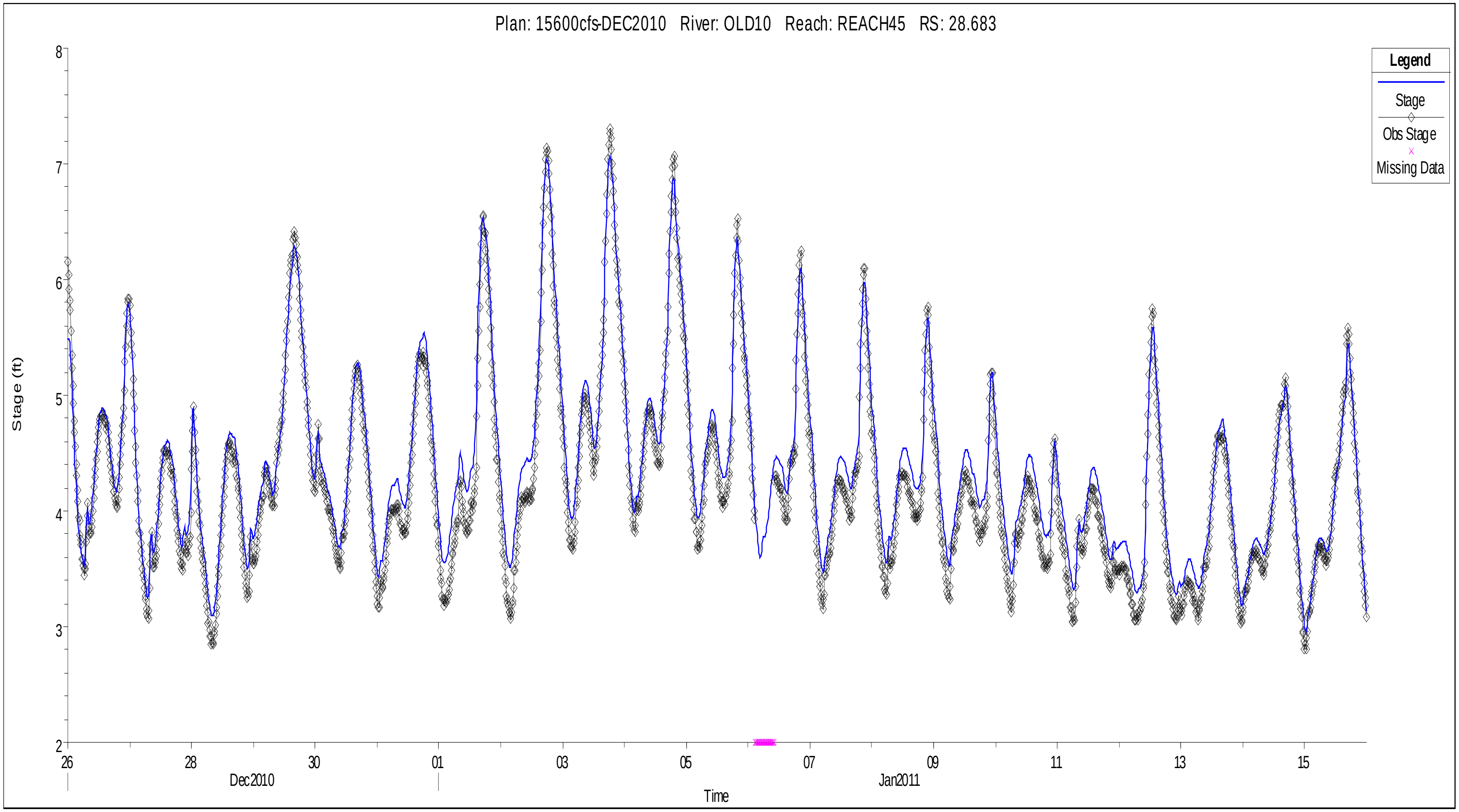


Figure A-7 March 17, 2011 – May 7, 2011 (Peak Flow @ Vernalis 28,900 cfs) San Joaquin River at Mossdale (MSD)

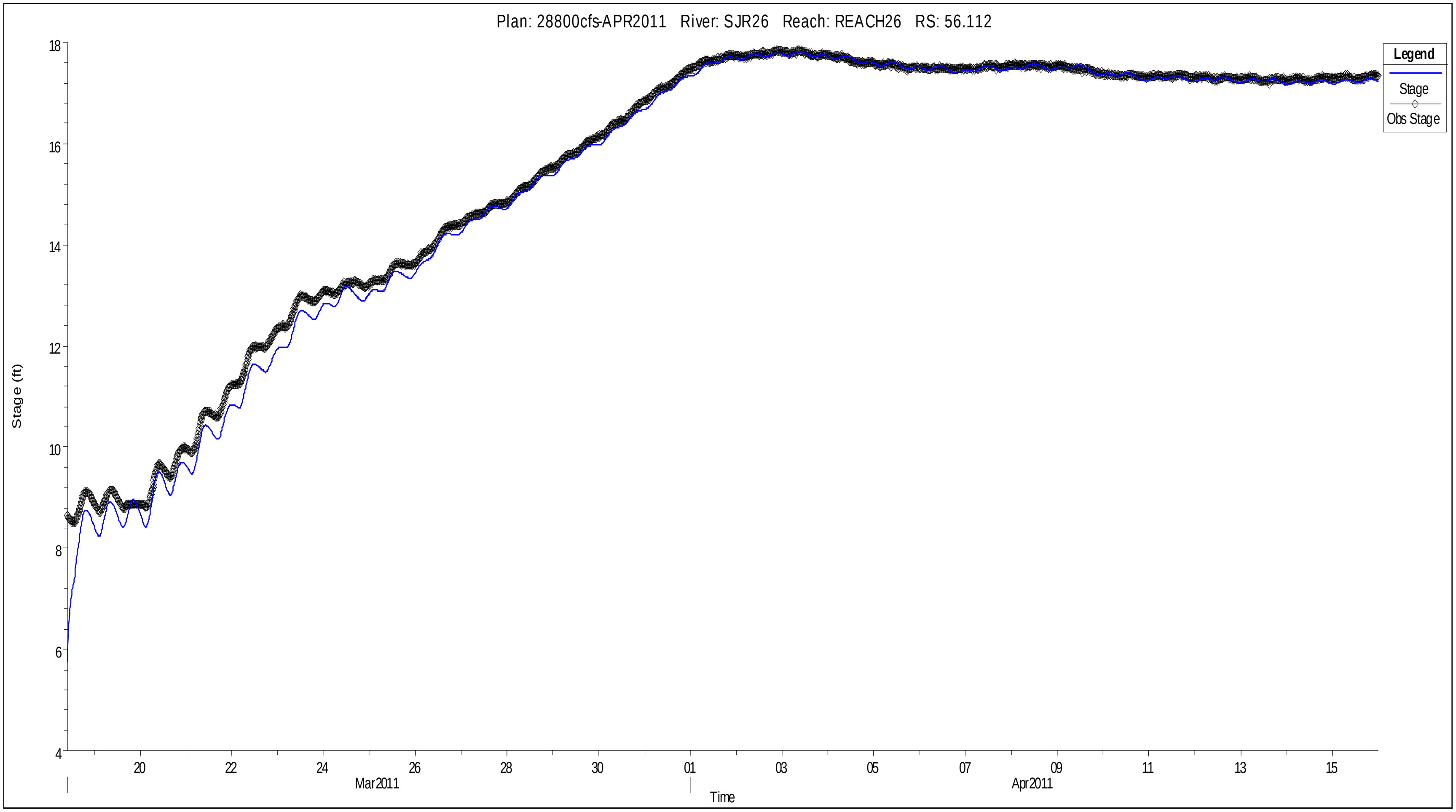


Figure A-8 March 17, 2011 – May 7, 2011 (Peak Flow @ Vernalis 28,900 cfs) San Joaquin River near Lathrop (SJL)

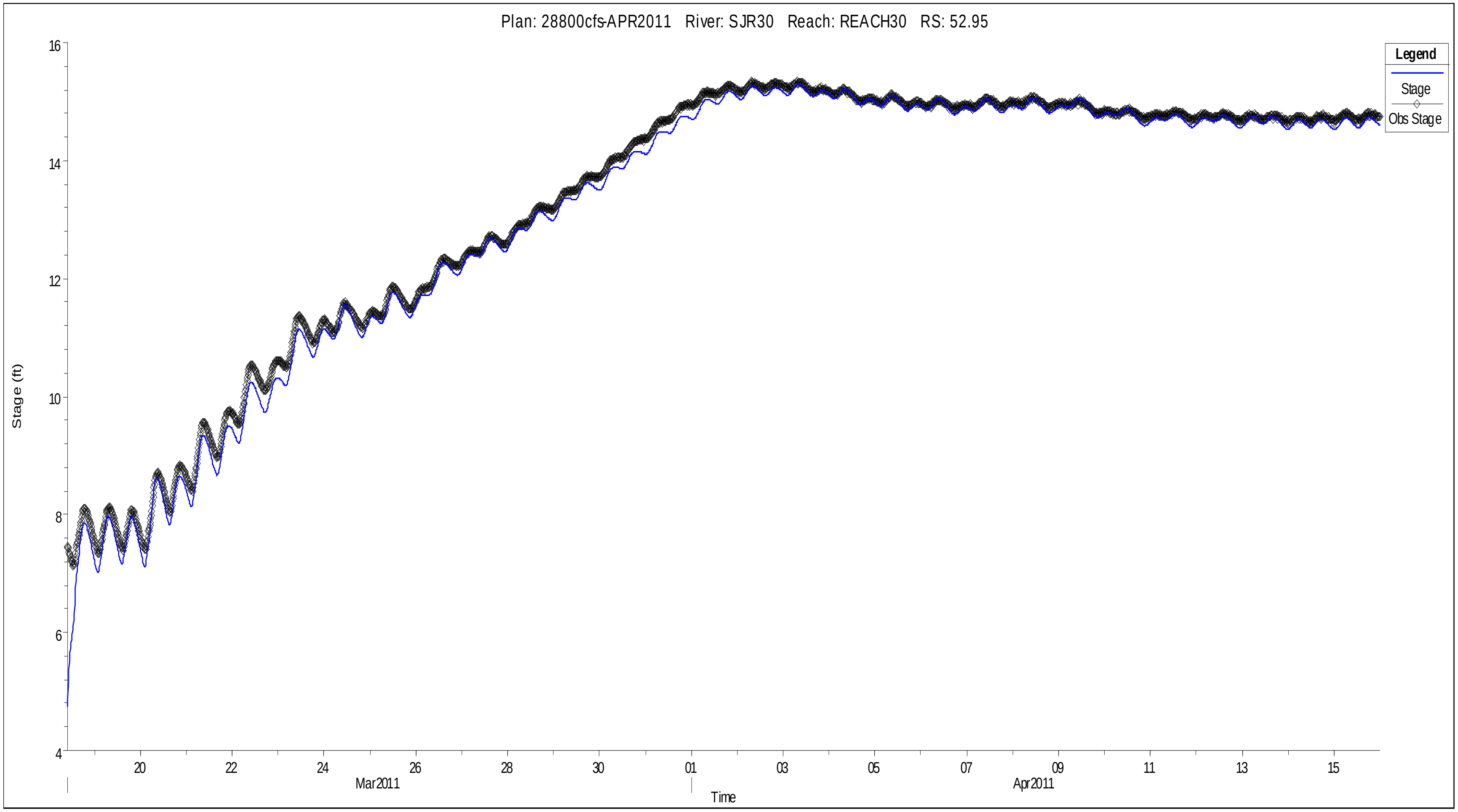


Figure A-9 March 17, 2011 – May 7, 2011 (Peak Flow @ Vernalis 28,900 cfs) San Joaquin River at Brandt Bridge (BDT)

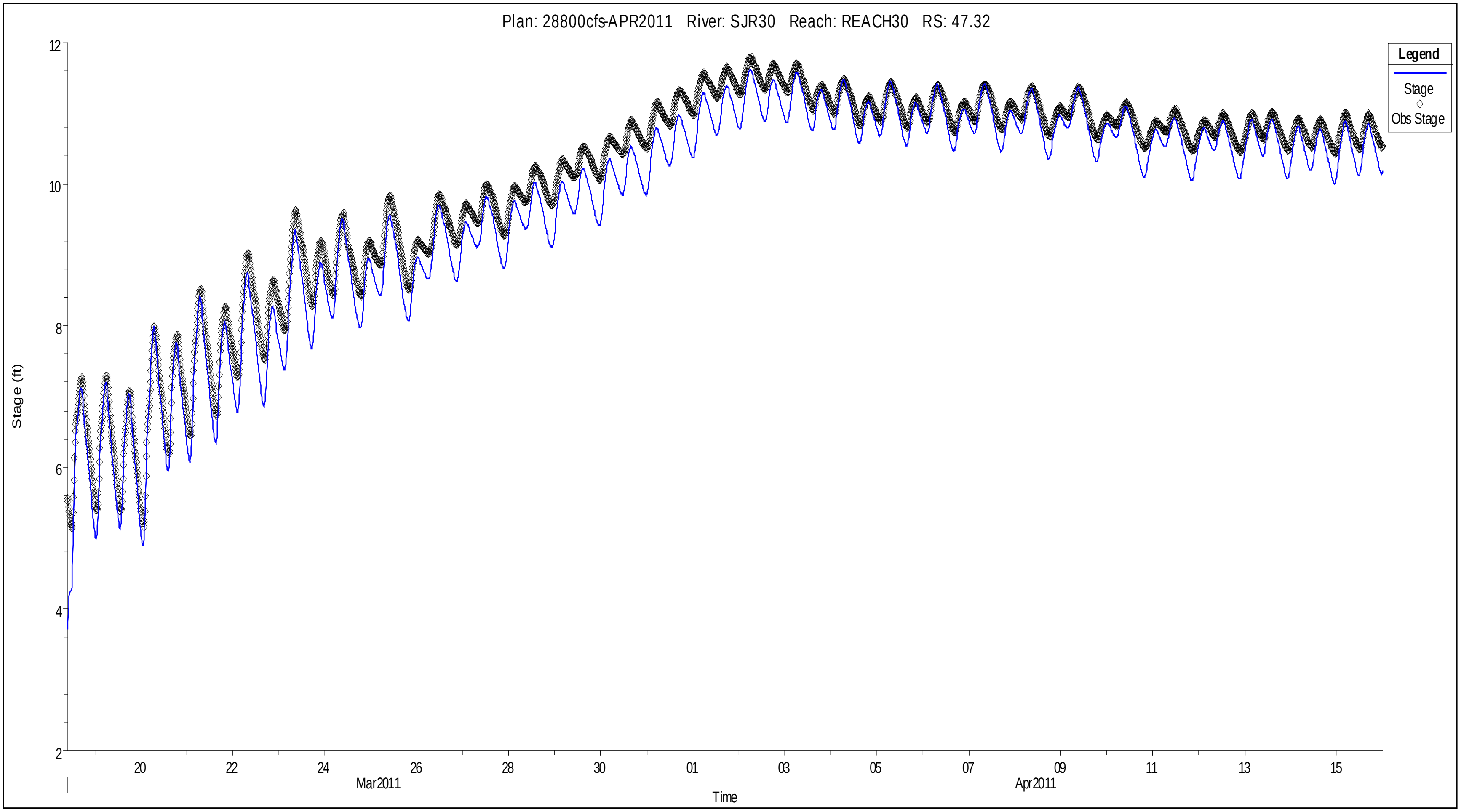


Figure A-10 March 17, 2011 – May 7, 2011 (Peak Flow @ Vernalis 28,900 cfs) Middle River at Mowry Bridge (MRU)

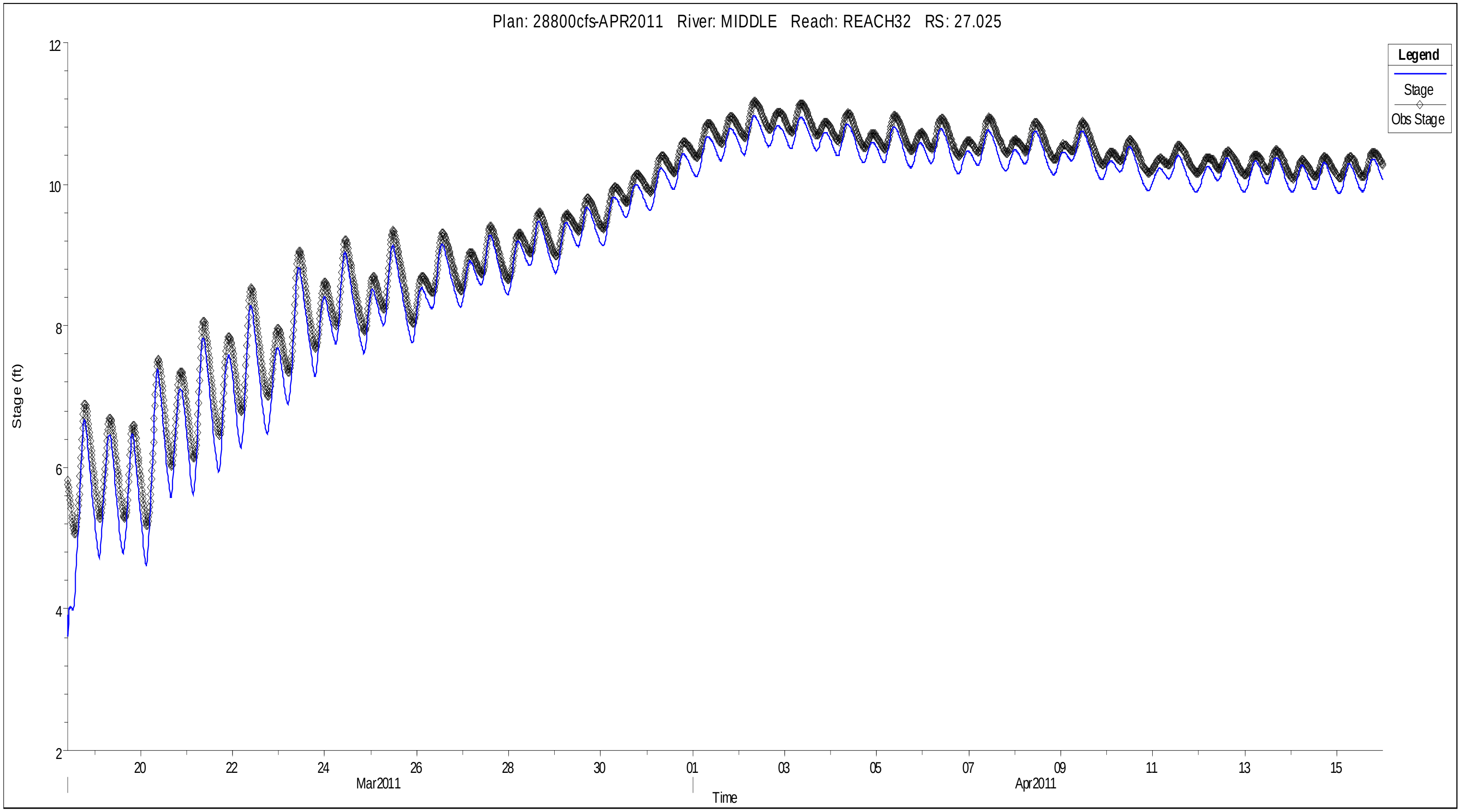


Figure A-11 March 17, 2011 – May 7, 2011 (Peak Flow @ Vernalis 28,900 cfs) Grantline at Tracy Rd. Bridge (GCT)

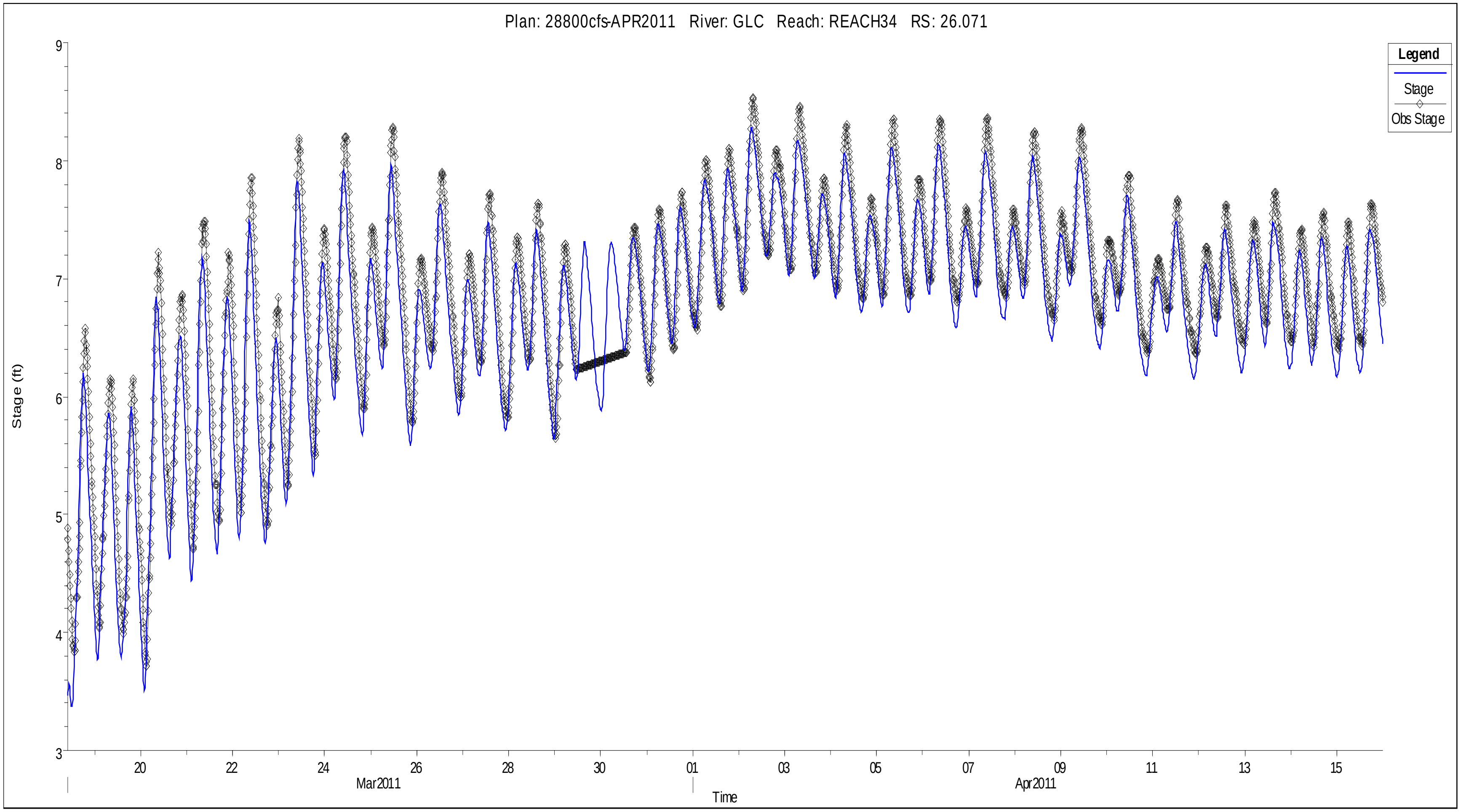


Figure A-12 March 17, 2011 – May 7, 2011 (Peak Flow @ Vernalis 28,900 cfs) Old River at Tracy Rd. Bridge (OLD)

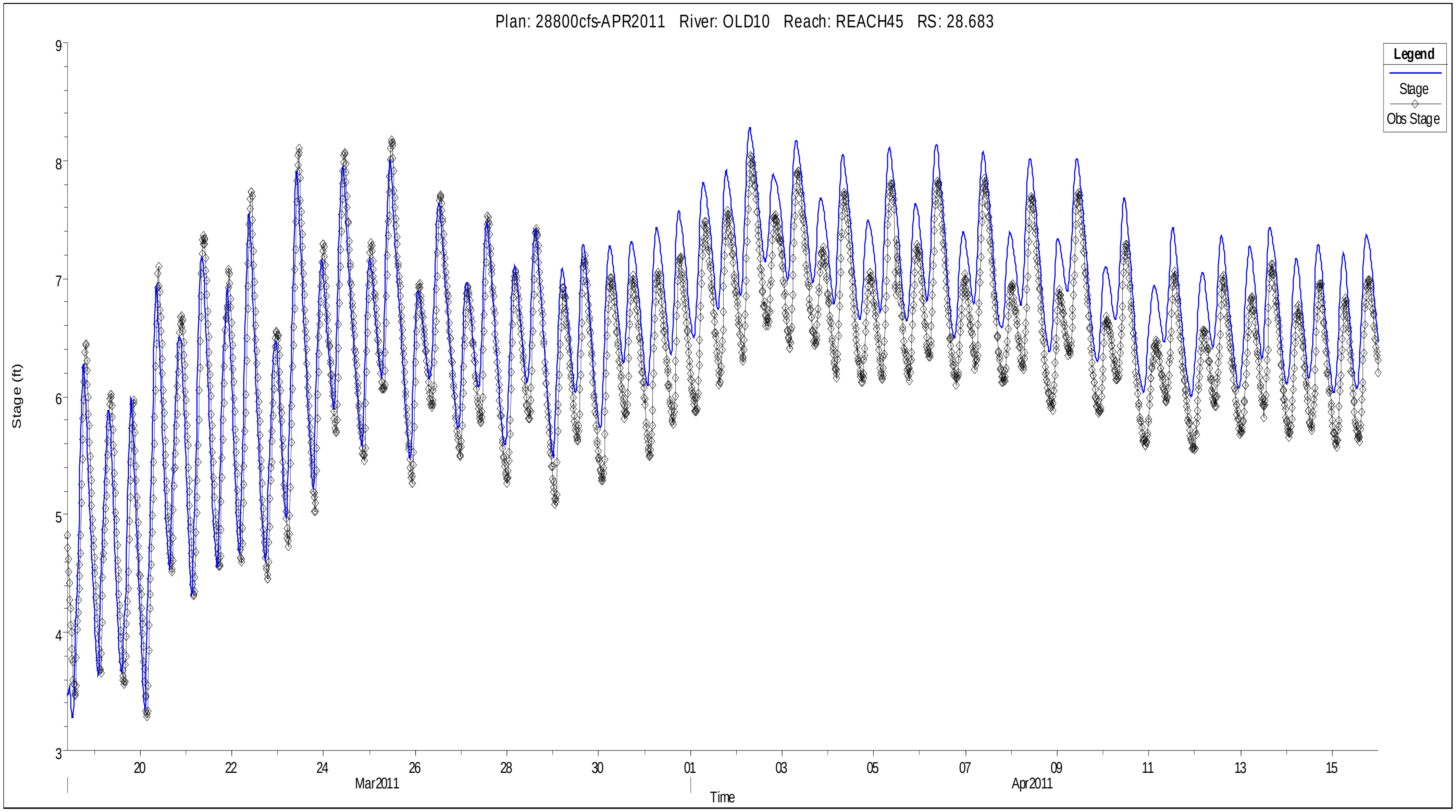


Figure A-13 March 3, 2006 – June 6, 2006 (Peak Flow @ Vernalis 34,800 cfs) San Joaquin River at Mossdale (MSD)

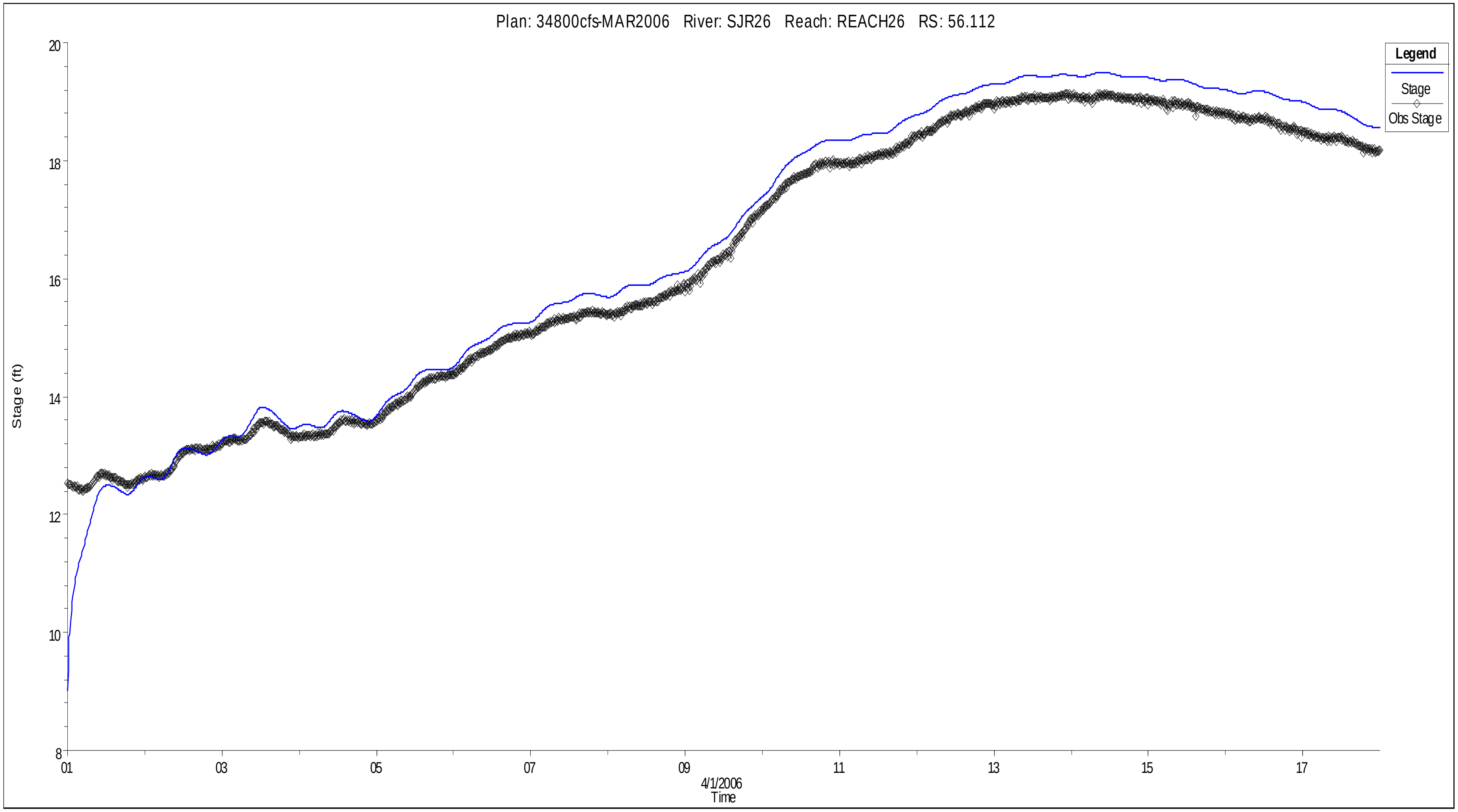


Figure A-14 March 3, 2006 – June 6, 2006 (Peak Flow @ Vernalis 34,800 cfs) San Joaquin River near Lathrop (SJL)

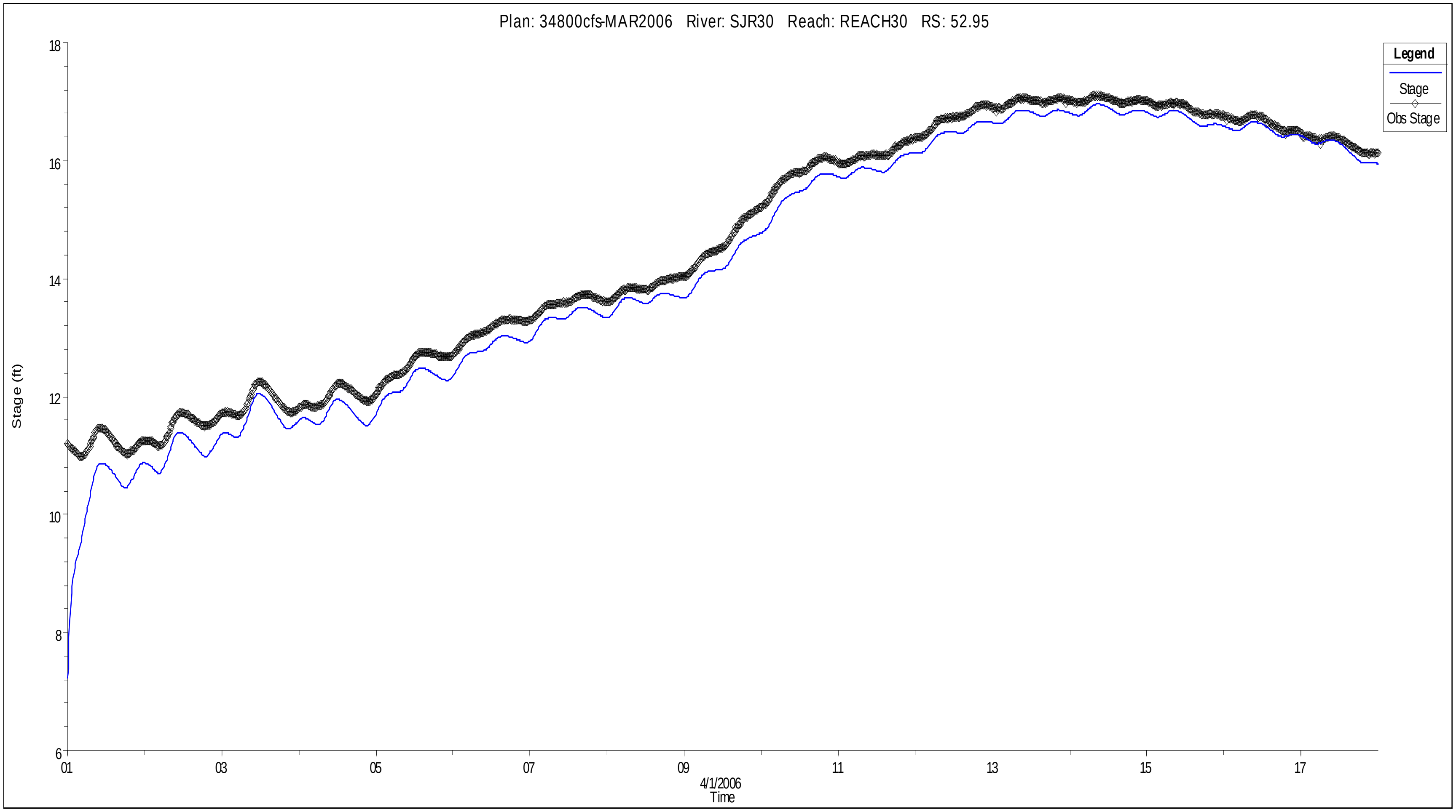


Figure A-15 March 3, 2006 – June 6, 2006 (Peak Flow @ Vernalis 34,800 cfs) San Joaquin River at Brandt Bridge (BDT)

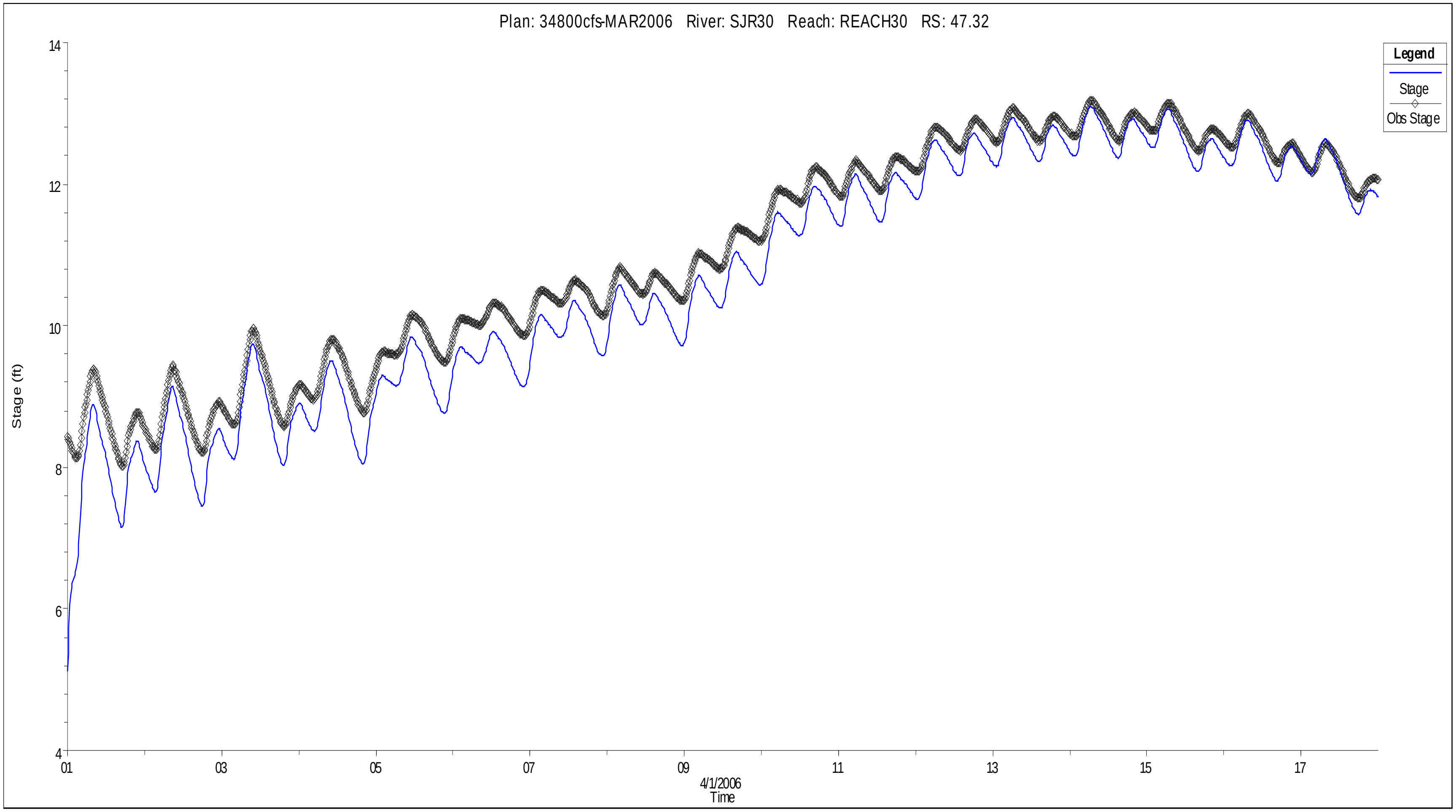


Figure A-16 March 3, 2006 – June 6, 2006 (Peak Flow @ Vernalis 34,800 cfs) Middle River at Mowry Bridge (MRU)

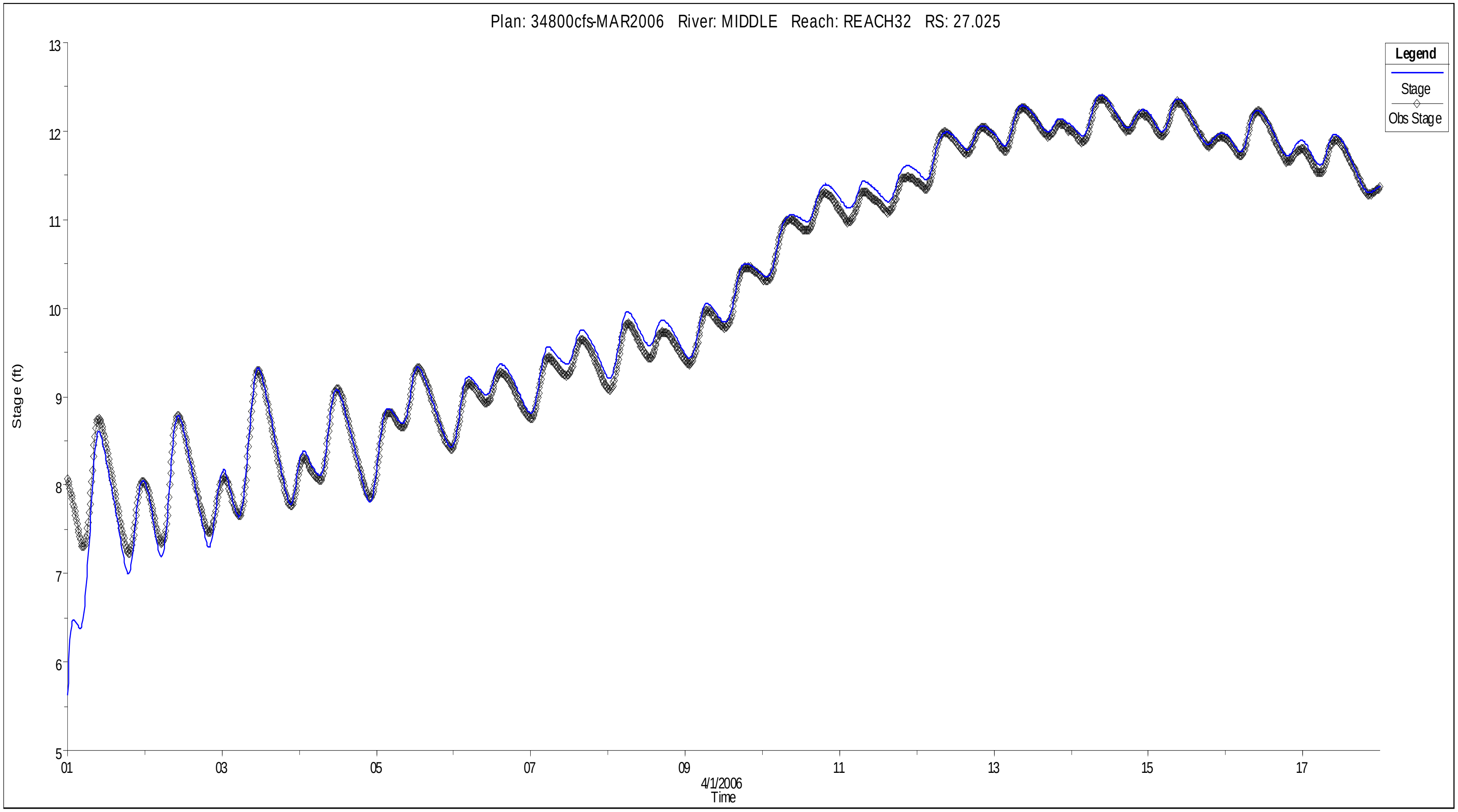


Figure A-17 March 3, 2006 – June 6, 2006 (Peak Flow @ Vernalis 34,800 cfs) Grantline at Tracy Rd. Bridge (GCT)

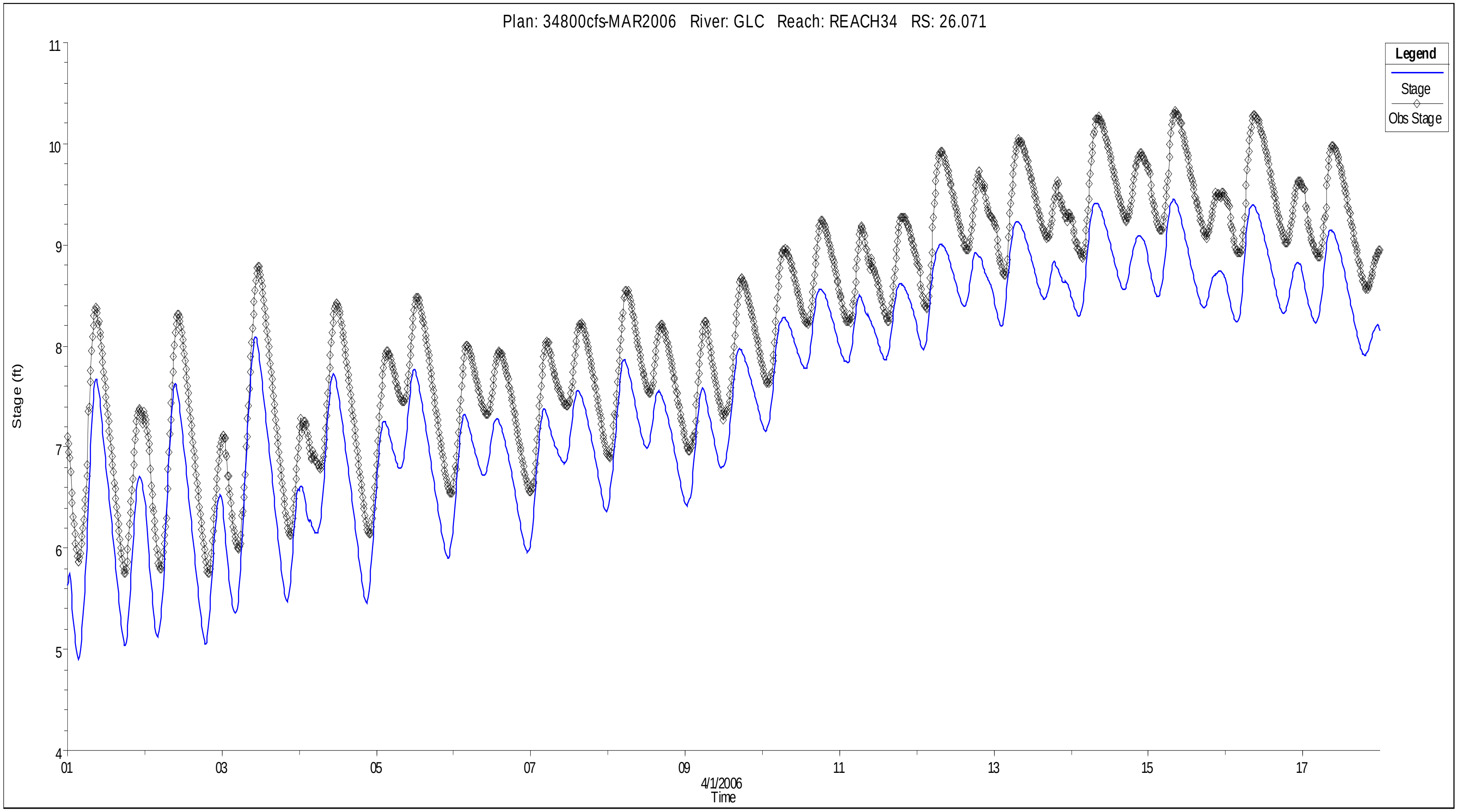


Figure A-16 March 3, 2006 – June 6, 2006 (Peak Flow @ Vernalis 34,800 cfs) Old River at Tracy Rd. Bridge (OLD)

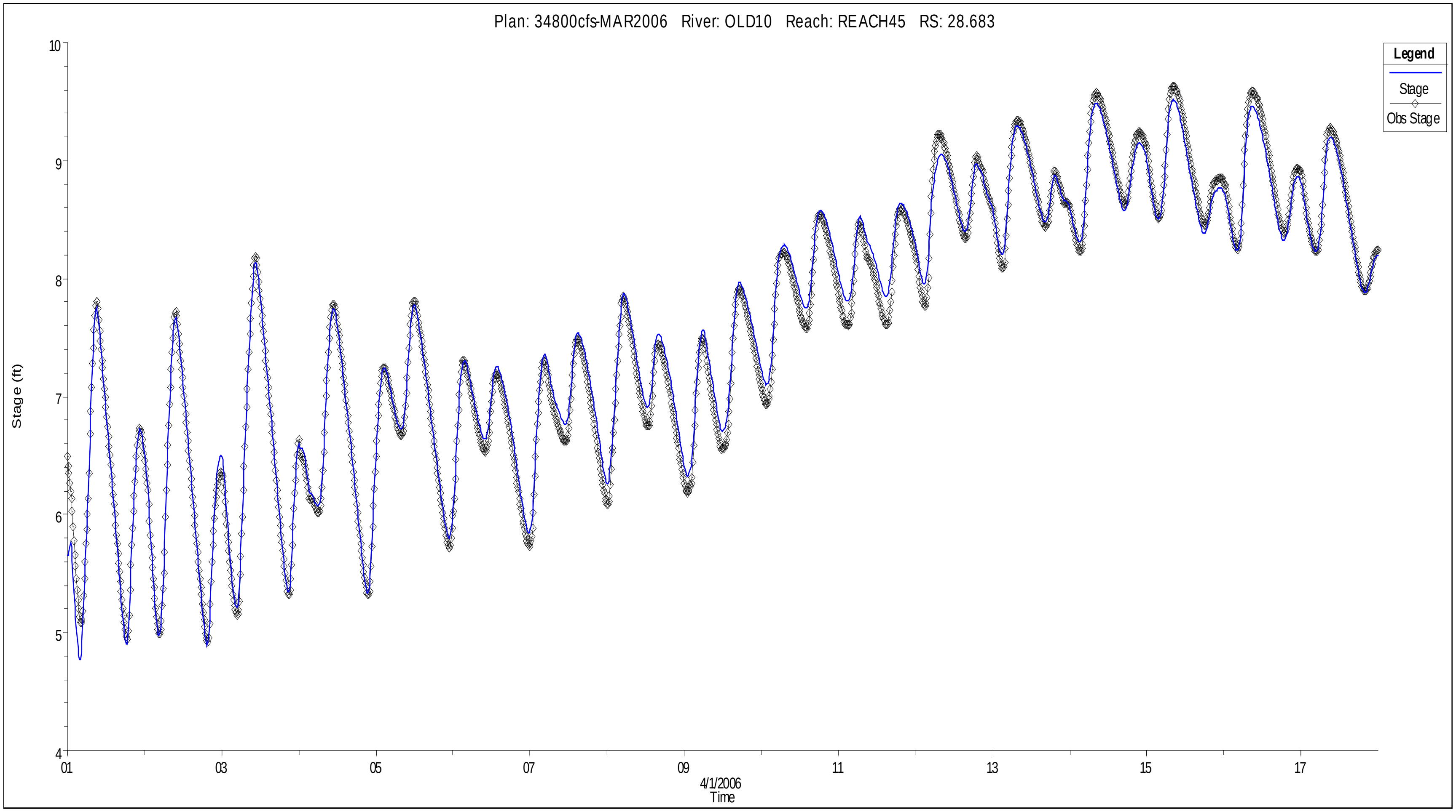


Table A-3 Calibration Results		Upper SJ River	Lower SJ River				Upper Old River	Middle River	Grantline Canal		Lower Old River	
Peak Flow @ Vernalis	Station	MSD	SJL	BDT	SJG	RRI	OH1	MRU	GCT	GLC	OLD-OLR	OAD - ODM
	XS	SJR 26 56.112	SJR 30 52.95	SJR 30 47.32	SJR 30 41.5	SJR 30 37.93	OLD 1 35.23	MIDDLE 27.025	GLC 26.071	GLC 0.09	OLD 10 28.683	OLD 10 1.735757
	Indicator	Flow (cfs)	Flow (cfs)	Flow (cfs)	Flow (cfs)	Flow (cfs)	Flow (cfs)	Flow (cfs)	Flow (cfs)	Flow (cfs)	Flow (cfs)	Flow (cfs)
1,470cfs21wz	Observed	2,810	2,083	2,451	3,220	7,150	2,320	N/A	6,050	7,466	N/A	2,210
Jan. - Feb.	Modeled	2,503	1,547	2,312	3,203	4,567	2,477	79	4,066	6,304	518	1,704
2010	Difference	-11%	-26%	-6%	-1%	-36%	7%	N/A	-33%	-16%	N/A	-23%
4,200cfs	Observed	4,900	2,670	3,030	4,031	8,455	3,291	148	11,000	11,030	N/A	3,310
Jan. - Feb.	Modeled	4,742	2,347	2,977	3,869	5,232	3,597	96	5,802	10,104	613	2,698
2010	Difference	-3%	-12%	-2%	-4%	-38%	9%	-35%	-47%	-8%	N/A	-18%
5,010cfs	Observed	5,770	2,845	3,011	4,504	8,993	3,456	192	10,100	10,081	N/A	2,100
Feb. - Mar.	Modeled	5,361	2,526	3,061	3,923	5,623	4,013	131	5,650	7,949	606	2,064
2010	Difference	-7%	-11%	2%	-13%	-37%	16%	-32%	-44%	-21%	N/A	-2%
7,400cfs	Observed	7,435	3,470	4,057	4,730	9,040	3,633	N/A	9,290	10,232	845	N/A
Feb.	Modeled	7,757	3,634	4,087	4,885	6,484	4,701	202	6,031	7,970	696	1,964
2011	Difference	4%	5%	1%	3%	-28%	29%	N/A	-35%	-22%	-18%	N/A
12,400cfs	Observed	12,400	4,920	5,912	6,700	9,986	5,590	N/A	11,100	11,108	1,130	N/A
Feb. - Mar.	Modeled	12,628	5,668	5,960	6,561	7,844	7,165	357	7,721	9,828	1,012	2,281
2011	Difference	2%	15%	1%	-2%	-21%	28%	N/A	-30%	-12%	-10%	N/A
15,600cfs	Observed	14,810	6,047	6,903	7,770	10,900	7,516	N/A	15,200	15,245	N/A	N/A
Dec. - Jan.	Modeled	15,694	6,943	7,119	7,648	8,938	8,983	507	9,372	12,559	1,242	2,885
2011	Difference	6%	15%	3%	-2%	-18%	20%	N/A	-38%	-18%	N/A	N/A
28,900cfs	Observed	24,600	10,900	10,876	11,800	13,591	12,560	N/A	17,700	17,329	2,604	N/A
Mar. - May	Modeled	25,279	11,019	11,173	11,676	14,185	14,434	1,205	15,496	16,995	2,556	3,404
2011	Difference	3%	1%	3%	-1%	4%	15%	N/A	-12%	-2%	-2%	N/A

Observed Peak Flow data

Simulated Peak Flow data

Peak Flow difference between modeled and observed stage with less than 10% of difference

Peak Flow difference between modeled and observed stage with more than 10% and less than 20% of difference

Peak Flow difference between modeled and observed stage with more than 20% of difference

No observed data available

Table A-4 Validation Results		Upper SJ River	Lower SJ River				Upper Old River	Middle River	Grantline Canal		Lower Old River	
Peak Flow @ Vernalis	Station	MSD	SJL	BDT	SJG	RRI	OH1	MRU	GCT	GLC	OLD-OLR	OAD
	XS	SJR 26 56.112	SJR 30 52.95	SJR 30 47.32	SJR 30 41.5	SJR 30 37.93	OLD 1 35.23	MIDDLE 27.025	GLC 26.071	GLC 0.09	OLD 10 28.683	OLD 10 1.735757
	Indicator	Stage (ft.)	Stage (ft.)	Stage (ft.)	Stage (ft.)	Stage (ft.)	Stage (ft.)	Stage (ft.)	Stage (ft.)	Stage (ft.)	Stage (ft.)	Stage (ft.)
12,800cfs	Observed	13,300	6,260	N/A	7,524	N/A	7,992	N/A	N/A	N/A	N/A	N/A
Feb 2006	Modeled	13,093	5,821	6,109	6,790	8,366	7,539	412	8,358	10,253	1,083	2,356
2006	Difference	-2%	-7%	N/A	-10%	N/A	-6%	N/A	N/A	N/A	N/A	N/A
16,200cfs	Observed	N/A	6,910	N/A	8,283	N/A	7,472	N/A	N/A	14,883	N/A	N/A
May 2005	Modeled	16,470	7,255	7,564	8,233	10,028	9,485	595	10,010	12,255	1,407	2,919
2006	Difference	N/A	5%	N/A	-1%	N/A	27%	N/A	N/A	-18%	N/A	N/A
19,800cfs	Observed	18,784	9,000	N/A	N/A	N/A	10,628	N/A	N/A	N/A	N/A	N/A
Dec. - Jan. 2006	Modeled	19,597	8,616	8,828	9,343	10,780	11,005	788	11,076	13,191	1,641	3,115
2006	Difference	4%	-4%	N/A	N/A	N/A	4%	N/A	N/A	N/A	N/A	N/A
34,800cfs	Observed	29,425	15,100	N/A	16,089	N/A	15,301	N/A	N/A	31,232	N/A	N/A
Mar. - Jun. 2006	Modeled	29,100	12,643	12,791	13,133	14,411	16,649	1,641	18,530	19,802	3,316	4,199
2006	Difference	-1%	-16%	N/A	-18%	N/A	9%	N/A	N/A	-37%	N/A	N/A
35,200cfs	Observed	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Jan. - Mar. 1998	Modeled	29,226	12,657	12,805	13,154	15,170	16,782	1,699	18,831	19,709	3,427	4,147
1998	Difference	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Observed Peak Flow data
Simulated Peak Flow data
Peak Flow difference between modeled and observed stage with less than 10% of difference
Peak Flow difference between modeled and observed stage with more than 10% and less than 20% of difference
Peak Flow difference between modeled and observed stage with more than 20% of difference
No observed data available

Figure A-17 December 15, 2010 – January 14, 2011 (Peak Flow @ Vernalis 15,600 cfs) San Joaquin River at Mossdale (MSD)

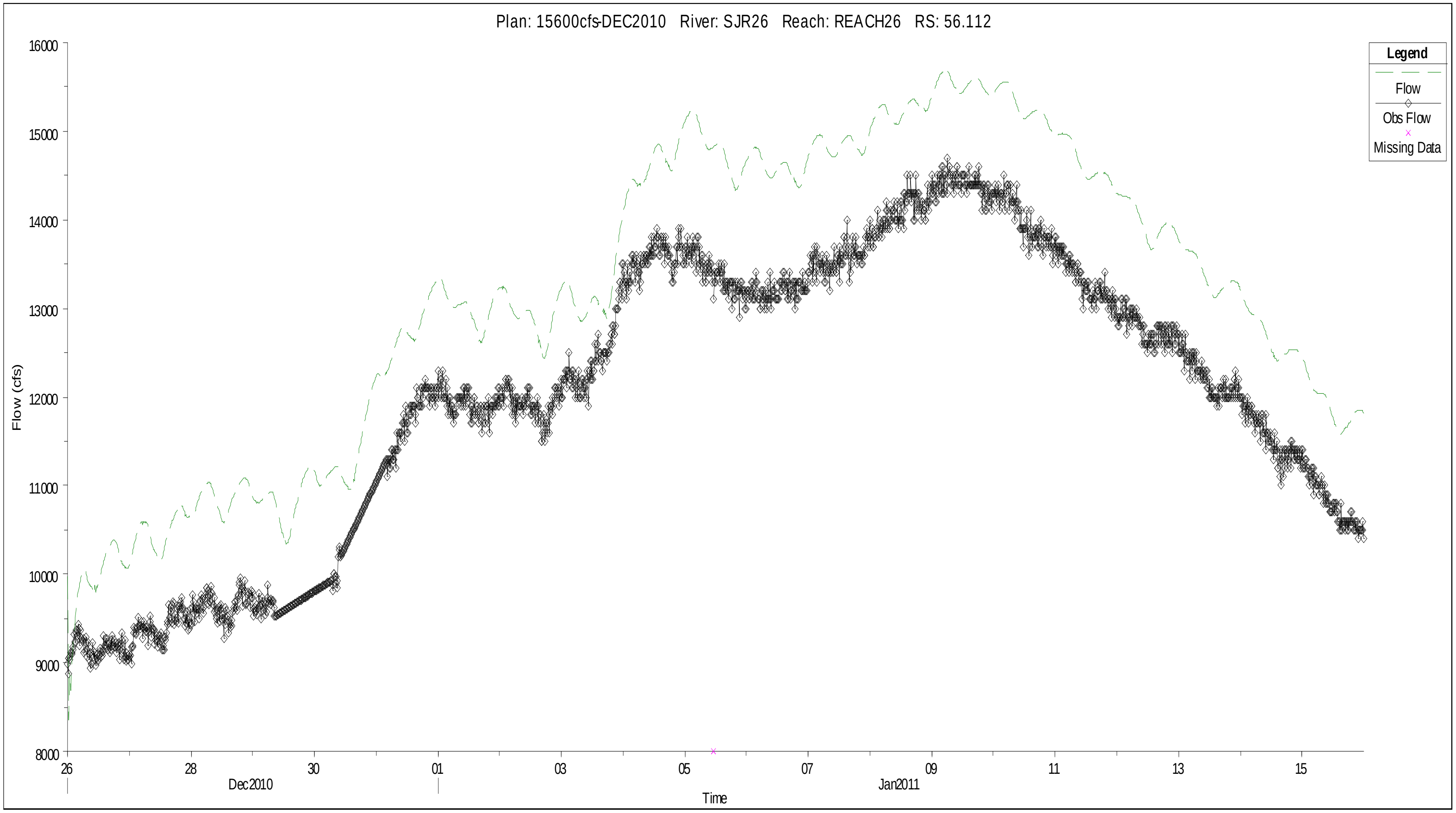


Figure A-18 December 15, 2010 – January 14, 2011 (Peak Flow @ Vernalis 15,600 cfs) San Joaquin River at Brandt Bridge (BDT)

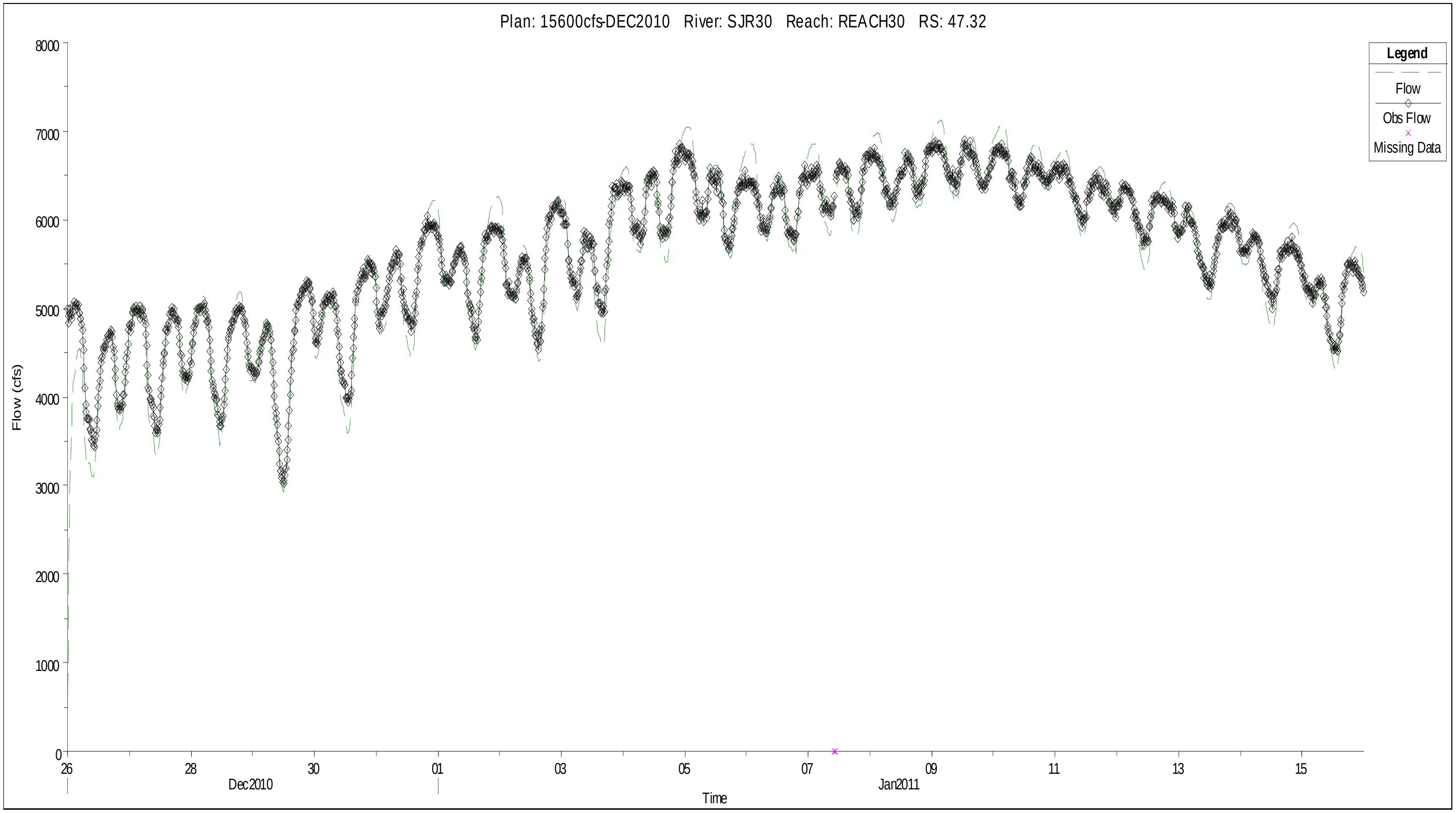


Figure A-19 December 15, 2010 – January 14, 2011 (Peak Flow @ Vernalis 15,600 cfs) San Joaquin River at Garwood Bridge (USGS) (SJG)

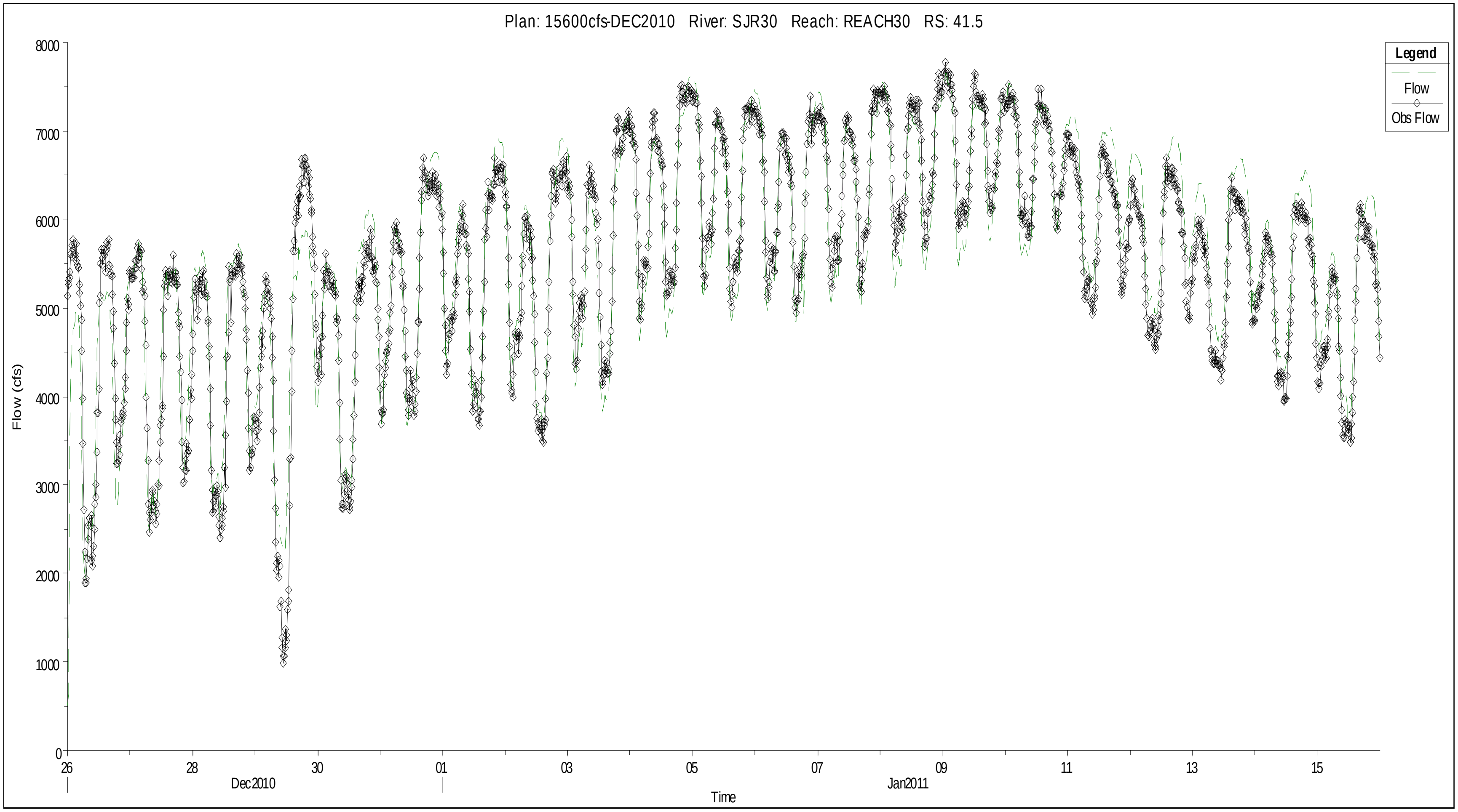


Figure A-20 December 15, 2010 – January 14, 2011 (Peak Flow @ Vernalis 15,600 cfs) Grantline Canal (USGS) (GLC)

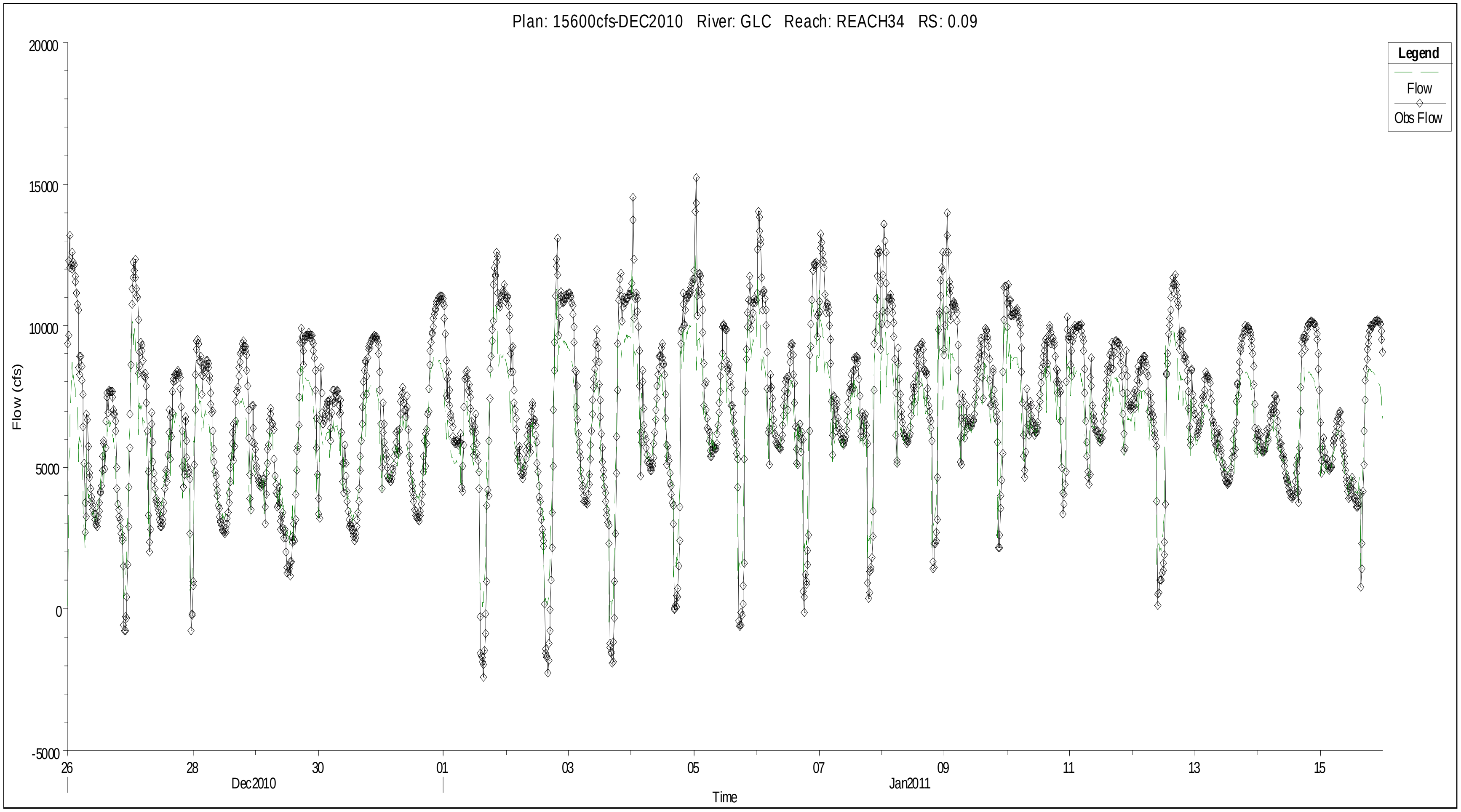


Figure A-21 March 17, 2011 – May 7, 2011 (Peak Flow @ Vernalis 28,900 cfs) San Joaquin River at Mossdale (MSD)

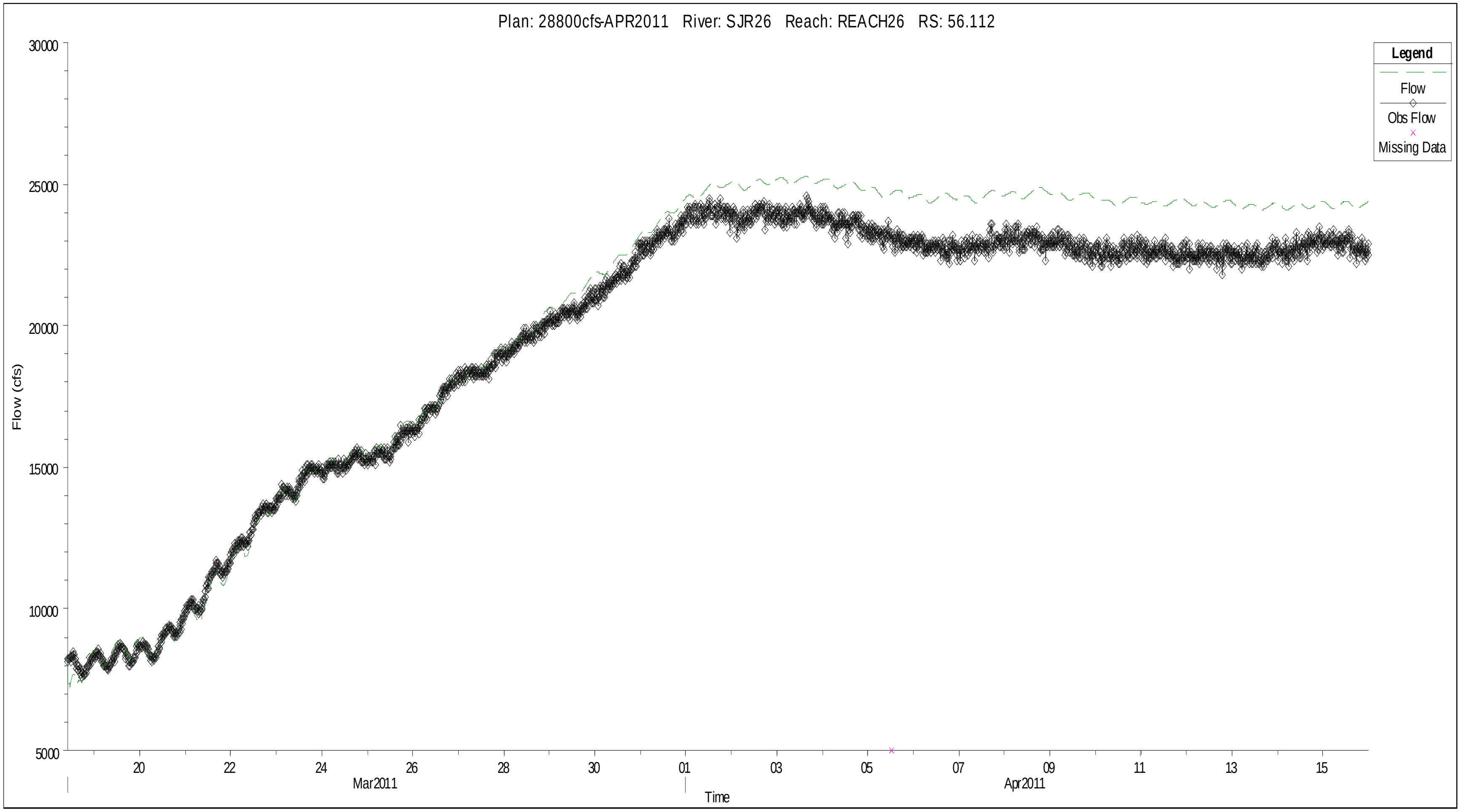


Figure A-22 March 17, 2011 – May 7, 2011 (Peak Flow @ Vernalis 28,900 cfs) San Joaquin River at Brandt Bridge (BDT)

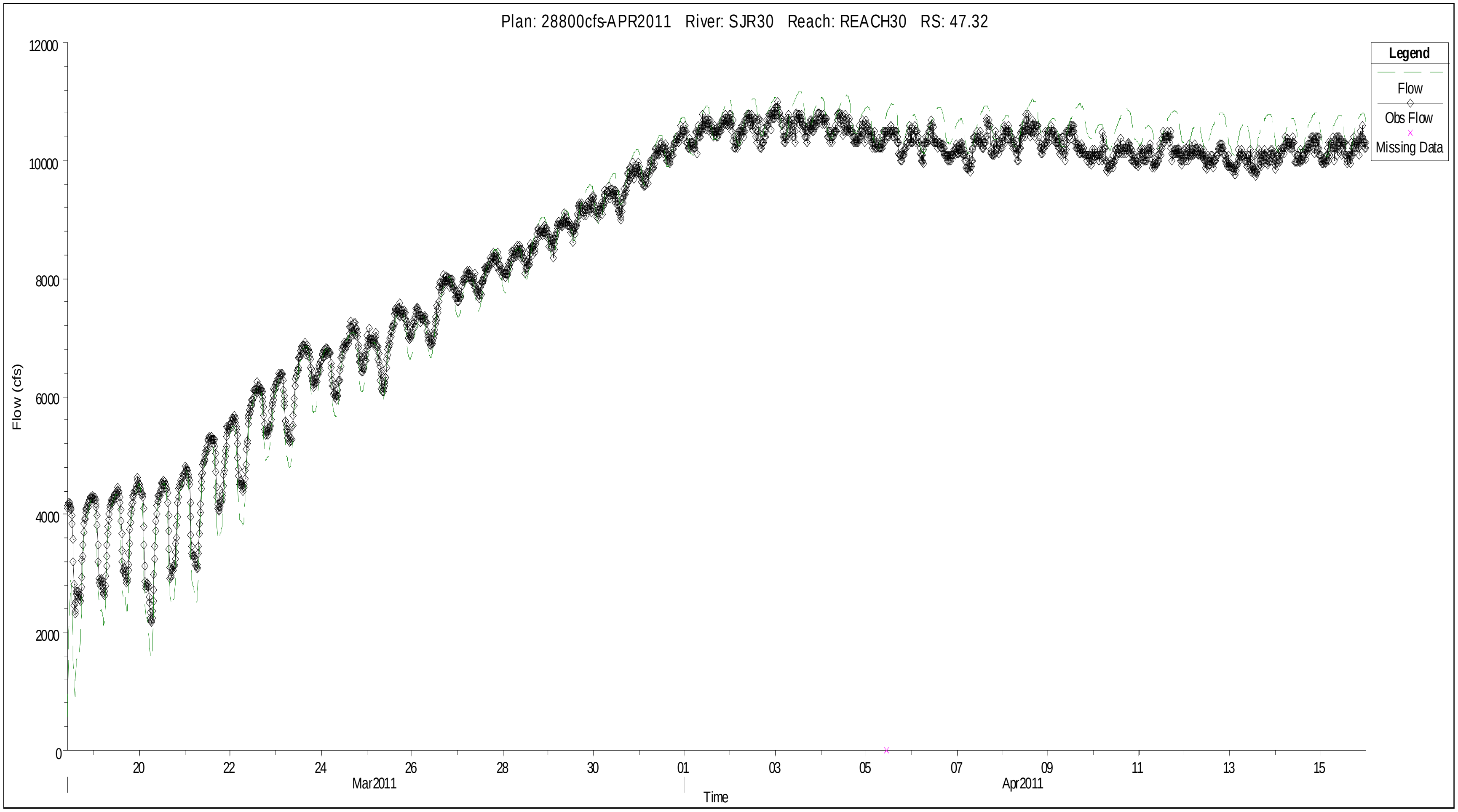


Figure A-23 March 17, 2011 – May 7, 2011 (Peak Flow @ Vernalis 28,900 cfs) San Joaquin River at Garwood Bridge (USGS) (SJG)

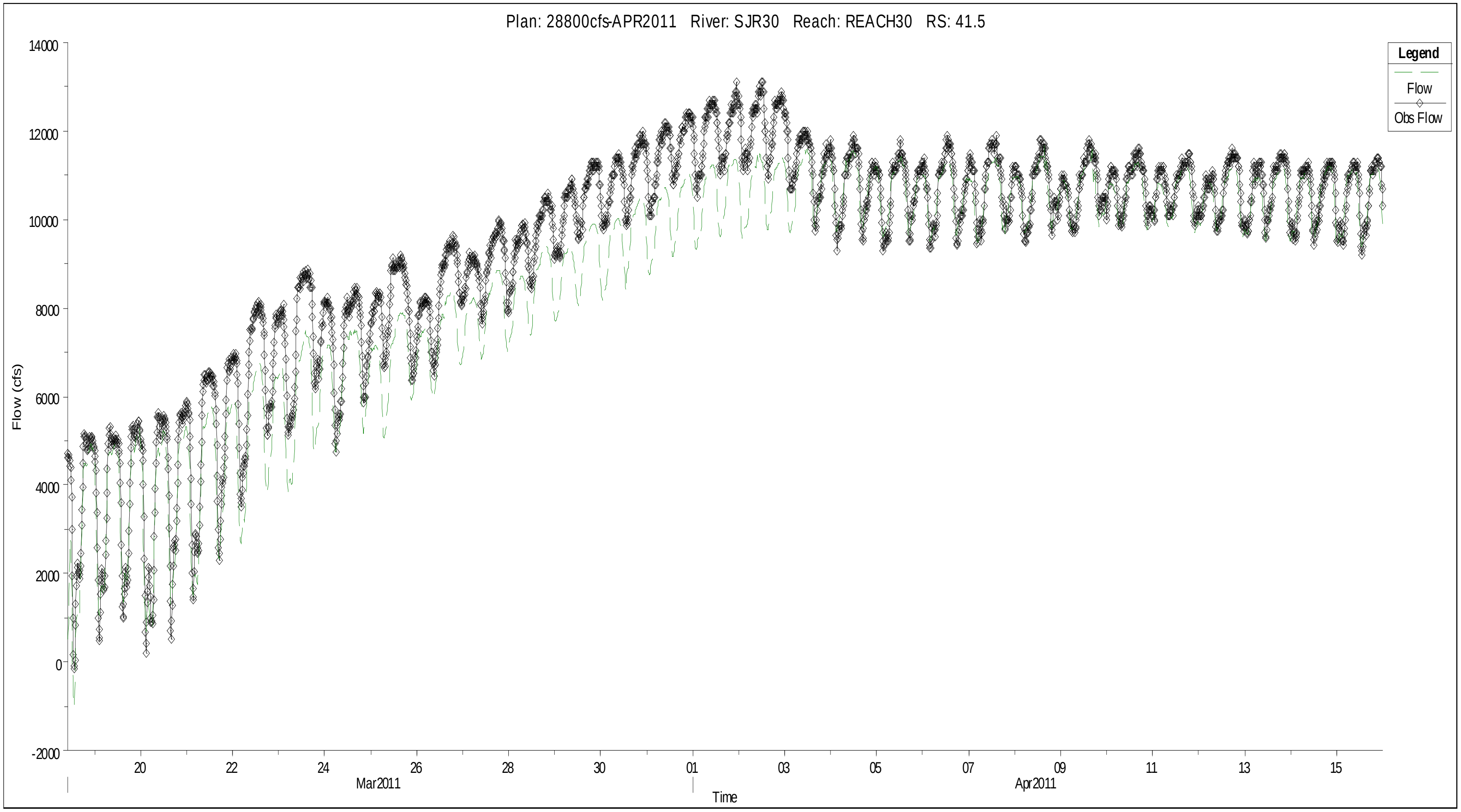


Figure A-24 March 17, 2011 – May 7, 2011 (Peak Flow @ Vernalis 28,900 cfs) Grantline Canal (USGS) (GLC)

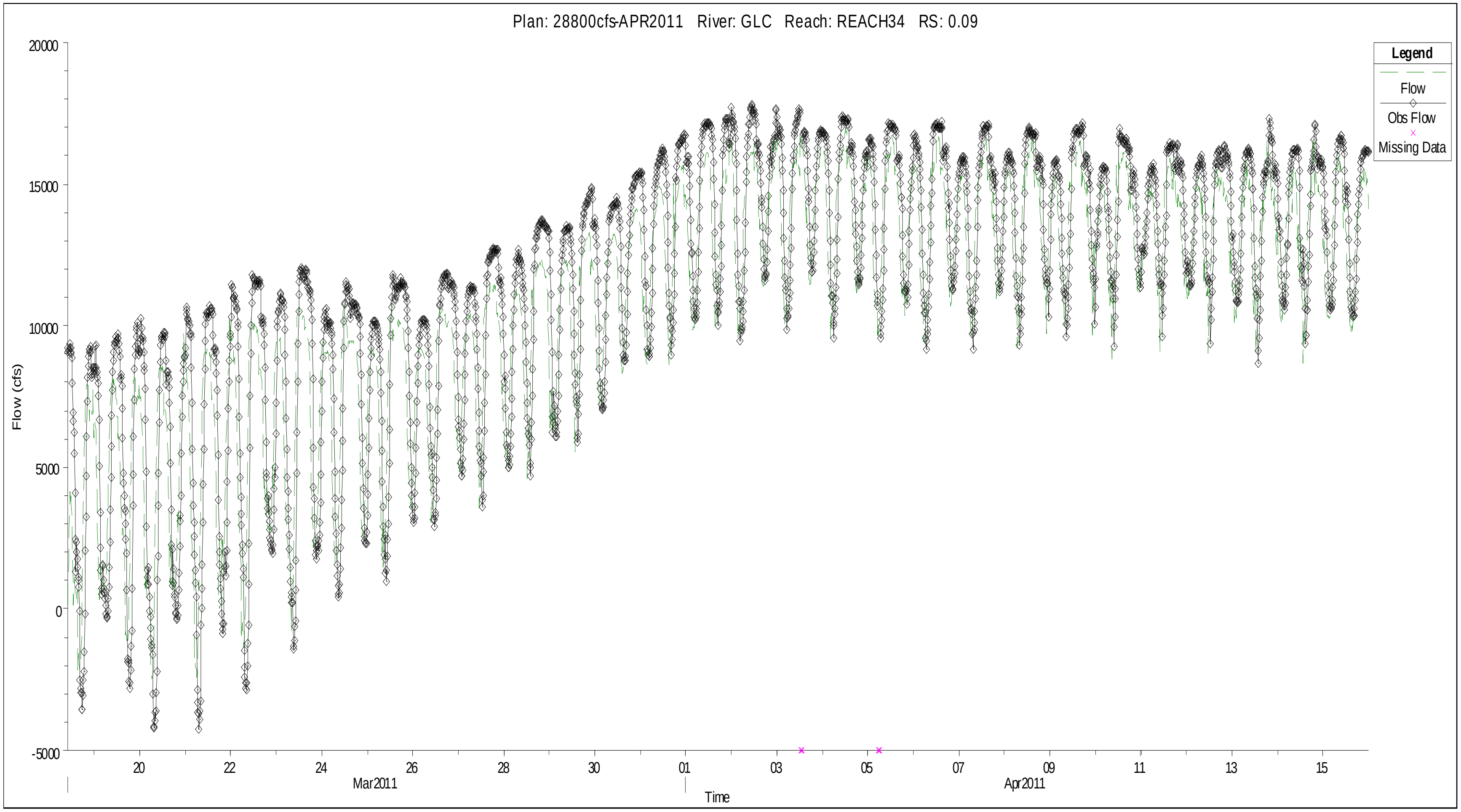


Figure A-25 March 17, 2011 – May 7, 2011 (Peak Flow @ Vernalis 28,900 cfs) Old River at Tracy Rd. Bridge (OLD)

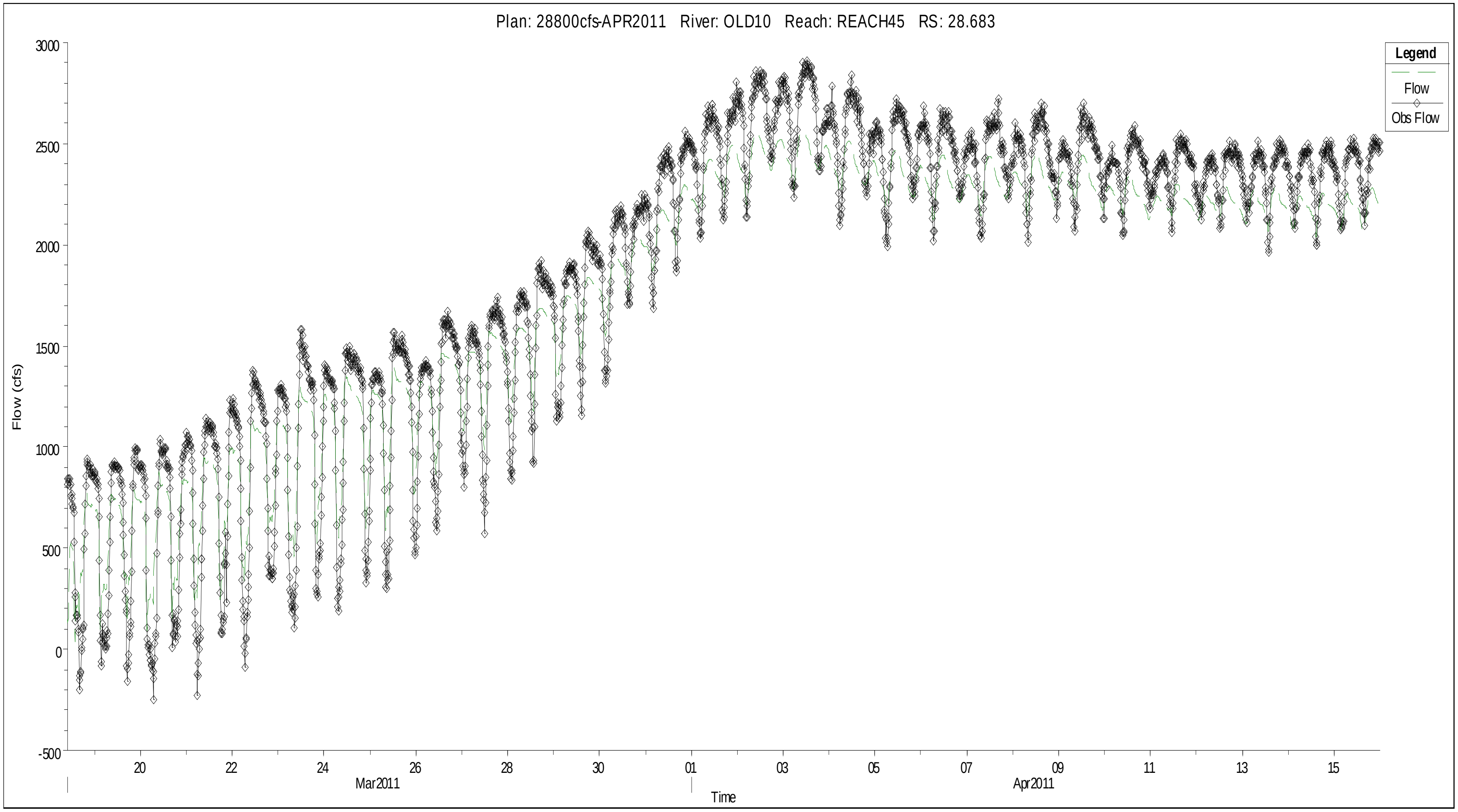


Figure A-26 March 3, 2006 – June 6, 2006 (Peak Flow @ Vernalis 34,800 cfs) San Joaquin River at Mossdale (MSD)

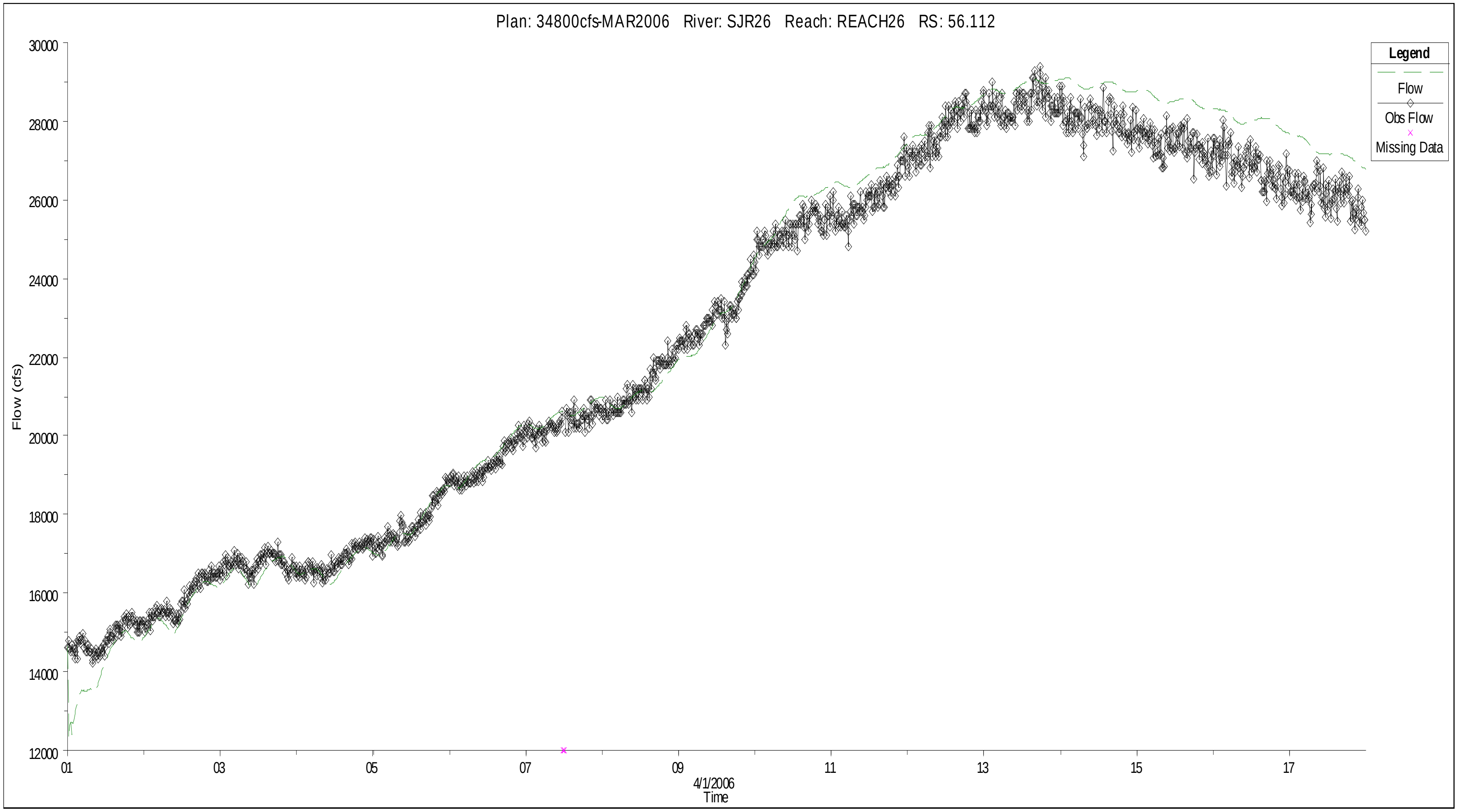


Figure A-27 March 3, 2006 – June 6, 2006 (Peak Flow @ Vernalis 34,800 cfs) San Joaquin River at Garwood Bridge (SJG)

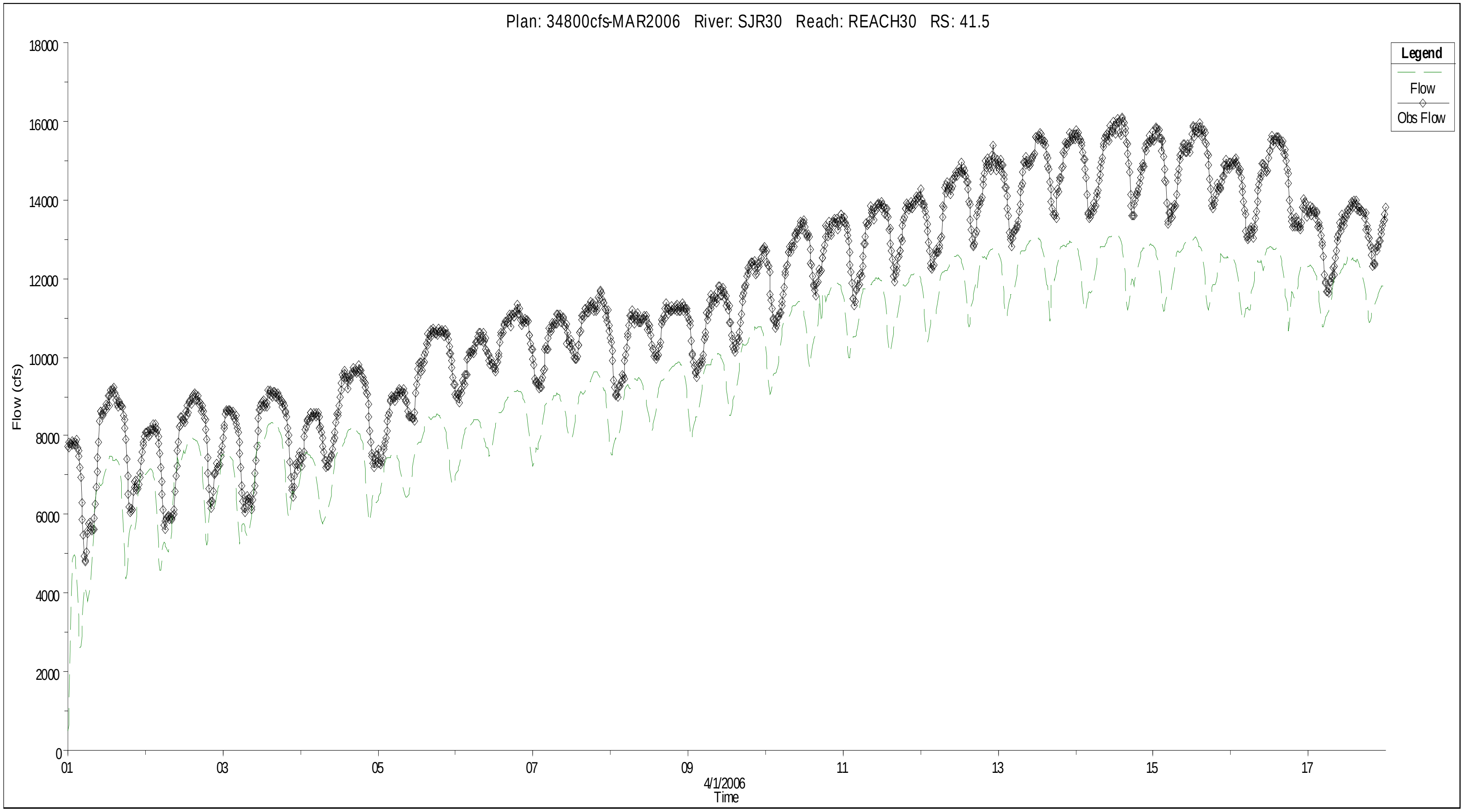
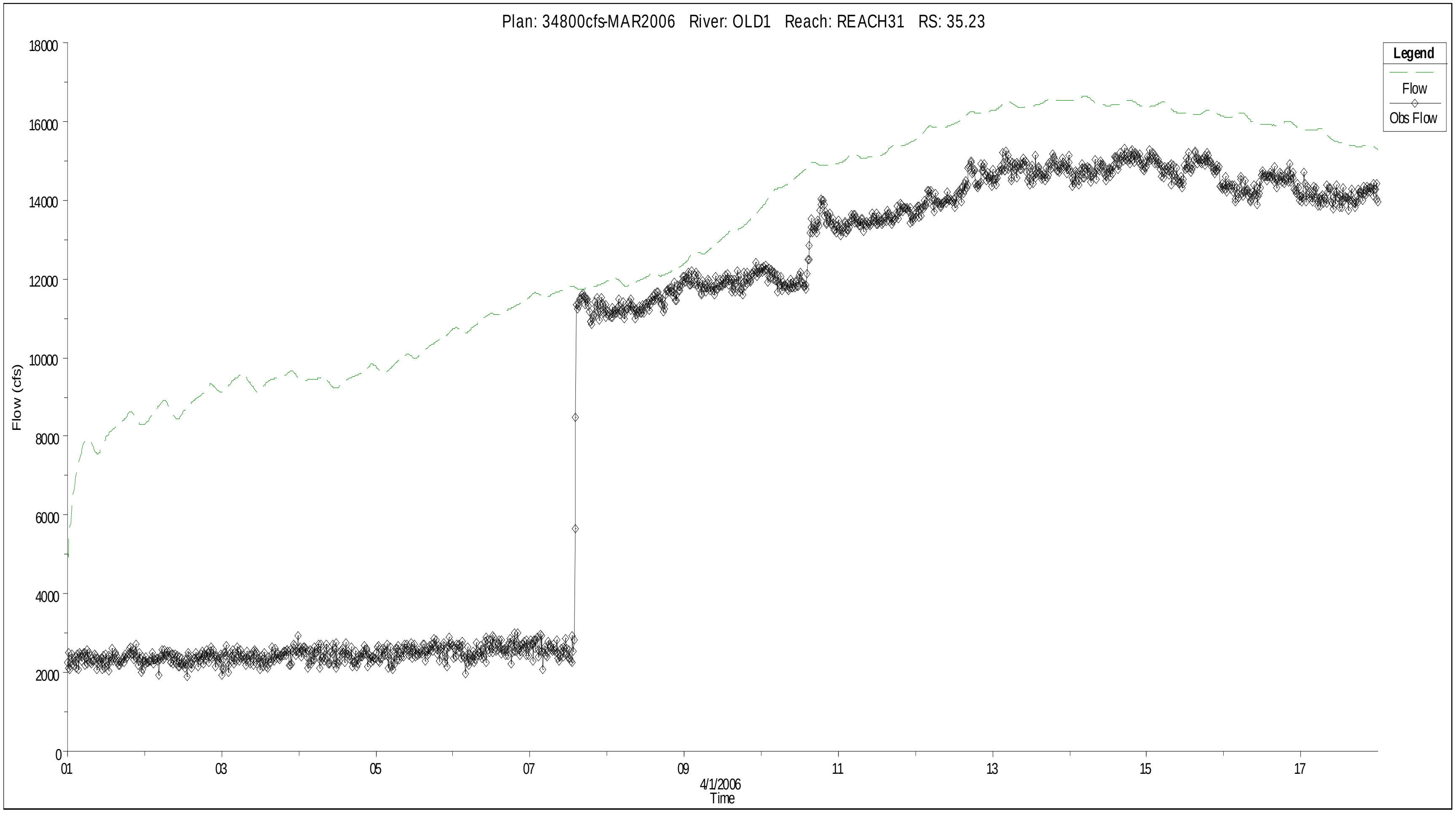


Figure A-28 March 3, 2006 – June 6, 2006 (Peak Flow @ Vernalis 34,800 cfs) Head of Old River (OH1)



116

Figure A-29 March 3, 2006 – June 6, 2006 (Peak Flow @ Vernalis 34,800 cfs) Grantline Canal (GLC)

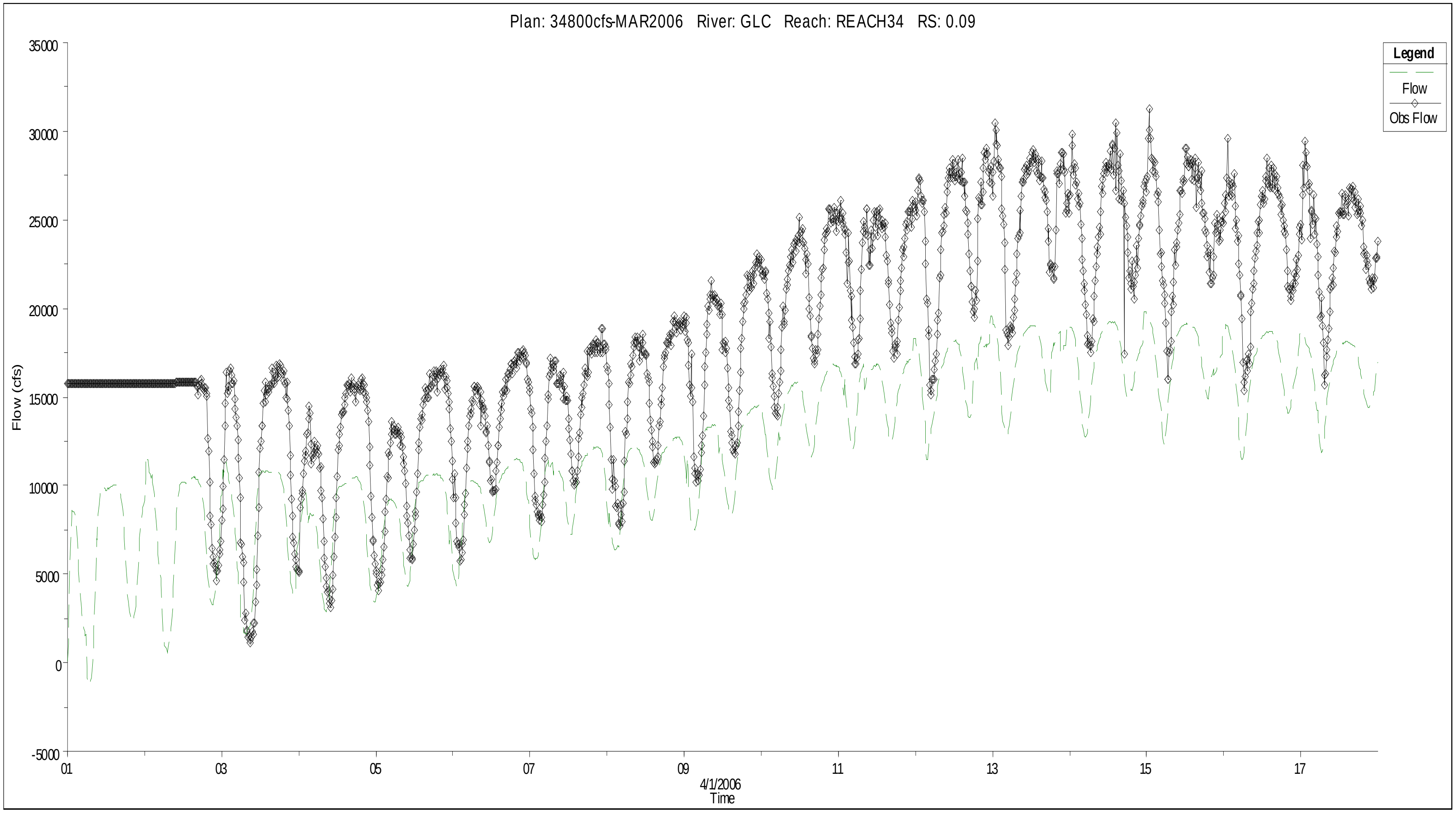


Table A-5 Calibration results, time lag for peak stage and peak flow (peak time observed – peak time simulated)		Upper SJ River	Lower SJ River				Upper Old River	Middle River			Grantline Canal			Lower Old River		
Peak Flow @ Vernalis	Station	MSD	SJL	BDT	SJG	RRI	OH1	MRU	MHR	MTB	DGL	GCT	GLC	OLD-OLR	OAD - ODM	OBD
	XS	SJR 26 56.112	SJR 30 52.95	SJR 30 47.32	SJR 30 41.5	SJR 30 37.93	OLD 1 35.23	MIDDLE 27.025	MIDDLE 23.195	MIDDLE 18.117	GLC 27.518	GLC 26.071	GLC 0.09	OLD 10 28.683	OLD 10 1.735757	OLD 10 1.565757
	Indicator	hr:min	hr:min	hr:min	hr:min	hr:min	hr:min	hr:min	hr:min	hr:min	hr:min	hr:min	hr:min	hr:min	hr:min	hr:min
1,470cfs Jan. - Feb. 2010	Stage	0:00	0:00	0:15	0:15	0:15	0:00	0:00	15:00	0:00	0:00	0:15	0:15	0:00	0:15	0:00
	Flow	1:30	0:45	-0:30	-1:50	-0:15	0:45	N/A	N/A	N/A	N/A	0:15	0:00	N/A	0:00	N/A
4,200cfs Jan. - Feb. 2010	Stage	0:00	0:00	0:15	0:15	0:00	0:00	0:15	0:15	0:00	0:00	0:15	0:15	0:15	0:15	0:15
	Flow	0:30	-1:00	0:15	0:45	0:00	0:30	0:30	N/A	N/A	N/A	-0:15	0:30	N/A	0:15	N/A
5,010cfs Feb. - Mar. 2010	Stage	0:00	0:00	0:15	0:15	0:00	0:00	0:00	0:00	0:15	0:00	0:00	0:00	0:15	0:15	0:00
	Flow	1:00	0:15	0:30	0:15	0:15	0:15	0:15	N/A	N/A	N/A	-0:30	0:00	N/A	0:30	N/A
7,400cfs Feb. 2011	Stage	0:30	0:30	0:00	0:15	0:00	-0:15	0:15	0:15	0:00	0:00	0:00	0:15	0:30	0:00	0:00
	Flow	0:30	-0:15	0:00	-0:15	-0:15	0:15	N/A	N/A	N/A	N/A	-0:15	0:15	0:45	N/A	N/A
12,400cfs Feb. - Mar. 2011	Stage	-0:45	0:00	0:30	0:15	-0:15	0:15	0:15	0:15	0:00	0:00	0:00	0:00	0:00	0:15	0:15
	Flow	-1:00	0:30	0:00	-0:15	0:00	0:45	N/A	N/A	N/A	N/A	-0:15	0:15	0:15	N/A	N/A
15,600cfs Dec. - Jan. 2011	Stage	-0:30	0:00	0:15	0:15	0:00	0:00	0:15	0:45	0:00	0:00	0:15	0:00	0:15	0:15	0:00
	Flow	0:30	0:00	0:00	0:15	0:00	0:30	N/A	N/A	N/A	N/A	-0:15	0:15	N/A	N/A	N/A
28,900cfs Mar. - May. 2011	Stage	0:00	0:00	0:15	0:15	0:15	-0:45	0:15	0:15	0:00	0:00	1:00	1:00	0:15	0:15	0:15
	Flow	0:00	1:00	1:00	0:30	-0:15	0:00	N/A	N/A	N/A	N/A	0:00	1:00	0:15	N/A	N/A

Peak stage time lag between observed and simulated data (blue)

Peak flow time lag between observed and simulated data (green)

Table A-6 Validation results , time lag for peak stage and peak flow (peak time observed – peak time simulated)		Upper SJ River	Lower SJ River				Upper Old River	Middle River			Grantline Canal			Lower Old River		
Peak Flow @ Vernalis	Station	MSD	SJL	BDT	SJG	RRI	OH1	MRU	MHR	MTB	DGL	GCT	GLC	OLD-OLR	OAD	OBD
	XS	SJR 26 56.112	SJR 30 52.95	SJR 30 47.32	SJR 30 41.5	SJR 30 37.93	OLD 1 35.23	MIDDLE 27.025	MIDDLE 23.195	MIDDLE 18.117	GLC 27.518	GLC 26.071	GLC 0.09	OLD 10 28.683	OLD 10 1.735757	OLD 10 1.565757
	Indicator	hr:min	hr:min	hr:min	hr:min	hr:min	hr:min	hr:min	hr:min	hr:min	hr:min	hr:min	hr:min	hr:min	hr:min	hr:min
12,800cfs	Stage	0:00	0:30	0:30	N/A	0:00	-0:45	0:00	0:15	0:00	0:00	0:00	N/A	0:00	0:15	0:00
Feb 2006	Flow	0:00	1:00	N/A	1:00	N/A	0:30	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
16,200cfs	Stage	N/A	-0:15	0:15	N/A	0:30	0:00	-0:15	0:30	0:15	-0:15	0:45	N/A	0:00	-0:45	0:15
May 2005	Flow	N/A	0:30	N/A	1:00	N/A	0:30	N/A	N/A	N/A	N/A	N/A	1:30	N/A	N/A	N/A
19,800cfs	Stage	0:30	0:00	0:15	N/A	0:00	N/A	0:00	0:45	0:00	0:00	0:00	N/A	0:15	0:30	0:00
Dec. - Jan. 2006	Flow	0:30	-0:30	N/A	N/A	N/A	0:30	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
34,800cfs	Stage	0:00	0:00	0:00	N/A	0:00	-0:45	0:15	0:15	0:00	0:30	1:15	1:15	-0:15	-0:15	0:15
Mar. - Jun. 2006	Flow	-0:15	-1:30	N/A	1:30	N/A	-1:00	N/A	N/A	N/A	N/A	N/A	1:15	N/A	N/A	N/A
35,200cfs	Stage	-0:15	N/A	0:15	N/A	0:00	0:00	0:00	N/A	0:00	N/A	0:45	N/A	0:00	N/A	0:00
Jan. - Mar. 1998	Flow	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Peak stage time lag between observed and simulated data (blue)

Peak flow time lag between observed and simulated data (green)

Table A-7 Existing Conditions - FLOW

Output Location	Reach	XS	Q Max 010	Q Max 025	Q Max 050	Q Max 100	Q Max 200	Q Max 500
A. Paradise Cut Weir	SJR 26	58.54	6,143	9,036	11,171	22,886	29,884	33,136
B. Paradise Cut at UPRR Bridge	PARAD	6.74	6,153	9,046	11,180	22,895	30,728	41,136
C. San Joaquin River at Calaveras River	SJR 30	37.59	12,201	14,092	15,395	22,928	25,210	25,301
D. Old River above Junction with Paradise Cut	OLD 2	30.00	14,948	16,786	18,095	26,095	28,802	28,629

Table A-8 Existing Conditions – Stage in NGVD 29

Output Location	Damage Area	Reach	XS	S Max 010	S Max 025	S Max 050	S Max 100	S Max 200	S Max 500
1. San Joaquin River Upstream of Banta-Carbona Canal	SJ28	SJR 26	71.95	27.28	28.70	29.74	34.97	38.62	39.58
2. San Joaquin River Downstream of Banta-Carbona Canal	SJ29	SJR 26	62.59	22.73	24.25	25.29	30.26	32.11	32.68
3. San Joaquin River upstream of UPRR Bridge	SJ31	SJR 26	57.05	18.01	19.59	20.65	25.67	28.03	29.14
4. San Joaquin River at Mossdale Bridge	SJ32	SJR 26	56.35	17.61	19.18	20.22	25.15	27.44	28.49
5. San Joaquin River at Old River Split	SJ33	SJR 26	53.58	15.37	16.89	17.91	22.55	24.43	25.05
6. San Joaquin River Downstream of Old River Split	SJ36	SJR 30	52.30	14.84	16.35	17.36	21.97	23.72	24.22
7. San Joaquin River at De Lima Road	SJ34	SJR 30	49.86	13.46	14.95	15.95	20.36	21.75	22.04
8. San Joaquin River Downstream of French Camp Slough	SJ35 and STK10_Up	SJR 30	42.86	8.50	9.28	9.88	11.49	12.22	12.78
9. San Joaquin River Upstream of Deep Ship Channel	SJ37	SJR 30	40.40	7.77	8.42	8.95	9.77	10.35	11.09
10. San Joaquin River Upstream Calaveras River	STK10_Down	SJR 30	38.14	7.59	8.19	8.70	9.24	9.75	10.54
11. San Joaquin River Downstream Calaveras River	STK07	SJR 30	36.94	7.56	8.17	8.68	9.20	9.71	10.51
12. Paradise Cut at west end of Stewart Tract	SJ30	PARAD	1.60	9.13	10.51	11.44	14.46	15.96	17.42
13. Old River at west end of Stewart Tract	SJ40	OLD 2	29.70	9.33	10.55	11.40	14.37	15.91	17.40
14. Old River Upstream of Tracy Blvd.	SJ42	OLD 8	29.29	8.36	9.59	10.47	13.13	14.57	16.01
15. Grantline Canal Upstream of Tracy Blvd.	SJ41	GLC	26.93	8.29	9.48	10.38	12.81	14.17	15.56
16. Middle River at Undine Road	SJ39	MIDDLE	27.03	10.84	12.14	13.05	16.66	17.79	18.30
17. Middle River Upstream of HWY 4	SJ38	MIDDLE	16.82	7.05	7.93	8.53	9.28	10.31	11.80

Appendix B – General Maps

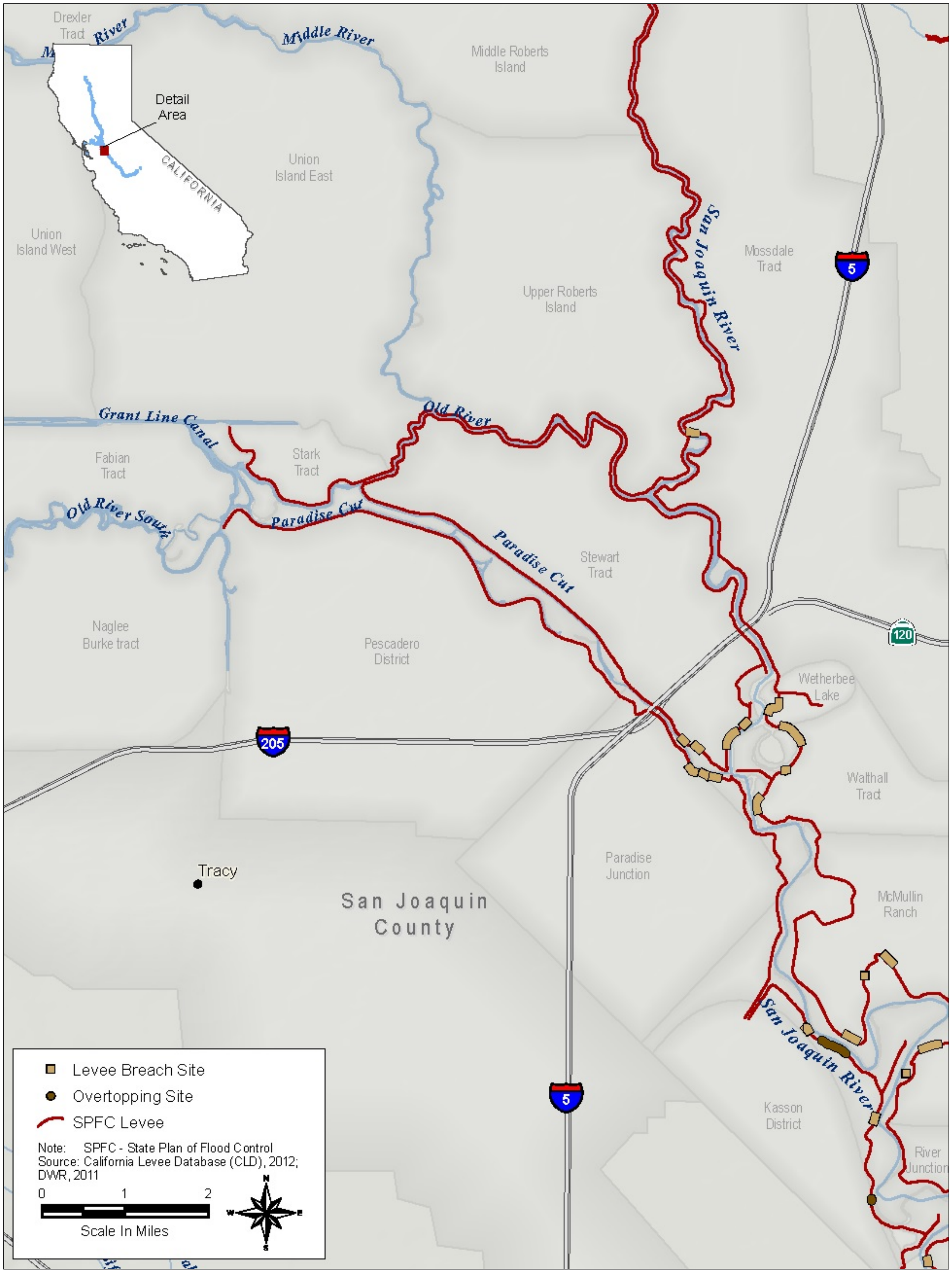


Figure B-1, Historical Breaches and Overtopping in the Study Area (DWR, 2012b)

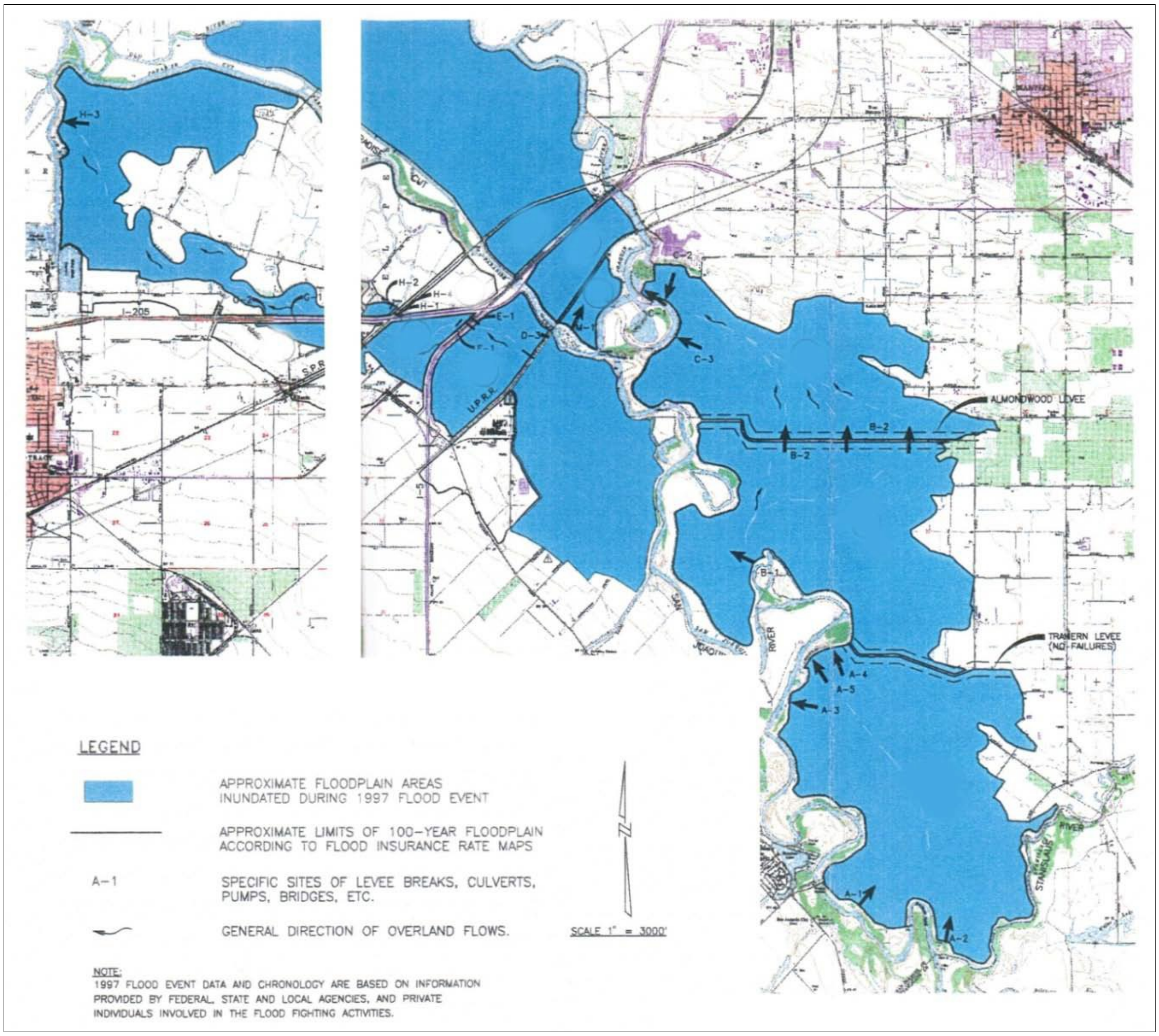


Figure B-2, Approximate Extent of 1997 Floods in the South Delta (South Delta Water Agency, 2007)

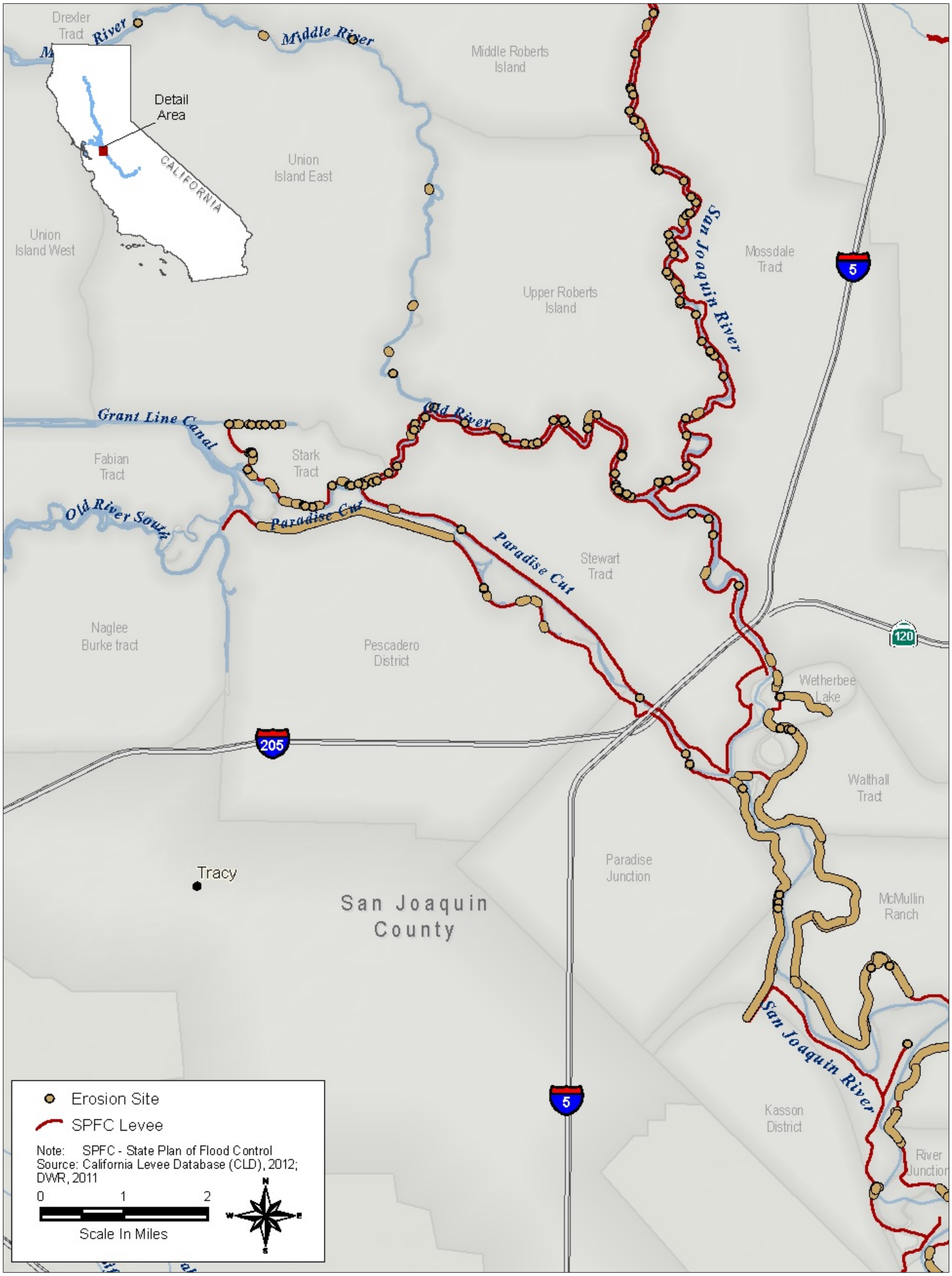


Figure B-3, Historical Erosion Sites in the Study Area (DWR, 2012b)

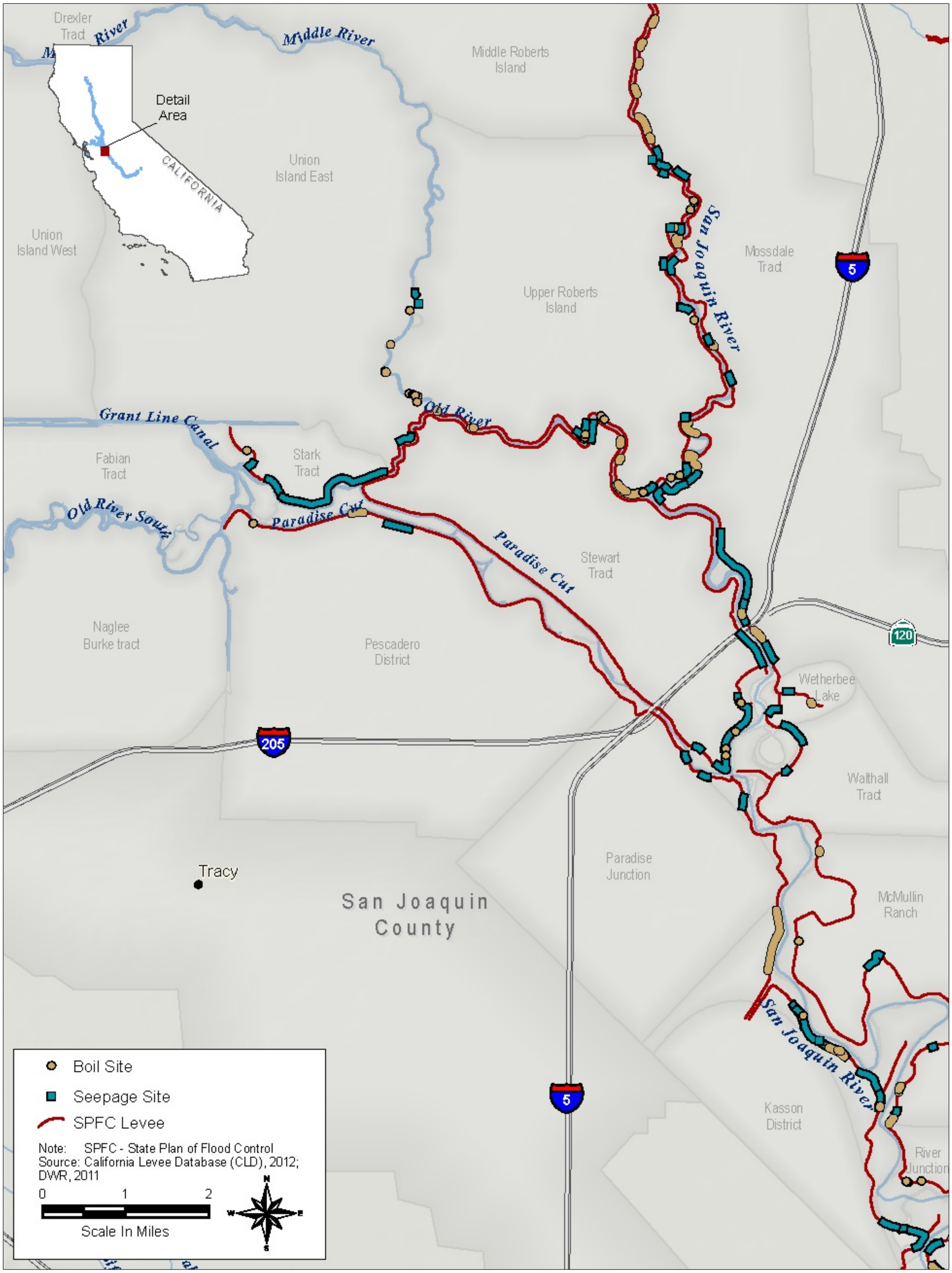


Figure B-4, Historical Seepage Sites in the Study Area (DWR, 2012b)

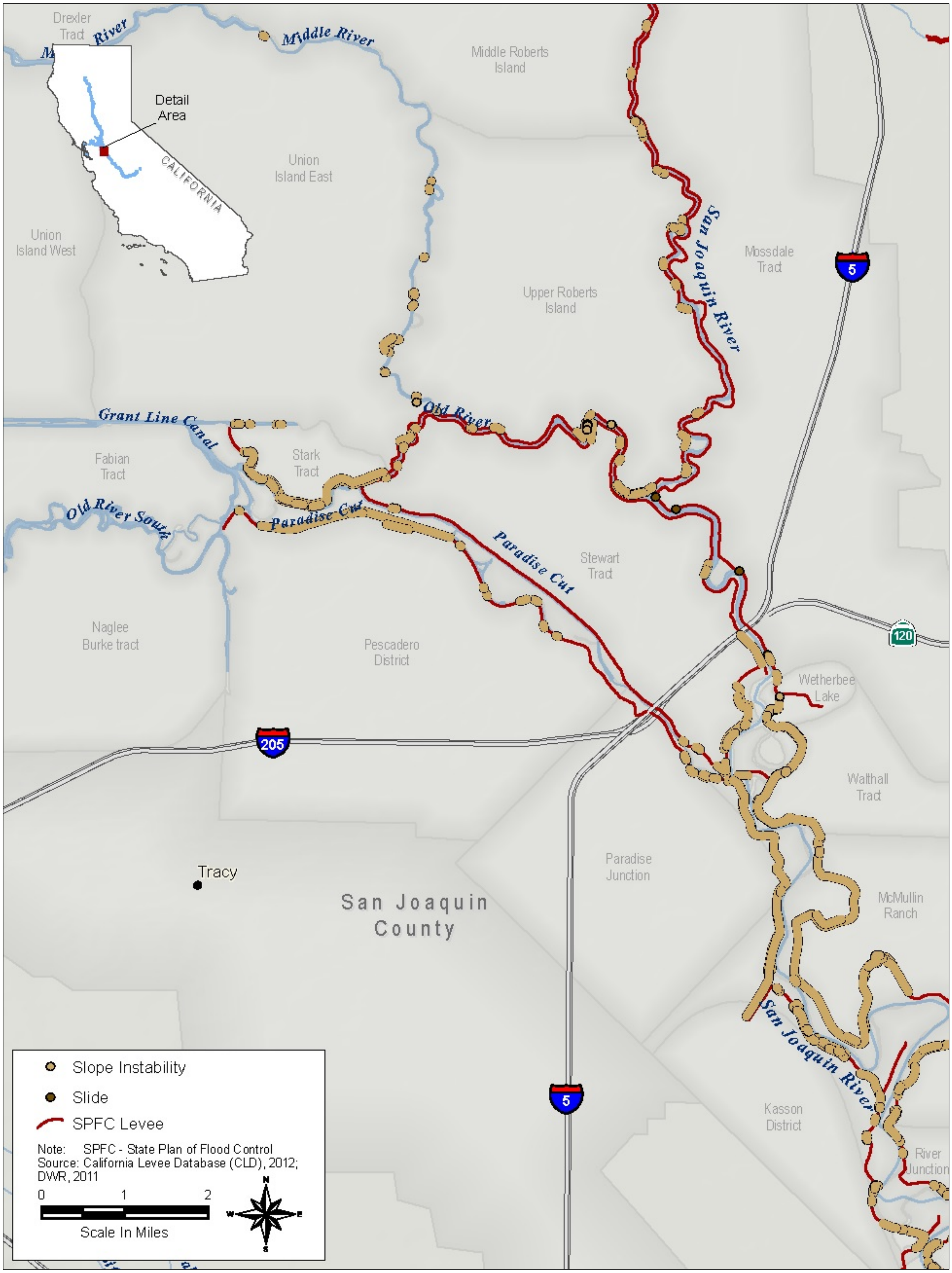


Figure B-5, Historical Slope Instability in the Study Area (DWR, 2012b)

Appendix C – HEC-RAS Model Modification

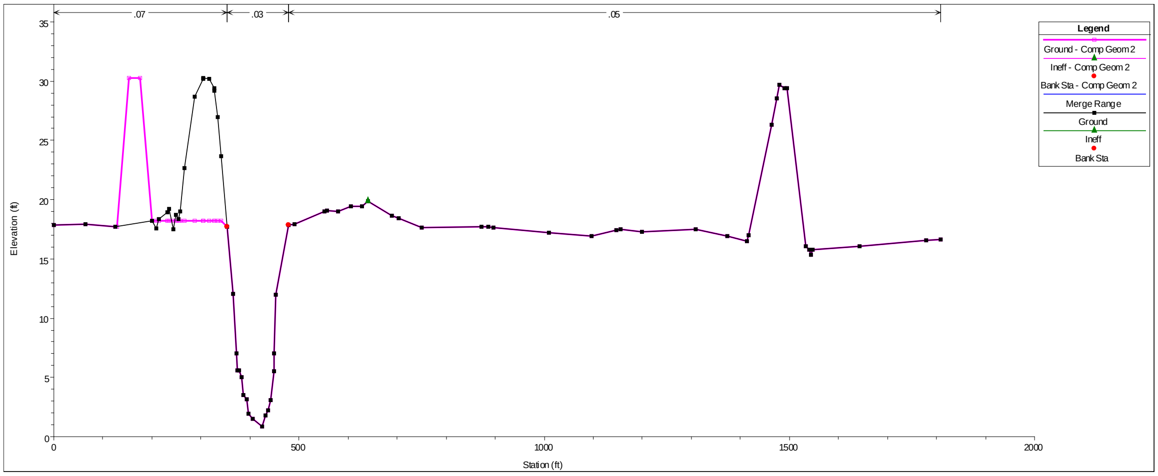


Figure B-1 New Design for UPRR #1 Cross section 6.8925

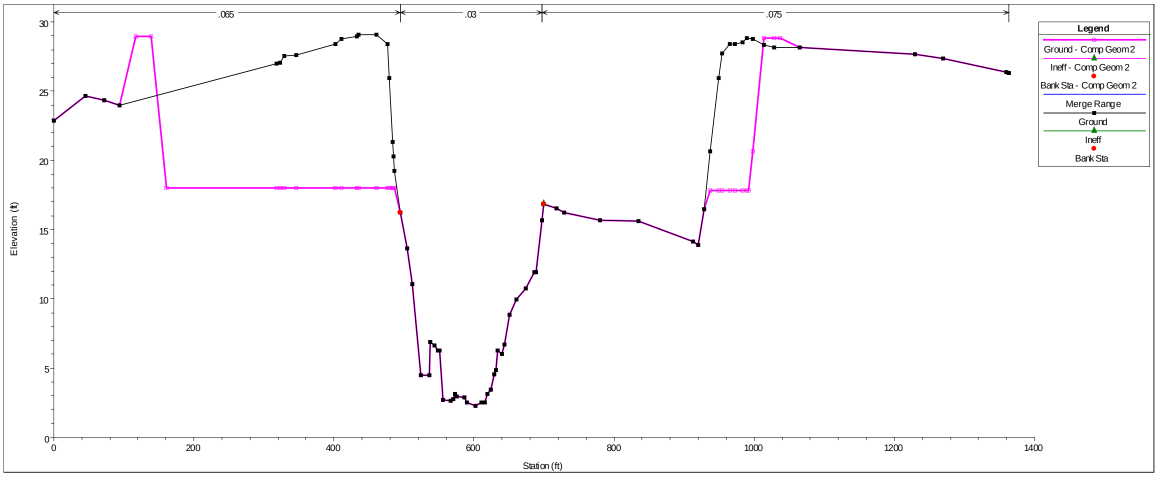


Figure B-2 New Design for UPRR #1 Cross section 6.7424

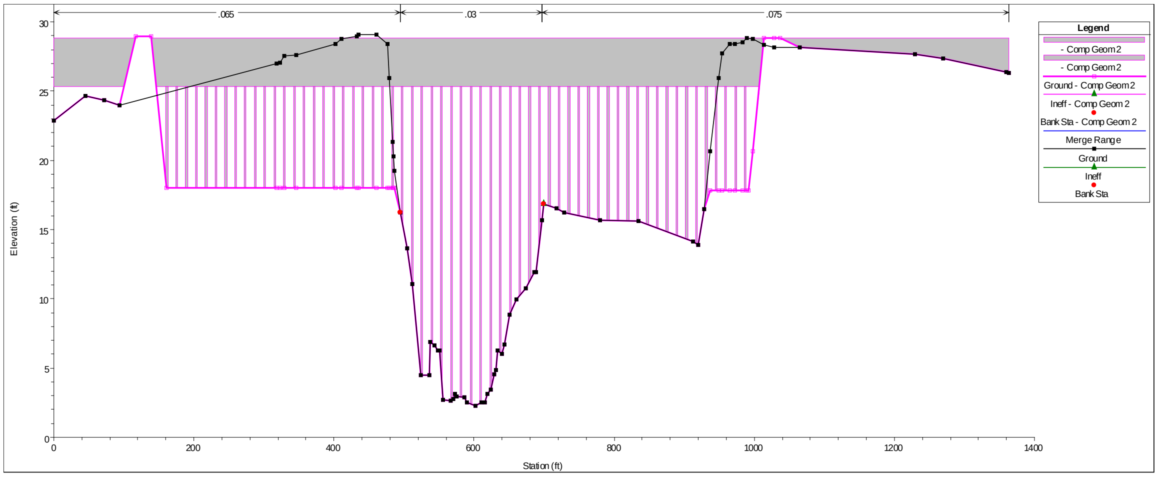


Figure B-3 New Design for UPRR #1 Cross section 6.7424 at Bridge

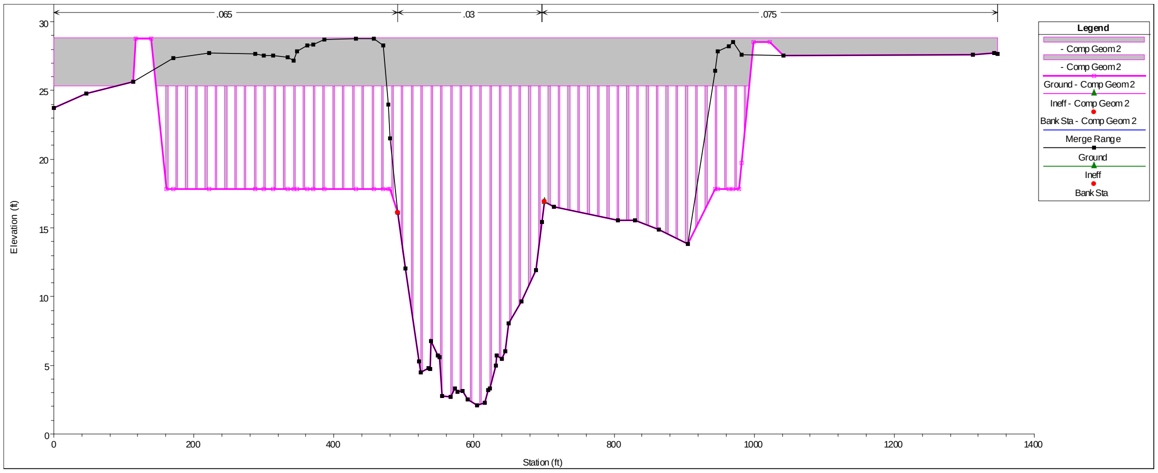


Figure B-4 New Design for UPRR #1 Cross section 6.7391at Bridge

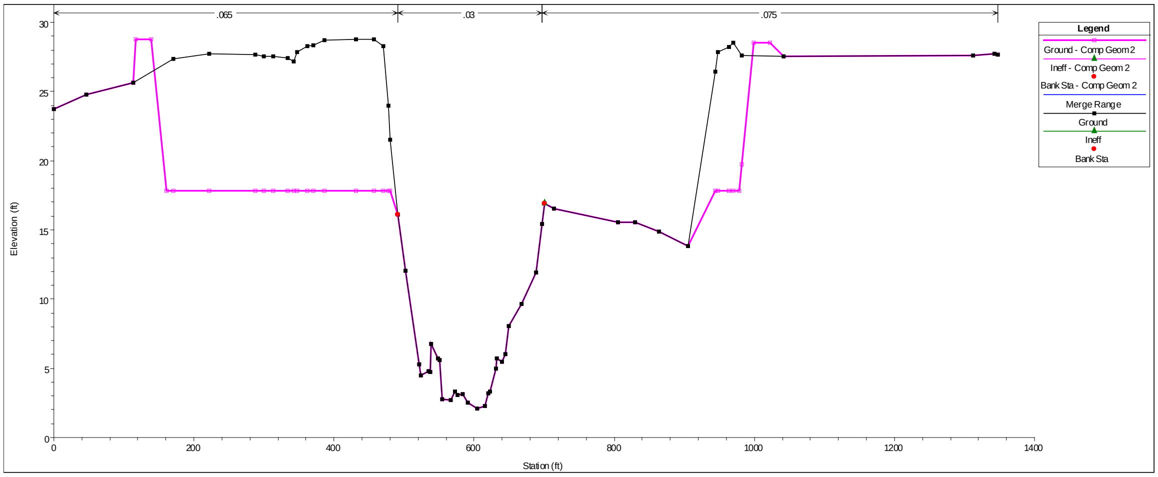


Figure B-5 New Design for UPRR #1 Cross section 6.7391

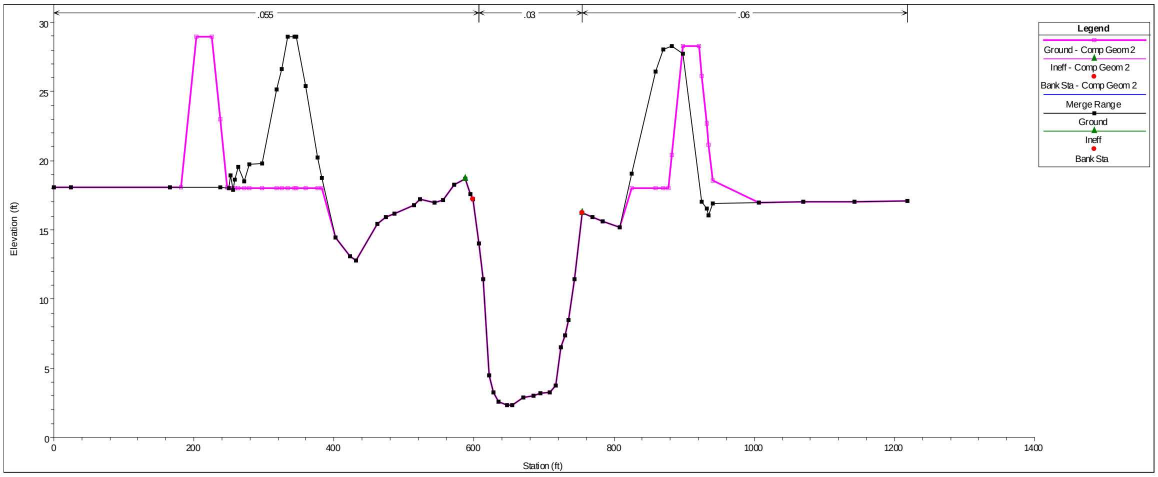


Figure B-6 New Design for UPRR #1 Cross section 6.6561

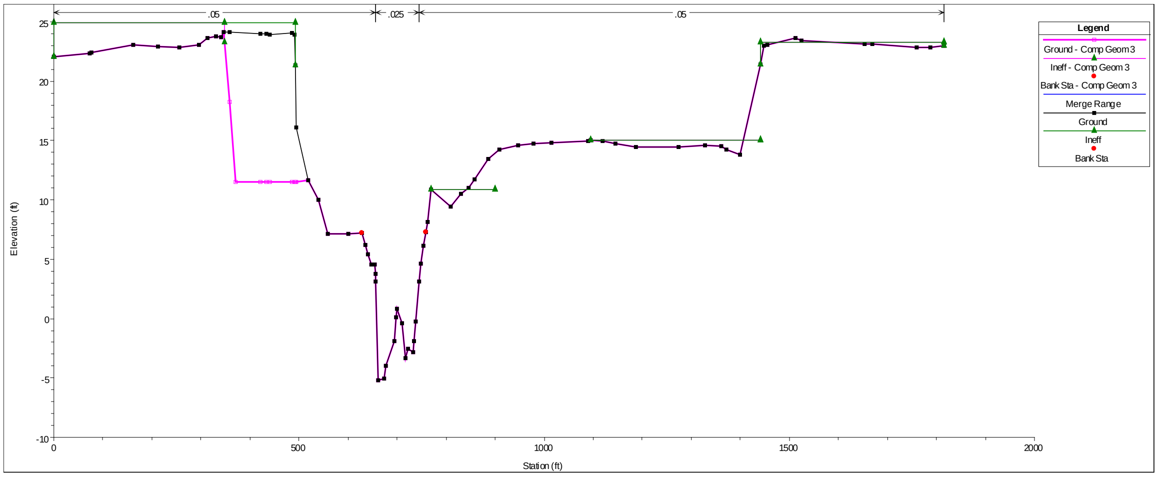


Figure B-7 New Design for UPRR #2 Cross section 5.445

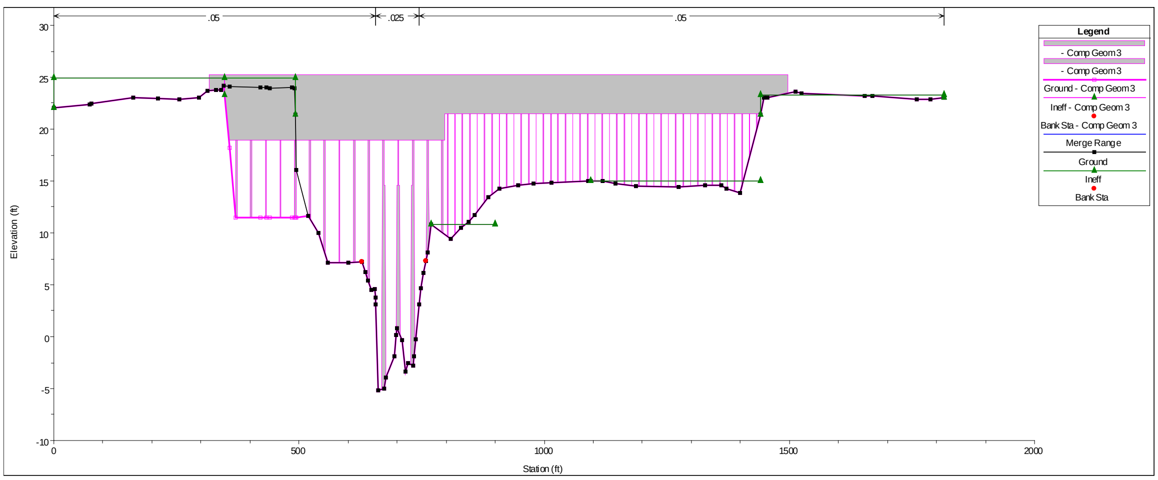


Figure B-8 New Design for UPRR #2 Cross section 5.445 at Bridge

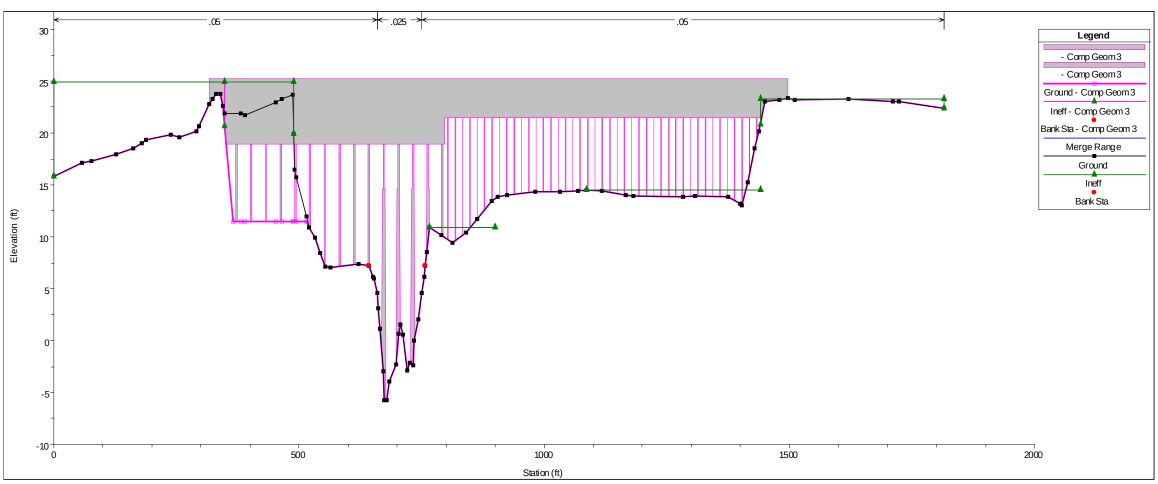


Figure B-9 New Design for UPRR #2 Cross section 5.4417 at Bridge

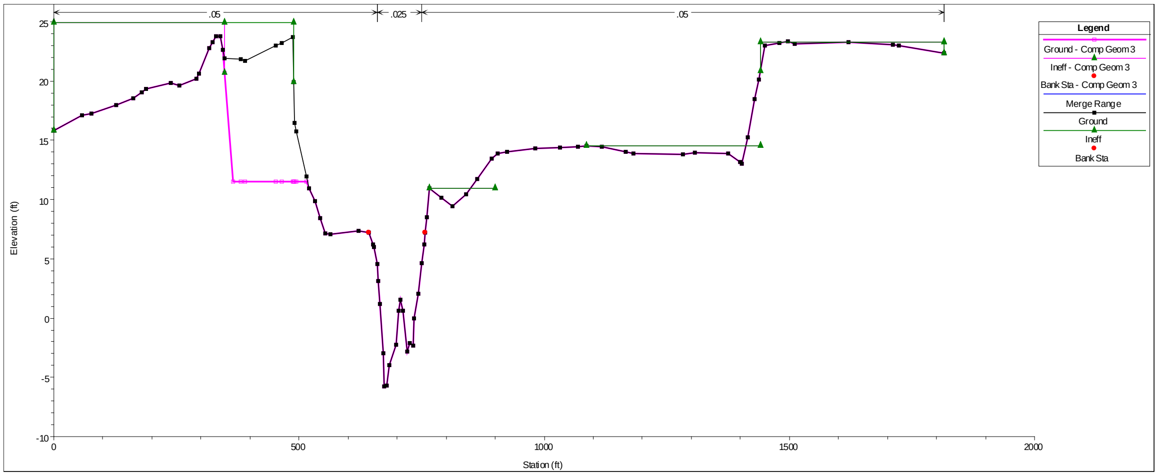
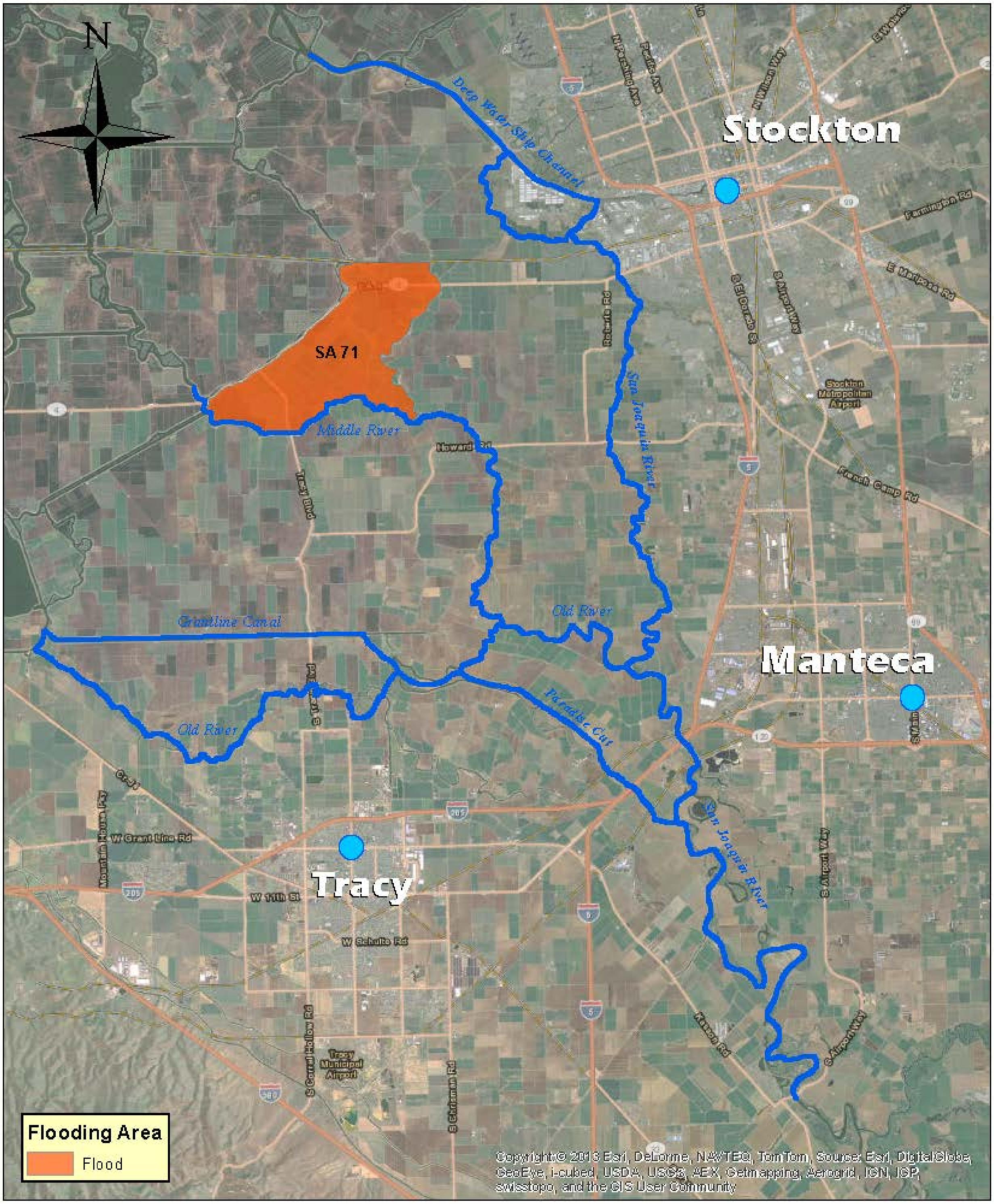


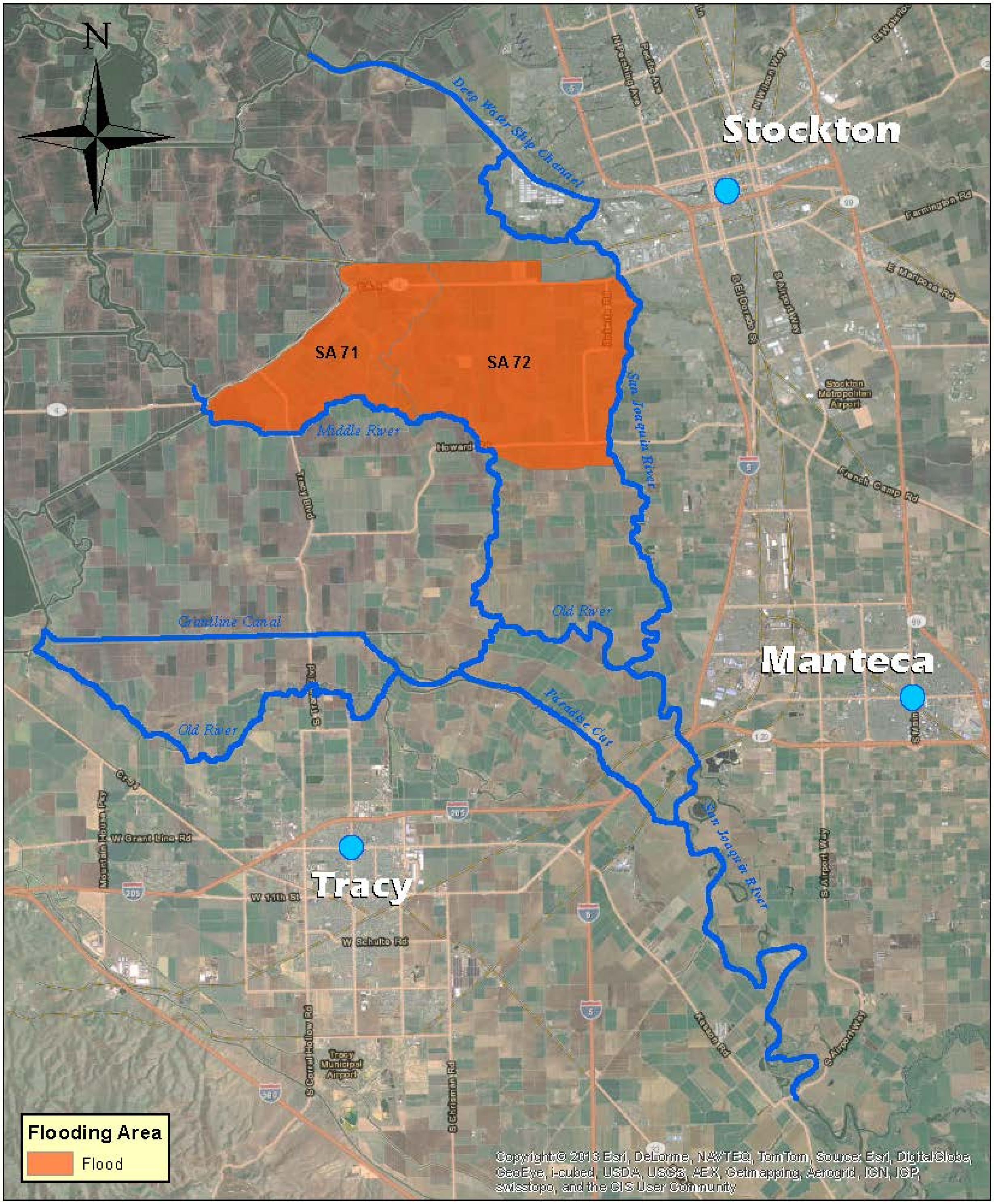
Figure B-10 New Design for UPRR #2 Cross section 5.4417

Appendix D – Hydraulics Results at Existing Conditions and with Feature Modifications

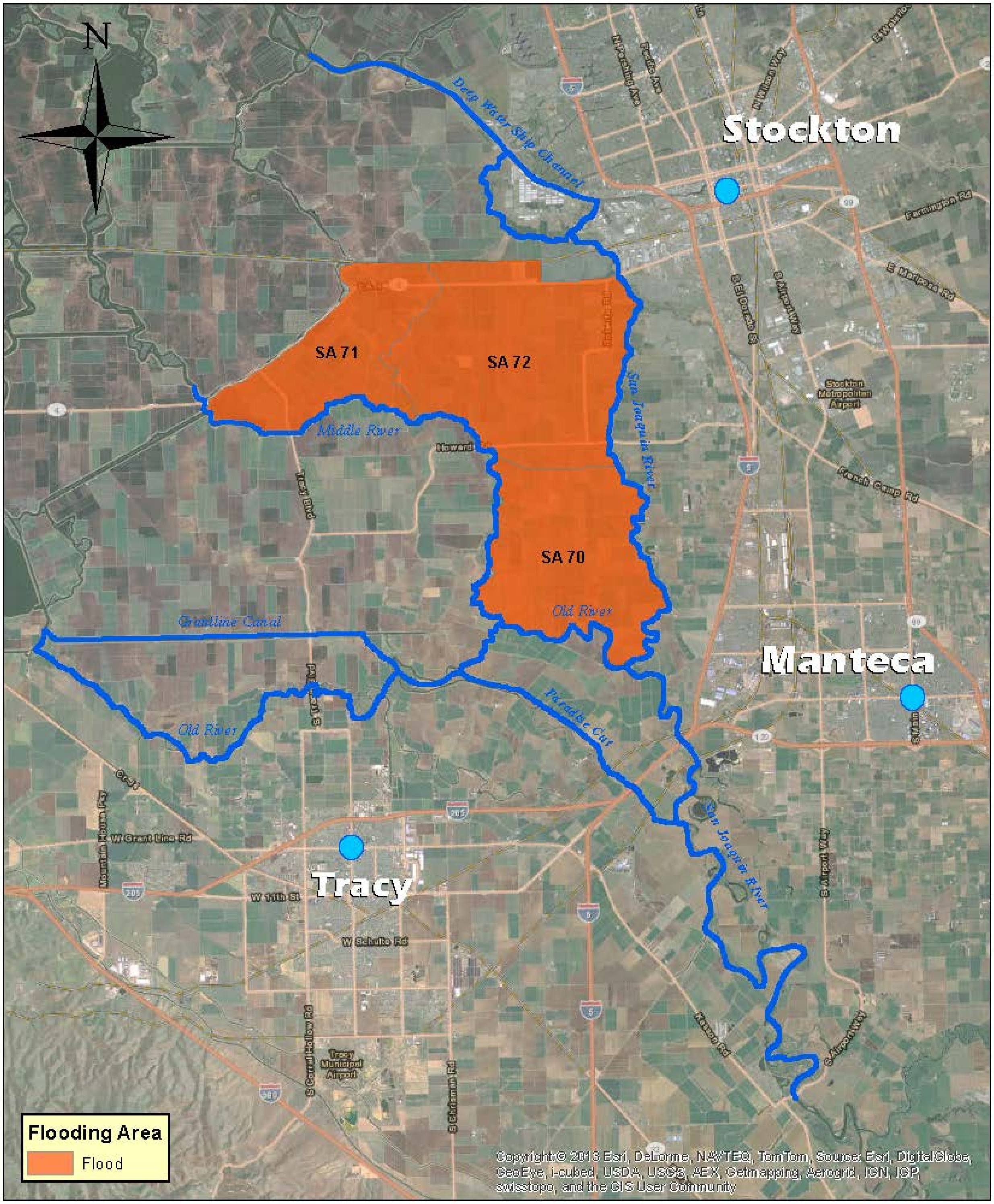
10 Year Flood Existing Conditions



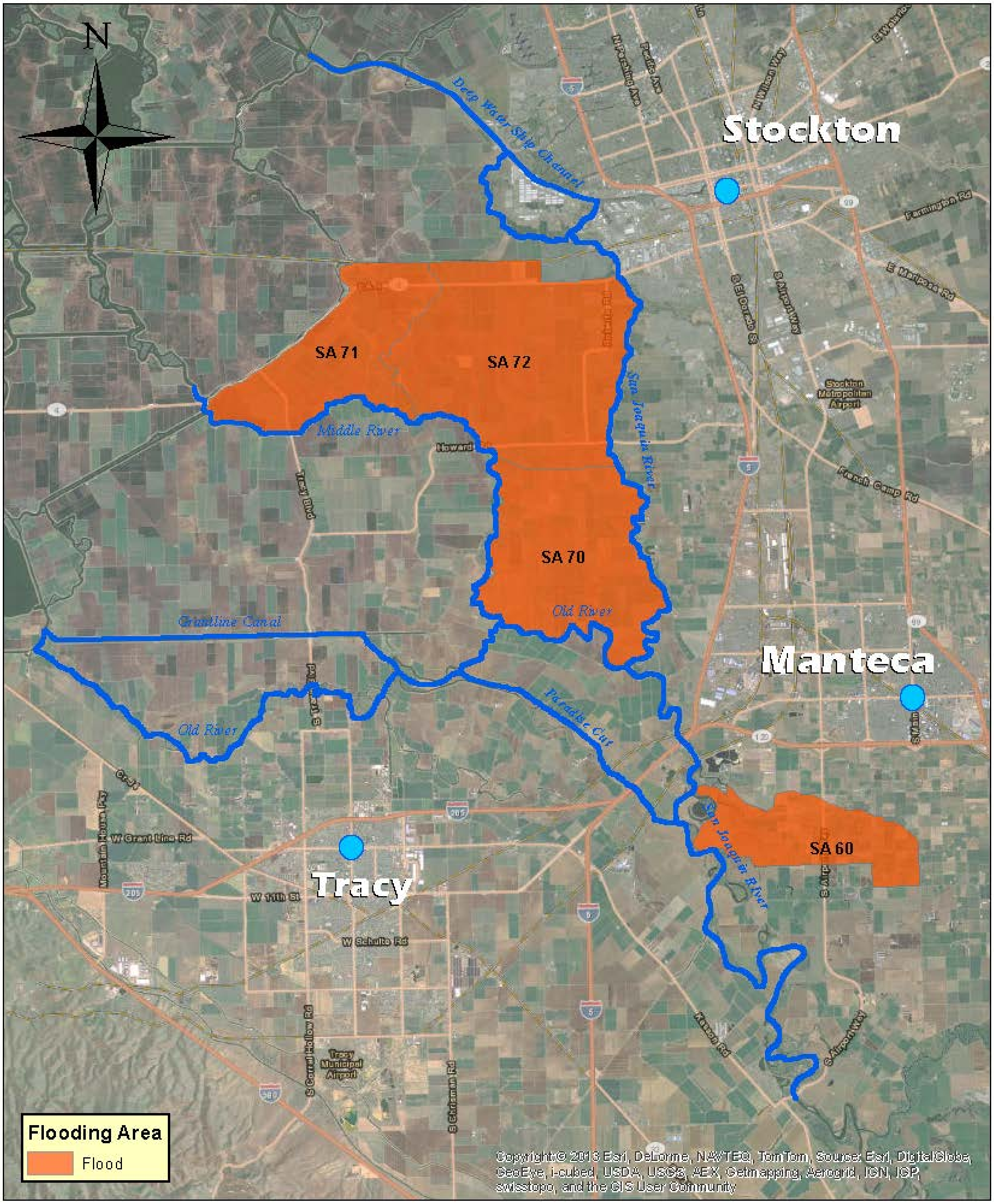
25 Year Flood Existing Conditions



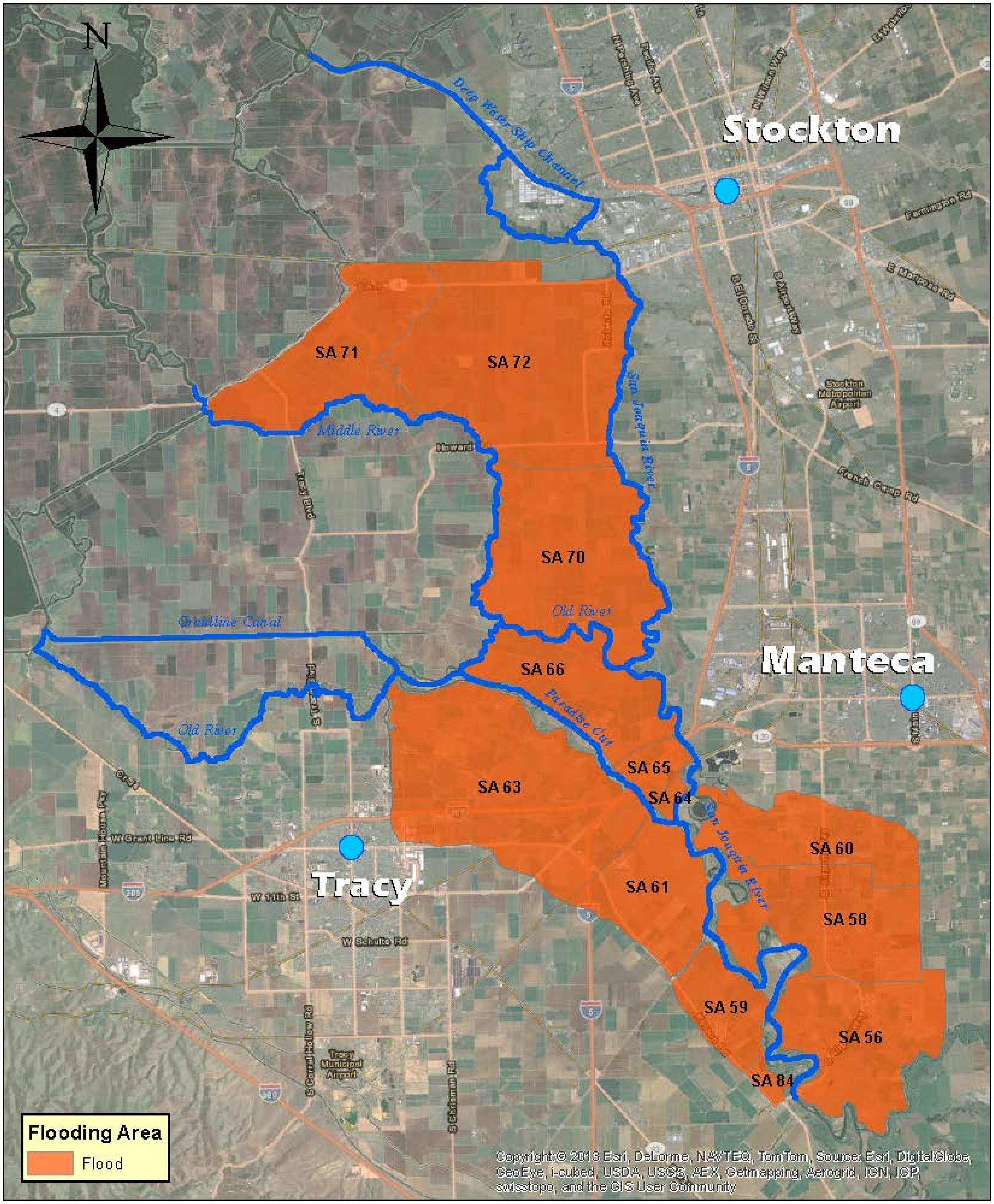
50 Year Flood Existing Conditions



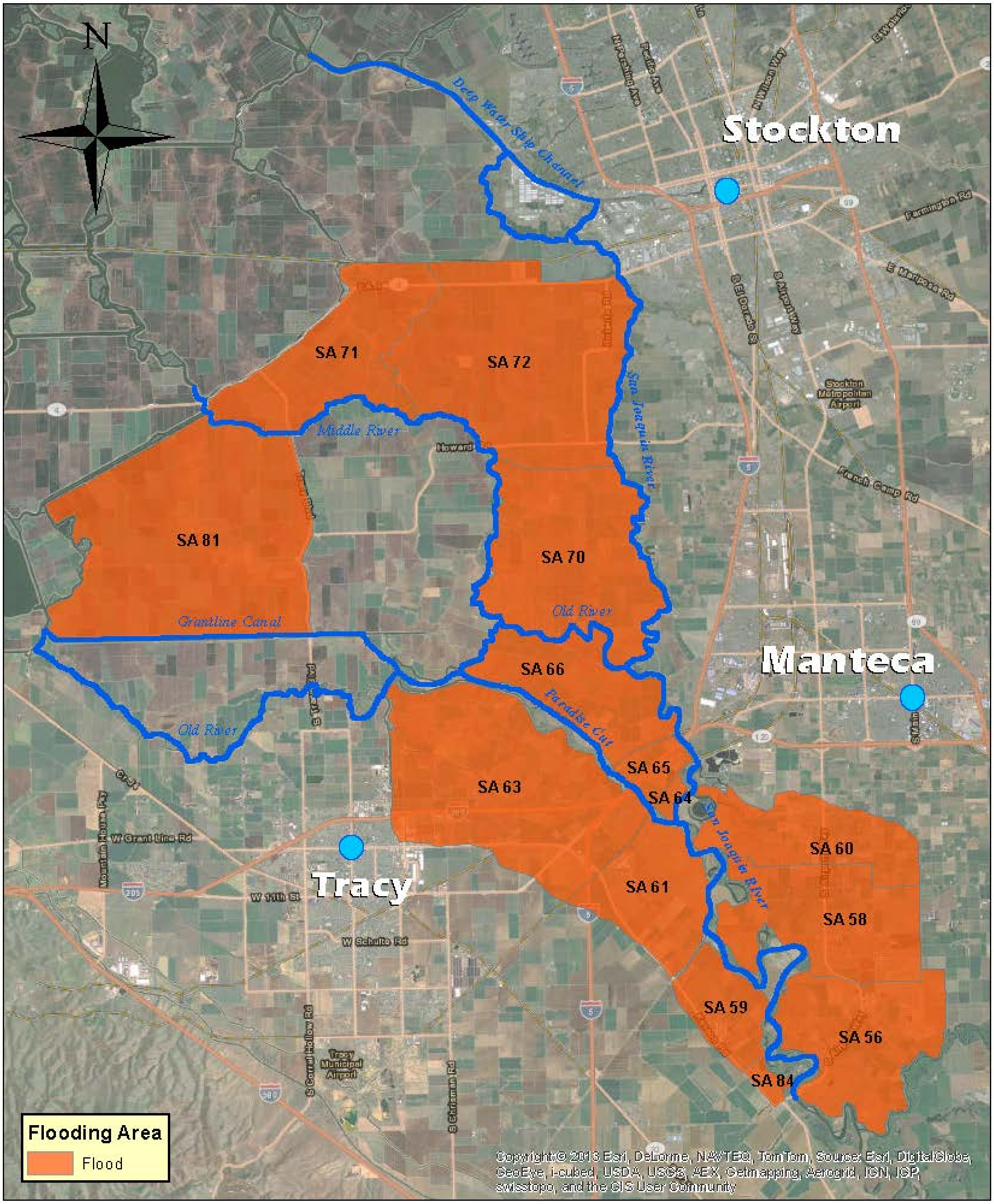
100 Year Flood Existing Conditions



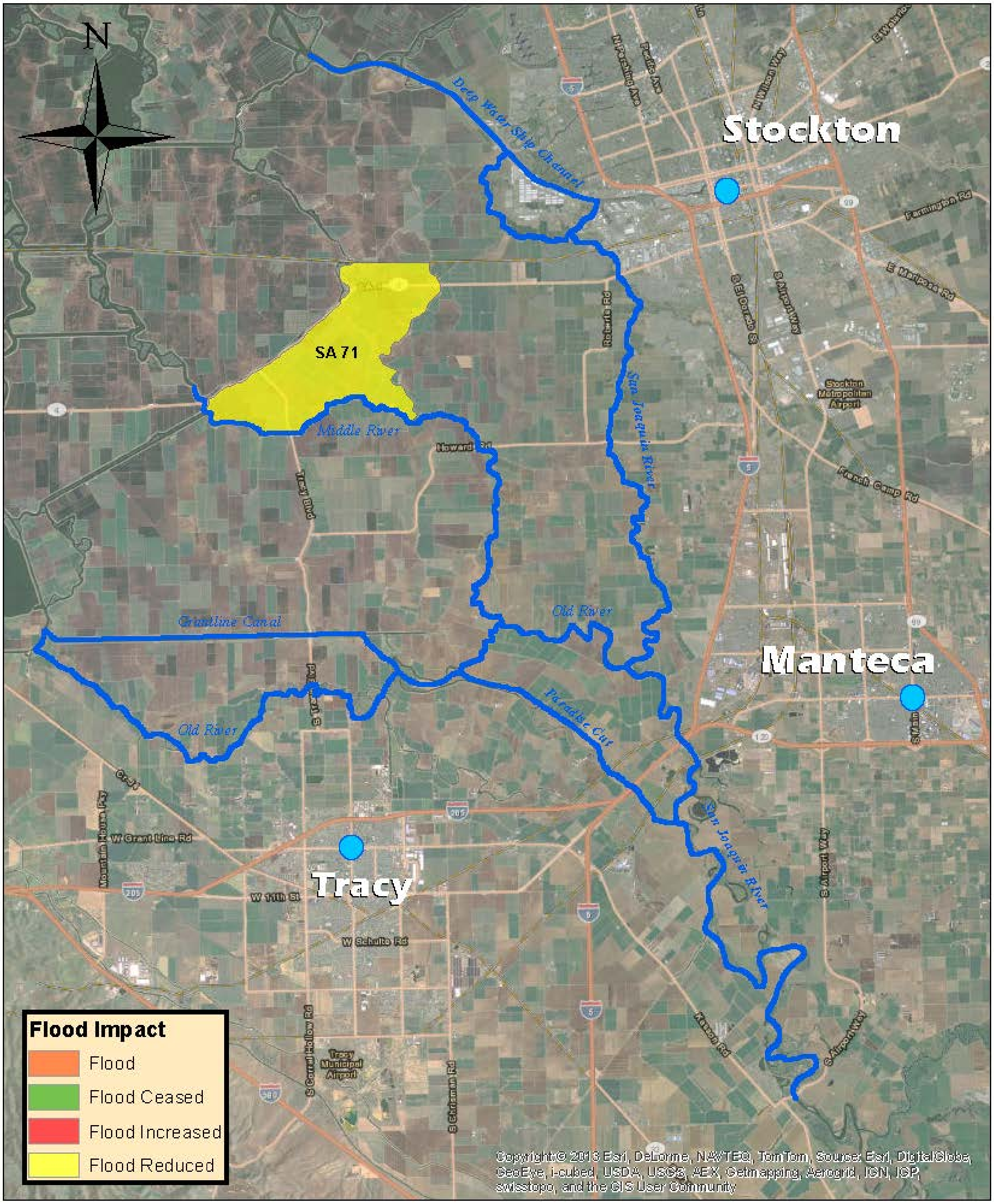
200 Year Flood Existing Conditions



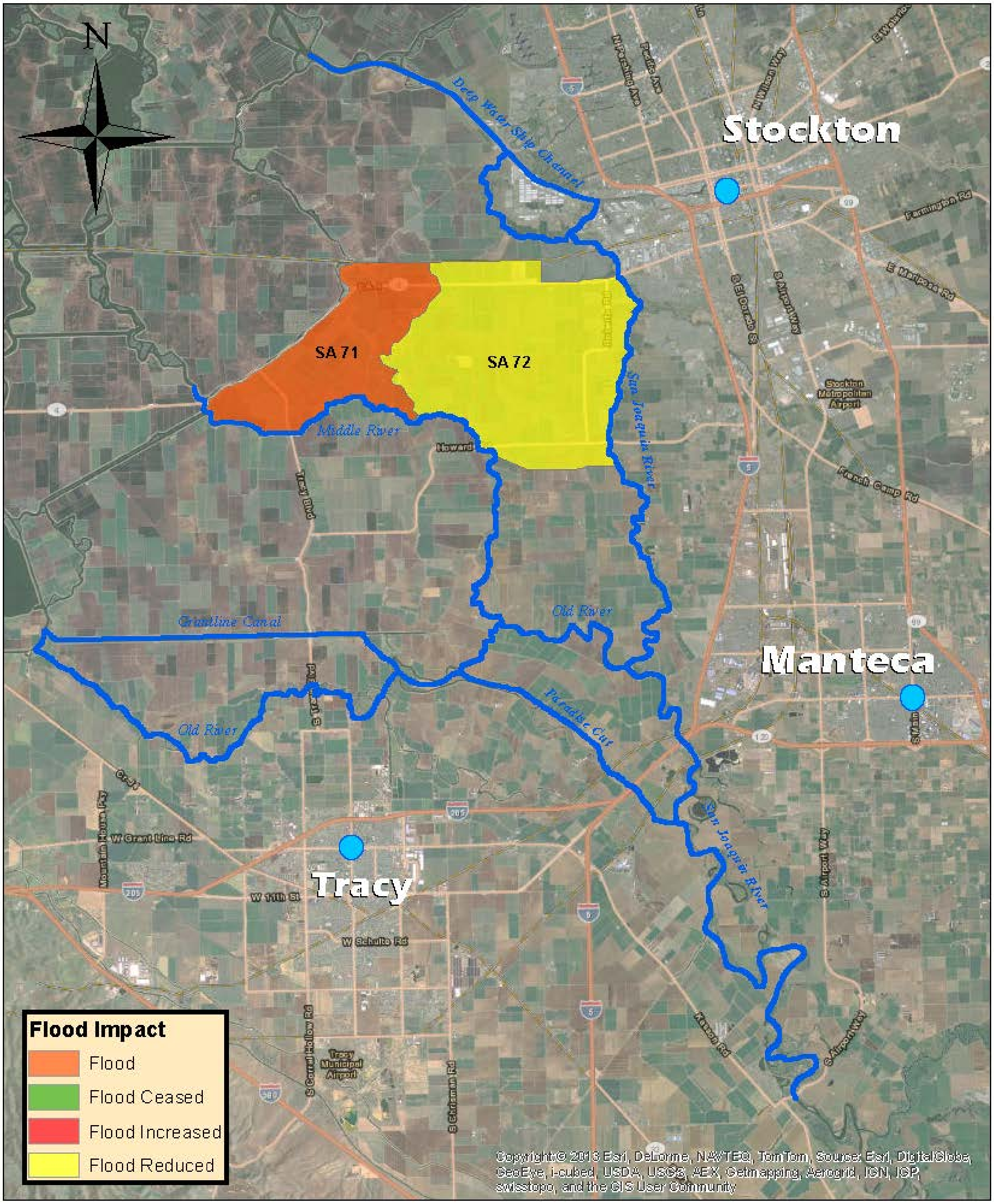
500 Year Flood Existing Conditions



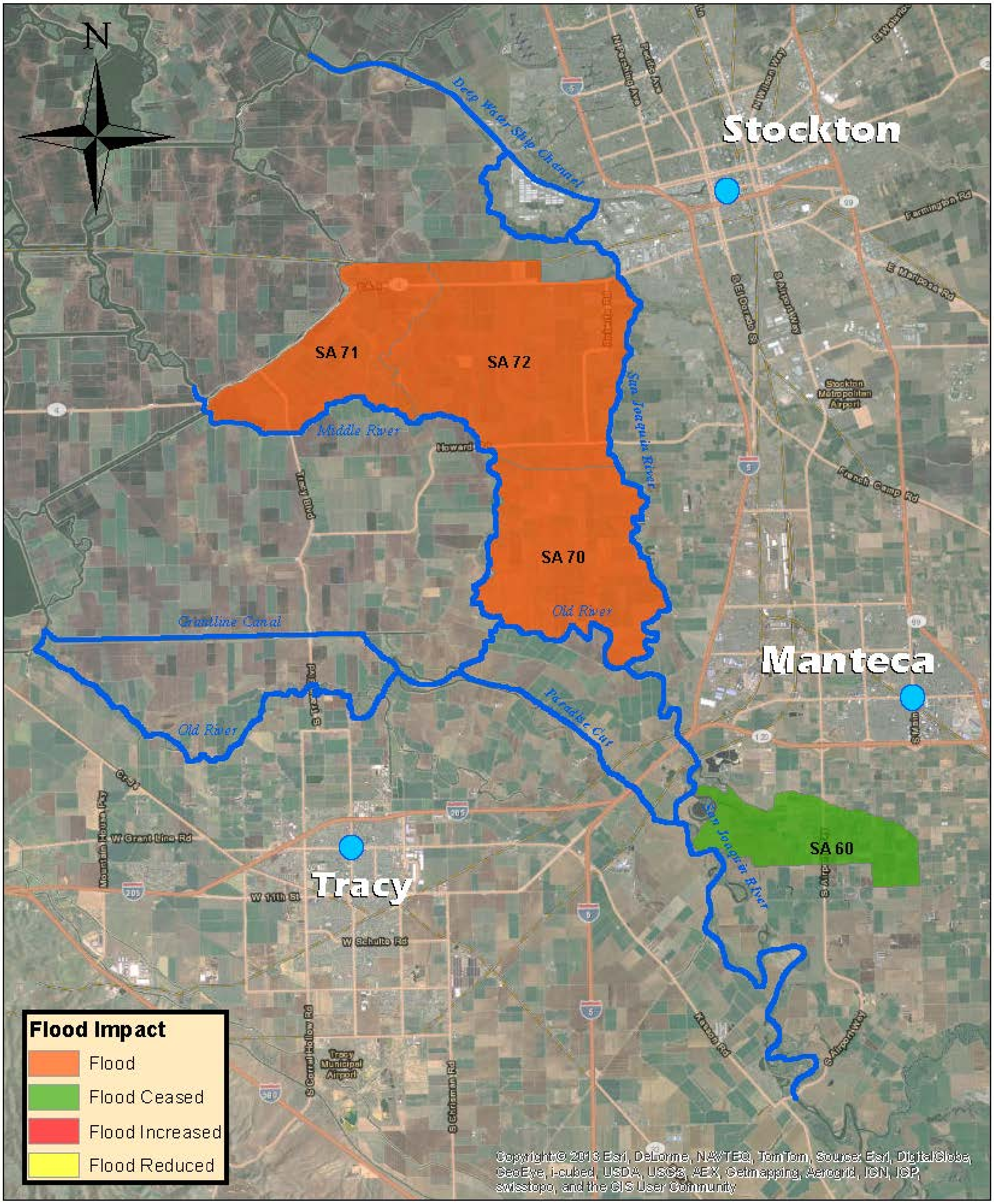
10 Year Flood - Weir at 2ft and Channel Dredging



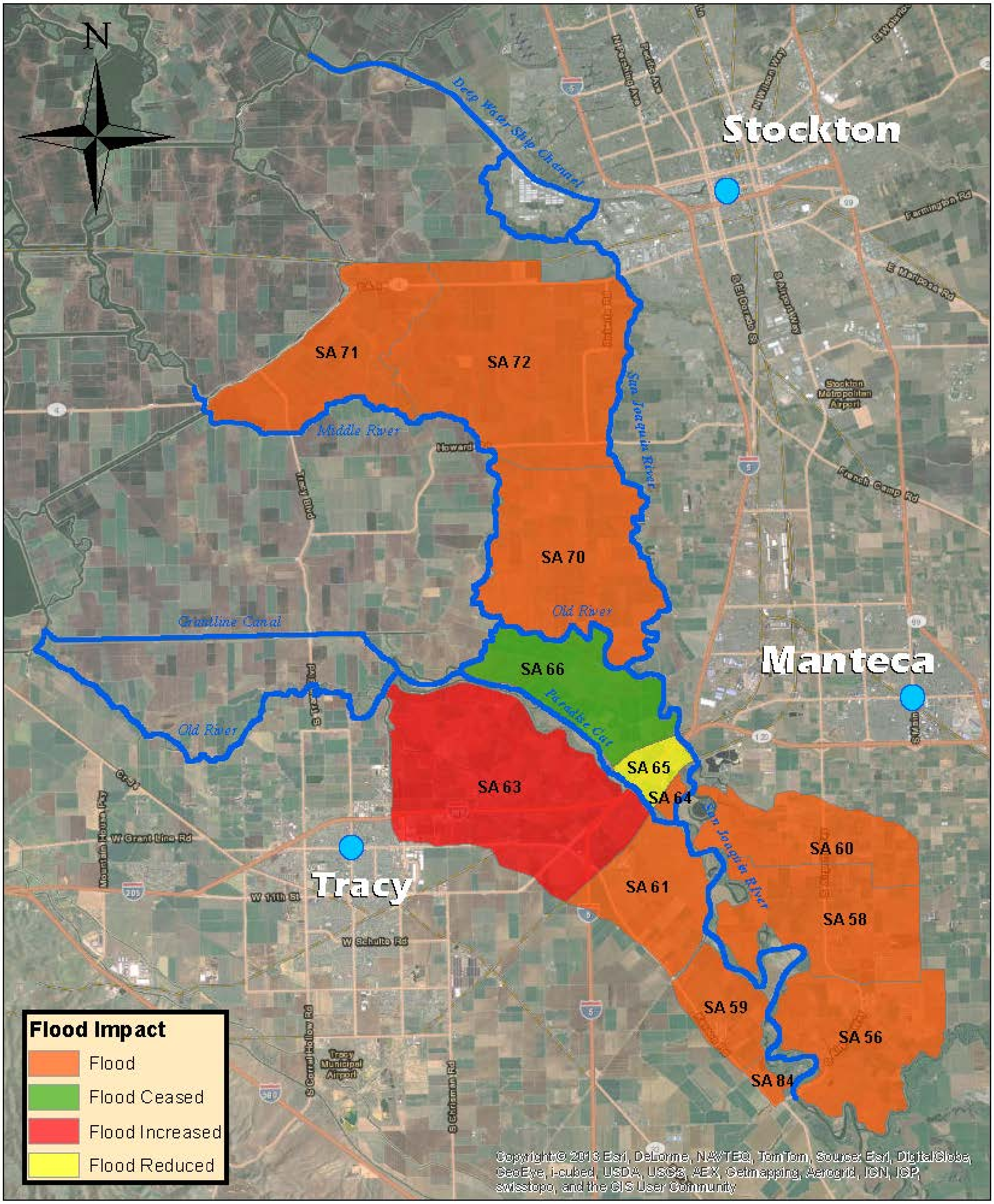
25 Year Flood - Weir at 2ft and Channel Dredging



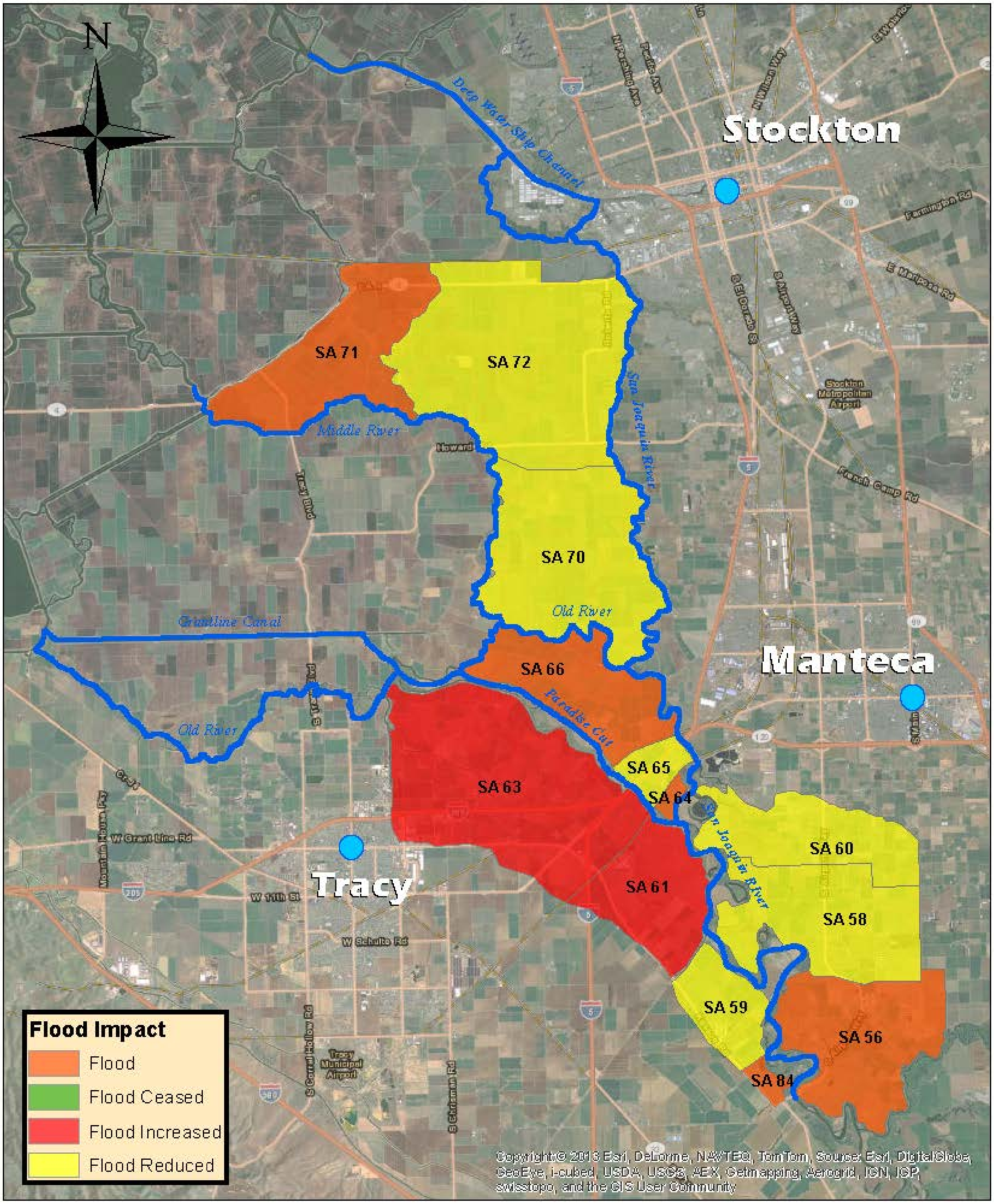
100 Year Flood - Weir at 2ft and Channel Dredging



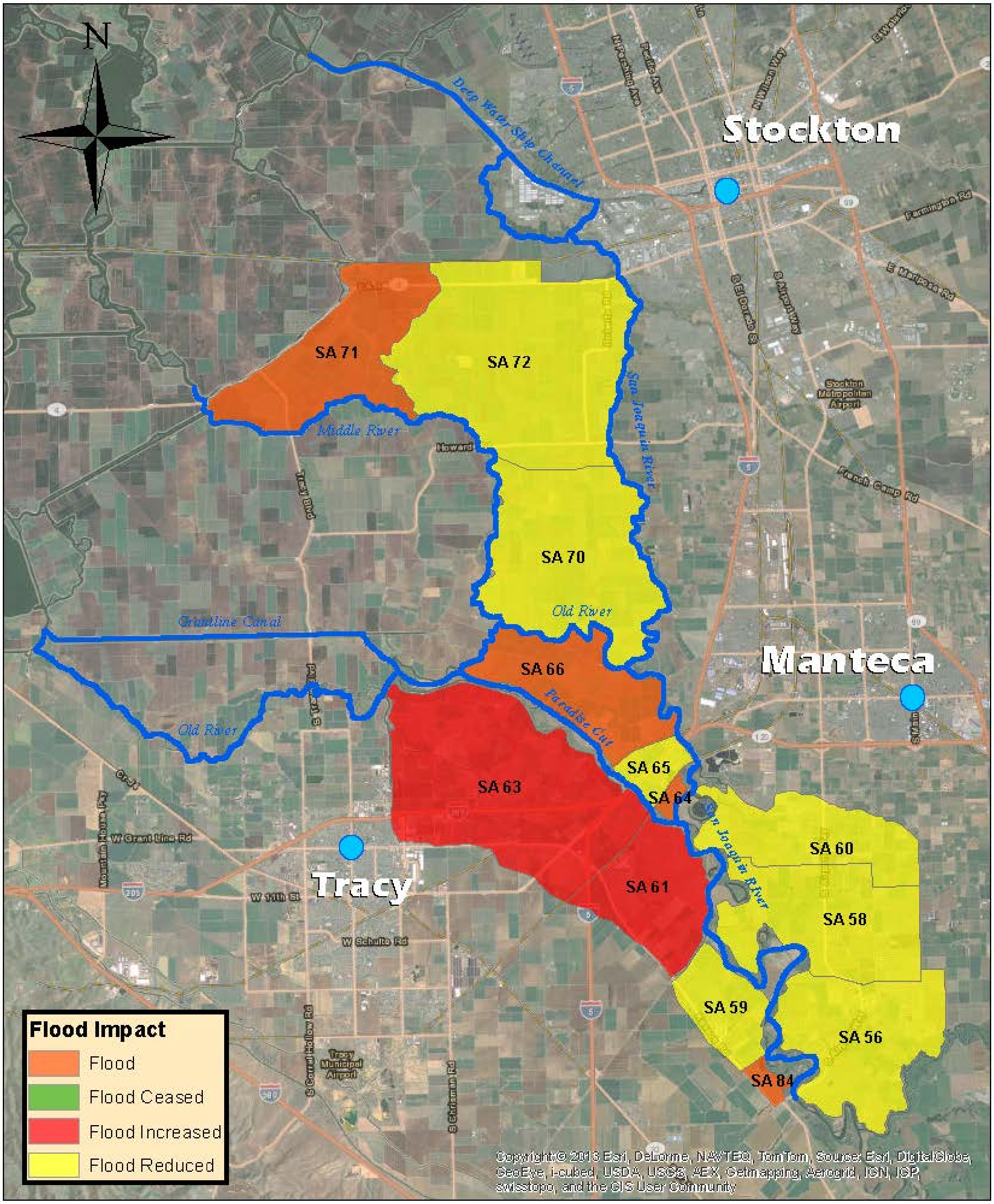
200 Year Flood - Weir at 15ft



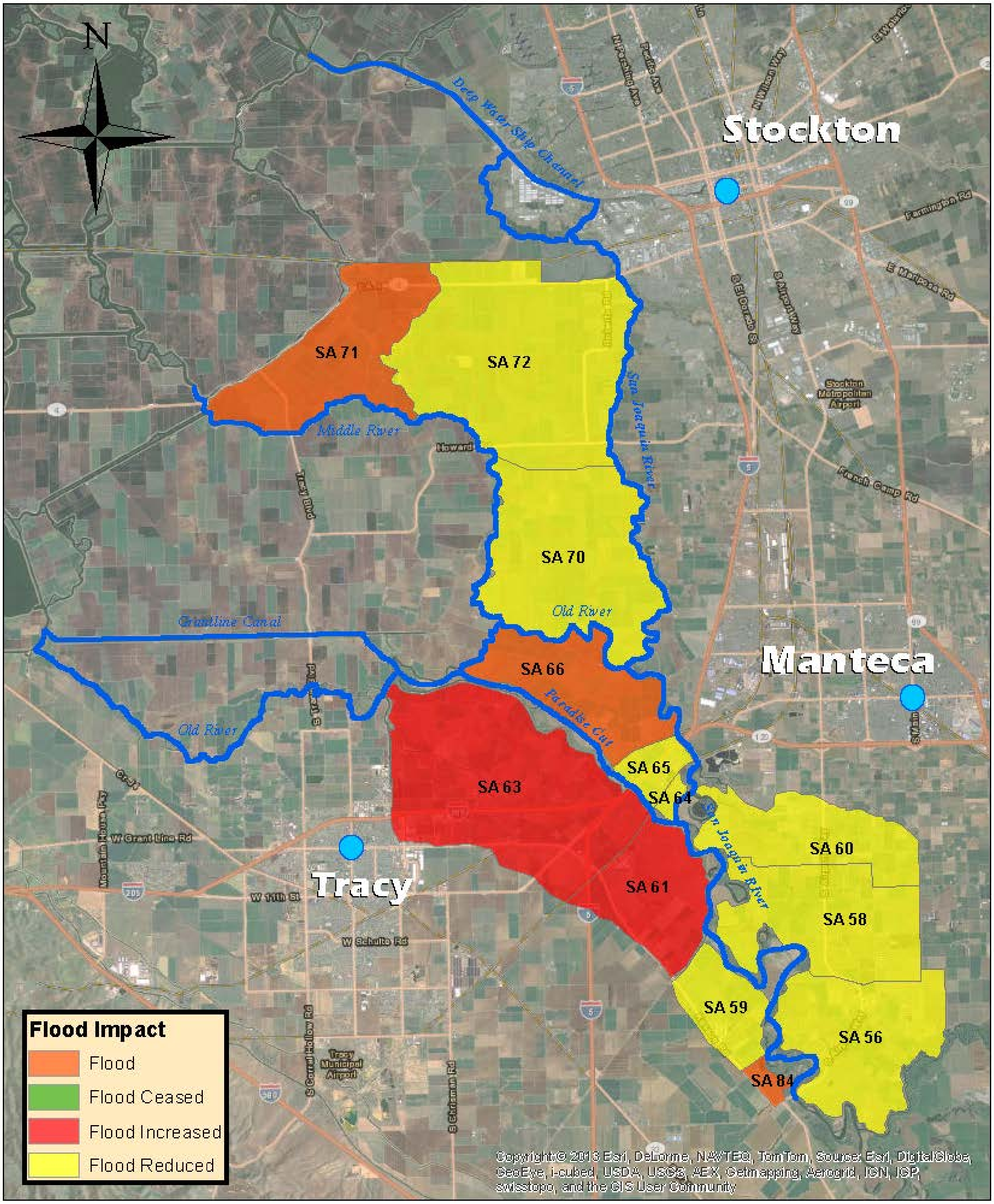
200 Year Flood - Weir at 15ft



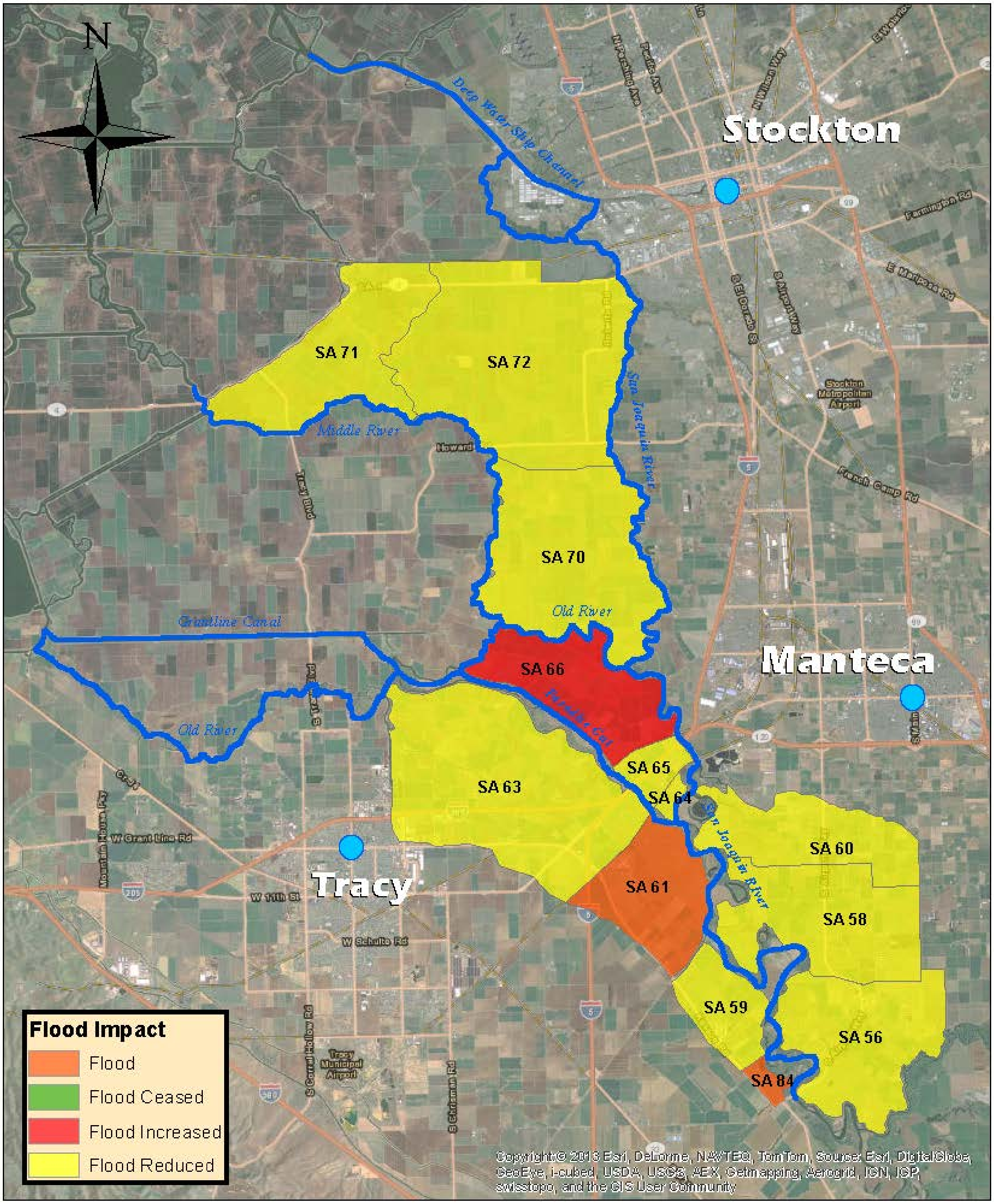
200 Year Flood - Weir at 6ft



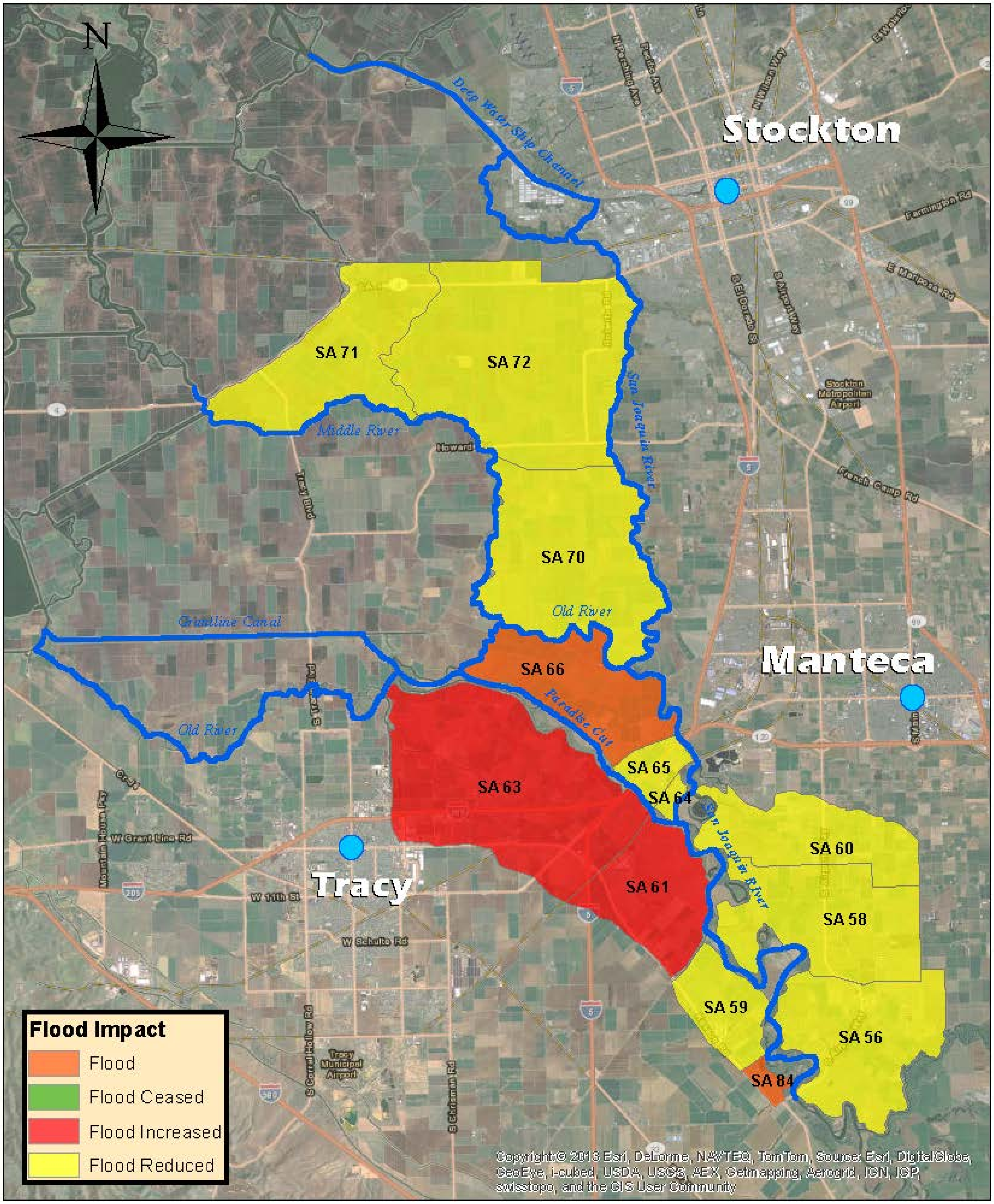
200 Year Flood - Weir at 2ft



200 Year Flood - Weir at 2ft and Channel Dredging



200 Year Flood - Weir at 2ft and Extended by 200ft



Appendix E – Construction Cost

Paradise Cut System Elements — **Romain Maendly**
Sacramento, CA — 7/21/2013

Paradise Cut
A
Lower Paradise Cut Weir by 0ft (15ft)
Opinion of Probable Construction Costs

Currency: USD-United States-JUNE 2011 Dollar

Grand Total Price: $ 352,000.00

Item	GC	Description	Quantity	UOM	Unit Price	Total Price	Comments
		Included Items				$ 136,900.00	
1	P	Permanent ROW	-	Ac	$17,000	$ -	p. 57/736 Att 8j Table4-2 from CVFPP, Range from $15 - $17,000 / Ac
2	P	Temporary Easement	10	Ac	$5,000	$ 50,000.00	p. 139 Table1 Att 8j from CVFPP
3	P	Hydroseeding	11	Ac	$2,000	$ 22,000.00	p. 139 Table1 Att 8j from CVFPP
4	P	Clearing and Grubbing	11	Ac	$5,000	$ 55,000.00	p. 139 Table1 Att 8j from CVFPP
5	P	Dewatering Extension	-	LF	$60	$ -	Sacramento Area Sewer District, 2011, extended from below
6	P	Cofferdam/River Diversion	-	LS	$50,000	$ -	Department of Water Resources, 2010. Paradise Cut Bypass Investigation.
7	P	Dewatering Costs	-	LS	$100,000	$ -	Department of Water Resources, 2010. Paradise Cut Bypass Investigation.
8	P	Channel Excavation to Levee Embankments	-	CY	$5.00	$ -	p. 139 Table1 Att 8j from CVFPP
9	P	Embankment Fill	-	CY	$16.00	$ -	p. 139 Table1 Att 8j from CVFPP
10	P	Widen or Excavation of Paradise Cut Weir	1,100	CY	$5.00	$ 5,500.00	p. 139 Table1 Att 8j from CVFPP
11	P	Temprorary Removal of Riprap at Paradise Cut Weir	-	CY	$12.00	$ -	Estimated ($6 to remove, $6 to put back in place)
12	P	New Riprap placement	-	CY	$50.00	$ -	NODOS Feasbility Study Cost Estimate
13	P	Waste Materials/ Spoils	1,100	CY	$4.00	$ 4,400.00	p. 139 Table1 Att 8j from CVFPP
		Mobilization/Field Oversight Expenses				$ 6,900.00	
1	P	Mobilization / Demobilization	1	LS	5%	$ 6,900.00	p. 139 Table1 Att 8j from CVFPP
		Parametric Contingency				$ 41,200.00	
1	P	Unallocated Items Allowance	1	LS	5%	$ 6,900.00	
2	P	Environmental Mitigation	1	LS	25%	$ 34,300.00	
					Running Subtotal:	$ 185,000.00	
		Markups				$ 5,600.00	
1	S	Subcontractor Markups	1	LS	0.0%	$ -	
2	P	Prime Contractor OH&P on Subs	1	LS	0.0%	$ -	
3	P	Prime Contractor OH&P on Self-Perform	1	LS	0.0%	$ -	
4	P	Contractor Insurance Program	1	LS	0.0%	$ -	
5	P	State Sales Taxes on Matls	1	LS	0.0%	$ -	
6	P	Escalation	1	LS	3.0%	$ 5,600.00	p. 139 Table1 Att 8j from CVFPP
					Running Subtotal:	$ 190,600.00	Total Estimated Constr Costs w/o contingency
		Project Administration & Management				$ 160,600.00	
1	--	Construction Oversight & Management	1	LS	15%	$ 28,600.00	p. 139 Table1 Att 8j from CVFPP
2	--	Engineering & Design	1	LS	15%	$ 32,900.00	p. 139 Table1 Att 8j from CVFPP
3	--	Permitting & Legal	1	LS	5%	$ 12,700.00	p. 139 Table1 Att 8j from CVFPP
4	--	Contingency	1	LS	30%	$ 79,500.00	p. 139 Table1 Att 8j from CVFPP
5	--	Engineering Services During Construction	1	LS	2%	$ 6,900.00	p. 139 Table1 Att 8j from CVFPP
					Grand Total:	$ 352,000.00	Total Estimated Constr Costs w/ Contingency
				Cost Range:	$ 300,000	$ 400,000.00	Per AACE cost estimate guidelines

Notes:

1) This OPCC is classified as a Class 4 cost estimate per AACE guidelines. Stated accuracy range = -20% to + 25%.
2) Pricing basis = 2nd Qtr 2010, escalation to midpoint of construction is not included.
3) P=Prime, S=Subcontractor
4) Pricing assumes competitive market conditions at time of tender (+3 bidders/trade).
5) Owner soft costs and project management expenses excluded.

Estimating Disclaimer - Engineer's Opinion of Probable Construction Costs

The estimate of costs shown and any resulting conclusions on the project financial, economic feasibility or funding requirements have been prepared from guidance in the project evaluation and implementation from the information available at the time the estimate was prepared. The final Costs of the project and resulting feasibility will depend on actual labor and material costs, competitive market conditions and other variable factors. Accordingly, the final project costs may vary from the estimate. Project feasibility, benefit/cost analysis, and risk must be reviewed prior to making specific funding decisions and establishment of the project budget.

AACE International CLASS 4 Cost Estimate - Class 4 estimates are generally prepared based on limited information and subsequently have fairly wide accuracy ranges. Typically, engineering is 10% to 40% complete. They are typically used for project screening, determination of feasibility, concept evaluation, and preliminary budget approval. Virtually all Class 4 estimates use stochastic estimating methods such as cost curves, capacity factors, and other parametric and modeling techniques. Expected accuracy ranges are from -15% to -30% on the low side and +20% to 50% on the high side, depending on the technological complexity of the project, appropriate reference information, and the inclusion of an appropriate contingency determination. Ranges could exceed those shown in unusual circumstances. As little as 20 hours or less to perhaps more than 300 hours may be spent preparing the estimate depending on the project and estimating methodology (AACE International Recommended Practices and Standards).

Paradise Cut System Elements
Sacramento, CA

Romain Maendly
7/21/2013

B

Lower Paradise Cut Weir by 4 ft

Opinion of Probable Construction Costs

Currency: USD-United States-JUNE 2011 Dollar

Item	GC	Description	Quantity	UOM	Unit Price	Total Price	Comments
					Grand Total Price:	$ 504,000.00	
		Included Items				$ 196,400.00	
1	P	Permanent ROW	-	Ac	$17,000	$ -	
2	P	Temporary Easement	10	Ac	$5,000	$ 50,000.00	
3	P	Hydroseeding	11	Ac	$2,000	$ 22,000.00	
4	P	Clearing and Grubbing	11	Ac	$5,000	$ 55,000.00	
5	P	Dewatering Extension	-	LF	$60	$ -	
6	P	Cofferdam/River Diversion	-	LS	$50,000	$ -	
7	P	Dewatering Costs	-	LS	$100,000	$ -	
8	P	Channel Excavation to Levee Embankments	-	CY	$5.00	$ -	
9	P	Embankment Fill	-	CY	$16.00	$ -	
10	P	Widen or Excavation of Paradise Cut Weir	5,800	CY	$5.00	$ 29,000.00	
11	P	Temprorary Removal of Riprap at Paradise Cut Weir	1,425	CY	$12.00	$ 17,200.00	
12	P	New Riprap placement	-	CY	$50.00	$ -	
13	P	Waste Materials/ Spoils	5,800	CY	$4.00	$ 23,200.00	
		Mobilization/Field Oversight Expenses				$ 9,900.00	
1	P	Mobilization / Demobilization	1	LS	5%	$ 9,900.00	
		Parametric Contingency				$ 59,000.00	
1	P	Unallocated Items Allowance	1	LS	5%	$ 9,900.00	
2	P	Environmental Mitigation	1	LS	25%	$ 49,100.00	
					Running Subtotal:	$ 265,300.00	
		Markups				$ 8,000.00	
1	S	Subcontractor Markups	1	LS	0.0%	$ -	
2	P	Prime Contractor OH&P on Subs	1	LS	0.0%	$ -	
3	P	Prime Contractor OH&P on Self-Perform	1	LS	0.0%	$ -	
4	P	Contractor Insurance Program	1	LS	0.0%	$ -	
5	P	State Sales Taxes on Matls	1	LS	0.0%	$ -	
6	P	Escalation	1	LS	3.0%	$ 8,000.00	
					Running Subtotal:	$ 273,300.00	
		Project Administration & Management				$ 230,100.00	
1	--	Construction Oversight & Management	1	LS	15%	$ 41,000.00	
2	--	Engineering & Design	1	LS	15%	$ 47,200.00	
3	--	Permitting & Legal	1	LS	5%	$ 18,100.00	
4	--	Contingency	1	LS	30%	$ 113,900.00	
5	--	Engineering Services During Construction	1	LS	2%	$ 9,900.00	
					Grand Total:	$ 504,000.00	
				Cost Range:	$ 400,000	$ 600,000.00	

Notes:

1) This OPCC is classified as a Class 4 cost estimate per AACE guidelines. Stated accuracy range = -20% to + 25%.
2) Pricing basis = 2nd Qtr 2010, escalation to midpoint of construction is not included.
3) P=Prime, S=Subcontractor
4) Pricing assumes competitive market conditions at time of tender (+3 bidders/trade).
5) Owner soft costs and project management expenses excluded.

Estimating Disclaimer - Engineer's Opinion of Probable Construction Costs

The estimate of costs shown and any resulting conclusions on the project financial, economic feasibility or funding requirements have been prepared from guidance in the project evaluation and implementation from the information available at the time the estimate was prepared. The final Costs of the project and resulting feasibility will depend on actual labor and material costs, competitive market conditions and other variable factors. Accordingly, the final project costs may vary from the estimate. Project feasibility, benefit/cost analysis, and risk must be reviewed prior to making specific funding decisions and establishment of the project budget.

AACE International CLASS 4 Cost Estimate - Class 4 estimates are generally prepared based on limited information and subsequently have fairly wide accuracy ranges. Typically, engineering is 10% to 40% complete. They are typically used for project screening, determination of feasibility, concept evaluation, and preliminary budget approval. Virtually all Class 4 estimates use stochastic estimating methods such as cost curves, capacity factors, and other parametric and modeling techniques. Expected accuracy ranges are from -15% to -30% on the low side and +20% to 50% on the high side, depending on the technological complexity of the project, appropriate reference information, and the inclusion of an appropriate contingency determination. Ranges could exceed those shown in unusual circumstances. As little as 20 hours or less to perhaps more than 300 hours may be spent preparing the estimate depending on the project and estimating methodology (AACE International Recommended Practices and Standards).

Paradise Cut System Elements — **Romain Maendly**

Sacramento, CA — 7/21/2013

C

Lower Paradise Cut Weir by 9 ft

Opinion of Probable Construction Costs

Currency: USD-United States-JUNE 2011 Dollar

Grand Total Price: $ 1,131,000

Item	GC	Description	Quantity	UOM	Unit Price	Total Price	Comments
		Included Items				**$ 441,400**	
1	P	Permanent ROW	-	Ac	$17,000	$ -	
2	P	Temporary Easement	10	Ac	$5,000	$ 50,000	
3	P	Hydroseeding	11	Ac	$2,000	$ 22,000	
4	P	Clearing and Grubbing	11	Ac	$5,000	$ 55,000	
5	P	Dewatering Extension	-	LF	$60	$ -	
6	P	Cofferdam/River Diversion	2	LS	$50,000	$ 100,000	
7	P	Dewatering Costs	1	LS	$100,000	$ 100,000	
8	P	Channel Excavation to Levee Embankments	-	CY	$5.00	$ -	
9	P	Embankment Fill	-	CY	$16.00	$ -	
10	P	Widen or Excavation of Paradise Cut Weir	10,800	CY	$5.00	$ 54,000	
11	P	Temprorary Removal of Riprap at Paradise Cut Weir	1,425	CY	$12.00	$ 17,200	
12	P	New Riprap placement	-	CY	$50.00	$ -	
13	P	Waste Materials/ Spoils	10,800	CY	$4.00	$ 43,200	
		Mobilization/Field Oversight Expenses				**$ 22,100**	
1	P	Mobilization / Demobilization	1	LS	5%	$ 22,100	
		Parametric Contingency				**$ 132,500**	
1	P	Unallocated Items Allowance	1	LS	5%	$ 22,100	
2	P	Environmental Mitigation	1	LS	25%	$ 110,400	
					Running Subtotal:	**$ 596,000**	
		Markups				**$ 17,900**	
1	S	Subcontractor Markups	1	LS	0.0%	$ -	
2	P	Prime Contractor OH&P on Subs	1	LS	0.0%	$ -	
3	P	Prime Contractor OH&P on Self-Perform	1	LS	0.0%	$ -	
4	P	Contractor Insurance Program	1	LS	0.0%	$ -	
5	P	State Sales Taxes on Matls	1	LS	0.0%	$ -	
6	P	Escalation	1	LS	3.0%	$ 17,900	
					Running Subtotal:	**$ 613,900**	
		Project Administration & Management				**$ 516,600**	
1	--	Construction Oversight & Management	1	LS	15%	$ 92,100	
2	--	Engineering & Design	1	LS	15%	$ 105,900	
3	--	Permitting & Legal	1	LS	5%	$ 40,600	
4	--	Contingency	1	LS	30%	$ 255,800	
5	--	Engineering Services During Construction	1	LS	2%	$ 22,200	
					Grand Total:	**$ 1,131,000**	
				Cost Range:	**$ 900,000**	**$ 1,400,000**	

Notes:

1) This OPCC is classified as a Class 4 cost estimate per AACE guidelines. Stated accuracy range = -20% to + 25%.
2) Pricing basis = 2nd Qtr 2010, escalation to midpoint of construction is not included.
3) P=Prime, S=Subcontractor
4) Pricing assumes competitive market conditions at time of tender (+3 bidders/trade).
5) Owner soft costs and project management expenses excluded.

Estimating Disclaimer - Engineer's Opinion of Probable Construction Costs

The estimate of costs shown and any resulting conclusions on the project financial, economic feasibility or funding requirements have been prepared from guidance in the project evaluation and implementation from the information available at the time the estimate was prepared. The final Costs of the project and resulting feasibility will depend on actual labor and material costs, competitive market conditions and other variable factors. Accordingly, the final project costs may vary from the estimate. Project feasibility, benefit/cost analysis, and risk must be reviewed prior to making specific funding decisions and establishment of the project budget.

AACE International CLASS 4 Cost Estimate - Class 4 estimates are generally prepared based on limited information and subsequently have fairly wide accuracy ranges. Typically, engineering is 10% to 40% complete. They are typically used for project screening, determination of feasibility, concept evaluation, and preliminary budget approval. Virtually all Class 4 estimates use stochastic estimating methods such as cost curves, capacity factors, and other parametric and modeling techniques. Expected accuracy ranges are from -15% to -30% on the low side and +20% to 50% on the high side, depending on the technological complexity of the project, appropriate reference information, and the inclusion of an appropriate contingency determination. Ranges could exceed those shown in unusual circumstances. As little as 20 hours or less to perhaps more than 300 hours may be spent preparing the estimate depending on the project and estimating methodology (AACE International Recommended Practices and Standards).

Paradise Cut System Elements | **Romain Maendly**
Sacramento, CA | 7/21/2013

D
Lower Paradise Cut Weir by 13 ft No Dredging
Opinion of Probable Construction Costs
Currency: USD-United States-JUNE 2011 Dollar

Grand Total Price: $ 1,207,000

Item	GC	Description	Quantity	UOM	Unit Price	Total Price	Comments
		Included Items				$ 471,100	
1	P	Permanent ROW	-	Ac	$17,000	$ -	
2	P	Temporary Easement	10	Ac	$5,000	$ 50,000	
3	P	Hydroseeding	11	Ac	$2,000	$ 22,000	
4	P	Clearing and Grubbing	11	Ac	$5,000	$ 55,000	
5	P	Dewatering Extension	-	LF	$60	$ -	
6	P	Cofferdam/River Diversion	2	LS	$50,000	$ 100,000	
7	P	Dewatering Costs	1	LS	$100,000	$ 100,000	
8	P	Channel Excavation to Levee Embankments	-	CY	$5.00	$ -	
9	P	Embankment Fill	-	CY	$16.00	$ -	
10	P	Widen or Excavation of Paradise Cut Weir	14,100	CY	$5.00	$ 70,500	
11	P	Temprorary Removal of Riprap at Paradise Cut Weir	1,425	CY	$12.00	$ 17,200	
12	P	New Riprap placement	-	CY	$50.00	$ -	
13	P	Waste Materials/ Spoils	14,100	CY	$4.00	$ 56,400	
		Mobilization/Field Oversight Expenses				$ 23,600	
1	P	Mobilization / Demobilization	1	LS	5%	$ 23,600	
		Parametric Contingency				$ 141,400	
1	P	Unallocated Items Allowance	1	LS	5%	$ 23,600	
2	P	Environmental Mitigation	1	LS	25%	$ 117,800	
					Running Subtotal:	$ 636,100	
		Markups				$ 19,100	
1	S	Subcontractor Markups	1	LS	0.0%	$ -	
2	P	Prime Contractor OH&P on Subs	1	LS	0.0%	$ -	
3	P	Prime Contractor OH&P on Self-Perform	1	LS	0.0%	$ -	
4	P	Contractor Insurance Program	1	LS	0.0%	$ -	
5	P	State Sales Taxes on Matls	1	LS	0.0%	$ -	
6	P	Escalation	1	LS	3.0%	$ 19,100	
					Running Subtotal:	$ 655,200	
		Project Administration & Management				$ 551,500	
1	--	Construction Oversight & Management	1	LS	15%	$ 98,300	
2	--	Engineering & Design	1	LS	15%	$ 113,100	
3	--	Permitting & Legal	1	LS	5%	$ 43,400	
4	--	Contingency	1	LS	30%	$ 273,000	
5	--	Engineering Services During Construction	1	LS	2%	$ 23,700	
					Grand Total:	$ 1,207,000	
				Cost Range:	$ 1,000,000	$ 1,500,000	Per AACE cost estimate guidelines

Notes:
1) This OPCC is classified as a Class 4 cost estimate per AACE guidelines. Stated accuracy range = -20% to + 25%.
2) Pricing basis = 2nd Qtr 2010, escalation to midpoint of construction is not included.
3) P=Prime, S=Subcontractor
4) Pricing assumes competitive market conditions at time of tender (+3 bidders/trade).
5) Owner soft costs and project management expenses excluded.

Estimating Disclaimer - Engineer's Opinion of Probable Construction Costs
The estimate of costs shown and any resulting conclusions on the project financial, economic feasibility or funding requirements have been prepared from guidance in the project evaluation and implementation from the information available at the time the estimate was prepared. The final Costs of the project and resulting feasibility will depend on actual labor and material costs, competitive market conditions and other variable factors. Accordingly, the final project costs may vary from the estimate. Project feasibility, benefit/cost analysis, and risk must be reviewed prior to making specific funding decisions and establishment of the project budget.

AACE International CLASS 4 Cost Estimate - Class 4 estimates are generally prepared based on limited information and subsequently have fairly wide accuracy ranges. Typically, engineering is 10% to 40% complete. They are typically used for project screening, determination of feasibility, concept evaluation, and preliminary budget approval. Virtually all Class 4 estimates use stochastic estimating methods such as cost curves, capacity factors, and other parametric and modeling techniques. Expected accuracy ranges are from -15% to -30% on the low side and +20% to 50% on the high side, depending on the technological complexity of the project, appropriate reference information, and the inclusion of an appropriate contingency determination. Ranges could exceed those shown in unusual circumstances. As little as 20 hours or less to perhaps more than 300 hours may be spent preparing the estimate depending on the project and estimating methodology (AACE International Recommended Practices and Standards).

Paradise Cut System Elements — **Romain Maendly**

Sacramento, CA — 7/21/2013

E

Lower Paradise Cut Weir by 13 ft; Dredge main channel to I5 feet

Opinion of Probable Construction Costs

Currency: USD-United States-JUNE 2011 Dollar

Grand Total Price: $ 10,117,000

Item	GC	Description	Quantity	UOM	Unit Price	Total Price	Comments
		Included Items				$ 3,950,900	
1	P	Permanent ROW	-	Ac	$17,000	$ -	
2	P	Temporary Easement	10	Ac	$5,000	$ 50,000	
3	P	Hydroseeding	11	Ac	$2,000	$ 22,000	
4	P	Clearing and Grubbing	140	Ac	$5,000	$ 700,000	
5	P	Dewatering Extension	8,000	LF	$60	$ 480,000	
6	P	Cofferdam/River Diversion	2	LS	$50,000	$ 100,000	
7	P	Dewatering Costs	1	LS	$100,000	$ 100,000	
8	P	Channel Excavation to Levee Embankments	-	CY	$5.00	$ -	
9	P	Embankment Fill	-	CY	$16.00	$ -	
10	P	Widen or Excavation of Paradise Cut Weir	14,100	CY	$5.00	$ 70,500	
11	P	Temprorary Removal of Riprap at Paradise Cut Wei	1,425	CY	$6.00	$ 8,600	
12	P	New Riprap placement	-	CY	$50.00	$ -	
13	P	Main Channel Excavation	262,600	CY	$5.00	$ 1,313,000	
14	P	Waste Materials/ Spoils	276,700	CY	$4.00	$ 1,106,800	
		Mobilization/Field Oversight Expenses				$ 197,600	
1	P	Mobilization / Demobilization	1	LS	5%	$ 197,600	
		Parametric Contingency				$ 1,185,400	
1	P	Unallocated Items Allowance	1	LS	5%	$ 197,600	
2	P	Environmental Mitigation	1	LS	25%	$ 987,800	
					Running Subtotal:	$ 5,333,900	
		Markups				$ 160,100	
1	S	Subcontractor Markups	1	LS	0.0%	$ -	
2	P	Prime Contractor OH&P on Subs	1	LS	0.0%	$ -	
3	P	Prime Contractor OH&P on Self-Perform	1	LS	0.0%	$ -	
4	P	Contractor Insurance Program	1	LS	0.0%	$ -	
5	P	State Sales Taxes on Matls	1	LS	0.0%	$ -	
6	P	Escalation	1	LS	3.0%	$ 160,100	
					Running Subtotal:	$ 5,494,000	
		Project Administration & Management				$ 4,622,400	
1	--	Construction Oversight & Management	1	LS	15%	$ 824,100	
2	--	Engineering & Design	1	LS	15%	$ 947,800	
3	--	Permitting & Legal	1	LS	5%	$ 363,300	
4	--	Contingency	1	LS	30%	$ 2,288,800	
5	--	Engineering Services During Construction	1	LS	2%	$ 198,400	
					Grand Total:	$ 10,117,000	Total Estimated Constr Costs w/ Contingency
				Cost Range:	$ 8,100,000	$ 12,600,000	Per AACE cost estimate guidelines

Notes:

1) This OPCC is classified as a Class 4 cost estimate per AACE guidelines. Stated accuracy range = -20% to + 25%.
2) Pricing basis = 2nd Qtr 2010, escalation to midpoint of construction is not included.
3) P=Prime, S=Subcontractor
4) Pricing assumes competitive market conditions at time of tender (+3 bidders/trade).
5) Owner soft costs and project management expenses excluded.

Estimating Disclaimer - Engineer's Opinion of Probable Construction Costs

The estimate of costs shown and any resulting conclusions on the project financial, economic feasibility or funding requirements have been prepared from guidance in the project evaluation and implementation from the information available at the time the estimate was prepared. The final Costs of the project and resulting feasibility will depend on actual labor and material costs, competitive market conditions and other variable factors. Accordingly, the final project costs may vary from the estimate. Project feasibility, benefit/cost analysis, and risk must be reviewed prior to making specific funding decisions and establishment of the project budget.

AACE International CLASS 4 Cost Estimate - Class 4 estimates are generally prepared based on limited information and subsequently have fairly wide accuracy ranges. Typically, engineering is 10% to 40% complete. They are typically used for project screening, determination of feasibility, concept evaluation, and preliminary budget approval. Virtually all Class 4 estimates use stochastic estimating methods such as cost curves, capacity factors, and other parametric and modeling techniques. Expected accuracy ranges are from -15% to -30% on the low side and +20% to 50% on the high side, depending on the technological complexity of the project, appropriate reference information, and the inclusion of an appropriate contingency determination. Ranges could exceed those shown in unusual circumstances. As little as 20 hours or less to perhaps more than 300 hours may be spent preparing the estimate depending on the project and estimating methodology (AACE International Recommended Practices and Standards).

Paradise Cut System Elements | **Romain Maendly**
Sacramento, CA | 7/21/2013

F

Lengthen Paradise Cut Weir by 200 ft; keep existing weir height

Opinion of Probable Construction Costs

Currency: USD-United States-JUNE 2011 Dollar

Grand Total Price: **$ 1,088,000**

Item	GC	Description	Quantity	UOM	Unit Price	Total Price	Comments
		Included Items				$ 424,200	
1	P	Permanent ROW	-	Ac	$17,000	$ -	
2	P	Temporary Easement	10	Ac	$5,000	$ 50,000	
3	P	Hydroseeding	12	Ac	$2,000	$ 24,000	
4	P	Clearing and Grubbing	12	Ac	$5,000	$ 60,000	
5	P	Dewatering Extension	-	LF	$60	$ -	
6	P	Cofferdam/River Diversion	-	LS	$50,000	$ -	
7	P	Dewatering Costs	-	LS	$100,000	$ -	
8	P	Channel Excavation to Levee Embankments	-	CY	$5.00	$ -	
9	P	Embankment Fill	-	CY	$16.00	$ -	
10	P	Widen or Excavation of Paradise Cut Weir	23,800	CY	$5.00	$ 119,000	
11	P	Temprorary Removal of Riprap at Paradise Cut Weir	-	CY	$12.00	$ -	
12	P	New Riprap placement	1,519	CY	$50.00	$ 76,000	
13	P	Waste Materials/ Spoils	23,800	CY	$4.00	$ 95,200	
		Mobilization/Field Oversight Expenses				$ 21,300	
1	P	Mobilization / Demobilization	1	LS	5%	$ 21,300	
		Parametric Contingency				$ 127,400	
1	P	Unallocated Items Allowance	1	LS	5%	$ 21,300	
2	P	Environmental Mitigation	1	LS	25%	$ 106,100	
					Running Subtotal:	**$ 572,900**	
		Markups				$ 17,200	
1	S	Subcontractor Markups	1	LS	0.0%	$ -	
2	P	Prime Contractor OH&P on Subs	1	LS	0.0%	$ -	
3	P	Prime Contractor OH&P on Self-Perform	1	LS	0.0%	$ -	
4	P	Contractor Insurance Program	1	LS	0.0%	$ -	
5	P	State Sales Taxes on Matls	1	LS	0.0%	$ -	
6	P	Escalation	1	LS	3.0%	$ 17,200	
					Running Subtotal:	**$ 590,100**	Total Estimated Constr Costs w/o contingency
		Project Administration & Management				$ 497,000	
1	--	Construction Oversight & Management	1	LS	15%	$ 88,600	
2	--	Engineering & Design	1	LS	15%	$ 101,900	
3	--	Permitting & Legal	1	LS	5%	$ 39,100	
4	--	Contingency	1	LS	30%	$ 246,000	
5	--	Engineering Services During Construction	1	LS	2%	$ 21,400	
					Grand Total:	**$ 1,088,000**	Total Estimated Constr Costs w/ Contingency
				Cost Range:	**$ 900,000**	**$ 1,400,000**	Per AACE cost estimate guidelines

Notes:

1) This OPCC is classified as a Class 4 cost estimate per AACE guidelines. Stated accuracy range = -20% to + 25%.
2) Pricing basis = 2nd Qtr 2010, escalation to midpoint of construction is not included.
3) P=Prime, S=Subcontractor
4) Pricing assumes competitive market conditions at time of tender (+3 bidders/trade).
5) Owner soft costs and project management expenses excluded.

Estimating Disclaimer - Engineer's Opinion of Probable Construction Costs

The estimate of costs shown and any resulting conclusions on the project financial, economic feasibility or funding requirements have been prepared from guidance in the project evaluation and implementation from the information available at the time the estimate was prepared. The final Costs of the project and resulting feasibility will depend on actual labor and material costs, competitive market conditions and other variable factors. Accordingly, the final project costs may vary from the estimate. Project feasibility, benefit/cost analysis, and risk must be reviewed prior to making specific funding decisions and establishment of the project budget.

AACE International CLASS 4 Cost Estimate - Class 4 estimates are generally prepared based on limited information and subsequently have fairly wide accuracy ranges. Typically, engineering is 10% to 40% complete. They are typically used for project screening, determination of feasibility, concept evaluation, and preliminary budget approval. Virtually all Class 4 estimates use stochastic estimating methods such as cost curves, capacity factors, and other parametric and modeling techniques. Expected accuracy ranges are from -15% to -30% on the low side and +20% to 50% on the high side, depending on the technological complexity of the project, appropriate reference information, and the inclusion of an appropriate contingency determination. Ranges could exceed those shown in unusual circumstances. As little as 20 hours or less to perhaps more than 300 hours may be spent preparing the estimate depending on the project and estimating methodology (AACE International Recommended Practices and Standards).

Paradise Cut System Elements — **Romain Maendly**
Sacramento, CA — 7/21/2013

G

Lengthen Paradise Cut Weir by 200 ft; and decrease height by 4 feet

Opinion of Probable Construction Costs

Currency: USD-United States-JUNE 2011 Dollar

Grand Total Price: $ 1,359,000

Item	GC	Description	Quantity	UOM	Unit Price	Total Price	Comments
		Included Items				**$ 530,500**	
1	P	Permanent ROW	-	Ac	$17,000	$ -	
2	P	Temporary Easement	10	Ac	$5,000	$ 50,000	
3	P	Hydroseeding	12	Ac	$2,000	$ 24,000	
4	P	Clearing and Grubbing	12	Ac	$5,000	$ 60,000	
5	P	Dewatering	-	LF	$60	$ -	
6	P	Cofferdam/River Diversion	-	LS	$50,000	$ -	
7	P	Dewatering Costs	-	LS	$100,000	$ -	
8	P	Channel Excavation to Levee Embankments	-	CY	$5.00	$ -	
9	P	Embankment Fill	-	CY	$16.00	$ -	
10	P	Widen or Excavation of Paradise Cut Weir	33,700	CY	$5.00	$ 168,500	
11	P	Temprorary Removal of Riprap at Paradise Cut Weir	1,425	CY	$12.00	$ 17,200	
12	P	New Riprap placement	1,519	CY	$50.00	$ 76,000	
13	P	Waste Materials/ Spoils	33,700	CY	$4.00	$ 134,800	
		Mobilization/Field Oversight Expenses				**$ 26,600**	
1	P	Mobilization / Demobilization	1	LS	5%	$ 26,600	
		Parametric Contingency				**$ 159,300**	
1	P	Unallocated Items Allowance	1	LS	5%	$ 26,600	
2	P	Environmental Mitigation	1	LS	25%	$ 132,700	
					Running Subtotal:	**$ 716,400**	
		Markups				**$ 21,500**	
1	S	Subcontractor Markups	1	LS	0.0%	$ -	
2	P	Prime Contractor OH&P on Subs	1	LS	0.0%	$ -	
3	P	Prime Contractor OH&P on Self-Perform	1	LS	0.0%	$ -	
4	P	Contractor Insurance Program	1	LS	0.0%	$ -	
5	P	State Sales Taxes on Matls	1	LS	0.0%	$ -	
6	P	Escalation	1	LS	3.0%	$ 21,500	
					Running Subtotal:	**$ 737,900**	Total Estimated Constr Costs w/o contingency
		Project Administration & Management				**$ 621,000**	
1	--	Construction Oversight & Management	1	LS	15%	$ 110,700	
2	--	Engineering & Design	1	LS	15%	$ 127,300	
3	--	Permitting & Legal	1	LS	5%	$ 48,800	
4	--	Contingency	1	LS	30%	$ 307,500	
5	--	Engineering Services During Construction	1	LS	2%	$ 26,700	
					Grand Total:	**$ 1,359,000**	Total Estimated Constr Costs w/ Contingency
				Cost Range:	**$ 1,100,000**	**$ 1,700,000**	Per AACE cost estimate guidelines

Notes:

1) This OPCC is classified as a Class 4 cost estimate per AACE guidelines. Stated accuracy range = -20% to + 25%.
2) Pricing basis = 2nd Qtr 2010, escalation to midpoint of construction is not included.
3) P=Prime, S=Subcontractor
4) Pricing assumes competitive market conditions at time of tender (+3 bidders/trade).
5) Owner soft costs and project management expenses excluded.

Estimating Disclaimer - Engineer's Opinion of Probable Construction Costs

The estimate of costs shown and any resulting conclusions on the project financial, economic feasibility or funding requirements have been prepared from guidance in the project evaluation and implementation from the information available at the time the estimate was prepared. The final Costs of the project and resulting feasibility will depend on actual labor and material costs, competitive market conditions and other variable factors. Accordingly, the final project costs may vary from the estimate. Project feasibility, benefit/cost analysis, and risk must be reviewed prior to making specific funding decisions and establishment of the project budget.

AACE International CLASS 4 Cost Estimate - Class 4 estimates are generally prepared based on limited information and subsequently have fairly wide accuracy ranges. Typically, engineering is 10% to 40% complete. They are typically used for project screening, determination of feasibility, concept evaluation, and preliminary budget approval. Virtually all Class 4 estimates use stochastic estimating methods such as cost curves, capacity factors, and other parametric and modeling techniques. Expected accuracy ranges are from -15% to -30% on the low side and +20% to 50% on the high side, depending on the technological complexity of the project, appropriate reference information, and the inclusion of an appropriate contingency determination. Ranges could exceed those shown in unusual circumstances. As little as 20 hours or less to perhaps more than 300 hours may be spent preparing the estimate depending on the project and estimating methodology (AACE International Recommended Practices and Standards).

Paradise Cut System Elements — **Romain Maendly**
Sacramento, CA — 7/21/2013

H
Lengthen Paradise Cut Weir by 200 ft; and decrease height by 9 feet
Opinion of Probable Construction Costs
Currency: USD-United States-JUNE 2011 Dollar

Grand Total Price: $ 2,120,000

Item	GC	Description	Quantity	UOM	Unit Price	Total Price	Comments
		Included Items				$ 827,700	
1	P	Permanent ROW	-	Ac	$17,000	$ -	
2	P	Temporary Easement	10	Ac	$5,000	$ 50,000	
3	P	Hydroseeding	12	Ac	$2,000	$ 24,000	
4	P	Clearing and Grubbing	12	Ac	$5,000	$ 60,000	
5	P	Dewatering Extension	-	LF	$60	$ -	
6	P	Cofferdam/River Diversion	2	LS	$50,000	$ 100,000	
7	P	Dewatering Costs	1	LS	$100,000	$ 100,000	
8	P	Channel Excavation to Levee Embankments	-	CY	$5.00	$ -	
9	P	Embankment Fill	-	CY	$16.00	$ -	
10	P	Widen or Excavation of Paradise Cut Weir	44,500	CY	$5.00	$ 222,500	
11	P	Temprorary Removal of Riprap at Paradise Cut Weir	1,425	CY	$12.00	$ 17,200	
12	P	New Riprap placement	1,519	CY	$50.00	$ 76,000	
13	P	Waste Materials/ Spoils	44,500	CY	$4.00	$ 178,000	
		Mobilization/Field Oversight Expenses				$ 41,400	
1	P	Mobilization / Demobilization	1	LS	5%	$ 41,400	
		Parametric Contingency				$ 248,400	
1	P	Unallocated Items Allowance	1	LS	5%	$ 41,400	
2	P	Environmental Mitigation	1	LS	25%	$ 207,000	
					Running Subtotal:	$ 1,117,500	
		Markups				$ 33,600	
1	S	Subcontractor Markups	1	LS	0.0%	$ -	
2	P	Prime Contractor OH&P on Subs	1	LS	0.0%	$ -	
3	P	Prime Contractor OH&P on Self-Perform	1	LS	0.0%	$ -	
4	P	Contractor Insurance Program	1	LS	0.0%	$ -	
5	P	State Sales Taxes on Matls	1	LS	0.0%	$ -	
6	P	Escalation	1	LS	3.0%	$ 33,600	
					Running Subtotal:	$ 1,151,100	Total Estimated Constr Costs w/o contingency
		Project Administration & Management				$ 968,700	
1	--	Construction Oversight & Management	1	LS	15%	$ 172,700	
2	--	Engineering & Design	1	LS	15%	$ 198,600	
3	--	Permitting & Legal	1	LS	5%	$ 76,200	
4	--	Contingency	1	LS	30%	$ 479,600	
5	--	Engineering Services During Construction	1	LS	2%	$ 41,600	
					Grand Total:	$ 2,120,000	Total Estimated Constr Costs w/ Contingency
				Cost Range:	$ 1,700,000.00	$ 2,650,000	Per AACE cost estimate guidelines

Notes:
1) This OPCC is classified as a Class 4 cost estimate per AACE guidelines. Stated accuracy range = -20% to + 25%.
2) Pricing basis = 2nd Qtr 2010, escalation to midpoint of construction is not included.
3) P=Prime, S=Subcontractor
4) Pricing assumes competitive market conditions at time of tender (+3 bidders/trade).
5) Owner soft costs and project management expenses excluded.

Estimating Disclaimer - Engineer's Opinion of Probable Construction Costs

The estimate of costs shown and any resulting conclusions on the project financial, economic feasibility or funding requirements have been prepared from guidance in the project evaluation and implementation from the information available at the time the estimate was prepared. The final Costs of the project and resulting feasibility will depend on actual labor and material costs, competitive market conditions and other variable factors. Accordingly, the final project costs may vary from the estimate. Project feasibility, benefit/cost analysis, and risk must be reviewed prior to making specific funding decisions and establishment of the project budget.

AACE International CLASS 4 Cost Estimate - Class 4 estimates are generally prepared based on limited information and subsequently have fairly wide accuracy ranges. Typically, engineering is 10% to 40% complete. They are typically used for project screening, determination of feasibility, concept evaluation, and preliminary budget approval. Virtually all Class 4 estimates use stochastic estimating methods such as cost curves, capacity factors, and other parametric and modeling techniques. Expected accuracy ranges are from -15% to -30% on the low side and +20% to 50% on the high side, depending on the technological complexity of the project, appropriate reference information, and the inclusion of an appropriate contingency determination. Ranges could exceed those shown in unusual circumstances. As little as 20 hours or less to perhaps more than 300 hours may be spent preparing the estimate depending on the project and estimating methodology (AACE International Recommended Practices and Standards).

Paradise Cut System Elements | **Romain Maendly**
Sacramento, CA | 7/21/2013

!

Lengthen Paradise Cut Weir by 200 ft; and decrease height by 13 feet; No Dredging

Opinion of Probable Construction Costs

Currency: USD-United States-JUNE 2011 Dollar

Grand Total Price: $ 2,328,000

Item	GC	Description	Quantity	UOM	Unit Price	Total Price	Comments
		Included Items				$ 908,700	
1	P	Permanent ROW	-	Ac	$17,000	$ -	
2	P	Temporary Easement	10	Ac	$5,000	$ 50,000	
3	P	Hydroseeding	12	Ac	$2,000	$ 24,000	
4	P	Clearing and Grubbing	12	Ac	$5,000	$ 60,000	
5	P	Dewatering Extension	-	LF	$60	$ -	
6	P	Cofferdam/River Diversion	2	LS	$50,000	$ 100,000	
7	P	Dewatering Costs	1	LS	$100,000	$ 100,000	
8	P	Channel Excavation to Levee Embankments	-	CY	$5.00	$ -	
9	P	Embankment Fill	-	CY	$16.00	$ -	
10	P	Widen or Excavation of Paradise Cut Weir	53,500	CY	$5.00	$ 267,500	
11	P	Temprorary Removal of Riprap at Paradise Cut Weir	1,425	CY	$12.00	$ 17,200	
12	P	New Riprap placement	1,519	CY	$50.00	$ 76,000	
13	P	Waste Materials/ Spoils	53,500	CY	$4.00	$ 214,000	
		Mobilization/Field Oversight Expenses				$ 45,500	
1	P	Mobilization / Demobilization	1	LS	5%	$ 45,500	
		Parametric Contingency				$ 272,700	
1	P	Unallocated Items Allowance	1	LS	5%	$ 45,500	
2	P	Environmental Mitigation	1	LS	25%	$ 227,200	
					Running Subtotal:	$ 1,226,900	
		Markups				$ 36,900	
1	S	Subcontractor Markups	1	LS	0.0%	$ -	
2	P	Prime Contractor OH&P on Subs	1	LS	0.0%	$ -	
3	P	Prime Contractor OH&P on Self-Perform	1	LS	0.0%	$ -	
4	P	Contractor Insurance Program	1	LS	0.0%	$ -	
5	P	State Sales Taxes on Matls	1	LS	0.0%	$ -	
6	P	Escalation	1	LS	3.0%	$ 36,900	
					Running Subtotal:	$ 1,263,800	Total Estimated Constr Costs w/o contingency
		Project Administration & Management				$ 1,063,600	
1	--	Construction Oversight & Management	1	LS	15%	$ 189,600	
2	--	Engineering & Design	1	LS	15%	$ 218,100	
3	--	Permitting & Legal	1	LS	5%	$ 83,600	
4	--	Contingency	1	LS	30%	$ 526,600	
5	--	Engineering Services During Construction	1	LS	2%	$ 45,700	
					Grand Total:	$ 2,328,000	Total Estimated Constr Costs w/ Contingency
				Cost Range:	$ 1,860,000	$ 2,910,000	Per AACE cost estimate guidelines

Notes:

1) This OPCC is classified as a Class 4 cost estimate per AACE guidelines. Stated accuracy range = -20% to + 25%.
2) Pricing basis = 2nd Qtr 2010, escalation to midpoint of construction is not included.
3) P=Prime, S=Subcontractor
4) Pricing assumes competitive market conditions at time of tender (+3 bidders/trade).
5) Owner soft costs and project management expenses excluded.

Estimating Disclaimer - Engineer's Opinion of Probable Construction Costs

The estimate of costs shown and any resulting conclusions on the project financial, economic feasibility or funding requirements have been prepared from guidance in the project evaluation and implementation from the information available at the time the estimate was prepared. The final Costs of the project and resulting feasibility will depend on actual labor and material costs, competitive market conditions and other variable factors. Accordingly, the final project costs may vary from the estimate. Project feasibility, benefit/cost analysis, and risk must be reviewed prior to making specific funding decisions and establishment of the project budget.

AACE International CLASS 4 Cost Estimate - Class 4 estimates are generally prepared based on limited information and subsequently have fairly wide accuracy ranges. Typically, engineering is 10% to 40% complete. They are typically used for project screening, determination of feasibility, concept evaluation, and preliminary budget approval. Virtually all Class 4 estimates use stochastic estimating methods such as cost curves, capacity factors, and other parametric and modeling techniques. Expected accuracy ranges are from -15% to -30% on the low side and +20% to 50% on the high side, depending on the technological complexity of the project, appropriate reference information, and the inclusion of an appropriate contingency determination. Ranges could exceed those shown in unusual circumstances. As little as 20 hours or less to perhaps more than 300 hours may be spent preparing the estimate depending on the project and estimating methodology (AACE International Recommended Practices and Standards).

Paradise Cut System Elements | **Romain Maendly**

Sacramento, CA | 7/21/2013

J

Lengthen Paradise Cut Weir by 200 ft; and decrease height by 13 feet; Dredge main channel to I5 feet

Opinion of Probable Construction Costs

Currency: USD-United States-JUNE 2011 Dollar

Grand Total Price: **$ 11,052,000**

Item	GC	Description	Quantity	UOM	Unit Price	Total Price	Comments
		Included Items				**$ 4,316,100**	
1	P	Permanent ROW	-	Ac	$17,000	$ -	
2	P	Temporary Easement	10	Ac	$5,000	$ 50,000	
3	P	Hydroseeding	12	Ac	$2,000	$ 24,000	
4	P	Clearing and Grubbing	140	Ac	$5,000	$ 700,000	
5	P	Dewatering Extension	8,000	LF	$60	$ 480,000	
6	P	Cofferdam/River Diversion	2	LS	$50,000	$ 100,000	
7	P	Dewatering Costs	1	LS	$100,000	$ 100,000	
8	P	Channel Excavation to Levee Embankments	-	CY	$5.00	$ -	
9	P	Embankment Fill	-	CY	$16.00	$ -	
10	P	Widen or Excavation of Paradise Cut Weir	53,500	CY	$5.00	$ 267,500	
11	P	Temprorary Removal of Riprap at Paradise Cut Weir	1,425	CY	$12.00	$ 17,200	
12	P	New Riprap placement	1,519	CY	$50.00		
13	P	Main Channel Excavation	262,600	CY	$5.00	$ 1,313,000	
14	P	Waste Materials/ Spoils	316,100	CY	$4.00	$ 1,264,400	
		Mobilization/Field Oversight Expenses				**$ 215,900**	
1	P	Mobilization / Demobilization	1	LS	5%	$ 215,900	
		Parametric Contingency				**$ 1,295,000**	
1	P	Unallocated Items Allowance	1	LS	5%	$ 215,900	
2	P	Environmental Mitigation	1	LS	25%	$ 1,079,100	
					Running Subtotal:	**$ 5,827,000**	
		Markups				**$ 174,900**	
1	S	Subcontractor Markups	1	LS	0.0%	$ -	
2	P	Prime Contractor OH&P on Subs	1	LS	0.0%	$ -	
3	P	Prime Contractor OH&P on Self-Perform	1	LS	0.0%	$ -	
4	P	Contractor Insurance Program	1	LS	0.0%	$ -	
5	P	State Sales Taxes on Matls	1	LS	0.0%	$ -	
6	P	Escalation	1	LS	3.0%	$ 174,900	
					Running Subtotal:	**$ 6,001,900**	Total Estimated Constr Costs w/o contingency
		Project Administration & Management				**$ 5,049,700**	
1	--	Construction Oversight & Management	1	LS	15%	$ 900,300	
2	--	Engineering & Design	1	LS	15%	$ 1,035,400	
3	--	Permitting & Legal	1	LS	5%	$ 396,900	
4	--	Contingency	1	LS	30%	$ 2,500,400	
5	--	Engineering Services During Construction	1	LS	2%	$ 216,700	
					Grand Total:	**$ 11,052,000**	Total Estimated Constr Costs w/ Contingency
				Cost Range:	**$ 8,800,000**	**$ 13,800,000**	Per AACE cost estimate guidelines

Notes:

1) This OPCC is classified as a Class 4 cost estimate per AACE guidelines. Stated accuracy range = -20% to + 25%.
2) Pricing basis = 2nd Qtr 2010, escalation to midpoint of construction is not included.
3) P=Prime, S=Subcontractor
4) Pricing assumes competitive market conditions at time of tender (+3 bidders/trade).
5) Owner soft costs and project management expenses excluded.

Estimating Disclaimer - Engineer's Opinion of Probable Construction Costs

The estimate of costs shown and any resulting conclusions on the project financial, economic feasibility or funding requirements have been prepared from guidance in the project evaluation and implementation from the information available at the time the estimate was prepared. The final Costs of the project and resulting feasibility will depend on actual labor and material costs, competitive market conditions and other variable factors. Accordingly, the final project costs may vary from the estimate. Project feasibility, benefit/cost analysis, and risk must be reviewed prior to making specific funding decisions and establishment of the project budget.

AACE International CLASS 4 Cost Estimate - Class 4 estimates are generally prepared based on limited information and subsequently have fairly wide accuracy ranges. Typically, engineering is 10% to 40% complete. They are typically used for project screening, determination of feasibility, concept evaluation, and preliminary budget approval. Virtually all Class 4 estimates use stochastic estimating methods such as cost curves, capacity factors, and other parametric and modeling techniques. Expected accuracy ranges are from -15% to -30% on the low side and +20% to 50% on the high side, depending on the technological complexity of the project, appropriate reference information, and the inclusion of an appropriate contingency determination. Ranges could exceed those shown in unusual circumstances. As little as 20 hours or less to perhaps more than 300 hours may be spent preparing the estimate depending on the project and estimating methodology (AACE International Recommended Practices and Standards).

Paradise Cut System Elements — **Romain Maendly**
Sacramento, CA — 7/21/2013

K
Lengthen Paradise Cut Weir by 400 ft; keep existing weir height
Opinion of Probable Construction Costs
Currency: USD-United States-JUNE 2011 Dollar

Grand Total Price: $ 1,808,000

Item	GC	Description	Quantity	UOM	Unit Price	Total Price	Comments
		Included Items				$ 705,800	
1	P	Permanent ROW	-	Ac	$17,000	$ -	
2	P	Temporary Easement	10	Ac	$5,000	$ 50,000	
3	P	Hydroseeding	13	Ac	$2,000	$ 26,000	
4	P	Clearing and Grubbing	13	Ac	$5,000	$ 65,000	
5	P	Dewatering Extension		LF	$60	$ -	
6	P	Cofferdam/River Diversion		LS	$50,000	$ -	
7	P	Dewatering Costs		LS	$100,000	$ -	
8	P	Channel Excavation to Levee Embankments	-	CY	$5.00	$ -	
9	P	Embankment Fill	-	CY	$16.00	$ -	
10	P	Widen or Excavation of Paradise Cut Weir	46,300	CY	$5.00	$ 231,500	
11	P	Temprorary Removal of Riprap at Paradise Cut Weir	-	CY	$12.00	$ -	
12	P	New Riprap placement	2,961	CY	$50.00	$ 148,100	
13	P	Waste Materials/ Spoils	46,300	CY	$4.00	$ 185,200	
		Mobilization/Field Oversight Expenses				$ 35,300	
1	P	Mobilization / Demobilization	1	LS	5%	$ 35,300	
		Parametric Contingency				$ 211,800	
1	P	Unallocated Items Allowance	1	LS	5%	$ 35,300	
2	P	Environmental Mitigation	1	LS	25%	$ 176,500	
					Running Subtotal:	$ 952,900	
		Markups				$ 28,600	
1	S	Subcontractor Markups	1	LS	0.0%	$ -	
2	P	Prime Contractor OH&P on Subs	1	LS	0.0%	$ -	
3	P	Prime Contractor OH&P on Self-Perform	1	LS	0.0%	$ -	
4	P	Contractor Insurance Program	1	LS	0.0%	$ -	
5	P	State Sales Taxes on Matls	1	LS	0.0%	$ -	
6	P	Escalation	1	LS	3.0%	$ 28,600	
					Running Subtotal:	$ 981,500	Total Estimated Constr Costs w/o contingency
		Project Administration & Management				$ 826,200	
1	--	Construction Oversight & Management	1	LS	15%	$ 147,300	
2	--	Engineering & Design	1	LS	15%	$ 169,400	
3	--	Permitting & Legal	1	LS	5%	$ 65,000	
4	--	Contingency	1	LS	30%	$ 409,000	
5	--	Engineering Services During Construction	1	LS	2%	$ 35,500	
					Grand Total:	$ 1,808,000	Total Estimated Constr Costs w/ Contingency
				Cost Range:	$ 1,400,000	$ 2,300,000	Per AACE cost estimate guidelines

Notes:
1) This OPCC is classified as a Class 4 cost estimate per AACE guidelines. Stated accuracy range = -20% to + 25%.
2) Pricing basis = 2nd Qtr 2010, escalation to midpoint of construction is not included.
3) P=Prime, S=Subcontractor
4) Pricing assumes competitive market conditions at time of tender (+3 bidders/trade).
5) Owner soft costs and project management expenses excluded.

Estimating Disclaimer - Engineer's Opinion of Probable Construction Costs

The estimate of costs shown and any resulting conclusions on the project financial, economic feasibility or funding requirements have been prepared from guidance in the project evaluation and implementation from the information available at the time the estimate was prepared. The final Costs of the project and resulting feasibility will depend on actual labor and material costs, competitive market conditions and other variable factors. Accordingly, the final project costs may vary from the estimate. Project feasibility, benefit/cost analysis, and risk must be reviewed prior to making specific funding decisions and establishment of the project budget.

AACE International CLASS 4 Cost Estimate - Class 4 estimates are generally prepared based on limited information and subsequently have fairly wide accuracy ranges. Typically, engineering is 10% to 40% complete. They are typically used for project screening, determination of feasibility, concept evaluation, and preliminary budget approval. Virtually all Class 4 estimates use stochastic estimating methods such as cost curves, capacity factors, and other parametric and modeling techniques. Expected accuracy ranges are from -15% to -30% on the low side and +20% to 50% on the high side, depending on the technological complexity of the project, appropriate reference information, and the inclusion of an appropriate contingency determination. Ranges could exceed those shown in unusual circumstances. As little as 20 hours or less to perhaps more than 300 hours may be spent preparing the estimate depending on the project and estimating methodology (AACE International Recommended Practices and Standards).

Paradise Cut System Elements | **Romain Maendly**
Sacramento, CA | 7/21/2013

L

Lengthen Paradise Cut Weir by 400 ft; and decrease height by 4 feet

Opinion of Probable Construction Costs

Currency: USD-United States-JUNE 2011 Dollar

Grand Total Price: $ 2,710,000

Item	GC	Description	Quantity	UOM	Unit Price	Total Price	Comments
		Included Items				**$ 1,058,000**	
1	P	Permanent ROW	-	Ac	$17,000	$ -	
2	P	Temporary Easement	10	Ac	$5,000	$ 50,000	
3	P	Hydroseeding	13	Ac	$2,000	$ 26,000	
4	P	Clearing and Grubbing	13	Ac	$5,000	$ 65,000	
5	P	Dewatering Extension	-	LF	$60	$ -	
6	P	Cofferdam/River Diversion	2	LS	$50,000	$ 100,000	
7	P	Dewatering Costs	1	LS	$100,000	$ 100,000	
8	P	Channel Excavation to Levee Embankments	-	CY	$5.00	$ -	
9	P	Embankment Fill	-	CY	$16.00	$ -	
10	P	Widen or Excavation of Paradise Cut Weir	61,300	CY	$5.00	$ 306,500	
11	P	Temprorary Removal of Riprap at Paradise Cut Weir	1,425	CY	$12.00	$ 17,200	
12	P	New Riprap placement	2,961	CY	$50.00	$ 148,100	
13	P	Waste Materials/ Spoils	61,300	CY	$4.00	$ 245,200	
		Mobilization/Field Oversight Expenses				**$ 52,900**	
1	P	Mobilization / Demobilization	1	LS	5%	$ 52,900	
		Parametric Contingency				**$ 317,400**	
1	P	Unallocated Items Allowance	1	LS	5%	$ 52,900	
2	P	Environmental Mitigation	1	LS	25%	$ 264,500	
					Running Subtotal:	**$ 1,428,300**	
		Markups				**$ 42,900**	
1	S	Subcontractor Markups	1	LS	0.0%	$ -	
2	P	Prime Contractor OH&P on Subs	1	LS	0.0%	$ -	
3	P	Prime Contractor OH&P on Self-Perform	1	LS	0.0%	$ -	
4	P	Contractor Insurance Program	1	LS	0.0%	$ -	
5	P	State Sales Taxes on Matls	1	LS	0.0%	$ -	
6	P	Escalation	1	LS	3.0%	$ 42,900	
					Running Subtotal:	**$ 1,471,200**	Total Estimated Constr Costs w/o contingency
		Project Administration & Management				**$ 1,237,900**	
1	--	Construction Oversight & Management	1	LS	15%	$ 220,700	
2	--	Engineering & Design	1	LS	15%	$ 253,800	
3	--	Permitting & Legal	1	LS	5%	$ 97,300	
4	--	Contingency	1	LS	30%	$ 612,900	
5	--	Engineering Services During Construction	1	LS	2%	$ 53,200	
					Grand Total:	**$ 2,710,000**	Total Estimated Constr Costs w/ Contingency
				Cost Range:	**$ 2,200,000**	**$ 3,400,000**	Per AACE cost estimate guidelines

Notes:

1) This OPCC is classified as a Class 4 cost estimate per AACE guidelines. Stated accuracy range = -20% to + 25%.
2) Pricing basis = 2nd Qtr 2010, escalation to midpoint of construction is not included.
3) P=Prime, S=Subcontractor
4) Pricing assumes competitive market conditions at time of tender (+3 bidders/trade).
5) Owner soft costs and project management expenses excluded.

Estimating Disclaimer - Engineer's Opinion of Probable Construction Costs

The estimate of costs shown and any resulting conclusions on the project financial, economic feasibility or funding requirements have been prepared from guidance in the project evaluation and implementation from the information available at the time the estimate was prepared. The final Costs of the project and resulting feasibility will depend on actual labor and material costs, competitive market conditions and other variable factors. Accordingly, the final project costs may vary from the estimate. Project feasibility, benefit/cost analysis, and risk must be reviewed prior to making specific funding decisions and establishment of the project budget.

AACE International CLASS 4 Cost Estimate - Class 4 estimates are generally prepared based on limited information and subsequently have fairly wide accuracy ranges. Typically, engineering is 10% to 40% complete. They are typically used for project screening, determination of feasibility, concept evaluation, and preliminary budget approval. Virtually all Class 4 estimates use stochastic estimating methods such as cost curves, capacity factors, and other parametric and modeling techniques. Expected accuracy ranges are from -15% to -30% on the low side and +20% to 50% on the high side, depending on the technological complexity of the project, appropriate reference information, and the inclusion of an appropriate contingency determination. Ranges could exceed those shown in unusual circumstances. As little as 20 hours or less to perhaps more than 300 hours may be spent preparing the estimate depending on the project and estimating methodology (AACE International Recommended Practices and Standards).

Paradise Cut System Elements — **Romain Maendly**

Sacramento, CA — 7/21/2013

California DWR

Paradise Cut - System Elements TM

M

Lengthen Paradise Cut Weir by 400 ft; and decrease height by 9 feet

Opinion of Probable Construction Costs

Currency: USD-United States-JUNE 2011 Dollar

Grand Total Price: $ 3,111,000

Item	GC	Description	Quantity	UOM	Unit Price	Total Price	Comments
		Included Items				$ 1,214,600	
1	P	Permanent ROW	-	Ac	$17,000	$ -	
2	P	Temporary Easement	10	Ac	$5,000	$ 50,000	
3	P	Hydroseeding	13	Ac	$2,000	$ 26,000	
4	P	Clearing and Grubbing	13	Ac	$5,000	$ 65,000	
5	P	Dewatering Extension	-	LF	$60	$ -	
6	P	Cofferdam/River Diversion	2	LS	$50,000	$ 100,000	
7	P	Dewatering Costs	1	LS	$100,000	$ 100,000	
8	P	Channel Excavation to Levee Embankments	-	CY	$5.00	$ -	
9	P	Embankment Fill	-	CY	$16.00	$ -	
10	P	Widen or Excavation of Paradise Cut Weir	78,700	CY	$5.00	$ 393,500	
11	P	Temprorary Removal of Riprap at Paradise Cut Weir	1,425	CY	$12.00	$ 17,200	
12	P	New Riprap placement	2,961	CY	$50.00	$ 148,100	
13	P	Waste Materials/ Spoils	78,700	CY	$4.00	$ 314,800	
		Mobilization/Field Oversight Expenses				$ 60,800	
1	P	Mobilization / Demobilization	1	LS	5%	$ 60,800	
		Parametric Contingency				$ 364,500	
1	P	Unallocated Items Allowance	1	LS	5%	$ 60,800	
2	P	Environmental Mitigation	1	LS	25%	$ 303,700	
					Running Subtotal:	$ 1,639,900	
		Markups				$ 49,200	
1	S	Subcontractor Markups	1	LS	0.0%	$ -	
2	P	Prime Contractor OH&P on Subs	1	LS	0.0%	$ -	
3	P	Prime Contractor OH&P on Self-Perform	1	LS	0.0%	$ -	
4	P	Contractor Insurance Program	1	LS	0.0%	$ -	
5	P	State Sales Taxes on Matls	1	LS	0.0%	$ -	
6	P	Escalation	1	LS	3.0%	$ 49,200	
					Running Subtotal:	$ 1,689,100	Total Estimated Constr Costs w/o contingency
		Project Administration & Management				$ 1,421,200	
1	--	Construction Oversight & Management	1	LS	15%	$ 253,400	
2	--	Engineering & Design	1	LS	15%	$ 291,400	
3	--	Permitting & Legal	1	LS	5%	$ 111,700	
4	--	Contingency	1	LS	30%	$ 703,700	
5	--	Engineering Services During Construction	1	LS	2%	$ 61,000	
					Grand Total:	$ 3,111,000	Total Estimated Constr Costs w/ Contingency
				Cost Range:	$ 2,500,000	$ 3,900,000	Per AACE cost estimate guidelines

Notes:

1) This OPCC is classified as a Class 4 cost estimate per AACE guidelines. Stated accuracy range = -20% to + 25%.
2) Pricing basis = 2nd Qtr 2010, escalation to midpoint of construction is not included.
3) P=Prime, S=Subcontractor
4) Pricing assumes competitive market conditions at time of tender (+3 bidders/trade).
5) Owner soft costs and project management expenses excluded.

Estimating Disclaimer - Engineer's Opinion of Probable Construction Costs

The estimate of costs shown and any resulting conclusions on the project financial, economic feasibility or funding requirements have been prepared from guidance in the project evaluation and implementation from the information available at the time the estimate was prepared. The final Costs of the project and resulting feasibility will depend on actual labor and material costs, competitive market conditions and other variable factors. Accordingly, the final project costs may vary from the estimate. Project feasibility, benefit/cost analysis, and risk must be reviewed prior to making specific funding decisions and establishment of the project budget.

AACE International CLASS 4 Cost Estimate - Class 4 estimates are generally prepared based on limited information and subsequently have fairly wide accuracy ranges. Typically, engineering is 10% to 40% complete. They are typically used for project screening, determination of feasibility, concept evaluation, and preliminary budget approval. Virtually all Class 4 estimates use stochastic estimating methods such as cost curves, capacity factors, and other parametric and modeling techniques. Expected accuracy ranges are from -15% to -30% on the low side and +20% to 50% on the high side, depending on the technological complexity of the project, appropriate reference information, and the inclusion of an appropriate contingency determination. Ranges could exceed those shown in unusual circumstances. As little as 20 hours or less to perhaps more than 300 hours may be spent preparing the estimate depending on the project and estimating methodology (AACE International Recommended Practices and Standards).

Paradise Cut System Elements — **Romain Maendly**
Sacramento, CA — 7/21/2013

N

Lengthen Paradise Cut Weir by 400 ft; and decrease height by 13 feet; No Dredging

Opinion of Probable Construction Costs

Currency: USD-United States-JUNE 2011 Dollar

Grand Total Price **$ 3,413,000**

Item	GC	Description	Quantity	UOM	Unit Price	Total Price	Comments
		Included Items				**$ 1,332,500**	
1	P	Permanent ROW	-	Ac	$17,000	$ -	
2	P	Temporary Easement	10	Ac	$5,000	$ 50,000	
3	P	Hydroseeding	13	Ac	$2,000	$ 26,000	
4	P	Clearing and Grubbing	13	Ac	$5,000	$ 65,000	
5	P	Dewatering Extension	-	LF	$60	$ -	
6	P	Cofferdam/River Diversion	2	LS	$50,000	$ 100,000	
7	P	Dewatering Costs	1	LS	$100,000	$ 100,000	
8	P	Channel Excavation to Levee Embankments	-	CY	$5.00	$ -	
9	P	Embankment Fill	-	CY	$16.00	$ -	
10	P	Widen or Excavation of Paradise Cut Weir	91,800	CY	$5.00	$ 459,000	
11	P	Temprorary Removal of Riprap at Paradise Cut Weir	1,425	CY	$12.00	$ 17,200	
12	P	New Riprap placement	2,961	CY	$50.00	$ 148,100	
13	P	Waste Materials/ Spoils	91,800	CY	$4.00	$ 367,200	
		Mobilization/Field Oversight Expenses				**$ 66,700**	
1	P	Mobilization / Demobilization	1	LS	5%	$ 66,700	
		Parametric Contingency				**$ 399,900**	
1	P	Unallocated Items Allowance	1	LS	5%	$ 66,700	
2	P	Environmental Mitigation	1	LS	25%	$ 333,200	
					Running Subtotal:	**$ 1,799,100**	
		Markups				**$ 54,000**	
1	S	Subcontractor Markups	1	LS	0.0%	$ -	
2	P	Prime Contractor OH&P on Subs	1	LS	0.0%	$ -	
3	P	Prime Contractor OH&P on Self-Perform	1	LS	0.0%	$ -	
4	P	Contractor Insurance Program	1	LS	0.0%	$ -	
5	P	State Sales Taxes on Matls	1	LS	0.0%	$ -	
6	P	Escalation	1	LS	3.0%	$ 54,000	
					Running Subtotal:	**$ 1,853,100**	Total Estimated Constr Costs w/o contingency
		Project Administration & Management				**$ 1,559,400**	
1	--	Construction Oversight & Management	1	LS	15%	$ 278,000	
2	--	Engineering & Design	1	LS	15%	$ 319,700	
3	--	Permitting & Legal	1	LS	5%	$ 122,600	
4	--	Contingency	1	LS	30%	$ 772,100	
5	--	Engineering Services During Construction	1	LS	2%	$ 67,000	
					Grand Total:	**$ 3,413,000**	Total Estimated Constr Costs w/ Contingency
				Cost Range:	**$ 2,700,000**	**$ 4,300,000**	Per AACE cost estimate guidelines

Notes:

1) This OPCC is classified as a Class 4 cost estimate per AACE guidelines. Stated accuracy range = -20% to + 25%.
2) Pricing basis = 2nd Qtr 2010, escalation to midpoint of construction is not included.
3) P=Prime, S=Subcontractor
4) Pricing assumes competitive market conditions at time of tender (+3 bidders/trade).
5) Owner soft costs and project management expenses excluded.

Estimating Disclaimer - Engineer's Opinion of Probable Construction Costs

The estimate of costs shown and any resulting conclusions on the project financial, economic feasibility or funding requirements have been prepared from guidance in the project evaluation and implementation from the information available at the time the estimate was prepared. The final Costs of the project and resulting feasibility will depend on actual labor and material costs, competitive market conditions and other variable factors. Accordingly, the final project costs may vary from the estimate. Project feasibility, benefit/cost analysis, and risk must be reviewed prior to making specific funding decisions and establishment of the project budget.

AACE International CLASS 4 Cost Estimate - Class 4 estimates are generally prepared based on limited information and subsequently have fairly wide accuracy ranges. Typically, engineering is 10% to 40% complete. They are typically used for project screening, determination of feasibility, concept evaluation, and preliminary budget approval. Virtually all Class 4 estimates use stochastic estimating methods such as cost curves, capacity factors, and other parametric and modeling techniques. Expected accuracy ranges are from -15% to -30% on the low side and +20% to 50% on the high side, depending on the technological complexity of the project, appropriate reference information, and the inclusion of an appropriate contingency determination. Ranges could exceed those shown in unusual circumstances. As little as 20 hours or less to perhaps more than 300 hours may be spent preparing the estimate depending on the project and estimating methodology (AACE International Recommended Practices and Standards).

Paradise Cut System Elements — **Romain Maendly**
Sacramento, CA — 7/21/2013

O

Lengthen Paradise Cut Weir by 400 ft; and decrease height by 13 feet; Dredge main channel to 15 feet

Opinion of Probable Construction Costs

Currency: USD-United States-JUNE 2011 Dollar

Grand Total Price: **$ 12,319,000**

Item	GC	Description	Quantity	UOM	Unit Price	Total Price	Comments
		Included Items				**$ 4,810,900**	
1	P	Permanent ROW	-	Ac	$17,000	$ -	
2	P	Temporary Easement	10	Ac	$5,000	$ 50,000	
3	P	Hydroseeding	13	Ac	$2,000	$ 26,000	
4	P	Clearing and Grubbing	140	Ac	$5,000	$ 700,000	
5	P	Dewatering Extension	8,000	LF	$60	$ 480,000	
6	P	Cofferdam/River Diversion	2	LS	$50,000	$ 100,000	
7	P	Dewatering Costs	1	LS	$100,000	$ 100,000	
8	P	Channel Excavation to Levee Embankments	-	CY	$5.00	$ -	
9	P	Embankment Fill	-	CY	$16.00	$ -	
10	P	Widen or Excavation of Paradise Cut Weir	91,800	CY	$5.00	$ 459,000	
11	P	Temprorary Removal of Riprap at Paradise Cut Weir	1,425	CY	$12.00	$ 17,200	
12	P	New Riprap placement	2,961	CY	$50.00	$ 148,100	
13	P	Main Channel Excavation	262,600	CY	$5.00	$ 1,313,000	
14	P	Waste Materials/ Spoils	354,400	CY	$4.00	$ 1,417,600	
		Mobilization/Field Oversight Expenses				**$ 240,600**	
1	P	Mobilization / Demobilization	1	LS	5%	$ 240,600	
		Parametric Contingency				**$ 1,443,400**	
1	P	Unallocated Items Allowance	1	LS	5%	$ 240,600	
2	P	Environmental Mitigation	1	LS	25%	$ 1,202,800	
					Running Subtotal:	**$ 6,494,900**	
		Markups				**$ 194,900**	
1	S	Subcontractor Markups	1	LS	0.0%	$ -	
2	P	Prime Contractor OH&P on Subs	1	LS	0.0%	$ -	
3	P	Prime Contractor OH&P on Self-Perform	1	LS	0.0%	$ -	
4	P	Contractor Insurance Program	1	LS	0.0%	$ -	
5	P	State Sales Taxes on Matls	1	LS	0.0%	$ -	
6	P	Escalation	1	LS	3.0%	$ 194,900	
					Running Subtotal:	**$ 6,689,800**	Total Estimated Constr Costs w/o contingency
		Project Administration & Management				**$ 5,628,500**	
1	--	Construction Oversight & Management	1	LS	15%	$ 1,003,500	
2	--	Engineering & Design	1	LS	15%	$ 1,154,000	
3	--	Permitting & Legal	1	LS	5%	$ 442,400	
4	--	Contingency	1	LS	30%	$ 2,787,000	
5	--	Engineering Services During Construction	1	LS	2%	$ 241,600	
					Grand Total:	**$ 12,319,000**	Total Estimated Constr Costs w/ Contingency
				Cost Range:	**$ 10,000,000**	**$ 15,000,000**	Per AACE cost estimate guidelines

Notes:

1) This OPCC is classified as a Class 4 cost estimate per AACE guidelines. Stated accuracy range = -20% to + 25%.
2) Pricing basis = 2nd Qtr 2010, escalation to midpoint of construction is not included.
3) P=Prime, S=Subcontractor
4) Pricing assumes competitive market conditions at time of tender (+3 bidders/trade).
5) Owner soft costs and project management expenses excluded.

Estimating Disclaimer - Engineer's Opinion of Probable Construction Costs

The estimate of costs shown and any resulting conclusions on the project financial, economic feasibility or funding requirements have been prepared from guidance in the project evaluation and implementation from the information available at the time the estimate was prepared. The final Costs of the project and resulting feasibility will depend on actual labor and material costs, competitive market conditions and other variable factors. Accordingly, the final project costs may vary from the estimate. Project feasibility, benefit/cost analysis, and risk must be reviewed prior to making specific funding decisions and establishment of the project budget.

AACE International CLASS 4 Cost Estimate - Class 4 estimates are generally prepared based on limited information and subsequently have fairly wide accuracy ranges. Typically, engineering is 10% to 40% complete. They are typically used for project screening, determination of feasibility, concept evaluation, and preliminary budget approval. Virtually all Class 4 estimates use stochastic estimating methods such as cost curves, capacity factors, and other parametric and modeling techniques. Expected accuracy ranges are from -15% to -30% on the low side and +20% to 50% on the high side, depending on the technological complexity of the project, appropriate reference information, and the inclusion of an appropriate contingency determination. Ranges could exceed those shown in unusual circumstances. As little as 20 hours or less to perhaps more than 300 hours may be spent preparing the estimate depending on the project and estimating methodology (AACE International Recommended Practices and Standards).

Paradise Cut System Elements | **Romain Maendly**
Sacramento, CA | 7/21/2013

D1

Widen opening at Railroad 1 (RR1) by 400 feet

Opinion of Probable Construction Costs

Currency: USD-United States-JUNE 2011 Dollar

Grand Total Price: $ 64,384,000

Item	GC	Description	Quantity	UOM	Unit Price	Total Price	Comments
		Included Items				$ 25,146,500	
1	P	Permanent ROW	10	Ac	$17,000	$ 170,000	p. 57/736 Att 8j Table4-2 from CVFPP, Range from $15 - $17,000 / Ac
2	P	Temporary Easement	5	Ac	$5,000	$ 25,000	p. 139 Table1 Att 8j from CVFPP
3	P	Hydroseeding	15	Ac	$2,000	$ 30,000	p. 139 Table1 Att 8j from CVFPP
4	P	Clearing and Grubbing	15	Ac	$5,000	$ 75,000	p. 139 Table1 Att 8j from CVFPP
5	P	Dewatering Extension	-	LF	$60	$ -	Sacramento Area Sewer District, 2011, extended from below
6	P	Demolish Railroad	500	LF	$2,333	$ 1,166,700	Estimated (assumed 1/3 of New Bridge Cost - Similar to Levee)
7	P	New Railroad Bridge	900	LF	$7,000	$ 6,300,000	Union Pacific Railroad Employee Personal Communication
8	P	Cofferdam/River Diversion	2	LS	$50,000	$ 100,000	Department of Water Resources, 2010. Paradise Cut Bypass Investigation.
9	P	Dewatering Costs	1	LS	$100,000	$ 100,000	Department of Water Resources, 2010. Paradise Cut Bypass Investigation.
10	P	Excavation of Rail Road Bridge #1	26,851	CY	$5.00	$ 134,300	Excavation at the location of the bridge
11	P	Levee Removal Cost	3,000	ft	$1,420	$ 4,261,400	Range from $5-$10 million/mile, took the average
12	P	New Setback Levee Cost	3,000	ft	$4,261	$ 12,784,100	Range from $20-$25 million/mile, took the average
		Mobilization/Field Oversight Expenses				$ 1,257,400	
1	P	Mobilization / Demobilization	1	LS	5%	$ 1,257,400	
		Parametric Contingency				$ 7,544,100	
1	P	Unallocated Items Allowance	1	LS	5%	$ 1,257,400	
2	P	Environmental Mitigation	1	LS	25%	$ 6,286,700	
					Running Subtotal:	$ 33,948,000	
		Markups				$ 1,018,500	
1	S	Subcontractor Markups	1	LS	0.0%	$ -	
2	P	Prime Contractor OH&P on Subs	1	LS	0.0%	$ -	
3	P	Prime Contractor OH&P on Self-Perform	1	LS	0.0%	$ -	
4	P	Contractor Insurance Program	1	LS	0.0%	$ -	
5	P	State Sales Taxes on Matls	1	LS	0.0%	$ -	
6	P	Escalation	1	LS	3.0%	$ 1,018,500	
					Running Subtotal:	$ 34,966,500	Total Estimated Constr Costs w/o contingency
		Project Administration & Management				$ 29,417,900	
1	--	Construction Oversight & Management	1	LS	15%	$ 5,245,000	
2	--	Engineering & Design	1	LS	15%	$ 6,031,700	
3	--	Permitting & Legal	1	LS	5%	$ 2,312,200	
4	--	Contingency	1	LS	30%	$ 14,566,600	
5	--	Engineering Services During Construction	1	LS	2%	$ 1,262,400	
					Grand Total:	$ 64,384,000	Total Estimated Constr Costs w/ Contingency
				Cost Range:	$ 52,000,000	$ 80,000,000	Per AACE cost estimate guidelines

Notes:

1) This OPCC is classified as a Class 4 cost estimate per AACE guidelines. Stated accuracy range = -20% to + 25%.
2) Pricing basis = 2nd Qtr 2010, escalation to midpoint of construction is not included.
3) P=Prime, S=Subcontractor
4) Pricing assumes competitive market conditions at time of tender (+3 bidders/trade).
5) Owner soft costs and project management expenses excluded.

Estimating Disclaimer - Engineer's Opinion of Probable Construction Costs

The estimate of costs shown and any resulting conclusions on the project financial, economic feasibility or funding requirements have been prepared from guidance in the project evaluation and implementation from the information available at the time the estimate was prepared. The final Costs of the project and resulting feasibility will depend on actual labor and material costs, competitive market conditions and other variable factors. Accordingly, the final project costs may vary from the estimate. Project feasibility, benefit/cost analysis, and risk must be reviewed prior to making specific funding decisions and establishment of the project budget.

AACE International CLASS 4 Cost Estimate - Class 4 estimates are generally prepared based on limited information and subsequently have fairly wide accuracy ranges. Typically, engineering is 10% to 40% complete. They are typically used for project screening, determination of feasibility, concept evaluation, and preliminary budget approval. Virtually all Class 4 estimates use stochastic estimating methods such as cost curves, capacity factors, and other parametric and modeling techniques. Expected accuracy ranges are from -15% to -30% on the low side and +20% to 50% on the high side, depending on the technological complexity of the project, appropriate reference information, and the inclusion of an appropriate contingency determination. Ranges could exceed those shown in unusual circumstances. As little as 20 hours or less to perhaps more than 300 hours may be spent preparing the estimate depending on the project and estimating methodology (AACE International Recommended Practices and Standards).

DWR - Paradise Cut System Elements | **Romain Maendly**
Sacramento, CA | 7/21/2013

D2
Raise RR1 bridge by 3 feet
Opinion of Probable Construction Costs

Currency: USD-United States-JUNE 2011 Dollar

Grand Total Price: $ 12,909,000

Item	GC	Description	Quantity	UOM	Unit Price	Total Price	Comments
		Included Items				**$ 5,046,700**	
1	P	Permanent ROW	-	Ac	$17,000	$ -	
2	P	Temporary Easement	5	Ac	$5,000	$ 25,000	
3	P	Hydroseeding	5	Ac	$2,000	$ 10,000	
4	P	Clearing and Grubbing	5	Ac	$5,000	$ 25,000	
5	P	Dewatering Extension	-	LF	$60	$ -	
6	P	Demolish Railroad	500	LF	$2,333	$ 1,166,700	
7	P	New Railroad Bridge	500	LF	$7,000	$ 3,500,000	
8	P	Raise approach to RR Bridge	600	LF	$200	$ 120,000	Assume cost of $1M / mile; interpolation, Gradient 1% (~3ft)
9	P	Cofferdam/River Diversion	2	LS	$50,000	$ 100,000	
10	P	Dewatering Costs	1	LS	$100,000	$ 100,000	
11	P	Channel Excavation to Levee Embankments	-	CY	$5.00	$ -	
12	P	Embankment Fill	-	CY	$16.00	$ -	
13	P	Waste Materials/ Spoils	-	CY	$4.00	$ -	
		Mobilization/Field Oversight Expenses				**$ 252,400**	
1	P	Mobilization / Demobilization	1	LS	5%	$ 252,400	
		Parametric Contingency				**$ 1,514,100**	
1	P	Unallocated Items Allowance	1	LS	5%	$ 252,400	
2	P	Environmental Mitigation	1	LS	25%	$ 1,261,700	
					Running Subtotal:	**$ 6,813,200**	
		Markups				**$ 204,400**	
1	S	Subcontractor Markups	1	LS	0.0%	$ -	
2	P	Prime Contractor OH&P on Subs	1	LS	0.0%	$ -	
3	P	Prime Contractor OH&P on Self-Perform	1	LS	0.0%	$ -	
4	P	Contractor Insurance Program	1	LS	0.0%	$ -	
5	P	State Sales Taxes on Matls	1	LS	0.0%	$ -	
6	P	Escalation	1	LS	3.0%	$ 204,400	
					Running Subtotal:	**$ 7,017,600**	Total Estimated Constr Costs w/o contingency
		Project Administration & Management				**$ 5,891,000**	
1	--	Construction Oversight & Management	1	LS	15%	$ 1,050,000	
2	--	Engineering & Design	1	LS	15%	$ 1,210,000	
3	--	Permitting & Legal	1	LS	5%	$ 460,000	
4	--	Contingency	1	LS	30%	$ 2,921,000	
5	--	Engineering Services During Construction	1	LS	2%	$ 250,000	
					Grand Total:	**$ 12,909,000**	Total Estimated Constr Costs w/ Contingency
				Cost Range:	**$10,000,000**	**$ 16,000,000**	Per AACE cost estimate guidelines

Notes:
1) This OPCC is classified as a Class 4 cost estimate per AACE guidelines. Stated accuracy range = -20% to + 25%.
2) Pricing basis = 2nd Qtr 2010, escalation to midpoint of construction is not included.
3) P=Prime, S=Subcontractor
4) Pricing assumes competitive market conditions at time of tender (+3 bidders/trade).
5) Owner soft costs and project management expenses excluded.

Estimating Disclaimer - Engineer's Opinion of Probable Construction Costs

The estimate of costs shown and any resulting conclusions on the project financial, economic feasibility or funding requirements have been prepared from guidance in the project evaluation and implementation from the information available at the time the estimate was prepared. The final Costs of the project and resulting feasibility will depend on actual labor and material costs, competitive market conditions and other variable factors. Accordingly, the final project costs may vary from the estimate. Project feasibility, benefit/cost analysis, and risk must be reviewed prior to making specific funding decisions and establishment of the project budget.

AACE International CLASS 4 Cost Estimate - Class 4 estimates are generally prepared based on limited information and subsequently have fairly wide accuracy ranges. Typically, engineering is 10% to 40% complete. They are typically used for project screening, determination of feasibility, concept evaluation, and preliminary budget approval. Virtually all Class 4 estimates use stochastic estimating methods such as cost curves, capacity factors, and other parametric and modeling techniques. Expected accuracy ranges are from -15% to -30% on the low side and +20% to 50% on the high side, depending on the technological complexity of the project, appropriate reference information, and the inclusion of an appropriate contingency determination. Ranges could exceed those shown in unusual circumstances. As little as 20 hours or less to perhaps more than 300 hours may be spent preparing the estimate depending on the project and estimating methodology (AACE International Recommended Practices and Standards).

DWR - Paradise Cut System Elements | **Romain Maendly**
Sacramento, CA | 7/21/2013

D3
Widen RR2 bridge opening by 160 ft
Opinion of Probable Construction Costs

Currency: USD-United States-JUNE 2011 Dollar

Grand Total Price: $ 4,792,000

Item	GC	Description	Quantity	UOM	Unit Price	Total Price	Comments
		Included Items				**$ 1,871,400**	
1	P	Permanent ROW	-	Ac	$17,000	$ -	
2	P	Temporary Easement	5	Ac	$5,000	$ 25,000	
3	P	Hydroseeding	1	Ac	$2,000	$ 2,000	
4	P	Clearing and Grubbing	5	Ac	$5,000	$ 25,000	
5	P	Dewatering Extension	-	LF	$60	$ -	
6	P	Demolish Railroad	160	LF	$2,333	$ 373,400	
7	P	New Railroad Bridge	160	LF	$7,000	$ 1,120,000	
8	P	Cofferdam/River Diversion	2	LS	$50,000	$ 100,000	
9	P	Dewatering Costs	1	LS	$100,000	$ 100,000	
10	P	Channel Excavation to Levee Embankments	13,982	CY	$5.00	$ 70,000	
11	P	Embankment Fill	-	CY	$16.00	$ -	
12	P	Waste Materials/ Spoils	13,982	CY	$4.00	$ 56,000	
		Mobilization/Field Oversight Expenses				**$ 93,600**	
1	P	Mobilization / Demobilization	1	LS	5%	$ 93,600	
		Parametric Contingency				**$ 561,500**	
1	P	Unallocated Items Allowance	1	LS	5%	$ 93,600	
2	P	Environmental Mitigation	1	LS	25%	$ 467,900	
					Running Subtotal:	**$ 2,526,500**	
		Markups				**$ 75,800**	
1	S	Subcontractor Markups	1	LS	0.0%	$ -	
2	P	Prime Contractor OH&P on Subs	1	LS	0.0%	$ -	
3	P	Prime Contractor OH&P on Self-Perform	1	LS	0.0%	$ -	
4	P	Contractor Insurance Program	1	LS	0.0%	$ -	
5	P	State Sales Taxes on Matls	1	LS	0.0%	$ -	
6	P	Escalation	1	LS	3.0%	$ 75,800	
					Running Subtotal:	**$ 2,602,300**	Total Estimated Constr Costs w/o contingency
		Project Administration & Management				**$ 2,189,400**	
1	--	Construction Oversight & Management	1	LS	15%	$ 390,300	
2	--	Engineering & Design	1	LS	15%	$ 448,900	
3	--	Permitting & Legal	1	LS	5%	$ 172,100	
4	--	Contingency	1	LS	30%	$ 1,084,100	
5	--	Engineering Services During Construction	1	LS	2%	$ 94,000	
					Grand Total:	**$ 4,792,000**	Total Estimated Constr Costs w/ Contingency
				Cost Range:	**$4,000,000**	**$ 6,000,000**	Per AACE cost estimate guidelines

Notes:
1) This OPCC is classified as a Class 4 cost estimate per AACE guidelines. Stated accuracy range = -20% to + 25%.
2) Pricing basis = 2nd Qtr 2010, escalation to midpoint of construction is not included.
3) P=Prime, S=Subcontractor
4) Pricing assumes competitive market conditions at time of tender (+3 bidders/trade).
5) Owner soft costs and project management expenses excluded.

Estimating Disclaimer - Engineer's Opinion of Probable Construction Costs

The estimate of costs shown and any resulting conclusions on the project financial, economic feasibility or funding requirements have been prepared from guidance in the project evaluation and implementation from the information available at the time the estimate was prepared. The final Costs of the project and resulting feasibility will depend on actual labor and material costs, competitive market conditions and other variable factors. Accordingly, the final project costs may vary from the estimate. Project feasibility, benefit/cost analysis, and risk must be reviewed prior to making specific funding decisions and establishment of the project budget.

AACE International CLASS 4 Cost Estimate - Class 4 estimates are generally prepared based on limited information and subsequently have fairly wide accuracy ranges. Typically, engineering is 10% to 40% complete. They are typically used for project screening, determination of feasibility, concept evaluation, and preliminary budget approval. Virtually all Class 4 estimates use stochastic estimating methods such as cost curves, capacity factors, and other parametric and modeling techniques. Expected accuracy ranges are from -15% to -30% on the low side and +20% to 50% on the high side, depending on the technological complexity of the project, appropriate reference information, and the inclusion of an appropriate contingency determination. Ranges could exceed those shown in unusual circumstances. As little as 20 hours or less to perhaps more than 300 hours may be spent preparing the estimate depending on the project and estimating methodology (AACE International Recommended Practices and Standards).

DWR - Paradise Cut System Elements | **Romain Maendly**
Sacramento, CA | 7/21/2013

D4
Raise left portion of RR2 Bridge
Opinion of Probable Construction Costs

Currency: USD-United States-JUNE 2011 Dollar

Grand Total Price: $ 8,352,000

Item	GC	Description	Quantity	UOM	Unit Price	Total Price	Comments
		Included Items				**$ 3,262,000**	
1	P	Permanent ROW	-	Ac	$17,000	$ -	
2	P	Temporary Easement	5	Ac	$5,000	$ 25,000	
3	P	Hydroseeding	1	Ac	$2,000	$ 2,000	
4	P	Clearing and Grubbing	5	Ac	$5,000	$ 25,000	
5	P	Dewatering Extension	-	LF	$60	$ -	
6	P	Demolish Railroad	300	LF	$2,333	$ 700,000	
7	P	New Railroad Bridge	300	LF	$7,700	$ 2,310,000	
8	P	Raise approach to RR Bridge	-	LF	$200	$ -	
9	P	Cofferdam/River Diversion	2	LS	$50,000	$ 100,000	
10	P	Dewatering Costs	1	LS	$100,000	$ 100,000	
11	P	Channel Excavation to Levee Embankments	-	CY	$5.00	$ -	
12	P	Embankment Fill	-	CY	$16.00	$ -	
13	P	Waste Materials/ Spoils	-	CY	$4.00	$ -	
		Mobilization/Field Oversight Expenses				**$ 163,100**	
1	P	Mobilization / Demobilization	1	LS	5%	$ 163,100	
		Parametric Contingency				**$ 978,600**	
1	P	Unallocated Items Allowance	1	LS	5%	$ 163,100	
2	P	Environmental Mitigation	1	LS	25%	$ 815,500	
					Running Subtotal:	**$ 4,403,700**	
		Markups				**$ 132,200**	
1	S	Subcontractor Markups	1	LS	0.0%	$ -	
2	P	Prime Contractor OH&P on Subs	1	LS	0.0%	$ -	
3	P	Prime Contractor OH&P on Self-Perform	1	LS	0.0%	$ -	
4	P	Contractor Insurance Program	1	LS	0.0%	$ -	
5	P	State Sales Taxes on Matls	1	LS	0.0%	$ -	
6	P	Escalation	1	LS	3.0%	$ 132,200	
					Running Subtotal:	**$ 4,535,900**	Total Estimated Constr Costs w/o contingency
		Project Administration & Management				**$ 3,816,100**	
1	--	Construction Oversight & Management	1	LS	15%	$ 680,400	
2	--	Engineering & Design	1	LS	15%	$ 782,400	
3	--	Permitting & Legal	1	LS	5%	$ 299,900	
4	--	Contingency	1	LS	30%	$ 1,889,600	
5	--	Engineering Services During Construction	1	LS	2%	$ 163,800	
					Grand Total:	**$ 8,352,000**	Total Estimated Constr Costs w/ Contingency
				Cost Range:	**$7,000,000**	**$ 10,000,000**	Per AACE cost estimate guidelines

Notes:
1) This OPCC is classified as a Class 4 cost estimate per AACE guidelines. Stated accuracy range = -20% to + 25%.
2) Pricing basis = 2nd Qtr 2010, escalation to midpoint of construction is not included.
3) P=Prime, S=Subcontractor
4) Pricing assumes competitive market conditions at time of tender (+3 bidders/trade).
5) Owner soft costs and project management expenses excluded.

Estimating Disclaimer - Engineer's Opinion of Probable Construction Costs

The estimate of costs shown and any resulting conclusions on the project financial, economic feasibility or funding requirements have been prepared from guidance in the project evaluation and implementation from the information available at the time the estimate was prepared. The final Costs of the project and resulting feasibility will depend on actual labor and material costs, competitive market conditions and other variable factors. Accordingly, the final project costs may vary from the estimate. Project feasibility, benefit/cost analysis, and risk must be reviewed prior to making specific funding decisions and establishment of the project budget.

AACE International CLASS 4 Cost Estimate - Class 4 estimates are generally prepared based on limited information and subsequently have fairly wide accuracy ranges. Typically, engineering is 10% to 40% complete. They are typically used for project screening, determination of feasibility, concept evaluation, and preliminary budget approval. Virtually all Class 4 estimates use stochastic estimating methods such as cost curves, capacity factors, and other parametric and modeling techniques. Expected accuracy ranges are from -15% to -30% on the low side and +20% to 50% on the high side, depending on the technological complexity of the project, appropriate reference information, and the inclusion of an appropriate contingency determination. Ranges could exceed those shown in unusual circumstances. As little as 20 hours or less to perhaps more than 300 hours may be spent preparing the estimate depending on the project and estimating methodology (AACE International Recommended Practices and Standards).

Appendix F – Levee Fragility Curve

Table 4-2. San Joaquin River Basin Levee Performance Curves (contd.)

ID		SJ26		SJ27		SJ28		SJ29		SJ30	
Name		3 Amigos		Stanislaus South		Stanislaus North		Banta Carbona		Paradise Cut	
Toe Elevation[3]		28.4		23.5		27.9		19.5		0.6	
AWSE		38.7		36.6		35.5		28.4		14.7	
Crest Elevation[3]		41.7		40.0		38.5		32.1		22.4	
Type of Project (ULE or NULE)		NULE		NULE		NULE		NULE		NULE	
Water Surface Elevation (NGVD29) (feet)	Associated Probability of Failure (breach) (percent)	28.41	0	23.52	0	27.93	0	19.49	0	0.58	0
		29.44	0	24.83	0	28.69	0	20.39	0	1.99	0
		30.47	0	26.14	1	29.45	1	21.28	0	3.40	1
		31.50	1	27.45	1	30.21	1	22.17	1	4.81	1
		32.53	2	28.76	2	30.97	2	23.07	2	6.22	2
		33.56	3	30.07	4	31.73	4	23.96	3	7.63	4
		34.59	5	31.38	6	32.49	6	24.86	5	9.04	6
		35.62	7	32.69	10	33.25	10	25.75	7	10.45	10
		36.65	12	34.00	17	34.01	17	26.64	12	11.86	17
		37.68	20	35.31	27	34.77	27	27.54	20	13.27	27
		38.71	31	36.62	41	35.53	41	28.43	31	14.68	41
		39.01	75	36.96	87	35.83	87	28.79	75	15.45	87
		39.31	91	37.30	97	36.13	97	29.16	91	16.22	97
		39.61	97	37.64	99	36.43	99	29.52	97	16.99	99
		39.91	99	37.98	100	36.73	100	29.88	99	17.76	100
		40.21	100	38.32	100	37.03	100	30.25	100	18.53	100
		40.51	100	38.66	100	37.33	100	30.61	100	19.30	100
		40.81	100	39.00	100	37.63	100	30.97	100	20.07	100
		41.11	100	39.34	100	37.93	100	31.34	100	20.84	100
		41.41	100	39.68	100	38.23	100	31.70	100	21.61	100
		41.71	100	40.02	100	38.53	100	32.06	100	22.38	100

Table 4-2. San Joaquin River Basin Levee Performance Curves (contd.)

ID		SJ31		SJ32		SJ33		SJ34		SJ35	
Name		Stewart Tract		East Lathrop		Lathrop/ Sharpe		French Camp		Moss Tract	
Toe Elevation[3]		13.7		16.6		12.7		10.7		4.4	
AWSE		23.4		22.8		18.2		17.0		11.7	
Crest Elevation[3]		28.8		30.9		29.0		26.0		19.4	
Type of Project (ULE or NULE)		NULE		NULE		NULE		NULE		NULE	
Water Surface Elevation (NGVD29) (feet)	Associated Probability of Failure (breach) (percent)	13.75	0	16.65	0	12.67	0	10.69	0	4.41	0
		14.72	0	17.27	0	13.22	0	11.32	0	5.14	0
		15.69	0	17.89	0	13.77	0	11.95	0	5.87	0
		16.66	1	18.51	0	14.32	0	12.58	0	6.60	0
		17.63	2	19.13	0	14.87	0	13.21	0	7.33	1
		18.60	3	19.75	0	15.42	0	13.84	0	8.06	1
		19.57	5	20.37	1	15.97	1	14.47	1	8.79	3
		20.54	7	20.99	1	16.52	1	15.10	1	9.52	4
		21.51	12	21.61	2	17.07	2	15.73	2	10.25	7
		22.48	20	22.23	3	17.62	3	16.36	3	10.98	11
		23.45	31	22.85	5	18.17	5	16.99	5	11.71	19
		23.99	75	23.66	7	19.25	9	17.89	8	12.48	51
		24.53	91	24.47	10	20.33	12	18.79	10	13.25	71
		25.07	97	25.28	12	21.41	16	19.69	13	14.02	83
		25.61	99	26.09	15	22.49	19	20.59	15	14.79	90
		26.15	100	26.90	17	23.57	22	21.49	18	15.56	94
		26.69	100	27.71	19	24.65	26	22.39	20	16.33	97
		27.23	100	28.52	21	25.73	29	23.29	23	17.10	98
		27.77	100	29.33	24	26.81	32	24.19	25	17.87	99
		28.31	100	30.14	26	27.89	35	25.09	27	18.64	100
		28.85	100	30.95	100	28.97	100	25.99	100	19.41	100

Table 4-2. San Joaquin River Basin Levee Performance Curves (contd.)

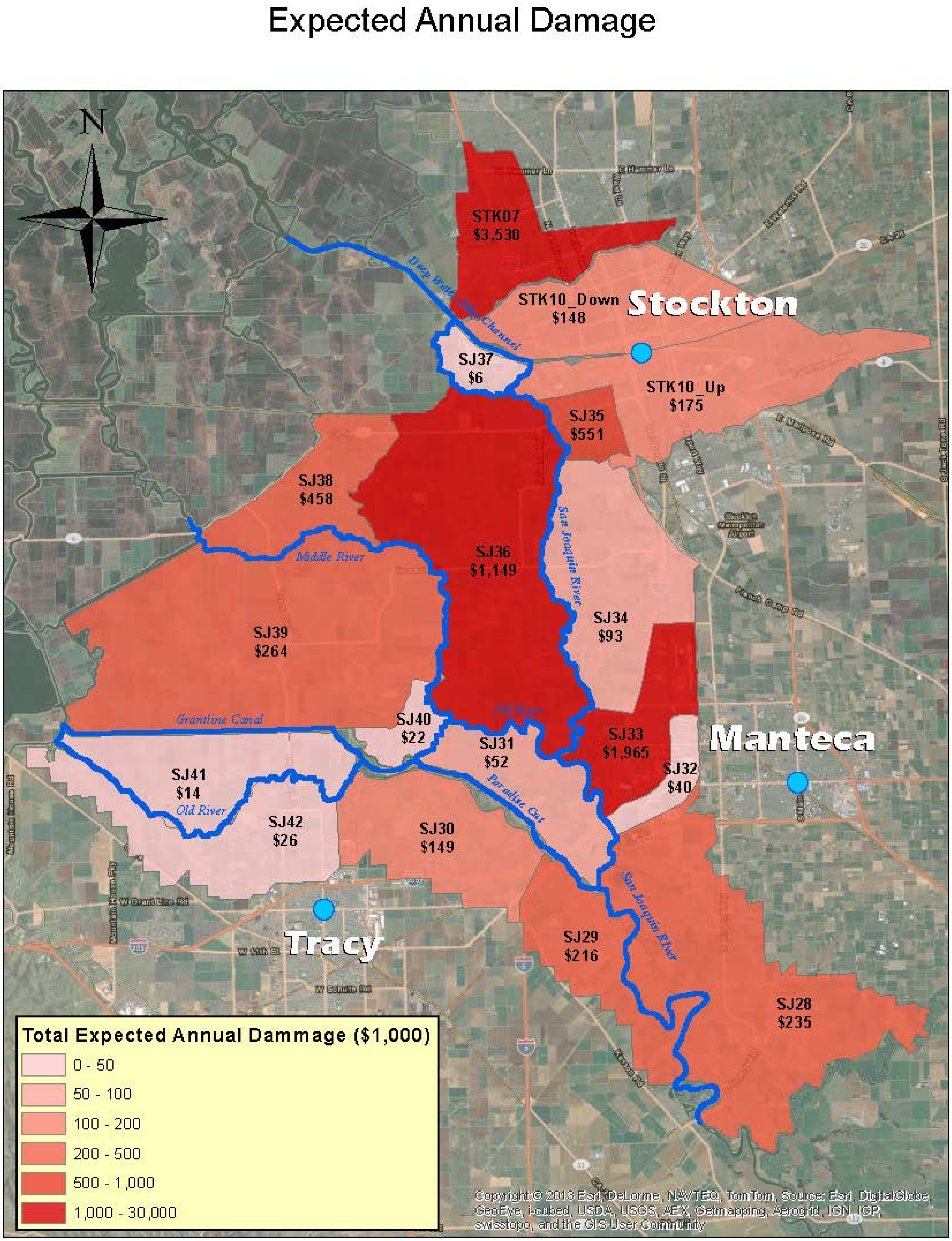
ID		SJ36		SJ37		SJ38		SJ39		SJ40	
Name		Roberts Island		Rough and Ready Island		Drexler Tract		Union Island		SE Union Island	
Toe Elevation[3]		4.6		2.7		-2.8		8.6		5.3	
AWSE		17.0		8.6		7.7		13.5		13.4	
Crest Elevation[3]		26.1		13.9		8.4		23.4		19.3	
Type of Project (ULE or NULE)		NULE		NULE		NULE		NULE		NULE	
Water Surface Elevation (NGVD29) (feet)	Associated Probability of Failure (breach) (percent)	4.58	0	2.75	0	-2.85	0	8.61	0	5.28	0
		5.82	0	3.34	0	-1.80	0	9.10	0	6.09	0
		7.06	0	3.93	0	-0.74	0	9.59	0	6.90	1
		8.30	1	4.52	0	0.31	0	10.08	1	7.71	1
		9.54	1	5.11	0	1.37	1	10.57	2	8.52	2
		10.78	2	5.70	0	2.43	1	11.06	3	9.33	4
		12.02	3	6.29	0	3.48	2	11.55	5	10.14	6
		13.26	4	6.88	0	4.54	3	12.04	7	10.95	10
		14.50	7	7.47	1	5.59	5	12.53	12	11.76	17
		15.74	12	8.06	1	6.65	8	13.02	20	12.57	27
		16.98	20	8.65	2	7.71	13	13.51	31	13.38	41
		17.89	52	9.18	3	7.78	29	14.50	75	13.97	87
		18.80	71	9.71	3	7.85	39	15.49	91	14.56	97
		19.71	83	10.24	4	7.92	45	16.48	97	15.15	99
		20.62	90	10.77	5	7.99	48	17.47	99	15.74	100
		21.53	94	11.30	5	8.06	50	18.46	100	16.33	100
		22.44	97	11.83	6	8.13	52	19.45	100	16.92	100
		23.35	98	12.36	7	8.20	53	20.44	100	17.51	100
		24.26	99	12.89	7	8.27	53	21.43	100	18.10	100
		25.17	100	13.42	8	8.34	54	22.42	100	18.69	100
		26.08	100	13.95	100	8.41	100	23.41	100	19.28	100

Table 4-2. San Joaquin River Basin Levee Performance Curves (contd.)

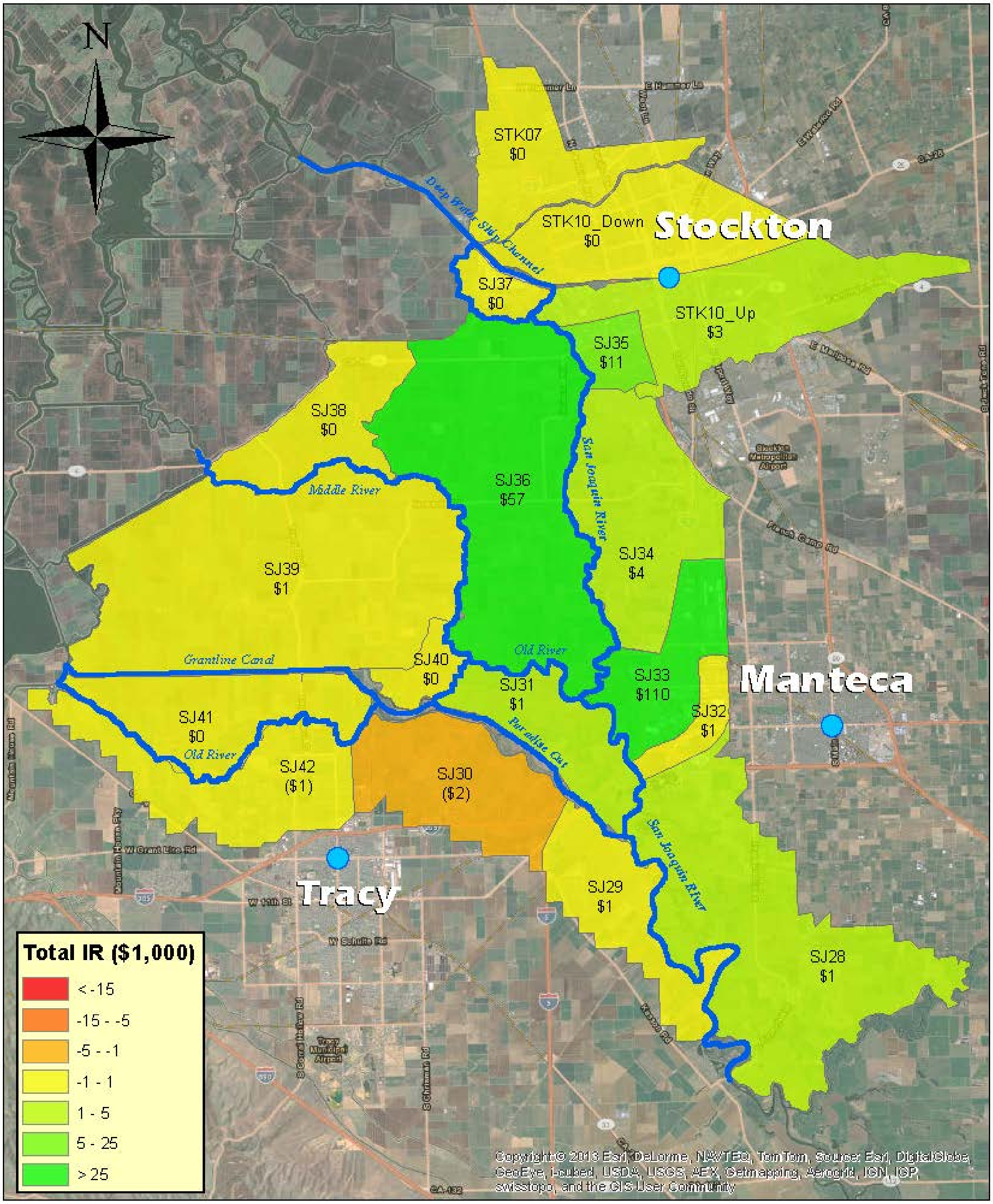
ID		SJ41		SJ42		SJ43	
Name		Fabian Tract		RD 1007		Grayson	
Toe Elevation[3]		5.5		6.3		31.6	
AWSE		10.4		10.4		42.4	
Crest Elevation[3]		21.3		19.3		46.2	
Type of Project (ULE or NULE)		NULE		NULE		NULE	
Water Surface Elevation (NGVD29) (feet)	Associated Probability of Failure (breach) (percent)	5.49	0	6.27	0	31.60	0
		5.98	0	6.68	0	32.68	0
		6.47	0	7.09	0	33.76	0
		6.95	0	7.50	0	34.84	0
		7.44	0	7.91	0	35.92	0
		7.93	0	8.32	0	37.00	1
		8.42	1	8.73	0	38.08	1
		8.91	1	9.14	1	39.16	1
		9.40	2	9.55	1	40.24	2
		9.89	3	9.96	2	41.32	4
		10.38	4	10.37	3	42.40	6
		11.47	8	11.26	6	42.78	7
		12.57	11	12.15	9	43.16	8
		13.67	15	13.04	12	43.54	9
		14.76	18	13.93	15	43.92	10
		15.86	21	14.82	17	44.30	11
		16.95	24	15.71	20	44.68	11
		18.05	28	16.60	22	45.06	12
		19.15	31	17.49	25	45.44	13
		20.24	33	18.38	27	45.82	14
		21.34	100	19.27	100	46.20	100

STK 07		STK 10_down	
Sargent_Barhart		Smith	
Derived from SJ37		Derived from SJ37	
REACH 30		REACH 30	
36.94		38.14	
5.00	0	5.00	0
5.47	0	5.53	0
5.93	0	6.06	0
6.40	0	6.60	0
6.87	0	7.13	0
7.34	0	7.66	0
7.80	0	8.19	0
8.27	0	8.72	0
8.74	1	9.26	1
9.21	1	9.79	1
9.67	2	10.32	2
10.09	3	10.80	3
10.51	3	11.28	3
10.93	4	11.75	4
11.35	5	12.23	5
11.77	5	12.71	5
12.19	6	13.19	6
12.61	7	13.67	7
13.03	7	14.14	7
13.45	8	14.62	8
13.87	100	15.10	100

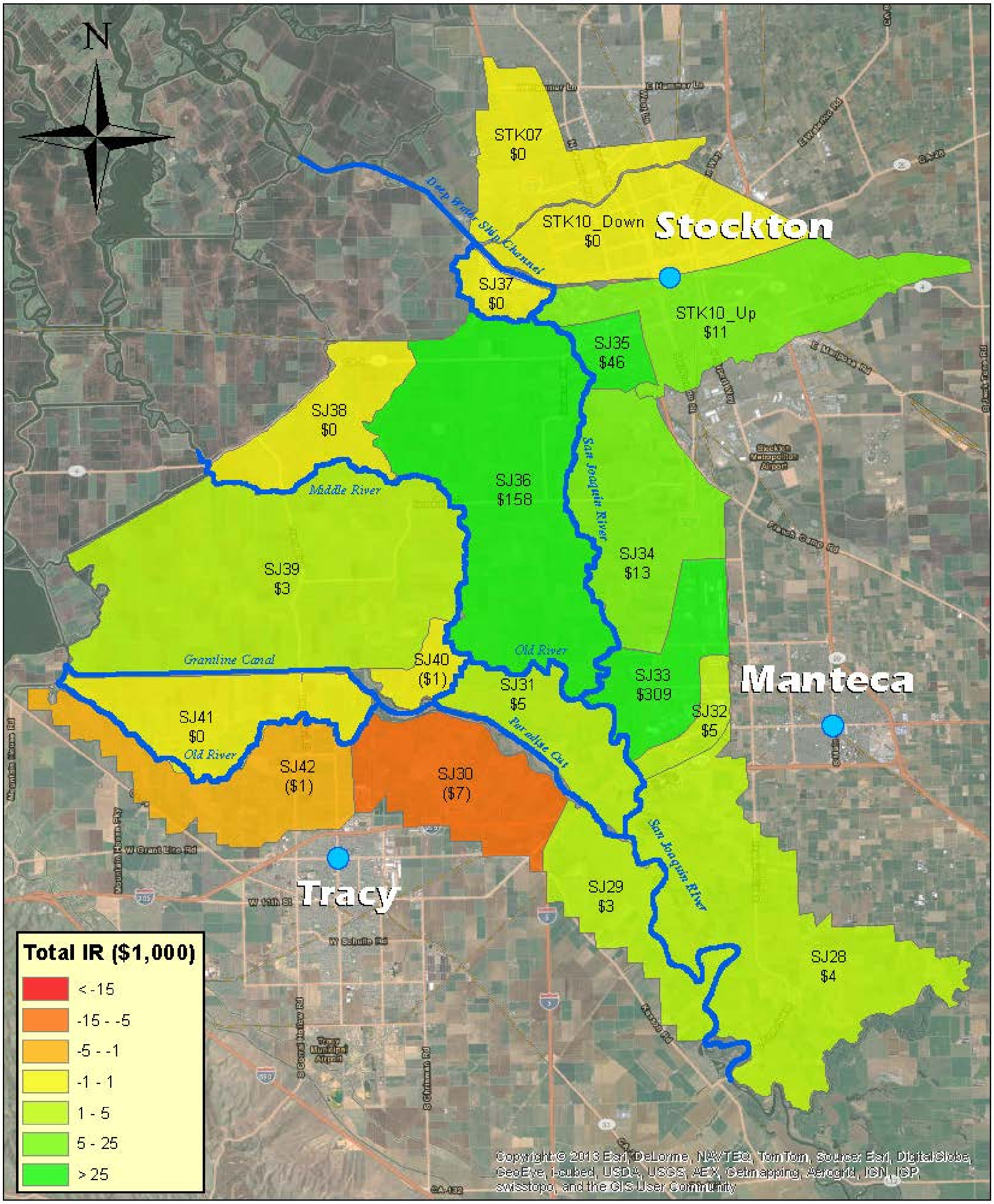
Appendix G – Economic Results



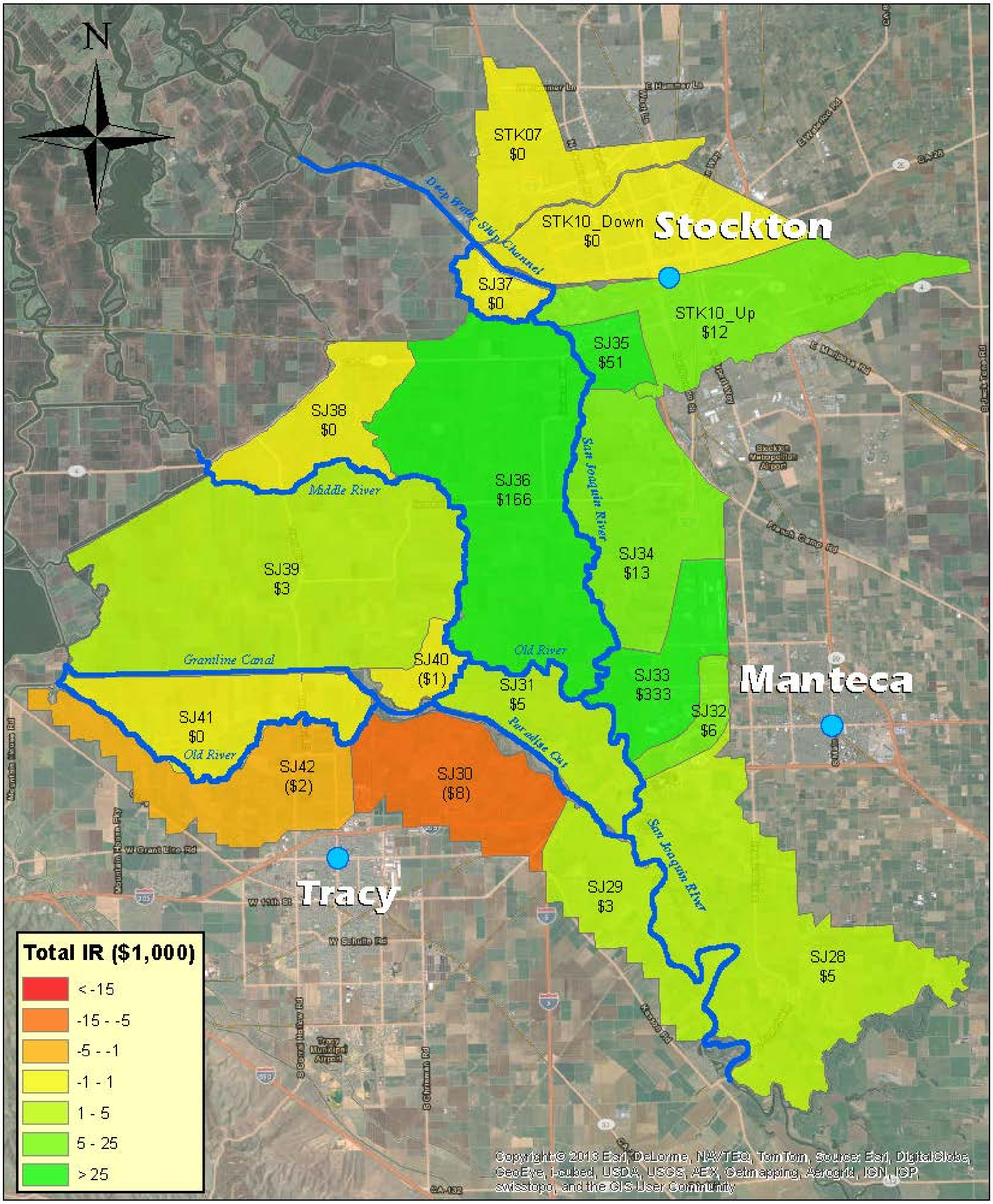
Inundation Reduction Benefits
Weir at 15ft



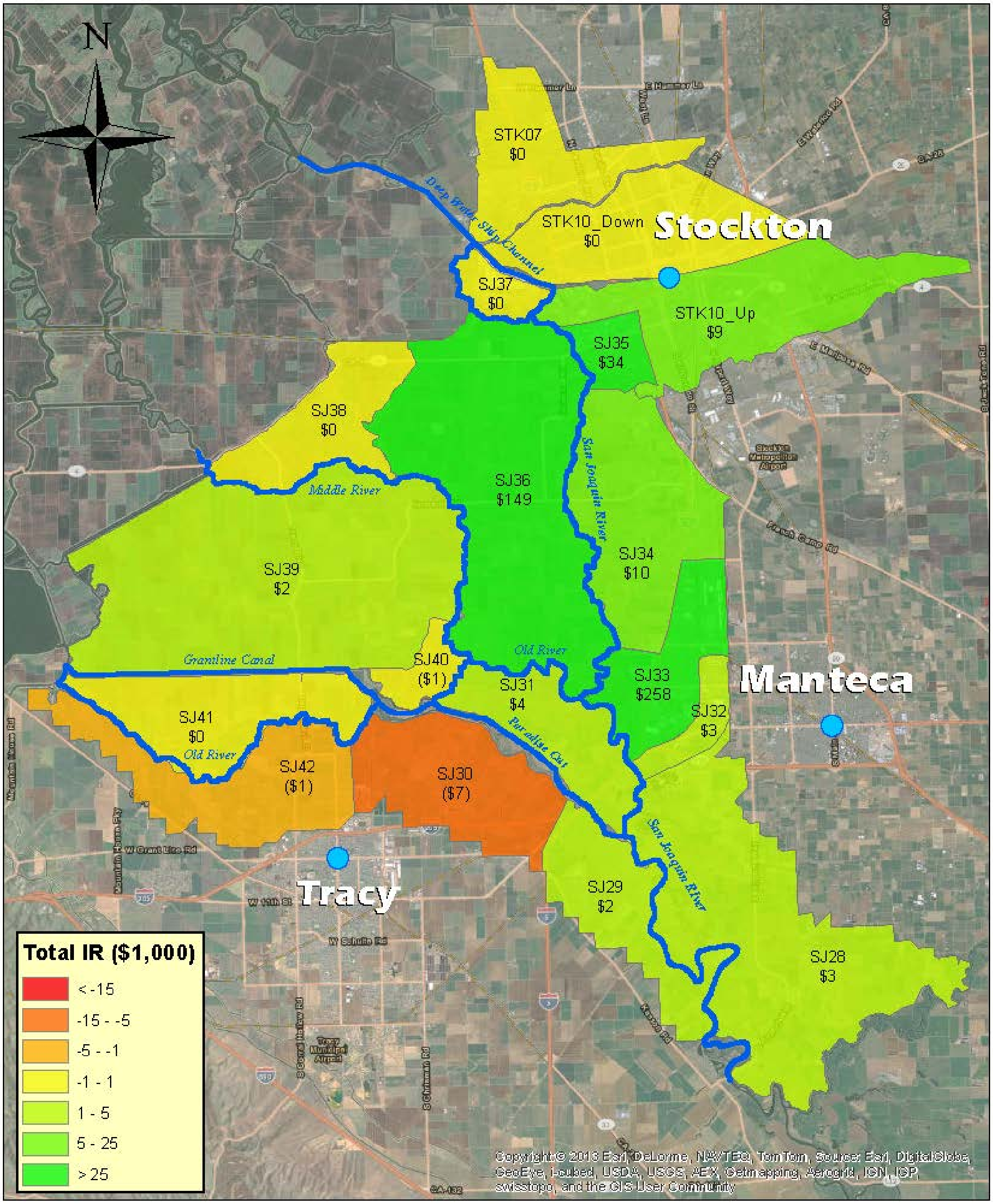
Inundation Reduction Benefits
Weir at 15ft and Extended by 200ft



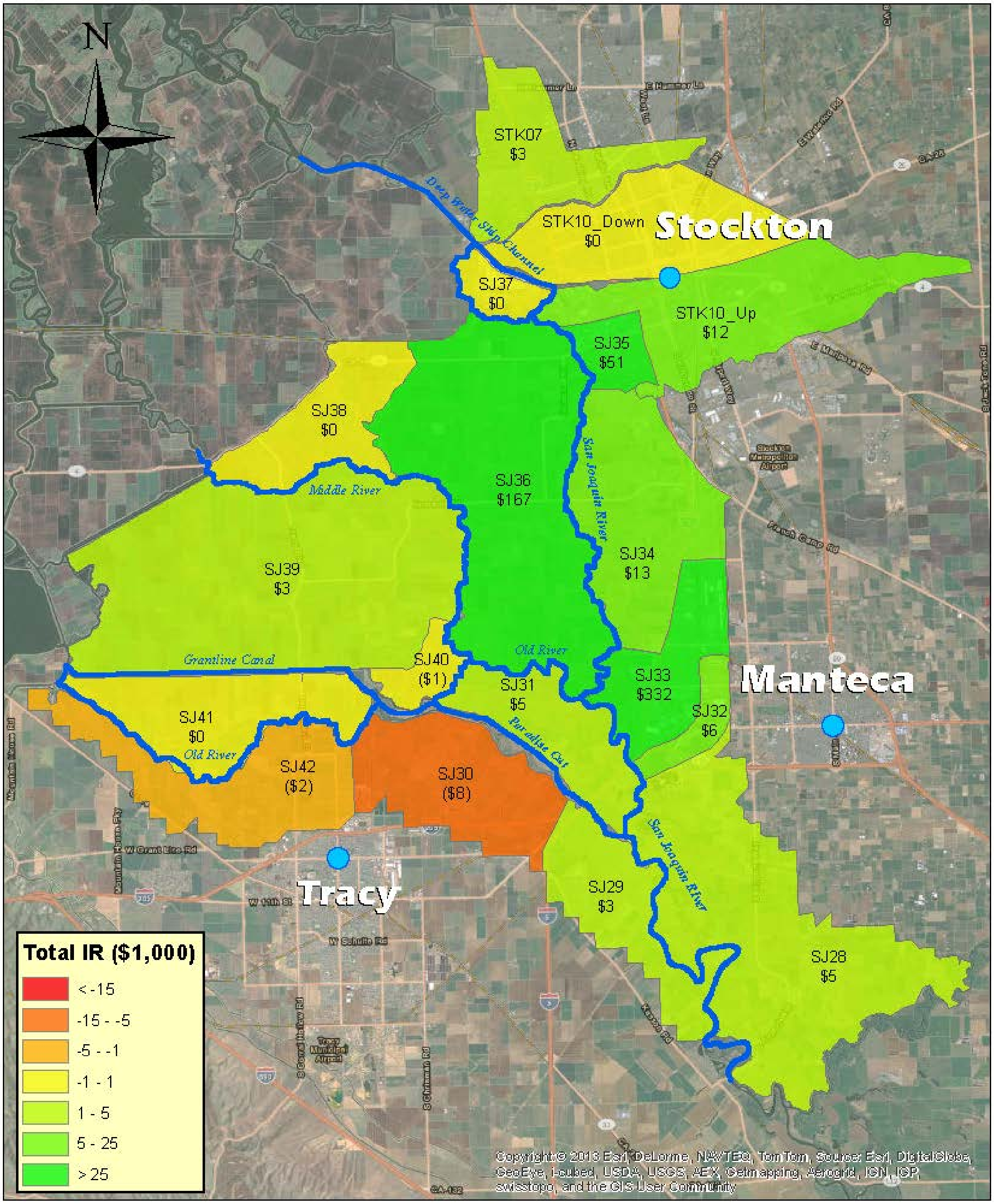
Inundation Reduction Benefits
Weir at 15ft and Extended by 400ft



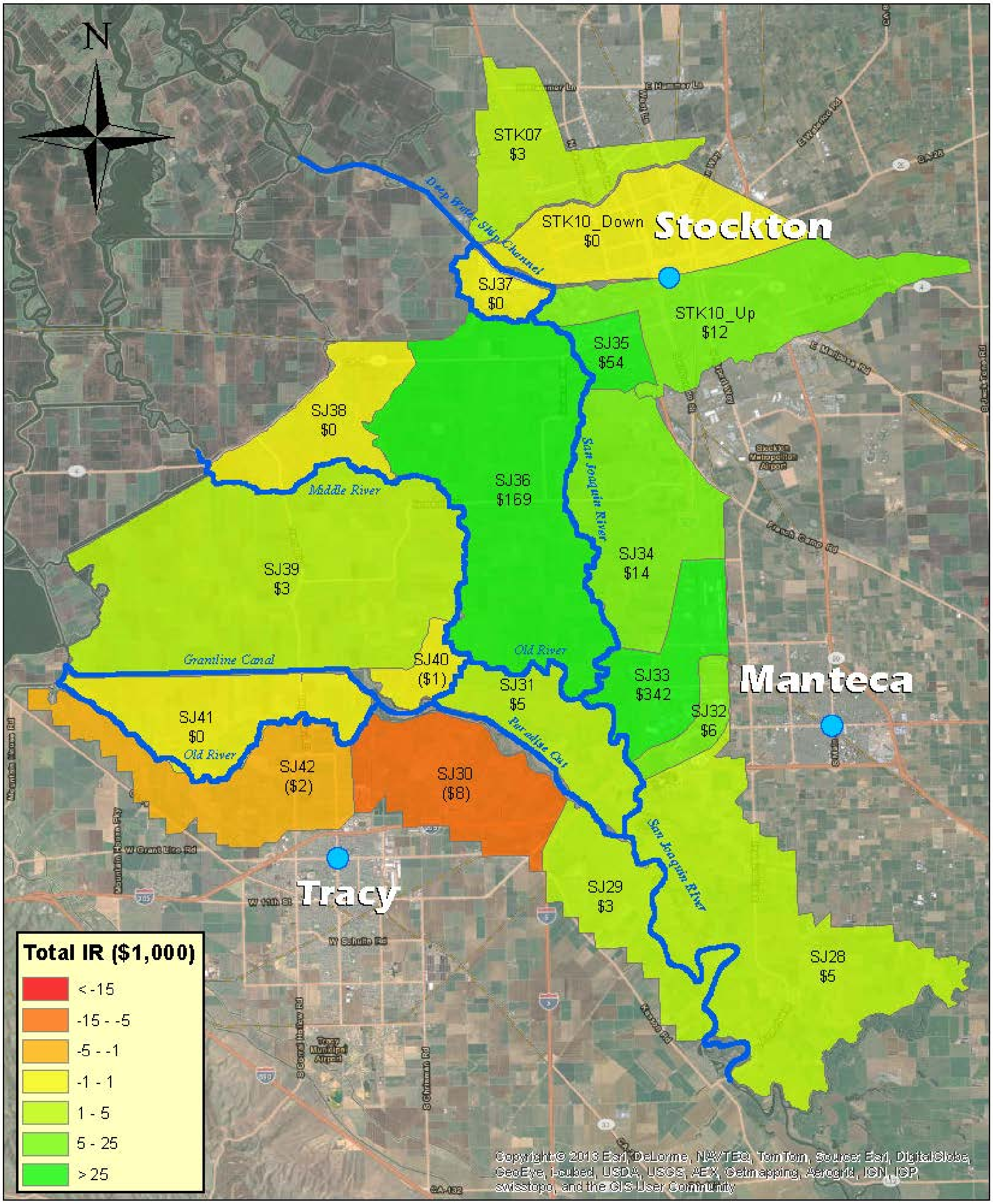
Inundation Reduction Benefits
Weir at 11ft



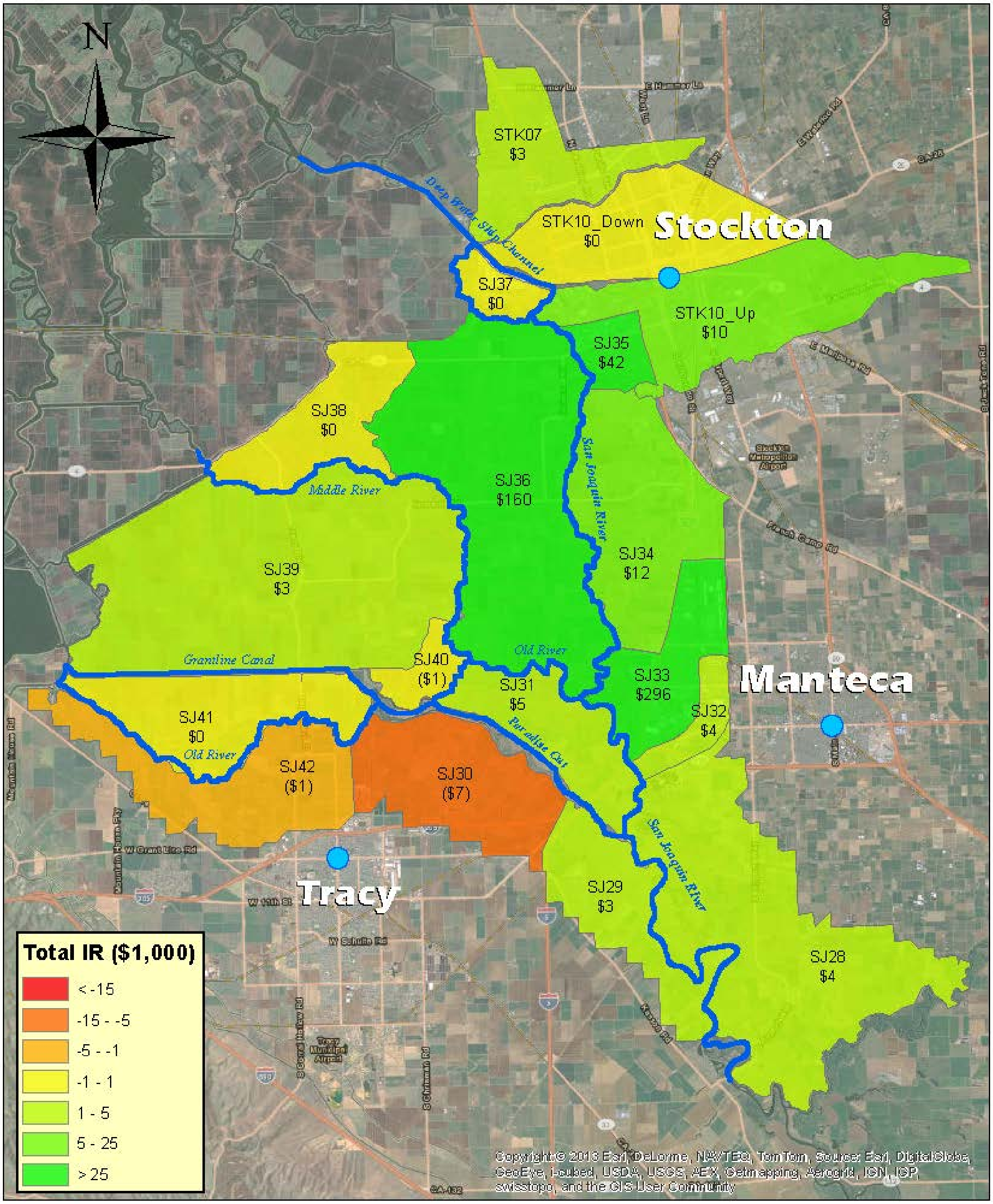
Inundation Reduction Benefits
Weir at 11ft and Extended by 200ft



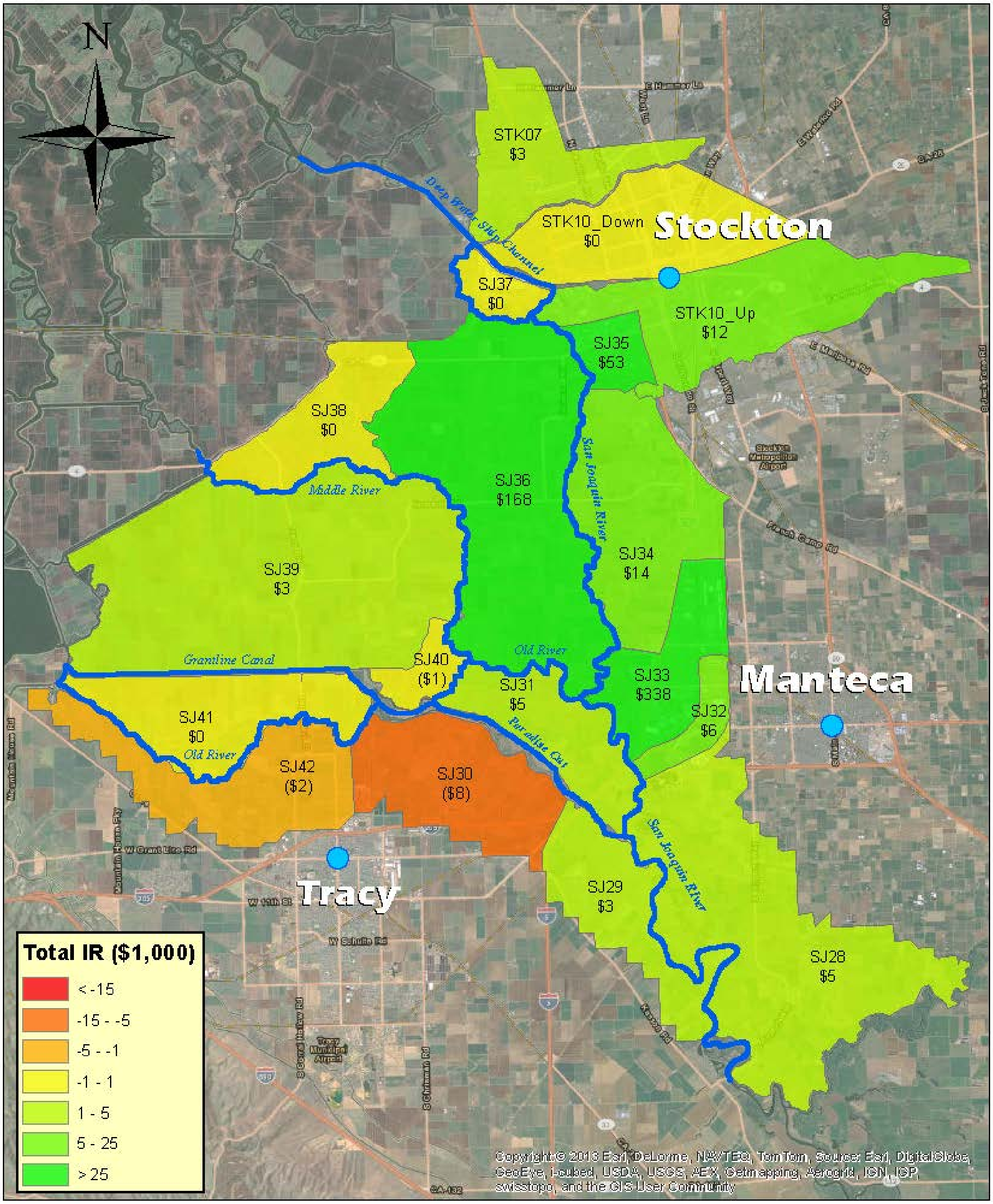
Inundation Reduction Benefits
Weir at 11ft and Extended by 400ft



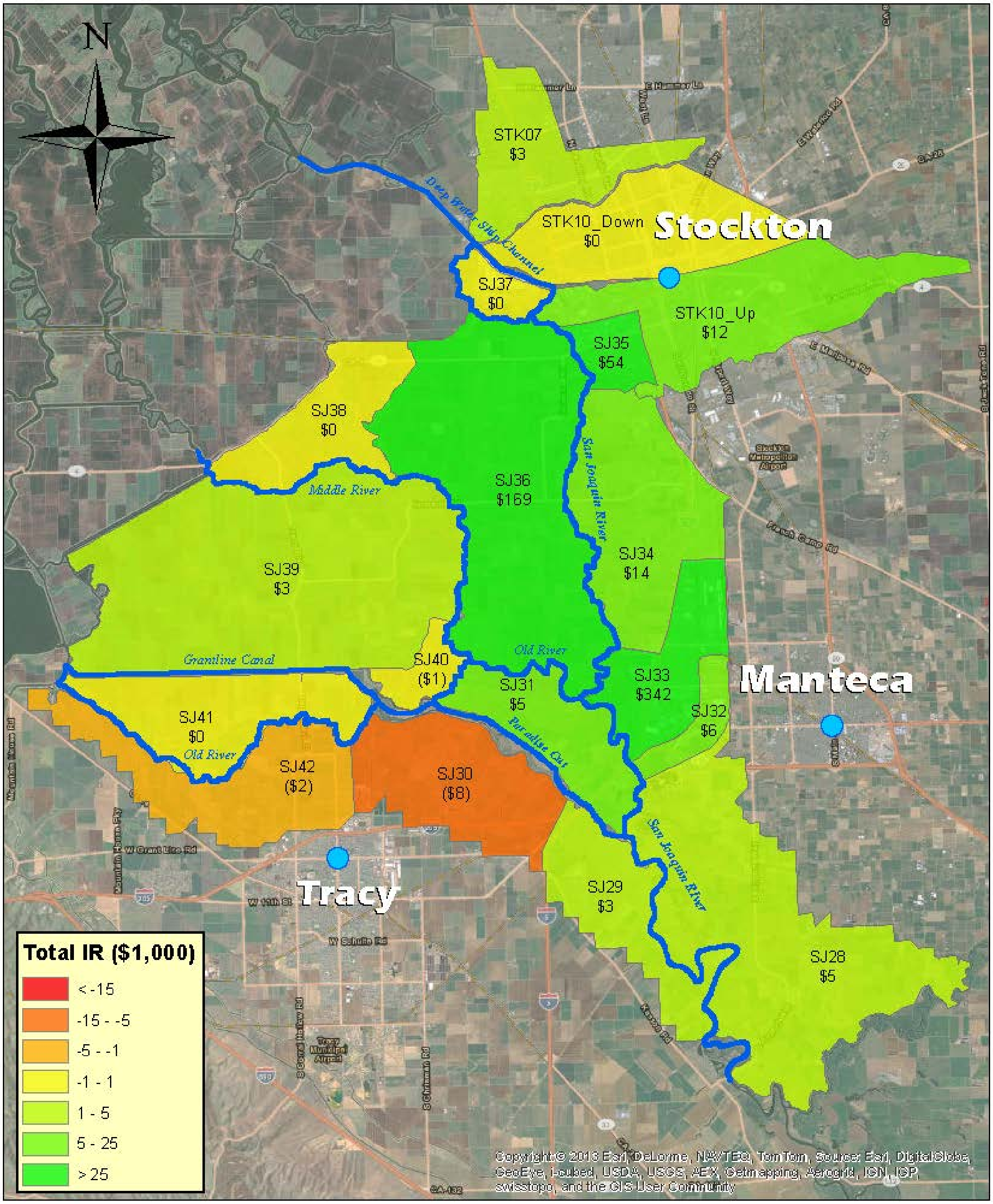
Inundation Reduction Benefits
Weir at 6ft



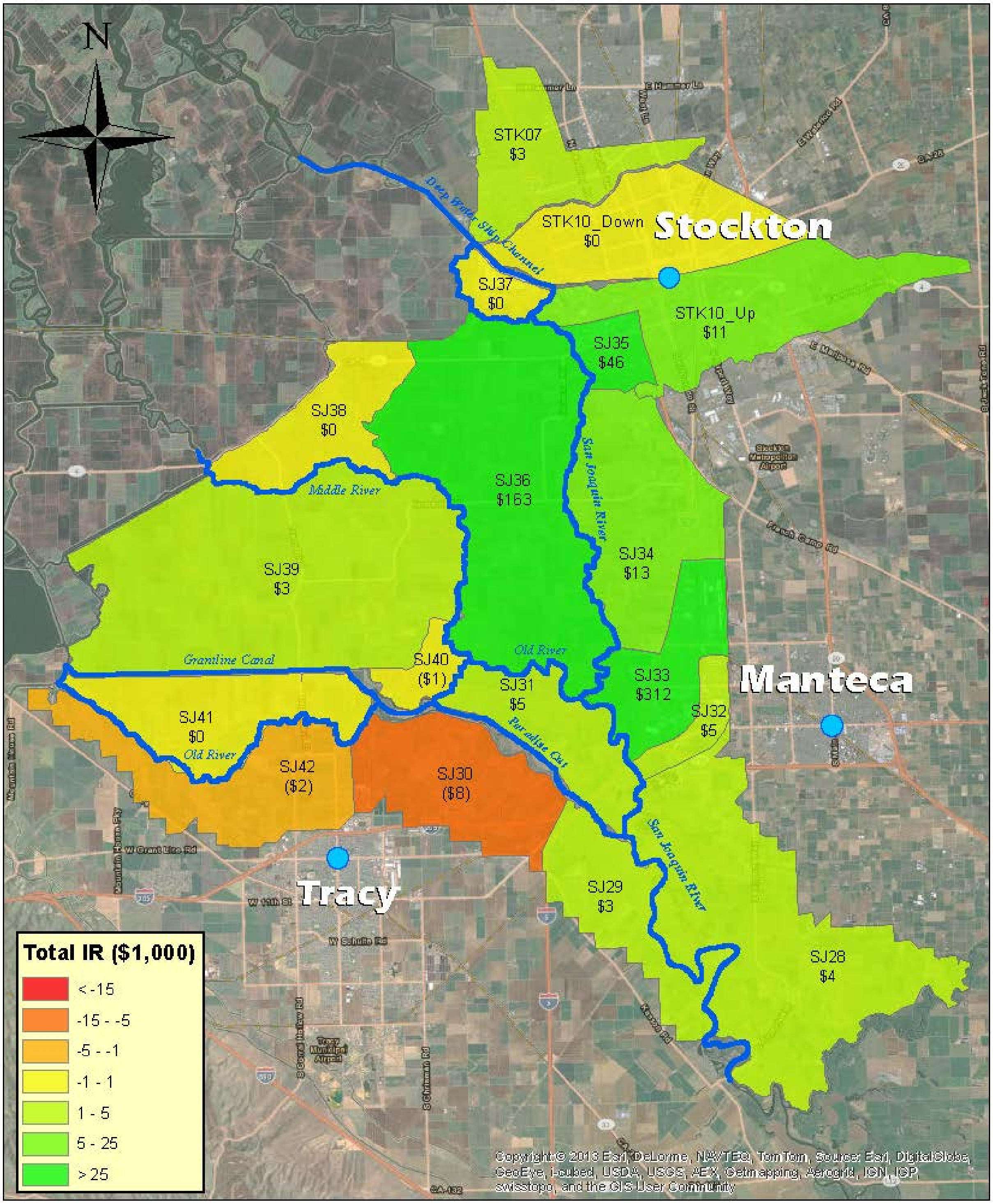
Inundation Reduction Benefits
Weir at 6ft and Extended by 200ft



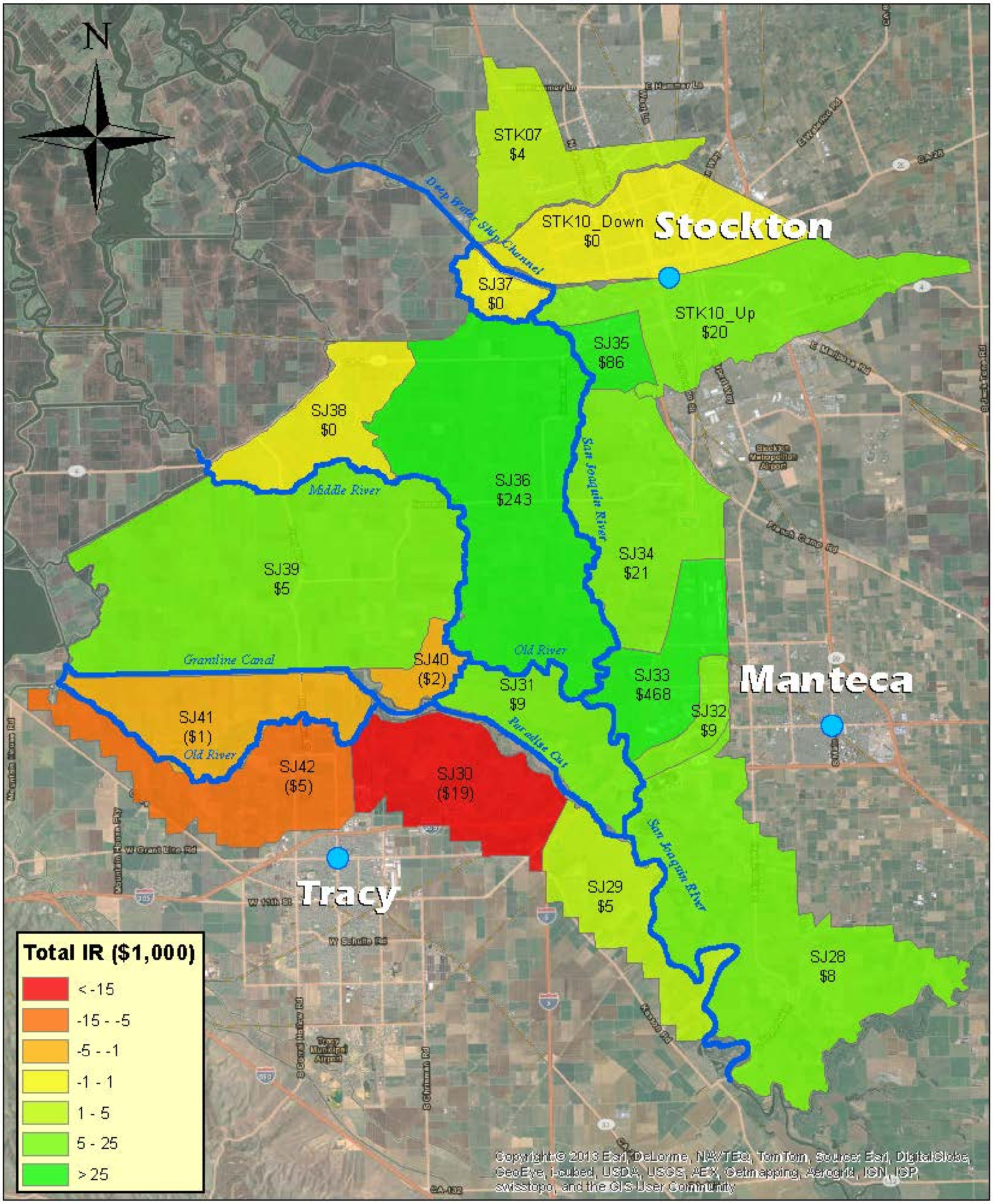
Inundation Reduction Benefits
Weir at 6ft and Extended by 400ft



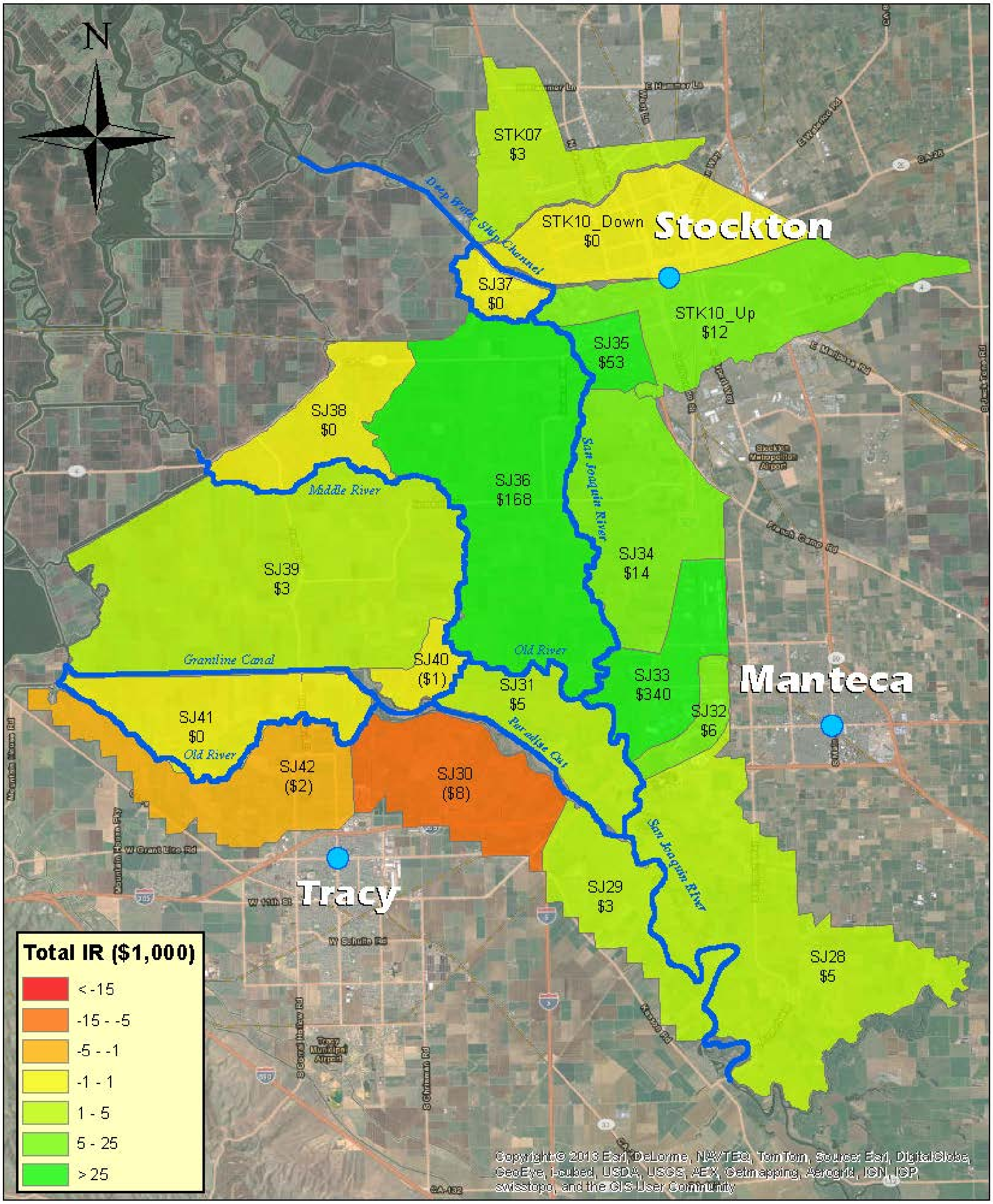
Inundation Reduction Benefits
Weir at 2ft



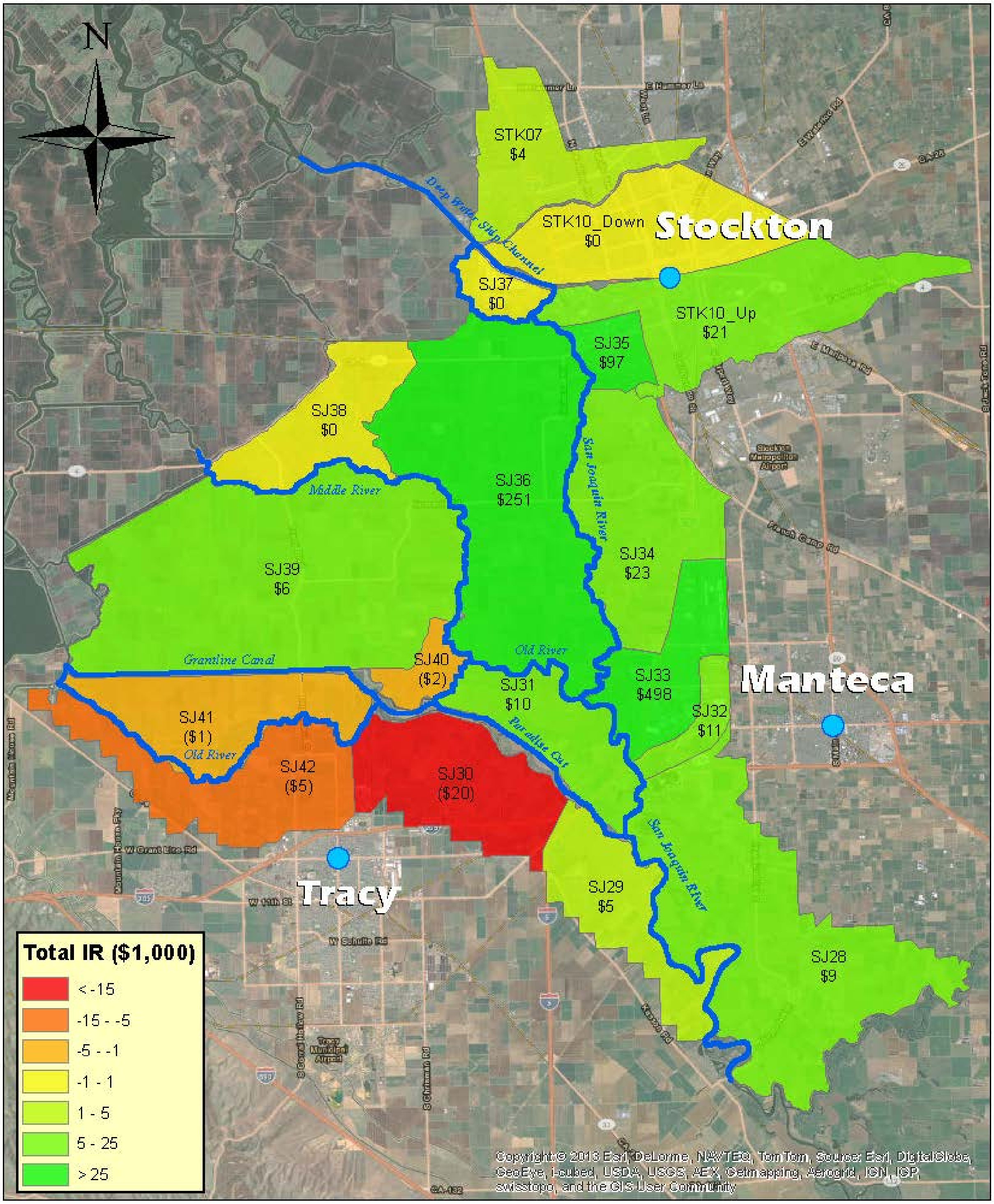
Inundation Reduction Benefits
Weir at 2ft and Channel Dredging



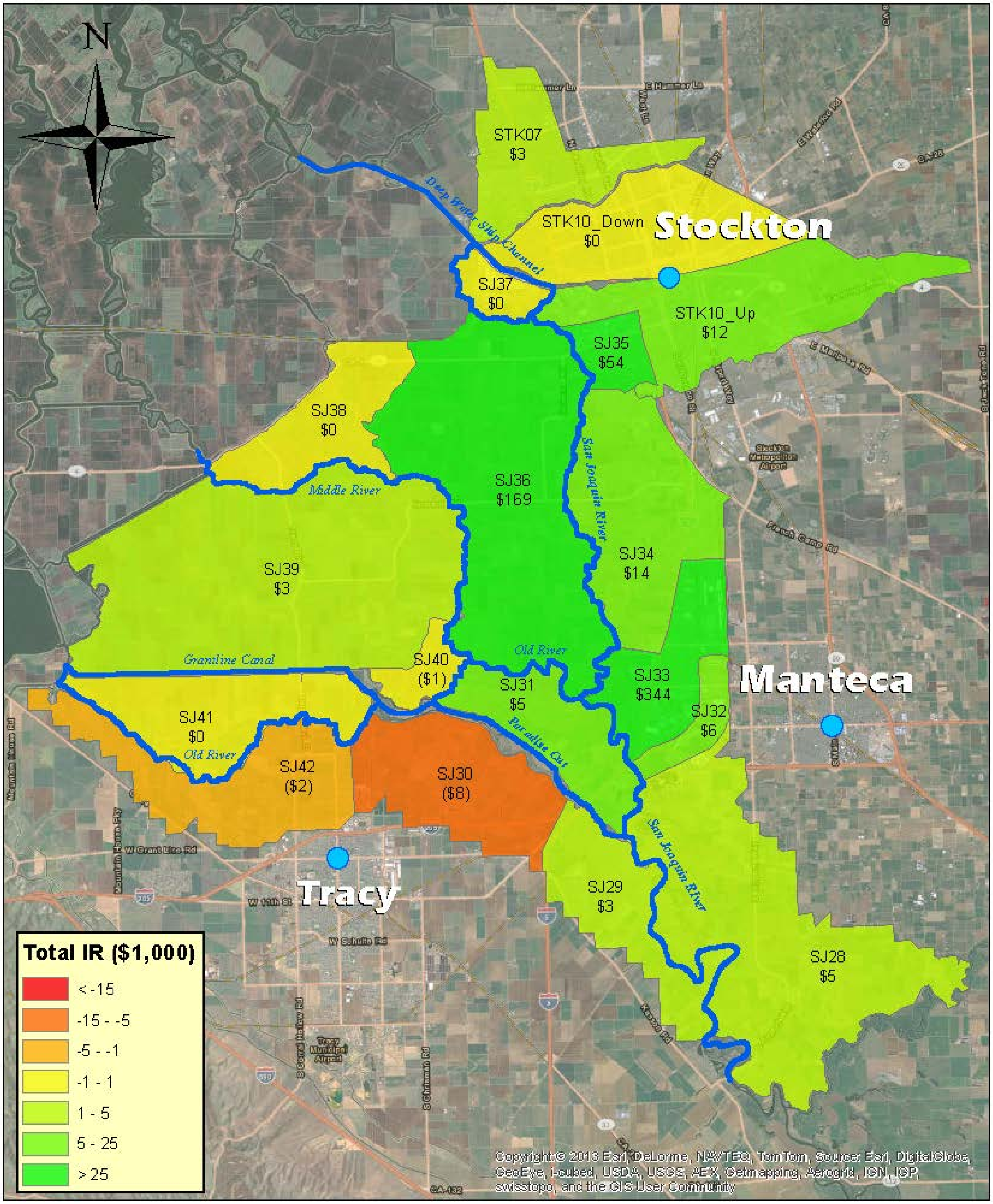
Inundation Reduction Benefits
Weir at 2ft and Extended by 200ft



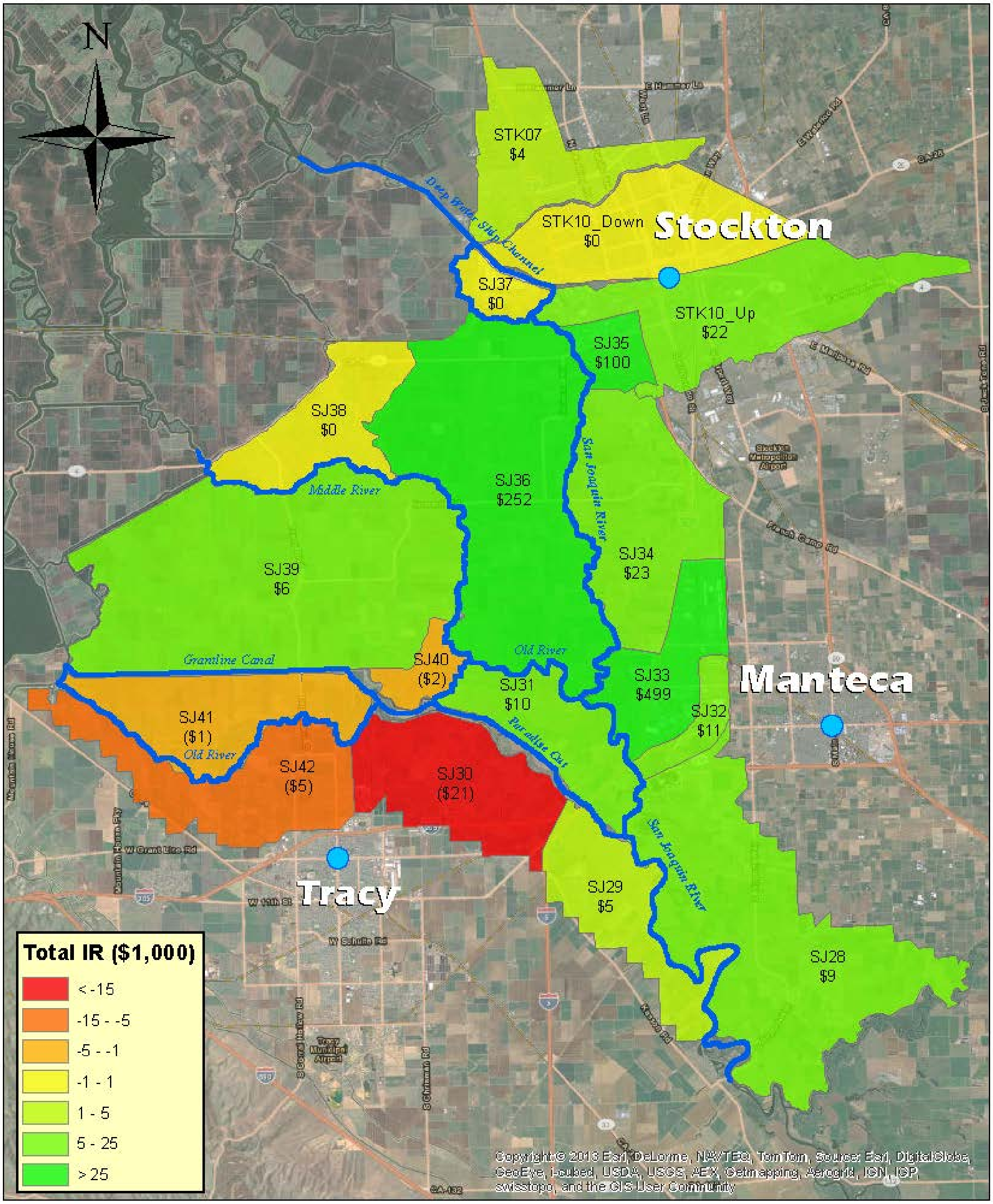
Inundation Reduction Benefits
Weir at 2ft, Extended by 200ft and Channel Dredging



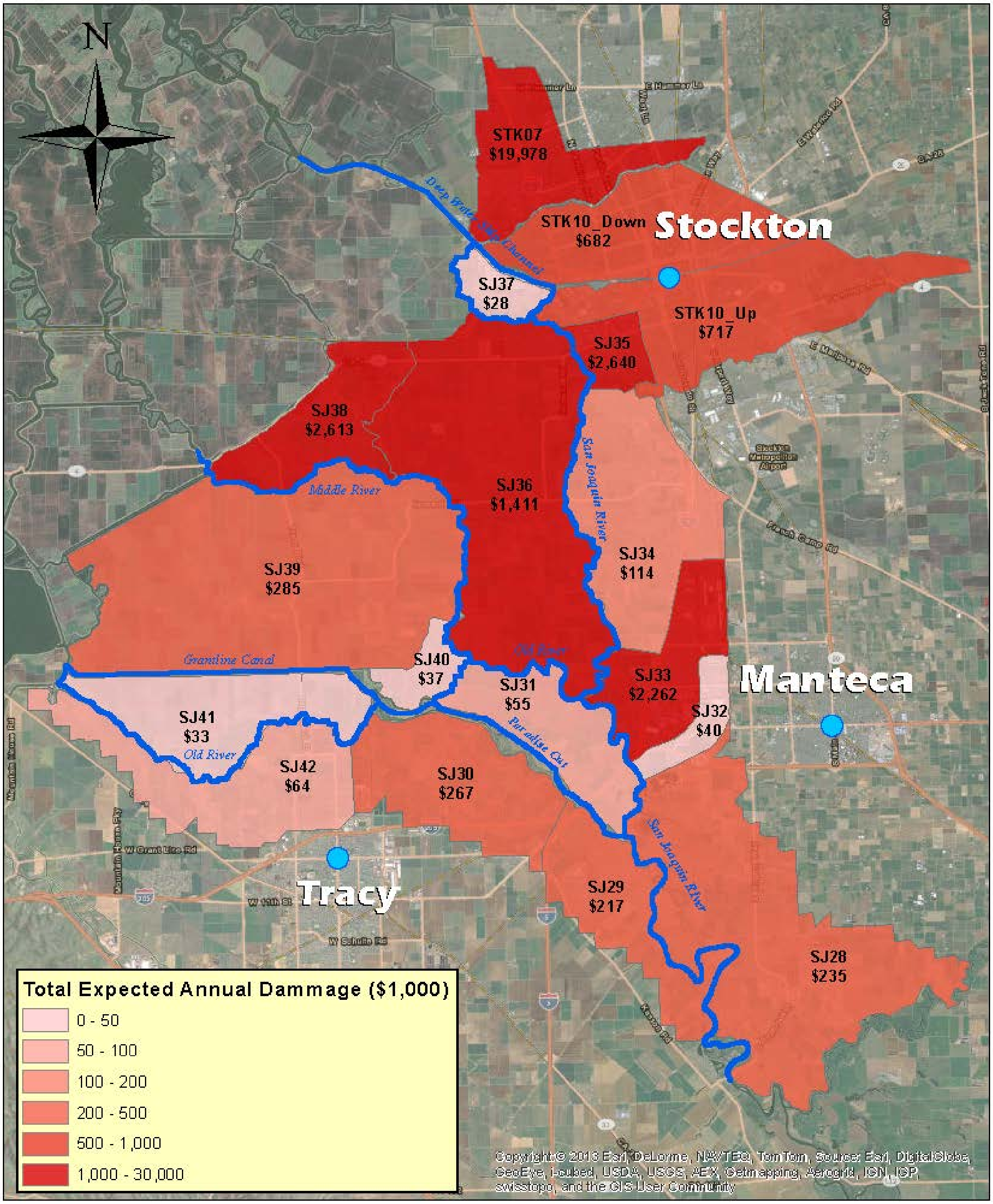
Inundation Reduction Benefits
Weir at 2ft and Extended by 400ft



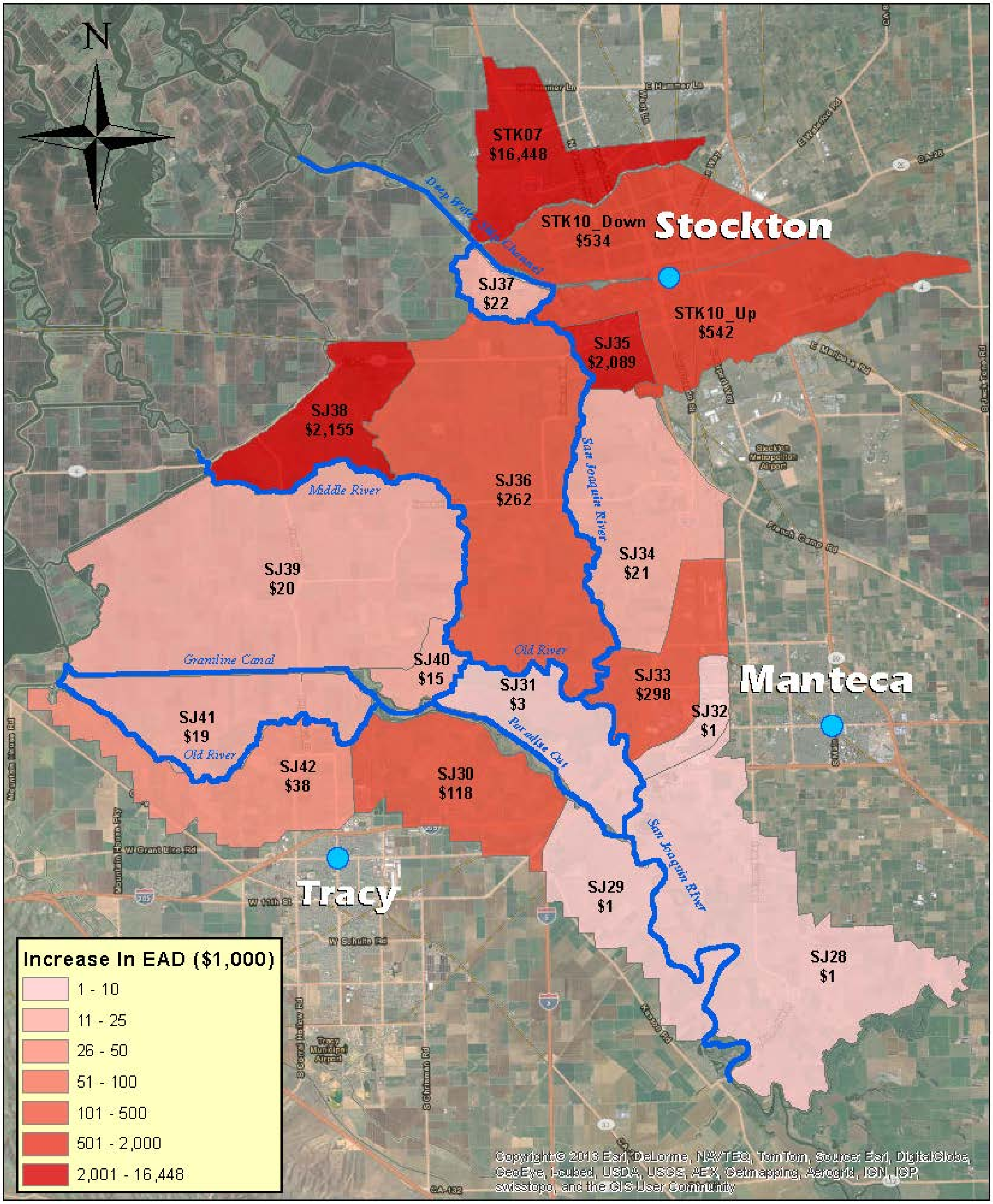
Inundation Reduction Benefits
Weir at 2ft, Extended by 400ft and Channel Dredging



Expected Annual Damage With Sea Level Rise (2ft)



Increase In Expected Annual Damage Between Current Condition And Sea Level Rise (2ft)



Inundation Reduction Benefits - With Sea Level Rise (2ft)
Weir at 2ft, Extended by 200ft and Channel Dredging